TOWARDS SUSTAINABLE TOURISM IN OUTBACK AUSTRALIA:

THE BEHAVIOUR AND IMPACT OF NATURE-BASED TOURISTS ON VEGETATION AND SELECTED WILDLIFE SPECIES

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For my parents and partner,

for my family by soul,

for nature, my trusted home.

Official statements

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Abstract

Nature-based tourism offers significant socio-economic incentives to successfully replace more intrusive land uses but also causes negative environmental impacts. Currently, knowledge is needed about the effectiveness of specific management actions such as the provision of different access modes and tour experiences at minimizing these impacts while maximizing visitor satisfaction.

Nature-based tourism activities were studied in the species-rich gorges of the Flinders Ranges in Outback Australia. This study developed a conceptual framework of visitor-environment relationships, constructed a regional visitor profile, assessed visitor monitoring methods to quantify usage intensity in relation to the access mode (roads vs. hiking trails), examined changes in vegetation and bird communities in relation to usage intensity and access mode, tested effects of approach behaviour among driving vs. hiking tourists on kangaroo behaviour, and designed a framework for a night-time wildlife tour.

The usage intensity of gorge sections was best determined from visitor numbers stratified by their behaviour, as the access mode fundamentally changed visitor behaviour in gorges. High compared to low usage recreational tracks altered species community composition, decreased total plant cover, increased non-native species cover, increased or decreased plant diversity depending on the track distance, increased soil compaction, and decreased bird numbers and species richness. Vegetation changes had secondary aversive effects on the bird community. The magnitude and spatial extent of these community impacts were greater along roads than trails. Visitor approach towards kangaroos varied with the access mode and necessitated individual recommendations for low-impact behaviour. The optimal night-time observation tour employed night-vision devices and bat detectors and coupled visitor satisfaction with low impact on wildlife. A range of factors (e.g., weather conditions) moderated the susceptibility of the wildlife to tourism disturbance.

To protect wildlife and habitat along recreational tracks in arid-lands gorges, it is recommended to (1) monitor usage intensity and the identified impact indicators within their effect zone, (2) curtail gorge usage by restricting vehicle access to sections and regulating high impact activities (e.g., wild camping), (3) base environmental education upon scientifically tested low-impact visitor behaviour, and (4) engage with tourism operators in the design of low-impact, yet satisfying tours based on scientific principles.

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Chapter 1
Thesis introduction

1.1 Scope and definition of the tourism industry and nature-based tourism

Tourism has become one of the most important business enterprises and employers across the world, currently providing 1 in every 13.1 jobs (World Travel and Tourism Council, 2009). Despite the recent economic recession, global growth of the gross domestic product for the travel and tourism economy is expected to average 4.0% per annum over the coming 10 years. In Australia, tourism consumption of goods and services generated more than A$88 billion during the financial year 2007–2008, with domestic and international consumption accounting for 73.4% and 26.6%, respectively (Australian Bureau of Statistics, 2009). In the same time period, the Australian tourism gross domestic product increased by 4.4% on 2006–2007 to more than A$40 billion, and the tourism industry employed nearly 500 000 persons (Australian Bureau of Statistics, 2009). Globally, the tourism industry constitutes a strong economic force that is embraced by many stakeholders for its bountiful financial revenue.

Numerous definitions of tourism have been proposed over the years (reviewed by Leiper, 2004). According to the World Tourism Organization (1995: 1) tourism concerns "the activities of persons travelling to and staying in places outside their usual environment for not more than one consecutive year for leisure, business and other purposes". This definition emphasizes the demand side of tourism instead of the supply side, based on the notion that the circumstances of the consumer rather than the nature of the goods/services determine whether a transaction is considered part of the tourism domain. Consequently, the consumption of the same good (e.g., a piece of clothing) may be classified as tourism in one instance (purchased during a holiday) but not in another instance (purchased in the local mall). The line between tourism and recreation (reviewed by McKercher, 1996) is vague and has been argued to be an artificial distinction without a practical management purpose (Mercer, 1991: in McKercher, 1996). McKercher (1996) concludes that "tourism is not an absolute concept and, as such, the delineation point between tourism and non-tourism, or recreational activities, cannot be precisely determined. Instead it is likely that the perceived differences between these activities occur at a series of points along a continuum" (p. 564) and tourism may be regarded as an "extreme form of recreation" (p. 565). Some authors speak of recreation mainly in regards to "day trips from home by local residents" (Sun and Walsh, 1998: 325). In this study, the terms 'tourism' and 'recreation' as well as 'tourist' and 'recreationist' or 'visitor', will be treated interchangeably because tourism and recreation activities can have similar effects on the environment.

Of the various forms of tourism, nature-based tourism especially with wildlife is popular (Wilkie and Carpenter, 1999; Field, 2001). In Australia, where the natural environment is a vital tourist asset, international visitors engage in a broad spectrum of nature-based activities which often involves visiting protected areas (Hatch and Blamey, 1998). Famous World Heritage Areas such as Uluru-Kata Tjuta National Park and Kakadu National Park have an extraordinarily high appeal and have experienced increases in visitor numbers of 150% and 250% between 1982 and 1992 (Driml and Common, 1995). The number of day visitors partaking in nature activities in the whole of Australia exhibited a strong increase of 17% during 2007, which clearly exceeded the overall mean growth of the Australian day visitor market of 10% (Tourism Australia, 2009).

Tourism staged in the natural environment has been denoted as 'natural area tourism', 'nature tourism' or 'nature-based tourism'. However, little consensus exists on the meaning or differences between these terms, which appears to be a problem intrinsic to the tourism taxonomy in general (HaySmith and Hunt, 1995); some people draw distinctions between the terms, others use them interchangeably. Newsome et al. (2005: 13) described natural area tourism as tourism in the natural environment and recognized three dimensions: (1) tourism in the environment (e.g., adventure tourism), (2) tourism about the environment (e.g., nature-based tourism) and (3) tourism for the environment (e.g., ecotourism). HaySmith and Hunt (1995: 203) utilized the term 'nature tourism' and defined it as "domestic or foreign travel activities that are associated with viewing or enjoying natural ecosystems and wildlife for educational or recreational purposes". However, they acknowledged that this term has been applied to many different contexts where recreational activities take place in a natural setting. This resembles Ingram and Durst's (1987: in Weaver, 2001) definition of 'nature-based tourism' as leisure travel that involves the utilization of the natural resources of an area, with ecotourism and adventure tourism seen as partially overlapping sub-categories of nature-based tourism (Weaver, 2001). Whilst ecotourism also centres around the natural (non-human) environment as the main attraction for tourists, it is distinct in that (1) the basis for this attraction is an inherent appreciation/educational interest in the natural environment and (2) an effort is taken to conserve or use that natural environment in a sustainable manner (Orams, 2001). Thus ecotourism is subsumed by the concept of sustainable tourism (Weaver, 2001), which encompasses all activities that do not threaten the economic, social, cultural or environmental integrity of the tourist destination in the long term (Butler, 1993). This study concentrates on nature-based tourism activities, following the above-given definition by Newsome et al. (2005), and investigates options of making them sustainable from an ecological point of view (resource sustainability) and from a tourism perspective (sustainability of the tourism experience). Notwithstanding the focus, many of the results will be applicable to natural area tourism (Newsome et al., 2005) in general.

Nature-based tourism that is managed sustainably can have various positive effects on wildlife and their habitat; for instance, when tourists participate in practical conservation work (Green and Higginbottom, 2001). In recent years, participant-funded conservation holidays, where tourists engage in wildlife research or management activities (Ellis, 2003), have come 'en vogue'. The Earthwatch Institute is a prominent example of an organization that recruits paying volunteers for research to achieve conservation goals. Every year this organization contributes to 100 projects with grants over A$6 million and around 4000 paying volunteers (Earthwatch Institute, 2009). Tourists that assist in environmental work or have a positive experience with the natural environment during their travels may develop a closer emotional relationship with nature or particular species (Oberbillig, 2000). This personal bond/appreciation together with an increased conservation awareness (Duff, 1993)—perhaps as a result of environmental education through the tourism operator—can have a lasting impetus on people's future behaviour towards the environment (Vickery, 1995). Subsequently, tourists may be more inclined to politically support or donate towards conservation projects or behave in an environmentally responsible manner. For example, visitor attitudes surveyed after viewing sea turtles at the Mon Repos Turtle Rookery in Queensland, Australia, suggested a greater willingness to support the turtles' conservation (Tisdell and Wilson, 2002). In fact, conservationists may use the charisma of iconic species to promote the protection of whole ecosystems (Eckert and Hemphill, 2005).

The greatest potential of nature tourism to contribute to conservation (e.g., Buckley, 2003), though, is rooted in the value of the natural resources for tourist attraction. This value can provide significant socio-economic incentives to successfully replace more intrusive types of land use and motivate government or private landowners to manage land for conservation (e.g., Goodwin et al., 1998; Sekercioglu, 2002). The annual tourism expenditure in the Great Barrier Reef is a classic case: at the time (Driml, 1994) visitors spent approximately A$776 million per annum in the local economies to visit the Great Barrier Reef World Heritage Area which clearly exceeded the gross turnover of commercial fishing of A$128 million per year. Nowadays in East Africa, conserving wildlife and their habitat is much more profitable than selling them for their trophy value, due to the non-consumptive demand by observers and photographers (Ceballos-Lascuráin, 1996). However, the protective power that tourism exerts over certain areas may at times impact on the surroundings where the consumptive demand of visitors is stilled. Many safari lodges for instance offer 'game meat' not hunted in the protected areas but on their neighbouring unprotected properties. In Australia, National Parks and private landowners may capitalise on the attractiveness that large mobs of kangaroos have for tourists (Croft and Leiper, 2001) and practice "protection for profit" (Driml, 1994: 1).

1.2 Impacts and management of nature-based tourism

In spite of the substantial positive effects of nature-based tourism, there are concerns about unacceptable impacts for wildlife and their habitat. In the 1920s and 1930s, such impacts were first recognized (historical context of recreation ecology reviewed by Liddle, 1997; Cole, 2004) on California Redwood trees (*Sequoia sempervirens*) that were damaged by excessive tourist travel (Meinecke, 1928) and on vegetation growing along various types of travel routes (Bates, 1935). Research on tourism impacts or 'recreation ecology', as it is known, gained attention among a broader research community when outdoor recreation became widely popular in the 1960s and 1970s. Since the 1980s, recreation ecology has dispersed from its mainly North American and European roots around the world, in particular to South Africa (e.g., Garland, 1987) and Australia (e.g., Liddle and Thyer, 1986).

To date, many studies have investigated the multitude of impacts of nature-based tourism or specific sub-categories (most notably wildlife tourism) and complex relationships have been identified (e.g., reviewed by Knight and Gutzwiller, 1995; Liddle, 1997; Hammitt and Cole, 1998; Sun and Walsh, 1998; Green and Higginbottom, 2001; Buckley, 2004a; Green and Giese, 2004). A conceptual framework for this study

(Fig. 1.1) summarizes the main relationships between the visitor domain and the natural environment and is elaborated on in the following. This nature-based tourism framework applies equally to impacts on flora (reviewed in Chapter 4) and fauna, but the underpinning examples that are supplied here focus on the latter.

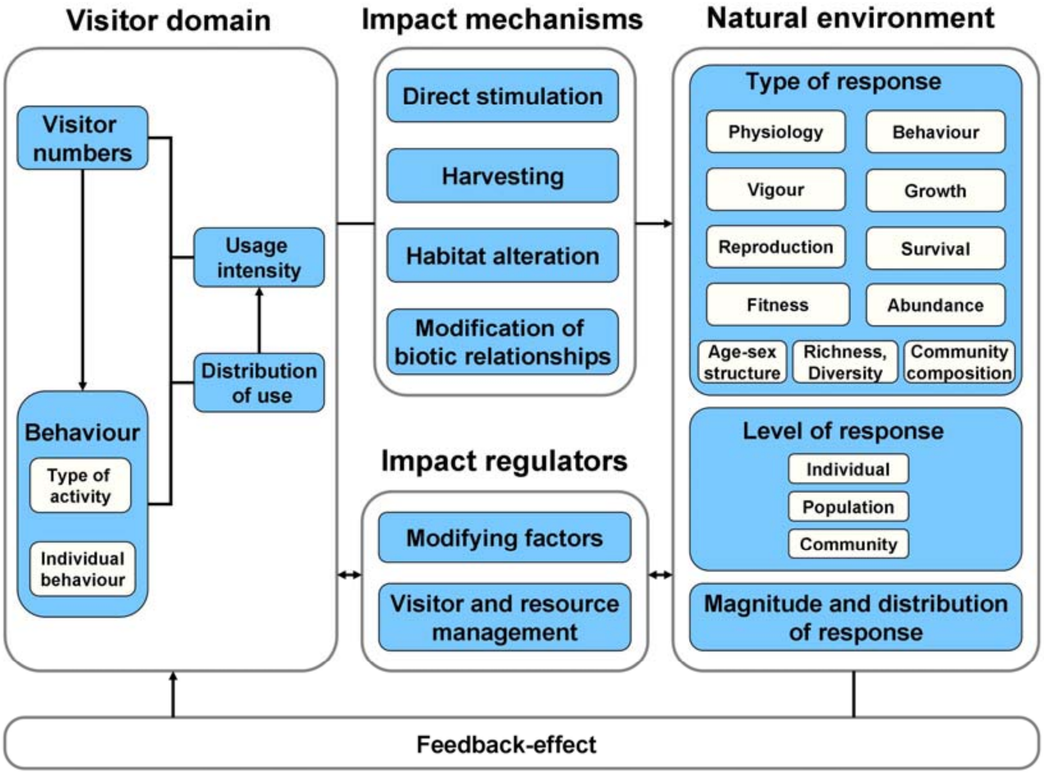


Fig. 1.1. A conceptual framework of the relationship between visitors who engage in nature-based tourism activities and the natural environment.

Visitor activities may affect the natural environment via four main pathways: direct stimulation, harvesting, habitat alteration and the modification of biotic relationships. The 'direct stimulation' via visual, acoustic, olfactory and sensory stimuli produced by human presence or infrastructure may lead to perturbation in the natural environment. Some authors term this impact mechanism 'disturbance' (e.g., Knight and Cole, 1995). However, according to Rykiel's (1985: 363) definition of disturbance "as a cause (which may be a system input) that results in a perturbation, which is an effect (or, change in system state)", it is more apt to denote tourism activity as a type of anthropogenic disturbance which causes perturbation in the environment via numerous mechanisms (disturbance pathways). For instance, artificial night lighting installed around tourism infrastructure or taken into the night during spotlighting tours transmits a visual stimulus that impinges on many different animal species (Chapter 7). A sensory stimulus in the form of a mechanical disruption of the environment triggered by physical contact with humans has a detrimental effect, for instance, when passing visitors crush eggs of ground-breeding birds or trample over vegetation (Chapter 4). Another form of direct impact is the harvesting of natural resources through intentional (e.g., hunting safaris, collection) or accidental (e.g., road accidents, trampling of plants) killing. Vehicle collisions, for example, pose a serious threat to wildlife crossing recreational tracks. Following a road upgrade in an Australian National Park, increased road mortality lead to the extinction of a whole population of Eastern Quolls (*Dasyurus viverrinus*) (Jones, 2000). Tourism activities may also exert indirect impacts when tourism-induced changes in the habitat elicit secondary effects on fauna or flora. Habitat destruction is generally considered a primary cause of biodiversity loss throughout the world. A most obvious form of habitat destruction associated with tourism is caused by large infrastructure developments such as hotels or car parks; more subtle habitat changes, however, can be insidious as well. For example, wood collection and clearing at campsites in Yosemite National Park reduced the nests of Steller's Jay (*Cyanocitta stelleri*) and American Robins (*Turdus migratorius*) by nearly one third (Garton et al., 1977). The deliberate or accidental provisioning of food constitutes another form of habitat alteration with many secondary effects (Orams, 2002). Indirect impacts also accrue when tourism activities modify biotic relationships. The introduction of exotic species along recreational tracks is a prime example as the invasion of plant species is capable of impairing a multitude of native plant (Chapter 4) and animal species (Blossey et al., 2001; Buckley, 2004b).

Flora and fauna that are subjected to tourism disturbance, initially respond with physiological changes that help survive during an emergency. During the so-called "fight or flight response" (Cannon, 1929) of higher animal species to disturbance, numerous endocrine mechanisms are activated to cope with the emergency (Munck et al., 1984), and the body prepares for behavioural defence reactions through increases in heart rate, respiration and body temperature (Mayes, 1979). Such physiological adjustments usually precede overt behavioural responses. For instance, when incubating penguins were approached by humans up to 15 m, they showed no behavioural changes, but their heart rates were significantly elevated above baseline rates (Giese, 1998). Only closer approaches triggered behavioural reactions. The physiological reaction to disturbance constitutes a stress response which, depending on its duration, frequency and magnitude, may cause adverse side-effects including immuno-deficiencies, developmental delays, weight loss or reduced reproductive success (Siegel, 1980; Hofer and East, 1998). Overtly, disturbed animals will assume vigilance behaviour to evaluate potential danger (e.g., Dyck and Baydack, 2003) or undertake evasive actions (e.g., Cassirer et al., 1992). Sometimes, aggressive responses occur (Bounds and Shaw, 1994). As a consequence less time can be spent on feeding (Knight et al., 1991; Roe et al., 1997), resting and in social interaction (Edington and Edington, 1990). Moreover, off-spring may be abandoned during flight reactions (Stuart-Dick, 1987), and animals may spatially or temporally avoid disturbed habitats even if they sustain better quality resources (Woodall et al., 1989; Griffiths and van Schaik, 1993; Olson et al., 1997).

There is no guarantee that short-term behavioural responses of individual animals translate into long-term deficits in reproduction and survival, and so into fitness deficits. Notwithstanding, there are obvious implications, given that the individual's current energy levels are depleted by physiological reactions as well as additional vigilance and flight, less new energy can be consumed due to reduced body maintenance activities, and the actual intake will be less efficient if displacement from optimum foraging places and times occurs. For example, elevated heart rates suggested that the energy expended by incubating penguins following close approaches by a human should be significantly higher than that of undisturbed penguins (Giese, 1998). In addition, when penguins were approached up to 5 m they exhibited aversive reactions and interrupted the incubation of their eggs. These changes in response to disturbance may explain why hatching success and chick survival of repeatedly disturbed colonies were reduced by 47% and 80%, respectively, compared to that of undisturbed colonies (Giese, 1996). Yarmaloy (1988) found that Mule Deer (*Odocoileus hemionus*) experimentally harassed by an all terrain vehicle altered their feeding and spatial-use patterns, which may explain why they produced fewer offspring the following year. Thus, if tourism disturbance persists or occurs frequently, impacts may extend to populations (e.g., Liley and Sutherland, 2007) and whole communities (e.g., bird communities in Chapter 5). Changes in these higher levels of biological organization may involve changes to population abundance and age-sex structure as well as changes in species community composition, species richness and diversity.

A central question in recreation ecology is how the usage intensity (amount of usage/level of usage) relates to the environmental response (Cole, 2004; Growcock, 2005). Generally, the type ('what biological variable'), level ('what organizational level is affected'), magnitude (intensity/strength; 'how big is the effect') and spatio-temporal distribution ('what area is affected', 'how persistent are the effects') of the effects (response) are a function of the usage intensity which itself is determined by the number of visitors and their behaviour (type of activity and individual behaviour). The environmental response is likely to increase with (1) greater numbers of visitors, (2) activities that involve prolonged usage and intensive physical contact with the environment (e.g., camping > stopping > passing visitors), (3) obtrusive individual behaviour (e.g., off-trail hiking > on-trail hiking) as all of these increase the usage intensity (see 8.2.1.1 for models of the relationship between usage intensity/amount of use and amount of impact/response). Thus, tourism impact studies should stratify visitor numbers by their behaviour (Chapter 3) as the same number of visitors can cause different damage to the environment depending on how they behave (Chapter 4–6). For instance, modes of approach to wildlife may vary depending on the means of transport used for travelling along recreational tracks which can cause different responses in wildlife (Chapter 6). The spatio-temporal distribution of visitor usage also affects the usage intensity and is partially a function of the visitor number and behaviour (Chapter 3).

A multitude of factors ('impact regulators') or interactions between them intervene in the visitor-environment relationship. In this study, unless they concern visitor management actions, they are referred to as 'modifying (moderating) factors' as they modify the outcome of the disturbance; in other words, they create the "disturbance context" (Steidl and Anthony, 1996: 484). Relevant factors include the season (Keane et al., 1979), time of day (Taylor and Knight, 2003b), climate (Bell and Bliss, 1973), weather (Carter and Goldizen, 2003) and openness of habitat (Lima et al., 1987; McLellan and Shackleton, 1989). Further, natural constraints determine where and when visitation and associated impacts can occur. In inaccessible and remote areas or seasons when access is hindered tourism impacts are less likely. For instance, trampling impacts in a steep mountain terrain were more confined to the immediate trailside whereas they extended further from the trail in flatlands (Chizhova, 2004). However, some impacts can spread from their primary impact points (e.g., the invasion of non-native species) to areas that are normally protected from usage effects due their inaccessibility. Other factors that also modify the effects of tourism disturbance include the properties of the individual animal and the group and species to which it belongs such as the group size (Roberts, 1996; Blumstein et al., 1999; Blumstein et al., 2001), closeness to other group members (Barry, 2005), age-sex class (Alberts, 1994; Recarte et al., 1998), physical condition or breeding stage (Wooley and Owen, 1978). Separate animal species have reacted with different levels of sensitivity to human disturbance (van der Zande et al., 1980; Blumstein et al., 2003; Gutzwiller and Barrow, 2003) which has been attributed, for instance, to food preferences (Canaday, 1995), degree of kinship (Lee et al., 2005), microhabitat specialization (Blakesley and Reese, 1988) and size (Cooke, 1980). Moreover, past experience with disturbance plays a role. Animals can habituate (Eibl-Eibesfeldt, 1970) to harmless disturbance if it is encountered repeatedly and becomes predictable, so that subsequent reactions to the same/similar stimuli wane (MacArthur et al., 1982). Cases of successful, intentionally promoted habituation have been described (Fossey, 1983; Blom et al., 2004) too. However, habituation cannot be assumed, even in areas with a long-standing history of tourism (Müllner and Pfrommer, 2001), and in some instances wildlife has even become sensitized by frequent tourism disturbance (Ellenberg et al., 2007). Conversely, wildlife can also become attracted to visitors or their infrastructure if they associate them with the availability of resources (Orams, 2002) (Chapter 5).

Tourism management is the vital factor for controlling visitor impacts on the environment and may be addressed through tourism planning frameworks (reviewed by Newsome et al., 2002) such as the Assessments of Recreational Carrying Capacities (Shelby and Heberlein, 1986), Recreation Opportunity Spectrum (Clark and Stankey, 1979), Limits of Acceptable Change (Stankey et al., 1985) and Visitor Impact Management (Graefe et al., 1990). These frameworks, incorporated into management plans of tourism areas, typically specify management objectives (including a definition of desired environmental conditions and unacceptable change) as well as strategies (broad conceptual approaches to management for achieving a desirable objective (Manning, 1979b)) and actions (specific management tools to implement various management strategies (Manning, 1979b)) for achieving them. Management strategies/actions to mitigate impacts may concentrate on the natural resources (e.g., site hardening, restoration/rehabilitation of sites or deliberate habituation of wildlife) or on the visitor domain. The management of visitors may involve the regulation of (1) visitor numbers, (2) visitor behaviour (including the factors that lead to a certain behaviour such as attitudes and expectations) and (3) the spatio-temporal distribution of visitor usage. A variety of strategies/actions for regulating the visitor domain exist such as those listed by HaySmith and Hunt (1995), Hall and McArthur (1998), Hammitt and Cole (1998), Green and Higginbottom (2001), Higginbottom (2004), Manning (2004) and Newsome et al. (2005). Strategies/actions range from regulating access to the accreditation of tour operators and the design/provision of low-impact tourism experiences. In addition, regulatory, legislative tools can be implemented (Cessford and Dingwall, 1997). Some management practices may be direct and exert a high degree of control over visitors (reviewed by Manning, 2004). For instance, certain behaviour such as littering may attract fines, or limits may be set to group sizes. Other management practices influence visitor behaviour indirectly instead of regulating it. For instance, visitors may be educated to low-impact behaviour and consequently choose to act that way rather than being coerced. Commensurate with employing management strategies/actions should be the implementation of a monitoring program that observes if the objectives of the tourism planning framework are met. This is achieved by measuring visitor (Chapter 2 and 3) and resource variables (Chapter 4 and 5) that indicate (Belnap, 1998; Buckley, 2004c) the current conditions of the ecosystem. Importantly, management procedures need to be adapted, if the objectives are not met.

At least in theory, tourism may potentially regulate itself when tourism-induced impacts have a feedback-effect on visitors. For instance, if visitors are repulsed by trash that other visitors have left behind, they may decide to properly dispose of their own trash. Alternatively, they may follow the bad example or disperse to a yet unspoilt area. If impacts are particularly subtle or require technical knowledge to be recognized (e.g., water pollution, invasion of exotic species), visitors may not even become aware of them. Essentially, the unpredictability of feedback-effects of resource impacts suggests that management cannot rely on them to prevent further impact. It is certainly a factor, though, that tourism operators have to be conscious of as unsatisfied visitors are unlikely to engage in the same tourism experience in the future or recommend it to others (Chapter 2).

1.3 Scope and aims of the thesis

Even though sustainability has become the paradigm of the tourism industry and a broad range of research exists on the impacts of nature-based tourism on the natural environment, current strategic management of impacts is hampered by a lack of information (e.g., Sun and Walsh, 1998; Buckley, 2001; Cole and Wright, 2004; Green and Giese, 2004; Beale, 2007) on (1) the effectiveness of specific management strategies/actions at regulating the relationship between the usage intensity and the environmental response, (2) the exact mechanisms that render a specific visitor behaviour more disruptive than alternative behaviour, (3) the influence of modifying factors on (1) and (2), and further (4) a lack of tour products that are scientifically tested to achieve high visitor satisfaction at comparatively low cost for wildlife.

This thesis examines particular issues emanating from this lack of knowledge in the context of nature-based tourism activities in the gorges of the Flinders Ranges. This well-promoted tourism destination lies in the semi-arid to arid South Australian Outback. The semi-arid parts receive on average between 250 and 500 mm rainfall per annum whilst the arid parts receive on average less than 250 mm (Leeper, 1970). The extensive semi-arid and arid zones of Australia (= 'arid lands': 44% are desert and 37% semi-arid grass and shrub lands (Williams, 1979)) largely encompass the rangelands. 'Rangeland' is the international term for areas where domestic stock are grazed on native vegetation and low or erratic rainfalls prohibit agricultural cropping or improved pastures (Newman and Condon, 1969). In this study, I often employ the term 'Outback' in place of 'rangelands' as it has become an internationally renowned brand for a unique Australian tourism experience. Apart from the pastoral zone the Outback encompasses the unoccupied areas of the western portion of the Australian continent, aboriginal lands and the deserts of inland Australia. The Australian Outback was chosen for study as its great species richness and high level of endemism make it biologically important and at the same time exceptionally attractive for nature-based tourists (Australian and New Zealand Environment Conservation Council, 1996). Further, there are very few studies on tourism impacts in semi-arid or arid ecosystems as recreation ecology in Australia has focused on alpine and sub-alpine environments (Sun and Walsh, 1998). The low level of attention that academic ecologists have generally paid to the impacts of nature-based tourism in Australia has been seen as a threat to the sustainability of the industry and its natural resources (Buckley, 1994); albeit in recent years the Sustainable Tourism Cooperative Research Centre has significantly advanced research in that field. Finally, the Australian Outback is an easily perturbed ecosystem with low fertility that experiences high environmental variance from frequent drought to occasional flood. Perennial vegetation is slow-growing and recruitment sporadic and so this region is particularly sensitive to disturbance since recovery is very slow and soil nutrients are readily lost from the system (Tongway et al., 2003).

Managing access to recreation areas is one in a range of tools available to protected-area managers to mitigate adverse visitor impacts. Instead of restricting access, the provision of a specific type of infrastructure (e.g., roads vs. hiking trails) may indirectly regulate the number of visitors or their behaviour. However, very little knowledge exists on how to best provide visitor access while avoiding as many of the adverse effects as possible. For instance, there is a lack of research that directly compares the environmental effects of roads and trails, although they are the most common recreational tracks in terrestrial ecosystems in Australia (Moon and Moon, 1998) and likely in many countries worldwide. The gorges in the Flinders Ranges offer excellent conditions to study visitor impacts in relation to the mode of access since some of the gorges are accessible to tourists via unpaved but well-maintained backcountry roads, whereas others are restricted to hiker access.

In this thesis, I adopt an observational and experimental approach to research short- and long-term effects of nature-based tourism activities on key attractions (vegetation, birds and kangaroos) in an environment that is accessible by roads or hiking trails and exposed to varying usage intensities. I will discuss the mechanisms that determine the magnitude and/or spatial extent of different types of environmental response and consider the influence of various modifying factors. Based on this knowledge, implications for visitor management and recommendations for low-impact behaviour will be discussed. This is complemented by research towards the design of a nocturnal observation tour of wildlife as an example of management of the visitor experience. Here, through the combination of methodology from the social and biological sciences, I aim to create a framework for a satisfying visitor experience that accrues from low-impact wildlife viewing and fulfils demand expressed by tourism stakeholders in the Flinders Ranges.

In the following, I will list the central aims of the individual components of this thesis and state the elements of the nature-based tourism framework (Fig. 1.1) that are addressed.

Five of the six data chapters (Chapter 3–7) of this thesis are formatted as separate manuscripts that have/will be submitted to peer-reviewed scientific journals for publication. These chapters comprise multi-authored works as they recognise the intellectual input of my supervisor and (in case of Chapter 3 and 5) of G. Hagenloh (see Acknowledgements); so the plural form is used to refer to the authors. However, I am the senior author of these chapters as I mainly conceptualised them, collected all field data and conducted the data analysis and writing up. A single common reference list is provided at the end of the thesis. Appendices are compiled there, too. Given that these chapters are intended as independent publications, they may share some common elements to fully inform potentially different readerships. Further, whilst throughout the thesis I refer to roads and hiking trails as being different 'access modes'/'access options', in Chapter 6 I instead employ the term 'transport style' and use 'access style' when I refer to on- vs. off-trail approach. This was more appropriate considering the free-standing character of the manuscript. Relevant hypotheses are developed and tested in the individual chapters.

Chapter 2: Visitor profile study

In summary, the central aim is:

→ to summarize the historical beginnings and recent developments of tourism in the Flinders Ranges and to create a character profile of tourists visiting the Flinders Ranges.

Relation to the elements of the nature-based tourism framework:

→ identifies preferred visitor activities as well as visitor attitudes and expectations which may influence individual visitor behaviour.

Chapter 3: Visitor monitoring study

In summary, the central aims are:

→ to determine the usage intensity of different gorge sections as the prerequisite for Chapter 4 and 5,

→ to characterise the type of visitor usage depending on the access mode to gorges,

→ to determine best practice visitor monitoring techniques.

Relation to the elements of the nature-based tourism framework:

→ identifies the usage intensity (visitor numbers stratified by behaviour) of the study sites,

→ researches the regulating impact of visitor management (vehicle vs. hiker access).

Chapter 4: Vegetation study

In summary, the central aim is:

→ to determine edge-effects of roads and trails on vegetation communities.

Relation to the elements of the nature-based tourism framework:

→ relates type (abundance, diversity, community composition), magnitude and spatial distribution of the long-term environmental response (vegetation, community level) to usage intensity (visitor numbers stratified by behaviour),

→ researches the regulating impact of visitor management (vehicle vs. hiker access),

→ researches the regulating impact of modifying factors (species of the disturbed subject),

→ all four impact mechanisms may be relevant.

Chapter 5: Bird study

In summary, the central aim is:

→ to determine edge-effects of roads and trails on bird communities.

Relation to the elements of the nature-based tourism framework:

→ relates type (abundance, species richness, community composition) and magnitude of the long-term environmental response (birds, community level) to usage intensity (visitor numbers stratified by behaviour),

→ researches the regulating impact of visitor management (vehicle vs. hiker access),

→ researches the regulating impact of modifying factors (vegetation variables, species of the disturbed subject, ecological traits of species),

→ all four impact mechanisms may be relevant.

Chapter 6: Kangaroo study

In summary, the central aim is:

→ to identify a low-impact approach to view kangaroos by driving vs. hiking visitors under consideration of visitor satisfaction.

Relation to the elements of the nature-based tourism framework:

→ relates type (behaviour) and magnitude of the short-term environmental response (kangaroos, individual level) to tourist behaviour,

→ researches the regulating impact of visitor management (driving vs. hiking visitors due to vehicle vs. hiker access to gorges),

→ researches the regulating impact of modifying factors (species and sex class of the disturbed subject, group size, vegetation cover, time of day and wind speed),

→ direct stimulation is the relevant impact mechanism.

Chapter 7: Nocturnal wildlife observation study

In summary, the central aim is:

→ to design a sustainable form of nocturnal observation of wildlife that can be offered by tourism providers in the Flinders Ranges and other areas of Outback Australia with similar ecology.

Relation to the elements of the nature-based tourism framework:

→ relates type (behaviour, abundance, species richness, community composition) and magnitude of the short-term environmental response (mammals, birds, reptiles; individual and community level) to individual tourist behaviour,

→ researches the regulating impact of visitor management (hiking in creek beds vs. stationary observations at artificial watering holes, provision of different observation equipment, variation in timing of tours),

→ researches the regulating impact of modifying factors (species of the disturbed subject, habitat differences, time of day and wind speed),

→ direct stimulation is the relevant impact mechanism.

Synthesis

Chapter 8 synthesizes the results of the preceding chapters. It discusses key findings and limitations, in the context of emergent themes; namely, the identification of tourism impacts and impact mechanism, and their management via access regulation, visitor education on low-impact behaviour and low-impact tour products. The Synthesis concludes by suggesting future research directions.

Chapter 2
Profile of tourists in the Flinders Ranges

"*We rode up to the extremity, and then all at once there came full upon us a sight such as one sees only in pictures of those weary lands where the shadow of a rock is counted an unspeakable blessing. In the heavens there was a mist or murky haze, which battled with the sun's bright rays, scattering the red in all directions, . . . and making it at the same time unnaturally impressive. Below this lurid, waste, and wild, an unbroken plain, an unruffled sea of land . . .*"

(Jessop, 1862: 198)

The impression of an early traveller in the Flinders Ranges from a vantage point.

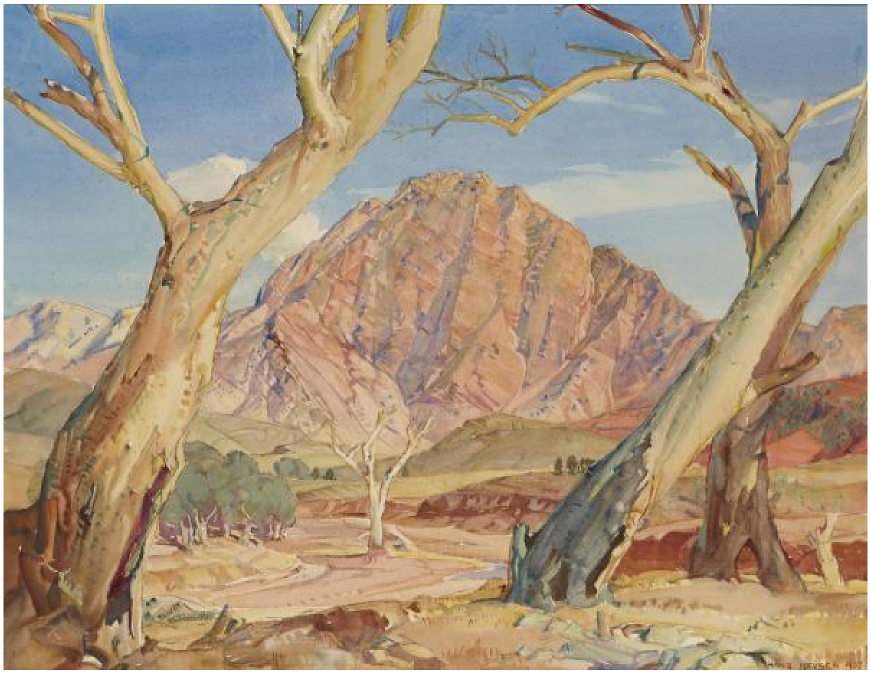


Fig. 2.1. "Guardian of the Brachina Gorge", 1937, watercolour over charcoal, 48.2 x 62.4 cm (image) by Hans Heysen, born Germany 1877, arrived Australia c.1884, died 1968. Reproduced with permission of the National Gallery of Victoria, Melbourne, Felton Bequest, 1937, © National Gallery of Victoria.

2.1 Abstract

The purpose of this chapter was to summarize the historical beginnings and recent developments of tourism in the Flinders Ranges and to create a character profile of tourists visiting the Flinders Ranges. In particular, the question was asked as to whether the visitor market was divided into a distinct hiker and driver segment, based on the visitors' inclination to engage in hiking (and/or walking) activities vs. scenic driving.

Data were collected by means of a questionnaire-based survey by interview at wild and designated campgrounds in some of the most frequented tourist sites in the study area. The results show that the majority of participants (89.8%) were from Australia, older than fifty years (61.4%) and travelled as adult couple (45.6%) or friends/relatives (29.8%) in a group of two (60.2%). Many people (67.5%) had visited the Flinders Ranges before and 71.6% of respondents were planning to revisit in the future, with peak visitation occurring between August and October. The gorges were particularly popular and almost everybody (96.5%) visited at least one of them. The main sources of information used to prepare for the trip were word-of-mouth (39.50%) and travel books (25.7%).

Cluster analysis combined with a similarity profile permutation test enabled a segmentation of the visitor market into a large driver segment (73.7%), and a smaller hiker segment (26.3%). Drivers typically spent much less daylight time with hiking in favour of scenic driving, and they also planned to go on shorter hikes during their stay than hikers did. Against expectation, a majority of hikers was not willing to camp away from their vehicles but the percentage of those hikers that did consider this option, still clearly exceeded the percentage of drivers that did. Although physical exercise motivated every second hiker to visit the Flinders Ranges, a large percentage of hikers stated that they had also come to relax. Drivers and hikers shared most of their motivations to visit the Flinders Ranges, and both were particularly keen on enjoying nature/camping/being outdoors. Most visitors judged their level of knowledge on tourism impacts as medium to very high, and many rated the possible impacts of tourism on the environment in the Flinders Ranges as medium to strong, with 19 potential impact categories being cited.

The results have clear implications for visitor management in terms of visitor behaviour and associated environmental impacts and visitor needs.

Key words: tourism history, visitor profile, market segmentation, Flinders Ranges.

2.2 Introduction

2.2.1 The historical beginnings of tourism in the Flinders Ranges

The anthropocentric history of the Flinders Ranges (see map; Fig. 2.2) is one of Aboriginal settlement commencing over 40 000 years ago and European occupation since the 19th century; the latter mainly for pastoralism and mining (Mincham, 1980). Another element to the history that has gained a high importance in the 20th century is tourism (Morelli, 1996).

Initially, touring in the Flinders Ranges was a crude adventure and the early traveller had to endure rough tracks and cope without any amenities. One of the few, genuine travellers, who explored the Flinders Ranges in the early days for purposes other than pastoralism or mining, was William Jessop. He ventured to many areas long before trails were built; for instance, to St Mary Peak, the highest peak in the Flinders Ranges. Today this hike is one of the most popular excursions in the region and follows a clearly defined track, but at the time Jessop wrote (1862: 256):

> "*I now began to ponder: Was that The Peak that I saw before me? . . . There was nothing for it but to get down into the tiresome gulley, and tiresome it was. I leapt, slid, and clomb. . . . Next I got into such an abominable bush and shrub, that I was obliged to button up, duck my head, and run through . . . and at last after leaping from one enormous block to another, after attacking a monstrous mass and recoiling from the assault, after winding in and out, up and down, now going round this way, then coming back to try the other, by dint of obstinate progression I had the satisfaction to find myself on the top.*"

More than half a century later in 1926, Hans Heysen, a young artist, discovered the Flinders Ranges for his artwork, and greatly popularized the area among the general public with the unique landscapes he portrayed in his paintings (e.g., Fig. 2.1). Heysen became one of South Australia's most significant artists and with the dissemination of his paintings, the Flinders Ranges finally gained their status as a tourist attraction (Morelli, 1996). Others wanted to see what Heysen said had made him "curiously aware of a very old land where primitive forces of Nature were constantly evident" (Art in Australia 1932: 18–19, in Barker et al., 2000). About this time the Paralana Hot Springs in the Arkaroola region started to draw visitors into the northern Flinders Ranges, as an early expression of spa and health tourism (Adelaide Chronicle, 1928c). The travellers came to seek relief from rheumatism by the aid of the mineral content of the hot springs.

Ironically, nowadays, signs warn the weary traveller to abstain from swimming or drinking the water as its radioactivity constitutes a health hazard.

Given the increased tourism demand in the 1930s, both Bond's (e.g., Bond's Scenic Motor Tours, 1936) and Bastin's buses pioneered weekly winter and spring tours as far north as Blinman (Mincham, 1980; Bonython, 1996), and plans for trains were contrived that would haul tourists and their vehicles travelling to the region (Adelaide Chronicle, 1928b, a). Apart from the scenic beauty, visitors were tempted to come to the Flinders Ranges to engage in consumptive varieties of tourism such as for the shooting of birds. This, however, induced a quarrel between tourism stakeholders and wildlife protection agencies that queried the wisdom of such a method of attracting tourists (Williams, President and Historian of the Friends of the Flinders Ranges National Park, pers. comm.). By 1945, tourism had increased to the extent that Wilpena Pound was proclaimed a National Pleasure Resort (Bonython, 1996), and the Adelaide Advertiser (Mountford, 1945: 5) predicted a prosperous future for the township of Blinman and surrounds:

> ". . . *for, with the development of motor transport, and the spread of tourist traffic, this town and the ranges about it promise to be the winter playground of South Australia, if not of the whole continent. . . . the roads lead outward into precipitous gorges, rugged, colourful ranges, and along watercourses lines with giant creek gums. . . . to the east are deep gorges that have no parallel in this State.*"

In 1947, Bond's Scenic Motor Tours built the Wilpena Chalet at the entrance to Wilpena Pound (Bonython, 1996), and since 1959 the Rasheed family has been operating and expanding the Chalet into the present Wilpena Pound Tourist Resort (Morelli, 1996). This family became instrumental in establishing the Flinders Ranges and Wilpena Pound as a key tourism asset of South Australia and sparked tourism development in the whole region. Notwithstanding their aspirations, they showed concern against possible negative effects of tourism. For instance, when The Age (1969: 10) reported about the discovery of a "spectacular gorge, described as comparable with the Great King's Canyon" in the Flinders Ranges, Kevin Rasheed cautioned that "Before it's opened up, we would like to have some controls over visitors, to protect the natural features and the wildlife".

Gradually, the Government purchased areas in the Flinders Ranges for national park purposes. In 1972 Flinders Ranges National Park (FRNP) was created, which by 1988, had reached its present size of 784 km^2 (Mincham, 1980). The control of the park was vested to the Government under the National Parks and Wildlife Act (Bonython, 1996). Much of today's Vulkathunha-Gammon Ranges National Park was proclaimed a park in 1970. In 1985 Balcanoona, a station that joins both the present Vulkathunha-Gammon Ranges National Park and Arkaroola Wilderness Sanctuary, was acquired to create a contiguous conservation area of nearly 1800 km^2 (Mincham, 1980) in the northern Flinders Ranges. Arkaroola itself had been purchased by Reg Sprigg in 1968 who commenced an extensive restoration and conservation project there that nowadays has developed into a tourism venue which stands out in its effort to promote sustainable practices (Chapter 7).

In 1994, a proposal for a big tourism development on the former Wilpena Station land catering for more than 3000 guests was finally fended off after seven years of persistent opposition from conservationists (Bonython, 1996). In 2008, Wilpena Pound Tourist Resort was purchased by 'Anthology the Travellers' Collection' as part of their quest to create "one of the world’s finest experiential travel brands" (http://www.anthologytravel/). The company's investment into Wilpena is considered a great step forward for tourism in the entire state of South Australia (South Australian Tourism Commission, 2008a).

2.2.2 Recent tourism developments in the Flinders Ranges

Already back in 1980, the minimum gross benefits of tourism in the Flinders Ranges with an estimated A$8.42 million exceeded that of pastoralism with an estimated A$4.80 million (Sinden et al., 1980). Today the economic benefits of tourism have multiplied many times, and the spending of domestic overnight visitors to the Flinders Ranges in 2007 amounted for an estimated A$122 million (South Australian Tourism Commission, 2008b). Domestic day trip visitors to the Flinders Ranges spent another estimated A$47 million. Thus, unsurprisingly, many landowners engage in the tourism industry and provide accommodations and/or guided tours on their properties and surrounds. The tour operators have organized themselves into the Flinders Ranges Tourism Operators Association (http://www.flindersrangesoperators.com.au/strategic_plan.htm) that advocates tourism in the Flinders Ranges and facilitates collaboration between tourism stakeholders. Many of them have also engaged with the Regional Tourism Project (http://www.regionaltourism.com.au/ARTRC/destinations/dest_project.html) initiated by the Australian Regional Tourism Network and funded by the Sustainable Tourism Cooperative Research Centre to research best-practice destination marketing and management in a regional context. Certainly, tourism operators around FRNP will benefit from the on-going expansion of the bitumen on the road between Hawker and Blinman which will make the area more accessible during all weather conditions. Aspirations of tourism stakeholders in the Flinders Ranges are also well supported by the state's intention to promote tourism throughout South Australia based on fundamental regional and state-wide planning strategies (reviewed by Planning for People, 2008). This includes initiatives such as the Responsible Nature-based Tourism Strategy, 2004–2009, the Flinders Ranges and Outback South Australia Integrated Strategic Tourism Plan, 2008–2014, and the Department for Environment and Heritage (DEH) Trails Strategy, 2008–2012; as well as strategies for long-distance trails passing through FRNP, and specific plans for FRNP management. Altogether, these approaches aim to encourage more people to engage in outdoor recreation in South Australia and to create a nature-based tourism sector which achieves economic viability, social responsibility and environmental sensitivity.

In recent years, the Flinders Ranges have come to attract tourists in ever-increasing numbers which can best be exemplified by the development in FRNP, the national park with the best established monitoring system of total visitor numbers in the region. The numerous visitor surveys (e.g., road surveys, questionnaires, counts of camping permits) that have been conducted there from 1976 till 1981 (reviewed by Hinsliff, 1996) estimated that an average of 40 000 overnight visitors came to the park per year for an average of 3.6 days each. In contrast in 2007/2008, FRNP received approximately 127 000 (overnight and day) visitors as estimated from traffic counters at the park entrance (Sandercock, Visitor Management, DEH, pers. comm.). The South Australian Tourism Commission (2008b) reports that in 2007, the Flinders Ranges and Outback South Australia, in total, attracted an estimated 589 000 overnight visitors that spent nearly two million nights there. In comparison, no consistent data exist for Vulkathunha-Gammon Ranges National Park but estimates suggest approximately 15 000 overnight visitors per year (Sandercock, Visitor Management, DEH, pers. comm.).

2.2.3 Visitor profile and market segmentation

The present survey studied the visitor market to FRNP and Vulkathunha-Gammon Ranges National Park to create a visitor profile with a focus on visitor demography, trip itineraries, motivations, preferred activities, environmental attitudes and tourism impact knowledge as there is very little information available on these critical visitor characteristics for the region. The survey also aimed to segment the market based on the visitors' inclination to engage in hiking (and/or walking) activities vs. scenic driving. These are the common activities which are marketed for the Flinders Ranges and for which specific infrastructure is provided. During a field trip in May 2006, observations of visitor usage at various gorges as well as discussions with park personnel and locals suggested a distinct divide in the visitor market, with some people strongly interested in hiking activities and others intending to explore primarily by car.

In general, visitor market segmentations have successfully been employed to identify heterogeneous visitor segments in nature-based tourism destinations (Laarman and Durst, 1987; Palacio and McCool, 1997; Hvenegaard, 2002; Weaver and Lawton, 2002; Poria et al., 2004; Mehmetoglu, 2005; Mehmetoglu, 2007) based on demographic criteria such as age, and on behavioural variables such as the type of activities preferred, or on socio-psychological factors such as visitor attitudes (Cochran, 1996). However, many of the existing segmentations have theoretical rather than empirical character (Hvenegaard, 2002). Therefore, Mehmetoglu (2007) suggested to segment nature-based tourism markets empirically according to the visitors' trip activities and characteristics, and to find out if the segments have distinct motivations for the current trip.

The activity-based segmentation undertaken in this study, relates to the core question of the thesis; namely whether different access modes and their associated primary activities (hiking vs. driving) influence visitor usage of gorges and as a consequence their environmental impacts. Further, different visitor market segments likely have different trip expectations, which in turn will affect their satisfaction with a particular tourism experience. Since the thesis attempts to reconcile environmental sustainability with the sustainability of the visitor experience (a function of satisfaction), it is necessary to uncover a potential segmentation in the visitor market that exerts an influence on both of these aspects of sustainability.

I conducted a typical segmentation analysis where the market is segmented based on a set of factors believed to be causal, and then tested how well the segments developed certain behaviours of interest (Fodness and Murray, 1997). The hypotheses that provided the base for the segmentation, namely the variables that were used in the clustering procedure (2.3.2), were as follows: (1) 'Drivers' would be more keen on spending a relaxing holiday, (2) were less inclined to perform physical exercise, (3) would therefore spend less time with hiking (and/or walking), (4) their hikes would also be shorter than that of 'hikers' and (5) they would be less inclined to camp at sites without vehicle access. Finally, possible differences between hikers and drivers in their travel motivations, environmental engagement and tourism impact knowledge were examined.

2.3 Methods

2.3.1 Study area

The survey was conducted in the Flinders Ranges (dashed line in Fig. 2.2), which begin near the Spencer Gulf and reach northward between Lake Frome and Callabonna almost to Lake Blanche. The predominant focus were nature-based tourism activities taking place in six gorges (Fig. 2.2, Table A 1.1) located in the central and northern Flinders Ranges from the Flinders Ranges National Park (Wilpena: lat. 31° 30` S, long. 138° 30` E) into the Vulkathunha-Gammon Ranges National Park (Balcanoona: lat. 30° 30`, long. 139° 30`). The natural assets of this tourism destination are described in detail in Chapter 3–7.

The thesis author and several trained volunteers administered the survey at wild and designated campgrounds within or close to the study gorges, and at the campground/visitor centre in Wilpena and Balcanoona, some of the most frequented tourist sites in the study area.

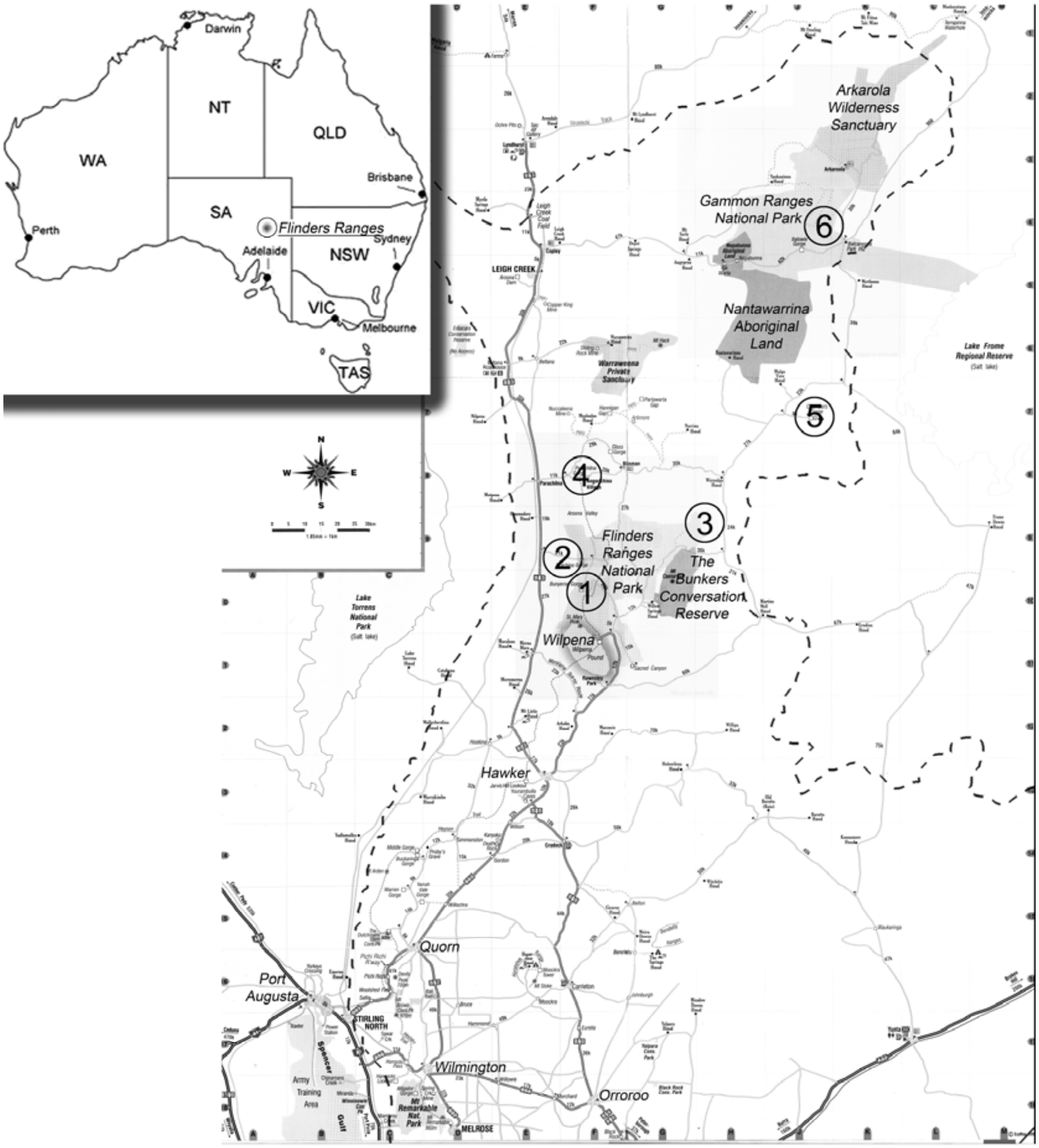


Fig. 2.2. Location of the Flinders Ranges (approximated with dashed line) in South Australia and the study area with the study gorges and their respective access mode: 1 = Bunyeroo (trail), 2 = Brachina (road), 3 = Wilkawillina (trail), 4 = Parachilna (road), 5 = Chambers (one part road, one part trail), 6 = Weetootla (trail). Map was reproduced with permission from EzyMap (dashed line and study site markings were added by the thesis author).

2.3.2 Survey

A questionnaire-based survey was developed following suggestions on optimal survey design by Rhodegier (1996), and where possible (to facilitate direct comparisons), questions were based on other research such as Hatch and Blamey (1998) and DEH (survey in the Flinders Ranges undertaken in 2005, unpublished data). In the first part of this survey (discussed in this chapter), open-ended, closed and 5-point Likert-scale questions assembled information on visitors (Table A 1.2a). In the beginning of this part of the survey, I examined the demographic characteristics of respondents followed by questions on their trip itineraries and means of preparation. Then, trip incentives and activities were assessed to identify a potential market divide into driver and hiker segments. The final questions investigated the environmental engagement and tourism impact knowledge of the survey respondents. The second part of the survey estimated visitation patterns of the study gorges and will be discussed in Chapter 3. Questionnaires had undergone some pilot testing prior to their use, and were adapted where necessary.

The questionnaire-based surveys were conducted by interview with adult tourists (>18 years) willing to participate (85% of those approached) from July to December in 2006 and 2007. This time period covered the two shoulder and the peak tourist season (spring) for the Flinders Ranges. In spite of being more labour-intensive, a direct face-to-face survey methodology was selected as it achieves high response rates, and the completeness of the given responses can be ascertained. Further, the second part of the survey required that the survey administrator presented and explained maps of the study area to the survey respondents. Finally, some additional comments of the respondents could be gathered to complement the discussion of the results.

A total of 357 questionnaires were collected from the survey, but 15 questionnaires were eliminated prior to analysis because of missing data. The responses from the visitor surveys were entered into Data Entry 4.0 for Windows (SPSS, 2007b) and subsequently analysed with SPSS for Windows 17.0 (SPSS, 2008). Responses to open-ended questions were categorized by manually extracting descriptive words used by participants, to compare the percentage of survey participants that had stated a particular answer category.

A hierarchical cluster analysis (unweighted, group-averaged) was employed in PRIMER v6 (Clarke and Gorley, 2006) to classify visitors to the Flinders Ranges into mutually exclusive groups, on the basis of their inclination to engage in hiking (and/or walking) vs. scenic driving during their vacation. Questions (or particular responses in a multiple response set) that in accordance with the hypotheses were likely to indicate this engagement (Table 2.1) were used to assemble the multivariate data matrix (survey participants x response variables). From that the Bray-Curtis similarity matrix was calculated as the base for the cluster analysis.

Further a similarity profile (SIMPROF) permutation test was calculated in PRIMER v6 which looks for statistically significant evidence of genuine clusters in samples which are a priori unstructured (Clarke and Gorley, 2006; Liu et al., 2007). It tests that the groups after being sub-divided at a node of a dendrogram have significant internal structure.

Following the market segmentation, chi-square tests were used in SPSS for Windows 17.0 to identify significant differences among segments in regards to their travel motivations, environmental engagement and tourism impact knowledge. For multiple response questions, separate chi-square tests had to be conducted for each response. The standardized residuals for each cell in the contingency table were calculated to determine at which level of a visitor characteristic (e.g., at which of the levels of the tourism impact rating) a significant difference between driver and hiker frequencies occurred. This is equivalent to calculating a simple effects test (Field, 2005) in an ANOVA as a follow-up procedure for the interaction between two factors. The standardized residuals were calculated as the difference between the observed and expected frequencies divided by an estimate of their standard deviation. Values <-1.96 or >1.96 are significant on the $P < 0.05$ level (Siegel and Castellan, 1988), and the frequency of observations in that cell should be regarded as significantly lower and higher, respectively, than expected.

2.4 Results

The survey revealed that the majority of participants (89.8%) were from Australia, particularly from South Australia (33.6%) and Victoria (35.5%). Most of them travelled as adult couple (45.6%) or friends/relatives (29.8%) in a group of two (60.2%) (vs. single travellers: 7.6%, and groups of three: 8.5%, of four: 11.7%, of five to ten: 7.6%, of more than ten travellers: 4.4%). A few groups (13.2%) consisted of parents travelling with their children. Tour groups (3.2%) or business associates travelling together (0.6%) were rare. The majority of people (61.4%) was older than fifty years (vs. ≤20: 3.8%, ≤30: 11.4%, ≤40: 14.6%, ≤50: 8.8%).

Many people (67.5%) had visited the Flinders Ranges before and 71.6% of respondents were planning to revisit in the future. Their trip duration in the past had lasted for 1 to 3 days (37.1%), 4 to 7 (35.9%) or more days (27%) whilst during their current visit they planned to stay 1 to 3 days (17.3%), 4 to 7 (51.5) or more days (31.2%). Visitation patterns were seasonal with peak visitation (62.6%) occurring between August and October. The gorges were a major tourist attraction with virtually every survey participant (96.5%) visiting at least one of them (Chapter 3 for details). The main sources of information used to prepare for the trip were word-of-mouth (39.50%) and travel books (25.7%). Fewer people consulted the internet (13.20%), maps (8.20%), brochures at accommodation (4.4%) or visitor information centres (3.2%), newspapers/magazines/advertisements (1.5%), or travel agents (1.8%). Nobody had relied on radio/television to prepare for the trip.

The cluster analysis suggested that a 2-cluster solution was appropriate for segmenting the visitor market as both clusters delineated relatively homogenous segments of survey respondents: the members of cluster 1, hereafter referred to as the 'driver' segment, resembled each other in their low inclination to hike (and/or walk) at 73% or more; the members of cluster 2, the 'hiker' segment, reached a similarity of 69%. At this level of partitioning, SIMPROF found statistically evident sub-structure within the clusters ($Л = 3.1$, $P = 0.001$); namely, significant differences between the groups and not within each group. Conversely, joining these two clusters would have resulted in a single cluster that was markedly less homogenous (more so than after joining any other clusters at different nodes of the dendrogram (Hair et al., 2006)).

According to the chosen segmentation, the tourist market consisted of a large segment of drivers (73.7%) and a smaller segment of hikers (26.3%). Consistent with expectations, drivers spent on average almost three times as much daylight time (from 7:30 am till 5 pm) with scenic driving and less than a third of daylight time with hiking compared to hikers (Table 2.1). Drivers also planned to go on shorter hikes during their stay than hikers did (Table 2.1). Against expectation, a majority of hikers was not willing to camp away from their vehicles but the percentage of those hikers that did consider this option, still clearly exceeded the percentage of drivers that did (Table 2.1). Physical exercise motivated every second hiker to visit the Flinders Ranges. Notwithstanding, a large percentage of hikers stated that they had also come to relax, which was a major travel incentive for the majority of drivers (Table 2.1).

Table 2.1. Visitor characteristics that were used in the cluster analysis to segment the Flinders Ranges visitor market into driver and hiker segments.

Visitor characteristic	Driver (%) *n* = 252	Hiker (%) *n* = 90
Mean (± 1 SE) % daylight time spent with		
Scenic driving	59.8 ± 1	20.8 ± 2
Hiking/walking	16.9 ± 1	56.8 ± 1
Length of hikes/walks		
≤1 km	27.8	4.4
1 km < x ≤ 3 km	47.2	38.9
3 km < x ≤ 5 km	19.0	20.0
5 km < x ≤ 10 km	4.0	22.2
>10 km	2.0	14.4
Willingness to camp away from car		
	4.4	34.4
Trip incentives (multiple responses)		
Relaxation	56.0	37.8
Physical exercise	20.2	46.7

Despite these differences, drivers and hikers shared most of their motivations to visit the Flinders Ranges (Table 2.2). Particularly important were the enjoyment of nature/camping/being outdoors, geology/landscape/scenic views and vegetation/wild-flowers. While both drivers and hikers were equally eager to view wildlife (in general), hikers were more articulate about the specific fauna groups that they wanted to observe; that is, a significantly higher percentage of hikers confirmed the importance of kangaroos/wallabies, birds and reptiles as being a main travel motive.

Table 2.2. Trip incentives for driver and hiker segments of the Flinders Ranges visitor market.

Trip incentives (multiple responses)	Driver (%) n = 252	Hiker (%) n = 90	Chi-square test
Enjoyment of nature/camping/being outdoors	72.2	70.0	
Geology/landscape/scenic views	56.7	52.2	
Vegetation/wildflowers	49.6	43.3	
Wildlife (in general)	49.6	58.9	
Solitude	36.1	40.0	
Kangaroos/wallabies*	22.2	44.4	$\chi^2_{(1)} = 16.22$, $P < 0.001$
Photography and/or art	21.4	17.8	
Birds*	19.8	52.2	$\chi^2_{(1)} = 34.22$, $P < 0.001$
Socialising with family/friends	18.3	12.2	
Educational experiences	17.9	18.9	
Aboriginal heritage and art	13.5	5.6	
Reptiles*	9.1	26.7	$\chi^2_{(1)} = 17.21$, $P < 0.001$

Note : Asterisks indicate significant chi-square tests.

Both drivers and hikers were equally active at supporting environmental organizations (multiple answers). Therefore the percentages for the whole survey sample are presented. Respondents supported environmental organisations as members (27.8%) and through donations (43.6%), and some actively engaged in volunteer work to support the environment (24%). Notwithstanding, 28.7% indicated that they were more involved in supporting other 'good causes'. Most visitors judged their level of knowledge on tourism impacts as medium to very high, and many rated the possible impacts of tourism on the environment in the Flinders Ranges as medium to strong (Table 2.3). However, the percentage of hikers that considered themselves very highly informed about tourism impacts and that rated tourism impacts as very high was significantly greater than that of drivers (Table 2.3). Notwithstanding, hikers cited similarly often the same potential impact categories of tourism on the environment in the Flinders Ranges. Altogether, 19 categories (multiple answers) of possible impacts were stated by drivers and hikers including littering (35.1%), destruction of plants for firewood and due to trampling (32.7%), disturbance of wildlife (29.5%), increase of air (scenic flights)/road traffic (25.4%), noise (20.5%), landscape changes (15.8%), build up with infrastructure (10.8%), overcrowding (9.6%), erosion and soil changes (8.2%), increase of weeds

(7.9%), roadkill (7.6%), increase of pest animals (5.0%), feeding of wildlife (4.7%), setup of new campfires/expansion of campsite areas (4.1%), disturbance of flora/fauna at waterholes (4.1%), general habitat destruction (3.2%), water pollution (2.3%), off-track traffic/wild camping (1.8%) and the pervasion of the ecosystem with access routes (1.8%). Only 5.3% of respondents had 'no idea' what negative impacts tourism might cause on the environment of the Flinders Ranges.

Table 2.3. Impact knowledge and impact ratings among driver and hiker segments of the Flinders Ranges visitor market.

Visitor characteristic	Driver (%) *n* = 252	Hiker (%) *n* = 90	Chi-square tests
Self-rated level of knowledge of tourism impacts*			$\chi^2_{(4)} = 18.19$, $P = 0.001$
1 = Very low	10.3	5.6	
2 = Low	12.3	10.0	
3 = Medium	30.6	20.0	
4 = High	30.2	26.7	
5 = Very high[a]	16.7	37.8	
Tourism impact rating*			$\chi^2_{(4)} = 12.76$, $P = 0.003$
1 = Very low	11.9	15.6	
2 = Low	12.3	7.8	
3 = Medium	28.6	34.4	
4 = High	40.1	25.6	
5 = Very high[a]	7.1	16.7	

Note : Asterisks indicate significant chi-square tests.

[a] At this level of the particular visitor characteristic, the standardized residuals of the cells of the contingency table, constructed for the chi-square test, indicated a significant difference between driver and hiker frequencies.

2.5 Discussion

The survey revealed that the majority of the participants were from Australia, older than fifty years and that most of them travelled as an adult couple or friends/relatives in a group of two. These results were highly consistent with a survey by the DEH in 2005 (unpublished data) of 305 visitors to Flinders Ranges National Park with self-administered questionnaires. This suggests that the present survey sample was representative of the population of visitors to the Flinders Ranges. The proportion of international visitors was comparatively small, which may be related to the fact that it is time-consuming to reach the Flinders Ranges. International visitors to Australia have to allocate their limited vacation time between widely spaced natural attractions so that they may first concentrate on internationally renowned sites such as Uluru-Kata Tjuta National Park. Consistent with expectations visitation patterns were highly seasonal with peak visitation occurring between August and October, when ambient temperatures are most comfortable. Given that this optimum travel season coincides with the school term (except for spring break), this may explain why most travel parties consisted exclusively of elder adults without children. Further, the Flinders Ranges are located too far away from major population centres as to attract a noticeable influx of weekend vacationists that might bring their children along. Hatch and Blamey (1998) too noticed that the older age classes, whose (if any) dependent children had left home, were one group of international visitors to Australia that was particularly drawn to participate in nature-based tourism activities. In the present survey, tour groups were rare which is consistent with a survey of 486 visitors by the DEH in 2001 (in Planning for People, 2008) with self-administered questionnaires. That survey found that 83% of respondents accessed FRNP by private vehicle, and only 7% came to the park on organized tours.

The re-visitation rate to the same or other parts of the Flinders Ranges was very high, and many people expressed their wish to return in the future. Gitelson and Crompton (1984) found that repeat visitors were more likely to be older individuals seeking relaxation which is consistent with the demographic characteristics and a typical travel motivation for many of my survey respondents. Five reasons were postulated (Gitelson and Richard, 1984) as to why people return to a destination including risk reduction, emotional attachment, meeting the same kind of people, a chance to explore sites that they had not explored in the past and a chance to introduce the destination to others. Ryan (1995a), too, suggested that the high loyalty of repeat visitors towards a previously satisfying destination may be strongly related to risk aversion. The distinction between repeat and non-repeat visitors is of importance as it determines certain aspects of visitor behaviour such as their willingness to travel distances (Moutinho and Trimble, 1991) and their patterns of dispersion. For example, repeat visitors to New Zealand remained much more concentrated in fewer locations (Oppermann, 1994), whilst "destination-naive" (Snepenger et al., 1990: 13) visitors would disperse further and were much more active during their stay (Oppermann, 1994). As a result, environmental impacts of repeat visitors should concentrate on fewer locations than those of first-time visitors. Indeed, several of the survey respondents remarked that they—due their previous experience in the Flinders Ranges—were more site-selective, and many would camp at a few of their favourite sites, year after year.

Current visitors spent more time in the Flinders Ranges compared to previous visitors as the proportion of visitors staying for 1–3 days had declined in favour of those staying 4–7 days. The increase in fuel prices over the years may have motivated current visitors to spend a longer time in the same area rather than travel between places. Additionally, some visitors may have learnt from previous experience that it is more relaxing to have sufficient time available on-site, given the relatively long journey to reach the destination. Finally, given that repeat visitors are speculated to be risk-averse, perhaps some of them dare to stay longer on their repeat visits because they trust that their experience will be satisfying.

In the course of travel planning, survey respondents used a variety of sources to prepare for their trip. In general, the need to prepare arises as travellers seek to find out what opportunities are available in their destination, where they can be found, and what costs are involved (Raitz and Dakhil, 1989). Gathering this knowledge will enhance the trip quality by reducing the degree of uncertainty associated with travelling (Goeldner and Ritchie, 2006). Initially, many travellers use their internal knowledge accrue from past experience as the basis for planning a repeat visit or a first-time visit to a destination with similar characteristics to a previously visited location. Even though, I did not investigate this type of information search, many of the survey respondents remarked upon relying on their past experience for having organized their current trip. In addition to internal information, tourists may choose from a wide range of external sources (Raitz and Dakhil, 1989; Murray, 1991). These can be classified broadly (Engel et al., 1995) into impersonal information from commercial (e.g., brochures and guide books) as well as non-commercial sources (e.g., magazines and newspapers), and personal information from commercial (e.g., auto clubs and travel agents) as well as non-commercial sources (e.g., friends and relatives, other formal or informal social networks). In accordance with previous studies on nature-based tourists (Hatch and Blamey, 1998) or canyoners (Hardiman, 2003) in Australia, the main source of information to prepare for the trip to the Flinders Ranges was by word-of-mouth, that is a personal non-commercial information source. Many travellers explained that this was the best way to ensure that information was accurate in terms of, for instance, conditions of roads and campsites as well as prices for tours or fuel. One traveller also remarked that fellow travellers were considerably more objective than travel agents or tourist brochures and that "they would tell the real story". Thus, these results confirm the significant impact of word-of-mouth promotion in destination marketing, which has been more generally observed in hundreds of studies on how consumers collect information about services and products (Engel et al., 1973). Even though, Gitelson's and Crompton's study (1983) on information sources used by U.S. pleasure vacationers corroborates my findings, it also reports that 11 other external sources were used by people (6% to 30%), and typically at least one other information source was employed besides consulting with relations. In my survey, only travel books played another major role. In contrast, internet or maps were not used as frequently, and travel agents were rarely consulted. However, it needs to be noted that the present survey asked respondents to state the primary source that had facilitated their trip preparation. Had they been asked to list all sources, likely more of them would have been identified as influential.

Which particular source of information is consulted for trip preparation, depends on a variety of factors, such as socio-demographic characteristics of the travellers (Gitelson and Crompton, 1983), their trip motivations (Gitelson and Crompton, 1983), the past experience and the degree of novelty associated with the destination (Snepenger et al., 1990). Gitelson and Crompton (1983), for instance, found that print media were used more than expected by older market segments (those over 59), which may explain why travel books played a pivotal role in informing my survey respondents. Travel agents seem to be overly important among destination-naive tourists and women travellers (Snepenger et al., 1990). Likely, because many of my survey respondents were repeat visitors and travelled as couples, the need to communicate with travel agents was low. Further, since solitude was an important trip motivator, the independent nature of the survey respondents may have motivated visitors to create their own itineraries and tour experience rather than pre-booking tours. Independent travellers also enjoy not planning every detail of their vacation in advance and tend to engage in serendipitous opportunities (Hyde and Lawson, 2003). In general, the greater the degree of novelty associated with a destination the greater is the need to conduct an extensive information search with a variety of information sources (Crompton, 1979). Gitelson and Crompton (1983) found that excitement (vs. relaxation) as a trip purpose negatively correlated with people seeking information from friends and that those seeking excitement are likely to utilize as many different types of information sources as possible. Given that relaxation was a major trip motivation for many of my survey respondents, may therefore explain why word-of-mouth played such an important role in their information search strategy. Finally, the choice of information source may also depend on the stage of the vacation (Hyde and Lawson, 2003).

Enjoying the natural environment, for instance, while camping, was the main motivation for people to travel to the Flinders Ranges. The next most popular reasons were admiring the landscape and geological formations as well as observing flora and fauna. Similarly, the DEH survey in 2005 (unpublished data) found that the single most important factor to visit FRNP, was to enjoy the natural environment for which 59% of visitors had voted. This was expected as the Flinders Ranges have, since the inception of tourism in the region (2.2.1), been promoted for their outstanding semi-arid to arid landscapes in an expansive natural environment that retains a sense of remoteness. In particular, the gorges with their richness of plant and bird life or their abundance of kangaroos and wallabies as well as reptiles have attracted much attention. Tour operators in the Flinders Ranges are well aware that their customers are strongly enthused by being in wilderness areas and viewing wildlife, and readily take advantage of using terms such as 'national park' and 'wilderness' to evoke an image of untouched nature teeming with wildlife. My findings are consistent with many other studies on travel motivations of nature-based tourists and more specifically ecotourists. For instance, observing wildlife; visiting state parks, national wildlife refuges, and hiking trails were rated as the top five general activity preferences in the North Carolina, U.S.A, ecotourism market, and camping and hiking tours as well as flora and fauna tours were listed among the top five specific travel attractions (Meric and Hunt, 1998). McCool et al (2007, in McCool, 1996) reported that visitors to a Canadian national park were seeking primarily freedom/serenity, challenge/adventure, naturalness, learning and appreciation of nature. Visitors to the Flinders Ranges treated their vacation as a relaxing getaway from the more crowded places and were not particularly keen on socialising with fellow travellers nor did they treat the trip as a family outing. The fact that relaxation was such a major trip motivator may be related to the high percentage of repeat visitors. Gitelson and Richard (1984), for instance, found that the different motivations of first-time and repeat visitors lead to different planned activity sets, and those seeking relaxation tended to choose familiar sites.

In spite of nature constituting the core travel motivation for many nature-based tourists, the nature-based tourism market is often not homogenous (Mehmetoglu, 2007), and various typologies have been proposed with respect to different types of nature-based experiences, activities and visitor characteristics. In this study, the tourist market was divided into a large segment of 'drivers' and a smaller segment of 'hikers'. This agrees with a recent self-administered, questionnaire-based survey of 99 people in FRNP by Synovate (in Planning for People, 2008) that commented on a divide in the visitor market; namely, 57% of visitors were more likely to seek out relaxed attractions and 43% of visitors were more interested in active recreation. The visitor segments of the present survey behaved differently in terms of their inclination to go hiking (and/or walking) vs. scenic driving. Clearly, the physical aspect of the vacation was much more important to hikers. Notwithstanding, many hikers preferred hikes of medium length (rather than very long hikes), and many wanted to use their vacation to relax and preferred not to camp away from their vehicle. Apparently, the hiker market in the Flinders Ranges enjoys physical activity but to a moderate extent that permits having ample time to explore nature. Numerous hikers commented that they found it more enjoyable not having to carry camping gear on their hikes and to return to their campsites in the afternoon to relax. Most drivers did not mind physical activity but their hikes were on average shorter, and almost no driver considered camping away from their vehicle. The limited vacation time as well as physical constraints and general preferences were cited as the critical factors that determined the desired length of hikes. Generally, many respondents decided to visit multiple places and go for a few shorter hikes rather than to pursue one extended hike at a single location. To a certain extent, a hiker resembles the specialist nature-based tourist in Mehmetoglu's (2005) discrimination of specialist vs. generalist nature-based tourists at two wilderness centres in northern Norway. The specialists clearly placed more emphasis on the travel motives of 'nature' (encompasses in order of importance 'to be close to nature', 'to experience nature', 'to visit natural attractions'), 'physical activities' (encompasses in order of importance 'to engage in challenging physical activities', 'to engage in non-challenging physical activities', 'to engage in nature-based activities') and the 'ego/status' (encompasses in order of importance 'to improve your self-confidence', 'to obtain a feeling of achievement', 'to have experiences to talk about'). The latter implies that specialist, nature-based tourists have a greater interest in achievement-driven activities. Another classification by Mehmetoglu (2007) recognized a continuum of nature-based tourists with two extreme ends: active and passive tourists. Hikers would correspond to the former in that active tourists were more strongly motivated by physical activities.

Interestingly, when participants in the DEH survey in 2005 (unpublished data) were asked which of several park attributes were most important to them, the biggest proportion of visitors (31%) chose walking tracks/trails, followed by camp sites (24%). Roads were only chosen by 4% of the respondents. This is surprising in so far as roads provide the most important access network in the Flinders Ranges since most places (including many trail heads) can only be reached via roads and few people would consider camping at sites without vehicle access. Perhaps visitors tend to expect road access in their tourism destination whereas trail access may be seen as a much-welcome infrastructure addition.

Even though, the observation of fauna and flora was a popular reason for drivers to visit the Flinders Ranges, their ambition to view a particular group of wildlife was not as pronounced as that of hikers. The hiker segment therefore resembled the 'hard' (vs. 'soft') nature-based tourists according to Laarman and Durst (1987) who classified tourists not only based on the level of physical rigour but also on the degree of interest. Whilst the latter represent those who only have a general idea about the nature activities in which they engaged, the former group can articulate specific information about such pursuits.

Only a fifth of all respondents of the present survey sought their journey to be an educational experience. This was surprisingly low as nature-based tourists tend to be well educated (e.g., Magro and Barros, 2004) and often have the need to be educated further during their vacation. Hatch and Blamey (1998), for instance, found in their survey that 69% of visitors felt that an educational or learning experience was important or very important in their decision to undertake nature-based tourism activities. However, according to their respondents the most important learning experience was seeing and observing animals, plants and landscapes. In the present survey, these categories were all offered as separate response options to visitors, when asked about their travel incentives. Thus, the underlying reasons for visitors to choose these options might have been the associated educational experience. This interpretation is supported by the findings of the DEH survey in 2005 (unpublished data) where even though learning was rated by few visitors (4%) as the single most important trip motivator, the single most important complaint was the signage (or lack thereof) about flora/fauna, which normally serves as a tool to educate visitors. The unexpectedly low interest in education may, however, also be related to the high percentage of repeat visitation, considering that people were able to accumulate site knowledge during previous visits (McKercher and Wong, 2004).

Visitors in the present survey appeared to be environmentally conscious. Many of them supported environmental organisations as members and/or through donations or actively engaged in volunteer work to support the environment. Most visitors also felt knowledgeable about tourism impacts in general and rated the possible impacts of tourism on the environment in the Flinders Ranges as medium to high. Hikers felt somewhat more informed, and the percentage of hikers that rated tourism impacts as very high was significantly higher than that of drivers. These findings suggest that visitors to the Flinders Ranges are more aware of the potential gravity of tourism impacts on the environment than evident from other studies. Taylor and Knight (2003b), for instance, report that approximately 50% of visitors surveyed at a U.S. state park, did not think that recreation was having any adverse impacts on wildlife, which represents the common opinion that recreation is not intrusive on wildlife (Flather and Cordell, 1995). Likewise, Priskin (2003) found that there were visitors who ranked even highly intrusive tourism activities as altogether benign.

As for the current survey, it cannot be determined for certain that the findings reflect actual environmental attitudes because respondents may have successfully guessed the politically correct answers (Ryan, 1995b: in Orams 1997). Therefore, an additional, open-ended question assessed whether visitors had sufficient knowledge to name different types of tourism impacts. In early studies on visitor perception of tourism-induced resource degradation, visitors tend to be very limited in their awareness of impacts, particularly when compared to that of experts. Back then, visitors rarely commented on any other impacts than litter, and visitor ratings of the severity of environmental impacts at a site rarely correlated with expert ratings (reviewed by Manning et al., 2004). In contrast, in the present survey many different types of impacts were listed by visitors. This reflects the general education of the public on environmental issues over the past decades. In consistence with other studies, the survey found that people are well aware of the more obvious impacts such as littering (Roggenbuck et al., 1993; Floyd et al., 1997) and plant damage (Shafer and Hammitt, 1995), but in general visitor perception and tolerance for different types of impacts varies widely. Lynn and Brown (2003), for example, found that litter, tree and plant damage, and fire rings had the greatest effect on the hiking experience in a Canadian natural area; trail extension and widening and trail erosion had a moderate effect; and muddiness had a minimal effect on experience. Noe (1997) discovered that some impacts such as littering are tolerated more easily in urban parks than in wilderness areas, which suggests that the perception of impacts also depends on the context. Although this research shows that visitors were aware of impacts associated with their activities, this does not mean that they will attempt to prevent them in the future (Mihali 2000).

Finally, where environmental impacts are evident, they also affect visitor satisfaction by detracting from the wilderness experience (Johnson and Kamp, 1996; Kliskey, 1998) and therefore subsequent visitation. Visitors, for instance, picnicked less at water sites with increasing litter, which they associated with an increase in water pollution (Dinius, 1981).

2.6 Conclusions

In conclusion, the results of this survey have numerous implications: Firstly, the fact that most visitors enjoy shorter hikes and prefer to camp at sites with vehicle access may influence the visitation patterns of gorges which in turn may influence resource conditions on-site such as vegetation and bird communities. This will be discussed in detail in Chapter 4 and 5. Secondly, trail strategies such as those proposed in the recent draft of the "Trail Master Plan for the Flinders Ranges National Park" by Planning for People (2008) may benefit from knowing that there is a larger market for short hikes in multiple locations than for extended hikes in a single location. This may assist them in achieving one of their project objectives (p. 3); namely, providing an "appropriate range of trails to match demand". Thirdly, awareness of different segments in the nature-based tourism market in the Flinders Ranges is a crucial step towards promoting this destination. Marketing may apply such knowledge to specifically target the needs and preferences of the different market segments. These findings also highlight the importance of segmenting visitor markets rather than relying on the evaluation of general tourism market trends. Fourthly, insights into visitor motivations are an important element of the management of protected areas. Park policy-makers need to realize how these motivations affect visitor behaviour so that visitor expectations can be met without compromising the natural resources. Visitor management in the Flinders Ranges, for instance, needs to be aware of visitor demand for camping outdoors coupled with the quest for solitude as this may lead to a dispersion of usage perhaps with unwanted side-effects such as wild camping. Fifthly, the findings highlight some gaps in knowledge of visitors on the less obvious tourism impacts. These could be systematically addressed in environmental education programmes. Finally, the findings underpin the great value of the natural environment as a trip incentive to visit the Flinders Ranges. Visitors nowadays, however, have a greater capability to recognize environmental impacts. Consequently, they may be more easily dissatisfied if conditions deviate from their expectations; that is, natural and unspoilt environments. This should motivate park managers to conserve the environment not only for its own sake but also to achieve visitor satisfaction. If these efforts succeed and are at the same time showcased appropriately, they are likely to maintain repeat visitor clientele and to attract future visitors who largely rely on the word-of-mouth promotion by previous visitors.

Chapter 3
Biodiversity refuges in arid-lands gorges under threat: Determinants of usage levels in tourist sites along roads and hiking trails

Fig. 3.1. Camping in Chambers Gorge, Flinders Ranges. Visitors camping wild (top right).

3.1 Abstract

The monitoring of visitor use in natural areas of high conservation value, such as the gorges of the Flinders Ranges in South Australia, is crucial for a variety of park management tasks including the assessment of tourism-related impacts. Such impacts are often studied by comparing resource conditions between high and low usage tourist sites. Thus visitor data need to be collected for the assignment of sites into different usage categories since they are rarely available a priori.

We assessed visitor use at 80 sites in the Flinders Ranges gorges and compared 11 visitor variables for their potential to differentiate usage levels between sites either exposed to vehicle or hiker traffic. For gorges permitting hiker access only, the number of passing visitors and then the percentage of stoppers and their stop time were best at differentiating usage levels. In contrast, for gorges permitting vehicle access the best discriminators were the number of day and night campers, their daily camp time and the percentage of stoppers and their stop time. This demonstrates the importance of recording more detailed visitor information than visitor numbers alone to reliably assess usage levels.

Further, the advantages and disadvantages of four visitor monitoring techniques were examined; namely, the direct monitoring of visitor use by staff observers, the assessment of proxy variables from which past and present use can be inferred, GPS tracking of visitors and the survey of visitors by an interview-based questionnaire. We recommend GPS tracking because of the reliability and detail of data and the many sites per day that can be sampled. Due to a strong, positive correlation, the campground size and the number of fireplaces may be recorded in proxy of the camper numbers to increase time-efficiency and robustness of measures against short-term fluctuations in usage. Survey data gathered in relation to specific site-use were tempered by the memory of visitors and their ability to describe or reference the visited sites on a map. Visitor surveys were therefore useful only as a supplementary method for differentiating usage levels on a coarser spatial scale.

Key words: protected area management, visitor numbers, visitor monitoring, GPS tracking, tourism survey, usage intensity, impact assessment.

3.2 Introduction

The gathering of information on visitor use patterns is collectively referred to as 'visitor monitoring', which is essential for a variety of planning tasks in park management—such as facilities planning and scheduling of maintenance, determination of demand trends, budgeting, calculation of the social, economic and political importance of the recreational use, tourism impact assessments and the development of natural resource and tourism management policies (Hornback and Eagles, 1998; Watson et al., 2000; Cessford and Muhar, 2003; Wardell and Moore, 2004). Visitor monitoring has acquired a new significance in protected area management with the realization that tourism use has impacts on the natural environment and that rising visitation levels pose a serious threat to sustainable management.

3.2.1 High and low usage tourism sites in environmental impact studies

Typical visitor use patterns in protected areas are patchy where visitor numbers, their activities, group sizes and the locations and facilities that they use vary in time and space. Aggregation in particular sites occurs for numerous reasons like the attraction to special landscape features or adequate camping conditions. Other sites, even in close proximity, may be visited considerably less or not at all. For instance, Arnberger and Hinterberger (2003) found that in a Danubian floodplain system 50% of visitor-kilometres referred to only 20% of total trail-kilometres, indicating a high concentration of visitors on a few trail segments. The concentrated use patterns of recreationists, also reported by numerous other studies (e.g., Magro and Barros, 2004; Growcock, 2005), spatially stratifies recreation areas into high and low usage sites, or any gradations in-between.

A popular methodology for relating environmental impacts with tourism use is to compare resource conditions or animal behaviour between sites of differing usage levels (e.g., McLellan and Shackleton, 1989; Belnap, 1998; Papouchis et al., 2001; Ikuta and Blumstein, 2003; Beale and Monaghan, 2004; McClung et al., 2004; Walker et al., 2005; Webb and Blumstein, 2005; Pelletier, 2006; Griffin et al., 2007), which we will refer to as 'hi-lo impact studies'. McClung et al. (2004), for example, examined the relationship between human disturbance and fitness parameters of Yellow-eyed Penguin (*Megadyptes antipodes*) chicks by comparing breeding areas with different levels of visitor frequency on Otago Peninsula, New Zealand. Belnap (1998) studied vegetation communities and soil variables of lightly and heavily used areas to identify potential impact indicators of tourism use in Arches National Park, U.S.A..

There appears to be a general lack, though, of comprehensive visitor data in natural or wilderness areas or their inadequacy prohibits integration into tourism impact studies for the management of natural resources (Newsome et al., 2002; Cole and Daniel, 2003; Cole and Wright, 2004; Wardell and Moore, 2004). Hadwen et al. (2007: 177), for instance, concluded that in many cases "existing monitoring programmes fail to deliver the necessary information to protected-area managers . . . which facilitate the development of proactive management strategies in most protected areas". Researchers attempting a hi-lo impact study therefore usually need to collect their own visitor data. This can be tempered by the fact that quantifying reliable visitor data requires a considerable logistic effort which competes with the time and money available for assessing the resource conditions. Further, little guidance is available on how and what visitor variables to monitor in order to satisfy the specific needs of a hi-lo impact study, namely the typically short time frame (as opposed to long-term) within which visitor data for many sites per study area (as opposed to a few high usage sites) have to be collected. Consequently, a bias of hi-low impact studies to be conduced on the assessment of resource use rather than visitor use may occur.

Here, we focus on the processes and challenges involved in the determination of usage levels in the context of further study on the comparison of vegetation and bird communities between high and low usage sites in the gorges of the Flinders Ranges, a well-promoted tourist region in South Australia. In particular, we examined visitor usage patterns of gorges that are either accessible by vehicle or by foot, and identified best-practice visitor monitoring, which may assist in other hi-lo impact studies with similar access options.

3.2.2 Visitor variables

Hi-lo impact studies may anticipate changes in a resource variable with an increasing tourism usage intensity provided that (1) the resource variable is potentially sensitive to usage, (2) the increase in usage is sufficiently strong and (3) the usage has not yet reached levels where a further increase cannot cause additional impacts as these have either reached their maximum levels (e.g., campsites entirely denuded of vegetation due to trampling) or the ecosystem has changed to an altered state that is insensitive to usage (e.g., displacement of sensitive flora or fauna with disturbance-robust species).

The usage intensity itself may increase with increasing numbers of visitors, an extended duration and higher frequency of usage, as well as activities or visitor behaviour that is physically more involved with the environment. Therefore, as the usage intensity may be a complex result of multiple variables (Hammitt and Cole, 1998), choosing the right visitor variables is one of the major challenges of a hi-lo impact study. Notwithstanding, to date, many hi-lo impact studies (e.g., McClung et al., 2004; Pelletier, 2006) have relied heavily upon visitor numbers as the main or sole measurement for determining usage levels.

Thus the power to detect visitor impacts and impact mechanisms should increase if more detailed information is collected that accounts for the complexity of visitor usage (Hadwen et al., 2005; Hadwen et al., 2007). Gonzalez et al. (2006), for example, investigated tourism impacts on nesting Spanish Imperial Eagles (*Aquila adalberti*). They stratified visitor numbers by behaviour and found that passing vehicles did not significantly affect the eagles while stopping vehicles did. Had they not chosen to record different user behaviour they might have wrongly inferred that all visitors had an impact instead of identifying the fraction that was actually responsible. In a hi-lo impact study, this could lead to a misclassification of sites into inappropriate usage categories: for instance, at a site with lower visitor numbers eagles may have been more disturbed than at a site with more visitors if the ratio of stopping to passing visitors was higher at the site with fewer visitors.

3.2.3 Visitor monitoring methods

Another important decision in a hi-lo impact study concerns the visitor monitoring methods. Traditionally, the main sources of information for the monitoring of visitor use have been visitor surveys, simple traffic counts, best guesses, rough estimates and anecdotal evidence. Visitor surveys are still an essential tool for park visitor research but visitor impacts on natural environments result more from what people do than what they say they do (Cessford and Muhar, 2003; Cole and Daniel, 2003). Further, the detail of the trip itineraries needed to examine variation in tourism usage intensity between sites, especially if it varies on a fine spatial scale, may not be adequately captured. Nevertheless, surveys may provide useful additional information for explaining travel patterns when they are combined with other monitoring methods.

There are a number of current advances in monitoring options (Hornback and Eagles, 1998; Watson et al., 2000; Cessford and Muhar, 2003) ranging from direct observations by staff observers, the use of on-site counters (devices recording and storing visitor counts at sites) through to proxy measures (e.g., visitor registration records) from which use can be estimated (Cessford and Muhar, 2003). Recently, improved video, digital imaging and transmission technology as well as global positioning systems (GPS) and other tracking devices like the Alge timing system (ankle mounted transmitters that are recognized by receivers located along a constrained network) have been proposed for visitor monitoring (O'Connor et al., 2005).

Arnberger et al. (2005) encouraged comparisons of the many available visitor monitoring methods, such as their cost and the quality of data gathered, in order to facilitate decision-making on the appropriate methods.

3.2.4 Study goal

The aims of this paper are: (1) To illustrate the process of differentiating usage levels of tourism sites, exemplified in the gorges of the Flinders Ranges, where no suitable tourism data existed. (2) To examine which of 11 tourist variables of passing, stopping and stationary/camping usage best described inter-site usage differences depending on access mode (sites with vehicle vs. foot access) to tourist sites. Based on preliminary observations, we hypothesized that camping variables would be more relevant in vehicle gorges as camping appeared to be rare in hiker gorges and that differences in numbers of passing tourists would be more relevant in hiker gorges since tourists seemed to aggregate in the beginning of these gorges while vehicle gorges appeared to be used throughout. (3) To compare the advantages and disadvantages of various monitoring techniques in terms of their costs, ease of use, site efficiency (daily sampling rate of sites) and sensitivity towards short-term fluctuations in visitor use. The monitoring of actual use directly by staff observers on-site, or through the assessment of proxy variables (e.g., number of fireplaces) and indirectly through GPS tracking was compared to the surveying of reported use through on-site interviews with tourists.

The ultimate goal of our visitor monitoring was to assign our study sites into high and low usage groups for a further analysis of the relationship between resource conditions and visitor use (Chapter 4 and 5).

3.3 Methods

3.3.1 Study area

This study was conducted in the central and northern Flinders Ranges from the Flinders Ranges National Park (Wilpena: lat. 31° 30` S, long. 138° 30` E) into the Vulkathunha-Gammon Ranges National Park (Balcanoona: lat. 30° 30`, long. 139° 30`). In 2007, the Flinders Ranges and Outback South Australia attracted an estimated 589 000 overnight visitors that spent nearly two million nights there (South Australian Tourism Commission, 2008b). This was more than any other region in South Australia except the capital, Adelaide. The Flinders Ranges offer a wide range of activities including bush-walking and scenic touring along designated recreational paths, camping on official and wild campsites, and Aboriginal and European cultural experiences.

This region is known for its spectacular scenery and gorges with extensive creek beds and its outstanding geological features. Four elements of the natural ecosystem are of regional and/or national significance: (1) a unique and very diverse vegetation community including 1233 native plant taxa (Brandle, 2001), (2) a diverse reptile community of approximately 90 species (Brandle, 2001) especially the rock-haunting variety, (3) more than 200 species of birds (Ried et al., 1996), and (4) four macropod species including the endangered southern population of the Yellow-footed Rock-wallaby (*Petrogale xanthopus xanthopus*) (Brandle, 2001).

The gorges in particular are magnets for tourism activities in the region and offer a refuge to most plant and wildlife species from the drier areas of the plains. This makes them the prime locations for people-nature interactions with a critical need for impact monitoring in relation to tourism use. However, any hi-lo impact study is hampered by the lack of visitor data, especially usage levels of the Flinders Ranges gorges and sites within at an appropriate scale. To date, visitor usage in the Flinders Ranges and Vulkathunha-Gammon Ranges National Park has mainly been assessed through survey questionnaires capturing general tourist profiles, visitor activities, satisfaction, expenditure, expectations and trip attributes like the duration of stay (reviewed by Morelli, 1996). In addition, some road surveys have been conducted and a few road counters established on major travel routes. The number of camping permits and park entrance fees have also been recorded by park personnel at different self-registration stations inside the parks (Shirley Meyer, Park Management; Melanie Vears, Park Administration; FRNP; pers. comm.) and by some private tourism operators (e.g., the

Flinders Ranges Tourist Services Pty Ltd). Generally, data on sites other than the commercial centres and some of the official campgrounds are sparse and virtually non-existent for our study sites inside the gorges. Visitor data for the Flinders Ranges gorges under private lease are even rarer since there are no entrance fees and camping is wild.

3.3.2 Study sites

The sample comprised seven major gorge systems. Three gorges were mainly exposed to vehicle traffic and the other four gorges only permitted access to hikers. In the absence of suitable visitor data, we used extensive preliminary observations combined with input from park personnel to stratify gorge sections into high and low usage zones. Study sites were placed equally into the pre-determined high and low usage zones to promote a balanced design for the subsequent study on resource impacts but this did not preclude post hoc re-classification. A minimum distance of 250 m and usually not more than 500 m was maintained between adjacent sites. Due to the meandering nature of the gorges, further spatial independence of sites was attained by distributing most of them into separate bends.

On each study site, we laid belt transects with the dimensions being 50 m (along the trajectory of the gorge) by 92.5 ± 3.6 m (mean ± 1 SE; depending on the width of the particular gorge section).

3.3.3 Actual use

We measured tourism use at each study site from July to December in 2006 and 2007. This time period covered the two shoulder and the peak tourist season (spring) for the Flinders Ranges. Due to the distance to any major cities, the Flinders Ranges and Vulkathunha-Gammon Ranges National Parks do not receive a noticeable influx of weekend vacationers (Danny Doyle, Acting District Ranger, Vulkathunha-Gammon Ranges National Park, pers. comm.); nor did we observe any obvious visitation peaks on any specific days during the week in our preliminary observations. Thus we monitored the number of passing tourists (all cars or hiker groups that passed with(out) stopping), the passing speed, the percentage of stopping tourists and their stop time directly on each site from 9 am till 5 pm for two days regardless of time of the week. The passing speed was calculated by measuring the time that tourists needed for passing through each of the 50 m wide transects. For stopping tourists the passing speed was calculated as the mean from the speed values recorded before and after the stop.

Further data on passing speed, percentage of stoppers and stop time were collected indirectly by GPS tracking of tourists on a total of at least 3 different days per gorge. Sample size varied between 15 to 42 participants per gorge. At the gorge entrances, tourists were approached and those compliant with participation in the study were equipped with GPS data loggers (Trackstick I, Procure It Australia Pty Ltd, Banyo, Queensland, Australia). These were dropped off either at the original pick-up location or at the opposite access/exit point of a gorge when the tourist(s) completed their visit.

The average values of the passing speed, the percentage of stoppers and their stop time collected at each site via the GPS tracking were included with the corresponding variables recorded via the direct monitoring. That way we did not duplicate variables of the exact same meaning in the principal components analysis (3.3.5) but increased the reliability of the data from the direct monitoring. GPS tracking did not yield any information on the absolute, daily number of passing tourists. It would however been possible to calculate the percentage of passing tourists from all tourists that were GPS-tracked in a particular gorge as an indication of the relative visitation of sites within a gorge. We did not pursue this option since the number of passing tourists recorded in the direct monitoring not only contained the same information but also described the relative visitation of sites between all gorges and so is a more meaningful measure of usage.

Apart from the velocity and stop-times of visitors, the GPS recorded the route that each participant had taken through a study site in the form of 'trackpoints', namely the current geographical position (latitude/longitude/altitude) of the visitors. We did not use the greater level of information contained in these data for classifying our study sites but we will give one example (3.5.3.3) as to how this knowledge, unobtainable with any of our other methods, may be implemented to advance the monitoring of visitor usage.

On ten different nights, we also noted the number of tourist groups camping overnight. The nocturnal dwell time of campers was relatively uniform as most people arrived before 5:00 pm and stayed till 9:00 am and so was not used as a variable. More variation occurred in the daily dwell time of campers which we measured together with the number of day campers between 9:00 am and 5:00 pm in concert with the direct monitoring of passing and stopping visitors. For the purpose of our study, we defined 'stopping' as a temporary interruption to the journey without the setting up of camping gear in contrast to stationary (camping) use of sites. We differentiated between night and day campers because their numbers are not necessarily correlated. Some sites may be practical for overnight camping but do not tempt visitors to stay throughout the day.

Finally, we measured proxy variables, for which preliminary observations suggested a relation with visitor usage; such as the size of any campgrounds, the numbers of fire places, trash items and interpretation signs. We included the full extent of any campground crossed by a transect as well as abutting campgrounds, as long as their boundaries were situated within 30 m to the transect. Transects had been placed so there was not more than approximately 10% of overlap with traversing campgrounds; the reason being was that in the associated studies on resource impacts in relation to usage, we did not intend to measure the effect of camping per se but of recreational tracks in general, independent of their dominant use. The size of the campground was calculated with the area measurement function of a GPS unit eTrex Vista Cx (Garmin, Olathe, Kansas, U.S.A.) by walking along its boundaries. All other proxy variables were measured on the belt transects and their associated campgrounds.

3.3.4 Reported use

We conducted questionnaire-based surveys by interview with adult tourists (>18 years) at wild and designated campgrounds within or close to our study gorges, and at the campground or visitor centre in Wilpena and Balcanoona, some of the most frequented tourist sites in the study area. A total of 357 questionnaires were collected from the survey, but 15 questionnaires were eliminated prior to analysis because of missing data. Questionnaires had undergone some pilot testing prior to their use, and were adapted where necessary. Surveys took place in the same time period as the actual use measurements. The first author and several trained volunteers administered the surveys to any tourist willing to participate (85% of those approached).

In the first part of the questionnaire, we asked questions to assemble visitor demographics, trip itineraries, trip motivations and preferred activities. A few selected findings are presented here in form of a visitor profile (3.4.1; further details in Chapter 2).

The second part of the questionnaire served to estimate usage of the study sites. Participants were presented with topographic maps and given a standard, brief orientation on the maps by pointing out certain landmarks that had been identified in a pilot study as outstanding/memorable features (e.g., certain campsites, springs/pools). Then they were asked (questions listed in Table 3.4) whether they had visited a particular gorge and, if so, the access points they had used. Specific site-use within gorges was assessed by asking participants to indicate those sites they had passed (answering to "how far did you travel into the gorge"), stopped or camped at and the duration of these activities. If they had forgotten, then this response was recorded. Finally, participants were asked to rate the reliability and completeness of their answers on a five-point scale (1 = very unreliable/incomplete to 5 = very reliable/complete).

3.3.5 Data analyses

The following analyses were carried out separately for vehicle and hiker gorges to identify high and low usage sites within each gorge type and to determine which tourism use variables drove possible differences in usage levels between sites depending on the access mode to the gorges.

Mean values were calculated for the multiple samples of visitor variables of observed use (= actual use variables excluding proxy variables). Pearson´s correlations were employed to identify relationships between the visitor variables of observed use, and between them and their proxy variables. All visitor variables were replaced by their ranks as a prerequisite to a principal components analysis (PCA). Ranking creates a common measurement scale, otherwise a PCA would be dominated by the input variables with the largest values. Furthermore, outlier-values, which would also make an unreasonable contribution to the PCA, are given much less weight (Clarke and Gorley, 2006). We interpreted our data so that high values of the visitor variables equalled high usage levels. The exception was 'passing speed' where a lower speed represented a longer dwell time (hence more use) and so the inverse value was ranked instead.

A PCA with PRIMER v6 (Clarke and Gorley, 2006) was calculated to ordinate our study sites on a 2-dimensional plot based on their variation in the 11 visitor variables recorded in our visitor monitoring. Euclidean distance was used as the distance measure which appropriately caters for the intrinsic characteristics of environmental variables (as listed in Clarke and Gorley, 2006) like our visitor variables.

We used the factor loadings to identify the PCA axis which separated sites based on a gradient in the usage intensity; namely the axis along which most of the visitor variables would increase/decrease in the same direction. A grouping of sites along this axis into high or low usage was performed visually (Manly, 2004) by looking for clusters of sites on the ordination plot. However, since the construction of a 2-

dimensional PCA from an original 11 dimensions reduces the information contained in the whole set of input variables, we checked the adequacy of this reduction: Clusters generated by the dendrogram from a hierarchical cluster analysis (unweighted, group-averaged; using Euclidean distance to construct the resemblance matrix as a base for the cluster analysis) were overlaid to see if they matched the groups of sites with similar levels of tourism use as identified by interpreting the PCA. Further a similarity profile (SIMPROF) permutation test was calculated which looks for statistically significant evidence of genuine clusters in samples which are a priori unstructured (Clarke and Gorley, 2006; Liu et al., 2007). It tests that the groups after being sub-divided at a node of a dendrogram have significant internal structure. We postulated this significance as a final condition for defining our clusters of sites differing in their usage levels.

To identify which tourism use variables drove differences in usage levels between sites in either vehicle or hiker gorges, factor loadings were calculated, with high loadings on a particular PCA axis being assigned the most weight. A visual expression of this relationship was achieved by superimposing the tourism variables as vectors on the PCA plots. To provide a further weighting as to which variables best differentiated usage, we looked for strong differences in the mean of the different visitor variables for high and low usage groups following the categorization.

We created one map of a gorge section containing two sample visitor tracks in ArcView GIS 3.2 (Environmental Systems Research Institute, 1999) to give an example of how detailed the visitor data from the GPS tracking are.

The responses from the visitor surveys were entered into Data Entry 4.0 for Windows (SPSS, 2007b) and subsequently analysed with SPSS for Windows 17.0 (SPSS, 2008). The point-scale data were treated as ordinal (Rhodeghier, 1996; Scheff et al., 2002) so that the mean ratings of completeness and reliability between questions could be compared with repeated measurements ANOVA followed by a Tukey LSD post hoc test with a Bonferroni correction. Since the data violated the assumption of sphericity, the Greenhouse-Geisser correction was applied which adjusts the degrees of freedom to produce a valid *F*-ratio (Field, 2005).

3.4 Results

3.4.1 Visitor profile

The survey revealed that the majority of participants (89.8%) were from Australia, and most of them travelled as elder (>50 years; 61.4%) adult couples (45.6%) or friends/relatives (29.8%) in a group of two (60.2%). The visitor demographics were similar to the ones found in a tourism survey of 305 visitors to Flinders Ranges National Park with self-administered questionnaires by the Department for Environment and Heritage in 2005 (unpublished data), which suggests that our visitor sample was representative.

Many people (67.5%) had visited the same or other parts of the Flinders Ranges before and planned to stay 1 to 3 days (17.3%), 4 to 7 (51.5) or more days (31.2%) during their current visit. The main motivations (multiple answers) for travelling to the Flinders Ranges were the enjoyment of the natural environment/being outdoors/camping (71.6%), geology and landscape/scenic views (55.6%), wildlife observation (52.0%), relaxation (51.2%), vegetation/wildflowers (48.0%), solitude (37.1%) and walking/hiking/physical exercise (27.2%).

The tourist market was segmented into a large segment of drivers (73.7%) and a smaller segment of hikers (26.3%). Drivers spent on average almost three times as much daylight time (59.8%) with scenic driving and less than a third of daylight time (16.9%) with hiking compared to hikers. Drivers also planned to go on shorter hikes during their stay than hikers. Notwithstanding, even hikers preferred hikes of medium length (less than 3 km) over longer hikes, and both hikers and drivers commented that, given the choice, they preferred to camp at sites with vehicle access.

The gorges were a major tourist attraction. Virtually everybody (96.5%) indicated their interest to visit a gorge, and 61.1% of visitors stated that they would spend half or up to all of their time there when asked for the proportion of the stay (none, some (25%), half, most (75%), all of it) that visitors intended to or had already spent in the gorges of the Flinders Ranges.

3.4.2 Actual use

3.4.2.1 Vehicle-accessed gorges

The original 11 tourism use variables measured in vehicle gorges (Table 3.1.1) were summarized into two statistically independent axes (PC1, PC2) by means of an unrotated PCA (Fig. 3.2.1a). These two axes with eigenvalues > 1 explained 58.8% and 10.3% (Table 3.1.1), respectively, of the total variation in tourism use between sites in these gorges, giving confidence that the site-relationships were accurately represented.

PC1 described a gradient in decreasing tourism use as revealed by the factor loadings (Table 3.1.1) and superimposed PCA vectors (Fig. 3.2.1a): All (ranked) visitor variables were significantly, negatively correlated with PC1. The number of day- and night-campers, day-camp time, camp size and the number of fireplaces showed the strongest negative correlations; (inverse) passing speed, percentage of stoppers and stop time were also significantly negatively correlated but less strongly. PC2 mainly described usage differences of sites based on a gradient in the percentage of stoppers and their stop time. It also discriminated sites with a higher percentage of stoppers and stop time from those with more camping. Thus, this axis facilitates discrimination based on different quantities and qualities of usage.

The ordination along PC1 formed two distinct associations which were confirmed by the partitioning attained with a hierarchical clustering procedure at a 62% Euclidean distance between the resulting clusters. At this level of partitioning, SIMPROF found statistically evident sub-structure within the clusters ($\pi = 7.0$, $P = 0.001$); namely, significant differences between the groups and not within each group. We chose to illustrate the clustering at this particular Euclidean distance, among other significant (SIMPROF) partitioning options, because it separated the sites into two groups of nearly balanced sample size with a distinct gap in-between, indicative of distinct usage levels. The three sites with the lowest PC1 values (marked as '1' (Fig. 3.2.1a) and grouped separately on the ordination plot) were correctly identified by the PCA as sites of highest use since they all contained big camping and rest areas.

Table 3.1. Factor loadings (Pearson´s correlations; r_P) of the ranked visitor variables (Var) on the component scores of the first two PCA axes derived from sites receiving (1) vehicle or (2) hiker traffic ordinated in visitor use space.

		(1) Sites with vehicle traffic				(2) Sites with hiker traffic			
		PCA axis 1		PCA axis 2		PCA axis 1		PCA axis 2	
Var	Description	r_P	*P*	r_P	*P*	r_P	*P*	r_P	*P*
P1	Passers (no. d^{-1})	-0.437	**	0.285		-0.756	**	-0.359	*
P2	Speed (km h^{-1})^a	-0.715	**	0.389	**	-0.698	**	0.635	**
P3	Stoppers (% of passers)	-0.819	**	0.415	**	-0.746	**	0.138	
P4	Stop-time (min $stopper^{-1}$)	-0.690	**	0.535	**	-0.935	**	0.065	
C1	Day-campers (no. d^{-1})	-0.901	**	-0.295		-0.509	**	-0.352	*
C2	Day-camptime (min day-$camper^{-1}$)	-0.840	**	-0.208		-0.437	**	-0.392	*
C3	Night-campers (no. $night^{-1}$)	-0.904	**	-0.187		-0.637	**	-0.389	*
S1	Camp size (m^2)	-0.899	**	-0.249		-0.615	**	-0.109	
S2	Fireplaces (no.)	-0.846	**	-0.350	*	-0.617	**	-0.123	
S3	Info signs (no.)	-0.565	**	-0.022		-0.566	**	-0.251	
S4	Trash items (no.)	-0.511	**	-0.034		-0.580	**	-0.176	
	Variance explained (%)	58.80		10.30		52.00		11.20	

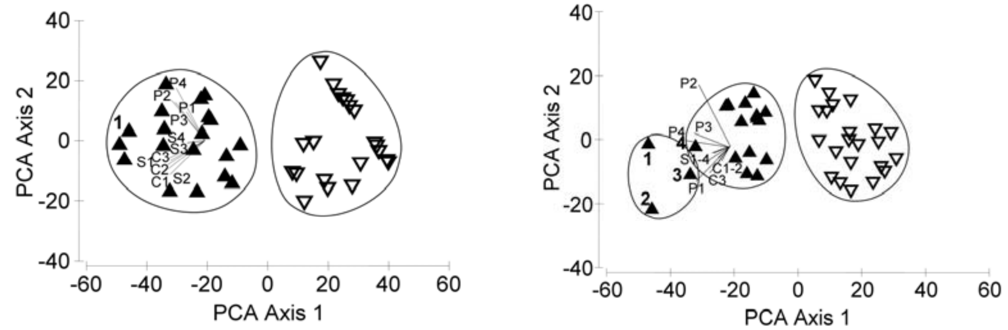
Note : $n_{\text{(sites with vehicle traffic)}} = 40$; $n_{\text{(sites with hiker traffic)}} = 40$.

^{a}The inverse value was used because low speed was thought to increase usage levels.

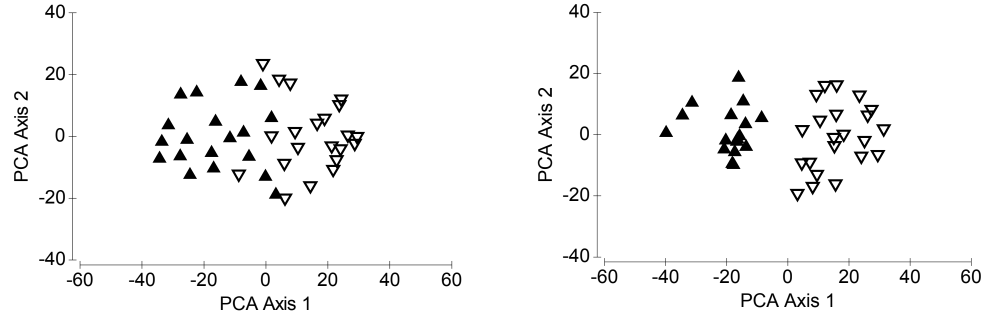
* $P < 0.05$, ** $P < 0.001$.

(1) Sites with vehicle traffic (2) Sites with hiker traffic

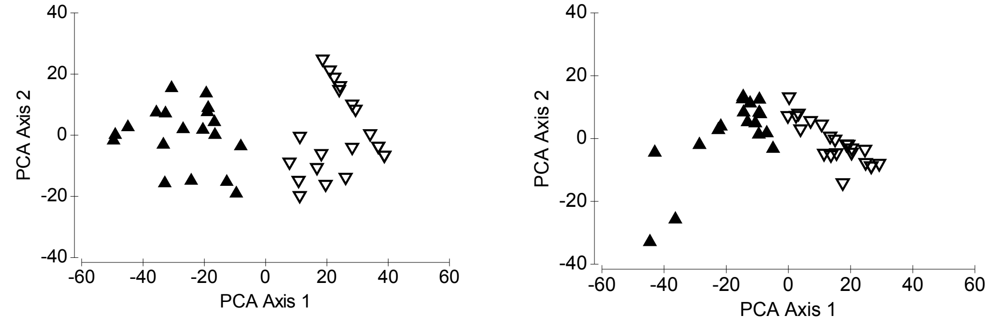
(a) With all use variables



(b) Without camping variables



(c) Without the number of passing tourists



(d) Without the % of stoppers and stop-time

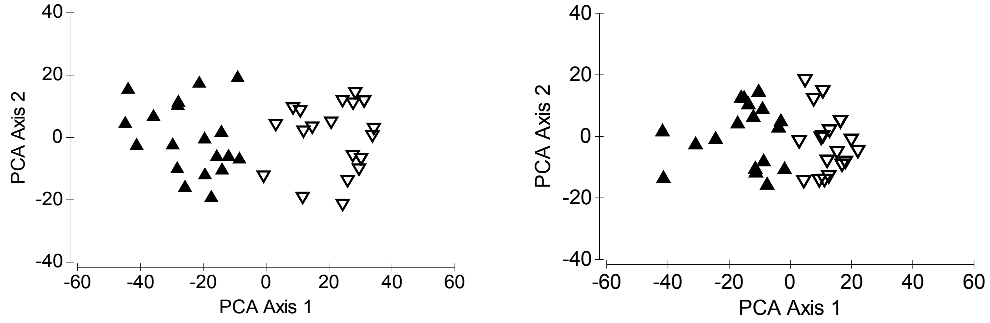


Fig. 3.2. PCA plots of (1) vehicle and (2) hiker sites ordinated based on visitor variables, superimposed as vectors (abbr. in (a): P1–P4, C1–C3, S1–S4 as in Table 3.1). Strong correlations are displayed as long vectors that run reasonably parallel to the PCA axis. The correlation is positive if the vector points in the same direction as the positive end of the axis. Cluster solutions are encircled and sites differentiated into high usage (▲) and low usage (∇). Sites with numerals (in (a)) are discussed in 3.4.2.1 and 3.4.2.2.

3.4.2.2 Hiker-accessed gorges

A 2-dimensional PCA was also a good representation of site-relationships in the higher 11-dimensional space for sites in hiker gorges. PC1 accounted for most of the variability (52%) and PC2 for a further 11.2% (Table 3.1.2), both with eigenvalues > 1.

PC1 (Fig. 3.2.2a) described a gradient in decreasing tourism use of sites within hiker gorges expressed as negative correlations of all visitor variables with the component scores of PC1 (Table 3.1.2). Here the separation was mainly driven by the number of passers, the percentage of stoppers and their stop time. Camping variables distinguished a few sites from the majority of sites but were weak differentiators for the main bulk of sites. For instance, site '1', '2' and '3' (Fig. 3.2.2a), located near the entrance of gorges, were exposed by the PCA because they belonged to the few places where people had camped. At site '4' (Fig. 3.2.2a), visitors were attracted to stop for a longer time at an information sign on aboriginal culture. PC2 mostly separated sites based on the passing speed of visitors.

Cluster analysis at a 43% Euclidean distance divided the sites into one cluster of only three sites with exceptionally high usage and two clusters of equal sample size characterised by high or low usage with significant sub-structure as determined by SIMPROF ($\Pi = 2.59$, $P = 0.001$).

3.4.2.3 Comparison between vehicle and hiker gorges

PCAs on the same visitor variables, but calculated without any camping variables (C1–C3, S1–S2; abbreviations as in Table 3.1), illustrated that camping was of much higher importance for ordinating vehicle sites than hiker sites. Whether camping variables were included or not, hiker sites were similarly distributed along PC1 (Fig. 3.2.2b). In contrast, the ordination for vehicle sites without camping variables (Fig. 3.2.1a) was much more condensed and the gap between high and low usage sites closed so that previously separated sites (Fig. 3.2.1a) showed some overlap in their PC1 scores. The pattern was exactly opposite when the number of passing tourists was excluded (Fig. 3.2.1c, 2c). When the percentage of stoppers and their stop-time were excluded, the separation of vehicle sites (Fig. 3.2.1d, 2d) was only mildly attenuated while the separation of hiker sites was weakened somewhat more.

The differences in the mean visitor values between vehicle sites assigned to the high or low usage groups (Table 3.2.1) were considerable for all camping variables including the camp size and the number of fireplaces as well as for the percentage of stoppers and their stop time. In contrast, hiker sites (Table 3.2.2) were markedly different only in the mean number of passers, the percentage of stoppers and their stop time. Even though the camping variables ostensibly differ in their means, it should be noted that their values stem from only a few high usage sites where any signs of camping usage were found (11–28% of sites depending on the variable) and so are not representative of the whole group of high usage sites; this contrasts with vehicle gorges where 90–95% of sites contributed to the means of the different camping variables.

Overall usage in hiker sites was lower than in vehicle sites as several variables indicative of high usage hiker sites were similar in value to those in low usage vehicle sites.

Table 3.2. Mean (± 1 SE) visitor variables (Var) after categorization of (1) vehicle and (2) hiker sites into high or low usage with PCA, cluster analysis and SIMPROF.

		(1) Sites with vehicle traffic				(2) Sites with hiker traffic			
		Low usage		High usage		Low usage		High usage	
Var	Description	Mean	SE	Mean	SE	Mean	SE	Mean	SE
P1	Passers (no. d^{-1})	16.88	1.71	23.79	1.75	3.91	0.90	16.56	1.29
P2	Speed (km h^{-1})	31.66	1.95	20.29	2.26	6.05	0.17	4.78	0.25
P3	Stoppers (% of passers)	5.23	1.49	30.46	5.09	7.58	2.66	37.03	4.05
P4	Stop-time (min $stopper^{-1}$)	1.29	0.58	9.38	2.38	3.28	1.20	17.11	1.88
C1	Day-campers (no. d^{-1})	0.26	0.10	4.82	1.39	0	0	0.11	0.06
C2	Day-camptime (min $day\text{-}camper^{-1}$)	55.10	20.96	337.53	17.79	0	0	31.56	21.27
C3	Night-campers (no. $night^{-1}$)	0.07	0.04	2.18	0.60	0	0	0.16	0.14
S1	Camp size (m^2)	374.10	202.08	57 149.32	33 382.75	0	0	934.50	818.66
S2	Fireplaces (no.)	1.76	0.65	18.74	3.83	0	0	4.83	4.37
S3	Info signs (no.)	0	0	0.47	0.12	0	0	0.17	0.09
S4	Trash items (no.)	0.24	0.12	1.53	0.50	0.09	0.06	1.06	0.34

3.4.2.4 Correlations between visitor variables

We found various significant correlations among the visitor variables at vehicle (Table 3.3.1) and hiker sites (Table 3.3.2): Camping variables were strongly correlated ($r_p > 0.8$) with each other and moderately to strongly ($0.5 < r_p < 0.9$) with all proxy variables. A moderate ($0.4 < r_p < 0.7$), negative correlation of speed with stopping (also for hiker sites), camping and all proxy variables, and of the percentage of stoppers with camping and proxy variables was found at vehicle sites.

Table 3.3. Pearson´s correlations between visitor variables at sites with (1) vehicle traffic and sites with (2) hiker traffic.

Var	(1) Sites with vehicle traffic	Passers	Speed	Stoppers	Stop-time	Day-campers	Day-camptime	Night-campers	Camp size	Fire-places	Info signs
P1	Passers (no. d^{-1})										
P2	Speed (km h^{-1})	-0.202									
P3	Stoppers (% of passers)	0.181	**-0.671**								
P4	Stop-time (min stopper^{-1})	0.175	**-0.354**	0.287							
C1	Day-campers (no. d^{-1})	0.098	**-0.531**	**0.736**	0.164						
C2	Day-camptime (min day-camper^{-1})	0.360	**-0.393**	**0.475**	0.398	**0.392**					
C3	Night-campers (no. night^{-1})	0.099	**-0.588**	**0.790**	0.182	**0.934**	**0.415**				
S1	Camp size (m^{2})	-0.012	**-0.436**	**0.644**	0.054	**0.866**	0.195	**0.851**			
S2	Fireplaces (no.)	0.082	**-0.451**	**0.691**	0.267	**0.828**	**0.472**	**0.838**	**0.802**		
S3	Info signs (no.)	0.235	-0.243	**0.627**	0.116	**0.567**	**0.427**	**0.567**	**0.429**	**0.525**	
S4	Trash items (no.)	**0.472**	**-0.430**	**0.414**	0.189	**0.346**	**0.448**	**0.411**	0.238	0.212	0.049
Var	(2) Sites with hiker traffic	Passers	Speed	Stoppers	Stop-time	Day-campers	Day-camptime	Night -campers	Camp size	Fire-places	Info signs
P1	Passers (no. d^{-1})										
P2	Speed (km h^{-1})	**-0.309**									
P3	Stoppers (% of passers)	**0.666**	**-0.454**								
P4	Stop-time (min stopper^{-1})	0.652	-0.255	0.469							
C1	Day-campers (no. d^{-1})	0.184	**0.006**	0.258	0.404						
C2	Day-camptime (min day-camper^{-1})	0.118	0.022	0.206	0.444	**0.921**					
C3	Night-campers (no. night^{-1})	0.126	0.054	0.229	0.222	**0.854**	**0.885**				
S1	Camp size (m^{2})	0.122	0.047	0.224	0.186	**0.814**	**0.830**	**0.991**			
S2	Fireplaces (no.)	**0.118**	0.057	**0.216**	0.185	**0.820**	**0.837**	**0.994**	**1.000**		
S3	Info signs (no.)	**0.365**	-0.210	0.546	0.130	**0.685**	**0.476**	**0.577**	**0.569**	**0.566**	
S4	Trash items (no.)	0.363	-0.149	0.415	0.402	0.804	0.595	0.546	0.517	0.521	0.746

Note : Significant correlations are marked in bold.

3.4.2.5 Detailed visitor monitoring with GPS tracking

Our example (Fig. 3.3) of how the GPS data can further be exploited illustrates visitors deviating from official trails to approach a scenic feature. This was not uncommon at sites where, for instance, natural ponds were visible but not directly accessible from the official path.

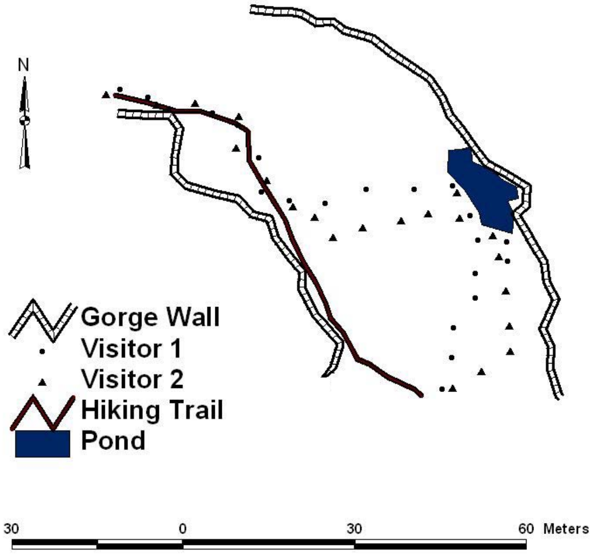


Fig. 3.3. Two examples of visitor tracks as recorded via GPS along a hiking trail in a Flinders Ranges gorge (lat. 30° 57` S, long. 139° 13` E), showing the deviation of visitors from the official trail.

3.4.3 Reported use

Most (257) of the 342 survey participants had already visited at least one of our study gorges, and a further 73 were planning to do so for the remainder of their trip. Differences in the percentage of visitation between vehicle (mean ± 1 SE = 65.8 ± 13.4) and hiker gorges (26.9 ± 9.8). were pronounced. Sites in the beginning of hiker gorges attracted more visitors on average than sites further inside (cumulative percentage of visitors in the beginning: 100%; middle: 48.9% ± 11.1, end: 24.5% ± 14.5). In contrast, tourist frequency in vehicle gorges appeared to be fairly similar throughout their entire length (cumulative percentage of visitors in the beginning: 100%; middle: 89.4% ± 8.3, opposite end: 83.9% ± 12.0). Furthermore, tourists seemed to prefer one access point into each gorge over alternatives (mean percentage of tourists accessing through the preferred access points: 86.4% ± 6.2).

Most respondents were able to answer at least some questions relating to their use of whole gorges (site-unspecific use) and site-specific use within a gorge (Table 3.4). However, memory of site-specific use was weaker, especially when people had to indicate sites where they had stopped and how long they had stopped there. Respondents' own perception of the correctness ($F_{(4.8,130)} = 33.71$, $P < 0.001$) and completeness ($F_{(2.3,148.5)} = 175.84$, $P < 0.001$) of their answers significantly differed between questions (Table 3.4) and followed the same pattern as for the memory. The more stops people had made, the more difficult it was to specify stopping locations: at 1–2 stops 74.7% of stopping locations could be referenced; at 3–5 stops the percentage dropped to 49.6% and at more than 5 stops to only 34.4%.

Table 3.4. Memory, self-estimated reliability and completeness of answers provided by tourists ($n = 257$) about their visitation to gorges in the Flinders Ranges and particular sites within these gorges. Post hoc tests: questions that do not share a common letter are significantly different in the estimated reliability (rel.) and completeness (compl.) of the answers given.

Details	Question	Visitors who remembered (%)[a]	Reliability of answer (mean ± 1 SE)[b]	Post hoc test (Rel.)	Completeness of answer (mean ± 1 SE)[c]	Post hoc test (Compl.)
Site-unspecific	Did you visit one of these gorges?[d]	100	4.71 (±0.03)	A	4.89 (±0.02)	a
	From which point did you access?	100	4.91 (±0.02)	A	NA	
Site-specific	How far did you travel into the gorge?[e]	98.5	3.61 (±0.05)	A,B	NA	
	Where did you camp?	78.6	3.82 (±0.08)	B,C	4.12 (±0.07)	b
	How long did you camp there?	92.6	3.53 (±0.12)	B,C	NA	
	How many times did you stop?	82.1	2.63 (±0.09)	C	2.35 (±0.09)	c
	Where did you stop?	65	1.93 (±0.08)	C,D	1.97 (±0.08)	c
	How long did you stop?	35	1.71 (±0.13)	D	NA	

Note : Questions that do not share a common letter in the post hoc test columns are significantly different in their estimated reliability (rel.) and completeness (compl.) of the given answers. [a]In contrast to visitors who answered "don't remember". Participants were asked to rate the [b]reliability ("How reliable do you think are your given answers?") and [c]completeness ("How complete do you think are your given answers?") of their answers on a 5-point scale (1= very unreliable/incomplete to 5 = very reliable/complete). [d]Six gorges were given as choice. [e]"Beginning", "middle", "opposite end" were given as choice.

3.5 Discussion

3.5.1 Determination of high and low usage tourist sites

Our results demonstrated a heterogeneous level of visitor use between the selected gorges of the Flinders Ranges and sites within them. Concentrated use at specific locations within a protected area is a typical visitation pattern (Hammitt and Cole, 1998; Marion and Farrell, 2002) that mainly results from the attraction of visitors to specific natural or artificial landscape features, the accessibility of a site, its spatial relation to other sites (that allows/hinders possible joint visits) and its adequacy for camping, resting or parking.

Usage levels of our study sites differed substantially between vehicle and hiker gorges. Overall, vehicle gorges attracted a much higher load of tourism traffic. For instance, the mean number of visitors that passed by low usage vehicle sites reached similar values as that at high usage hiker sites. Thus variation in usage levels is context-based, in our study area by the mode of access. Regardless of context, in each gorge sites with little use contrasted strongly with well used sites, the reasons being will be discussed in 3.5.2.

The variation in visitor use between sites provides the foundation for a hi-lo impact study. Samples of both hiker and vehicle sites were divided into two groups of contrasting usage level. In both cases the division between the groups by their separation along PC1 (the first PCA axis) was pronounced and would validate a subsequent comparison of resource conditions between high and low usage sites. For the purpose of the hi-lo impact study the first two clusters with the lower PC1 values (Fig. 3.2.2a) for the data from the hiker gorges could be pooled to create a more balanced data set which aids various statistical analyses (Field, 2005).

If the separation of sites was more continuous along PC1 rather than in clusters, the level of usage may be better expressed as a continuous variable, namely the individual PC1 scores for each site, than in a categorical form of high vs. low usage. The hi-lo impact study could also be conducted with the certain percentage of sites with the highest and lowest PC1 values while the rest are excluded for being too similar. Finally, as in the case of PC2 for vehicle sites, a comparison may not only involve different quantities but also qualities of usage (e.g., sites that are used by tourists for stops vs. sites used for camping).

Typically, an inter-site comparison of resource conditions in relation to different usage levels either replaces or supplements a monitoring of impacts at the same site to uncover tourism-related changes over time. The great advantage of the former is that management actions can be taken before sites have diverged from a desired state which may be difficult to restore (Hadwen et al., 2007).

3.5.2 Choice of visitor variables

Mode of access affected which visitor variables were responsible for the discrimination of usage levels in our study sites. We considered variables to be efficient discriminators when they clearly drove the separation of sites along PC1. Visitors in vehicle gorges nearly always travelled in their vehicle rather than alighting and walking. Hence, we hereafter refer to tourists at vehicle sites as 'drivers' and those at hiker sites as 'hikers'.

Numbers of passing tourists discriminated usage levels better between sites in hiker gorges than in vehicle gorges. While vehicle traffic extended uniformly along most of the road through vehicle gorges, a gradient of use was found along the trail in hiker gorges, where the number of passing tourists decreased from the beginning (preferred access point) towards the end. A limited vacation time may favour short to medium hikes. In contrast, most people have time to explore the whole length of a vehicle gorge, especially if the journey is to be continued at the opposite end. Given that the majority of people in our study area were 50 years or older, physical limitations might have further restricted the length of hikes. More intensive use (or signs thereof) in the beginning sections of hiking trails have previously been reported (Bright, 1986; Hammitt and Cole, 1998).

Camping activities were operational in driving site-differences in vehicle gorges but were negligible for differentiating sites in hiker gorges. With the exception of sites in the very beginning, virtually no camping took place in hiker gorges. Given that visitors to the Flinders Ranges have a grand choice of official and wild campgrounds available, they tend to camp where they can remain close to their vehicles. That relieves them from having to carry equipment, water or firewood (the policy is not to collect firewood on-site) and offers the safety of a vehicle nearby. The mean number of day and night campers and the mean number of fire places were clearly higher at the high usage sites in vehicle gorges than at low usage sites. More extreme were the differences in the average campground size, but that was mainly due to a few exceptionally large camp grounds on high usage sites. The same variables differed little in hiker gorges where no camping took place on low usage sites and very little on high usage sites. Further, in hiker gorges visitors spent a very short time camping during the day, even on high usage sites. We noted that tourists that planned to go for a longer hike often arrived the night before to break up camp early in the morning so they could avoid the high ambient temperatures during the days. In high usage vehicle sites, people camped throughout the day and sometimes even stayed for a few days in a row without necessarily leaving their camp site.

The percentage of stoppers and their stop time were mildly efficient discriminators in both types of access mode. In vehicle gorges this difference is ascribed to the existence of 'ordinary' sites that visitors ignored and 'attraction' sites, distributed throughout the gorge, containing car parking, scenic or informative features and shade. In hiker gorges, we noticed that hikers behaved differently at the beginning of their hikes where they took more time to observe the scenery and were more inclined to take longer breaks (e.g., for picnicking or photography).

Of minor (albeit statistically significant) importance for discriminating usage between sites was the passing speed. Hikers already travel at a speed that enables a comfortable observation of their surroundings and even though drivers may reduce their velocity while travelling through scenic sites, they generally drive rather slowly because of the rough unpaved roads and the chance of wildlife crossings. Equally unimportant discriminators were the number of trash items and information signs as both were rare. However, in the few places with information signs the percentage of stoppers increased markedly.

3.5.3 Comparison between visitor monitoring methods

Each of the methods we have employed to monitor actual visitor use have advantages and disadvantages in terms of costs, ease of use, site efficiency (daily sampling rate of sites) and their sensitivity towards short-term fluctuations in visitor use. These costs and benefits need to be considered before a method is utilized in a hi-lo impact study.

3.5.3.1 Direct monitoring via staff observers

The direct monitoring of use required a vehicle and associated fuel (and maintenance) costs, which were substantial due to the long distances between sites. Another drawback was the low site efficiency since only one site could be monitored per day and person with the exception of the night-camper numbers (many sites can be assessed in one evening). Further, on-site counts may be more sensitive to temporal fluctuations in visitor use than the recording of proxy variables.

Little initial training was required, and given the comparatively low traffic volume in our study area inter-observer reliability was high as validated by no significant differences in simultaneous data taken independently by two observers in a pilot study. However, direct monitoring may become increasingly more error prone with higher traffic volumes, faster traffic and more variables to be quantified. Arnberger et al. (2005), for instance, found that at peak times (>120 visitors per hour), observers compared to video-interpreters underreported visitor numbers of walkers and bikers by 30%. Under such circumstances, traffic thresholds need to be identified beyond which the monitoring task is allocated to several observers.

On-site counting had the advantage that it was the only method that allowed quantification of the absolute number of passing tourist units (vehicles or hiker groups) at a site. Traffic, beam or gate counters would also quantify the passage of vehicles or pedestrian traffic but they would be too expensive for a large sample of sites. Further, they may be prone to underestimation (multiple persons counted as a single passage) or overestimation (triggered by another mammal species). Since the number of passing tourists was the variable of choice to discriminate sites accessible on foot based on usage, it needs to be pointed out that relative numbers can be used instead of absolute numbers—as the intention was to compare relative and not absolute usage of sites—and those can be calculated from the GPS tracking data as well.

3.5.3.2 Assessment of proxy variables

It may be possible to replace some of the variables of observed use with proxy variables of use. Instead of measuring the number of day and night campers, the number of fire places and the campground size may be assessed, as long as a strong, positive correlation has been confirmed (Cope et al., 2000; Cessford and Muhar, 2003). Bratton (1978), for instance, found a strong correlation between visitation levels and disturbances such as bare soil at campsites and the number of fire places. The main advantage is that proxy variables can be measured on several sites per day (reduced monitoring effort; (English et al., 2003)) and that they should be less sensitive towards short-term fluctuations in visitor use as they are unlikely to vary from day to day. The number of information signs and trash items were too rare in our study area to be of any use for the task at hand.

3.5.3.3 Indirect monitoring via GPS tracking

For an indirect observation of visitor activities GPS tracking was employed, which is a relatively new method in visitor monitoring (O'Connor et al., 2005; McKercher and Lau, 2008). The GPS-recorded travel routes of visitors were downloadable into the software (Track Stick Manager) provided by the manufacturer (Procure It Australia Pty Ltd, Banyo, Queensland, Australia) and could then be exported into spreadsheet, text and Google Earth file format. Data were also accessible for import into geographical information system (GIS) software for a sophisticated spatial analysis of visitor activity. The training to handle the GPS units and software was slightly more demanding compared to the other monitoring techniques.

Overall, GPS tracking was most rewarding as no other technique provided such detailed data at such a high site-efficiency with most visitors travelling to many different locations per day. Further, GPS data may be more reliable than similar data gathered by human observers particularly if the traffic volumes are high. The data gathered with GPS tracking can also be analysed in ways far beyond the goal of this study to construct intricate models of visitor behaviour, travel routes and park usage (O'Connor et al., 2005). Our example of visitor tracks illustrated that usage may vary even within study sections and that visitors may not necessarily adhere to pre-defined routes. Such knowledge will aid hi-lo impact studies in detecting the actual cores of the disturbance so they can properly relate impacts (e.g., trampling of vegetation) with the distance to the recreational disturbance.

One major drawback of GPS tracking, however, was the relatively high initial cost. Fortunately, prices of GPS units have dropped dramatically in the last decade and there is some powerful GIS software available now as freeware (e.g., QGIS). In addition, the use of GPS units is so versatile that this investment may easily pay off if the tracking units are employed for various other tasks. Other practical disadvantages of GPS units are: (1) they may be stolen because of their utility, (2) they may be tampered with, (3) they may be displaced and lose satellite coverage, (4) they may fail to be returned through oversight, and (5) they may change visitor behaviour, especially illegitimate activities, through the perception of being constantly monitored. To overcome these disadvantages we (1) chose a GPS model whose utilities were already disguised as it lacked a display, and we hid them even further by enclosing the GPS unit in a sealed case which (2) also secured it from tampering, (3) then we installed it with a tape on the car dashboard or in the top pockets of a hiker´s backpack or jacket, (4) provided an easy self-regulated drop-off location and a postal address for return, and (5) provided a participation statement that indicated the privacy of the data and that goals of the project were research not enforcement.

3.5.3.4 Questionnaire-based visitor surveys

Survey data related to specific site-use were impaired by the lack of memory of visitors and their ability to describe or reference the sites of their journey on a map. Fewer people remembered where they had camped or stopped than whether they had visited a particular gorge or from which side they had accessed it. In addition, the lower ratings of correctness and completeness of the answers given about specific site-use cast doubt on the reliability of these data. The questions on more transient use of sites (i.e., any stopping events compared to camping) appeared especially difficult to answer.

Travel diaries might have provided a more reliable data set since visitors record the information whilst they are travelling. But even so, there are limits to the amount of information that you can ask of people being on vacation. Moreover, we would have had to distribute a system of site markers to facilitate the correct identification of sites for the descriptions in the diary.

Given that conducting and evaluating the survey was also very time-consumptive and that a discrepancy may exist between what people do and what they report they do, we cannot recommend visitor surveys as a stand-alone method for quantifying usage levels between sites where variation in use occurs on a small spatial scale.

However, some valuable additional information was retrieved that gave a good indication of difference in usage on a coarser spatial scale (between gorges, sections of a gorge, access points). Further, the visitor profiling helped to interpret the results from the other monitoring methods like the lower engagement in hiking activities and the preference to camp at sites with vehicle access.

3.6 Conclusions

Our examination revealed that access options were a major factor influencing visitor behaviour in the Flinders Ranges gorges which determines our recommendation here for the monitoring of visitor usage in tourism destinations where sites are accessible by roads and trails from a few access points, and where the visitor market resembles ours (preference for low to moderate physical activity and camping at sites with vehicle access).

Gorges with vehicle access attracted the main influx of campers and while most people explored these gorges from the beginning to the opposite end only some of multiple sites were selected for camping. Therefore, we recommend using camping variables including those that were quantified in proxy, namely the camp size and number of fireplaces, to discriminate between vehicle-accessed sites based on usage. The number of passing tourists was too uniform to differentiate usage level. In gorges with hiker access the pattern was exactly opposite. Here, within-gorge visitation varied strongly as sites towards the middle or opposite end of the more accessible entrance point were substantially less frequented as visitors usually remained within a few kilometres from where they had accessed a gorge. Very little camping occurred. Hence, the number of passing tourists should be recorded to discriminate site usage in hiker gorges. For both modes of access, the percentage of stoppers and their stop-time may attain some additional discrimination of sites. Despite the likelihood of similarities of visitor behaviour in other tourism destinations with similar access options to their recreational paths, it is still essential to consult with park personnel and to conduct preliminary observations to confirm the patterns that led to the recommendations we are providing here.

Based on our examination of several visitor-monitoring methods we suggest tracking visitors with a GPS as it is (1) unbiased, (2) provides a high resolution of data if desirable and (3) has the potential for simultaneous sampling of multiple sites. However, for quantifying absolute visitor numbers usage needs to be monitored directly by human observers on-site. To reduce sampling effort visitor numbers may be recorded at the access points and in the middle of the gorges rather than throughout the whole gorge. Questionnaire-based visitor surveys appeared to have low value for differentiating usage levels as the information required about the trip itinerary was simply too detailed for people to recall. Notwithstanding, visitor surveys gave a good indication of difference in usage on a coarser spatial scale and they can retrieve additional information that aids in interpreting the results from the other monitoring methods.

Finally, we recommend designing a hi-lo impact study where equal effort is allocated to the visitor and resource monitoring. In protected areas, where tourism use varies on a small spatial scale it may be of great benefit to GPS-track a larger number of visitors and generate a fine-scale map of usage as a base for further monitoring of resource conditions. Without such detailed visitor information, usage levels may be misjudged and as a consequence visitor impacts overlooked.

Chapter 4
Impacts of tourism hotspots on vegetation communities in arid-lands gorges are more pervasive along roads than hiking trails

Fig. 4.1. Seeds of Horehound (*Marrubium vulgare*; a weed species) spread via vehicle tyres (left). Sturt's Desert Pea (*Swainsona formosa*; a native species with a high visitor attraction value), Chambers Gorge, Flinders Ranges (right).

4.1 Abstract

Vegetation communities along recreational tracks may suffer from substantial edge-effects through the exposure to trampling stress, modified environmental conditions such as greater soil compaction and the increased competition with species that benefit from disturbance. We assessed impacts on trackside vegetation by comparing high and low usage tourism sites at the 1–10 m distance from recreational tracks in arid-lands gorges of the Flinders Ranges, a popular Outback tourism destination in South Australia. The central aim was quantification of the relative strengths and spatial extent of tourism impacts along recreational tracks traversing gorges with vehicle access (roads) compared to gorges restricted to hiker access (trails).

Vegetation variables and soil compaction strongly depended on the interaction between the tourism usage intensity and the distance from tracks. Road-distance gradients appeared weak under low usage conditions except that the mean percentage of total plant cover was significantly greater at 2–4 m from roads when compared to any other distances. In contrast, the mean percentage of total plant cover remained similar as one moved away from high usage roads, presumably because growth-enhancing conditions prevailing near roads were overridden by aversive conditions associated with high usage. Further, the mean soil compaction significantly increased towards high usage roads and community composition was significantly altered with a marked increase in the percentage cover with non-native species. Plant diversity (Simpson´s $E_{1/D}$) showed a unimodal behaviour over the 1–5 m distance with a peak after 3 m from high usage roads.

Even though most of the roadside effects were also prevalent along trails several distinctions were prominent: (1) Significant differences in vegetation variables and soil compaction between high and low usage sites were greater beside roads than trails. (2) Roadside gradients pervaded the ecosystem further (by 1–4 m). (3) Plant cover was not enhanced under low usage conditions of trails. Notwithstanding, the net effect of a reduced plant cover under high vs. low usage conditions was the same as for roads given that plant cover decreased beside high usage trails. (4) Plant diversity increased towards high usage trails, presumably as a response to a continuous increase in disturbance not beyond intermediate levels where disturbance-tolerant species coexist with disturbance-sensitive species. In contrast the unimodal pattern of plant diversity recorded near roads suggests that disturbance increased beyond intermediate levels where only the most disturbance-tolerant species survive. (5) When we tested the same relationships along creek beds neighbouring (average distance = 50 m) recreational tracks the percentage cover with non-native species and the plant diversity markedly increased with usage intensity, but only near roads. Therefore, the overall spatial extent of the roadside impacts was far greater than initially apparent from assessments at the road verge. To our knowledge, this is the first demonstration that the self-perpetuation of certain impacts from their points of introduction to other, disjointed sites with a predisposition to disturbance may depend on the type of access track to a recreation site.

To protect plant communities along recreational tracks in arid-lands gorges, we recommend (1) the regulation of access to gorges (closure of some gorges or strategically chosen sections for vehicle access and/or any usage), and (2) the regulation of camping and parking through systematic attraction of visitors to designated sites and deterrence from unofficial sites.

Keywords: tourism impacts, roads, trails, trampling, habitat modification, weed invasion, non-native species, vegetation community, spatial extent, self-perpetuation of impacts.

4.2 Introduction

An intricate network of recreational tracks admits visitor traffic to many natural tourism areas worldwide. Tracks traverse the landscape and fragment plant habitat which exposes abutting plant communities to edge-effects (reviewed by Murcia, 1995): The physiognomy of tracks as well as their perpetual use and maintenance may interfere with vegetation via a direct, mechanical disturbance, a modification of plant habitat and a facilitated spread and establishment of non-native and native species that thrive in disturbed areas. In the face of growing tourism numbers where recreational demand conflicts with the protection of resource conditions, we need to elucidate how vegetation variables relate to visitor usage along travel corridors in order to mitigate aversive effects. Given the popularity of roads and hiking trails for facilitating easy access throughout protected areas, our key objective is to determine whether trackside impacts and their spatial extent would differ between sites with vehicle access and hiker access. So far, impacts of both platforms (driving vs. hiking) on the total abundance of plants, the composition and diversity of plant communities have mostly been investigated independently. A direct comparison can aid tourism management in making informed decisions about access options to tourism sites.

Plant abundance next to recreational tracks may be lower (Cole, 1978; Boucher et al., 1991) or greater (Hall and Kuss, 1989) than in less disturbed sites. Differences in abundance are dictated by numerous factors and complex processes that govern the trackside environment. For example, trampling as one force (reviewed by Cole, 2004) may damage plant tissue (Meinecke, 1928) and cause an overall reduction in plant vigour and reproductive output (Liddle, 1997) which may lead to a reduction in the total cover, height and biomass of vegetation (Cole, 2004). Plant abundance may further be affected indirectly through changes in the micro-environment next to tracks: soil abrasion and compaction are prominent examples of habitat modification that accrue from trampling (Chappell et al., 1971; Belnap, 1998). Compression of the soil structure leads to a reduction in air and water movement, reduced water infiltration (Bogucki et al., 1975; Hart, 1982; Hammitt and Cole, 1998) and a decreased water retention, except for in coarse-textured soils (Gallet and Rozé, 2002). Such conditions are inhospitable for root (Bhuju and Ohsawa, 1998) and vegetative growth (Settergren and Cole, 1970) as well as soil organisms (Zabinski, 1997) which are vital for decomposing organic material to provide nutrients to stimulate new plant growth. Notwithstanding, the track shoulder may retain higher quantities of moisture due to an increased water runoff from the compacted and barren centre (Bayfield, 1973; Cole, 1978) of most tracks which may stimulate vegetation growth (Johnson et al., 1975; Amor and Stevens, 1976). The continuous use of roads by vehicles may further modify the plant habitat by impacting the trackside environment with emissions from exhaust fumes (Spencer and Port, 1988; Spencer et al., 1988; Morgan, 1998), or raised dust may cover plants and inhibit various physiological processes resulting in a decreased plant productivity (Farmer, 1993).

Under the semi-arid conditions in our South Australian study area, alterations in the physical and chemical environment next to recreational tracks are particularly potent at instigating changes in the community composition as native plants are adapted to a normally very limited (Friedel et al., 1993; James et al., 1995) water and nutrient supply with a heterogeneous distribution (Tongway and Ludwig, 1994; Dunkerley and Brown, 1995; Forman et al., 2003). Recreational tracks may therefore facilitate the establishment of invasive, non-native species that are well-known for their proficiency to withstand modified environmental conditions (Bates, 1935; Liddle and Greig-Smith, 1975), particularly if competition with other disturbance-sensitive species is alleviated (Frenkel, 1970). In Australian grasslands, for instance, a greater richness of exotic species adjacent to roadsides has been attributed to higher nutrient concentrations from vehicle emissions which fostered non-native species growth and suppressed the growth of native species (Morgan, 1998). Likewise, trailsides were susceptible to species invasions (Bright, 1986; Hall and Kuss, 1989; Tyser and Worley, 1992). Depending on the frequency and intensity of the tourism disturbance, changes in community composition are reflected in the decline (Andrés-Abellán et al., 2005), increase (Bright, 1986) or unimodal behaviour (Benninger-Truax et al., 1992) of plant diversity.

We conducted our study in selected gorges in the Flinders Ranges, a popular tourism destination in South Australia (South Australian Tourism Commission, 2008b) where some of the gorges are accessible via unpaved but well-maintained backcountry roads and others are restricted to hiker access. The central question was how tourism impact indicators (Belnap, 1998) respond to an increase in usage along roads or hiking trails. To address our question we assessed vegetation variables and soil compaction at the 1–10 m distance to roads or hiking trails at high and low usage tourism sites. We focused on this particular distance band as we expected that it would encompass the zone of greatest environmental change due to road (e.g., Watkins et al., 2003; Godefroid and Koedam, 2004) and trail (e.g., Benninger-Truax et al., 1992; Chizhova, 2004) usage.

Even though many of the described impact mechanisms may affect vegetation communities equally along roadsides and trailsides in our study area, we suspected that changes in plant metrics and soil compaction emanating from an increase in usage would be more severe and more pervasive along roads than along hiking trails for several reasons. As previously determined for our study area (Chapter 3), most visitors explore vehicle gorges throughout their entire length but camp or stop only at some of multiple sites. In contrast, in hiker gorges visitors concentrate their activities (such as hiking and break stops) in the beginning to the middle and rarely pursue any camping activities whatsoever. These patterns accrued from the preference of the majority of visitors (Chapter 2) for scenic driving over hiking, for short to medium over long hikes and for camp sites with vehicle access, coupled with the fact that access was typically attained from only one or two points at the gorge entrances. Consequently, high usage conditions of roads result from increases in camping usage and stopping of visitors whereas they result from increases in the number of passing and stopping visitors along trails. Camping, being a temporally extended and physically more involved form of usage, should aggravate impacts. Impacts on plants and their habitat may further be exacerbated along roads because vehicles cause heavy-weight trampling and pollution;

particularly in high usage sites where camping or stopping visitors manoeuvre their vehicles excessively, for instance, to seek optimum parking. Roads that receive frequent usage also require maintenance efforts which typically affect the surroundings more than the maintenance needed for well-used trail sections.

The following non-exclusive hypotheses were tested: (1) Plant metrics and soil compaction would differ between high and low usage sites, suggesting that the increase in tourism usage impacts on plants and their habitat. At high usage sites and close to tracks, we expected that plant cover would decrease (due to trampling or dust pollution) or increase (due to water runoff or 'fertilization' with pollutants); further, that the percentage cover of non-native species and soil compaction would increase. Consistent with the predictions of the Intermediate Disturbance Hypothesis (Connell, 1978), we expected that plant diversity would increase towards low usage tracks (where intermediate levels of disturbance were likely not yet exceeded) and either increase, decrease or behave unimodal towards high usage tracks (depending on whether intermediate levels of disturbance were exceeded). (2) Changes in plant metrics and soil compaction emanating from an increase in usage would be more severe and more pervasive along roads than along hiking trails. (3) Species' reactions to tourism usage would differ: we envisaged species to be either attracted to, repelled from or to behave neutrally towards high usage sites. (4) We expected that certain impacts noticed beside tracks would self-perpetuate to the banks of creek beds due to their natural predisposition to disturbance. Thus, the same variables as along tracks were recorded along neighbouring (average distance of 50 m) creek beds to assess whether the simultaneous presence of multiple corridors of disturbance (recreational tracks and creek beds) would extend the ecological effect zone of trackside impacts.

4.3 Methods

4.3.1 Study area

This study was conducted in a very popular tourism destination in South Australia, the central and northern Flinders Ranges, from the Flinders Ranges National Park (Wilpena: lat. 31° 30` S, long. 138° 30` E) into the Vulkathunha-Gammon Ranges National Park (Balcanoona: lat. 30° 30` S, long. 139° 30` E). The geomorphologically diverse Flinders Ranges encompass six bioclimatic regions (Nix, 1982) and provide a versatile mixture of habitats for a rich vegetation community with a record of 1233 native plants, including more than 200 species holding some status of conservation threat and 14 endemic taxa (Brandle, 2001). Given the sporadic rainfalls that vary from approximately 200–500 mm per annum (Brandle, 2001) much of the vegetation is typical of semi-arid communities (Kuchel, 1980). Slow growth and recovery rates as a response to the dry conditions and unpredictable water availability make the vegetation of the Flinders Ranges particularly sensitive to visitor impacts.

Our study focused on gorges as they attract some of the most intense visitor traffic in the region. Moreover, they support high plant species richness due to their propensity to retain water and to provide shady refuges from the drier, surrounding plains. With an average of approximately 70 plant species per site, gorges hosted by far the richest plant community compared to 14 other landform elements that were assessed in a comprehensive, biological survey of the Flinders Ranges (Brandle, 2001). Typically, gorges are traversed by intermittently flowing creek beds that are fringed by riparian woodlands of *Eucalyptus camaldulensis* and common understory species such as *Melaleuca glomerata* or *Myoporum montanum* as well as numerous ephemeral herbs. Occasional, heavy flows of water can sweep through the watercourses out to the surrounding plains. During our study period from July to December in 2006 and 2007 no substantial rainfall events occurred and the creek beds were largely dry except for some pockets of water where drainage was impeded. In these damp areas sedges and rushes may proliferate. Much like the rest of the Flinders Ranges with their 300 non-native plant taxa (Brandle, 2001)—including 'proclaimed' weed plants such as *Echium vulgare*—the gorges have been subjected to the invasion of non-native species such as *Rumex vesicaria*, *Sisymbrium erisimoides* and *Cirsium vulgare*. Different types of sandy and loamy soils occur. Visitors can enjoy the scenery and species richness of the gorges from a network of roads and trails that also provide access to a variety of popular, official and unofficial campsites.

4.3.2 Study design

We selected seven major gorge systems, three of which were mainly accessed by vehicles and four were exclusively accessible to hikers. In either gorge type, we established transects at 40 sites, a minimum of 250 m and usually not more than 500 m apart. The chosen areas (Fig. 4.2) were on average (± 1SE) 92.5 ± 3.6 m wide and had to contain a distinctly marked recreational track (roads: 5 ± 0.2 m wide; trails: 1.2 ± 0.15 m wide) and a creek bed (11.6 ± 0.9 m wide), which were separated by at least 30 m (46.9 ± 4.5 m) from the track. Roads were unpaved but graded and composed of gravel, dirt or a mix of the two.

Because we proposed a comparison between lightly and heavily used areas, we had previously classified (Chapter 3) our study sites as low or high usage ($n_{\text{(low usage roads)}} = 21$; $n_{\text{(high usage roads)}} = 19$; $n_{\text{(low usage trails)}} = 22$; $n_{\text{(high usage trails)}} = 18$) based on differences in the number of passing tourists, their passing speed, the percentage of stopping tourists, their stop time, the number of day- and night-campers and the average camp-time by day (Table 3.2). Further, we included proxies which reflect usage (based on preliminary observations): the size of traversing and abutting (boundaries situated within 30 m to the visitor census plots) campgrounds, the numbers of fire places, trash items and interpretation signs. Visitor census plots (which contained the plant census plots; see next paragraph) had been placed so there was not more than approximately 10% of overlap with traversing campgrounds as we did not intend to measure the effect of camping per se but of recreational tracks in general independent of their dominant use. Further, we wanted to avoid creating internal edges within the study plots which could have attenuated track-distance gradients. This visitor monitoring effort ascertained the differences in visitor usage of gorges depending on the access mode as described in the introduction.

On either side of the recreational track (Fig. 4.2b, c) and the creek bed (Fig. 4.2d) at these pre-determined sites, two belt transects of 50 m x 10 m (Fig. 4.2a) were established. Within each transect, 20 1 m x 1 m frame quadrats (Kent and Coker, 1995) were randomly sampled at a 1–10 m distance to the track or creek bed bank (Fig. 4.2), so that each distance treatment was replicated ($n = 2$) at each transect. Although the creek beds were mostly dried out, the marked succession from pure rock to mineral soil and the presence of plants was used to demarcate the bank for the placement of the first sampling quadrat. We visually estimated the species-cover of all living, vascular plant species (Table 4.2, Table A 2.1) 1.5 m or less in height as the area of the sampling quadrat over which the vertical projection of the above-ground parts of the plants exerted an influence. The percentage of total plant cover at each quadrat was calculated as the sum of individual species covers. As vegetation was layered, percentage cover values ('overlapping cover') may sum to more than 100% (Sutherland, 2006). The percentage cover with non-native species was calculated by dividing the cover of non-native species by the percentage of total plant cover. Species diversity was expressed through the heterogeneity diversity index Simpson´s $E_{1/D}$ (advantages of this measure over its alternatives are reviewed by Magurran, 2004). Nomenclature and status as native or non-native species to the Flinders Ranges followed Barker et al. (2005).

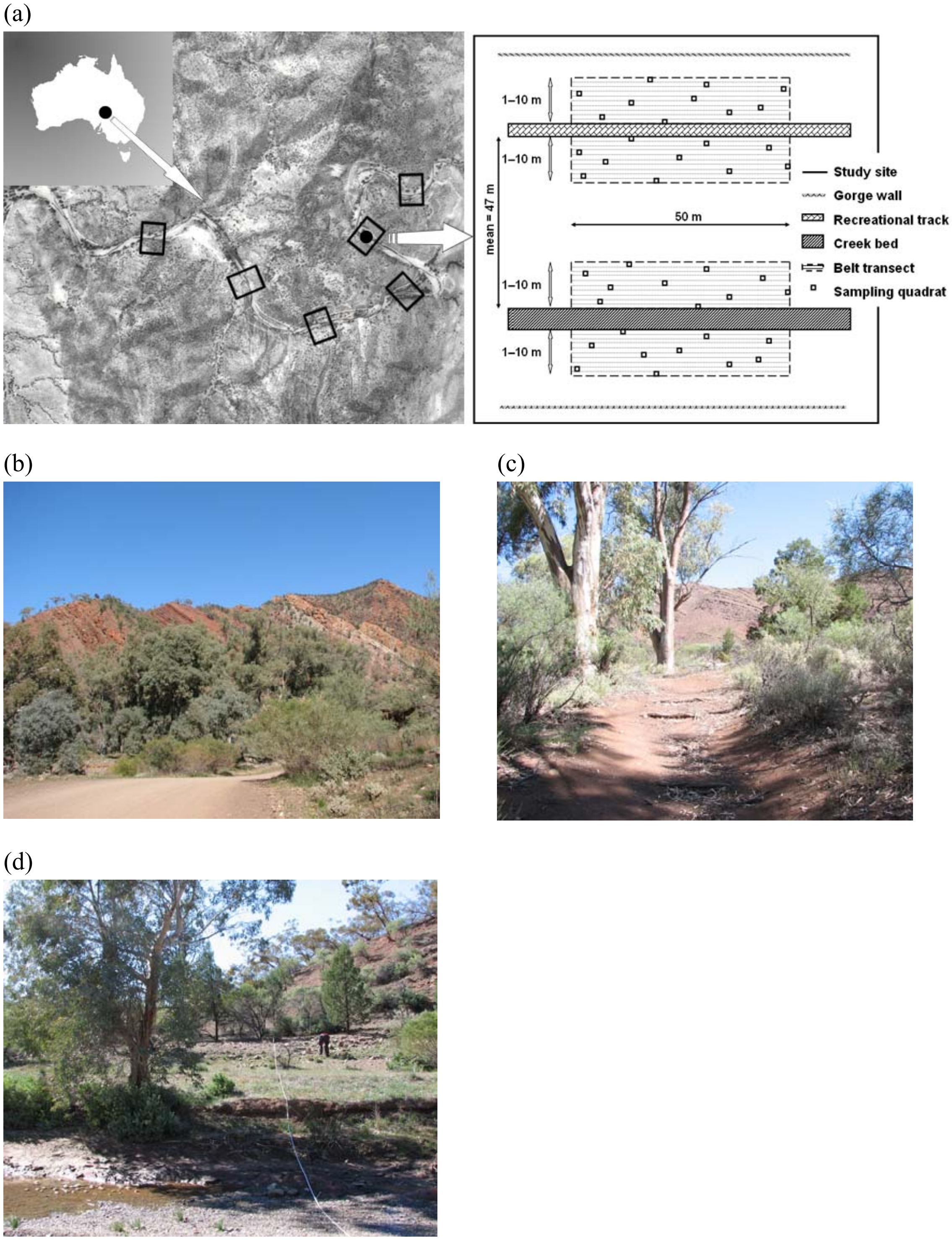


Fig. 4.2. Illustration of the experimental set up by (a) a sample of study sites in Brachina Gorge (lat. 31° 34` S, long. 138° 56` E; aerial photograph, survey/frame no. 2320/24, reproduced with permission of the South Australian Department of Lands) and the distribution of sampling quadrats within each study site. Representative sections of (b) a road verge, (c) a trail verge and (d) a creek bed.

Three measurements of soil compaction equidistant of 1 m were taken with a hand-held dial penetrometer (Pocket Geostester, Zoli Maurizo, Italy) at each distance from the track or creek bed, measuring the force (in kg cm^{-2}) necessary to penetrate the upper soil stratum (Lipiec and Hatano, 2003). The use of a penetrometer provides an easy method of conducting *in situ* compaction tests as an alternative, for instance, to traditional laboratory compression tests of soil cores (Dawidowski et al., 2002). Depending on the soil strength, tips of different diameter were applied which was figured into the later calculation of compaction values according to the formula recommended by the manufacturer. Recorded compaction values refer to the maximum value read from the dial of the instrument as it was pressed onto the soil surface until fully compressed or the full length of the shaft (approximately 50 mm) was inserted into the soil. The average value of the multiple readings was used in the statistical analyses.

4.3.3 Data analyses

Each of the following analyses was conducted separately for vehicle and hiker gorges. Had we merged the data sets in the first place, then most vehicle sites would have been categorized as high usage sites because roads received more overall usage than trails (Chapter 3) and the effect of the usage level would have been confounded with the effect of the access mode. Therefore, we first analysed how low and high usage sites behaved in each gorge type, and secondly, compared the emergent patterns between gorge types.

Prior to multivariate analysis, species cover data were square-root-transformed to downweight high-abundance species, and the data gathered at the creek beds were excluded. To relate vegetation community patterns to usage intensity and distance from the tracks, a four-way factor permutational multivariate analysis of variance+, PERMANOVA+ (Anderson et al., 2008), with 999 permutations and type III sum of squares was performed on a Bray-Curtis similarity matrix of the species data in PRIMER v6 (Clarke and Gorley, 2006). PERMANOVA+ is embedded in PRIMER v6 via an add-on module and extends the original DOS version of PERMANOVA (Anderson, 2001) by various functionalities (e.g., the handling of unbalanced data sets) (Chapter 5 for details).

The experiment was examined as a split-plot design (Quinn and Keough, 2004; Doncaster and Davey, 2007). Study sites (random, vehicle gorges: 40 levels, hiker gorges: 40 levels) were treated as the experimental whole-plot units/subjects that were nested in the between-subject treatments 'gorge' (random, vehicle gorges: 3 levels, hiker gorges: 4 levels) and 'usage intensity' (fixed, 2 levels), the latter two factors being crossed with each other. The within-subject treatment 'distance' (fixed, 10 levels), which was crossed with all other factors, was 'applied' to sampling quadrats (i.e., sub-plot units; $n = 800$) that were randomly distributed within the belt transects to ensure an equal correlation of all pairs of measures in the same whole-plot unit (SPSS, 2005; West et al., 2007). The two samples from the same distance to the track at each site represent replication ($n = 2$) at the lowest design level. The random factors, 'gorge' and 'site', allowed us to generalize about spatial variation in response to disturbance created by recreational tracks. Final models were extracted by excluding factors with P-values > 0.25 (Winer et al., 1991; Underwood, 1997) from initial models in a manual, stepwise backward selection procedure (Crawley, 2007). Differences among levels of a factor were identified with post hoc pairwise tests (999 permutations). These also allowed specification of simple main effect tests (Field, 2005) as a follow-up to significant interactions to identify the level of one factor at which significant differences of the other factor occurred.

Multivariate patterns were visualized by ordinating the sampling quadrats in a two-dimensional species-space with non-metric multidimensional scaling (nMDS) in PRIMER v6. As nMDS displays samples without attempting statistical inference, it can be used to identify visual patterns in community composition even in complex, nested designs where the independence of samples may be violated. To reduce the number of displayed sampling quadrats, we averaged the distance replicates and chose one vehicle and one hiker gorge to represent community patterns at the 1–5 m and 6–10 m distance from tracks in relation to usage intensity.

To examine which species were consistently associated with high or low usage conditions at the 1–5 m and 6–10 m distance, we conducted an Indicator Species Analysis (Dufrêne and Legendre, 1997) from the PC-ORD package (McCune and Mefford, 1997). This method calculates an indicator value from the relative abundance of a species in the different factor levels and its relative frequency of occurrence at the multiple sites belonging to each level (Dufrêne and Legendre, 1997). The perfect indication value of 100 (with 0 being the minimum) occurs for a species that is present in all sites belonging to one particular factor level, and absent in all others. A Monte Carlo randomization procedure tested the indicator values for statistical significance.

Univariate analyses of the same relationships that had been investigated for the multivariate data were conducted by fitting four-way factor ANOVA models on the mean percentage of total plant cover and of non-native species cover, the mean Simpson´s diversity index $E_{1/D}$ and mean soil compaction. Initial models were reduced following the same procedure applied for the selection of the final PERMANOVA+ models. Significant interaction effects were followed-up with simple main effect analyses. For consistency, we have presented the results of the simple effects for usage intensity x distance even when this interaction was not significant, which was the case for one model where the *P*-value had just exceeded the level of significance.

To test whether the univariate effects of the usage intensity and distance were not only prevalent adjacent to tracks but also creek beds, univariate variables recorded close (1–5 m) to tracks were compared with those recorded close to creek beds and contrasted with the data gathered far (6–10 m) from tracks and creek beds. Therefore, a conjoint factor 'section/block-distance' (fixed; 4 levels: close/track, close/creek, far/track, far/creek) was created. This factor was used to replace the factor 'distance' in the design that was consistently applied in the previous analyses. A significant interaction of the section/block-distance with usage intensity was followed-up with simple effect analyses.

Data were transformed as needed to approximate the assumptions for ANOVA (Quinn and Keough, 2004). Denominator degrees of freedom that are not integers indicate a numerical approximation with the Satterthwaite (1946) method. All transformations ($x' = \sqrt{x}$; $x' = \log10(x+1)$) and univariate statistical analyses were carried out with SPSS for Windows 17.0 (SPSS, 2008). The 0.05-level of probability was accepted as significant in all analyses. Means ± 1 SE are presented unless otherwise indicated.

4.4 Results

4.4.1 Species community and indicator species

A total of at least 126 plant species (Table 4.2, Table A 2.1) belonging to 38 families and 86 genera was recorded in the 1600 1 m x 1 m sampling quadrats with two genera (*Bromus* sp., *Juncus* sp.) not identified to species level. The three most common Families were the Chenopodiaceae, Fabaceae and Asteraceae with 16, 16 and 13 species, respectively. A fifth (20.6%) of the recorded species were not native to the Flinders Ranges.

PERMANOVA+ detected a significant interaction between usage intensity and distance on the overall community composition of vegetation growing along roads (Table 4.1.1) and trails (Table 4.1.2). Pairwise comparisons revealed similar patterns for the effect of usage along roads and trails in that at the 2–3 m distance plant assemblages supported along high usage tracks were significantly different from those growing along low usage tracks, which was consistent across gorges. Trackside gradients, on the other hand, were inconsistent at both high and low usage sites adjacent to roads when pooled data from the different gorges were used. In contrast, pairwise comparisons split by gorge elucidated clear distance effects independent of usage intensity: In all three vehicle gorges, assemblages inhabiting the 1st metre from roads were significantly different from those growing between the 5th to the 10th metre; in two vehicle gorges, even the vegetation communities growing at 2–3 m from the road differed from those growing further away. Among hiker gorges, the trackside gradients were somewhat more uniform and also depended on the usage intensity: Assemblages growing at 1–3 m from high usage trails were significantly different from assemblages growing at the 9–10 m distance whereas assemblages growing at 1–3 m from low usage trails were different from assemblages growing at any further distances (pairwise comparisons were all significant except between metre 3 and 4) suggesting that high usage trails exerted a wider influence on the adjacent plant community than low usage trails.

Table 4.1. Final PERMANOVA+ models including all main terms and interactions which significantly (bold values) explained variation in plant community composition adjacent to (1) roads and (2) trails in arid-lands gorges.

	(1) Next to roads			(2) Next to trails		
	df	pseudo-*F*	*P(perm)* [a]	df	pseudo-*F*	*P(perm)* [a]
Usage intensity	1, 2.01	1.42	0.196	1, 4.10	2.62	**0.010**
Gorge	2, 34	10.90	**0.001**	3, 32	2.28	**0.002**
Usage intensity x gorge	2, 34	1.71	**0.011**	3, 32	0.81	0.740
Site(usage intensity x gorge)	34, 724	4.47	**0.001**	32, 715	5.04	**0.001**
Distance	9, 18.05	2.07	**0.004**	9, 32	2.41	**0.001**
Usage intensity x distance	9, 724	1.39	**0.004**	9, 715	1.49	**0.001**
Gorge x distance	18, 724	1.61	**0.001**	27, 715	1.19	**0.009**

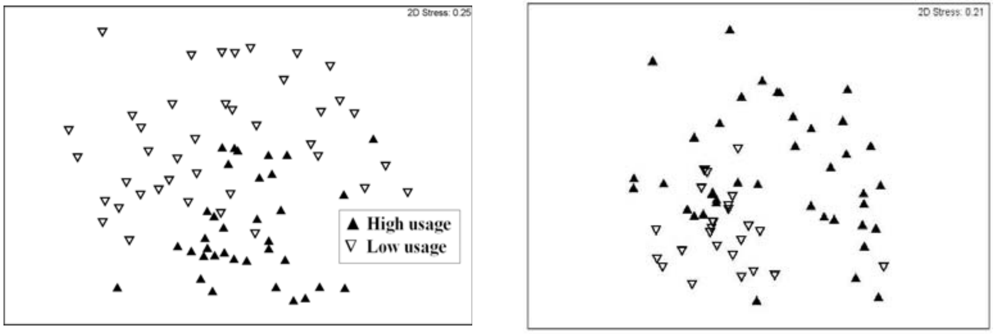
Note: Terms for which *P(perm)* > 0.25 (Winer et al., 1991; Underwood, 1997) were excluded from final models (denoted as 'NA') unless they figured in higher order or nested terms. The factors 'site(usage intensity x gorge) x distance' and 'usage intensity x gorge x distance' are not listed because of *P(perm)* > 0.25 for all effects.

[a] In PERMANOVA (Anderson, 2001) the distribution of the pseudo-*F* statistic is obtained by using a permutation procedure.

The nMDS ordination (Fig. 4.3) based on floristic composition of the two gorges we have chosen to display clearly stratified sites by usage intensity both at 1–5 and 6–10 m from the road (Fig. 4.3.1a, b) and at 1–5 m from the trail (Fig. 4.3.2a, b). Thus, the nMDS results illustrated a more extreme difference in communities based on usage intensity than the PERMANOVA+ as the differences also persisted further from the tracks. However, these results need to be interpreted with caution as the stress of the nMDS plots was high (≥0.2).

(1) Next to a road (1) Next to a trail

(a) 1–5 m distance



(b) 6–10 m distance

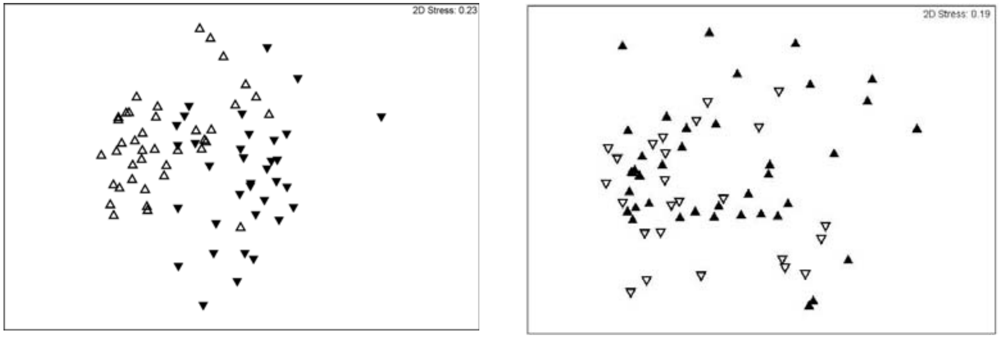


Fig. 4.3. NMDS plots of sampling quadrats based on floristic composition at the (a) 1–5 m vs. (b) 6–10 m distance showing differences in plant assemblages between high (▲) and low (∇) usage sections of (1) a road in Brachina Gorge (lat. 31° 34` S, long. 138° 56` E) and (2) a trail in Weetootla Gorge (lat. 30° 49` S, long. 139° 24` E). No scales are shown on the axes as the orientation of a nMDS diagram is arbitrary (Clarke and Gorley, 2006).

There was a considerable overlap in high (27.1%) and low (41.6%) usage indicator species between roads and trails. Very few indicators (Dufrêne and Legendre, 1997) were found for low usage conditions, whatever the distance or the access mode to the gorge, compared to the greater number of species that were indicative of high usage conditions (Table 4.2.1a, b; Table 4.2.2a, b), particularly at the 1–5 m distance from recreational tracks. Very conspicuous was the high number of non-native species in high usage conditions of roads and trails; notably among them, two proclaimed weed species, *Asphodelus fistulosus* and *Marrubium vulgare*. Species with preference for high usage conditions, however, also included native species. In fact, at the further distances and in hiker gorges, the disturbed 'niches' of the plant habitat were increasingly occupied by native species (fraction of native vs. non-native species at 1–5 m from roads: 0.2; at 6–10 m: 0.6; at 1–5 m from trails: 0.7 and at 6–10 m: 1.7). Other native species such as *Rhagodia parabolica*, *R. spinescens* and *Swainsona phacoides* preferred the presumably least disturbed sites at the 6–10 m distance from low usage recreational tracks.

Table 4.2. Plant species that were significantly indicative (Dufrêne and Legendre, 1997) of (a) high or (b) low tourism usage intensity at a 1–5 m vs. 6–10 m distance from (1) roads or (2) trails in arid-lands gorges (IV = indicator values = % perfect indication; ranging from 0–100).

Scientific names	(1) IV next to roads		(2) IV next to trails	
	1–5 m	6–10 m	1–5 m	6–10 m
(a) High usage indicators				
Ajuga australis		2.6		
* *Anagallis arvensis*	4.9		3.6	
* **_Asphodelus fistulosus_**	30.6	16.5		
Atriplex stipitata			3.7	
* *Carthamus lanatus*	4		3.1	
Cassinia laevis			2.8	2.2
* *Centaurea melitensis*	19.2		13.9	
* *Citrullus colocynthis*	2.6			
* *Echium plantagineum*	22.3	11.5	17.5	13.3
* *Fumaria muralis*				2.8
* **_Marrubium vulgare_**	7.4			
* *Medicago minima* var. *minima*	8.3	3.7	6.6	
* *Medicago praecox*	14.5	3.7	9.5	
Nicotiana velutina	2.1			
Portulaca oleracea	4.6			
Ptilotus obovatus var.		15.6	11.1	16.2
* *Salvia verbenaca*		2.6		3.3
Sclerolaena cuneata				11.2
Solanum ellipticum			12.4	9.2
* *Sonchus tenerrimus*	5.9		4.5	
Zygophyllum apiculatum		8.3	4.7	9.2
(b) Low usage indicators				
Cymbopogon ambiguus			12.4	
Cyperus alterniflorus			7.7	
Cyperus gymnocaulos	27.3	10.2	25.4	10.2
Eremophila freelingii		2.9		3.2
Olearia decurrens	3.3		3.1	
Rhagodia parabolica		4.3		4.9
Rhagodia spinescens		11	6.1	10.9
Rumex brownii	4.7		4.5	
Swainsona phacoides		7.1		7.3

*Non-native species; denoted in bold if 'proclaimed' in South Australia; i.e., landholders are legally obliged to control them http://www.wmssa.org.au/weeds.htm).

4.4.2 Total plant and non-native species cover, plant diversity and soil compaction

The univariate vegetation variables and soil compaction strongly depended on the interaction between the usage intensity and the distance from roads and trails (Table 4.3, Fig. 4.4).

The fact that none of the dependent variables exhibited an ostensible gradient with distance from low usage trails suggested that low usage conditions had a negligible effect on the trailside environment. Only the mean percentage of non-native species cover (Fig. 4.4.2b) decreased slightly with distance from low usage trails. In contrast, as one moved away from high usage trails the mean percentage of total plant cover (Fig. 4.4.2.a) significantly increased and the mean percentage of non-native species cover (Fig. 4.4.2b), mean plant diversity (Fig. 4.4.2.c) and mean soil compaction (Fig. 4.4.2.d) significantly decreased. The gradients were strongest within the first 4 m. However, mean soil compaction was only significantly higher directly beside trails compared to other distances. Significant differences between high and low usage trails were also confined to the first 4 m where high usage conditions were associated with a reduced mean percentage of total plant cover (1st to 3rd m; Fig. 4.4.2a) and increased mean percentage of non-native species cover (1st to 4th m; Fig. 4.4.2b), mean plant diversity (1st to 3rd m; Fig. 4.4.2c) and mean soil compaction (1st m; Fig. 4.4.2d).

Likewise, towards low usage roads there was a comparatively weak increase in the mean percentage of non-native species cover (trend; Fig. 4.4.1b) but also in mean soil compaction (Fig. 4.4.1d). However, vegetation growth was substantially enhanced as indicated by the marked increase in the percentage of total plant cover at 2–4 m from low usage roads (Fig. 4.4.1a) compared to any other distances. In contrast, at the verge of high usage roads no increase in plant cover was discernible but rather there was a slight decline in the 1st m compared to the other distances. Thus unfavourable conditions may have prevented vegetation benefiting from the growth-enhancing conditions prevalent close to low usage roads. Further, the mean percentage cover with non-native species (Fig. 4.4.1b) was significantly greater up to 4 m from high usage roads compared to further away. Plant diversity (Fig. 4.4.1c) increased over the first 3 m up to a maximum, where it was distinctly higher than along low usage roads; after this point it dropped to significantly lower values, similar to the ones observed in the vicinity of low usage roads. Soil compaction (Fig. 4.4.1d) decreased with distance to high usage roads over the first 5 m. Significant differences between high and low usage roads occurred up to 5 m with a reduction in the mean percentage of total plant cover (2nd to 5th m; Fig. 4.4.1a) and an increase in the mean percentage of non-native species cover (1st to 4th m; Fig. 4.4.1b), mean plant diversity (1st to 5th m; trend for the 4th m; Fig. 4.4.1c) and mean soil compaction (2nd to 4th m; Fig. 4.4.1d) at high usage sites. The fact that similar average plant cover and soil compaction values were recorded directly beside low and high usage roads suggested that the former zone had suffered from a similar degree of disturbance as the latter despite the overall lower usage prevailing at the whole site.

Even though the interaction effect of usage intensity and distance on the mean percentage of non-native species cover (Table 4.3.1b) and plant diversity (Table 4.3.1c) was not consistent across all vehicle gorges, as inferred from the triple interactions, a closer inspection revealed that the patterns were similar across all gorges albeit more or less pervasive. For instance, the increase in the percentage of non-native species cover from low to high usage sites affected the roadsides up to 7 m at Brachina Gorge (lat. 31° 34` S, long. 138° 56` E) whereas the other two vehicle gorges were affected only up to 4 m.

Table 4.3. Final ANOVA models including all main terms and interactions which significantly (bold values) explained variation in (a–c) vegetation variables and (d) soil compaction adjacent to (1) roads or (2) trails in arid-lands gorges.

(1) Next to roads				(2) Next to trails		
(a) Total plant cover (summed % of overlapping cover per sampling quadrat)						
	df	*F*	*P*	df	*F*	*P*
Usage intensity	1, 2.02	15.01	0.060	1, 3.67	5.29	0.089
Gorge	2, 1.98	3.97	0.203	3, 3.73	0.75	0.578
Usage intensity x gorge	2, 34	0.52	0.599	3, 32	0.50	0.688
Site(usage intensity x gorge)	34, 742	6.61	**<0.001**	32, 715	8.56	**<0.001**
Distance	9, 742	8.18	**<0.001**	9, 30.18	0.39	0.930
Usage intensity x distance	9, 742	4.11	**<0.001**	9, 715	2.53	**0.007**
Gorge x distance	NA NA	NA	NA	27, 715	1.83	**0.007**
Usage intensity x gorge x distance	NA NA	NA	NA	NA NA	NA	NA
(b) Non-native species cover (% of total plant cover)						
	df	*F*	*P*	df	*F*	*P*
Usage intensity	1, 2.01	8.83	0.096	1, 3.86	10.58	**0.033**
Gorge	2, 0.06	201.38	0.764	3, 2.59	3.37	0.194
Usage intensity x gorge	2, 40.86	0.38	0.686	3, 32	0.39	0.760
Site(usage intensity x gorge)	34, 706	6.03	**<0.001**	32, 742	5.40	**<0.001**
Distance	9, 18.41	27.53	**<0.001**	9, 742	12.32	**<0.001**
Usage intensity x distance	9, 18.06	2.24	0.070	9, 742	2.75	**0.004**
Gorge x distance	18, 18	0.15	1.000	NA NA	NA	NA
Usage intensity x gorge x distance	18, 706	2.89	**<0.001**	NA NA	NA	NA
(c) Simpson´s diversity index $E_{1/D}$						
	df	*F*	*P*	df	*F*	*P*
Usage intensity	1, 2.01	12.49	0.071	1, 3.39	1.87	0.255
Gorge	2, 1.10	10.16	0.196	3, 3.96	1.54	0.336
Usage intensity x gorge	2, 36.46	0.80	0.456	3, 32	0.85	0.479
Site(usage intensity x gorge)	34, 706	4.13	**<0.001**	32, 715	4.73	**<0.001**
Distance	9, 18.17	6.30	**<0.001**	9, 30	3.94	**0.002**
Usage intensity x distance	9, 18.09	2.89	**0.026**	9, 715	3.34	**0.001**
Gorge x distance	18, 18	0.50	0.922	27, 715	1.83	**0.001**
Usage intensity x gorge x distance	18, 706	2.06	**0.006**	NA NA	NA	NA
(d) Soil compaction						
	df	*F*	*P*	df	*F*	*P*
Usage intensity	1, 2.10	48.26	**0.018**	1, 3	1.18	0.349
Gorge	2, 1.96	226.76	**0.005**	3, 2.8	1.11	0.474
Usage intensity x gorge	2, 34	0.09	0.910	3, 32	0.82	0.501
Site(usage intensity x gorge)	34, 742	6.92	**<0.001**	32, 742	12.71	**<0.001**
Distance	9, 742	19.05	**<0.001**	9, 742	6.07	**<0.001**
Usage intensity x distance	9, 742	4.22	**<0.001**	9, 742	2.19	**0.021**
Gorge x distance	NA NA	NA	NA	NA NA	NA	NA
Usage intensity x gorge x distance	NA NA	NA	NA	NA NA	NA	NA

Note: Terms for which $P > 0.25$ (Winer et al., 1991; Underwood, 1997) were excluded from final models (denoted as 'NA') unless they figured in higher order or nested terms. The factor 'site(usage intensity x gorge) x distance' is not listed because of $P > 0.25$ for all effects.

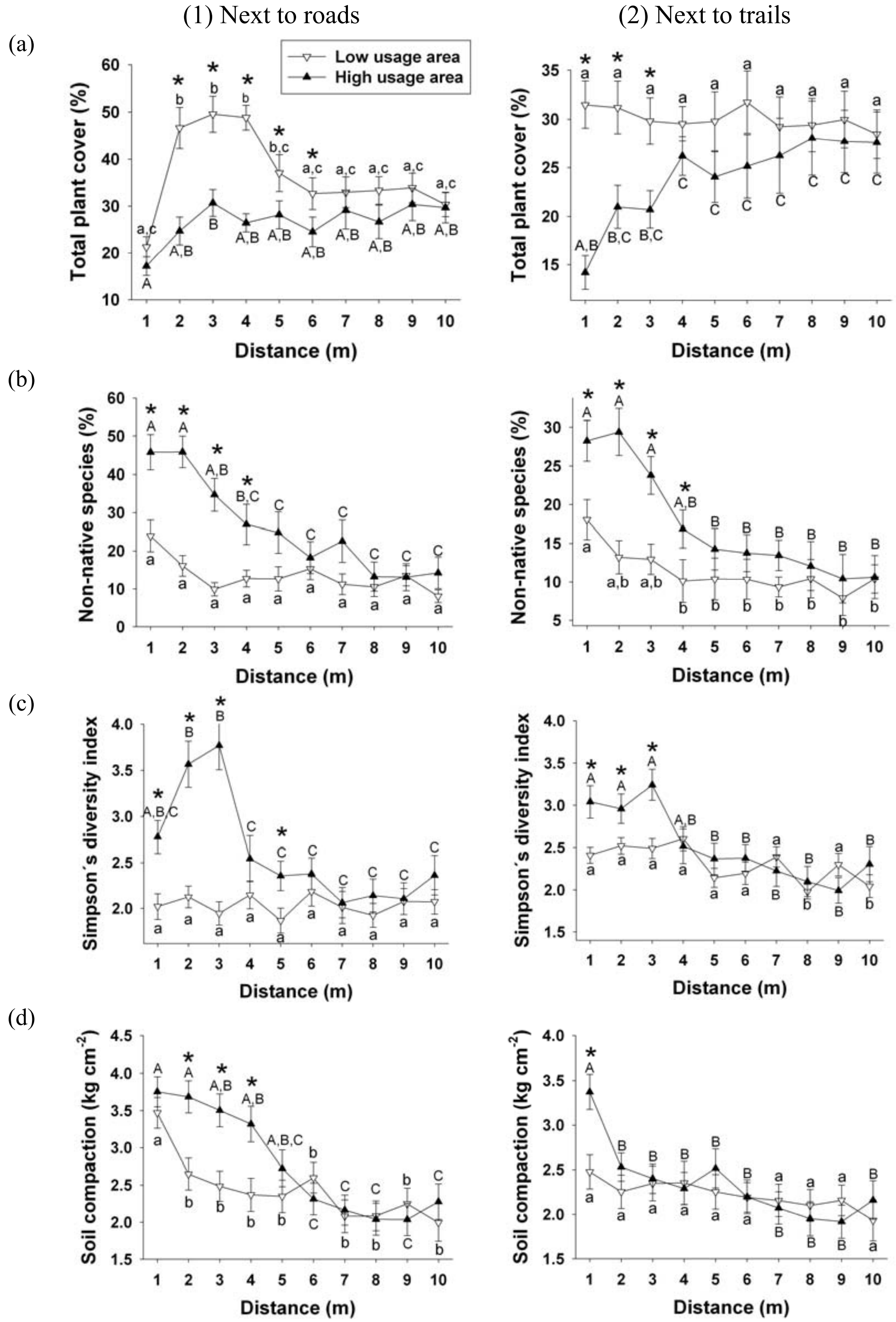


Fig. 4.4. Mean (± 1 SE) (a) percentage of total (overlapping) plant cover (per 1 m^2), (b) percentage of non-native species cover (of total plant cover), (c) Simpson diversity index $E_{1/D}$ and (d) soil compaction in relation to the tourism usage intensity (high (▲) or low (∇)) and distance to (1) roads or (2) trails in arid-lands gorges. Asterisks indicate significant simple effects of usage intensity at a particular distance. Bars that do not share a common letter are significantly different at a particular level of usage intensity.

Tourism impacts were not confined to the trackside but also exerted their effect to the banks of intermittently flowing creek beds neighbouring to high usage roads (Table 4.4.1, Fig. 4.5.1). Both the percentage of non-native species cover (Table 4.4.1b; Fig. 4.5.1b) and plant diversity (Table 4.4.1c; Fig. 4.5.1c) were significantly greater within 1–5 m from creek beds under high usage conditions consistent with the findings from the roads. The fact that the effects were much smaller at 6–10 m from roads and creek beds (Table 4.4.1b, c; Fig. 4.5.1b, c) implied that the ecological effect zone of tourism impacts was not continuous but prevailed at two disjointed areas. Interestingly, plant cover (Table 4.4.1a; Fig. 4.5.1a) along creek beds showed the opposite trend to roads with a somewhat higher mean percentage of total plant cover under high usage conditions. Along creek beds neighbouring high usage trails, plant diversity (Table 4.4.2c; Fig. 4.5.2c) was also slightly higher compared to low usage trails but the effect size was very small.

Table 4.4. Final ANOVA models including all main terms and interactions which significantly (bold values) explained variation in (a–c) vegetation variables and (d) soil compaction adjacent to recreational tracks (roads vs. trails) or creek beds in arid-lands (1) vehicle or (2) hiker gorges.

(1) Inside vehicle gorges				(2) Inside hiker gorges		
(a) Total plant cover (summed % of overlapping cover per sampling quadrat)						
	df	*F*	*P*	df	*F*	*P*
Usage intensity	1, 2	2.50	0.254	1, 3.13	0.04	**0.855**
Gorge	2, 5	2.44	0.182	3, 2.89	1.82	0.323
Usage intensity x gorge	2, 34	0.59	0.562	3, 32	1.81	0.165
Site(usage intensity x gorge)	34, 108	3.37	**<0.001**	32, 114	2.60	**<0.001**
Sect./block-dist.	3, 6	2.39	0.168	3, 114	0.44	**0.723**
Usage intensity x sect./block-dist.	3, 108	9.08	**<0.001**	3, 114	5.37	0.002
Gorge x sect./block-dist.	6, 108	3.60	**0.003**	NA NA	NA	NA
Site(usage intensity x gorge) x sect./block-dist.	108, 1440	2.64	**<0.001**	114, 1440	3.09	**<0.001**
(b) Non-native species cover (% of total plant cover)						
	df	*F*	*P*	df	*F*	*P*
Usage intensity	1, 2	4.59	0.165	1, 4.75	13.92	**0.015**
Gorge	2, 2	2.14	0.289	3, 1.77	7.76	0.136
Usage intensity x gorge	2, 34	3.87	**0.031**	3, 32	0.14	0.933
Site(usage intensity x gorge)	34, 108	3.80	**<0.001**	32, 114	5.39	**<0.001**
Sect./block-dist.	3, 6	6.75	**0.024**	3, 114	13.10	**<0.001**
Usage intensity x sect./block-dist.	3, 108	8.89	**<0.001**	3, 114	2.43	0.069
Gorge x sect./block-dist.	6, 108	2.77	**0.015**	NA NA	NA	NA
Site(usage intensity x gorge) x sect./block-dist.	108, 1440	2.11	**<0.001**	114, 1440	1.80	**<0.001**
(c) Simpson´s diversity index $E_{1/D}$						
	df	*F*	*P*	df	*F*	*P*
Usage intensity	1, 2	15.36	0.059	1, 3.28	2.84	0.183
Gorge	2, 4	1.85	0.267	3, 2.90	1.86	0.316
Usage intensity x gorge	2, 34	1.48	0.241	3, 32	2.38	0.088
Site(usage intensity x gorge)	34, 108	2.39	**<0.001**	32, 105	2.48	**<0.001**
Sect./block-dist.	3, 6	5.15	**0.043**	3, 9.85	2.94	**0.037**
Usage intensity x sect./block-dist.	3, 108	11.47	**<0.001**	3, 105	2.27	0.084
Gorge x sect./block-dist.	6, 108	3.21	**0.006**	9, 105	1.52	0.150
Site(usage intensity x gorge) x sect./block-dist.	108, 1440	1.61	**<0.001**	105, 1440	1.46	**0.002**
(d) Soil compaction						
	df	*F*	*P*	df	*F*	*P*
Usage intensity	1, 2	1.76	0.315	1, 3.32	1.58	0.290
Gorge	2, 2	29.48	**0.033**	3, 2.73	3.20	0.196
Usage intensity x gorge	2, 34	0.98	0.385	3, 32	0.72	0.546
Site(usage intensity x gorge)	34, 114	3.12	**<0.001**	32, 114	6.72	**<0.001**
Sect./block-dist.	3, 114	12.57	**<0.001**	3, 114	5.00	**0.003**
Usage intensity x sect./block-dist.	3, 114	3.69	**0.014**	3, 114	1.04	0.379
Gorge x sect./block-dist.	NA NA	NA	NA	NA NA	NA	NA
Site(usage intensity x gorge) x sect./block-dist.	114, 1440	3.14	**<0.001**	105, 1440	3.20	**<0.001**

Note: Terms for which *P* > 0.25 (Winer et al., 1991; Underwood, 1997) were excluded from final models (denoted as 'NA') unless they figured in higher order or nested terms. The factor 'site(usage intensity x gorge) x distance' is not listed because of *P* > 0.25 for all effects.

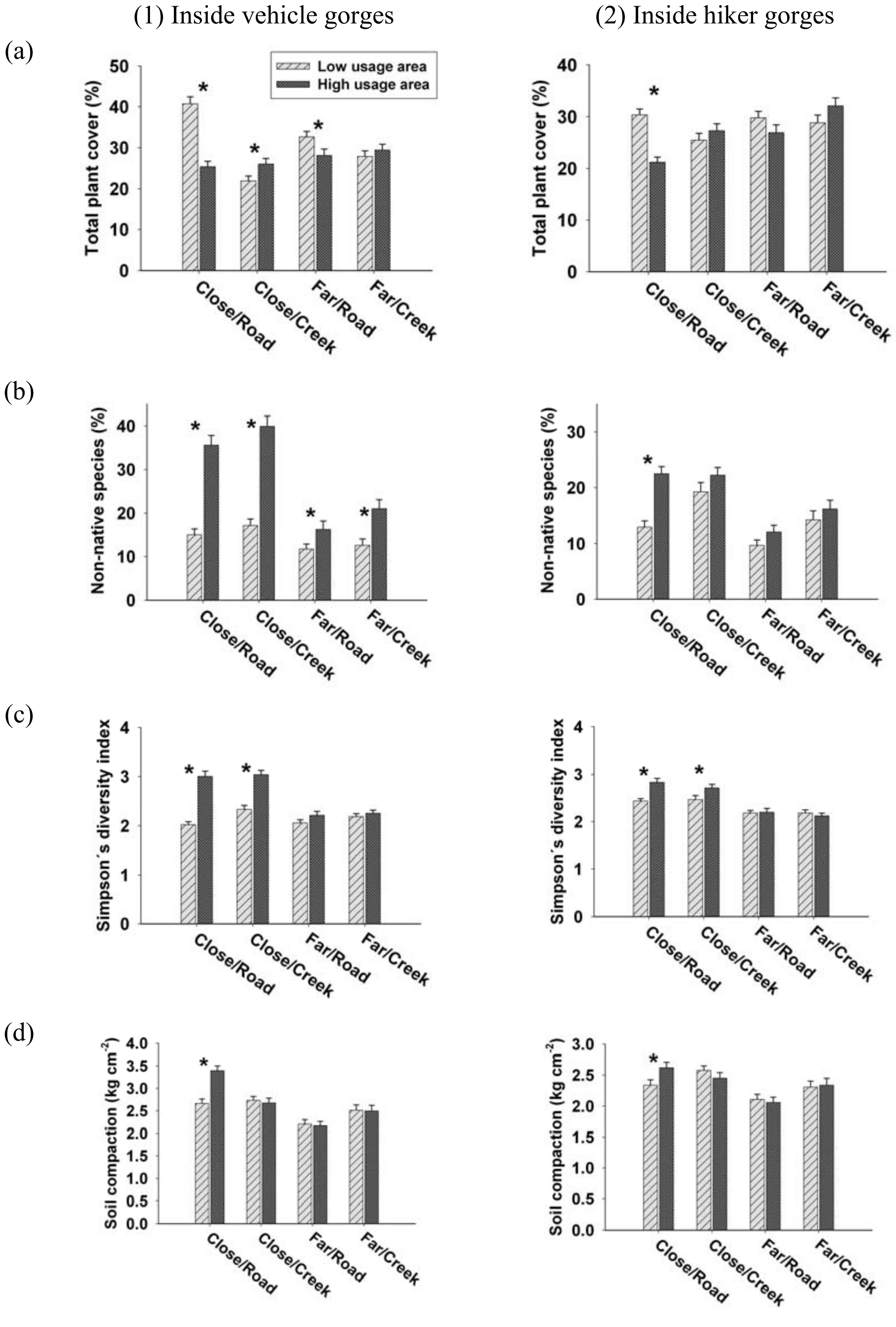


Fig. 4.5. Mean (± 1 SE) (a) percentage of total (overlapping) plant cover (per 1 m^2), (b) percentage of non-native species cover (of total plant cover), (c) Simpson diversity index $E_{1/D}$ and (d) soil compaction in relation to the tourism usage intensity and section/block-distance (close = 1–5 m vs. far = 6–10 m from recreational tracks or creeks) in arid-lands (1) vehicle or (2) hiker gorges. Asterisks indicate significant simple effects of usage intensity at a particular section/block-distance.

4.5 Discussion

4.5.1 Effect of usage intensity and distance from roads and trails on the trackside vegetation and soil compaction

4.5.1.1 Total plant cover and soil compaction

Our results show an interaction between the distance to roads or hiking trails and their level of usage on the condition of trackside vegetation and soil compaction. Beside low usage trails, there was no evidence for a track-distance gradient for any of the dependent variables; at most, the percentage cover of non-native species was slightly increased up to 3 m from trails. Thus, the mere existence of a trail did not ostensibly affect the adjacent vegetation or soil compaction in our hiker gorges. In contrast, next to low usage roads plants grew substantially better at the 2–4 m distance than closer or further away. An increased water runoff (Johnson et al., 1975; Lightfoot and Whitford, 1991; Norton and Smith, 1999) from roads towards their edges and a higher nutrient availability from exhaust emissions (Spencer and Port, 1988; Spencer et al., 1988; Angold, 1997) may have stimulated the plant growth close to roads as both water and nutrients are limited resources in arid ecosystems (Friedel et al., 1993; James et al., 1995). Johnson et al. (1975), for instance, discovered that the plant density, ground cover, volume and above-ground biomass were 2.9, 5.4, 7 and 6.7 times, respectively, greater next to an unpaved road in the Mojave Desert, U.S.A., than further away. They considered a profound change in the water regime due to the "water harvesting" (p. 114) qualities of the road, which redistributed water to the verge, as the most likely explanation for the drastic boost in plant productivity. Even though an increased water runoff from trails is frequently reported as an aversive condition that promotes trail degradation and soil erosion (Kuss, 1983; Deluca et al., 1998), it has only marginally been discussed (Bright, 1986) as a promoter of vegetation growth at trailside verges. We suspect that our study trails have not been associated with an increase in vegetation productivity because they were too narrow and not sufficiently compacted to facilitate water redistribution effective to plant growth. Further, the input of additional nutrients from hikers was likely negligible compared to inputs from vehicle emissions.

Although aversive roadside conditions were not so intense as to override the growth-enhancing effects at 2–4 m from low usage roads, they clearly affected the vegetation closest to the road where the lowest plant cover of all distances was recorded. In this zone, plants were likely subjected to the same adverse conditions that had reduced plant growth near high usage roads and trails compared to low usage conditions or further distances. Trampling stress, for instance, exerted from passing or parking vehicles, foot traffic and maintenance activities may affect vegetation in the vicinity of roads (Cilliers and Bredenkamp, 2000) and trails (Weaver and Dale, 1978; Kuss, 1983), and has been identified in a wide range of ecosystems including sand dunes (Hylgaard and Liddle, 1981; Brown and McLachlan, 2002), deserts (Cole, 1986; Brown and Schoknecht, 2001), (sub)tropical rainforests (Sun and Liddle, 1993), (sub)alpine ecosystems (Whinam and Chilcott, 1999, 2003) and arctic tundra (Monz, 2002). Significant adverse effects of trampling encompass a reduction in plant cover, density and vigour, particularly of trampling-sensitive species. Trampling impacts along trails may be less prominent than along roads as hikers tend to damage vegetation less than vehicles (reviewed by Liddle, 1997), and trails may require less frequent and high impact (e.g., grading) maintenance activities. These considerations conform with our findings in that the difference in total plant cover between high and low usage conditions was somewhat greater and more noticeable further from roads than trails. In addition, the reduction in total plant cover that occurred in the 1st m beside low usage roads compared to the further distances was not as great along low usage trails.

Another consequence from trampling is soil compaction which may have impeded plant growth in high usage areas and close to tracks. Soils abutting high usage roads were more compacted than those abutting low usage roads up to 5 m and were more compacted at the 1–5 m distance compared to further distances. This matches the spatial extent of increases in soil compaction reported by Godefroid and Koedam (2004) along forest roads. Soil compaction was also higher in the 1st m near high usage trails compared to any further distances and to low usage trails. An increase in soil compaction is a well-documented impact exerted from recreational use (Weaver and Dale, 1978; Hylgaard and Liddle, 1981; Marion and Cole, 1996; Belnap, 1998). In a Spanish recreation area, average soil compaction was 50% greater in the most visited sites compared to the least visited sites (Andrés-Abellán et al., 2005). Unsurprisingly, soil compaction changes due to high usage were greater and more pervasive near roads than trails as compaction strongly depends on the amount of pressure applied (Slaughter et al., 1990; Liddle, 1997) which is many times greater when a vehicle passes than a hiker. Moreover, total usage of roads and their maintenance were more intensive than was the case for trails, and some vehicles used the road shoulder for parking or manoeuvring. Our findings are consistent with Lei (2004) who reported a significantly greater compaction, higher bulk density, and a lower percentage of pore space for motor vehicle trails and parking lots compared to human hiking/biking trails. Soil compaction decreases soil porosity and aeration, water infiltration and retention as well as hydraulic conductivity and also impinges on the decomposing flora, all of which impair vegetation growth (Manning, 1979a; Liddle, 1997). Recovery from compaction can be very slow and may take hundreds of years, particularly for soils of loamy sand texture which were typical of the alluvial floodplains (Webb, 2002) in our study gorges.

Further detrimental conditions that may have been compromising plant growth along our tracks (mostly pertinent to roads) include exhaust emissions (Bignal et al., 2007)—although this may be more relevant in areas with higher traffic loads—and dust pollution. The latter is particularly relevant as we witnessed numerous patches along roads where plants were entirely covered in dust, sometimes up to several millimetres in depth. In a dry environment this may affect photosynthesis, respiration and transpiration (Farmer, 1993). Sharifi et al. (1997), for instance, reported that windblown dust on several species of shrub at a Mojave Desert site reduced maximum rates of net photosynthesis to 21% compared to undusted plants. Further, maximum leaf conductance, transpiration and water-use efficiency were significantly reduced, and temperatures of dusted leaves and stems were higher than those of control plants due to greater absorption of infrared radiation. In total, heavily dusted shrubs grew smaller leaf areas which suggested an overall lowered primary production.

4.5.1.2 Community composition and plant diversity

High levels of tourism usage also promoted substantial changes in the floristic composition up to 5 m from recreational tracks. Different species thrived at different positions along the gradient of disturbance protruding from the trackside. In particular, non-native species cover increased towards high usage roads and trails although the effect was greater and more pervasive near roads. A similar trackside gradient in non-native species cover existed under low usage conditions but it was comparatively weak. Apparently, disturbance along low usage tracks had not acquired the strength yet to substantially enhance growth of non-native species. Our findings are consistent with other studies from a broad range of ecosystems including forests, woodlands, grasslands and sand dunes, which have reported changes in community composition accompanied by an increase in non-native species cover, richness and/or diversity along roads (Morgan, 1998; Tyser et al., 1998; Ullman et al., 1998; Parendes and Jones, 2000;

Gelbard and Belnap, 2003), trails (Dale and Weaver, 1974; Benninger-Truax et al., 1992) and other types of edges (Luken et al., 1991; Fox et al., 1997).

The stimulation of non-native species growth along tracksides has been ascribed to the collaboration between (1) a facilitated propagule dispersal and (2) favourable growing conditions. The latter result from (a) an altered mechanical, chemical and physical environment and (b) the release from competition with disturbance-sensitive plants which grow less on disturbed sites or are impeded in their competitive strength. Tracks may act as conduits for the spread of exotic species (Clifford, 1959; Lonsdale and Lane, 1994; Forman and Alexander, 1998) as human objects become vectors for reproductive units of invasive plants (Fig. 4.1). For example, von der Lippe and Kowarik (2007) demonstrated long-distance dispersal (>250 m) of seeds and reported regular 'seed rains' released by vehicles ranging from 635 to 1579 seeds/m^2 per year within three tunnels along an urban motorway in Germany. Hiking and camping gear can also facilitate the spread of non-native species (Turton, 2005). The trackside edge then favours the establishment and growth of those species that can cope well with disturbance which is a typical trait of non-native species (Tyser and Worley, 1992; Forman and Deblinger, 2000; Trombulak and Frissell, 2000; Gelbard and Belnap, 2003; Watkins et al., 2003). In a review of 63 studies of 299 non-native plant species, Lozon and MacIsaac (1997) found that the establishment of 86% of the non-native plant species studied was associated with disturbance. In a second survey, the establishment of 97% of 404 non-native plant species was linked to human-induced disturbance. Amor and Stevens (1976), for instance, documented a decline in the frequency of non-native species with distance to a road as they appeared to benefit from water runoff and more diffuse light in the road shoulder of Australian sclerophyll forests.

Many of the non-native species we have identified as indicators for high usage conditions are also known to prosper in other disturbance contexts such as livestock grazing and are frequently evident to casual observers that travel along roads or explore riparian ecosystems in South Australia. Even though many of these species are already widely dispersed throughout our study area—so a further human-facilitated dispersal may not be crucial to their establishment—they apparently have greatly benefited from conditions in the trackside. Species that colonize tracksides often have adaptive traits (Benninger-Truax et al., 1992) in common that facilitate quick growth or survival in the face of disturbance (Hall and Kuss, 1989). Native species that colonize early successional stages may also be adapted, and it was therefore not surprising to detect a considerable number of natives among the high usage indicator species. Godefroid and Koedam (2004), for instance, reported an increase in the number of ruderal species, disturbance indicators, nitrogen-demanding species and indicators of basic conditions near forest paths which included native and non-native species. They too noted very few indicator species growing in the less disturbed zones compared to the great number of species that typically inhabited the immediate areas near their roads. Interestingly, the percentage of native species indicators for high usage conditions increased with distance to the track and in hiker gorges. Presumably native species that colonize disturbed zones have advantages over non-native species when the disturbance level is intermediate rather than high.

In some instances the causal relationships between tourism usage and some of the low usage indicators may be reversed: the sedges *Cyperus alterniflorus* and *C. gymnocaulos* as well as the 'Swamp Dock' *R. brownii* are likely associated with low tourism usage not because they are susceptible to disturbance but because their presence indicates conditions which tourists (e.g., the proportion of campers) consistently avoid, namely damp or swampy grounds.

The changes in the plant community resulted in a pronounced track-distance gradient of the plant diversity in high usage areas. The behaviour along high usage roads was unimodal over the 1–4 m distance, consistent with the predictions of the Intermediate Disturbance Hypothesis (IDH) (Connell, 1978). Presumably, only the more disturbance-tolerant species were able to survive directly beside roads whilst intermediate levels of disturbance at a 3 m distance were facilitating the invasion of non-native species and native coloniser plants without excluding native, disturbance-sensitive species. Further away, plant diversity declined sharply likely because the disturbance-sensitive species regained their competitive superiority and outcompeted those species that had invaded the more disturbed zones. Along high usage trails, plant diversity decreased with the distance, which indicates a continuous decline in the disturbance gradient consistent with the downslope part of the IDH curve. Thus, except for in the 1st m, diversity patterns matched between roads and trails; notwithstanding, the interaction effect of usage intensity and distance was more pronounced near roads. The application of IDH may explain the opposite trends regarding the response of plant diversity when others compared more or less disturbed tourism areas or different distances from recreational tracks. For instance, Andrés-Abellán et al. (2005) observed an average decrease in plant diversity of 33% in high usage tourism sites compared to less disturbed sites in a Spanish recreation area. At the most visited sites plant species richness was reduced by 90% compared to the least visited sites. In contrast, Bright (1986) reported a greater diversity of herbaceous species near trails than in control plots in woodlands in the U.S.A., which is consistent with Hall and Kuss´s findings (1989). Kobayashi et al. (1997), on the other hand, described a unimodal pattern consistent with the IDH for a herbaceous community in Japan.

4.5.2 Spatial extent of road- and trailside impacts

Knowing the spatial extent of trackside impacts is of decisive importance (Laurance and Yensen, 1991) for a sustainable tourism management. Usually, the 'effect zone'—the area in which significant, ecological changes take place in terms of species, soil and water (Forman and Deblinger, 2000; Forman et al., 2003)—extends clearly beyond the boundaries of access routes which may substantially reduce the size of the functional interior (Fraver, 1994) of the neighbouring ecosystems. For instance, a considerable 2.5–8.5% of a Belgium forest were impacted in spite of a comparatively small edge-effect of 3–10 m from both sides of every forest path (Godefroid and Koedam, 2004). The spatial extent of the trackside effect zone is a convolute function of environmental factors including topography, weather conditions, vegetation type as well as disturbance properties such as the usage intensity, itself a function of visitor numbers, individual user behaviour and type of activities. Further, track properties such as width, surface type, presence of shoulders and level of improvement are influential (Brooks and Lair, 2005). Given this complexity, it is not surprising that the width of the effect zone largely varies between studies. Still, we noticed two major trends: short effect-distances of ≤15 m and long effect-distances of ≥50 m. Trailside effects have usually been restricted to the vicinity of the track (Dale and Weaver, 1974; Hall and Kuss, 1989; Benninger-Truax et al., 1992; Chizhova, 2004) whereas roadside effects have extended over a short (Morgan, 1998; Olander et al., 1998; Watkins et al., 2003; Godefroid and Koedam, 2004) or a long distance (Angold, 1997; Forman and Deblinger, 2000; Gelbard and Belnap, 2003; Gelbard and Harrison, 2003; Flory and Clay, 2006).

Our findings highlight the importance of the interaction between usage intensity and distance for assessing the effect zone of recreational tracks: track-distance gradients were clearly exacerbated or became noticeable only under high usage conditions. Narrow trails with little usage and maintenance activities, for instance, had little impact on their surroundings in our study area. Along high usage trails, impacts percolated a short distance into the trailside environment consistent with the patterns we have delineated from the other studies above. The actual extent of the trailside effects, however, also depended on the variable that was measured (Chen et al., 1992; Watkins et al., 2003). The roadside assessments can be grouped among those studies that have reported short-distance effects for roads. The division of roadside effect zones may at least partially be related to the level of usage and road improvement. Unpaved roads with light usage (0–15 vehicles per day for logging, hunting and recreational use: Watkins et al., 2003; exclusive use by foresters' vehicles: Godefroid and Koedam, 2004), such as ours, tend to exhibit narrow effect zones whilst multi-lane, substantially improved roads (Angold, 1997) exerted a far-reaching influence from their edges. According to Angold (1997), for instance, edge effects along roads in heathlands were closely correlated with the amount of traffic and extended furthest adjacent to a dual carriageway compared to minor roads. Not only are the effect zones of paved and busier roads larger but the acuity of the impacts is often greater. In the Mojave Desert, cover of invasive *Bromus tectorum* grass was three times higher along verges of paved roads compared to four-wheel-drive tracks, and non-native species cover was 50% higher in interior sites near paved roads than near four-wheel-drive tracks (Gelbard and Belnap, 2003). As initially described we suspect that the much higher camping activity, the greater potential of vehicles to alter their environment and the more extensive maintenance required at high usage road sections compared to trails were the reasons for the greater magnitude and larger effect zone of the impacts following an increase in usage.

Whilst camping most likely was a major determinant for the greater effect zone of tourism usage along roads compared to trails, stopping of tourists must have had a considerable influence on the effect zone of impacts along both types of recreational tracks. This is demonstrated by the fact that low usage roads received similar, mean visitor numbers as high usage trails but showed little trackside gradients—except for the plant cover changes that were best explained by water runoff rather than usage. The major discriminant between the two, which must have driven the development of trackside gradients along high usage trails, was the substantially higher number of visitors that were stopping there compared to low usage trails. This likely had an effect along high usage roads too but our design cannot separate it from the camping influence.

Apart from impacts on the immediate trackside environment, we also presented evidence that recreational use of roads affected the banks of creek beds even though they were on average almost 50 m away. At 1–5 m from creek beds, non-native species cover and plant diversity were significantly greater compared to low usage conditions, in accordance with the patterns from the neighbouring high usage roads. Deciphering the mechanisms which led to these findings requires further investigation. However, we propose two possible explanations. Firstly, some visitors may have been travelling off-trail along creek beds. Tyser and Worley (1992), for example, found unexpectedly high levels of non-native species 100 m from backcountry which to them suggested that non-native species may have been introduced in off-trail areas either by hikers or horse riders. However, if this mechanism was relevant in our study one may have expected to also witness trampling impacts from high usage such as a reduction in plant cover or an increase in soil compaction; neither of which we found along creek beds. In fact, plant cover near creek beds showed the opposite trend of more cover under high usage conditions. Secondly, high propagule pressure exerted from the prospering source populations of disturbance-increaser plants near high usage roads may have driven their establishment along the naturally disturbed creek banks where they met favourable growing conditions. Although inundations of Australian creeks in the arid lands occur very occasionally, vegetation communities in riparian zones normally differ significantly from that of surrounding areas due to a different soil and groundwater regime (Hancock et al., 1996). These zones are particularly susceptible to infestation with non-native species as they are exposed to "fluvial disturbance from floods and the nonfluvial disturbance regimes of adjacent upland areas" (Gregory et al., 1991: 543). High propagule pressure combined with adequate growing conditions may even explain why the total plant cover increased with high usage along creek beds where trampling impacts were not a hindrance.

The presence of multiple disturbances is a common phenomenon in many ecosystems (Hobbs and Huenneke, 1992) and additive as well as synergistic effects between different types of disturbance have been observed (Hodgkin, 1984; Noy-Meir, 1988). Parendes and Jones (2000: 70) have alluded to a similar finding as ours in an experimental forest in Oregon, U.S.A., where according to their review of previous studies, exotic plant species were mostly confined to roadsides, streams, and recent "clearcuts adjacent to roads". The later suggests an interaction between clearcuts and roadsides as the prerequisite for the establishment of exotic species. Strikingly, we did not encounter the same pattern of 'impact dispersion' along creek beds neighbouring trails, presumably because propagule pressure was less intense. To our knowledge, this is the first demonstration that the potential of certain impacts to self-perpetuate from their points of introduction to other, disjointed sites with a predisposition to disturbance may depend on the type of access track to a recreation site.

4.6 Conclusions and management implications

This study suggests that recreational tracks may affect plant cover in arid-lands gorges and contribute to a shift in species composition towards a higher proportion of non-native and native plants that thrive under disturbed conditions. Overall, the factor that most consistently and significantly exerted an influence on the trackside vegetation was the interaction between distance to roads and trails and their usage level. Low usage tracks exerted only a light impact on the verge community except for the large increase in plant cover at 2–4 m from roads. Effects were comparable along roads and trails in that total plant cover decreased whereas non-native species cover, plant diversity and soil compaction increased towards high usage tracks. Road- and trailside environments also had a considerable number of species in common that indicated high or low levels of tourism usage. Generally, track-distance gradients were prominent between 1–5 m. Despite these similarities, the effects were more pronounced and somewhat more pervasive along roads. Further, a few qualitative differences occurred. For instance, plant diversity did not continuously increase towards the road verge as it did along trails but dropped sharply in the immediate road shoulder which indicated high disturbance conditions that few species were able to tolerate. Finally, we presented evidence that the effect zone of roads was greatly enhanced because non-native species cover and plant diversity increased along the shallow banks of creek beds that neighboured high usage roads, despite an average separation of nearly 50 m.

Tourism management in arid-lands gorges therefore needs to consider that recreational tracks may act as major agents for changes in vegetation communities. Such changes are most pronounced in the immediate trackside environment but also manifest in the riparian zone of neighbouring creek beds, particularly where usage is high. Furthermore, vehicular access to gorges may be associated with a greater intensity and spatial extent of impacts than when access is granted exclusively to hikers. At this stage, it may be difficult to eradicate many of the non-native species that are already widely dispersed in our study gorges. Notwithstanding, measures need to be taken to reduce disturbance to support a healthy and competitive, native plant community that can oppose or at least maintain a balance with intruding species. To achieve this, visitor usage may need to be curtailed to less than current high usage levels. As the presence of camping and stopping tourists in high usage sites was necessary to inflict a substantial impact on the vegetation adjacent to roads, we recommend controlling any unofficial camping, which is currently very popular throughout vehicle gorges in our study area. Instead camping usage should concentrate at a few places, preferably near the access points to gorges. In addition, vehicles may be directed to sites where stopping is encouraged, for instance, by providing parking bays or information signs along the route; in the case of hikers picnic tables may serve the same purpose. However, such actions must be subtle and not attract campers to these bays or detract from the wilderness experience by creating obtrusive infrastructure.

More extreme measures such as the closure of gorges or sections for vehicle access have successfully been implemented in one of our study gorges. This may have success in other gorges as long as they do not connect routes within a network of existing roads. In hiker gorges, the middle or opposite ends of the more accessible entrance point were substantially less frequented as visitors usually remained within a few kilometres from where they had accessed a gorge. Thus, the probability that the number of high usage sites may increase over time—which constitutes an imminent threat of the camping usage in vehicle gorges—is low. Notwithstanding, hiker access to our study gorges could be restricted to one access point and then some zones would be exempted from all but minimal usage. We suspect a high visitor acceptance as all of our hiker gorges had one favourite access point.

In our study, a conglomerate of passing, stopping and camping usage determined the classification into high or low usage. When usage is complex and different types of visitor behaviour are interspersed, this may be the most feasible way of classifying sites and establishing dose-dependence relationships. However, where possible, independent mechanistic relationships between the amount of passing, stopping or camping usage with environmental impacts need to be established based on a continuous gradient of usage intensity, so thresholds for restricting usage can be ascertained. Finally, a broad range of modifying factors not considered here may determine the nature and degree of tourism-induced impacts on the vegetation community including characteristics of the vegetation (Calais and Kirkpatrick, 1986; Marion and Cole, 1996) and soil (Whinam and Chilcott, 1999) such as their resilience and resistance to disturbance, as well as the topography, climate and season (Dale and Weaver, 1974; Hammitt and Cole, 1998).

Chapter 5

Bird communities of arid-lands gorges: Vegetation moderates impacts of tourism usage along roads and hiking trails

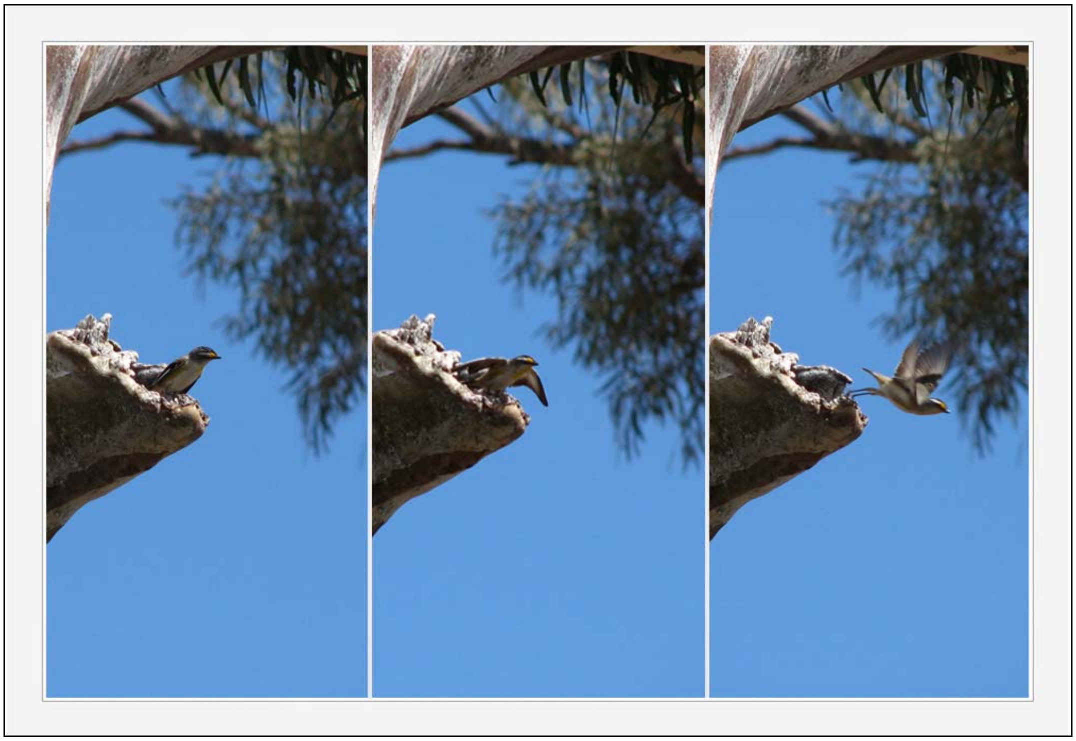


Fig. 5.1. Striated Pardalote (*Pardalotus striatus*) in Wilkawillina Gorge, Flinders Ranges.

5.1 Abstract

Bird communities inhabiting ecosystems adjacent to recreational tracks may be aversely affected by disturbing stimuli such as noise from passing tourism traffic, mortality through collision with vehicles, habitat alteration and modification of biotic relationships (e.g., increase of aggressive competitor species). This study investigated the effects of tourism usage of recreational tracks (roads vs. hiking trails) on bird communities in arid-lands gorges of the Flinders Ranges, a popular Outback tourism destination in South Australia where recreational demand potentially conflicts with avifauna protection.

A comparison of high and low usage tourism sites revealed that high (due to more stopping and camping traffic) usage significantly decreased individual abundance and species richness of birds along roads. The latter also occurred along high (due to more passing and stopping traffic) usage trails albeit to a slightly lesser extent. Further, community composition changed considerably depending on the ecology of the species. Species overrepresented at high usage roads and trail sections were bigger, more aggressive birds with a generalist diet, reminiscent of the kind of species associated with urbanized or otherwise disturbed environments. In contrast, species indicative of low usage mostly encompassed smaller birds with a more specialised diet as well as ducks and doves. Birds overrepresented at high usage sites were viewed significantly more often in high trees (>6 m), and birds repelled from high usage sites preferred to use ground and shrub layers, even though all these strata types were equally available under both usage conditions. This suggests that lower microhabitats were linked to higher sensitivity to disturbance.

However, vegetation complexity was a more important factor influencing bird abundance than tourism usage. Sites with a better developed shrub and tree layer sustained higher species abundance and richer communities. Importantly, we found that vegetation variables moderated the negative effect of high usage on the number of individuals recorded along roads to the extent that it was entirely mitigated at sites with the best developed shrub and tree layer. Likewise, there was a trend for high usage impacts on bird species richness along roads and trails to be moderated as well.

To protect avifauna along recreational tracks in arid-lands gorges, we recommend (1) the closure of some gorges or sections for vehicle or any access, (2) the monitoring of usage indicator species and vegetation conditions, and (3) the minimization of open

space created for tourism infrastructure particularly for high usage activities such as wild camping.

Keywords: tourism impacts, roads, trails, recreational tracks, bird community, number of birds, species richness, community composition, habitat modification, heterogeneity of habitat, structure and floristics of vegetation, gorge, arid.

5.2 Introduction

Bird watching is a large component of nature tourism with a high economic value and popularity (Valentine, 1984; U.S. Fish & Wildlife Service, 1996). In the U.S.A., about 69 million people over age 16 (i.e., almost a third of the U.S. population over 16) viewed, identified or photographed birds in the 12 months prior to a national survey on recreation and the environment (Cordell and Herbert, 2002). A growth of more than 330% since 1983 makes bird watching the fastest-growing outdoor recreational activity in the U.S.A. (Cordell and Herbert, 2002), and the interest for bird watching is growing worldwide including Australia (Jones and Buckley, 2001).

Birdwatching or other tourism activities performed along recreational tracks like roads or hiking trails may affect the physiology, behaviour, the reproduction and survival and eventually the abundance of birds via numerous pathways: Firstly, low thresholds to visual and acoustic stimulation render some bird species susceptive to direct forms of disturbance and when exceeded can trigger sensitive reactions (Johns, 1992) such as a spatial avoidance of recreational tracksides (van der Zande and van der Vos, 1980; Forman and Deblinger, 2000). Secondly, birds may suffer from mortality if individuals are killed while crossing or otherwise utilizing a road (Forman and Alexander, 1998). Thirdly, the vegetation along tracksides is often considerably altered (Chapter 4) making these habitats less suitable for many bird species (Hammitt and Cole, 1998). Finally, relationships between different bird species (e.g., edge-tolerant species may dispel other less competitive species from the habitat, (Grey et al., 1997)) or between bird species and other animal groups (e.g., predators may gain easy access to bird habitat via tracks, (Miller et al., 1998)) may be modified along recreational tracks. The severity of the effects and thus the danger for the conservation of bird species depends on whether the changes are temporary or long-term and whether they affect certain individuals, populations, the species as a whole or an entire bird community (Knight and Gutzwiller, 1995). The tourism impacts on bird communities that are the focus of this study are a result of long-term changes in the abundance and/or distribution of numerous bird species which constitutes a serious conservation concern.

Since avian communities are also very sensitive to changes in habitat characteristics (Mac Nally, 1990), it is essential in tourism impact studies to monitor tourism-induced changes in bird habitat and to identify natural variability in vegetation that may increase inter-site variation in bird metrics. This may be particularly relevant in arid Australian ecosystems with their typically heterogeneous distribution of vegetation (Dunkerley and Brown, 1995; Forman et al., 2003). In fact, variables such as the structure and floristics of vegetation may be more important predictors of bird variables than anthropogenic disturbance (Pavey and Nano, 2009). Structurally (reviewed by Tews et al., 2004) or floristically (Fleishman et al., 2003) complex habitats may provide more niches which can explain the positive relationship with metrics (e.g., abundance, species richness) of many different animal groups including birds. Further, wildlife may perceive human disturbance as less threatening among abundant vegetation (quantified with structural variables such as cover, height, volume or foliage density) as this offers ample possibilities to hide (e.g., Chapter 6).

A number of sites in Australia have been recognized as excellent birdwatching locations (Jones and Buckley, 2001). As gorges provide a particularly rich habitat for a diverse bird community in the semi-arid to arid Australian Outback and are also a popular tourism attraction, this study was conducted in selected gorges in the Flinders Ranges in South Australia. Whilst some of these gorges are accessible to tourists via unpaved but well-maintained backcountry roads, others are restricted to hiker access. Managing access to recreation areas is one in a range of tools available to protected-areas managers to mitigate aversive visitor impacts. However, to our knowledge no study has directly compared the influence of visitor usage of roads with that of hiking trails on bird communities, even though these access options are most popular throughout natural tourism destinations in Australia and possibly worldwide. Thus, the central question in our study was how bird metrics (total number of individuals and of particular species, species richness, community composition) were affected along roads and hiking trails. We addressed this question by examining bird communities between high and low usage sites, separately for vehicle and hiker gorges, and compared the emergent patterns between the two gorge types (access modes).

We expected that impacts (differences between high and low usage sites) recorded along roads would be more severe than along hiking trails for several reasons. Previous to this study, our sites had been classified as high or low usage based on an extensive visitor monitoring (Chapter 3). According to the monitoring, high usage vehicle sites received more stopping and camping traffic than low usage sites but similar numbers of passing tourists, whereas high usage hiker sites received more stopping and passing traffic than low usage sites but a similar amount of (very little) camping activity (Chapter 3); camping activities at high usage vehicle sites, due to their temporally extended nature and greater potential for interaction between visitors and their environment (e.g., via habitat modification or disturbance of birds), are likely more disruptive to bird communities than passing hikers at high usage hiker sites compared to low usage sites. These patterns accrued from the preference of visitors (Chapter 2) for scenic driving over hiking, for short to medium over long hikes and for camp sites with vehicle access, coupled with the fact that access was typically attained from only one or two points at the gorge entrances. Another factor that may aggravate possible changes in bird metrics following an increase in usage along roads, may be that an increase in vehicles is likely more perturbing or perilous (vehicle collisions (Taylor and Goldingay, 2004; Ramp et al., 2006)) for birds than an increase in foot traffic. Finally, an associated study on vegetation impacts at the same study sites (Chapter 4) asserted that an increase in usage along roads had altered trackside vegetation (e.g., lower percentage of total plant cover, higher percentage of non-native species) more severely than along trails. This can have secondary effects on bird metrics.

The following non-exclusive hypotheses were tested: (1) There would be differences in bird metrics between high and low usage sites, suggesting that an increase in tourism usage has an impact on birds. We expected a lower species richness at high usage sites as not all bird species would tolerate more disturbed conditions. For the same reason, we expected a lower total number of birds at high usage sites. However, an increase in the number of species and individuals that benefit from disturbance may also (over)compensate for the loss in abundance of disturbance-sensitive species. (2) Impacts recorded along roads would be more severe than along hiking trails. (3) Species' reactions to tourism usage would differ: we envisaged species to be either attracted to, repelled from or to behave neutrally towards high usage sites. (4) In addition, we investigated the link between differences in the sensitivity of species to disturbance and microhabitat usage; in particular, we asked whether the usage of specific habitat strata was associated with high vs. low usage conditions. We expected that the number of birds utilizing lower habitat strata compared to higher strata would be lower at high than low usage sites due to the closeness to the source of the disturbance. (5) Natural (instead of tourism-induced) differences in the habitat would have a covariate effect: a structurally and floristically more complex vegetation and sites with a higher water availability would support a more abundant and species-rich bird community. (6) Tourism impacts would be mitigated by favourable habitat conditions (= interactive effect of the usage intensity and the habitat).

5.3 Methods

5.3.1 Study area

This study was conducted in a popular tourism destination in South Australia, the central and northern Flinders Ranges, from the Flinders Ranges National Park (Wilpena: lat. 31° 30` S, long. 138° 30` E) into the Vulkathunha-Gammon Ranges National Park (Balcanoona: lat. 30° 30` S, long. 139° 30` E). As a corridor of higher rainfall, the Flinders Ranges extend northwards into the arid zone, allowing fauna typical of wetter regions to expand their distribution further north. They also provide a wide variety of microclimates due to small-scale topography and landforms (Ried et al., 1996). Therefore, in spite of covering only 4% of the South Australian land area, the Flinders Ranges support approximately 50% of the total non-marine bird species of South Australia (Paton, 1980; Ried et al., 1996). A recent survey of the region (Brandle, 2001) compiled 241 bird species belonging to 65 families; seventy of these species hold some form of conservation significance rating, three of which were recorded during our study; namely the Elegant Parrot, the Peregrine Falcon and the Redthroat (scientific names of all bird species as in Table 5.3, Table A 3.1).

One of the best places to observe birds in the Flinders Ranges are the gorges which are a core attraction for visitors and the focus of our study. Due to the retention of water and provision of shade, gorges support a diverse multi-layered vegetation which creates suitable habitat for many bird species (Wolf, pers. obs.). The dominant vegetation community in all of these gorges are riparian woodlands (Brandle, 2001) where River Red Gums (*Eucalyptus camaldulensis*) form a tall canopy that is frequented by flocks of birds such as Little Corellas and Australian Ravens. A common sight is also birds of prey and Tree Martins which hunt and nest along the cliff faces of the gorge walls or above/among the tall eucalypt trees. Another ubiquitous tree is the Pointed Mallee (*Eucalyptus socialis*) which grows in dense stands along intermittently flowing creek lines and creates a lush mid-storey layer that is a prime location for honeyeaters, parrots and Striated Pardalotes. On the plains adjacent to the creek lines, bushlands composed of different species of chenopods (e.g., *Maireana* sp.), *Eremophila*, *Senna*, *Dodonaea* and *Acacia* teem with small birds such as robins and fairy-wrens. A few bird species also use the ground among the low-growing bushes and ephemeral herbs, and waterbirds hide among sedges near the scattered pools of water. The horizontal distribution of vegetation varies considerably, and a strong contrast exists between dense vegetation patches with a particularly pronounced shrub thicket and rather barren areas.

The Flinders Ranges are a key tourism asset for South Australia and significantly contribute to the regional economy. In recent times, many landholders have commenced providing tourist accommodation and guided tours, many of which take visitors to the gorges. Visitors, whether as part of a tour or travelling on their own, can enjoy the scenery and species richness of the gorges from a network of roads and trails that also provide access to a variety of popular, official and unofficial campsites.

5.3.2 Study sites

We selected seven major gorge systems that were either mainly accessed by vehicles ($n_{\text{vehicle gorge}} = 3$) or exclusively accessible to hikers ($n_{\text{hiker gorge}} = 4$) and established in both gorge types transects at 40 sites, starting close to the gorge entrance and a minimum of 250 m and usually not more than 500 m apart. We believe that we minimized pseudoreplication, due to re-sampling the same birds, as most transects were located at least 400 m apart and in separate meanders of a gorge. The chosen areas were on average 92.5 ± 3.6 m wide (= average width of gorge sections) and had to contain a distinctly marked recreational track (roads: 5 ± 0.2 m wide; trails: 1.2 ± 0.15 m wide) and a creek bed (11.6 ± 0.9 m wide), which were separated by at least 30 m (46.9 ± 4.5 m). Roads were unpaved and composed of gravel, dirt or a mix of the two.

On each study site, we previously (Chapter 3) had laid belt transects with the dimensions being 50 m (along the trajectory of the gorge) by 92.5 ± 3.6 m to classify the sites as low or high usage ($n_{(\text{low usage roads})} = 21$; $n_{(\text{high usage roads})} = 19$; $n_{(\text{low usage trails})} = 22$; $n_{(\text{high usage trails})} = 18$) based on differences in (Table 3.2) the number of passing tourists, their passing speed, the percentage of stopping tourists, their stop time, the number of day- and night-campers and the average camp-time by day. Further, we included proxies which reflect usage (based on preliminary observations): the size of traversing and abutting (boundaries situated within 30 m to the visitor census plots) campgrounds, the numbers of fire places, trash items and interpretation signs. Visitor census plots (which contained the bird census plots; 5.3.3) had been placed so there was not more than approximately 10% of overlap with traversing campgrounds as we did not intend to measure the environmental effects of camping per se but of recreational tracks in general independent of their dominant use. This visitor monitoring effort ascertained the differences in visitor usage of gorges depending on the access mode as described in the introduction.

5.3.3 Census of the avifauna

Bird sampling was conducted throughout the day during July to December 2006 and 2007. Wet and windy conditions were avoided as they can negatively influence observation abilities (Bibby et al., 2000). Drab clothing was worn as birds have reacted to the colour of observers´ clothing (Gutzwiller and Marcum, 1993). The nomenclature and taxonomy for bird species follows Simpson and Day (2004).

We used standardized area counts (Loyn, 1986; Bibby et al., 2000) during which we counted each bird seen or heard in 20 min while surveying a square plot of 50 x 50 m. The plots were demarcated on one side by the recreational track from which they extended 50 m in the direction of the creek bed. During the first 5 min of the census a single observer stood still and quiet at the centre of the plot and performed a standard point count using binoculars (10 x 42). In the last 15 min, the observer moved around slowly, stopping at suitable vantage points to look for birds and accessing vegetation patches to flush cryptic individuals and to approach any species that could not be identified from a distance. In this way small birds hidden in patches of dense shrub or the foliage of tall eucalypt trees were unequivocally identified and correctly counted. In contrast, traditional survey methods such as transect or point counts may have caused an inappropriate bias towards sites with less shrub and tree cover where the bird detectability was higher (Craig and Roberts, 2001). Potential errors of the area count method are likely to affect observations at all sites and should therefore not bias inter-site comparisons (Craig and Roberts, 2001).

Each plot was surveyed five times during the study period by two independent observers who had standardized their observation techniques. Prior to analysis, the individual species-counts of the ten sampling occasions were summed up to the total number of individuals and the total number of species (species richness) per site.

Plotting of species accumulation curves confirmed that an adequate sample had been taken as the species curve levelled off from seven observations onwards.

During each census the species-abundance and the vertical position (five classes: ground, shrub, small trees up to 6 m, tall trees, air/cliff face) of a bird at first notice was recorded. Species that were flying overhead were not counted as we could not determine whether they were utilizing the area or passing through, unless they were swallows, martins or birds of prey (Craig and Roberts, 2001) which typically use an area by circling above it. The flight direction of birds that were flushed was followed briefly to avoid recording the same individuals again.

5.3.4 Sampling of habitat characteristics

In order to investigate the relationship between bird communities and tourism-induced changes or natural variation in habitat, data on structure and floristic composition of vegetation were collected at all sites within three 5 m x 5 m quadrats for bush assessments and one 20 m x 20 m quadrat for tree assessments.

The bush sampling quadrats were distributed randomly within each bird census plot but not within 5 m of the recreational track as that area was most heavily impacted on by tourism usage and thus sampled separately (Chapter 4). Within these quadrats, the cover and height of the different bush species was measured with 16-mm electrical conduit pipes joined together and marked in (centi)metre sections. The cover was recorded by measuring the maximum length and width of each bush with the 'pipe measure' as the major and minor axis of an ellipse for area calculation. The area that each bush species covered in total was divided by the total area of the bush sampling quadrats to calculate a species-percentage cover. These values were summed up to the total percentage (overlapping) cover with bushes per site. We recorded the height from the base of the bush to its highest part with the 'pipe measure', excluding any singular branches that were protruding higher than the bulk of a bush. The height values were averaged to calculate the mean height of bushes per site.

Within the tree sampling quadrat, which was centred in the bird census plot, visual estimates of the projected canopy cover were taken and the diameter at breast height (DBH; with a tape meter) of all tree species and their height (with an optical height meter PM-5/1520 SUUNTO, Espoo, Finland) measured. The multiple stems of eucalypt trees growing as so-called 'mallees' were added up and recorded as one tree if they appeared to spring from one underground lignotuber. DBH and height values were averaged per site.

Diversity of bushes and trees per site was expressed through the heterogeneity diversity index Simpson´s $E_{1/D}$ (advantages of this heterogeneity measure over its alternatives are reviewed by Magurran, 2004) based on species-cover values. All these assessments produced a total of eight variables (Table 5.1) which will be referred to as the 'main vegetation variables' throughout the text.

To determine how much vertical substrate was available in the habitat, a 2-m long pipe was held vertically beside the vegetation at 120 random sampling points within the bird census plots (again not within 5 m of the recreational track). The number of 0.1 m long sections (cylinders) that contained vegetation within a radius of 0.1 m from the pole was counted to determine the vertical structure of the vegetation, following the 'pole technique' described by Mills et al. (1991): each cylinder that contained vegetation was considered a 'hit'. This added up to a maximum of 20 hits per two-metre layer per sampling point and therefore to a maximum of 120 x 20 hits per site. Large numbers of hits per site indicate that hits were obtained from many sampling points within the bird census plot and different vertical layers of the vegetation whilst for small numbers it is less conclusive whether the hits may have been obtained from different sampling points and/or different vertical layers.

A comprehensive assessment of the immediate track-side vegetation was undertaken in a separate study (Chapter 4) where all vascular plants up to 1.5 m in height were sampled at a 1–10 m distance on either side of the recreational track. The results showed that the main edge-effect zone was situated within a 5 m distance to high usage roads and trails with a lower mean percentage of total plant cover, higher mean Simpson´s $E_{1/D}$ diversity and a greater mean percentage of weed cover compared to low usage sites. The effects were somewhat more pronounced and pervasive near roads.

To determine whether campsites (5.3.2) contained more cleared space than their surroundings, we estimated the total cover of all vascular plants up to 1.5 m in height in 20 1 m x 1 m sampling quadrats randomly distributed within the campsites and in 20 sampling quadrats within up to 30 m distance to the boundary of campsites but with more than 5 m distance to a recreational track.

Given the aridity of our study area, we also estimated the size of any water pools as they may influence the abundance and richness of our bird community (Schneider and Griesser, 2009).

5.3.5 Data analyses

Each of the following analyses was conducted separately for vehicle and hiker gorges. Had we merged the data sets in the first place, then most vehicle sites would have been categorized as high usage sites because roads received more overall usage than trails (Chapter 3) and the effect of the usage level would have been confounded with the effect of the access mode. Therefore, we first analysed how low and high usage sites behaved in each gorge type, and secondly, compared the emergent patterns between gorge types.

5.3.5.1 Species community and indicator species

To reduce the number of vegetation variables, a principal components analysis (PCA) with PRIMER v6 (Clarke and Gorley, 2006) was employed. This ordinated our study sites on a 2-dimensional plot based on their variation in the eight main vegetation variables. Euclidean distance served as the distance measure as it caters for the intrinsic characteristics of environmental variables (as listed in Clarke and Gorley, 2006). Prior to PCA the vegetation variables were replaced by their ranks. Ranking creates a common measurement scale; otherwise a PCA would be dominated by the input variables with the largest numbers. Furthermore, outlier-values, which would also make an unreasonable contribution to the PCA, are given much less weight (Clarke and Gorley, 2006). We admitted the PCA axes scores as continuous variables in several of the following analyses to account for the covariate effect of vegetation variability. In case of significant effects of a particular PCA axis, the factor loadings determined which of the original vegetation variables were instrumental in differentiating our study sites.

A visual inspection of the confidence intervals had indicated that tourism usage had no significant effect on the main vegetation variables and their derived PCA axes. At the most there was a slight trend for higher values of PCA axis 1 (PC1) at low usage sites compared to high usage sites. Thus, significant effects of the PCA axes on bird numbers or species richness mainly expressed the effect of environmental heterogeneity rather than a feed-back effect of tourism-induced changes in vegetation. In contrast, vegetation variables recorded in the immediate trackside were significantly related to the usage intensity (Chapter 4) and therefore not included as separate factors in the multi- and univariate analyses.

Bird community composition was related to tourism usage intensity by conducting a two-way factor permutational multivariate analysis of variance+, PERMANOVA+ (Anderson et al., 2008). PERMANOVA+ is embedded in PRIMER v6 via an add-on module and extends the original DOS version of PERMANOVA by various functionalities (e.g., the handling of unbalanced data sets). PERMANOVA (Anderson, 2001) itself tests the response of a variable or multiple variables (as in a species data set) to experimental factors based on any resemblance measure (McArdle and Anderson, 2001). A partitioning process of the total sum of squares according to the specified experimental design is carried out analogous to the partitioning process employed in an ANOVA, but on a distance matrix. For each model term, a distance-based pseudo-*F* statistic is calculated, and permutation procedures facilitate the calculation of *P*-values. One of the great advantages of PERMANOVA over ANOVA is that it does not assume that the original variables are normally distributed, which multivariate species data normally are not. Compared to ANOSIM, it accommodates more complex designs, for instance, with several nested factors and a combination of fixed and random factors. Prior to analysis, bird count data were square-root-transformed to downweight high-abundance species. We performed PERMANOVA+ on a Bray-Curtis similarity matrix of the species data with 999 permutations. In our study design, the sites represented replication ($n_{\text{vehicle gorges}} = 40$ levels; $n_{\text{hiker gorges}}$: 40 levels) at the lowest design level and were spatially blocked by the factor 'gorge' (random, vehicle gorges: 3 levels, hiker gorges: 4 levels). The treatment factor of interest was 'usage intensity' (fixed, 2 levels) which was crossed with gorge. Further, the five PCA axes and the size of water pools were included as covariates into the PERMANOVA+ models. Final models were extracted by excluding factors with *P*-values > 0.25 (Winer et al., 1991; Underwood, 1997) from initial models in a manual, stepwise backward selection procedure (Crawley, 2007). A significant interaction between gorge and usage intensity was followed up with post hoc pairwise tests (999 permutations) which provided simple main effect tests (Field, 2005) for identifying the level of one factor at which significant differences of the other factor occurred.

Finally, multivariate patterns were visualized by ordinating the sampling quadrats in a two-dimensional species-space with non-metric multidimensional scaling (nMDS) in PRIMER v6. As nMDS displays samples without attempting statistical inference, it can be used to identify visual patterns in community composition even in complex, nested designs where the independence of samples may be violated.

To test whether species were under- or overrepresented at high vs. low usage conditions, three-way hierarchical loglinear (hiloglinear) analyses (model factors: gorge x usage intensity x bird species) were conducted and followed up with chi-square tests (usage intensity x bird species) in SPSS for Windows 17.0 (SPSS, 2008). During this analysis a hiloglinear model was fitted to the cell frequencies of a multicontingency table of the model factors; thereby the natural logarithm of the expected cell frequencies is expressed as a linear (additive) function of the first and higher order interaction effects among the model factors (Field, 2005). Initially, a saturated model was fitted which was then automatically stepwise-reduced. Neither for the data from vehicle nor hiker gorges, the triple interaction was significant—that is, the dual interaction of usage intensity x bird species was independent of the gorge. Thus, for calculating the chi-square tests the data from the different gorges could be pooled without violating the assumption of independent data. Only species with more than 10 records were included in the chi-square tests to ensure that no more than 20% of the expected cell frequencies were less than 5 and none below 1 (Field, 2005). For each cell in the dual contingency table, the standardized residual was calculated as the difference between the observed and expected frequencies divided by an estimate of their standard deviation. Values <-1.96 or >1.96 are significant on the $P < 0.05$ level (Siegel and Castellan, 1988), and the frequency of observations in that cell should be regarded as significantly lower and higher, respectively, than expected; that is, the frequency of a particular species is associated with high vs. low usage conditions. In the following, species significantly associated with high usage sites are said to be 'attracted' to (indicative of) whilst species significantly associated with low usage are said to be 'repelled' from high usage conditions.

To test if birds at high usage sites were more frequently observed in lower habitat strata we also performed the above described procedure of a hiloglinear analysis (gorge x usage intensity x height level) with a follow-up chi-square test (usage intensity x height level). In case of a significant association (height level with usage condition), we tested whether that relationship simply reflected the potentially differing availability of this height level under the different usage conditions. Therefore, in addition to the initial inspection of confidence intervals (5.3.5.1; second paragraph) we performed a PERMANOVA+ on the cover of bushes and trees (<6 m and >6 m) in relation to usage intensity and employed the same design as in the community analysis except that no covariables were input.

5.3.5.2 Number and species richness of birds

Step-wise multiple regression was used to analyse the relationship of the number of birds and the species richness of the community with the usage intensity and habitat characteristics of the study sites. Usage intensity, gorge, the PCA axes and the size of water pools were included as factors in the initial regression model. To test whether the habitat characteristics affect the relationship between the bird metrics and the usage intensity, the first order interaction between the usage intensity and the PCA axes was also included by using their cross-products.

Data were transformed if needed to approximate the assumptions for multiple regression (Neter et al., 1990; Quinn and Keough, 2004). Multicollinearity between the independent variables used in the regression was weak as indicated by collinearity statistics (Field, 2005) such as variance inflation factors. All transformations ($x' = \sqrt{x}$; $x' = \log10(x+1)$) and univariate statistical analyses were carried out with SPSS for Windows 17.0 (SPSS, 2008). The 0.05-level of probability was accepted as significant in all analyses. Means ± 1 SE are presented unless indicated otherwise.

5.4 Results

5.4.1 Habitat characteristics

The main vegetation variables (Table 5.1) were summarized into five statistically independent axes by means of an unrotated PCA, all with eigenvalues > 1. We focus in our presentation of the results on the first two axes as they were significant predictors of bird metrics in the PERMANOVA+ and/or regression analysis.

PC1 and PC2 explained 35.2% and 18.2%, respectively, of the total variation in vegetation characteristics between sites in vehicle gorges (Table 5.1.1), indicating that the extracted components represented the site relationships reasonably well. All (ranked) vegetation variables were positively correlated with PC1, and significant, moderate to strong factor loadings showed up for the cover, height and diversity of bushes as well as for the cover and height of trees (Table 5.1.1). This suggests a separation of sites into those supporting a better developed shrub and tree layer and other sites where the vegetation was less developed. PC2 described a gradient in decreasing height and DBH of trees.

In hiker gorges, PC1 and PC2 accounted for a considerable 47.2% and 17.2%, respectively, of the total variation in vegetation characteristics between sites (Table 5.1.2), again indicating that the extracted components represented the site relationships well. The cover and height of bushes as well as the tree cover were significantly positively correlated with PC1 which implies a similar pattern of site separation to what we had observed in vehicle gorges. In addition, the vertical structure of the vegetation strongly increased along PC1 (Table 5.1.2). Tree diversity was the main (negative) correlate with PC2.

Table 5.1. Vegetation variables recorded at study sites next to (1) roads or (2) trails in arid-lands gorges, and factor loadings (Pearson´s correlations; r_P) of the ranked vegetation variables on the component scores of the first two PCA axes obtained from sites ordinated in vegetation variable space.

	(1) Next to roads				(2) Next to trails			
Vegetation variable	PCA axis 1		PCA axis 2		PCA axis 1		PCA axis 2	
	r_P	P	r_P	P	r_P	P	r_P	P
Vertical structure[a]	0.140		0.003		**0.860**	**	-0.052	
Bushes								
Cover (summed %)	**0.789**	**	0.161		**0.913**	**	0.082	
Height (mean cm)	**0.837**	**	0.070		**0.531**	**	-0.295	
Diversity (Simpson´s $E_{1/D}$)	**0.776**	**	0.242		0.019		0.248	
Trees								
Cover (summed %)	**0.584**	**	-0.036		**0.799**	**	0.256	
Height (mean m)	**0.447**	*	**-0.720**	**	0.095		0.280	
DBH (mean cm)	0.074		**-0.732**	**	0.168		0.112	
Diversity (Simpson´s $E_{1/D}$)	0.156		**0.338**	*	-0.112		**-0.546**	**
Variance explained (%)	35.20		18.20		47.20		17.20	

[a] Number of 0.1 m x 0.1 m cylinders of a 2-m pole containing vegetation, sampled at 120 points per site.

* $P < 0.05$, ** $P < 0.001$, $n_{\text{(sites next to roads)}} = 40$; $n_{\text{(sites next to trails)}} = 40$.

Campsites abutting or partially traversing our bird census plots contained 12.9% ± 1.3 of vegetation cover up to 1.5 m in height in vehicle gorges and 18.6% ± 3.9 in hiker gorges whereas in the camp-free surroundings 32.3% ± 2.2 and 39.2% ± 4.3, respectively, were recorded.

5.4.2 Species community and indicator species response to tourism usage and vegetation

According to the PERMANOVA+ models the community composition of the avifauna observed along roads (Table 5.2.1) significantly differed between high and low usage sites. Pairwise comparisons revealed that this effect was not consistent across hiker gorges (as indicated by the significant interaction; Table 5.2.2) and instead was significant in one gorge, marginally not significant in two gorges and nonsignificant in the fourth. An influence of tourism usage was also suggested by the nMDS ordinations which displayed a stratification of sites by usage intensity along roads (Fig. 5.2.1) and trails (Fig. 5.2.2). However, the nMDS results need to be interpreted with caution considering the high stress of the plots (>0.2). Vegetation characteristics, too, significantly influenced the bird community along roads (Table 5.2.1) and trails (Table 5.2.2) as indicated by the significant effect of PC1. Thus habitats with better developed vegetation (= higher PC1 values) supported a different community than habitats with less developed vegetation.

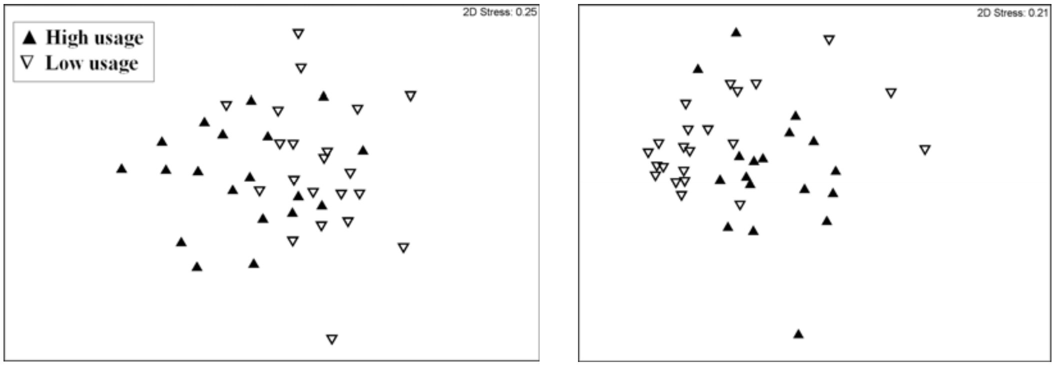
Table 5.2. Final PERMANOVA+ models including all main terms and interactions which significantly (bold values) explained variation in bird community composition next to (1) roads or (2) trails in arid-lands gorges.

(1) Next to roads				(2) Next to trails		
	df[a]	pseudo-*F*	*P(perm)* [b]	df	pseudo-*F*	*P(perm)* [b]
Treatment variable						
Usage intensity	1, 35	3.16	**0.001**	1, 3	0.88	0.536
Gorge	2, 35	2.95	**0.001**	3, 31	4.87	**0.001**
Usage intensity x gorge	NA NA	NA	NA	3, 31	2.27	**0.001**
Vegetation variable						
PCA axis 1	1, 35.90	2.30	**0.003**	1, 31	1.92	**0.016**

Note: Terms for which *P(perm)* > 0.25 (Winer et al., 1991; Underwood, 1997) were excluded from final models (denoted as 'NA') unless they figured in higher order or nested terms.

[a] Denominator degrees of freedom that are not integers are approximated following the Satterthwaite (1946) method.

[b] In PERMANOVA (Anderson, 2001), the distribution of the pseudo-F statistic is obtained by using a permutation procedure.



(1) Next to roads

(2) Next to trails

Fig. 5.2. NMDS plots of sampling quadrats based on avifauna composition, indicating differences in avifauna assemblages between high (▲) and low (∇) tourism usage sites next to (1) roads or (2) trails in arid-lands gorges. No scales are shown on the axes as the orientation of a nMDS diagram is arbitrary (Clarke and Gorley, 2006).

Numerous species responded sensitively (Table 5.3) to high usage whilst others were attracted (Table 5.3) to or tolerant (Table A 3.1) of these conditions. Species distinctive of high usage conditions were for instance Meliphagidae (e.g., honeyeaters and miners), Artamidae (e.g., Australian Magpie and Grey Butcherbird), Corvidae (e.g., Australian Raven) and Cacatuidae (e.g., Galah, Little Corella). Species with a preference for low usage conditions came from a wide range of families and also included several water birds and doves. Vehicle and hiker sites shared a considerable percentage of species that were attracted to high usage sites (75%) and a smaller percentage of species that were repelled from high usage sites (14.3%).

Table 5.3. Bird species that were significantly more frequent (according to a chi-square test and subsequent analysis of standardized residuals) and thus indicative of (a) high or (b) low tourism usage sites next to (1) roads or (2) trails in arid-lands gorges, and the vertical strata in which they were observed in the majority of sightings during the study.

Scientific name	Common name	Strata choice	(1) Next to roads	(2) Next to trails
(a) High usage indicators				
Manorina flavigula	Yellow-throated Miner	Low trees	**High usage**	**High usage**
Gymnorhina tibicen	Australian Magpie	High trees	**High usage**	**High usage**
Cacatua sanguinea	Little Corella	High trees	**High usage**	**High usage**
Cacatua roseicapillus	Galah	High trees	**High usage**	**High usage**
Ocyphaps lophotes	Crested Pigeon	Ground	**High usage**	**High usage**
Barnardius zonarius barnardi	Australian Ringneck	Shrub	**High usage**	**High usage**
Cracticus torquatus	Grey Butcherbird	Low trees	**High usage**	**High usage**
Lichenostomus ornatus	Yellow-plumed Honeyeater	Low trees	**High usage**	**High usage**
Manorina melanocephala	Noisy Miner	Shrub	**High usage**	**High usage**
Corvus coronoides	Australian Raven	High trees	**High usage**	Nonsignificant
Lichenostomus plumulus	Grey-fronted Honeyeater	Low trees	**High usage**	Nonsignificant
Psephotus haematonotus	Red-rumped Parrot	Low trees	**High usage**	Not tested
(b) Low usage indicators				
Malurus lamberti	Variegated Fairy-wren	Shrub	**Low usage**	**Low usage**
Pardalotus striatus	Striated Pardalote	Low trees	**Low usage**	**Low usage**
Anas gracilis	Grey Teal	Ground	**Low usage**	**Low usage**
Merops ornatus	Rainbow Bee-eater	High trees	**Low usage**	**Low usage**
Geopelia striata	Peaceful Dove	Ground	**Low usage**	**Low usage**
Pachycephala rufiventris	Rufous Whistler	Low trees	**Low usage**	**Low usage**
Zosterops lateralis	Silvereye	Shrub	**Low usage**	Not tested
Acrocephalus stentoreus	Australian Reed-warbler	Ground	**Low usage**	Not sighted
Anas castanea	Chestnut Teal	Ground	**Low usage**	Not sighted
Dicaeum hirundinaceum	Mistletoebird	Shrub	**Low usage**	Nonsignificant
Dromaius novaehollandiae	Emu	Ground	**Low usage**	Nonsignificant
Anas superciliosa	Pacific Black Duck	Ground	**Low usage**	Nonsignificant
Acanthiza chrysorrhoa	Yellow-rumped Thornbill	Shrub	Nonsignificant	**Low usage**
Acanthiza apicalis	Inland Thornbill	Shrub	Nonsignificant	**Low usage**
Petroica goodenovii	Red-capped Robin	Shrub	Nonsignificant	**Low usage**
Geopelia cuneata	Diamond Dove	Ground	Nonsignificant	**Low usage**
Climacteris picumnus	Brown Treecreeper	Shrub	Nonsignificant	**Low usage**
Falco berigora	Brown Falcon	Air, cliff	Nonsignificant	**Low usage**

Note: Chi-square analysis of the interaction effect between tourism usage intensity and bird species (Road: $\chi^2_{(46)} = 608.16$, $P < 0.001$; Trail: $\chi^2_{(42)} = 973.4$, $P < 0.001$). Marked in bold are the significant preferences of certain bird species for particular tourism usage conditions. Species with less than 10 observations ('not tested') were not included in the chi-square test.

High trees were significantly more often used at high usage sites, across all vehicle gorges. The ground and shrubs were more frequented at low usage sites in one of the three vehicle gorges, and either ground or shrub usage was more common at low usage sites in the two remaining vehicle gorges (Fig. 5.3.1). Under low usage conditions in hiker gorges there was a significant predominance of birds utilizing shrub layers whilst high trees were favoured at high usage sites (Fig. 5.3.2). These differences did not reflect differences in the availability of these strata types as the cover of bushes (vehicle gorges: pseudo-$F_{(1,34)} = 0.42$, $P_{(perm)} = 0.641$; hiker gorges: pseudo-$F_{(1,32)} = 0.235$, $P_{(perm)} = 0.838$) and of trees >6 m (vehicle gorges: pseudo-$F_{(1,34)} = 0.622$, $P_{(perm)} < 0.617$; hiker gorges: pseudo-$F_{(1,32)} = 0.218$, $P_{(perm)} < 0.772$) did not significantly vary between high and low usage sites. The number of birds utilizing low trees or circling in the air/cliff-dwelling was not associated with a particular usage level in either gorge type.

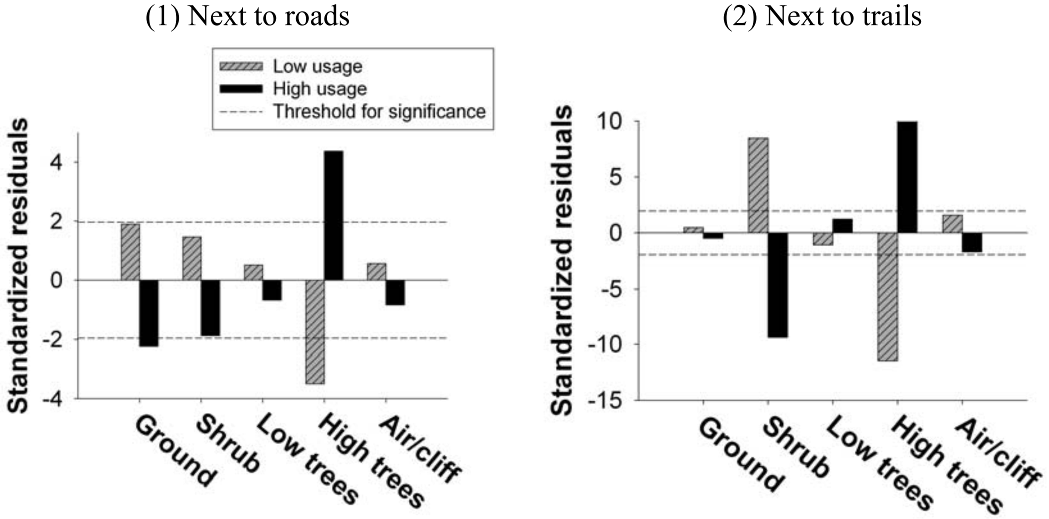


Fig. 5.3. Standardized residuals for the chi-square analysis of the interaction effect between tourism usage intensity and vertical strata choice of birds observed next to (1) roads or (2) trails ($\chi^2_{(4)} = 463.49$, $P < 0.001$) in arid-lands gorges. As the triple interaction between usage intensity of roads x gorge x strata choice was significant (hiloglinear analysis: $\chi^2_{(8)} = 46.12$, $P < 0.001$), separate chi-square analyses were conducted for each vehicle gorge ($\chi^2_{(4)}$, Brachina Gorge = 15.49, $P < 0.004$; $\chi^2_{(4)}$, Chambers Gorge = 130.75, $P < 0.001$; $\chi^2_{(4)}$, Parachilna Gorge = 51.95, $P < 0.001$) and an average value of the standardized residuals is presented. Bold reference lines indicate the threshold for significance, indicating that a particular stratum was used significantly more or less frequently than expected depending on the usage intensity.

5.4.3 Number of birds and species richness in response to tourism usage and vegetation character

The bird community comprised 75 species (roads: *n* = 6341 sightings; trails: *n* = 5982 sightings) (Table 5.3; Table A 3.1).

Multiple regression analysis revealed a strong positive relationship of PC1 with the number of birds (Table 5.4.1a; Fig. 5.4.1a) and the species richness (Table 5.4.1b; Fig. 5.4.1b) of the bird community observed along roads. Thus, a habitat with taller bushes and trees and a more extensive bush and tree cover as well as a greater diversity of bushes (Table 5.1.1) sustained significantly greater numbers of birds and a richer bird community. In contrast, high tourism usage negatively impacted on the number of birds (Table 5.4.1a; Fig. 5.4.1a) and the bird species richness (Table 5.4.1b; Fig. 5.4.1b). However, the significant interaction (Table 5.4.1a) between PC1 and high usage, manifested as a change in the slope of the regression lines for different usage levels (Fig. 5.4.1a), suggests that a more complex vegetation (greater PC1 values) mitigated the impact of high usage. Consequently, at sites with the best vegetation development similar numbers of birds were counted in high and low usage areas. The species richness of the community was similarly less impacted in more complex vegetation; albeit this was only a trend (Fig. 5.4.1b).

Table 5.4. Step-wise multiple regression models including all main terms and interactions which significantly (bold values) explained variation in (a) number of birds and (b) bird species richness recorded in 50 m x 50 m plots next to (1) roads or (2) trails in arid-lands gorges.

(1) Next to roads						(2) Next to trails					
(a) Number of birds											
	ΔR^2	*B*	*SE B*	*β*	*P*		ΔR^2	*B*	*SE B*	*β*	*P*
(Constant)		177.94	4.68		**<0.001**	(Constant)		149.55	3.21		**<0.001**
PCA axis 1	0.56	1.42	0.22	0.57	**<0.001**	PCA axis 1	0.45	0.92	0.15	0.72	**<0.001**
High usage	0.19	-41.24	6.80	-0.43	**<0.001**	PCA axis 2	0.08	-0.41	0.17	-0.28	**0.020**
PCA axis 1 x high usage	0.07	1.33	0.37	0.31	**0.001**						
(b) Bird species richness											
	ΔR^2	*B*	*SE B*	*β*	*P*		ΔR^2	*B*	*SE B*	*β*	*P*
(Constant)		19.18	0.52		**<0.001**	(Constant)		21.17	0.44		**<0.001**
PCA axis 1	0.47	0.14	0.02	0.69	**<0.001**	PCA axis 1	0.61	0.11	0.01	0.72	**<0.001**
High usage	0.17	-3.16	0.75	-0.41	**<0.001**	High usage	0.09	-2.16	0.66	-0.30	**0.002**

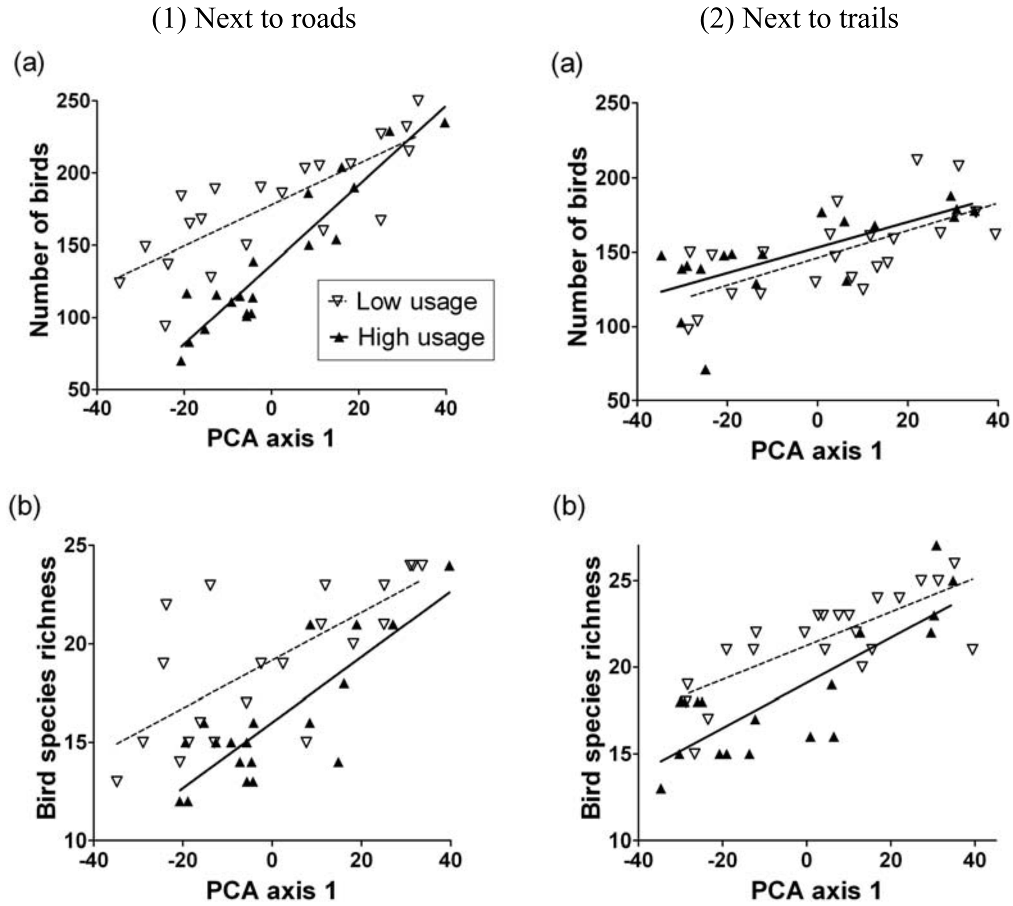


Fig. 5.4. (a) Total number and (b) species richness of birds in relation to high (▲) or low (∇) tourism usage intensity and PCA axis 1. Birds were censused on 50 m x 50 m plots during 20-min counts on 10 independent occasions next to (1) roads or (2) trails in arid-lands gorges. Cover, height and diversity of bushes and tree cover and height increase along PCA axis 1 for roads (Table 5.1.1). Cover and height of bushes as well as tree cover and vertical structure of the vegetation increase along PCA axis 1 for trails (Table 5.1.2).

The number of birds (Table 5.4.2a; Fig. 5.4.2a) and bird species richness (Table 5.4.2b; Fig. 5.4.2b) also significantly increased with PC1 along trails. According to the factor loadings (Table 5.1.2), bush and tree cover and the height of bushes as well as the vertical structure of the vegetation positively influenced bird numbers and species richness. In contrast to the results from the road data, high usage did not reduce bird numbers along trails (Table 5.4.2a; Fig. 5.4.2a), but still significantly reduced species richness (Table 5.4.2b; Fig. 5.4.2b) although to a less acute extent, as indicated by less spatial separation between the regression lines at different usage levels. A trend for an interaction effect between PC1 and high usage on species richness was noticeable too

(Fig. 5.4.2b), suggesting the same protective effect of vegetation complexity as determined for the road data. Finally, a slightly lower number of birds was apparent in sites where tree diversity was reduced (= higher PC2 values; Table 5.4.2).

Overall, PC1 explained the greatest percentage of variation (= highest R^2-values) in the number and species richness of bird communities along both roads (Table 5.4.1) and trails (Table 5.4.2) which testifies to its greater predictive importance compared to tourism disturbance.

5.5 Discussion

5.5.1 Impacts of tourism usage on bird metrics

5.5.1.1 Number of individuals

Bird metrics differed between high and low usage sites, indicating an impact of tourism usage, and these differences depended on the access mode. Low usage sites supported significantly greater numbers of individuals than high usage sites. However, this was only apparent along roads; high usage did not reduce the number of individuals recorded along trails. A reduction in bird numbers could be a consequence of (1) birds avoiding sites with increased visitor usage intensity (reviewed by Liddle, 1997; Buckley, 2004b) or (2) a lower survival or reproduction of birds due to disturbance along high usage roads (e.g., Pearce-Higgins et al., 2007). Tourism usage also reduced the number of birds over a disturbance gradient in Australian rainforest where semi-disturbed (walking trails) and disturbed sites (picnic grounds) hosted significantly lower numbers of birds than undisturbed sites (Jones and Nealson, 2005). Notwithstanding, disturbed sites may also attract birds, and the number of birds drawn to these sites can outweigh the number of birds that are repelled. For instance, Densmore and French (2005) observed a greater density of birds at high-visitation recreation areas used for camping and picnicking relative to the surrounding natural habitat. Similar patterns were reported for urbanized areas in contrast to less developed areas (Marzluff et al., 2001). These patterns are often (e.g., Emlen, 1974) ascribed to the presence of a few, highly abundant species that successfully utilize anthropogenic resources such as food.

The fact that usage intensity had no significant effect on bird numbers along trails suggests that tourism impacts may have been less intrusive there than adjacent to roads. Stronger differences between high and low usage sites along roads may, as argued in the introduction, result from (1) elevated levels of direct disturbance (usage in vehicle gorges is more prolonged due to the increased camping activity, higher noise emissions from vehicles), (2) the effect of road-kill, which was evidenced by bird corpses found along the road (mainly Emus and birds of prey), and (3) the stronger and more pervasive modification of the immediate environment of high usage roadsides (Chapter 4) as well as the larger number of campgrounds and their modified habitat character in vehicle gorges.

5.5.1.2 Species richness and community composition

Like the number of individuals, high usage reduced the species richness of bird communities, in this case along roads and trails. This corresponds to Densmore and French (2005) who reported that in their sample of Australian recreation areas only 67% of the total study species were seen, whereas in surrounding natural areas 87% of the total species were seen. Jones and Nealson (2005) recorded significantly greater numbers of species at undisturbed sites than along walking trails or picnic areas in Australian rainforest and eucalypt habitat. Urbanization, too, has lead to lower bird species richness, and McKinney (2006: 247) referred to it as a force that causes "biotic homogenization" considering that only a few tolerant species may adapt to disturbed conditions.

The changes in bird abundance and richness were accompanied by changes in community composition with numerous bird species preferring an either high or low usage condition. Many of our high usage indicator species are common inhabitants of urban and recreation areas or edge habitat throughout Australia, and the following species are typically found there in greater abundance (Sewell and Catterall, 1998; Luck et al., 1999; Parsons et al., 2003; Densmore and French, 2005; Piper and Catterall, 2006): Noisy Miner, Australian Magpie, Crested Pigeon, Galah, Grey Butcherbird, Australian Ringneck and Australian Raven. In contrast, species that tended to avoid more disturbed sites included many smaller-bodied passerines such as the Variegated Fairy-Wren, Rufous Whistler, Striated Pardalote and Silvereye.

We suspect several reasons why some species were attracted to high usage sites whilst others were deterred. Conspicuously, most of the species that preferred high usage sites are open country foragers. The main vegetation measurements at high usage areas may not have identified more open space within (but >5 m away from recreational tracks) our bird census plots, but open space was certainly increased in the immediate vicinity to high usage roads and trails (Chapter 4) and especially on abutting campsites. Indeed, we frequently observed birds to perch in the vegetation within our census plots from where they forayed into the cleared space of abutting campgrounds to forage, a pattern also found elsewhere (Arnold and Weeldenburg, 1990; Piper and Catterall, 2006). Luck et al. (1999) noted Australian Magpie and Little Raven foraging for invertebrates and small vertebrates at the edges of mallee patches and suspected that microhabitat characteristics of edges attracted fauna (e.g., basking reptiles) that served as a reliable food source. The importance of open space for attracting birds, rather than the provision of supplementary food sources from visitors using campgrounds, is demonstrated by Piper and Catterall (2006) in that roadsides with relatively wide verges sustained bird assemblages similar to those found at picnic area edges.

Notwithstanding, birds might profit from additional resources available at campgrounds. The species that we found to be attracted to high usage sites are all comparatively inquisitive in nature and most of them consume a general diet, both of which are typical traits for species appropriating novel and anthropogenic resources from disturbed sites. In our study area, we have witnessed incidents of intentional and unintentional feeding, birds utilizing water from rain collecting systems or sewage and infrastructure (e.g., information huts) for shelter or perching.

Another explanation for the observed community changes is that the increase of some species at disturbed sites impinged on the rest of the species. For example, the aggressive and predatory nature of several of our high usage indicator species such as the Noisy Miner or Grey Butcherbird may eliminate smaller, less aggressive species from otherwise suitable habitat (e.g., Dow, 1977; Sewell and Catterall, 1998). Grey et al. (1997), for instance, demonstrated that the abundance of honeyeaters and other insectivorous birds strongly increased within three months after removal of Noisy Miners from Australian woodland sites.

Moreover, direct disturbance from visitors may disquiet some species more easily than others. Many of our high usage indicator species are known to easily habituate to human disturbance. Likewise, birds associated with Australian recreation areas were not actively avoiding peak visitation times suggesting a certain level of habituation (Densmore and French, 2005). Other species, though, may be very sensitive and not easily habituate. Differences in the sensitivity of species within the same community have been attributed to food preferences (Canaday, 1995), geographic distribution, size (Cooke, 1980) and microhabitat specialization (Blakesley and Reese, 1988).

Our data demonstrated that the number of birds utilizing lower habitat strata compared to higher strata was greater at low than high usage sites even though all strata were equally available under both usage conditions. The habitat of birds utilizing lower vegetation strata is more affected by tourism activities and these birds are also more exposed to direct disturbance or may more likely collide with vehicles. Interestingly, our species indicator list (Table 5.3) reveals that the majority of high usage indicators were predominantly viewed in low or high trees whereas the low usage indicators were mostly viewed in ground or shrub layers. This suggests that high usage was not associated with a shift of birds from lower to higher strata (Gutzwiller et al., 1998), independent of species, but that species with preference for lower habitat strata were repelled (Blakesley and Reese, 1988). For instance, ducks and doves which were viewed most of the time while they were feeding in the water/on the ground reacted very shyly to our presence and usually took flight at long distances. Another sensitive group were the smaller passerines that preferentially resided in dense shrub. These species may therefore suffer severely when a loss of shrub layer decimates foraging and breeding substrate or refuge cover. Similarly, as urban development increased in the U.S.A., there was a decrease in ground-nesting species and an increase in tree-nesting species (Lindsay et al., 2002). Our results also agree with Sewell and Catterall (1998) who reported that Australian bushland (open forest or woodland, usually eucalypt-dominant) birds preferably utilized habitat heights below 3 m in bushland settings compared to other native species that were normally attracted to urbanized areas and preferred heights above 8 m in the bushland settings. They reported as well that this pattern occurred across a significant proportion of species rather than a few particularly abundant species. Our argument that high usage indicator species may be attracted to open ground does not contradict our observation that they were mostly viewed in the tall canopy. As described above our census plots were often used for perching adjacent to open ground.

Remarkably, despite the sporadic camping activity tourism usage of hiker gorges affected the species richness and community composition similarly as in vehicle gorges. Likely the increased usage by visitors taking breaks at high usage trail sections was responsible. However, even the increased foot traffic may play a role as some birds have low thresholds to disturbance, and they are repelled from seemingly unobtrusive activities such as hiking. Such low thresholds to disturbance have been obtained in other studies where reductions in abundance of various bird species have been observed at a very low volume of passing traffic (Madsen, 1985). The fact that some species were attracted to high usage hiker sites, even though they mostly lack campgrounds and their associated resources, may be related to the increase in usage by visitors who stopped there and took picnic breaks. Occasionally we even observed birds perching in scenic areas where visitors regularly took breaks and fed birds to achieve close-up photographs.

5.5.2 Habitat effect on bird metrics

The functional relationship between bird metrics and tourism usage or infrastructure in protected landscapes is complex, and habitat covariates may assume an important predictor role. The species richness of a bird community in the Chihuahuan Desert, U.S.A., and the relative abundance of numerous bird species not only depended on road and other infrastructure development variables or their interactions but also (and in some cases solely) on habitat variables such as the cover of different vegetation types and the site elevation (Gutzwiller and Barrow, 2003). In our study, vegetation structure and floristics, as condensed in the first PCA axis (PC1), exerted a strong positive influence on the total number of birds and the species richness of the bird community along roads and trails. In fact, these habitat characteristics were more influential for bird metrics than tourism disturbance which supports our hypothesis that natural variability in vegetation—in addition to tourism-induced modifications—exerts a covariate effect on bird metrics.

The physical structure of the habitat has long been recognized as an important determinant for bird metrics. We measured three structural properties (vertical structure of the habitat, cover and height of bushes and trees) that may be descriptive of the amount and spatial extent of available resources (foraging and nesting substrate, shelter from predators; (Urban and Smith, 1989; Leimgruber et al., 1994)), and ultimately the quantity and types of niches that are available (Lynch and Whigham, 1984). Numerous aspects of vegetation structure were positively correlated with the habitat occupancy or distribution of birds (Anderson and Shugart, 1974; Wray and Whitmore, 1979), species composition and abundance (MacArthur and MacArthur, 1961; Dean, 2000). Wiens and Rottenberry (1981), for instance, reported that some bird species in North American shrub steppe increased in abundance as vegetation cover and height increased.

An increase in avian diversity was also related to an enhanced vegetation structural diversity (Monadjem, 2002). Although birds may be able to utilize different plant species to satisfy similar needs or only use a small proportion of all plant species growing in the habitat, vegetation composition and diversity nevertheless affect the avian community: A higher vegetative diversity may translate into broader niche dimensions and therefore support more bird species. For instance, an avian community in the Mojave Desert, U.S.A., was more closely associated with floristics than with structural vegetation properties (Fleishman et al., 2003) which is consistent with other studies (Rotenberry, 1985).

An important finding of our study was that the deleterious effect of high tourism usage on the total bird number along roads was mitigated if the vegetation was better developed, as indicated by the significant interaction between PC1 and high usage. In the context of regression such interactions are referred to as 'moderator effects' because the slope of the relation between the dependent variable and one explanatory variable (high usage) varies with (is moderated by) the values of another explanatory variable (PC1) (Hair et al., 1998). There was no significant interaction effect of PC1 and high usage on species richness but a slight trend was apparent which suggested a similar relation as for bird numbers. Likely birds perceive lusher vegetation as a protective barrier which could buffer direct disturbance stimuli exerted from visitors.

5.6 Conclusions and management implications

Our comparison of high and low usage tourism sites in Australian arid-lands gorges substantiated that high usage significantly decreased the number of birds inhabiting roadsides and the species richness of the avifauna community in road- and trailsides. Further, considerable changes in the community composition occurred with numerous species exhibiting significant attraction to or repulsion from high usage roads and trails; particularly species using lower habitat strata avoided high usage sites. Conversely, at sites with a better developed shrub and tree layer the number of individuals and the species richness drastically increased and some of the aversive effects of tourism usage were mitigated. Overall, tourism usage exerted less predictive power over bird metrics than vegetation variables, and the impacts were somewhat more aggravated along roads than trails.

These results have direct implications for the management of tourism impacts on avifauna in arid-lands gorges: (1) The observed impacts reinforce the idea that access to gorges should be controlled to conserve their avifauna. Managers may close some gorges or sections to vehicle traffic and allow exclusive hiker access. However, when gorges contain the connecting road within a network of roads, one can expect strong opposing reactions from various stakeholders. Further, the impact was not substantially graver at vehicle than hiker sites as to expect that this management action might have a dramatic effect. It may be necessary to reduce the overall usage of passing, stopping and camping visitors to mitigate deleterious effects, either by closing off certain parts of each gorge, or an entire gorge while allowing unrestricted access to others. Hiker gorges are the preferred location for such management actions as they are already mostly accessed from one side, and the majority of visitors concentrate in the beginning up to the middle. By closing off the farther sections and alternate access points, spatial refuges from any tourism usage can be created (Pearce-Higgins and Yalden, 1997; Pearce-Higgins et al., 2007). This will also benefit cryptic bird species whose conservation is a particular challenge as they are not readily noticed and thus any problems associated with them may be obscured. However, given that behavioural responses of birds next to roads and trails do not necessarily translate to overall population responses—some birds may leave disturbed places in favour of less disturbed places—we argue for caution that these management actions may, at times, focus primarily on reducing local population losses. (2) Given that species varied greatly in their sensitivity to tourism usage, it would be more effective to monitor the abundance of sensitive (indicator) species rather than the total number of individuals as that can mask the changes in composition: the total number of birds recorded at high usage hiker sites was not markedly lower than at low usage sites, in spite of significant and meaningful differences in species composition. (3) Our findings support the idea that avian communities are highly sensitive to changes in habitat characteristics (Mac Nally, 1990), and some impacts may even be buffered in well-vegetated areas. Hence, avifauna monitoring of arid-lands gorges needs to assess vegetation variables as their effect on bird metrics can outweigh and therefore obscure the effects of human disturbance. Further, it is particularly important to maintain intact vegetation by minimising the creation of open space as its presence clearly alters bird communities (Green and Catterall, 1998). Consequently, some of the numerous wild campsites that are currently dispersed throughout vehicle gorges may need to be closed and revegetated. This would especially benefit more sensitive bird species that preferably utilize ground and shrub layers in undisturbed parts of the park.

Clearly, the mechanisms that drive sensitive species from impacted areas or attract others require further research and a more detailed establishment of dose-response curves, so that tourism impacts on avifauna in protected areas can be managed more efficiently.

Chapter 6

Guidelines for the kangaroo whisperer: Finding ways to minimize disturbance during approach of kangaroos on foot and by car

Fig. 6.1. Yellow-footed Rock-wallaby (*Petrogale xanthopus*) and dummy counterpart in Brachina Gorge, Flinders Ranges.

6.1 Abstract

We examined how tourists approach free-living kangaroos during encounters in a popular Outback tourism destination, the Flinders Ranges of South Australia. We then simulated the typical properties of approaches to quantify the behavioural reactions of Red Kangaroos (*Macropus rufus*) and Euros (*M. robustus erubescens*) and the relation to the disturbance context (including species, sex class, group size, time of day, cover, and wind speed).

Approach varied by access (on-trail, off-trail), transport (on-trail: hiking, driving; off-trail: hiking) and approach style (on-trail: tangential/continuous, tangential/stop-and-go; off-trail: direct/continuous, direct/stop-and-go, direct/stop-and-go/talking, tangential/switchbacks/stop-and-go). On-trail, 53% of kangaroos took flight when the closest distance to them was approached or attained whilst (by design) all subjects off-trail took flight. The mean (± 1 SE) flight initiation distance (FID) was significantly shorter following an on-trail (78 ± 2.7 m) than an off-trail approach (90 ± 2.7 m). Kangaroos fled less often (41% vs. 75%) and spent more time in maintenance activities (40% vs. 10%) if approached in a vehicle than on foot. The mean FID and flight path (FP) after approach on foot was reduced when made in a stop-and-go fashion. Euros fled at a significantly shorter FID along a shorter FP than Red Kangaroos. FID was longest in females with young-at-foot and shortest in females with obvious pouch-young. Viewing distance was closest if the approach was made in the evenings, the habitat provided cover and the day was calm.

The varying intrusiveness of the different approach styles is attributed to differences in the previous experience with similar disturbance, the predictability, directness and continuity of the approach as well as changes in approach direction, additional behaviour such as talking and the disturbance context. The results suggest that wildlife tourists should be educated to the best choice of approach behaviour and viewing conditions and thereby reduce aversive reactions in kangaroos and mediate closer observations to the visitors' greater satisfaction and the kangaroos' better welfare.

Keywords: wildlife tourism, kangaroos, visitor impacts, approach, behaviour, flight, disturbance context.

6.2 Introduction

Close encounter with animals in their natural environment is a key factor for determining visitor satisfaction with non-consumptive (Duffus and Dearden, 1990) wildlife tourism experiences (Moscardo et al., 2001; Orams, 2002; Moscardo and Saltzer, 2005). Distance is often overcome by approaching wildlife but they in turn perceive humans as potential predators, especially in non-captive settings, where the lack of protective barriers and irregular visitation reduce the likelihood for habituation (Poole, 1981; Wilson, 1999).

Without physiological measurements (e.g., heart rate, stress hormone levels), behavioural changes are the first signs of reaction to tourist encounters (reviewed by Knight and Cole, 1995; Green and Giese, 2004). Disturbed animals will assume vigilance behaviour to evaluate potential danger (e.g., Dyck and Baydack, 2003) or undertake evasive actions (e.g., Cassirer et al., 1992). Rarely, aggressive responses occur (Bounds and Shaw, 1994). The consequence is that less time can be spent on body maintenance through feeding and resting (Knight et al., 1991; Lott and McCoy, 1995; Roe et al., 1997) or on social interaction (Edington and Edington, 1990). Furthermore, tourists can drive animals from habitats with better quality resources (e.g., food, breeding space) (Woodall et al., 1989; Griffiths and van Schaik, 1993). Hence, the individual’s current energy levels are depleted by physiological defence reactions as well as additional vigilance and flight (Giese, 1998), less new energy can be consumed due to reduced body maintenance activities, and the actual intake will be less efficient if displacement from optimum foraging places and times occurs. In addition, the interruption of social behaviour can lower offspring survival (Stuart-Dick, 1987; McClung et al., 2004; Müllner et al., 2004), hinder mating between adults or disrupt social organization within animal communities. Therefore, if tourism disturbance persists or occurs frequently, changes in key behaviour may result in aversive, long-term effects for survival and reproduction of the individual animals (Piatt et al., 1990; Green and Giese, 2004), translating into consequences for whole populations and species communities (Reynolds and Braithwaite, 2001).

Given that vigilance and flight behaviour are costly activities, prey need to decide whether to disregard the threat, attend to it or to flee; and if taking flight, when to flee, how far and on what trajectory (Lima and Dill, 1990; Ramp et al., 2005). A major factor influencing these decisions in encounters with people is the person’s starting and ending distance and the mode of their approach to the animal. Longer starting distances may lead to longer flight initiation distances (Blumstein, 2003; Cooper, 2005), presumably because prey perceive continued pursuit as a greater threat. Generally, the closer the approach (= ending distance), the greater the change in behaviour (Cassini, 2001; Papouchis et al., 2001; Ikuta and Blumstein, 2003). Leaving a frequently used track to approach off-trail seems to augment the response more than an on-trail approach (Mainini et al., 1993; Miller et al., 2001). Foot approach, experienced by kangaroos as a major threat from ambulatory hunters for tens of thousands of years (or for millions of years from carnivorous marsupials such as the *Thylacinus cynocephalus* which presumably were more similar to humans than to vehicles), tends to elicit a greater response than a vehicle approach (McLellan and Shackleton, 1989; Andersen et al., 1996), which only in recent decades has become the major transport for hunting kangaroos in the Australian rangelands. Furthermore, behavioural responses depend on the direction (Richens and Lavigne, 1978) and speed (Burger, 1981b) of the approaching person. A directed (Burger and Gochfeld, 1990) and quick (predator-like) (Burger, 1981a) approach, for instance, triggered stronger reactions than an undirected and slow approach.

Finally, the intensity of the response may also depend on a variety of modifying factors like species (Blumstein and Daniel, 2002), group size (Blumstein and Daniel, 2003b), time of day (Burger and Gochfeld, 1991; Taylor and Knight, 2003b) and habitat characteristics such as the degree of the animal’s exposure (Cooke, 1980; Burger and Gochfeld, 1990; Pierce et al., 1993). Moreover, experience with similar stimuli plays a role. Animals can habituate to harmless and predictable disturbance (Eibl-Eibesfeldt, 1970) and consequently react less strongly to tourism activities (MacArthur et al., 1982).

In Australia, encounters with kangaroos are a highly sought after attraction (Croft, 1999; Croft, 2000) that brands the continent as a tourism destination abundant with unique wildlife. Our experiments were carried out in the Flinders Ranges National Park (FRNP) and at the University of New South Wales Arid Zone Research Station at Fowlers Gap (FG), Australia. Both areas are known for their substantial populations of kangaroo species and excellent opportunities to view them. Two kangaroo species, Red Kangaroos (*Macropus rufus*) and Euros (*M. robustus erubescens*), were studied. Both are common and were used as exemplars to direct further research and management of tourism with themselves and sympatric endangered species like the Yellow-footed Rock-wallaby (*Petrogale xanthopus*).

Even though the tourist-kangaroo interface has rarely been investigated, experiments to elucidate the relationship between kangaroos and their predators (Blumstein and Daniel, 2003a) suggest that kangaroos react sensitively to human intervention. Here, we focus on a very common form of intervention, the direct disturbance by approaching tourists that may lead to short-term behavioural changes in kangaroos. We assumed that the greater the perceived risk from the disturbance, then the greater the percentage of kangaroos taking flight, the longer the flight initiation distances and flight paths, and the greater the time spent with alertness and flight vs. maintenance behaviour. Kangaroo flight is an energy-demanding process (Dawson and Taylor, 1973), and likely there is a trade-off between expenditure of energy as well as time spent on behaviour that protects against disturbance and that invested in fitness-maximizing maintenance activities (Frid and Dill, 2002). The magnitude of this is a function of the cumulative disturbances an individual receives from approaches by tourists. Further, this trade-off may be particularly acute under the drought-stricken condition in the arid lands of the Australian Outback, where animals already suffer from tight energy budgets due to limited food supplies.

Our study was divided into two parts: First, we observed the spectrum and frequency of different modes of approach by tourists during kangaroo encounters either while driving or hiking (the common means of transport for exploring the Australian Outback), and with real and dummy kangaroos (the latter to increase sampling rate). The results guided our choice of approach simulations in the second part. Here, we simulated some of the observed tourist approach behaviour to determine flight reactions and behavioural time budgets of individual kangaroos in FRNP and FG in relation to different access, transport and approach styles and various modifying factors including species, sex class, group size, time of day, availability of cover and wind speed.

We tested the following non-exclusive hypotheses: (1) Approach styles (and/or their frequencies) would differ between driving and hiking tourists as visitors driving a vehicle experience their environment at a greater speed and from a more secluded position than hikers. Consequently, they may overlook wildlife beside roads entirely so that they pass-by without watching, or they spot wildlife too late so that they have to turn back to watch. They may also be less inclined to stop during their approach. (2) Kangaroos would react to human approach with alertness and flight. (3) Off-trail approach would be more disturbing than on-trail approach which kangaroos may perceive as less threatening as it is more predictable and less direct. (4) Foot approach would be more disturbing than approach by vehicle due to the long history of kangaroos with ambulatory hunters. (5) A stop-and-go approach may be less disturbing than continuous forms of approach as the latter suggests continued pursuit. (6) A direct approach, resembling a targeted attack, would be more disturbing than a tangential approach. (7) A change of approach direction would aggravate the response as it may signal that the prey has been detected. (8) Talking would aggravate the response as kangaroos may react aversively to noise. (9) The disturbance context would moderate the reaction of kangaroos to approach: we predicted that different species, sex classes and group sizes would react more or less sensitively to approach; further that the time of day, availability of cover and wind speed would have an influence. The related, complex hypotheses are detailed in the discussion.

6.3 Study areas

The FRNP (lat. 31° 27` S, long. 138° 41` E) covers 95 000 ha in central South Australia. The Park is a popular and a well-promoted nature-based tourism destination that offers a wide range of activities including bushwalking, camping, scenic touring, birdwatching and Aboriginal and European cultural experiences. The vegetation is a mixture of arid-adapted species on shales or slopes and moist-adapted species in gorges. It includes woodlands of cypress pines, mallee and black oak and porcupine grasslands. Red Kangaroo and Euro densities are estimated to be around 15–25 individuals km^{-2} (Peter Watkins, Operation Manager Bounceback, pers. comm.). There is some culling of these species by shooting in the management of the endangered Yellow-footed Rock-wallaby (Department for Environment and Heritage, 2006).

FG (lat. 31° 05' S, long. 141° 43' E) covers an area of 39 888 ha in western New South Wales and is held by the University of New South Wales, Sydney, for the purpose of research, teaching and tourism. The climate is dry and mildly arid (Bell, 1973) and similar to FRNP. The station is typical of Australia's southern sheep rangelands with a chenopod shrub steppe and scattered trees such as mulga and black oak. The densities of Red Kangaroos (estimated between 1985 and 1987; (Edwards et al., 1996)) and Euros (estimated between 1984 to 1986; (Clancy, 1989)) are typically at around 10 to 20 and 3 to 20 individuals km^{-2}, respectively. There is no culling of kangaroos.

Dingoes (*Canis lupus dingo*), the replacement of now-extinct natural predators of kangaroos, have been excluded from both study areas by ongoing control and the trans-continental 'dingo fence'.

6.4 Observations of tourist behaviour during encounters with dummy and live kangaroos

6.4.1 Methods

6.4.1.1 Tourist behaviour during dummy encounters

The behaviour of tourists during encounters with kangaroo dummies was recorded using ad libitum sampling (Altmann, 1974) by two observers from separate vantage points. Samples were taken from several areas in FRNP from 9 am to 5 pm on randomly chosen days between August and October 2007. Sites were established in characteristic kangaroo habitat where tourists could expect to encounter kangaroos after reading the Park’s interpretative materials. The kangaroo dummy was a stuffed animal toy with generalized kangaroo features, brown fur with white patches and 50 cm in height. Two dummies were placed in obvious locations close to (about 30 m) frequently used recreational tracks that were either restricted to hiker access or open to and mainly used by tourists for scenic driving. At least one observer was positioned in hearing distance to the oncoming tourist groups and both were seated so that they could view tourists from the dummy’s perspective.

For each passing tourist group (one or more people travelling together within 10 m proximity) that had discovered the dummy, we recorded general travel party characteristics such as group size and spread as well as the occurrence of different approach styles. An approach commenced on-trail and was in some cases continued off-trail. The direction of an on-trail approach was always tangential whereas the direction of an off-trail approach was either direct or tangential. The principal on-trail approach styles were: 'tangential/passer-by' (observation while passing-by without stopping), 'tangential/continuous' (after initial discovery from a distance animal is approached directly to the closest on-trail distance for main observation), 'tangential/back-up' (late discovery of the animal while passing-by; backup is required for observation), 'tangential/stop-and-go' (stop-and-go approach with intermittent periods of observation), 'tangential/stop-and-watch' (main observation takes place at the original point of first discovery). The principal off-trail approach styles were: 'direct/continuous', 'direct/stop-and-go', 'tangential/switchbacks/stop-and-go' (similar to a zigzag motion toward the 'animal' with intermittent periods of observation).

The observations were stopped once the dummy was recognized as a fake; for example, talking about it, laughter, searching/looking around for 'a candid camera', sudden interruptions of behaviour (e.g., stopping in the middle of taking a picture) and head shaking or frowning. It was, however, not critical to determine the exact point of recognition as the approach behaviour was typically determined long before the dummy was recognized.

6.4.1.2 Tourist behaviour during live animal encounters

The behaviour of tourists during encounters with real kangaroos was recorded at the same or similar study sites that were known for their high kangaroo densities. The same observation procedures were applied. Some conditions, such as the initial encounter distance, could not be standardized in the same way as it was possible for the dummy setup. However, in most long-distance encounters (>60 m) tourists did not become aware of the kangaroos and so the data set included mostly those observations at shorter distances commensurate with the dummy setup.

6.4.1.3 Data analyses

We refined the observation data to that which the two observers found consensus and excluded the rest (5%). Chi-square tests were applied to analyze differences between the behavioural data from dummy and live observations. When no significant differences were found, data were pooled. The unit of replication are the individual tourist groups; each group was included only once in the data set. Further chi-square tests were applied on (pooled or unpooled) data to detect differences between hiker and driver behaviour. We calculated the standardized residual for each cell in the contingency table, which is the difference between the observed and expected values, divided by an estimate of their standard deviation. Values <-1.96 or >1.96 are significant on the 0.05-level of probability (Siegel and Castellan, 1988), and the frequency in that cell is significantly lower or higher, respectively, than expected.

6.4.2 Results

We collected data of 194 dummy and 84 live kangaroo encounters for driving tourists and 120 dummy and 80 live kangaroo encounters for hiking tourists (vs. 24% of drivers and 11% of hikers who did not notice live kangaroos; not included in the further analyses). Most (85%) travel parties consisted of 2–4 members. These groups generally remained in close (≤5 m) proximity to each other (90% of the hiker groups and 95% of the driver groups once disembarked from their car).

All observations commenced as an on-trail approach since recreational paths necessarily led by the dummy or kangaroos. Chi-square analyses revealed no significant differences between dummy and live observations for an on-trail approach so we pooled the data. Virtually every visitor group adopted one approach style throughout the observation; in the few cases where several approach styles occurred per group, the initial style was recorded. We found strong differences in on-trail approach styles between drivers and hikers ($\chi^2_{(4)} = 219.99$, $P < 0.001$). Drivers adopted a tangential/passer-by (driver: 26%, hiker: 5%), tangential/back-up, (driver: 14%, hiker: 1%) and tangential/continuous (driver: 31%, hiker: 7%) approach significantly more frequently than hikers. Hikers adopted a tangential/stop-and-watch (driver: 4%, hiker: 58%) approach significantly more often than drivers. The remaining tangential/stop-and-go approach was similarly frequent in both groups (driver: 24%, hiker: 30%).

None of the drivers approached the kangaroo off-trail by vehicle, but 24% disembarked their vehicle and some of them continued their approach off-trail afoot. Significantly more groups left the trail or road during observations of live kangaroos (driver: 15%, HK: 20%) than a dummy (driver: 2%, hiker: 2%) (driver: $\chi^2_{(1)} = 18.63$, $P < 0.001$, hiker: $\chi^2_{(1)} = 18.01$, $P < 0.001$). Further analysis of the former, showed no significant differences between (disembarked) driver and hiker groups in going off-trail, or the approach styles adopted off-trail. Three types of off-trail approach were observed: direct/continuous (driver: 17%, hiker: 40%), direct/stop-and-go (driver: 50%, hiker: 40%) and tangential/switchbacks/stop-and-go (driver: 33%, hiker: 20%).

6.5 Observations of kangaroo reactions to simulated tourist behaviour

6.5.1 Methods

6.5.1.1 Study transects

We established six line-transects in FRNP and four transects at FG. The transects averaged (± 1 SE) 9 km (± 0.5) for foot and 19 km (± 3.6) for in-vehicle approaches. The potential for pseudoreplication through re-sampling the same kangaroo individuals was minimized by using two geographic regions and spatially distinct areas so that within each region the centre points of the loop transects were between 3 to 8 km apart.

Starting points of creek bed hikes were at least 1 km apart. Further, hiking transects led into different trajectories demarcated by ridges or roads that traverse FRNP and FG. Finally, the same transect was never sampled during two consecutive observation periods.

Kangaroo-human encounters (mainly station/park workers, some researchers and drive-through traffic, a few tourists) were infrequent in these areas, and so the potential for kangaroos to habituate to humans was judged to be low to moderate. The transects sampled representative habitat for the Euro (hills and slopes) and the Red Kangaroo (open plains) (Dawson, 1995).

6.5.1.2 Approach of kangaroos and sampling of flight response

Each of two observers in drab clothing walked singly on two randomly chosen transects per day in the 3 h past sunrise or before sunset from September 2007 to February 2008 so that all transects were equally sampled. The direction of the walks was rotated daily to reduce temporal biases. The two observers collaborated in a pilot study to standardize their behaviour and ensure inter-observer reliability. No observer effect was found in the analysis of the results. Days with unusual weather (e.g., rain) were excluded for possible effects on kangaroo reactivity (Croft, 1981). Observations were made with a binocular (10 x 42). For each encounter, group size, time of day and wind speed (from a Kestrel anemometer Pocket Weather Meter 2000; Kestrel, Sylvan Lake, Michigan, U.S.A.) were recorded. Groups were defined as two or more animals of the same species within a distance of 50 m (Croft, 1981; Heathcote, 1987) that are able to communicate visually with each other (Colagross and Cockburn, 1993).

The individual closest to the observer was chosen as the focal animal. We recorded its species, age-sex class, the availability of cover (natural features suitable for hiding and covering more than 30% of the kangaroo) within 2 m and the observer's starting distance (Blumstein, 2003; Cooper, 2005) from a Bushnell rangefinder Yardage Pro 1000 (Bushnell, Overland Park, Kansas, U.S.A.). The observer approached the focal animal at a constant pace (Burger and Gochfeld, 1990; Blumstein, 2002) by using one of eight different approach treatments (see next paragraph; Table 6.1). Once the focal animal took flight (aversive movements away from the observer following an alert/orientation response towards the observer) the approach was stopped and the kangaroo observed until it stopped.

The distance between the observer's current position and the focal animal's position at the commencement of flight (memorized from visual landscape cues (Taylor and Knight, 2003b)) was measured from the rangefinder as the flight initiation distance (FID). The distance between the observer's current position and the focal animal's final position was recorded as the final flight distance. The angle between the FID and final flight distance vectors was measured with a Suunto compass DS 56 (Suunto, Vantaa, Finland). FID, final flight distance and the angle were used to calculate the flight path (FP)—the distance between the initial and final position of the focal animal—by means of simple trigonometric relationships. The safety distance kangaroos gained to the observer by fleeing was calculated by subtracting FID from final flight distance. Most kangaroos fled tangentially to the observer and so for every metre of safety distance gained, the kangaroos hopped additional metres. We defined flight effort as the ratio of FP to safety distance, which equals 1 if the kangaroo hops directly away from the observer. Whilst by design all off-trail approaches lead to flight, on-trail approach did not always trigger flight, and in that case we measured the closest distance achievable to the kangaroo.

The choice of approach treatments (Table 6.1) was guided by the spectrum and frequencies of behaviour encountered during the tourist observations. On-trail, we used the two most frequent styles from the repertoire of five observed, for approaches in a vehicle or on foot. As we saw no visitor drive off a formed track but hikers did, we confined off-trail approaches to those on foot. Approach on foot took place at a constant walking pace of about 0.5 m sec^{-1} and (sport utility) vehicle approach at about 20 km h^{-1} (recorded average pass-by speed for visitors observing wildlife from their vehicle). Stop-and-go approach was standardized to a stop of 15 s after every 5 paces. A tangential off-trail approach was conducted at a 45° angle to the direct line between observer and kangaroo with a switchback after every 5 paces and a stop of 15 s. A tangential on-trail approach could not be standardized to a specific approach angle since that was determined by the course of the track. Talking was a very common form of supplementary behaviour for hiker groups. Therefore, we tested for its additional effects by performing one of the three off-trail approach styles, namely the direct/stop-and-go, with or without talking. We talked during the stops of the direct/stop-and-go/talking approach at a medium voice level.

6.5.1.3 Recording of behavioural time budgets

Because an on-trail approach did not necessarily lead to flight we wanted an additional response measure. Thus, the observer recorded the behaviour of the focal animal for 5 min immediately after an on-trail approach to FID or closest distance. We calculated the percentage of time spent in vigilance behaviour, hiding and aversive movements vs. maintenance activities such as feeding, grooming and social interactions (defined after King et al. (2005)). Subjects were deemed to be 'hiding' if flight placed them in cover and obscured from the observer. The recording of the behaviour of kangaroos that took flight commenced when they came to rest.

6.5.1.4 Data analyses

The various measurements of a response to an approach were analysed in relation to: access style (on-trail vs. off-trail), transport style (on-trail: hiking, driving; off-trail: hiking) and approach style (on-trail: tangential/continuous, tangential/stop-and-go; off-trail: direct/continuous, direct/stop-and-go, direct/stop-and-go/talking, tangential /switchbacks/stop-and-go). The individual animal was taken as the unit of replication.

Table 6.1. Summary of approach treatments (simulated tourist approach behaviour) to which Euros and Red Kangaroos were subjected. The predictability (predict.), continuity (cont.), directness, change of direction and any behaviour added (extra behav.) onto the baseline approach behaviour presumably determine the perceived risk level of the disturbance and so the kangaroo response.

Access style	Transport style	Approach style	Predict.	Direct	Cont.	Change of direction	Extra behav.
On-trail	Driving	tangential/continuous	X		X		
		tangential/stop-and-go	X				
	Hiking	tangential/continuous	X		X		
		tangential/stop-and-go	X				
Off-trail	Hiking	direct/continuous		X	X		
		direct/stop-and-go		X			
		direct/stop-and-go/talking		X			X
		tangential/switchbacks/stop-and-go				X	

Chi-square tests were used to compare the number of kangaroos that took flight in response to access, transport and approach style. We conducted ANOVAs to test for the influence of access style on mean FID, FP and flight effort. For any tests performed on access style, we used only data from the on-trail hiker approach and the off-trail direct/stop-and-go and direct/continuous approach, so that any differences could be attributed to differences in predictability of risk (associated with travel along defined tracks) and differences in the approach angle. Had we included vehicle on-trail approach or the other off-trail approach styles, then specific causal relationships (Table 6.1) would have been complicated to define.

We partitioned the data set to carry out separate statistical analyses for on- and off-trail approach treatments. Multi-factorial ANOVA models were fitted to examine the effects on mean FID and FP of the following fixed, crossed factors: (1) on-trail: transport style, approach style and several modifying factors and (2) off-trail: approach style and several modifying factors. Modifying factors represent the "disturbance context" (Steidl and Anthony, 1996: 484), and we included 'species' (Euros vs. Red Kangaroos), 'sex class' (female with no obvious young vs. male vs. female with young-at-foot vs. female with visible pouch young), 'group size' (ungrouped individuals vs. grouped individuals), availability of 'cover' (none vs. some), 'time of day' (mornings vs. evenings) and 'wind speed' ($<10 \text{ km h}^{-1}$ vs. $\geq 10 \text{ km h}^{-1}$). Wind speed was originally measured as a continuous variable and then categorized as scatterplots suggested a cut-off point in FID and FP values at the 10 km h^{-1} level. We optimized the original ANOVA models, containing all main effects and biologically relevant first order interactions, by excluding factors with *P*-values > 0.25 (Winer et al., 1991; Underwood, 1997) from initial models in a manual, stepwise backward selection procedure (Crawley, 2007). Therefore, starting distance, which had initially been included as a covariate (Blumstein, 2003; Cooper, 2005), was not retained.

The nature of significant differences for factors with more than two levels was assessed with Hochberg’s GT2 post hoc comparison because it offers good power for unbalanced data sets (Field, 2005). If significant interaction effects were detected, simple main effect analyses (Field, 2005) were conducted to identify the level of one factor at which significant differences of the other factor occurred. If necessary, data were transformed ($x' = \sqrt{x}$; $x' = \log_{10}(x+1)$) prior to analysis to satisfy the assumptions of a normal distribution of errors and to ensure homogeneity of variance. For all analyses the α-level of the *P*-value was set to 0.05.

The percentage of time spent with different activities was examined with a Kruskal-Wallis test, a non-parametric test to compare differences between two or more groups, since percent data with their binomial distribution do not comply with assumptions for parametric tests such as normal distribution. A Mann-Whitney U test was used for post-hoc analyses (Field, 2005).

From a tourism perspective FID or closest distance values translate into the closest possible observation distance. We defined three distance categories for the assessment of the viewing experience based on FID/closest distance values where 0–30 m = excellent, 31–60 m = good and >61 m = poor. These judgments were made from personal experience in unaided observations (i.e., no binoculars, etc.) consistent with the minimal use (0.5% of tourist groups) of viewing aids by our tourist sample. Separate chi-square analyses tested for differences in the frequency of kangaroo individuals in the three distance categories depending on the levels of the following factors: access style (on-trail: hiking/tangential/continuous pooled with hiking/tangential/stop-and-go vs. off-trail: hiking/direct/continuous pooled with hiking/direct/stop-and-go), transport style (on-trail: hiking vs. driving), on-trail approach style, off-trail approach style and some of the modifying factors (pooled over all treatments because effects were similar on- and off-trail) (Table 6.4). All these factors can be manipulated through visitor behaviour; for example, by choice of the time of observations and the habitat where they are undertaken.

All statistical analyses were carried out with SPSS for Windows 15.0 (SPSS, 2007a).

6.5.2 Results

Over four months we recorded data from 779 individual kangaroos during on-trail approaches and 454 individuals during off-trail approaches with no bias towards morning or evening walks. Red Kangaroos were sighted and approached 2.7 times more often than Euros. In 365 on-trail cases kangaroos did not flee (no FID and FP data). In total (on- and off-trail), 32 kangaroos took flight at first sight before any approach treatment could be applied (no FID and FP data) and in 61 cases kangaroos went out of sight after the approach (no FP data). Some cases were excluded from further analysis because of missing data. Altogether, 809 FID and 756 FP were estimated and 744 behavioural time budgets calculated (on-trail only), with about equal numbers for all treatments.

By design all subjects off-trail took flight as this was the end-point of the approach. In contrast, flight was provoked in only 53% of all cases when closest distance was approached or attained on-trail. Flight was significantly more likely if the approach was on foot (75%) than in a vehicle (41%) ($\chi^2_{(1)} = 72.55$, $P < 0.001$). By either method a tangential/stop-and-go (59%) was slightly more likely to provoke flight than a tangential/continuous (50%) approach ($\chi^2_{(1)} = 5.62$, $P = 0.018$).

Mean FID (± 1 SE) was significantly shorter following an on-trail (78 ± 2.7 m) than an off-trail approach (90 ± 2.7 m) ($F_{(1,412)} = 13.83$, $P < 0.001$). On-trail, we found a significant interaction between approach style and transport style (Table 6.2) for FID (Fig. 6.2a) and FP (Fig. 6.2b). On foot a tangential/stop-and-go approach significantly reduced FID and FP but there was no such effect if driving.

Table 6.2. Final ANOVA models including all main effects and first order interactions which significantly (bold) explained variation in the mean flight initiation distance (FID) and mean flight path (FP) of Euros and Red Kangaroos in relation to simulated tourist on-trail approach.

	df		***F***		***P***	
Factor	FID	FP	FID	FP	FID	FP
Transport style	1, 379	1, 346	0.24	8.45	0.622	**0.004**
Approach style	1, 379	1, 346	9.53	0.26	**0.002**	0.612
Approach style x transport style	1, 379	1, 346	4.37	8.83	**0.037**	**0.003**
Species	1, 379	NA NA	22.59	NA	**<0.001**	NA
Sex class	3, 379	NA NA	5.06	NA	**0.002**	NA
Time of day	1, 379	1, 346	8.34	19.39	**0.004**	**<0.001**
Cover	1, 379	1, 346	24.44	9.29	**<0.001**	**0.002**
Time of day x cover	NA NA	1, 346	NA	8.96	NA	**0.003**
Wind speed	1, 379	NA NA	9.15	NA	**0.003**	NA

Note :Terms for which *P* > 0.25 (Winer et al., 1991; Underwood, 1997) were excluded from final models (denoted as 'NA') unless they figured in higher order terms. The factors 'observer', 'transect', 'group size' and 'starting distance' are excluded because of *P* > 0.25 for all effects. $n_{(FID)} = 390$, $n_{(FP)} = 353$.

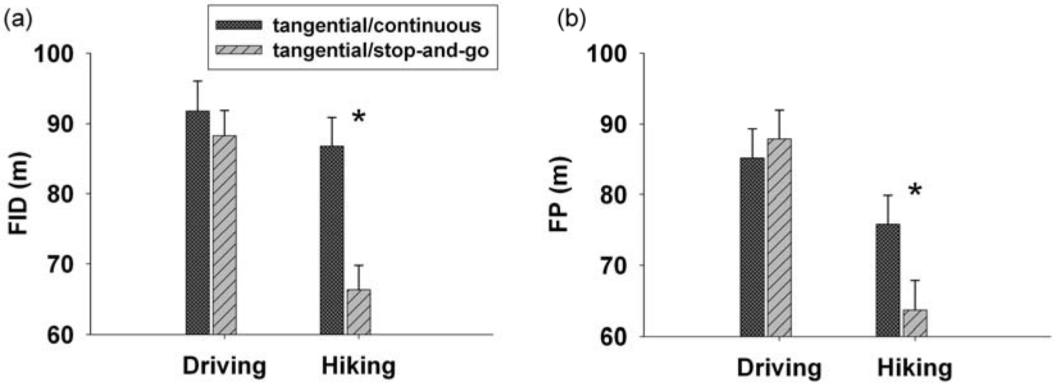


Fig. 6.2. Mean (+ 1 SE) (a) flight initiation distance (FID) and (b) flight path (FP) of Euros and Red Kangaroos in relation to transport and on-trail approach styles of simulated tourist approach. Asterisks indicate significant effects of an approach style at a particular transport level.

Off-trail, approach style likewise significantly influenced mean FID and FP (Table 6.3, Fig. 6.3). The shortest FID was with a direct/stop-and-go approach and the longest with a tangential/switchbacks/stop-and-go. The other two off-trail approach styles caused an intermediate FID and were not significantly different from each other. FP was significantly shorter after a direct/stop-and-go approach compared to the other styles (trend for direct/continuous).

Table 6.3. Final ANOVA models including all main effects and first order interactions which significantly (bold) explained variation in the mean flight initiation distance (FID) and mean flight path (FP) of Euros and Red Kangaroos in relation to simulated tourist off-trail approach.

	df		***F***		***P***	
Factor	FID	FP	FID	FP	FID	FP
Approach style	3, 409	3, 396	9.71	6.01	**<0.001**	**0.001**
Species	1, 409	1, 396	50.69	18.00	**<0.001**	**<0.001**
Sex class	3, 409	NA 396	9.49	NA	**<0.001**	NA
Time of day	NA NA	1, 396	NA	5.67	NA	**0.018**
Cover	1, 409	NA 396	11.37	NA	**0.001**	NA
Wind speed	1, 409	1, 396	9.03	6.90	**0.003**	**0.009**

Note: Terms for which $P > 0.25$ (Winer et al., 1991; Underwood, 1997) were excluded from final models (denoted as 'NA') unless they figured in higher order terms. The factors 'observer', 'transect', 'group size' and 'starting distance' are excluded because of $P > 0.25$ for all effects. $n_{(FID)} = 419$, $n_{(FP)} = 403$.

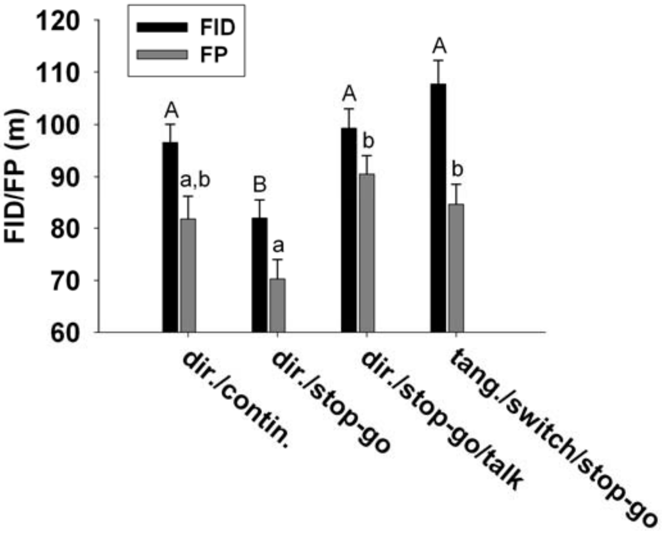


Fig. 6.3. Mean (+ 1 SE) flight initiation distance (FID) and flight path (FP) in relation to off-trail approach styles. Error bars that do not share a common letter are significantly different from each other (Hochberg's GT2 post hoc test).

Species, sex class, time of day, cover and wind speed significantly influenced mean FID and FP (Table 6.2, Table 6.3). The pattern of influence and its magnitude were similar between an on- and an off-trail approach and so only the latter (Table 6.3) are illustrated (Fig. 6.4). Euros fled at a significantly shorter FID than Red Kangaroos and showed a significantly shorter FP as well (Fig. 6.4a). FID was longest in females with young-at-foot and shortest in females with obvious pouch-young. Males and females unencumbered with obvious young had an intermediate FID (Fig. 6.4b). There was a trend for groups to have a longer FID than singletons (Fig. 6.4c). FP was significantly shorter in the evenings than in the mornings (Fig. 6.4d), and FID was significantly shorter in habitat with cover (Fig. 6.4e). On-trail, FP was significantly reduced in the evenings if the habitat contained cover (Fig. 6.4f). FID and FP were significantly shorter on calm than windy days (Fig. 6.4g).

Through flight, both kangaroo species gained on average about 25 m in safety distance to the observer independent of access style. However, there was a significant interaction effect between species and access style on mean flight effort ($F_{(1,304)} = 5.34$, $P = 0.02$). For every safety metre gained, Euros had to hop about 4 m independent of access style, while for Red Kangaroos flight effort almost doubled from 3.8 to 7.8 when approached off-trail ($\mathrm{F}_{(1,304)} = 11.48$, $P = 0.001$).

On-trail, both kangaroo species invested 40% of their time in maintenance activities following a vehicle approach compared to 10% if the approach was on foot ($\chi^2_{(1)} = 85.16$, df = 1, $P < 0.001$). On-trail approach style caused no significant difference.

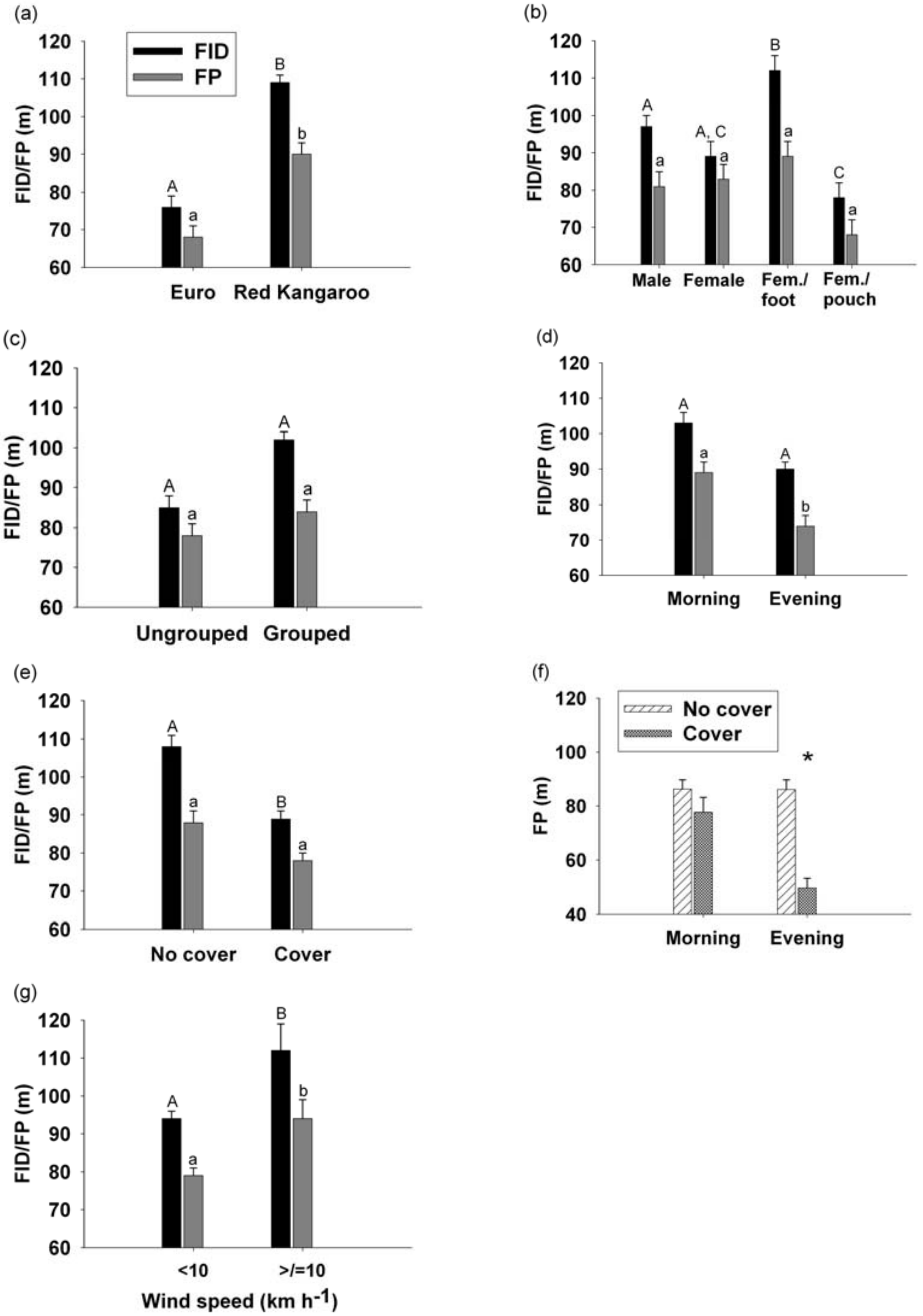


Fig. 6.4. Mean (+ 1 SE) flight initiation distance (FID) and flight path (FP) of Euros and Red Kangaroos after simulated tourist off-trail approach in relation to (a) species, (b) sex class (female = kangaroos without offspring that was obvious to the observer; fem./foot = female with young-at-foot; fem./pouch = female with pouch-young), (c) group size, (d) time of day, (e) cover, and (g) wind speed. Similar patterns and magnitude of effects were found in response to on-trail approach. The (f) interaction between time of day and cover on FP was unique for on-trail approach. Asterisks indicate significant effects of one factor at a level of another factor. Error bars that do not share a common letter are significantly different.

Most approaches would allow poor viewing as more than two thirds of all kangaroos had minimum approach distances (measured as FID or closest distance) of ≥60 m (Table 6.4). Viewing however improves with closer categories (close to medium) of approach distance if the observer was on-trail, if the approach was made in the evenings, if the habitat provided cover and the day was calm. Further, when the observer moved on foot, then viewing was better when the approach was made in a stop-and-go fashion. Close to medium distance encounters with Euros were significantly more likely than with Red Kangaroos.

Table 6.4. Comparison of tourist viewing quality of Euros and Red Kangaroos in relation to access, transport, approach styles and "disturbance context" (Steidl and Anthony, 1996: 484). Very good (0–30 m), good (31–60 m) or sub-optimal to poor (>60 m) viewing quality is a function of closest approach distance.

Factor	χ	df	*P*	Factor-level	0–30 m[a]	31–60 m[a]	>60 m[a]
				Total	3.2	21.3	75.5
Access style[b] of hikers	10.47	2	0.005	**On-trail approach**	**6.7**	**29.8**	63.5
				Off-trail approach	3.7	19.8	76.4
On-trail approach style of drivers	6.78	2	0.034	**tangential/continuous[c]**	**1.8**	18.8	79.3
				tangential/stop-and-go[c]	0	**25.9**	74.1
On-trail approach style of hikers	7.78	2	0.020	tangential/continuous	3.2	27.9	68.8
				tangential/stop-and-go	**10.7**	**32.1**	57.3
Off-trail approach style of hikers	23.39	6	0.001	direct/continuous	2.3	13.6	84.1
				direct/stop-and-go	**5.5**	**27.3**	67.3
				direct/stop-and-go/talking	3.8	5.7	90.5
				tangential/ switchbacks/stop-and-go	1.9	14.6	83.5
Species	72.58	2	<0.001	**Euro**	**7.3**	**33.7**	59.0
				Red	1.7	16.7	81.6
Time of day	8.32	2	0.016	Morning	4.6	20.1	75.3
				Evening	**6.0**	**30.2**	63.8
Cover	9.96	2	0.007	No Cover	3.5	20.0	76.5
				Cover	**6.7**	**29.3**	64.0
Wind speed	6.12	2	0.047	**<10 km h^{-1}**	5.2	**27.5**	67.3
				≥10 km h^{-1}	5.9	15.7	78.4

Note : The factor level which provided a closer viewing experience is marked in bold.

[a] Row % animals. [b] Off-trail: only continuous and stop-and-go approach were used to validate the comparison.

[c] None of the factor levels can be recommended.

6.6 Discussion

When humans disturb wildlife the same economic principle used by prey encountering predators should govern the animal's response (Gill and Sutherland, 2000): the greater the perceived risk from the disturbance, then the stronger is the response elicited. In our study, we interpreted a higher percentage of subjects taking flight, fleeing at a longer FID and travelling on a longer FP, greater flight effort to gain the same average safety distance and/or spending less time with maintenance activities as a more severe response. To determine the level of risk, animals track short-term changes in a combination of factors that characterize the disturbance along with factors related to natural predation risk (Frid and Dill, 2002). In our study, the mode of approach and its intrinsic properties (Table 6.1) by simulated tourists determined the disturbance character in a varying disturbance context. The latter included characteristics of the focal kangaroos and the prevailing environmental conditions.

6.6.1 Kangaroo response to different modes of human approach

6.6.1.1 Access style

Predictability of the travel route resulting from the guidance along designated tracks and directness of approach (a function of approach angle as in Burger (1990)) were the main predictors for the perceived risk level driving the differences in the kangaroos´ response to access style.

If animals know from previous experience that they have nothing to fear from visitors that travel along recreational tracks and they come to expect them to stay on a particular route, then they might habituate (Whittaker and Knight, 1998). Consequently, they are predicted to take flight to human intruders less frequently and/or allow for a closer on-trail approach. Indeed when kangaroos took flight following an on-trail approach the FID was shorter by 13% than off-trail. A similar response was found by Taylor and Knight (2003b) for American Bison (*Bison bison*), Mule Deer (*Odocoileus hemionus*) and Pronghorn Antelope (*Antilocapra americana*). Confinement of visitor use to designated tracks is less extreme than fencing off whole areas from visitor use, which has also been reported to relax animals (Cassini, 2001; Ikuta and Blumstein, 2003). Even so both management actions enable animals to decide how close they get to the prospective observer's location and not vice versa provided that tourists comply with track use. Most of them did so in our study area, likely because the tracks were clearly defined. Thus the delineation of tracks was sufficient to reduce visitor impacts on kangaroos and similar observations have been reported for other sites and species (Miller et al., 2001; Taylor and Knight, 2003b).

In addition, if tourists stay on-trail then their approach will typically be less direct to a wildlife subject than any unconstrained off-trail approach. Prey may perceive intruders approaching more directly as a greater predation threat than those passing by at an oblique angle, because directness may convey detection and intent to capture. A shorter FID after less direct forms of approach have been observed in numerous studies, including Burger and Gochfeld (1990) on Black Iguanas (*Ctenosaura similis*), Cooper (2003) on Desert Iguanas (*Dipsosaurus dorsalis*) and Walther (1969) on Thomson´s Gazelles (*Gazella thomsoni*). Contrary findings were reported by Bulova (1994) for two lizard species, and he hypothesized that the delaying of flight, when faced with a direct approach, might be an attempt to remain unnoticeable in situations of greatest risk. Fernandez-Juricic et al. (2005) detected the same pattern as Bulova (1994) for four bird species. They argued that perceived risk decreases with an increase in the probability to detect a predator, which is typical for directly approaching intruders due to their greater approach speed.

Studies that compare the intrusiveness of on- vs. off-trail approach may ascribe variation in flight response to the predictability of the risk alone if the off-tail approach is applied directly parallel to the trail (King et al., 2005). Thus some studies (e.g., Mainini et al., 1993) have ascribed differences between an on- and off-trail approach to predictability, without considering the explanatory power of approach directness. Other studies, in contrast, have treated tangential off-trail and on-trail approach treatments (e.g., Freddy et al., 1986) interchangeably, thereby ignoring any effects of predictability.

A novel result that we discovered was that flight effort (ratio of flight path to safety distance) depended on the interaction between access style and species. While flight effort was independent of access style for Euros, Red Kangaroos hopped almost twice as many metres for every metre of safety distance gained, despite similar average values for safety distance, when they were approached off-trail. Whether this is an indication of a lower flight efficiency or some sort of strategy to circle the threat is uncertain, but either way, it will most probably cause an increase in energy expenditure. This finding also emphasizes how useful it can be to examine a broader range of response variables, to discover any hidden costs through energy expenditure following human intrusion.

6.6.1.2 Transport style

Another significant predictor for the risk level perceived by animals is the means of transport used to approach wildlife. In our study area, visitors approached on foot or by car. The many previous studies that have compared the effects of these two means of transport on wildlife responses imply that they are very common in many nature-based tourist destinations, worldwide. Since we never observed drivers to continue their approach by taking their car off-trail, hiker and vehicle approach were compared only for on-trail access. A significantly lower proportion of kangaroos took flight when approached by car in support of previous conclusions that pedestrians induce a more intense wildlife response than motorized vehicles; for example, a higher percentage of flush response (Holmes et al., 1993; Klein, 1993; Gonzalez et al., 2006) or a longer FID (Schultz and Bailey, 1978; McLellan and Shackleton, 1989; Andersen et al., 1996; King et al., 2005). Moreover, our behavioural observations showed that kangaroos treated an approach on foot with more alarm than a vehicle approach as the time spent in vigilance behaviour, hiding or aversive movements increased by 30%. This result contrasts with King et al.´s (2005) study on four macropod species in a wildlife sanctuary, as they found no significant differences in behavioural time budgets between hiker and vehicle approaches. They argued that the macropods in their study area might not be habituated and therefore exhibit the same caution to human intrusion of any sort. Thus previous experience likely modifies responsiveness to an approach.

Persecution history may be one possible explanation for the more severe reactions to approach on foot that we have observed. Red Kangaroos and Euros evolved more than a million years ago (Dawson, 1995) and have faced a changing array of predators. People entered the continent 50 000 years or more ago and so vehicles are a very recent phenomenon in evolutionary terms. Kangaroos have had little time to adapt from a long history of close-range daytime hunting by people on foot to predominantly long-range night-time hunting from a vehicle now. The Brown Bear (*Ursus arctos*) is another species that has suffered severe persecution from pedestrian hunters and likewise performs the strongest aversive reactions to approaches by people on foot (McLellan and Shackleton, 1989). Furthermore, certain qualities of each mode of transport may have affected the kangaroos´ responses. For instance, vehicles were likely to be noticed from a greater distance so that the kangaroos were less startled as they drew closer (Papouchis et al., 2001).

6.6.1.3 Approach style

In our study area, tourists approached kangaroos either in a continuous movement pattern or with momentary stops. The importance of such movement patterns in the animal's response to an approach appears to be another neglected field of research in recreation ecology. Taylor and Knight (2003a), who reviewed 54 papers out of peer-reviewed journals that examined wildlife response distances to human activity, found that 30 papers did not specify the pattern of movement towards their study animals at all. The movement pattern was reported as continuous in 19 papers and interrupted in 5. There were no papers which explicitly compared the flight response between continuously approached animals and those approached with interruptions. An interrupted versus a continuous movement pattern could have one of two effects. Either the stop-and-go approach elicits a shorter FID and/or FP, because of its more tentative nature that could be interpreted by the animal as a sign of low intention to pursue it. Or a pattern of stopping could be interpreted as an attempt to stalk the animal by cautiously sneaking up on it.

Our results clearly support the first of these hypotheses. The FID was reduced by about 21% for a stop-and-go approach on-trail and afoot in comparison to its continuous counterpart. The same pattern was found off-trail with a 15% reduction in the FID after a direct/stop-and-go approach compared to a direct/continuous approach. The kangaroos visibly relaxed during the stops with some of them changing from a more upright alert stance to a lower one, making fewer movements with their ears and/or showing less body tension. However, an interrupted approach only reduced the FID if the observer was on foot.

The repeated stopping and starting of our vehicle might have created additional disturbing noises for the kangaroos. Drivers normally pass through the study site or stop once to examine some phenomenon, and so the behaviour of our vehicle may have been perceived as atypical and alarming. In our observations of driving tourists, 30% oriented to but did not stop to observe a kangaroo or the dummy near the track. In comparison, few hikers (5%) did not stop. The decision to stop is likely a function of the speed with which the decision needs to be made and the convenience as well as the attraction. For drivers travelling at speed it may be too quick and inconvenient but simple and a trivial challenge for hikers. Furthermore, drivers need to concentrate on the road or track whereas hikers have more time to inspect their surroundings.

Tangential approach, in spite of being less direct, was not associated with the shortest FID and FP relative to any of the direct approaches. We attribute this to the presence of another risk factor, the change in approach direction. Following our observations of actual tourist behaviour, we applied our tangential approach style in combination with switchbacks. Kangaroos must have perceived such a change in the person's approach path as a higher risk due to its unpredictable nature, and one that perhaps was indicative of stalking. Few studies have assessed the effect of a tangential approach in combination with a sudden change in approach path towards an animal. Cooper (1998), being a notable exception, reported that the probability of flight increased significantly when bypassing observers abruptly turned towards Keeled Earless Lizards (*Holbrookia propinqua*). This was attributed to the prey's notion that the probability of detecting it and therefore its risk of being attacked had suddenly increased.

We witnessed a large variety of tourist behaviour that may add to the impact of approach behaviour towards wildlife. Key amongst these is conversations within the group or even directed towards the animal. Thus we assessed the effect of talking at medium voice levels in combination with one of our basic approach styles, the direct/stop-and-go. Talking proved to have an aversive effect and lengthened FID relative to a mute direct/stop-and-go approach. We expected any increase in ambient noise, such as through talking, would exacerbate the perceived risk level. However, we were surprised at the magnitude of the response with a longer average FID than even a direct/continuous approach. Therefore, attention should be paid to other behaviour that is as common and possibly influential as talking appears to be. Cassini et al. (2004), who used voice level as one factor in rating intrusiveness of tourists that were approaching South American Fur Seals (*Arctocephaalus australis*), observed a much higher percentage of flush response and aggressive seal behaviour, when the intruders´ behaviour was classified as intermediately to intensely disturbing rather than calm. However, movement speed and hand movements were also used as criteria for the level of intrusiveness, and so we cannot solely ascribe their results to be a function of voice volume.

6.6.2 Disturbance context

The response of wildlife to a human approach has consistently been reported to be a function of its disturbance context; namely, the 'when' (timing, weather conditions, etc.) and 'where' of the encounters and the 'who' (species, sex class, etc.) is involved (Steidl and Anthony, 1996). In our study, we found that intrinsic characteristics of the kangaroos such as species and sex class were influential. Group size only played a minor role. Habitat cover, wind speed and time of day were identified as important environmental factors influencing kangaroo reactions to human approach.

6.6.2.1 Species, sex class and group size

Flight response as a species-specific trait has been reported in numerous bird and mammal studies (e.g., Burger, 1981a; Borkowski et al., 2006). In our study, Red Kangaroos were more flighty than Euros. Their FID was on average 26% longer and their FP was 17% longer. This difference may be related to habitat preferences: Red Kangaroos inhabit open plains and so may be more wary since they are more easily discovered by predators. Flight over plains might also be less costly than in the hilly terrain, where the Euros tend to dwell, and therefore not delayed as long. Red Kangaroos were also more affected by an off-trail approach than Euros expressed in the greater flight effort. This could mean that their flight style becomes less efficient when faced with a new or less common approach style.

We observed a high level of variability in the flight response between the four sex classes that we differentiated. Especially pronounced were differences in the mean FID of female kangaroos depending on their reproductive state. Since reproductive females with young are most sensitive to predation (Dawson, 1995; Banks, 2001), and numerous mammal studies have found higher reactivity of females to disturbance (Horejsi, 1981; Langbein and Putman, 1992; Bullock et al., 1993; Vandenheede and Bouissou, 1993), we expected females in general to exhibit the largest FID and/or FP. However, we found a more complex result. Female kangaroos without offspring that were obvious to the observer (i.e., small or no pouch-young) had a medium FID, which was similar to that for male kangaroos. Females with young-at-foot had a much longer FID and FP, and those for females with obvious (medium to large) pouch-young were much shorter. This suggests a different flight strategy when protection of the young is a high priority (Recarte et al., 1998): Females with obvious pouch-young might delay flight as long as possible and flee only as far as necessary because they carry the considerable extra weight of the young, which costs additional energy for gaining and maintaining speed (Colagross and Cockburn, 1993) and makes it difficult to manoeuvre. It also involves the risk of the young being expelled from the pouch and getting lost (Stuart-Dick, 1987). Females with young-at-foot, on the other hand, have to consider the lower flight efficiency of their young, and might therefore flee early and further.

Previous research has supported contrasting theories on the effect of group size on vigilance and flight behaviour of animals. A reduced individual vigilance and flight response by groups of conspecifics is anticipated due to a shared responsibility for vigilance (Quenette, 1990; Blumstein et al., 1999; Blumstein et al., 2001; Blumstein and Daniel, 2003b), a collectively greater predator detection rate (Lett et al., 2004), and/or the dilution of risk to become the target in the presence of other prey (James et al., 2004). In contrast, an increased individual vigilance and flight response with larger group size may result from an increase in the prey detection probability, higher predation rates following the principles of density-dependent predation (Sih, 1984) and a higher probability that group members with an increased sensitivity to disturbance are present and hence raise the overall sensitivity of the group. In our study, single individuals had a lower mean FID than grouped ones. This suggests that the negative sides of aggregation outweighed the positive sides, resulting in a somewhat stronger flight response when aggregating. However, the effect was minor with an average difference of about 10 m.

6.6.2.2 Habitat cover, time of day and wind speed

Habitat cover provides some security in an animal’s immediate environment against detection by a predator and subsequent attack. The visual protection may allow it to outwait a predator until a particular approach distance threshold (Frid and Dill, 2002) has been exceeded but cover can also obstruct the animal’s view of approaching predators (Elton, 1939). Our study sites were typical of the open habitat of the Australian arid lands (Williams, 1979). Even so when the sparse cover was used, the FID and FP were reduced for on-trail approaches and the FID for off-trail approaches. Thus our results were congruent with the decreased level of vigilance or flight in habitat with cover (close enough to hide quickly) reported by other studies on various species (Altmann, 1958; Dill and Houtman, 1989; McLellan and Shackleton, 1989; Bleich, 1999; Papouchis et al., 2001; Wahungu et al., 2001). However, there was an interaction between time of day and cover for FP after an off-trail approach as detailed in the following.

Diurnal rhythms are a common phenomenon affecting a multitude of physiological and behavioural processes in animals. The FID (trend) and FP were significantly shorter in the evening than in the morning. A similar result has been reported for American Bison and Mule Deer (Taylor and Knight, 2003b). For kangaroos we suspect an influence of the diurnal activity and feeding patterns. Feeding by Red Kangaroos normally becomes more frequent in the early evenings and continues till a few hours after sunrise with a slight lag period in the middle of the night (Watson and Dawson, 1993). There is another peak in activity and feeding after sunrise through into the early morning. Kangaroos with a full gut then rest around midday and in the early afternoons. Higher activity in the mornings when kangaroos are close to satiation and moving towards rest sites may lead to higher reactivity towards disturbance. In the evening, kangaroos are hungry and the priority is to feed if not going to water to drink. Then they may be more tolerant to disturbance because they are more absorbed with grazing. This might also explain the interaction effect between habitat cover and time of day that we found. While the FP after an on-trail approach in the mornings remained long, independent of habitat cover, it was reduced by 30 m in areas with cover in the evenings. Kangaroos seek run-on areas with higher moisture retention for grazing (Montague-Drake and Croft, 2004) given the general aridity of our study sites. Such areas are likely to have more cover and so kangaroos might be reluctant to leave, especially not at times of high feeding priority. This underpins the importance to examine interactions between variables defining the disturbance context.

Finally, the weather can determine the prey's perceived risk level of a situation as it affects predator detection rates. Wind direction and speed are often key to detecting and judging the distance from a potential predator. Thus wind can carry away olfactory cues, mask auditory cues through its continuous white noise, and mask visual cues as it moves vegetation and thereby diverts from the movements of potential predators. Therefore, we expected kangaroos to take flight more readily with stronger winds, which matched with our finding of a longer FID on windy than calm days. Increased vigilance or flight reactions of macropodid marsupials during windy conditions have been reported by others (Blumstein and Daniel, 2003a; Carter and Goldizen, 2003).

6.7 Conclusions and management implications

This study demonstrated that Red Kangaroos and Euros react to human approach with alert and flight behaviour and that the acuteness of the response depended on various properties of approach behaviour and the disturbance context. Kangaroos reacted most strongly to the simulated tourist approach off-trails, and so visitors should stay on trails to reduce disturbance. This has a dual benefit because it not only improves animal welfare but also reduces detrimental effects on other ecosystem components (e.g., trampling effects on vegetation). If the immediate response of individual kangaroos were the only criterion to evaluate, then a vehicle approach would be rated as less intrusive (given that fewer drivers noticed live kangaroos at all; less kangaroos took flight and behavioural changes were less pronounced). However, impact studies need to be placed in their site-specific context. Cars might have elicited a milder immediate response from individual kangaroos, but may have had a greater cumulative impact since the volume of vehicle traffic exceeded pedestrian traffic in our study site (Chapter 3). From our results, an approach on foot should be by using a stop-and-go movement pattern but switchbacks and talking should be avoided. Disturbance will be less and close contact more successful for both hiking and driving tourists if the habitat has some cover and calm evenings are chosen for the excursion. We can apply our results to govern management of impacts on sympatric threatened species like the Yellow-footed Rock-wallaby but management would need to be adaptive as more information is gathered on the species of interest.

Visitor management in protected areas may conduct manipulative experiments following our framework to develop knowledge on common behaviour of visitors (and specific segments of the visitor market such as driving vs. hiking tourists) towards target species and to identify low-impact variants of behaviour as a base for visitor education. In the case of kangaroos, for instance, we recommend testing other vehicle approach styles which may reduce the FID with a similar efficiency as the stop-and-go movement for approach on foot. Also, the visitor behaviour following an observation needs to be assessed. For instance, many drivers who disembarked from their vehicle, once they were satisfied with their kangaroo observation, remained on-site to take a pit stop. At that point the noise level was raised considerably and visitors moved around more rapidly or ventured into off-track terrain. As a consequence, some of the kangaroos that had not taken flight initially, did take flight then.

Generally, we found a two-stage approach very constructive in order to identify the relevant experimental manipulations for this approach impact study. Thus we recommend that future research is based on (1) the quantification of the spectrum and frequencies of tourist approach behaviour during encounters with the species in question, and (2) a design that accommodates and accounts for the results from the tourist observations. This approach will better frame management actions in the study area but may compromise generalization across sites and species. Taylor and Knight (2003a) note that the variety of methods that are employed to study wildlife response to visitor behaviour hinders generalizations among studies. Furthermore they criticize studies where approach treatments used are not clearly defined and explained. Our methodology meets the second criticism and given that the repertoire of tourist behaviour is finite, many commonalities are likely between sites and species so that generalization is not compromised.

In our examination of tourist behaviour, we trialled the use of a realistic kangaroo dummy as an attractant for the passing hiker or driver. This met two challenges. Firstly, if animals are free-living and do not aggregate predictably in a spatially confined area, either attracted through feeding or for other reasons (e.g., to breed), achieving a representative sampling rate from opportunistic sightings of human-wildlife interactions can be unrealistic (e.g., Papouchis et al., 2001). Secondly, standardizing conditions constitutes a problem. For instance, animals located at different distances to a trail might elicit a different human response. We found that the initial behaviour of the tourist was consistent between approaches to the dummy and real kangaroos, although the final behaviour deviated from consternation to hilarity on recognition of the fake. Thus the dummy had some value in standardizing the disturbance context and accruing a larger sample of tourist behaviour.

Impacts could be lessened by containment of visitors and establishment of buffer zones which are typical solutions arising from tourism-impact studies. Our study area is too big for constant surveillance of visitor approach distances, and there are few 'hotspots' where kangaroos aggregate, so they could be protected by fences constructed at a pre-determined distance. Nor do we think that prescribing a minimum approach distance would find easy implementation in educational programs, as people have to reliably estimate these distances.

To stimulate self-restricted, low-impact behaviour visitor education programmes needs to communicate the results from impact studies. People are often not aware how their activities affect wildlife or greatly underestimate their own impact (Taylor and Knight, 2003b). If people understood what impact they have on wildlife in the short- and long-term, then they are more likely to comply with low-impact behaviour. From our results we suggest giving park visitors an explanation of the diversity and consequences of kangaroos´ response to human approach and providing them with easy-to-follow instructions on how to approach (transport and approach styles) and advice on the most favourable environmental viewing conditions. Importantly, people need to be informed that their approach behaviour also affects their own observation experience. Thus kangaroos that are less disturbed, allow for closer and longer-lasting observations that are more rewarding to the tourist.

Finally, the potential for kangaroos to habituate to human disturbance and the influential factors in that process should be assessed. In some parts of our study area with a great influx of visitors and where kangaroos are getting fed by visitors, they have indeed habituated. In the remaining and much greater parts, there is little evidence that kangaroos have habituated, though, likely because of the lower visitation rates. In particular, we observed that the Yellow-footed Rock-wallaby virtually without exception flees from observing visitors even at the few sites where tour guides frequently bring their clientele for observations. Understanding habituation better could assist us with the identification of conditions when wildlife observation needs to be most cautious; namely when wildlife does not habituate.

Chapter 7

Wildlife by candlelight: A comparison of nocturnal observation techniques for their impact on wildlife and visitor satisfaction

Fig. 7.1. Night-vision attained (left) with a generation-2 night vision device and an external infrared light focused on the part of the image that appears brightest. *Note*: image is unfocused as it was taken without camera adapter. A night-vision device mounted on a tripod (top right) and a bat detector (bottom right).

7.1 Abstract

Nocturnal observation of wildlife is a highly popular tourist attraction. However, very little research exists about its impact on wildlife and thus the possible trade-off in minimizing impact and maximizing visitor satisfaction in night-time tours.

We recorded the species-abundance and observation distance of all mammal, bird and reptile species in 144 nocturnal observation periods of 1.5 h each near a homestead in the Australian rangelands. We compared the results achieved with different illumination equipment (white vs. red vs. infrared light/night vision device), watch modes (sitting at artificial watering points vs. hiking in creek beds), observation times (starting at vs. 2 h past dusk) and wind speed. Further, kangaroo and bird behaviour were analysed in relation to the different illumination techniques. We recorded a higher abundance and species richness of the non-bat fauna and a higher bat activity while sitting at artificial watering points directly after dusk during calm nights compared to the other observation conditions. Red light elicited a similar behavioural effect as white light of the same photometric intensity and both elicited activities indicative of disturbance and avoidance. A night vision device enhanced by infrared light facilitated closer observations and viewing of species which were seen less under white or red light. In addition, fewer kangaroos and birds were vigilant or took flight, and more time was spent with maintenance behaviour and social interactions.

In a questionnaire-based survey, the majority of our respondents had previously participated in night-time tours of Australian wildlife and conveyed their future interest in such tours. Engaging with night vision equipment and bat detectors was highly appealing. The preferred tours were those that combined a stationary observation at watering points with hiking along creek beds. Tours should involve an introductory talk of <15 min, commence directly after dusk and last 1–1.5 h. The most desirable group size included <8 participants. Numerous features of the wildlife viewed and the conduct of the tour determined satisfaction with night-time tours. Participants need to be educated on aversive effects on wildlife imposed by night-time tours as the majority assumed impacts to be low or very low.

We conclude that a satisfying fauna-viewing experience can accrue from a low-impact observation style using the optimal methods arising from our research.

Key words: nocturnal observation of wildlife, night vision device, spotlight, infrared light, impact, animal behaviour, wildlife tourism, visitor satisfaction, tour experience.

7.2 Introduction

Wherever animals lead a nocturnal or crepuscular lifestyle, wildlife tours may be extended into the night. This is a common practice in many ecosystems worldwide like the Central to South American rainforests and wetlands, North American deserts and African rangelands. In Australia where almost all the native mammal fauna are nocturnal, night-time tours are frequently used as a viewing opportunity. During an opportunistic internet search, we have identified at least 50 Australian businesses (Wolf and Hagenloh, unpublished data) that explicitly advertise nocturnal observation as part of their tours. Moreover, a study by the Sustainable Tourism Cooperative Research Centre (Higginbottom and Buckley, 2003) revealed that 66% of the 484 Australian businesses or organisations providing non-consumptive tourism activities with free-ranging terrestrial wildlife continued their observations into the night. However, despite the seeming global popularity, there is a lack of research into a sustainable tour design which considers both the impacts on wildlife and visitor satisfaction. The principal question in our study was how to facilitate a low-impact, yet satisfying observation of free-ranging, nocturnal wildlife. We exemplified our study design in the Australian rangelands—where landholders are progressively relying on tourism as a supplementary or alternative income to pastoralism—to examine factors that are relevant to most night-time observation tours independent of the specific location.

From a tourist´s point of view, night-time observation can be rewarding, with a sense of adventure into a realm people do not typically inhabit and the opportunity to view species and behaviour (Ord et al., 1999) not normally encountered during the day. Generally, the level of visitor satisfaction with wildlife tours depends on features of the wildlife (e.g., size and rarity) and the tour experience (e.g., service quality) (reviewed by Moscardo et al., 2001). In the first part of our study, we assessed the past experience of tourists with night-time tours and their preferences for various tour features like the observation techniques employed; the location, timing and duration of the tour; the educational component such as introductory talks; and tour group size. Further, we identified desirable features of the wildlife experience to formulate observation conditions where this experience can best be provided and assessed the tourists' awareness of the impact they may have while participating in nocturnal observations.

Nocturnal observations may threaten wildlife with many of the same impacts identified for daytime tourism activities (e.g., reviewed by Knight and Cole, 1995; Buckley, 2004a; Green and Giese, 2004). Additionally, animals get exposed to often bright artificial light, removing the cloak of darkness and exposing them to predators and likely generating aversive responses. The extensive experimentation with different lighting systems for nocturnal animal exhibits at zoos (e.g., Davis, 1961; Jacobi, 1965; House and Doherty, 1975; Partridge, 1997) emphatically reflects our dilemma of how to achieve adequate viewing while best providing for undisturbed, nocturnal animal behaviour. Wildlife scientists have faced the same challenge and yet research on wildlife responses to different illumination techniques remains rare and often anecdotal.

Most tourism operators use spotlights with white or red light to facilitate night-time observation. However, bright, white lights can dazzle animals and temporally impair their night vision which may augment predation risk or cause disruption to natural patterns of movement and foraging. Furthermore animals that are impinged by spotlighting may react with vigilance and flight, thereby altering their behavioural budgets and energy expenditure. Possums, for instance, were agitated and retreated readily from a relatively low intensity 30-watt white light (Wilson, 1999).

In contrast, red light is commonly assumed to be less intrusive chiefly because the photo-receiving rod cells in the retina of the eye are insensitive to it and so night vision is preserved. Likewise the cone photoreceptor cells that are abundant in diurnal species (Zeigler and Bischof, 1993; Ahnelt and Kolb, 2000) and present in nocturnal species (Arrese et al., 2002; Wang et al., 2004), are often less sensitive to red light than to light consisting of shorter wavelengths. Whether reactions to red light are elicited (e.g., Zervanos and Davis, 1968; Greenhall et al., 1971; Downs et al., 2003) and, if so, are less than with white light (Finley, 1959; Russell, 1980) will depend on the light intensity and species differences in red light sensitivity. Thus red and white light must be standardized to the same photometric light intensity to discern the influence of the light quality on the acuteness of the response.

Unlike for white and red light, all the available evidence suggests that most mammal and bird species are unconscious of infrared illumination. We used infrared light to enhance the viewing quality attained with night vision goggles (Fig. 7.1). Originally developed for the military, night vision devices (NVDs) are increasingly employed in behavioural studies such as of the Brown Rat (*Rattus norvegicus*) (Southern et al., 1946), Vampire Bats (*Desmodus rotundus*) (Wilkinson, 1985) and cranes (*Grus* spp.) (Allison and DeStefano, 2006). Allison and DeStefano (2006: 1036), who reviewed equipment for nocturnal wildlife studies, concluded that "night-viewing technologies are an exceptional, non-intrusive, functional tool for wildlife ecology studies". Even a few tour operators (e.g., Hummer Tours, 2007; Penguin Tours, 2007) have recently started to use night-vision technology. To our knowledge, there are no scientific studies that have quantified the value of night-vision equipment coupled with infrared light to minimize impact on wildlife during nocturnal observation tours as an innovative alternative to spotlighting.

Another critical component of every tour design is the location and observation time since the spatio-temporal patterns of wildlife distributions affect sighting probability. To achieve high visitor satisfaction, observations need to be scheduled for when and where many animals from a diversity of species can be viewed at close range. Around homesteads in the Australian rangelands with their otherwise dry and sparsely vegetated landscape matrix, animals typically aggregate near open water storages and creek beds. As natural water bodies tend to dry out, artificial watering points may be the most reliable free-standing water source there. Artificial watering points were established in the Australian rangelands to support domestic livestock and the needs of people but they have subsequently attracted a range of wildlife (Andrew and Lange, 1986; James et al., 1999). Their retention or establishment in protected areas is contentious (Croft et al., 2007), unlike Africa (Thrash, 1998) where their value for wildlife observation by tourists is highly regarded (van Rooyen et al., 1994) as long as they are appropriately located and managed (Owen-Smith, 1996; Harrington et al., 1999). The importance of riparian zones for terrestrial wildlife in semi-arid to arid landscapes has also been well-recognised (Doyle, 1990; Fleishman et al., 2002). At times, water may be found in intermittently flowing creek beds whose abundant vegetation shelters animals from inclement weather and provides foraging and roosting sites. The location may favour different platforms for making observations on wildlife: Waterholes, whether artificial or natural, provide an opportunity for stationary observation from a vehicle or hide. A narrow creek-bed is best traversed on foot whereas a wider creek-bed may allow vehicular access. Furthermore, the viewing experience will be modified by its time in relation to the activity patterns of the subject species and the meal and leisure schedule of the participants (and employees). Likewise, the experience takes place within an environmental context where inclement weather such as strong winds may degrade the satisfaction obtained by the participants.

Thus the illumination technique, the mode of observation (the location coupled with a particular observation platform), the time and the weather conditions all contribute to a nocturnal wildlife tour and its impact on the subject animals as well as the satisfaction of the participants. In the second part of our study we therefore tested the following non-exclusive hypotheses: (1) Illumination with white light will cause behavioural changes with more alert/flight reactions in wildlife than compared to infrared light (and observation with a NVD). Red light of the same intensity as white light will likely cause a similar response. The consequence of these aversive/avoidance responses will be longer observation distances, and lower animal numbers and fewer species as the observation progresses. (2) Animal numbers, species richness and species community composition vary by the watch mode and observation time. Observation distance may also vary. For instance, sensitivity of species to observations may change at different times so they may tolerate a closer/farther observation. Our aim was to determine the best watch mode and timing for wildlife viewing. Whether the effect of the watch mode was due to a change in the location (tank vs. creek bed) or the observation platform (stationary vs. ambulatory) cannot be distinguished from our design. (3) Wind increases the wariness of wildlife as it hinders predator detection. We predicted that windy nights would lead to greater protective crypsis and/or heightened reactivity, and therefore result in lower numbers and species richness and extended observation distances.

We conclude the paper by consolidating our findings from the visitor survey and the wildlife observation research to recommend a tour design that aims for low impact on wildlife and high visitor satisfaction.

7.3 Visitor survey on nocturnal observation of wildlife tours

7.3.1 Methods

A visitor survey (Table A 4.1) was conducted in the Vulkathunha-Gammon Ranges National Park and the adjacent Arkaroola Wilderness Sanctuary, 650 km north of Adelaide in the northern Flinders Ranges, South Australia. The private sanctuary comprises 61 000 ha with permanent water holes and intermittently flowing creeks traversing several gorges. Numerous 'Advanced Ecotourism'-accredited guided tours are on offer including the 'Bats and Bubbly' tour which advertises nocturnal observations of Yellow-footed Rock-wallabies (*Petrogale xanthopus*) and Euros (*Macropus robustus erubescens*) at water holes and the tracking of bats with a "bat box". Our research was welcomed in keeping with one of Arkaroola’s aims "to deliver practical conservation through controlled tourism" (Arkaroola 2008, http://www.arkaroola.com.au/breaking news.php).

We surveyed 258 adult visitors (>18 years) with questionnaires at campgrounds and visitor centres from July to September 2007. Three questionnaires were discarded because of missing data. The first author and several trained volunteers administered the surveys to any tourist willing to participate (88%). Open-ended, closed and 5-point Likert-scale questions assembled information on visitor demographics, past experience with nocturnal observation of Australian wildlife and factors contributing to visitor satisfaction. Additional comments made by participants were noted and complement the discussion wherever relevant. Technical equipment (e.g., bat detector) deployed for night-time observation was briefly introduced to ascertain that people were familiar with it. Finally, participants rated the level of impact that they believed night-time tours may have on wildlife.

The responses from the visitor surveys were entered into Data Entry 4.0 for Windows (SPSS, 2007b) and subsequently analysed with SPSS for Windows 17.0 (SPSS, 2008). Means ± 1 SE are presented. Responses to open-ended questions were sub-grouped by manually extracting descriptive words used by participants, so the frequencies of the subgroups could be compared.

7.3.2 Results

Most of the 255 survey participants (94.4%) were from Australia, in particular South Australia (43.7%) and Victoria (31.9%), 50 years or older (58%) and travelled as adult couples (53.2%) or friends/relatives (30.2%). The visitor demographics resembled those found in a tourism survey of 305 visitors to the Flinders Ranges National Park with self-administered questionnaires by the Department for Environment and Heritage in 2005 (unpublished data).

About a third of respondents (36.8%) had previously participated in nocturnal observation tours of wildlife, primarily in South Australia (32.3%) or Queensland (28.0%). Those who had participated more than once (10.9%) were asked to comment only on their most recent tour experience. Average enjoyment of these tours was rated highly (4.3 ± 0.1) on a 5-point Likert scale with 1 = very low to 5 = very high. The most commonly sighted animal groups (multiple answers) comprised possums (40.5%), birds (29.7%), kangaroos/wallabies (27.3%), penguins (21.2%), bettongs (rat-kangaroos) (18.2%) and bats (12.1%); plus 14 other less frequent groups were mentioned. Observations had been largely facilitated with torches (flashlights) (69.6%) and spotlights emitting white (23.9%) or red light (4.3%) (multiple answers). None of the tours had used NVDs or bat detectors.

Average interest in night-time tours in the Australian arid-lands was high (3.9 ± 0.1 on a 5-point Likert scale with 1 = very low to 5 = very high) with 67.1% of people indicating a strong to very strong interest. The most desirable choice for exploring the nocturnal fauna was a combination (75.2%) of creek bed hikes (alone: 16.8%) and stationary observations at water tanks (alone: 8.0%). Tours should commence around dusk (61.1%) rather than 2 h past dusk (19%) (vs. depending on animal activity: 18.3%, doesn't matter: 0.8%, early mornings: 0.8%).

The most popular technical devices (multiple answers) from a list of six were night vision equipment (61.1%), thermal detectors (48%) and bat detectors (41.7%) which outcompeted more ordinary equipment (red spotlight: 15.1%; white spotlight: 6%; torch: 4.4%). A tour duration of 1 h (57.1%) was favoured over 0.5 h (7.1%), 1.5 h (22.2%) or longer periods (13.5%). Group size should not exceed 8 people (preferred were 7.8 ± 0.2 participants). An introductory talk was considered vital by most people (98.4%) but needs to be concise (preferred were 12.9 ± 0.4 min).

Important contributors to visitor satisfaction (open-ended question; multiple answers) included wildlife features such as the abundance (61.1%), species richness (54.4%), approachability/closeness of the observation/ease of viewing (44.4%), animals not seen before (34.9%), interesting behaviour (23.8%), uniqueness of the species (7.9%) and tour features such as service (54.4%), group size (54.0%), novelty of the experience/adventure (43.7%), comfort (43.7%), scenery (32.9%), learning experience/knowledgable guide (25.8%), no waiting periods/punctuality (17.5%) and fulfilment of a proposed plan (9.5%). The type of animal behaviour people were most interested in was social interaction (42.1%), followed by body maintenance (40.5%) or general locomotion (16.7%). Few tourists (0.8%) were keen to observe alertness or flight reactions.

Possible impacts of nocturnal observation of wildlife were mostly rated as very low (28.6%) to low (29.4%) vs. medium (33.3%) or high (4.0%) to very high (4.8%).

7.3.3 Discussion

According to our visitor survey a broad range of wildlife species was subjected to nocturnal observation in Australia and more than a third of respondents had previously partaken in night-time tours. Interest in future participation was also considerable.

Respondents commented that their level of satisfaction with the tour depended on the extent to which their expectations would be met and some felt that tours needed to adhere to a proposed schedule. This is consistent with Hammitt et al. (1993) who found that the number and variety of animals seen had to match expectations so that the wildlife experience was perceived as high quality. Like other customers, tourists have formed expectations of the wildlife they will see and the tour experience itself. These need to be met or exceeded for the contented customer to promote the product to others (Söderlund, 1998).

We have identified several important wildlife features for visitor satisfaction that were also recognized by others (reviewed by Moscardo et al., 2001): the number and variety of animals seen, close observations, uniqueness and species not encountered before. Ease of viewing was considered an advantage. Moscardo et al (2001) also documented that large animals of iconic or endangered status were attractive tourism targets particularly when viewed in their natural surroundings. In contrast, threatening wildlife experiences received negative ratings (Moscardo and Saltzer, 2005). Our findings conform with Saltzer (2003) in that her survey respondents best enjoyed natural animal behaviour. Our respondents, for instance, did not wish to witness or cause alert or flight behaviour, and some participants commented that they interpreted this behaviour as an aversive response to their own presence. There was a strong interest in social interactions between animals. However, respondents stated that they would be content to observe body maintenance or locomotion as long as there was some sort of action.

Respondents favoured a tour that first observed wildlife and scenery during a creek bed hike which ideally culminated in a stationary observation at a water tank of about 1 h. Most respondents wished to commence with the observations directly after dusk so that they could "witness the sunset and then dine afterwards". The use of a night vision device or bat detector was highly appealing. Yet night-time tours had mostly relied on conventional torches and spotlights, failing to capitalize on the excitement of people with technical paraphernalia. Group size may strongly impact on visitor satisfaction (e.g., Hughes and Macbeth, 2005), and our survey respondents expressed concerns for tours with >8 participants. If NVDs are used then group sizes will be limited by the availability of the equipment because a spotlight can illuminate the view for many observers but an NVD is a device exclusive to the user.

Other desirable tour characteristics which were also reported in Moscardo et al. (2001) encompass a good service, the novelty of the experience or sense of adventure, the comfort and a scenic route/setting. In addition, interpretation and a knowledgeable guide seem to play a central role in the learning experience provided by the tour. Our respondents considered a quality introductory talk as vital and expected "interesting information about the wildlife and observation techniques"; however, a concise (<15 min) talk was preferred. Another relevant factor was punctuality as waiting periods can lead to dissatisfaction (Hughes and Macbeth, 2005).

Naturally, good weather conditions enhance a tour experience (Moscardo et al., 2001) and our survey respondents, especially the fraction of campers, found strong winds with their propensity to raise dust in the air a nuisance that they rather avoided at night. They also commented that "the night-time observation will be an enjoyable break from the heat during the day".

Impacts of night-time tours on the subject wildlife were probably underestimated, a phenomenon also recognized by others (Taylor and Knight, 2003b).

7.4 Nocturnal observation of wildlife under different viewing conditions

7.4.1 Methods

7.4.1.1 Study area

The experimental, night-time observations were conducted at the University of New South Wales Arid Zone Research Station at Fowlers Gap (lat. 31° 05’ S, long. 141° 43’ E) 108 km north of Broken Hill in the far west of New South Wales. Fowlers Gap is typical of Australia’s southern sheep rangelands with a dry to mildly arid (Bell, 1973) climate and chenopod shrub steppe and scattered trees such as mulga and black oak. The station covers some 39 888 ha and is held by the University of New South Wales, Sydney, for the purpose of research, teaching and tourism in the context of a pastoral enterprise with wool and sheep production. Fowlers Gap contributes to regional research and development for the wildlife tourism industry in the rangelands of the Australian Outback. The observation experiments were undertaken here instead of Arkaroola for logistical reasons.

Fowlers Gap is home to a rich fauna with four species of large kangaroos, a number of small, exclusively nocturnal mammals and seven recorded species of bats. There is no culling of kangaroos. Dingoes (*Canis lupus dingo*), the replacement of now-extinct natural predators of kangaroos, have been excluded by ongoing control and the trans-continental 'dingo fence'. Non-native mammals like the Red Fox (*Vulpes vulpes*) and the European Rabbit (*Oryctolagus cuniculus*) are also present. Like other drylands of the world, the station supports a diverse reptile community with close to 40 species, many of which tend to be more active at night. A diverse avifauna including waterbirds and a few amphibians complete the vertebrate community.

Four artificial watering points in the form of earthen tanks (mean width ± 1 SE: 37.1 ± 2.9 m; mean length ± 1 SE: 55.3 ± 5.2 m) filled with free-standing water were chosen. The vegetation around the tanks was sparse and primarily consisted of grasses and shrubs except for one tank that was framed by trees (<8m). Further, four intermittently flowing creek beds were selected which were dry during the study except for a few ground hollows with remnant water. Creek beds form scenic water channels that sustain an abundant riparian vegetation with shrubs and grasses and a canopy dominated by River Red Gum (*Eucalyptus camaldulensis*). These distinct creek lines are also comparatively easy to follow at night. Our hikes had an average length (± 1 SE) of 4.5 km ± 0.2 which was usually achieved in the 1.5 h that limited the observations.

To minimize the influence of pseudoreplication through re-sampling the same fauna, tanks were located in spatially distinct areas with a large intervening buffer of 7 to 16 km. Starting points of creek bed hikes were at least 1 km apart. Further, hiking transects led into different trajectories demarcated by ridges or the Silver City Highway that traverses the station. Finally, the same tank or creek bed hike was never sampled during two consecutive observation periods, and normally observations at the same location were spaced apart by at least one day.

7.4.1.2 Nocturnal observations

We conducted 144 nocturnal observations lasting 1.5 h each from January to May (summer to autumn) 2007. Observations were stationary at water tanks and ambulatory in creek beds ('watch mode') and took place either directly or 2–2.5 h after dusk ('timing'). For illumination ('light mode') white or red light was used or infrared light coupled with a NVD. The design was balanced for all factors. Each study site was subjected to the same treatment combination three times, and all combinations were dispersed randomly throughout the study period. During the observations under the different treatment conditions, we recorded the species-abundance and closest observation distance of all mammal, bird and reptile species, and the behaviour of selected species by scanning our surroundings with a spotlight, as detailed in the following paragraphs. Ambient wind speed was measured with a Lambrecht K6 anemometer (Lambrecht Meteorological Instruments, Göttingen, Lower Saxony, Germany) four times during each observation unit and averaged prior to analysis. Nights with precipitation, thunderstorms or winds >30 km h^{-1} were avoided.

The spotlight 'Striker' (Lightforce Australia Pty Ltd, Hindmarsh, South Australia, Australia) was equipped with a 100-watt halogen globe (Osram, Munich, Bavaria, Germany) and interchangeable Lightforce red or infrared light filters. Infrared light is not visible to the naked eye but greatly enhances the ambient light and therefore the visibility attained with a NVD (Fig. 7.1). The white light was dimmed with a Lightforce output control and standardized to the same photometric intensity of 8 lux as the red light. We measured the intensity at a 2 m-distance from a tank´s shoreline on the direct, opposite site to the observer with a LM 37 luxmeter (Dostman Electronic, Wertheim-Reicholzheim, Baden-Württemberg, Germany). For comparison: the light intensity on a cloudless night with full moon reaches approximately 0.3 lux and streetlights may cast a halo of 10 lux. In creek beds, the light settings were standardized to 8 lux at a distance of 45 m to the observer (= the average tank width plus the distance of the observer and the luxmeter to the tank). The infrared light was adjusted to a subjective viewing quality comparable to what was attained with white or red light. The spotlights were powered with a standard, portable 12-V/18AH sealed lead acid battery. Our NVG-7 generation-2 night vision goggles (ATN, San Francisco, California, U.S.A.) were mounted on a tripod during tank observations and worn with a flip-up headset during the creek bed hikes.

For the observations at tanks, a single observer was positioned at a 6 m distance to the shoreline of the tank and opposite to the favoured access site as revealed by some prominent animal paths. Equipment was arranged 0.5 h before the observation to obviate any disturbance later on. During the observations, the tank, its surroundings and the night sky were slowly scanned with the light beam for the presence of animals. We recorded the species-abundance of all mammal, bird and reptile species (Table 7.1; nomenclature as in Strahan and Conder (2007) for mammals, Cogger (2000) for reptiles, Simpson (2004) for birds) and estimated the closest observation distance during their stay (using the tank size and the distance between landscape cues for reference). The number of animals present simultaneously was generally low enough to trace movements of each individual. The light beam was diverted from previously recorded individuals and only occasionally directed close enough to ascertain the animal´s position or to scan for newcomers.

We limited our behavioural observations to kangaroos and birds due to the reliability of the sightings. Observations commenced once a kangaroo or bird had reached the perimeter of the tank or the water surface. That way the maximum distance between observer and animal was restricted which ensured a certain minimal light exposure. Further, it enabled us to examine any interruptions to drinking and feeding from the tank water. Rarely (2%) did kangaroos or birds not reach the shoreline/water surface or leave beforehand. The individual closest to the observer was assigned to be the focal individual of any grouped animals, namely those within 10 m of each other (definition is based on preliminary observations of grouped and grouped individuals at water tanks). The behaviour of newcomers was only sampled if no other individuals were present that had already been sampled in the previous 10 min. We felt that this time was sufficient to ensure the independence of the data as preliminary observations suggested that birds and kangaroos returned to their previous behaviour within this timeframe. Other researchers (King et al., 2005) have observed kangaroos to resume their previous behaviour usually within 5 min after approached by an observer. The behaviour was recorded after 10 s and after 30 s of continuous, direct light exposure in three behavioural categories: (1) alert and flight behaviour ('hiding' included) of kangaroos (quadrupedal crouching or bipedal stand with head raised from ground), birds (alarm calls, head raised from ground) and both groups (head movements as if scanning, aversive movements away from observer/light beam, placement of body behind visual obstructions), (2) social (maintenance) behaviour of kangaroos (attention focused on another animal, bipedal stand facing another individual, hissing, boxing, chasing, young-at-foot accesses pouch or sucks at mother´s teat, sniffing each other), birds (attention focused on another animal, pecking, chasing, mounting), (3) body maintenance of kangaroos (feeding: head near ground and biting or chewing; drinking: tongue lapping water; resting: lying or quadrupedal crouching with head kept stationary; grooming: licking or rubbing body parts), birds (feeding/drinking: beak/head/whole body under water, head on the ground and gleaning or probing; resting: sitting on ground/tree/water surface without movement, head tucked under wing; grooming: picking through feathers, cleansing feathers in water). Locomotion was grouped with body maintenance if the animal pursued a drinking or feeding opportunity (e.g., kangaroos seeking stable ground to access a drinking site); or it was categorized as social behaviour if individuals approached each other to interact; if none of these applied (and individuals moved away from the observer) it was interpreted as aversive behaviour to the observer and grouped with alertness/flight. Finally, light exposure was continued for another 3 min to calculate the percentage of time spent with alert/flight behaviour and the percentage of animals leaving the tank within this timeframe. Thus, individuals were exposed to light for a total of 3.5 min.

An AnaBat II bat detector with a zero crossings analysis interface module (ZCAIM) (Titley Electronics, Ballina, New South Wales, Australia) recorded echolocation calls of bats during each observation period. To maximize sound reception, the detector microphone was placed 0.5 m above and at a 30–45° angle to the ground (Lloyd et al., 2006) facing the tank at a 5 m distance. The detector was calibrated on-site for sensitivity towards echolocating bats vs. background noises such as wind and insects; typically sensitivity levels were set between 6 to 8 on a scale of 10. When a bat passed the detector, a delay switch triggered a recording. This was stored on a compact flash card after the processing via the ZCAIM which divides the high-frequency calls by a predetermined ratio to produce calls that are audible to the human ear. The AnaBat CFC read software transferred the data from the compact flash card onto the PC where they were plotted as sonograms (frequency vs. time graphs) with ANALOOK for Windows v. 3.2. (both software products by Chris Corben, 2007, www.hoarybat.com). Typically, AnaBat files contain only a single bat vocalization sequence, with a sequence being a series of calls produced by a single individual in a single pass and a call being an individual, discrete vocal pulse (O'Farrell et al., 1999). For taxonomic identification, morphological traits of bat calls, mainly their maximum/minimum frequencies and general shape (O'Farrell et al., 1999), were matched with bat calls from a reference library (Pennay et al., 2004) including the far-west region of New South Wales. Bats were identified to species level, or to genus level if the similarity in the call structure hindered the differentiation of species within a genus. The latter was the case for species within the genera *Nyctophilus* and *Mormopterus*. Only search phase calls—emitted by bats while they navigate searching for food—were identified (McKenzie et al., 2002) since they are comparatively regularly shaped pulses (Pennay et al., 2004). Bat activity was expressed as the mean number of sequences/passes recorded in 1.5 h of observation.

Night hikes were conducted at a constant pace of 2–3 km h^{-1} in the middle of the dried-up creek beds while the light beam was moved from one bank to another and up to the tree tops. The same variables were recorded as during the tank observations except that the observation distance was noted at the moment of encounter as that equated to the minimum observation distance. Behavioural observations from a stationary position also followed the protocols applied at tanks; however, observations commenced at the moment of encounter and stopped after 30 s since animals regularly left before a follow-up observation over 3 min could have been accomplished. Bats were recorded from a pouch-held AnaBat II bat detector.

7.4.1.3 Data Analyses

7.4.1.3.1 Species community and indicator species

The dependent variables were standardized by the 1.5 h observation period. Prior to multivariate analysis, species data were square-root-transformed to downweight high-abundance species. Bats were analysed separately to other wildlife. One-way or two-way-crossed analyses of similarities (ANOSIM) were performed on a Bray-Curtis similarity matrix of the species data with PRIMER v6 (Clarke and Gorley, 2006) to test for differences in wildlife communities related to the watch mode or timing and light mode, respectively. Global and pairwise R-values (= ANOSIM statistics) can reach a maximum value of 1 which would signify no overlap in species communities between treatments (Clarke and Gorley, 2006). For these overall tests for treatment effects, all observation units were included in the analysis. However, to account for a possible interaction of the study sites with the within-subject treatments, namely timing and light mode, each study site ($n = 8$) was also analysed with individual ANOSIMs. Significant effects of the light mode were followed-up with pairwise comparisons between factor levels.

Indicator species for each level of the watch mode, timing and light mode were deduced from Indicator Species Analysis (Dufrêne and Legendre, 1997), as available in the PC-ORD package (McCune and Mefford, 1997). This method calculates an indicator value from the relative abundance of a species in the different factor levels and its relative frequency of occurrence at the multiple sites belonging to each level (Dufrêne and Legendre, 1997). The perfect indication value of 100 (with 0 being the minimum) occurs for a species that is present in all sites belonging to one particular factor level, and absent in all others. A Monte Carlo randomization procedure tested the indicator values for statistical significance.

7.4.1.3.2 Number of wildlife, species richness and observation distance

General linear mixed-effect models were fitted to analyse the effect of the watch mode, timing and light mode on the number, species richness and observation distance of the non-bat fauna and on the number of passes and species richness of bats. Further analysis was conducted on the number of Red Kangaroos (*Macropus rufus*) and the number of Inland Broad-nosed Bats (*Scotorepens balstoni*) because these two species were identified as indicators for infrared light/NVD observations.

We treated our experiment as a partly nested design (Quinn and Keough, 2004; Littell et al., 2006) whereby the study sites (random, 8 levels) constitute the experimental whole-plot units/subjects that are nested in the watch mode (fixed, 2 levels) but crossed with the observation timing (fixed, 2 levels) and the light mode (fixed, 3 levels). The two within-subject treatments, timing and light mode, were applied completely randomly over the observation periods (i.e., sub-plot units; $n = 144$), ensuring that all pairs of measures in the same whole-plot unit were equally correlated (SPSS, 2005; West et al., 2007). The sub-plot units were further 'treated' with wind speed as an environmental covariate.

Separate models were run for each dependent variable using MIXED in SPSS for Windows 17.0 (SPSS, 2008) with restricted maximum likelihood algorithms and estimations employing type III sum of squares. All main and interaction effects of the fixed factors (including the covariate) and the random factor were admitted in the initial full-factorial model. A non-significant factor/covariate was removed from more complex models using backward elimination if Akaike information criterion values improved/decreased, namely when goodness-of-model-fit increased. The use of Akaike information criterion is an information-theoretic approach of model selection (Burnham and Anderson, 2004) that aims to minimize the unexplained variability in the data set with the fewest number of predictor variables.

Whenever the light mode was a significant predictor, Bonferroni post hoc tests determined where the significant differences occurred. In case of a significant interaction, simple effects tests (Field, 2005) revealed the effects of one factor at each level of the other factor. Raw data were transformed as needed to improve normality assumed by the restricted maximum likelihood algorithm (Littell et al., 1998). All analyses were tested for statistical significance at the $P < 0.05$ level. Means ± 1 SE are presented unless otherwise indicated.

7.4.1.3.3 Behaviour

For each 1.5 h observation period, the frequencies/percentages of kangaroos or birds displaying one of the three behavioural categories were calculated. To examine the change in behaviour due to continued light exposure ANOVA was used: the effect of interest was the interaction between the behavioural categories and the light mode on the difference in the percentages of the behavioural categories after 30 s and 10 s.

To examine whether the behavioural frequencies after 30 s of light exposure differed with the light mode, a chi-square test in SPSS for Windows 17 was applied. We only present the data analysis from 30 s of light exposure as the patterns were similar but more pronounced than after 10 s. Here, the individual animal was treated as the unit of replication (kangaroos: $n = 371$; birds: $n = 175$); that is, our precautions against pseudoreplication (7.4.1.1) let us assume that each individual had been randomly drawn from an infinite population. Three kangaroo and six bird cases were excluded from these behavioural analyses because animals had taken flight before the behavioural data after 30 s of light exposure could be taken. For each cell in the contingency table, the standardized residual was calculated as the difference between the observed and expected frequencies divided by an estimate of their standard deviation. Values <-1.96 or >1.96 are significant on the $P < 0.05$ level (Siegel and Castellan, 1988), and the frequency of observations in that cell should be regarded as significantly lower and higher, respectively, than expected.

The percentage of time spent with different activities within the follow-up observation of 3 min was examined with a Kruskal-Wallis test, a non-parametric test to compare differences between two or more groups, since percent data with their binomial distribution do not comply with assumptions for parametric tests such as normal distribution. A Mann-Whitney U test was used for post-hoc analyses (Siegel and Castellan, 1988). A chi-square test examined the frequency of kangaroos and birds taking flight within the 3.5 min of light exposure.

7.4.2 Results

7.4.2.1 Species community and indicator species

The species community recorded during 216 observation hours comprised a total of 17 non-bat species ($n = 793$) and five bat species ($n_{passes} = 3343$) (Table 7.1). The non-bat fauna was dominated by kangaroos and waterbirds. The Gould´s Wattled Bat was the most active bat species. Tanks and creek beds had all bat species and 11 non-bat species in common, and a total of 14 non-bat species was sighted at each location.

Table 7.1. Percentage of non-bat species and bat activity (number of passes) for stationary observations at water tanks or ambulatory observations in creek beds and corresponding indicator species values (Dufrêne and Legendre, 1997) with 100 = perfect indication. Species of the same class are presented in order of their decreasing frequency at water tanks.

			Sitting at water tanks (72 x 1.5 h)		Hiking in creek beds (72 x 1.5 h)	
Class/Subclass	Scientific name	Common name	% (*n* = 507)	Indicator value	% (*n* = 286)	Indicator value
Non-bat fauna						
Mammals/Marsupials	*Macropus robustus erubescens*	Euro	21.7	45.4	16.8	
Mammals/Marsupials	*Macropus giganteus/fuliginosus* [a]	Eastern/Western Grey Kangaroo	21.1	49.5	21.3	
Mammals/Marsupials	*Macropus rufus*	Red Kangaroo	15.6	52.4	11.9	
Mammals/Monotremes	*Tachyglossus aculeatus*	Short-beaked Echidna	0		1.4	
Mammals/Placental	*Vulpes vulpes*	Red Fox	9.3	36.3	8.7	
Mammals/Placental	*Oryctolagus cuniculus*	European Rabbit	0.8		6.3	13.6
Birds	*Anas gracilis*	Grey Teal	11.6	40.3	0.7	
Birds	*Fulica atra*	Eurasian Coot	7.9	26.6	2.1	
Birds	*Anas superciliosa*	Pacific Black Duck	3.4	18.1	0	
Birds	*Cacatua sanguinea*	Little Corella	3.2		26.2	43.5
Birds	*Eurostopodus argus*	Spotted Nightjar	2.6		0.7	
Birds	*Tachybaptus novaehollandiae*	Australasian Grebe	1.6		0	
Birds	*Cygnus atratus*	Australian Wood Duck	0.6		0	
Birds	*Tyto alba*	Barn Owl	0.4		0.7	
Birds	*Ninox novaeseelandiae*	Southern Boobook	0.4		0.7	
Reptiles	*Underwoodisaurus milii*	Thick-tailed Gecko	0		1.8	
Reptiles	*Gehyra variegata*	Tree Dtella	0		0.7	
			% (n_{passes} = 2283)	Indicator value	% (n_{passes} = 1060)	Indicator value
Bats						
Mammals/Placental	*Chalinolobus gouldii*	Gould´s Wattled Bat	61.9	74.3	41.2	
Mammals/Placental	*Scotorepens greyii*	Little Broad-nosed Bat	18	47.1	24.2	
Mammals/Placental	*Nyctophilus geoffroyi/timoriensis* [b]	Lesser/Greater Long-eared Bat	9		28.3	39.5
Mammals/Placental	*Scotorepens balstoni*	Inland Broad-nosed Bat	8.5	36.8	5.2	
Mammals/Placental	*Mormopterus* sp.[b,c]	South Eastern/Inland Freetail-Bat	2.5	24.1	1.1	

[a]These species appear too similar to be distinguished at night. [b]These species cannot be distinguished unambiguously from AnaBat (Titley Electronics, Ballina, New South Wales, Australia) recordings. [c]Unnamed by science.

ANOSIMs on the total sample of non-bat fauna were significant for watch mode (Global $R = 0.226$, $P = 0.001$), timing ($R = 0.067$, $P = 0.002$) and light mode ($R = 0.033$, $P = 0.014$). The small Global R-values (Clarke and Gorley, 2006), however, suggested that the overall community differences related to the timing or the light mode were negligible. The results were similar when the data set was divided by the two watch mode levels prior to calculating the ANOSIMs. In contrast, separate ANOSIMs for each tank yielded much higher Global R-values ranging from 0.5 to 0.7 for the timing and 0.5 to 0.8 for the light mode, with all P-values < 0.05. All pairwise comparisons differed significantly ($P < 0.05$) between light modes, indicating that all three illumination techniques were associated with a distinct non-bat fauna assemblage. Apparently, these treatment effects had been disguised due to the interaction of the timing and the light mode, respectively, with the study sites. Notably, separate ANOSIMs for each creek bed detected significant differences only in relation to the timing ($R = 0.2$–0.38, $P < 0.05$) but not to the light mode.

Similarly, the watch mode (Global $R = 0.19$, $P = 0.001$), timing (Global $R = 0.065$, $P = 0.003$) and light mode (Global $R = 0.088$, $P = 0.001$) had a significant but small overall effect on the bat communities; whereas site-specific effects at tanks and creek beds were strong, as revealed by Global R-values ranging from 0.4 to 0.9 for the timing and 0.5 to 0.9 for the light mode with all P-values < 0.05. All pairwise comparisons of the light treatments were significant except at one site where red and white light communities showed no significant difference and at another site where red and infrared light/NVD communities resembled each other.

Species showed more fidelity to a particular watch mode than to the observation time or the light mode. All three kangaroo species, the Red Fox and four bat species were significant indicators of observations at tanks (Table 7.1). Waterbirds were only seen at tanks, with three of them being significant indicators. In contrast, Little Corellas together with European Rabbits and Lesser/Greater Long-eared Bats were indicative of creek bed observations. The two reptile species and the Short-beaked Echidnas which were only found in creek beds were too rare to qualify as indicators (Dufrêne and Legendre, 1997). Euros (indicator value/IV: 40.4), Little Corellas (IV: 38.3), Gould´s Wattled Bats (IV: 48.7) and Little Broad-nosed Bats (IV: 51.6) were typically ($P = 0.001$) encountered early at night. Red Kangaroos (IV: 37.6) and Inland Broad-nosed Bats (IV: 28.5) were significantly associated with infrared light/NVD.

7.4.2.2 Number of wildlife, species richness and observation distance

The mean number of the non-bat fauna (Table 7.2a) was significantly higher at tanks (tank: 7.0 ± 0.4; creek bed: 3.8 ± 0.3). However, numbers depended on the wind speed: on calm nights with <3 km h^{-1} between 10 to 15 animals were seen at tanks and 5 to 10 in creek beds (Fig. 7.2a). In contrast, at wind speeds approximating 30 km h^{-1}, numbers were similarly low for both watch modes. The mean number of the non-bat fauna was significantly higher early in the night than later (early: 6.9 ± 0.4; late: 3.9 ± 0.3). Likewise, non-bat species richness (Table 7.2b) was significantly higher at water tanks especially early at night than in creek beds (Fig. 7.2b); a significant decrease occurred with wind speed (Fig. 7.2c).

The non-bat fauna was viewed at a closer range in creek beds (tank: 36 ± 0.9 m; creek: 22 ± 0.9 m) (Table 7.2c) and with infrared light/NVD (Fig. 7.2d).

Table 7.2. Final, general linear mixed-effect models of the non-bat fauna variables in relation to the watch mode, timing, light mode and wind speed.

(a) Number of non-bat fauna			
	df	*F*	*P*
Watch mode	1, 139	24.64	**<0.001**
Timing	1, 139	44.48	**<0.001**
Wind speed	1, 139	70.77	**<0.001**
Watch mode x wind speed	1, 139	3.73	0.055
(b) Species richness of non-bat fauna			
	df	*F*	*P*
Watch mode	1, 139	60.34	**<0.001**
Timing	1, 139	23.57	**<0.001**
Wind speed	1, 139	26.45	**<0.001**
Watch mode x timing	1, 139	6.74	**0.010**
(c) Observation distance (m) of non-bat fauna			
	df	*F*	*P*
Watch mode	1, 134	159.53	**<0.001**
Timing	1, 134	0.02	0.893
Light mode	2, 134	15.51	**<0.001**
Watch mode x timing	1, 134	0.04	0.836
Watch mode x light mode	2, 134	0.04	0.958
Timing x light mode	2, 134	0.55	0.580

Note : Bold values indicate significance.

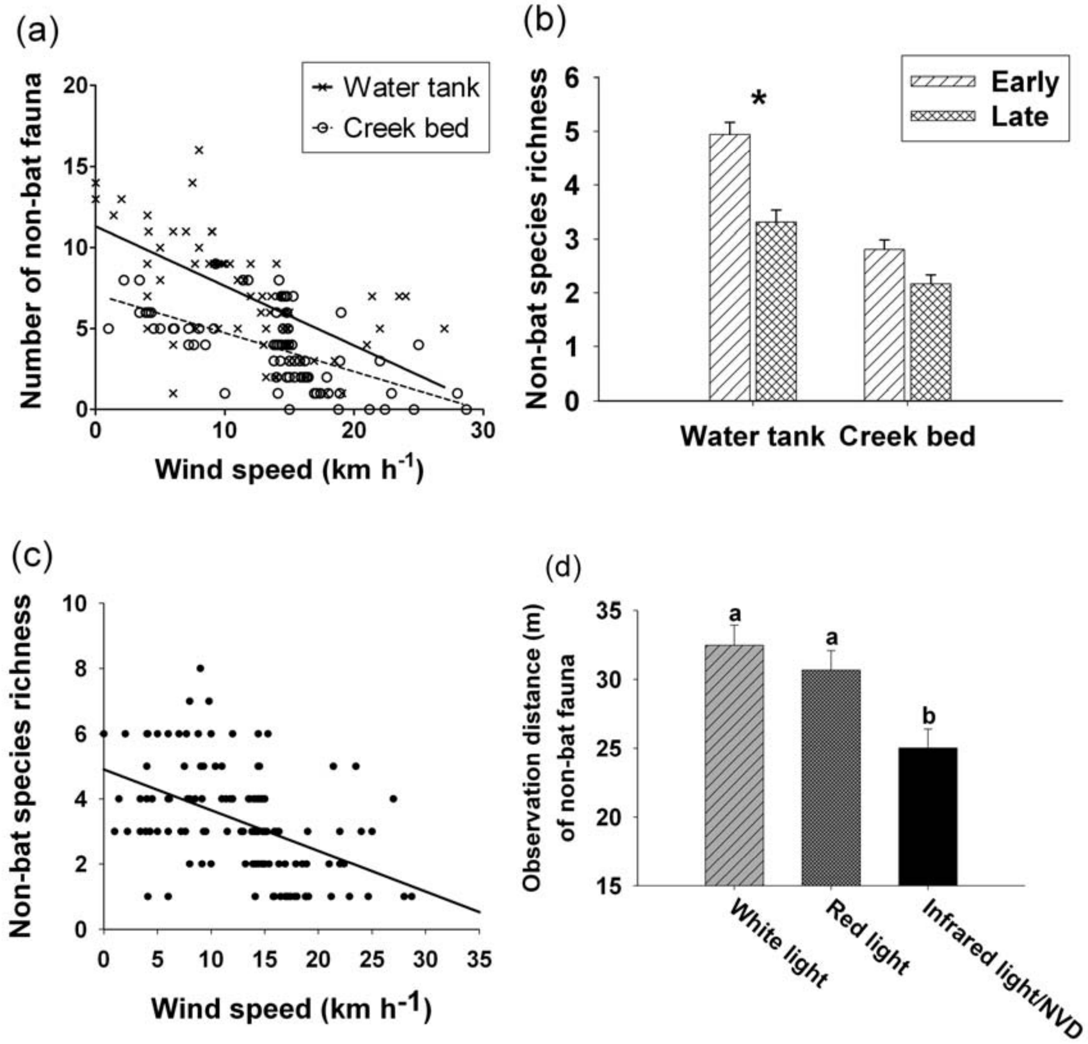


Fig. 7.2. Non-bat fauna viewing attained under different observation conditions in the Australian rangelands. Number of non-bat fauna observed per 1.5 h in relation to (a) watch mode x wind speed. (Mean (+ 1 SE)) species richness of non-bat fauna in relation to (b) watch mode x timing, and (c) wind speed. Mean (+ 1 SE) observation distance in relation to (d) light mode. Asterisks indicate significant simple effects of one factor at a particular level of another factor. Bars that do not share a common letter are significantly different. Scatter plots show best-fit (sub)plot line(s).

The mean bat activity recorded as number of passes (Table 7.3a) was significantly higher at water tanks, particularly early at night, than in creek beds (Fig. 7.3a). In contrast, there was a trend for bat activity to decrease with increasing wind speed (Fig. 7.3b). Mean species richness of bats (Table 7.3b) was significantly higher at tanks (tank: 2.9 ± 0.1; creek bed: 2.2 ± 0.1).

Table 7.3 Final, general linear mixed-effect models of the bat fauna variables in relation to the watch mode, timing, light mode and wind speed.

(a) Number of bat passes			
	df	*F*	*P*
Watch mode	1, 137	71.92	**<0.001**
Timing	1, 137	8.93	**0.003**
Light mode	2, 137	6	**0.004**
Wind speed	1, 137	1.73	0.190
Watch mode x timing	1, 137	9.75	**0.002**
(b) Species richness of bats			
	df	*F*	*P*
Watch mode	1, 138	25.17	**<0.001**
Light mode	2, 138	1.37	0.258
Watch mode x light mode	2, 138	2.70	0.071

Note : Bold values indicate significance.

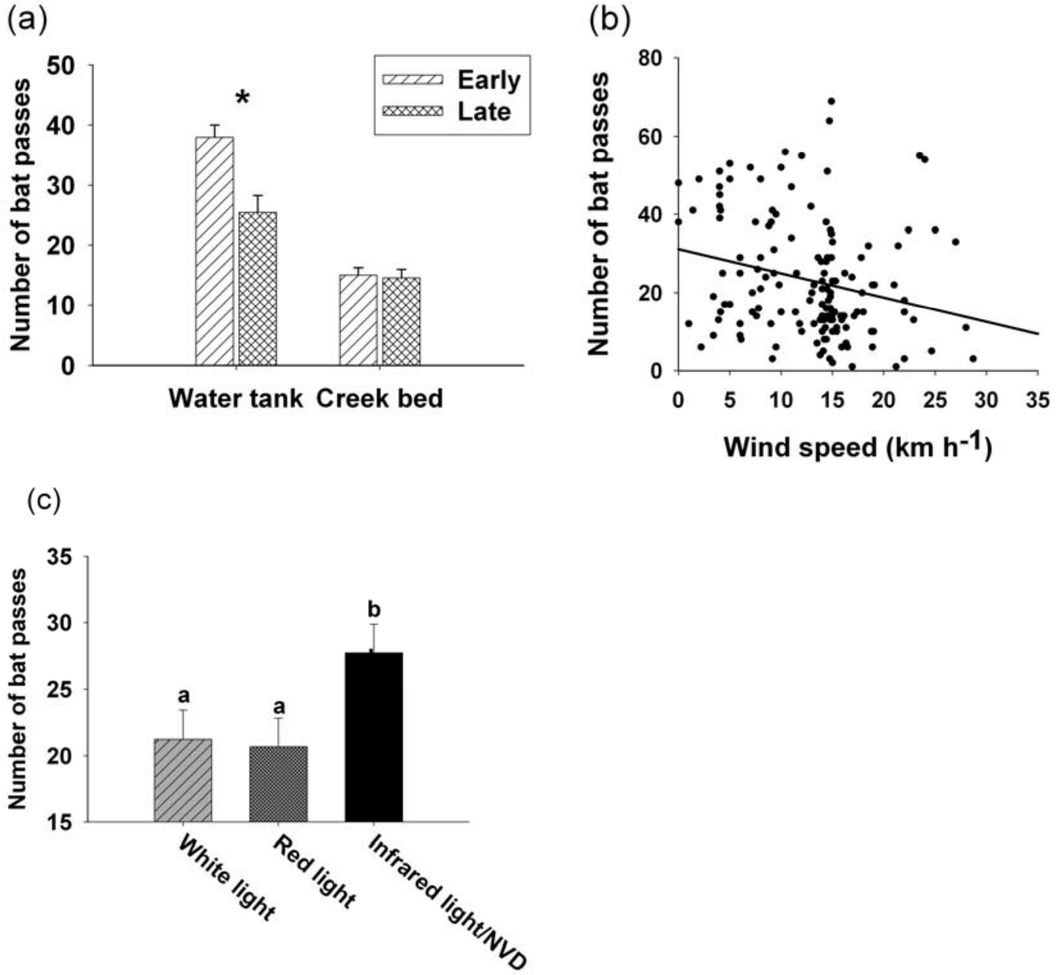


Fig. 7.3. Mean (+ 1 SE)) number of bat passes recorded per 1.5 h in the Australian rangelands in relation to (a) watch mode x timing, (b) wind speed and (c) light mode. Asterisks indicate significant simple effects of one factor at a particular level of another factor. Bars that do not share a common letter are significantly different. Scatter plots show the best-fit plot line.

While the light mode did not affect the overall mean number of the non-bat fauna, significantly less Red Kangaroos were seen during white and red light observations compared to infrared light/NVD observations (Table 7.4a; Fig. 7.4a), particularly early at night. In addition, infrared light/NVD observations increased the mean bat activity (Table 7.3a, Fig. 7.3c) slightly, particularly those of Inland Broad-nosed Bats at tanks (Table 7.4b; Fig. 7.4b). In creek beds, white and red light observations were both associated a with lower activity trend for Inland Broad-nosed Bats than with infrared light/NVD (Table 7.4b; Fig. 7.4b).

Table 7.4. Final, general linear mixed-effect models of the number of (a) Red Kangaroos and (b) Inland Broad-nosed Bat activity in relation to watch mode, timing, and light mode.

(a) Number of Red Kangaroos	df	*F*	*P*
Watch mode	1, 131	7.68	**0.032**
Timing	1, 131	1.91	0.169
Light mode	2, 131	18.00	**<0.001**
Timing x light mode	2, 131	7.87	**0.001**

(b) Number of passes by Inland Broad-nosed Bats	df	*F*	*P*
Watch mode	1, 138	18.30	**<0.001**
Light mode	2, 138	17.83	**<0.001**
Watch mode x light mode	2, 138	2.31	0.103

Note : Bold values indicate significance. The factor 'wind speed' was excluded from final models for alle effects following model selection procedures as detailed in 7.4.1.3.2.

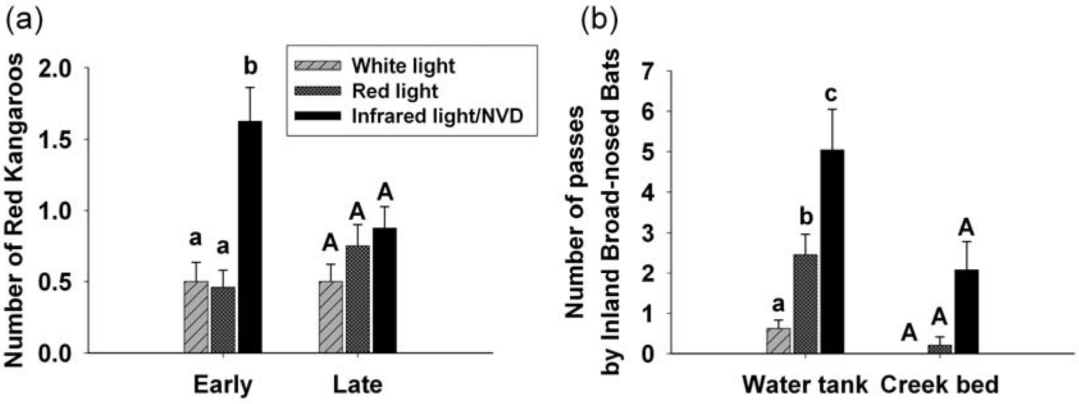


Fig. 7.4. Mean (+ 1 SE) (a) number of Red Kangaroos and (b) passes by Inland Broad-nosed Bats recorded per 1.5 h in the Australian rangelands in relation to the light mode. Bars that do not share a common letter are significantly different.

7.4.2.3 *Behaviour*

We recorded the behaviour of 371 kangaroos and 175 birds. After 10 s of exposure to white or red light, alertness/flight (kangaroos and white light: 42.0%, red light: 37.8%; birds and white light: 49.1%, red light: 43.8%) and body maintenance (kangaroos and white light: 53.8%, red light: 50.5%; birds and white light: 45.3%, red light: 43.8%) occurred at similar percentages among kangaroos and birds. With infrared light/NVD, on the other hand, 56.7% of kangaroos and 67.3% of birds performed body maintenance whereas only 21.3% of kangaroos and 14.3% of birds were alert/took flight. Social interaction was rare under white (4.2%, 5.7%) or red light (11.7%, 12.3%) and more common with infrared light/NVD (22.0%, 18.4%) for kangaroos and birds, respectively.

There was a significant interaction between the behaviour and the light mode for the difference in the percentages of the behavioural categories after 30 s and 10 s (kangaroos: $F_{(4,135)} = 6.52$, $P < 0.001$, Fig. 7.5a; birds: $F_{(4,135)} = 2.73$, $P = 0.032$, Fig. 7.5b). The increase in alert/flight behaviour after sustaining the white and red light exposure for 30 s was more than double that after infrared light/NVD exposure and associated with an almost equal decrease in body maintenance.

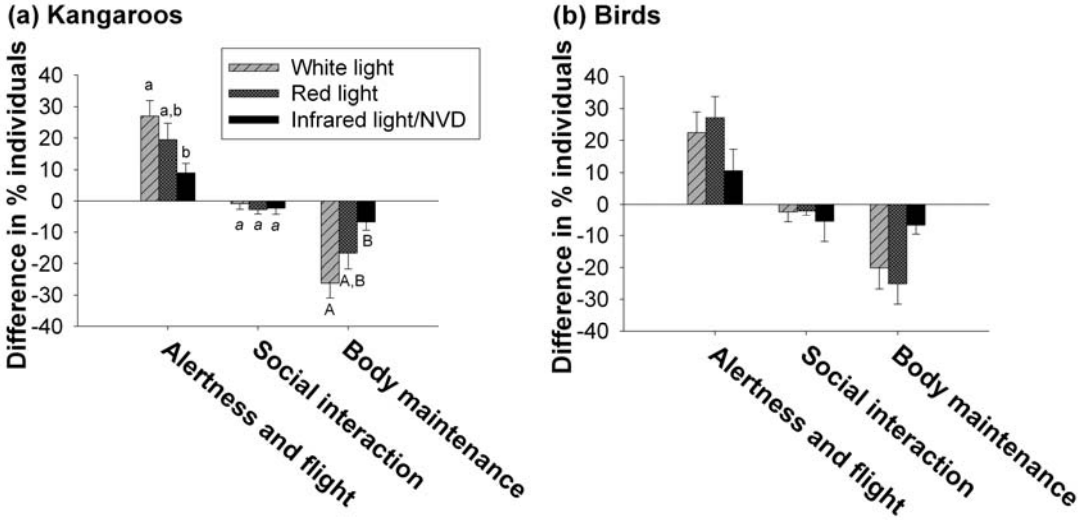


Fig. 7.5. Mean (+ 1 SE) difference in the percentage of individual (a) kangaroos and (b) birds displaying a particular behavioural category between 30 s and 10 s of exposure to different light modes. Bars that do not share a common letter are significantly different. Despite a significant interaction of the behavioural category with the light mode for birds the simple effects tests were (marginally) nonsignificant and therefore no letters are included on that graph.

Alert/flight behaviour after 30 s was significantly more frequent (Fig. 7.6a, b) with a related decrease in body maintenance (kangaroos: $\chi^2_{(4)} = 37.79$, $P < 0.001$; birds: $\chi^2_{(4)} = 15.76$, $P = 0.003$); a similar albeit less pronounced trend was noted for red light exposure. In contrast, infrared light/NVD usage was associated with relatively little change in the behavioural frequencies: body maintenance and social interaction occurred significantly more often and alertness/flight less often than expected relative to the behaviour performed under white and red light usage.

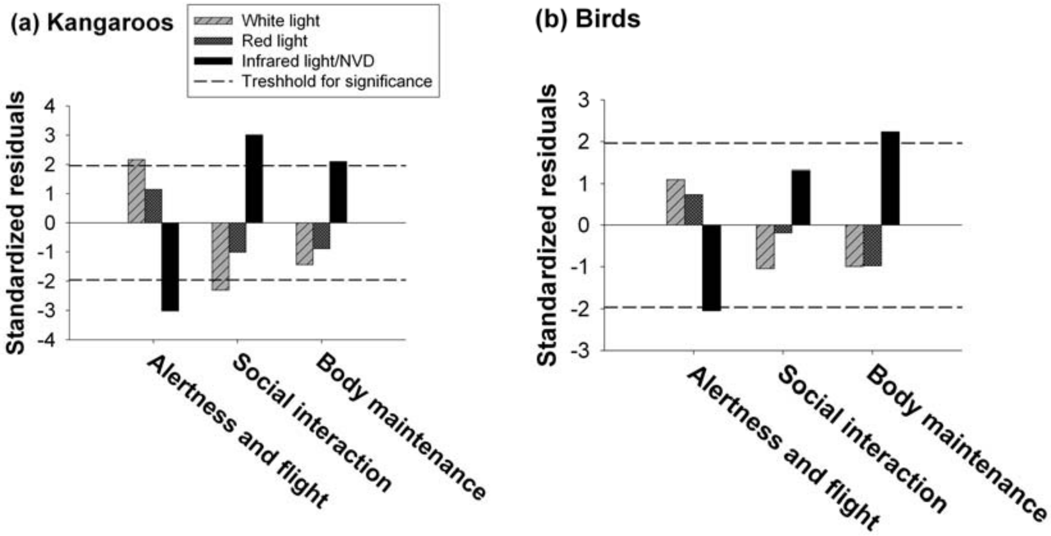


Fig. 7.6. Standardized residuals for the chi-square analysis of the interaction effect between the behavioural category and the light mode ($\chi^2_{(6)} = 155.63$, $P < 0.001$) after 30 s of exposure of (a) kangaroos or (b) birds to different light modes. Dashed reference lines indicate the thresholds of significance.

The percentage of time that kangaroos and birds spent with alert/flight behaviour in the 3 min after the first 30 s of light exposure was significantly higher with white light (kangaroos: 38%; birds: 18%) and red light (kangaroos: 36%; birds: 16%, trend only) than with infrared light/NVD (kangaroos: 16%; birds: 9%) (kangaroos: $\chi^2_{(2)} = 81.65$, $P < 0.001$; birds: $\chi^2_{(2)} = 13.21$, $P = 0.001$). None of the kangaroos or birds took flight within the 3.5 min of infrared/NVD exposure. In contrast, during white light observations 8.5% of kangaroos and 15% of birds took flight and during red light observations 6.1% of kangaroos and 10.9% of birds took flight (kangaroos: $\chi^2_{(2)} = 8.02$, $P = 0.018$; birds: $\chi^2_{(2)} = 4.81$, $P = 0.090$).

7.4.3 Discussion

7.4.3.1 Mode of illumination

The results support our first hypothesis that white and red light may disturb some wildlife species. For instance, bat activity, in particular that of Inland Broad-nosed Bats, and the numbers of Red Kangaroos were consistently lower when viewed with white or red light relative to infrared light/NVD. Artificial light may pervade the darkness around tanks and creek beds disturbing wildlife before they are noticed and therefore result in fewer animal sightings; especially those species that are more sensitive to illumination. Moreover, the non-bat fauna kept a farther distance from the source of white or red light, and kangaroos and birds reacted with alertness and flight coupled with a reduction in body maintenance and social interaction. Studies (reviewed by Rich and Longcore, 2006) show that artificial lighting has profound consequences on animals´ physiology, behaviour and fitness including terrestrial mammals, bats, birds, reptiles, amphibians and fishes. Several species of house-dwelling bats, for example, delayed their emergence and juveniles were smaller when houses were illuminated with floodlights (Boldogh et al., 2007). This is not surprising given that bat emergence is dependent on natural ambient light levels (Rydell et al., 1996; Lang et al., 2006).

Like artificial lighting around human settlements, illumination aimed directly at wildlife especially during a prolonged and pursuant observation may be highly disturbing. For instance, possums responded in agitation towards white and red spotlights which simulated tourism activities (Wilson, 1999) and were displaced from the illuminated areas. The emergence numbers of Soprano Pipistrelle Bats (*Pipistrellus pygmaeus*) were lower when roost entrances were illuminated with white or red light, and more bats emerged when red light intensity was progressively lowered (Downs et al., 2003) in the quest for the most unobtrusive monitoring technique.

Early reports of red light sensitivity of animals stem from laboratory experiments with Eastern Woodrats (*Neotoma floridana*) who exhibited the same patterns of entrainment of circadian rhythm under red as under white bulbs (Zervanos and Davis, 1968). However, in other studies reactions of wildlife to red light were rather weak. For example, King and King (1994) found that various mammal and bird species briefly orientated towards a red spotlight and then resumed their previous activity a few seconds later. Longer-lasting observations did not alter wildlife behaviour. Given that their maximum observation distances exceeded ours by hundreds of metres, at a similar maximum spotlight output, we conjecture that their study animals were exposed to lower light intensities. Even despite the long distances a few bird species were nonetheless still deterred from the red light.

Our results did not reveal strong evidence that red light is less disturbing than white light if both are standardized to the same photometric intensity. At best, there was a slight lowering of reactivity given that fewer kangaroos were alert/took flight after red light exposure, and Inland Broad-nosed Bat activity under red light was intermediate to white and infrared light/NVD observations. Yet, our findings largely conform with Wilson´s (1999) in that she did not detect differences in the response of possums to differently coloured (red, green, semi-opaque) light of the same intensity. In studies that emphasize the red light tolerance of wildlife compared to white light (Russell, 1980; King and King, 1994) effects of light quality and quantity are often confounded. Nevertheless, in some studies where these effects are discernible light quality did indeed make a difference (Mann et al., 2002; Downs et al., 2003). For example, vocalization rate of Cave Myotis (*Myotis velifer*) in response to simulated tourist activity in a cave was lower when red light was used than a lower-intensity white light and resembled the rate noted under no-light conditions (Mann et al., 2002).

Since red light filters have apparently failed to provide a unanimous solution for obviating aversive responses of wildlife, infrared light/NVD may currently be the best remedy. Procter-Gray and Ganslosser (1986), for instance, switched from using a 30-watt red spotlight to a night vision scope when Lumholtz´s Tree-kangaroos (*Dendrolagus lumholtzi*) appeared transfixed on the light. Overall, the experience with NVDs was consistently positive and highlights the potential for a significant stress relief in a wide range of species during nocturnal observations (e.g., Southern et al., 1946; Hill and Clayton, 1985; McMahon and Evans, 1992).

7.4.3.2 Watch mode (location/observation platform) and timing

Stationary observations at tanks and ambulatory observations in creek beds attracted moderately distinct bat and non-bat assemblages and indicator species, thus supporting the second hypothesis. Further, the fauna viewing experience was richer sitting at tanks with higher numbers and species to be seen. These effects may be attributed to the fact that (1) habitat factors of water tanks/artificial watering points may have been more attractive to wildlife than creek beds and/or (2) a quietly sitting observer may have disturbed wildlife less and captured more of the wildlife on view than an ambulatory observer.

Indeed, water-dependent native animals are attracted to artificial watering points in arid rangelands worldwide. For instance, kangaroos frequently converge there to drink (Newsome, 1965; Norbury and Norbury, 1993) perhaps commuting longer distances from their feeding grounds (Montague-Drake and Croft, 2004), and usage increases during droughts or dry summer periods (Dawson et al., 1975). In other drylands of the world large herbivores also concentrate in the proximity to watering points (Knight et al., 1988) to maintain their water and mineral salt balance.

Water birds enriched the viewing experience at tanks further. Both abundance and diversity of the avifauna is typically much greater at or in the vicinity of water points (Croft et al., 2007). Despite the arid conditions in Inland Australia water birds are abundant throughout the big water systems (Kingsford, 1995) and their distribution also extends onto artificial watering points (Williams and Wells, 1986) where they engage in a range of activities (Rosenstock et al., 1999). Predominantly, we observed them to be bathing, foraging and drinking. Occasionally, we also saw a Spotted Nightjar hunting insects near the shoreline.

An active bat community complemented the observations at tanks. Our study is consistent with Velez (2001) in that bat activity was higher near tanks than along creek beds. Notably, she reports that both of these habitats were used more than the surrounding open plains which lacked water and structural complexity. Water bodies have previously been recognized as significant drinking sites and foraging grounds for insectivorous bats (Law et al., 1998; Ciechanowski, 2002) as their low-clutter, smooth water surface facilitates easy detection of prey via echolocation better than the structured surface of creek bed vegetation (Siemers et al., 2001).

Non-native species likewise attend artificial watering points (reviewed by James et al., 1999). We commonly observed Red Fox at our tanks, which came there to drink, scavenge, hunt and sleep. During infrared/NVD observations they even investigated the bat detector a couple of times.

In contrast to artificial watering points, the fauna viewing experience along creek beds was rather diminished. This was surprising as strips of woodlands along creek beds play a pivotal role in conserving diversity of bird communities (Mac Nally et al., 2000; Fleishman et al., 2002) and terrestrial mammals (Doyle, 1990) in semi-arid to arid environments. Bats normally benefit from wind protection and roosting sites in riparian habitats and use wooded corridors as commuting channels (Murray and Kurta, 2004). During our study, the creek beds may have been less attractive for wildlife as they were largely dry. Furthermore, the viewing conditions in creek beds were less opportune since the vegetation and the meandering of the creek bed obstructed the view. In addition, the hiking in the rugged terrain particularly with night vision equipment also distracted from the observations, and the noises from the walking may have scared away wildlife before it was sighted. Wilson (1999), for instance, found that possums were distressed by noises typical of human movements such as the scrunching of gravel and snapping of twigs.

The closer wildlife observations in creek beds may partially be explained by the fact that wildlife at a further distance was not noticeable there. However, since the observer at tanks was positioned opposite to the favoured access site of wildlife, the observation distance must have been strongly determined by the tank size and could so be modified at will.

In further support of our second hypothesis, the fauna viewing depended on the observation time and was richest directly after dusk when the number and species richness of the non-bat fauna and the bat activity were higher. Some species like the Euro were consistently encountered more often early at night. Such diurnal rhythms are a common species-specific trait that has been well-studied (Halle and Stenseth, 2000). Kangaroos, for instance, spend most of the day resting (Croft, 1989; Clarke et al., 1995) and feed more frequently in the early evenings with a slight lag period during the night (Dawson, 1995). Red Kangaroos are most active in the few hours after sunset and drink from late afternoon till morning with a peak in the first part of the night (King et al., 1998). Amongst the avifauna, waterbirds and Little Corellas which were considerably more abundant early at night are primarily diurnal so it is likely that they were less active later at night.

The peak in bat activity in the 1–2 h after dusk conforms with previous studies (Kuenzi and Morrison, 2003; Bartonicka and Rehák, 2004). Milne et al. (2005) who researched temporal patterns of bats in the Northern Territory, Australia, reported a similarly strong decline in activity as we did from the first 2 h after sunset to the next 2 h. Explanations include the availability of insects which can peak shortly after dusk (Rydell et al., 1996) or a temperature drop, which may directly or indirectly (via insect abundance) influence bat activity.

7.4.3.3 *Wind speed*

Windy conditions had an overall aversive effect on viewing success with less numbers and species to be observed, strengthening our third hypothesis. During windy conditions, Red Kangaroos and Euros took flight more readily in response to an approach by human observers (Chapter 6). Carter and Goldizen (2003) found that vigilance significantly increased in Brush-tailed Rock-wallabies (*Petrogale penicillata*) during high winds. During these nights wallabies often did not emerge to feed and appeared 'unnerved'. Stronger winds increase the risk that predators are not detected as they mask olfactory, auditory and visual cues. For the same reasons, they may also compromise a human observer’s ability to detect wildlife.

There was a trend for the number of bat passes to decrease with increasing wind speed which likely hindered bats in their flight. Verboom and Spelstra (1999), for instance, found that at high wind speeds bats directed their activities closer to protective tree lines.

7.5 Conclusions

In conclusion, night-time observation of wildlife around a homestead in the Australian rangelands provided a contemporary experience of the Australian fauna with a reasonable number of wildlife sightings and species richness. Visitors have a good chance of encountering large and unique wildlife as kangaroos congregate near watering points where they display active, natural behaviour. They may also become acquainted with wildlife such as bats or echidnas which they may not be familiar with. Yet, expectations of participants in night-time tours should not be raised beyond reason as the viewing of free-ranging wildlife remains somewhat unpredictable.

We suggest conducting a tour on a calm, fair-weather day to increase the viewing success and commence it with a 0.5 h creek bed hike during daylight. That way, participants can admire the scenery and experience the contrast between day and night. The physical activity may also aid their concentration during the duration (0.5–1 h) of a further stationary observation at a water point such as the earthen tanks found on most pastoral properties (and National Parks) in the Australian rangelands. The equipment necessary for the latter observation should be set-up opposite favoured access sites to water by wildlife. The size of the water point will likely determine the closeness of the observations. At the same time the tour operator may explain about the equipment and encourage appropriate viewing behaviour as potential impacts of night-time viewing have been underrated by tourists.

A night vision device enhanced by infrared light will facilitate the observations as it proved less intrusive on wildlife in our study than white or red spotlights, and it provided the best viewing experience. We used a generation-2 device which offers improved images and enhanced tube life over previous generations while being more affordable and accessible than later generations. However, successful wildlife viewing by night can also be achieved with less expensive generation-1 devices (Ord et al., 1999). We recommend night vision goggles/binoculars over monoculars since they facilitate depth perception and relax both eyes. Magnification can be added to encompass long viewing distances at tanks but should be avoided (more weight, reduced field of vision) during the ambulatory component of the night-time tour.

As survey respondents were generally keen to try out novel technical equipment, bat detectors will be an excellent compliment to the tour experience. It remains to be tested, though, whether the bat recordings are better examined upon return from the tour or directly in the field which is possible if the detector is connected to a laptop computer.

Given that a single quiet observer conducted our experiments, complimentary studies are needed on additional factors that negatively influence wildlife impacts and visitor satisfaction such as the tour group size and the level of noise. Also the optimum frequency for repeating the tour at the same location without deterring wildlife and the optimum seasons need to be researched. Any tour design also needs to be test-staged with different visitor groups. Our survey sample was largely composed of Australian adult couples over 50 years in age. Groups with children or younger adults and international visitors may have different needs and also cause a different disturbance to wildlife.

Importantly, we agree with Rodger et al. (2007) who pointed out the need for scientific studies that improve the protection for wildlife of interest to tourists as critical for the long term sustainability of the wildlife tourism industry. Many wildlife tours, whether by day or night, could benefit from the combined effort of social and biological sciences to create satisfying visitor experiences that accrue from low-impact wildlife viewing.

Chapter 8
Synthesis

8.1 Nature conservation and tourism: a paradox?

This thesis began by describing the potentially symbiotic relationship between tourism and natural area conservation. People enjoy visiting natural areas and engaging with wildlife, and land managers seek to attract visitors for the financial revenue which consequently ensures that natural areas are secured from potentially more destructive types of land use. In addition, when visitors have an enriching experience with the natural environment during their travels, they may be more inclined to support its conservation. A positive experience is also the prerequisite for future visitation or recommendation to others. This, in turn, attracts further financial revenue which consolidates that a particular tourism site merits conservation. However, considering the resource degradation caused by nature-based tourism activities—as documented in this thesis or elsewhere—one expects that the more attractive a site is, the more likely it is that it will be degraded. This, in turn, may diminish the quality of the experience and thus visitor satisfaction. Numerous studies (e.g., Budowski, 1976; Martin and Uysal, 1990; Dearden and Harron, 1994; Hughes, 2002) have expressed their concern about this issue, and McArthur and Hall (1996) have described it as paradoxical situation. Thus the question arises as to whether tourism usage can in any circumstance be compatible with conservation. Is the reality that while tourism purports to contribute to conservation, in practice its actions destroy environments and it acts as nothing but a slower force of degradation compared to other industries?

A comprehensive answer to this question is beyond the scope of this thesis. What seems clear, though, is that to fully capitalize on the positive sides of tourism for protected areas or private lands, the degradation of resources needs to be decreased to ecologically acceptable levels and to levels beyond visitor perception. To achieve that, knowledge is necessary on the relationship between visitor usage and environmental impacts, the management of this relationship and the promotion of low-impact variants of visitor behaviour.

This thesis has advanced such knowledge for nature-based tourism activities in the gorges of the Flinders Ranges in the South Australian Outback, and other areas with similar ecology and usage patterns. The central aim was to better understand the management effect of access regulation (road vs. hiking trail access) on various short- and long-term environmental impacts, and to identify low-impact variants of common visitor behaviour such as approach to wildlife and night-time observation of wildlife. In Chapter 1 of the thesis, a framework was presented to introduce the multifaceted relationship between nature-based tourism activities and their environmental impacts. This framework accommodates the relationships that were investigated in this thesis as well as most other relationships that are the subject of recreation ecology. In Chapter 2 ('visitor profile study') a profile of the typical Flinders Ranges tourists was constructed. It highlighted their demand for being/camping outdoors coupled with the quest for solitude and their aspiration to view unique Australian flora and fauna. Scenic driving and easy hiking were the favourite activities of most of the visitors, albeit the former was more important for the driver segment (74%) and the latter for the hiker segment (26%) of the Flinders Ranges visitor market. Both market segments preferred to camp at sites with vehicle access. Visitors were aware of their impacts but recognized some types of impact more readily than others. In Chapter 3 ('visitor monitoring study'), a comprehensive monitoring of visitor usage was conducted that underpinned the popularity of gorges among Flinders Ranges tourists. Further, it showed that the access mode to gorges caused distinct differences in visitor usage. The respective causes for the presence of high and low usage sites were discussed. Chapter 4 ('bird study') and 5 ('vegetation study') revealed a multitude of long-term effects of visitor usage on vegetation and bird communities, and their dependence on the access mode to gorges. Chapter 6 ('kangaroo study') and 7 ('nocturnal observation study') have identified low-impact variants of visitor approach to kangaroos and nocturnal observation of wildlife in the Australian Outback. Importantly, these studies have revealed that the less intrusive behaviour attained a better viewing experience that accrued from closer observations and sightings of more species and more 'natural' behaviour; that is, less flight and alert behaviour in response to visitors.

This chapter synthesizes the key findings of the thesis and discusses them in the context of the questions on (1) how to identify tourism impacts and their mechanisms, and how to manage tourism via (2) access regulation, (3) education based on visitor impact research and (4) research on low-impact tour experiences that achieve high visitor satisfaction. The identification of visitor impacts and their management is the vital step towards attaining compatibility between nature conservation and tourism, and ultimately towards sustainable tourism. The Synthesis concludes by addressing some limitations of the thesis and future research directions.

In spite of the strong management focus, the Synthesis does not attempt to construct a tourism management plan. Rather it shows what the implications of the findings from the thesis are for management. To create a comprehensive tourism management plan for the Flinders Ranges, many factors would have to be considered that were not within the scope of the thesis including political (e.g., public acceptability) and managerial (e.g., funding, staffing, policies) issues.

8.2 Towards sustainable tourism

8.2.1 Identification of visitor impacts and impact mechanisms

8.2.1.1 Observational studies

To better manage nature-based tourism activities, the effectiveness of management interventions at reducing environmental impacts needs to be assessed. This requires that impacts are reliably identified. The occurrence of some environmental changes is undoubtedly a product of human activity such as tourism disturbance. For instance, the presence of petroleum residue in samples of otherwise undisturbed lake water can be ascribed to tourism usage without the assessment of sites that lack tourism usage (controls) because the concentrations would inevitably equal zero at the latter (Buckley, 2004c). In contrast, to identify tourism-induced changes in most other environmental variables their conditions need to be compared between different sites that vary in their tourism usage or between different points in time at the same sites where the usage varies over time. A classical comparison involves sites without usage and sites with some usage or sites before commencement of usage and sites after commencement of usage. A combination of these comparative approaches leads to what is known as BACI (Before/After, Control/Impact) design.

However, sampling designs must adapt to a lack of control sites or records prior to tourism establishment. In Chapter 3–5 of the thesis, this was achieved by defining impacts as differences in environmental variables between high vs. low (instead of 'no') usage sites. Consequently, this design was referred to as a 'hi-lo impact study'. In Chapter 4 the hi-lo impact design was extended by an additional comparison, namely between vegetation and soil samples taken at different distances to the source of the disturbance; based on the assumption that resources at close distance will be impacted on more than at further distances. The hi-lo impact studies of this thesis successfully detected tourism impacts on vegetation and bird communities, and high usage was related to altered species composition, decreased total plant cover, increased non-native species cover, increased or decreased plant diversity depending on the distance to the disturbance, increased soil compaction and decreased bird numbers and bird species richness. Further, the ecological effect zone (Chapter 4) of vegetation impacts was determined to extend up to 5 m from recreational tracks (or up to 50 m considering the self-perpetuation of impacts from high usage roads to neighbouring creek beds).

The success of hi-lo impact studies to detect visitor impacts depends partially on the magnitude of the difference in the usage intensity between high and low usage sites: the impacts should increase as the difference in the usage intensity ('amount of use') increases. However, little is known about the actual form of this dose-response relationship and therefore about the rate of increase. Findings from trampling studies and campsite impact assessments suggest that the dose-response relationship (Fig. 8.1a) is curvilinear (asymptotic) rather than linear (Cole, 2004). Accordingly, the biggest increase of impact occurs at small increases in usage. As the usage intensity increases the rate of increase in impact decreases. A threshold is passed once substantial impacts have occurred, and any further increase in usage will cause only minimal additional impact. For instance, comparatively low levels of trampling may cause substantial changes in vegetation such as species replacement and reduction in total plant cover. High levels of trampling, however, may cause little additional change in vegetation because disturbance-sensitive species have been replaced with more resistant species. In its most extreme expression, no plant cover remains that could be affected by trampling, so that nothing changes (Liddle, 1997; Cole, 2004) even if usage increases dramatically. Similarly, Marion and Cole (1996) found that rapid changes in soil and vegetation conditions occurred when campsites were initially opened to use whilst they stabilized with on-going disturbance. Differences in impacts were not linearly proportional to differences in amount of use. For instance, whilst their high usage sites were camped on 5–10 times more often than their low usage sites, the mean campsite area and non-vegetated area were only 2.9 and 3.3 times greater, respectively. Declining rates of campsite expansion at higher usage levels were said to arise because the increase in visitor usage affected mostly specific areas within a campsite (e.g., picnic tables) where levels of impact increase towards their maximum. Alternatively, Growcock (2005) presented evidence for a logistic relationship (Fig. 8.1b) where low levels of recreational use do not cause significant damage until a primary threshold is reached. Such a threshold to disturbance was found for vegetation communities with high resistance against initial damage (Monz, 2002; Whinam and Chilcott, 2003). The secondary threshold that Growcock (2005) postulated is the equivalent to the single threshold in Cole's (2004) model.

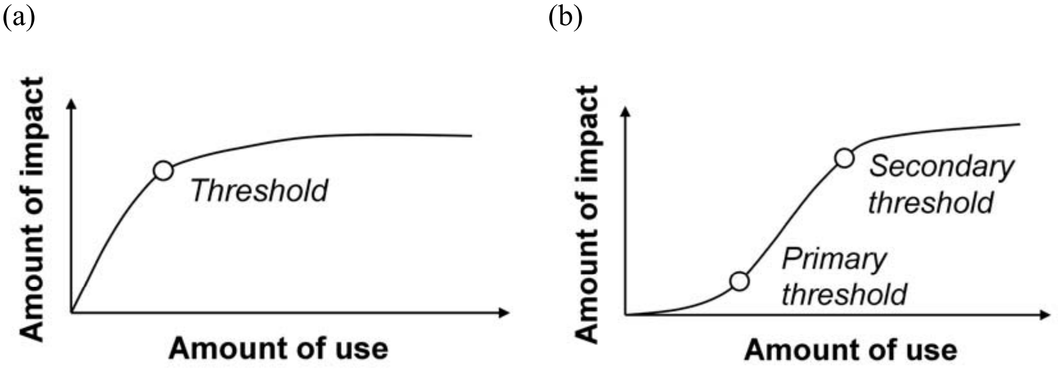


Fig. 8.1. The (a) curvilinear (modified after Cole, 2004) or (b) logistic (modified after Growcock, 2005) relationship between amount of use (usage intensity) and amount (magnitude) of impact.

A failure to detect a difference in a resource variable that abides by the described dose-response relationships means that either (1) tourism usage does indeed not influence the variable in question (no matter how much usage increases) or (2) tourism usage does influence the particular variable but the increase in usage from a low to a high state did (in this instance) not cause an additional impact because the increase (a) was too small and/or (b) elicited a disproportionately low response in impact. The latter situation arises when low and high usage values precede the first threshold in Growcock's (2005) model or when they surpass the second threshold in Growcock's (2005) model or the single threshold in Cole's (2004) model; that is, when these values are located on the part of the dose-response curve with the weakest rate of increase. The situation is complicated by the fact that the amount of use at which the thresholds occur may differ between dependent variables. For example, vegetation height is often noticeably impacted on by trampling long before vegetation cover or composition change (Cole and Bayfield, 1993). Further, while either of these models may be applicable to tourism impacts on soils and vegetation, they may not be valid for the many impacts on wildlife; at least no such relationships have been explicitly described in regards to wildlife (Kuss et al., 1990). Thus, as a general rule, the probability that a hi-lo impact study detects impacts will increase the closer the low usage conditions resemble control conditions and the farther the high usage conditions deviate from these. Furthermore, the lack of a difference in the response variable should not be prematurely interpreted as an indication of its immunity against visitor disturbance.

The success of hi-lo impact studies with a nested structure in detecting impacts also depends on how well the usage intensity level, representative for the whole study site/whole-plot unit, characterises the conditions in the sub-plot units. In the vegetation study, for instance, the soil and the vegetation at different distances to the recreational tracks were (due to their immobility) consistently exposed to different sub-plot levels of disturbance. Therefore, vegetation sampled in the first metre beside low usage roads was under low usage influence on the whole-plot level but under high usage influence on the sub-plot level (Chapter 4). That explained the lack of a difference in the percentage of total plant cover and soil compaction in the first metre beside high and low usage roads, and the fact that the values recorded there significantly differed from the further distances sampled beside low usage roads. The vegetation study also demonstrated that sub-plot variation in tourism disturbance levels can increase when other types of disturbance exert their influence. This was exemplified by the susceptibility of the naturally disturbed banks of creek beds to further disturbance influences (e.g., increase of non-native species) that had likely originated at the immediate tracksides. In regards to the proper determination of usage intensity levels of the whole-plot units, the thesis demonstrated that the close surroundings need to be accounted for as well. For instance, in the vegetation study the open space of campsites adjacent to the study sites was linked to bird community changes on the study sites. In conclusion, care should be taken that the experimental design of a hi-lo impact study considers all the relevant on- and off-site dimensions of tourism disturbance as well as additive/synergistic effects of other types of disturbance that may affect whole-plot disturbance levels (referred to as 'usage intensity') and/or increase sub-plot variation in disturbance levels.

Finally, a very important decision in a hi-lo impact study concerns the visitor variables to monitor for the determination of usage levels. A novel approach was taken in this thesis by focusing in detail on the process of choosing visitor variables (Chapter 3) to raise awareness that hi-lo impact studies often neglect the visitor monitoring in favour of the resource monitoring, and rely on monitoring visitor numbers without accounting for variation in visitor behaviour. The comprehensive visitor monitoring made it possible to identify the 'culprit' portion of visitors that was responsible for impacts, depending on the access mode to gorges (8.2.2.1). Chapter 3 also presented a novel comparison of the advantages and disadvantages of four visitor monitoring techniques. Other environmental scientists that attempt hi-lo impact studies may benefit from this knowledge as they are not normally trained in visitor monitoring techniques and the existing literature on this topic caters more for continuous, large-scale visitor monitoring programmes carried out by park managers or researchers employed by parks. In fact, the focus of the monitoring conducted for whole tourism planning frameworks may strongly depend on the expertise of the personnel involved. McArthur (1999), for instance, found at Jenolan Caves, New South Wales, where tourism planning frameworks were implemented mainly by environmental scientists, that the environmental monitoring had progressed well but the social research clearly lagged behind. Conversely, on Kangaroo Island, South Australia, where tourism stakeholder organisations were driving the implementation of a tourism planning framework, the market and experiential dimensions had preceded the environmental dimensions.

8.2.1.2 Manipulative studies

The observational approaches taken in this thesis to further our understanding of long-term visitor impacts on the environment were complemented by two manipulative experiments. These were directed towards short-term behavioural impacts of visitor observations on wildlife. The inherent strength of manipulative experiments is that specific disturbance stimuli can be tested, as they are controlled at will, and related to specific short-term behavioural responses in wildlife. Further, variants of visitor behaviour can be rated as more or less intrusive, based on the notion that the greater the perceived risk from the disturbance, the stronger is the elicited response in wildlife (Gill and Sutherland, 2000). Altogether, this reveals cause-response relationships and some of the disturbance mechanisms that underlie long-term changes in wildlife (Green and Giese, 2004).

For instance, valuable insights were gained from the studies on how variants of visitor approach behaviour affect kangaroo behaviour. Kangaroos reacted to an approaching human with vigilance and/or flight, and low-impact types of approach were identified based on a whole suite of response variables such as the length of the flight path. The study also revealed numerous mechanisms, namely certain qualitative differences of the tested approach variants, that were likely responsible for the perceived risk level of the disturbance and consequently the type and magnitude of the response. These included the predictability, continuity, directness and change of direction in the approach and any behaviour added onto the baseline approach behaviour such as talking during the approach. Particular care was taken to clearly define and explain the approach treatments to encounter previous criticism that it is difficult to make generalizations regarding the importance of external variables to wildlife response between studies, partially because they fail to present the necessary detail to make inferences about communalities (Taylor and Knight, 2003a). The nocturnal observation study, too, lead to the establishment of cause-effect-relationships. In particular, different qualities of light were attributed to a gradient in adverse response in numerous mammal and bird species. As such, white and red light of the same photometric intensity elicited similar adverse behaviour, albeit the latter was slightly less intrusive; and the least intrusive and most rewarding observation was attained with a night vision device enhanced by infrared light.

The great challenge for a manipulative visitor impact study is to achieve a realistic simulation of actual visitor-wildlife encounters. The more realistic, the more personalized the educational message will be (8.2.3). This challenge was addressed in the kangaroo study by thoroughly observing tourist approach behaviour prior to the decision on which approach treatments to test. That way a behavioural repertoire of the whole range of approach variants was compiled and even some approach styles, not previously considered (e.g., stop-and-go with switchbacks), were exposed and subsequently tested. However, the richness of such a repertoire normally, as in the kangaroo study, surpasses the number of variants that can be tested. Certain variants need to be selected as treatments; for instance, based on the potential to uncover disturbance mechanisms with them, the frequency with which they occur, the potential for translating the results into instructions on low-impact behaviour and the usefulness of the results for tourism stakeholders. In the kangaroo study, only a selection of the complete repertoire of observed visitor behaviour was presented. Most of the additional behaviour was not examined as the study was scientific in nature and thus intended to uncover disturbance mechanisms rather than test random behavioural variants, even if that could have advanced visitor management too. The most common approach variants among hiking and driving tourists were tested so that final recommendations for low-impact behaviour would be applicable to a wide audience. The tested treatments were also chosen for the ease (e.g., 'stay on-trail/you may go off-trail', 'do not/you may talk') of translating them into guides on low-impact behaviour. The choice of treatments in the nocturnal observation study was largely driven by the initial discussion with tour operators/guides and considerations of what tour experiences may excite visitors (8.2.4). In conclusion, manipulative visitor impact studies benefit from compiling a repertoire of actual visitor behaviour from which to choose treatments that balance scientific and managerial outcomes.

8.2.1.3 The disturbance context

Both the observational and the manipulative visitor impact studies confirmed the need to account for the disturbance context (Steidl and Anthony, 1996). Some of the factors that could modify the susceptibility of flora or fauna to tourism disturbance were controlled for by the study design, such as the observation time (Chapter 6 and 7). A whole range of other factors covaried with the treatment conditions of interest including the species, sex class, weather conditions (wind speed) and vegetation conditions. Several of these factors were identified as influential and some of the underlying causes for their influence were revealed.

A factor that consistently influenced the reaction to the disturbance was the species of the disturbed subject. In Chapter 4 and 5, for instance, disturbance elicited pronounced changes in community composition due to the fact that some plant and bird species were either attracted or repelled from disturbed sites, whilst other species did not exhibit any significant changes in abundance. Some of the underlying reasons for these differences in response were discussed such as ecological properties of invasive, non-native plants vs. native plants or of bird species that preferred to utilize high vs. low habitat strata. In the manipulative studies, too, the species influenced the reaction to the disturbance with Red Kangaroos exhibiting a higher sensitivity than Euros.

A very important habitat factor that modified the susceptibility to tourism disturbance was the vegetation condition. In fact, the bird study demonstrated that the disturbance context can be a more important predictor of the dependent variables than the actual disturbance itself. This was recently found as well by Pavey and Nano (2009). Importantly, vegetation variables moderated some of the negative effects of high usage on birds. For instance, the decrease in the number of individuals recorded along high usage roads was mitigated to insignificant levels at sites with the best developed shrub and tree layer. Similarly, kangaroos that were approached (Chapter 6) reacted less sensitively in areas with better cover. These patterns were attributed to the better protection or more promising resource conditions of better vegetated areas that animals leave reluctantly despite disturbance. Other factors that were remarkably influential were the wind speed and timing of the observation. Generally, calm conditions decreased the susceptibility to the disturbance (Chapter 6 and 7). Viewing/approach of kangaroos was less intrusive/more rewarding in the evening (compared to mornings) and nocturnal observations were less intrusive/more rewarding early at night (compared to late at night). The individual modifying factors were discussed in detail in the respective chapters (5–7).

In conclusion, visitor impact studies should account for the disturbance context because (1) it reduces the variation in the data set and thus increases the probability to expose significant visitor impacts, (2) it aids in developing recommendations for low-impact behaviour (e.g., when and where should visitors observe wildlife without disturbing it profoundly) as the disturbance context may modify the outcome of the visitor-environment interaction, and (3) it can determine which variables (e.g., only the reactive species) to record during a resource monitoring programme. Importantly, not only the main effects should be considered but also interaction effects between the modifying factors, and between them and the visitor disturbance. For instance, in the kangaroo study, the species of the disturbed subject interacted with one of the approach treatment levels: Red Kangaroos had to move further during their flight to gain metres of safety distance, when they were approached off-trail but not on-trail. Euros on the other hand had to move similar distances independent on whether the approach took place on- or off-trail.

8.2.1.4 Management implications of detecting impacts and understanding their causes

The acquired knowledge on visitor impacts along recreational tracks can be incorporated into monitoring programmes of visitor usage and resource conditions which should be integral to tourism planning frameworks. For instance, plant and bird indicator species and other tourism-sensitive variables (such as the percentage of plant cover, etc.) were identified which deserve particular attention in a monitoring programme as they indicate on-site usage conditions and changes over time. Moreover, the findings of this thesis provide some guidance on where, namely within the ecological effect zone, to monitor resource variables. Monitoring programmes then confirm the effectiveness of certain management actions or signal that management needs to be adapted to contain impacts within acceptable limits.

Further, the establishment of cause-response relationships, such as between different access options to gorges and visitor and resource impacts (8.2.2.1), can influence decisions on management strategies/actions for access regulation (8.2.2.2). Finally, knowledge on low-impact visitor behaviour can be implemented into environmental education (8.2.3) and the provision of sustainable tour products (8.2.4).

8.2.2 Regulation of access to visitor areas

8.2.2.1 Effects of different access modes on visitor impacts

A major challenge for land managers is to select the strategies/actions that will be most effective in preventing or mitigating visitor impacts since very few studies have evaluated the relative effectiveness of the possible options. Marion and Farrell (2002) recommended that scientists assist managers in the selection and evaluation of the success of management actions and help establish the causal relationships between usage and impacts. This thesis has assessed the effects of access regulation via the provision of different types of recreational tracks, namely roads and hiking trails, on visitor behaviour and short- and long-term environmental changes in arid-lands gorges. Even though the development of a road and trail system is a common spatial containment strategy (Leung and Marion, 1999) for visitor use, the relative impacts of the different access modes have not been thoroughly examined.

This thesis found that the access mode to a gorge influenced (1) the type, magnitude and spatial distribution of visitor usage, (2) the type, magnitude and spatial distribution patterns of long-term impacts on vegetation and bird communities, and (3) visitor approach behaviour as well as the type and magnitude of associated short-term behavioural responses of individual kangaroos.

The visitor monitoring study substantiated that the type of access to a gorge profoundly influenced visitor usage of gorges: the respective, inter-site differences in usage attained a discrimination of both vehicle and hiker gorge sections into high or low usage but the nature of the usage differences was a function of the access mode. Gorges with vehicle access attracted the main influx of campers and while most people explored these gorges from the beginning to the opposite end only some of multiple sites were selected for camping. In gorges with hiker access the pattern was exactly opposite. Here, within-gorge visitation varied strongly as sites towards the middle or opposite end of the more accessible entrance point were substantially less frequented as visitors usually remained within a few kilometres from where they had accessed a gorge. Camping usage was highly sporadic. For both modes of access, the percentage of stoppers and their stop-time varied distinctly between sites. The fact that some sites were more heavily used than others was expected, as visitors tend to aggregate in the same places (Hammitt and Cole, 1998) for reasons of accessibility/convenience or suitability of sites for various activities. It was a novel finding, however, that the distribution of high usage sites depended on the access mode to gorges: high usage sites were concentrated in the beginning of hiker gorges but scattered throughout the entire length of vehicle gorges. Consequently, in the case of vehicle gorges variation in visitor usage was very small-scale; that is, gorge sections only a few hundred metres apart attracted very different levels of visitor attention—which future visitor monitoring has to account for. The observed changes in visitor behaviour are likely relevant for roads and trails in general, and not exclusively for those traversing gorges, as long as they are accessible only from a few (typically two) sides and provided that the properties of the visitor market (preference for: scenic driving over hiking, shorter hikes in multiple locations rather than long hikes in one location, camping at sites with vehicle access) resemble those ascertained for the Flinders Ranges.

Considering these usage differences as well as other track characteristics, ecosystem edges along roads were subjected to a different disturbance regime than along trails. High usage sites along roads were exposed to camping usage, which is a temporally extended form of usage where visitors engage closely with their environment. This was rare along hiking trails. Further, visitors travelling on roads were manoeuvring vehicles which may be more perilous (vehicle collisions) or perturbing to the environment due to the noise and weight of the vehicle; particularly in high usage sites where stopping or camping visitors frequently seek off-track parking and get in and out of their vehicles. Roads that receive frequent usage require maintenance efforts which typically affect the surroundings more than the maintenance needed for well-used trail sections. Finally, if high usage alters vegetation communities differently along roads than trails (e.g., more pronounced trackside changes and habitat modifications due to campgrounds), then that may have secondary effects on bird communities.

Some or all of these differences between roadsides and trailsides must have led to the differences in tourism impacts (i.e., differences between high and low usage sites and/or between different distances to the trackside) on vegetation communities. Most notably the impacts were greater and more pervasive along roads. Not only did the immediate roadside effects pervade the ecosystem further (by 1–4 m) than trailside effects, but impacts also invaded other disjointed (on average at a 50 m distance) sites with a susceptibility to disturbance. Thus the potential of impacts to self-perpetuate throughout the ecosystem was a function of the access mode. Like vegetation communities, bird communities reflected the different environmental conditions of roads compared to trails. High usage significantly decreased the number of individuals and the species richness of the bird community along roads, whereas along high usage trails only the latter occurred and to a slightly lesser extent. Bird community changes between high and low usage sites were also more pronounced along roads than trails.

Apart from such long-term changes due to different disturbance regimes governing road- and trailsides, the access mode also affected how driving and hiking tourists approached kangaroos during encounters and the short-term responses of the kangaroos. Some on-trail approach styles were more typical for drivers and others were more typical for hikers. These differences accrued mainly because visitors driving a vehicle experience their environment at a greater speed and from a more secluded position. Consequently, many of them overlook wildlife beside roads entirely so that they pass-by without watching, or they spot wildlife too late so that they have to turn back to watch. Moreover, visitors who have already encountered numerous kangaroos along the route may decide that stopping the vehicle for yet another kangaroo is not worth the effort. Drivers are generally less inclined to stop during their approach and typically approach in a continuous motion. Hikers are physically more absorbed by their environment and often notice wildlife from a far distance where much of the observation takes place. If they approach to observe from a closer vantage point, then frequently an intermittent approach is chosen. The off-trail approach always took place by foot and was similarly common among driving and hiking tourists. Given that the kangaroo study only tested selected approach styles, the whole scope of differences in kangaroo response due to different access modes was not evaluated. However, the findings based on the selected approach treatments revealed that the responses to vehicles were less overt than to hikers as fewer kangaroos changed their behaviour and took flight at all. These results, though, were weighed up against the overall traffic volume. Cars might have elicited a milder immediate response from individual kangaroos, but may have had a greater cumulative impact since the volume of vehicle traffic exceeded pedestrian traffic in the study area. Interestingly, stop-and-go motion only mitigated impacts of hiking but not driving tourists. This demonstrates that, if managers provide different access tracks to visitor areas, they need to adapt their recommendations for low-impact behaviour accordingly.

8.2.2.2 Managing access and associated impacts

These findings have practical implications for the management of visitor access. Where road access is granted one can expect a greater anthropogenic disturbance and associated resource impacts than along trails or in trackless areas. The latter was not examined in the thesis but park personnel confirmed cross-country hiking to be of rare occurrence. Impacts that accrue from different access modes to gorges in the Flinders Ranges (or locations with similar usage patterns) may be addressed on (1) the gorge-level through spatial segregation (via zoning and closure), and (2) the site-level (i.e., along access tracks and at nodes where visitors aggregate within gorges) via spatial segregation, containment and configuration strategies (Leung and Marion, 1999) as explained in the following.

Spatial segregation delineates where and what type of usage is allowed via zoning and closure and is a common management practice to protect some resources/areas from visitor impacts or to separate potentially conflicting types of use. Zoning is also a common means of accounting for differences in the impacts associated with different modes of travel/access. A survey of U.S. National Park managers (Leung and Marion, 1999), for instance, revealed that spatial segregation was frequently practiced to protect sensitive areas or to separate incompatible types of activities. A good example where zoning is applied in Australia is the Great Barrier Reef (Driml and Common, 1996). The Great Barrier Reef Marine Park has been zoned into sections that are, for instance, reserved for preservation and scientific research; others are closed seasonally to protect nesting turtles and birds and in some zones fishing is allowed; some areas are open to non-consumptive tourism activities similar to terrestrial National Parks in Australia. Control on compliance with the zoning restrictions is practiced through a system of permits which operators need to obtain on the grounds that they abide by permit conditions.

Management in the Flinders Ranges that pursues spatial segregation of different access options could vary the ratio between gorges (or sections) that contain a road, a trail or no track. Given the expected gradient in impacts one can decide which type of access (or not) is acceptable in the different gorges (or sections) and thus balance environmental protection with visitor needs. Further, different visitor expectations can be accounted for; some visitors may prefer the solitude along hiking trails and others enjoy the comfort and safety element of travelling along roads. The strategic placement of zones where access is restricted is critical as it affects visitor compliance and satisfaction. Generally, a local prohibition on motor vehicles or any access is more easily justified if there are other parts where public access and motor vehicles are permitted. Maintaining, for instance, the farther sections of a hiker gorge (towards the less favoured access point) trackless should meet acceptance among the public as visitor demand to travel in these areas is low. However, the convenience of protecting areas that are not in demand by visitors should not distract from protecting biologically important areas.

Even though large parts of wilderness should remain trackless, tracks need to be built where use is consistent to avoid the development of informal tracks (Hammitt and Cole, 1998). The provision of tracks constitutes the most common form of spatial containment applied in protected areas, namely the concentration of visitor usage on-track (Leung and Marion, 1999). Wherever access tracks are built they should adhere to optimum track design to facilitate on-trail and to prevent off-trail usage. Such an educated choice in the layout of recreational facilities is referred to as 'spatial configuration' (Leung and Marion, 1999). For instance, to minimize soil erosion, trail grades should be kept below 10% and trails should be orientated at an oblique angle to the prevailing slope (reviewed in Marion and Leung, 2004). Well-designed trails prevent the pervasion of usage in off-track areas, trail braiding and soil erosion. Tracks in poor condition may result from a bad choice in location, design failures, a lack of maintenance, or from overuse (Hammitt and Cole, 1998; Monz, 1999).

Different access tracks are prone to suffer from different problems. The choice to build a road (and its various forms of improvement) needs to be carefully deliberated, as roads and the maintenance that they require can be quite disturbing to the environment compared to trails (Newsome et al., 2005). Thus even without the usage that typically follows the establishment of a road, the physical properties of the road are more intrusive. The planning of roads also needs to address additional challenges such as permitting wildlife to cross safely. Importantly, access roads near campsites require particular attention as campsite impacts usually affect the access tracks leading to and from the campsites (Hammitt and Cole, 1998), as seen from the impacts that were identified in this thesis.

Controlling visitor behaviour during wildlife encounters from roads and trails can be achieved by zoning on the gorge-level (which determines the principal transport and approach style of visitors) or on the site-level. The latter is often thought to be achieved in the form of minimum approach distances between wildlife and visitors. In the kangaroo study, however, it was argued that the study area was too big for constant surveillance of visitor approach distances, and there were few 'hotspots' where kangaroos aggregated, so they could be protected by fences constructed at a pre-determined distance. The effectiveness of prescribing a minimum approach distance and promoting them in educational programs was questioned as people may have difficulties to reliably estimate these distances. Therefore to control visitor behaviour during wildlife encounters environmental education (8.2.3) seems the most promising tool.

In the areas examined in this thesis, the construction of roads was succeeded by the development of numerous camp/picnic sites, most of them being unofficial. One intervention to this process would be to generally prohibit camping in gorges. It is indeed common practice to limit overnight usage and allow only for day use in many protected areas worldwide as camping is commonly perceived as a particularly destructive type of use. Marion et al. (1993: in Hammitt and Cole 1998), for instance, found that two-thirds of the surveyed U.S. National Parks that practiced some limitations in backcountry use, only limited overnight camping use. However, there are not enough accommodation options available in the Flinders Ranges to compensate for a prohibition in camping use. Further, such a restriction would be a major hurdle for attracting sufficient numbers of visitors to the area as most of them come to experience the outdoors by camping. Furthermore, the sheer size of the area makes reinforcement of such rules virtually impossible. Therefore, the only feasible option is to discourage or prohibit camping (and to a certain degree also stopping) in particular areas (e.g., those critical to flora and fauna such as water holes) and encourage it elsewhere (Leung and Marion, 1999). In particular, camping usage should concentrate at a few places that are preferably near the access points to gorges and, as soon as wild camping self-propagates to other sites, it should be controlled. If wild campsites continue to develop visitors need to be deterred and sites rehabilitated. The latter ensures that the naturalness of the site is regained more rapidly. Visitor usage causing resource changes in hiker gorges, in contrast, does not show such a strong potential for self-propagation as visitors prefer short to medium hikes and thus will remain within the beginning to middle parts of gorges, even in the future.

At the same time, while some sites are closed, other designated camp sites need to be made attractive and obvious to the visitor. Spatial containment strategies can aim to direct stopping and camping visitors to these designated locations, for instance, by providing parking bays or information signs along the route (Pearce-Higgins and Yalden, 1997; Pearce-Higgins et al., 2007). Fire grates and picnic tables in designated areas can also result in aggregation of visitors and keep other areas undisturbed (Leung and Marion, 1999). However, such actions are somewhat contentious and must be subtle enough so as not to detract from the wilderness experience by creating obtrusive infrastructure.

Finally, a judicious set-up of the designated camp/picnic sites, again a form of spatial configuration, can prevent further impact. The areal extent of usage within the site premises, for instance, may be limited when fire grates, tables, ablutions, flat and well-drained campsites and shade persuade visitors to use the designated area rather than the immediate surroundings (Hammitt and Cole, 1998). A clear demarcation to the surroundings is also key to help constrain site expansion in the long-term. Marion and Farrell (2002), for instance, found that hillside campsites contained usage well and that the steep off-site topography was more effective than management regulations or educational messages at containing usage on-site. The findings from the bird study of this thesis suggested that the creation of open space needs to be minimized. This could be achieved by creating little secluded camping bays surrounded by vegetation rather than one big, open campsite space which would also contribute to privacy and therefore increase the chance that solitude-seeking visitors share campsites.

8.2.3 Environmental education based on visitor impact research

Environmental education is crucial for managing visitor impacts as it disseminates knowledge acquired in visitor impact research and can inform visitors (or tourism operators, etc.) about (1) the range of impacts of their own actions, (2) alternative low-impact behaviour, (3) the compatibility of low-impact behaviour and satisfying viewing experiences, (4) the reasons for particular management actions, and additionally (5) it can abate unnecessarily high visitor expectations. In a large protected area, where visitor compliance is virtually impossible to monitor, effective visitor education to stimulate self-restricted behaviour is particularly important. Alcock (1991) even emphasized that education is the most important wildlife management strategy because it decreases adverse visitor behaviour which often arises more from ignorance than deliberate destruction. Likewise, Hammitt and Cole (1998) argued that, as long as impacts are not unavoidable (e.g., plant removal during construction of infrastructure), education can alleviate many problems otherwise caused by illegal, careless, unskilled, and uninformed actions. Surprisingly, environmental education is a yet underutilised management strategy (Orams, 1996a, b). However, not all education initiatives are successful and it takes some strategy to increase their success. Orams (1997: 295), for instance, tested the effectiveness of an education programme for managing tourists at an Australian holiday resort where visitors can interact with wild dolphins. His findings suggest that certain education strategies are particularly powerful at "turn(ing) visitors into 'greenies'". Accordingly, a crucial component of the programme is to describe the specific environmental problems/issues that are relevant to the particular tourism experience and then suggest simple solutions and actions for each visitor to take against these problems.

This thesis described a broad range of environmental impacts that are induced by tourists travelling along roads and trails in a semi-arid to arid landscape. However, even though tourists have the cognitive ability to notice and distinguish their impacts (Hillery et al., 2001), they are often not aware how strongly their activities affect wildlife and their habitat, and so greatly underestimate their own impact (Taylor and Knight, 2003b). There is also a clear subjectivity as to what type of impacts are (or are not) noticed. The visitor profile study of the thesis demonstrated, for instance, that visitors were aware of obvious impacts like littering but tended to be oblivious to more subtle (at least to the untrained observer) impacts like the invasion of weedy plants. Similarly, studies on human perception of the environment revealed that the ability to notice 'wear-and-tear' impacts is less developed than the sensitivity to impacts resulting from overt pollution (litter, human waste) and vandalism (Marion and Lime, 1986). The media coverage of these topics may be one factor that controls the development of such differing sensitivities in perception. For example, whilst the majority of respondents to the visitor profile survey rated the overall impacts of tourism in the Flinders Ranges as medium to strong, the majority of respondents to the nocturnal observation survey (Chapter 7) assumed impacts of night-time observation of wildlife to be low or very low. Likely, the consequences of nocturnal observation are not as well-known because research on this topic is sparse and so is the coverage in the media compared to general tourism impacts.

If people understood what impact they have on wildlife in the short- and long-term, then they may be more likely to comply with low-impact behaviour; particularly if they are instructed on behavioural alternatives. Visitors that intend to go camping in the Flinders Ranges gorges, for instance, could be informed about their impacts on vegetation and bird communities and motivated to avail themselves of the designated campsites rather than unofficial sites, as a means of containing the areal extent of impacts. An explanation of the consequences of approaches by humans to kangaroos should be accompanied with instructions on how to approach least intrusively as well as advice on the most favourable environmental viewing conditions. Importantly, the visitor surveys and observations performed for this thesis allow managers to personalise the educational message. This is another crucial factor that increases the chance of successfully motivating environmentally responsible behaviour (Orams, 1997). Hikers, for instance, may need to be convinced that their actions can perturb kangaroos more strongly than cars as kangaroos have experienced foot approach, as a major threat from ambulatory hunters for tens of thousands of years. This is not immediately intuitive since cars are noisier, larger and approach more rapidly, which species that are not sensitized to humans afoot may perceive as more disturbing.

Importantly, people need to be informed that their behaviour also affects their own observation experience. This may be the easiest way to encourage visitor compliance. Both the kangaroo and the nocturnal observation study gave clear indications on when, where and how to observe particular wildlife in order to be less intrusive as compared to alternative techniques. When wildlife is less disturbed, they normally allow for closer and longer-lasting observations that are more rewarding to the tourist. Further, evidence was presented against the fallacy that the best observation is always attained through the most direct forms of approach (e.g., direct off-trail approach) and overt illumination (e.g., white spotlights). Visitors that are educated on these issues should be less likely to attempt high-impact behaviour in the vain attempt of improving the experience.

Even though visitors can be motivated to behave in a self-responsible manner, management actions (such as the ones devised in 8.2.2.2) may have to be taken at times. To increase support and understanding among the public, explanations should be given about the reasoning behind these actions because they may not be well perceived by visitors and contribute as much or more to their dissatisfaction than the degradation of resources. For instance, visitors that come to the Flinders Ranges to enjoy the solitude and freedom, for which the region is marketed, may be disappointed to find out that they are not allowed to camp wherever they like. This may frustrate them more than the increase in non-native plants that they potentially facilitate. As a consequence, they may report to others that local park management is unnecessarily restrictive, simply because visitors are not informed about the reasons for the restrictions. For the same reason, they may also refuse to abide by park rules. Thus, land managers need to be aware that both the degradation of environmental conditions or actions taken against them can compromise the reciprocal relationship (8.1) between visitors and their natural destinations.

Another means to increase visitor satisfaction, apart from keeping visitors informed about reasons for regulations, is to manage unnecessarily high expectations. According to the survey respondents on night-time observation of wildlife, the level of satisfaction depended on the extent to which their expectations would be met. Like other customers, tourists have formed expectations about the wildlife they will see and the tour experience itself. These need to be met or exceeded for the contented customer to promote the product to others (Söderlund, 1998). The findings from the kangaroo and nocturnal observation studies could be employed to inform visitors on what they can realistically expect to see under different observation conditions. This will reduce the inconsistency between expectations and actual experience, which should lead to a more satisfied visitor who is less likely to attempt intrusive actions to improve the experience.

8.2.4 Sustainable tour experiences

Probably the most important element of a successful environmental education programme is to give visitors the opportunity to take actions 'on the spot' (Orams, 1997). The participation in activities based on the framework for a night-time observation tour proposed in this thesis allows visitors to act on the motivation created by the educational content of the tour experience. Further, whilst it is more difficult to animate visitors to adhere to a certain code of conduct when they visit natural areas or observe wildlife on their own, tour operators that provide specially designed low-impact wildlife tours have the opportunity to actively showcase low-impact behaviour. The demand for these tours is substantial as travellers seek the assistance (e.g., expertise and safety) provided by tour operators and guides in their aspiration to view unique Australian wildlife in their natural habitat (Wolf, pers. obs.). Thus, many private landowners have caught up with this potential of low-impact tourism and offer guided 'eco'-tours by now.

Even though tour operators would likely benefit from the cooperation and knowledge of scientists in their desire to provide tours that are minimally intrusive to wildlife, few of them ask scientists for help. Rodger et al. (2007), for instance, surveyed wildlife tour operators in Tasmania, Western Australia and the Northern Territory to assess the importance of science in their business and found that few tour operators cooperate with scientists in protecting wildlife observed on their tours. Where scientists were involved, they mainly contributed general information and interpretation but none of them conducted impact assessments of the observations on wildlife undertaken.

In contrast, the night-time observation study of this thesis is an original demonstration of how wildlife tours/tour operators and participants can benefit from scientific assessments and how science can be advanced from research on wildlife tours. The study employed a three-tier approach to the tour design: (1) initial input from tour operators/guides, (2) assessment of visitor needs via an interview-based questionnaire and (3) examination of the wildlife response to various observation conditions. The initial (informal) discussions with the tour operators/guides were essential in guiding the choice on the variants of the observation behaviour to be tested. For instance, it was remarked upon that hiking experiences and stationary observations at water tanks might be the best platform choices to view wildlife as they take visitors out of the car and into the environment. Further, one guide explained that he had trialled using a bat detector during his tours which apparently had captured considerable visitor interest. However, the detector had only been employed to make echolocation signals audible. This sparked the decision to exploit the potential of such a gadget more by using it for the identification of different species of bats as well as the assessment of bat responses to different observation conditions. Finally, it became apparent that tour operators/guides were most concerned about the use of bright lights as they feared or had witnessed adverse responses of nocturnal wildlife to them. Consequently, an affordable non-intrusive alternative to conventional spotlights, namely the night-vision device, was researched in the study. The visitor survey, on the other hand, provided valuable insights on the desired qualities of the most essential tour features as well as features of the wildlife experience. This knowledge was used to evaluate the tour design from a tourist perspective (i.e., to maximize visitor satisfaction). Finally, the core of the study was the assessment of wildlife responses to different observation conditions. The knowledge acquired from this assessment was of most interest to the scientist (as cause-effect relationships were established) but also encompassed the main information for identifying low-impact, yet satisfying observation conditions. Thus all the components of the study's methodology were crucial for the final recommendation of the tour design.

In conclusion, the benefits of this comprehensive approach are mutual. Tour operators that offer this kind of experience will likely achieve visitor satisfaction and protect the resources upon which their income depends. Also, tours that have been scientifically tested for adverse environmental effects and any such effects have been mitigated gain credibility as being a truly eco-friendly venture, which enhances their marketing potential. Visitors benefit from the enhancement of current viewing opportunities, protection of wildlife for future viewing and tour designs that cater for their needs. Scientists profit from research opportunities that advance knowledge in recreation ecology and tourism science. Finally, wildlife gains much-needed protection by the means of an industry that strives to be sustainable.

8.3 Limitations of the thesis

Some limitations of the individual studies (Chapter 3–7) of the thesis were discussed in the respective 'Conclusions' and are not reiterated here. Notwithstanding, there were other factors that limited the scope of the overall thesis.

Firstly, due to time restrictions, this study examined only a sample of all possible effects of nature-based tourism activities in the Flinders Ranges. Likely many more components of the natural environment are affected and many more adverse reactions are likely to occur. However, a choice was made to focus on ecosystem components that are important from an ecological perspective and from a visitor perspective—consistent with the concurrent theme of accounting for both. Further, given the complexity of the thesis and the availability of time, ecosystem components had to be chosen for which sampling methods are well-established and which are reasonably abundant to ensure sampling efficiency.

Secondly, the data had to be collected within the relatively short time-frame of a Ph.D. thesis. Certainly, long-term data would be of great interest in all of the conducted studies to infer trends over time or over several seasons. Consequently, the results are most representative for the time/seasons in which they were sampled. The visitor data, for instance, were collected within the shoulder and peak tourist season in the Flinders Ranges. Visitors in the off-season may behave/disperse differently. However, impacts were related to visitation patterns when usage was most intense, which seems a logical choice, and proxy variables served as indicators for past usage. Again, these seasons were also chosen to maximize the sampling efficiency of visitor surveys.

Finally, a great amount of other visitor behaviour needs to be investigated to capture the full range of visitor impacts. For instance, the visitor observations in the kangaroo study exposed many behavioural variants that were not examined further; instead the most common behaviour was researched to extend the applicability of the results to as wide an audience as possible. Further, it seemed more insightful to broaden the scope of the overall thesis than to expand extensively on each, singular topic. Instead the thesis encompasses a progression from observational to manipulative studies and develops a framework for a sustainable tour design. That way a strategic direction was given for future visitor impact research to fully capitalize on the various methods available for study.

8.4 Future research directions

Impacts of nature-based tourism activities in the arid lands of Australia are little understood. This thesis has generated knowledge on short- and long-term effects of the most common visitor activities (driving, hiking, camping) in the Australian Outback on important ecosystem components (such as vegetation, birds, kangaroos and bats). Related research topics that deserve increased attention in the future concern the major relationships between visitor usage and environmental impacts as introduced by the nature-based tourism framework in Chapter 1 and as expanded upon in the following:

(1) Research is needed on visitor impacts on cryptic species such as reptiles or insects that are not the primary focus of visitors to Outback Australia or most other natural destinations. So far, recreation ecology research has focused on the 'big' and attractive species, primarily mammals and birds, which receive much attention by tourists and thus have a great economic value to the tourism industry. The bias towards "valued ecosystem components" (Ward and Jacoby, 1992: in Hughes and MacBeth, 2002) or a general "taxonomic chauvinism" that may favour the publication of studies on 'popular' organisms (Bonnet et al., 2002: 1) currently limits our understanding of the full scope of tourism impacts which likely extend to these other, neglected organisms.

(2) Similarly, there is a great gap in knowledge on the more subtle, indirect and/or complex effects of tourism impacts. Several were addressed in this thesis (but could be expanded on further) such as the additive/synergistic effects of multiple types of disturbance (Chapter 4) or tourism-induced changes in one ecosystem component that

affect other components (e.g., vegetation changes that impact on bird communities, Chapter 5).

(3) The gap between short-term physiological and behavioural effects in wildlife and the potentially associated long-term effects for the individual, population and species needs to be bridged. This is a very important albeit challenging task that could lead to a greater clarification that short-term changes in wildlife in response to tourism activities are indeed a welfare concern. However, as long as this research is underrepresented it seems wise to adopt a precautionary principle and view these short-term changes as an indication of harmful longer-lasting consequences.

(4) Behavioural repertoires of visitors during wildlife encounters need to be researched and communalities exposed that are independent of the disturbance context; that is, the most common behavioural components of visitor behaviour that occur in a particular situation (e.g., during encounters with free-ranging wildlife during travels in vehicles along roads, during encounters with habituated wildlife that may allow handfeeding, etc.) need to be identified. Next, the impacts of these behavioural variants on different wildlife species need to be assessed so that more widely applicable disturbance mechanisms can be postulated.

(5) More knowledge is needed on the factors that intervene in the relationship between visitor usage and the environmental response, such as the disturbance context. The wide range of tourism situations with their great variety of factors that potentially modulate the outcome of this relationship has been a great hurdle for recreation ecologists in finding general disturbance principles. Studies that focus on the disturbance context rather than treating it as a nuisance will be important. For instance, the same type of tourism disturbance could be tested under varying environmental conditions. Research on the disturbance context has great potential to improve environmental education as it often allows managers to give recommendations on when and where to view without causing much perturbation and achieving more satisfaction.

(6) A better understanding of the underlying reasons as to why a particular factor of the disturbance context (such as the species of the disturbed subject) modifies the usage-response relationship is essential. This, for instance, could help uncover mechanisms that drive sensitive species from impacted areas or attract others and therefore, allows predictions for a species with similar properties, even if its response was not examined before.

(7) A highly pressing issue in regards to the disturbance context is the habituation of wildlife. Almost no research exists on this topic. To resolve the question if, when and why habituation to disturbance occurs (including why different species habituate more readily than others to human presence) could greatly advance knowledge on low-impact behaviour as well as basic behavioural ecology (e.g., optimal foraging theory, vigilance behaviour). This knowledge would also help to predict which species are likely to be most sensitive to tourism in different regions of Australia and elsewhere.

(8) There are many more management interventions whose effectiveness needs to be gauged (also in terms of visitor compliance) so land managers can make informed decisions on what the appropriate strategies/actions are in the respective situations. Further, the effectiveness of implementing multiple management actions simultaneously needs to be considered to resolve the question as to what combination gains the maximum effect.

(9) Finally, as recreation ecology investigates the interface between tourists and the environment, it is strongly recommended to conduct more research on how to improve visitor experiences so that they marry a sustainable resource usage with a sustainable (satisfying) visitor experience. Many tour experiences could profit from the three-tier research approach that was employed for the nocturnal wildlife observation research. These tests can be expanded at will to answer very detailed questions on optimal design such a the best tour group size, the best frequency for repeating the tour at the same location without deterring wildlife, and necessary modifications depending on different tour group compositions (e.g., with clients of different age classes). The systematic collection of knowledge from experienced tour guides on how to behave during wildlife encounters could provide valuable complimentary information in this sector of research.

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Appendix 1

Table A 1.1. (a) Vehicle and (b) hiker gorges (presented in Fig. 2.2) and the approximate geographical location of the gorge sections studied in Chapter 3–5.

(a) Vehicle gorges	Latitude	Longitude	(b) Hiker gorges	Latitude	Longitude
Brachina	S31.33310	E138.57692	Chambers II	S30.95057	E139.22821
Brachina	S31.33243	E138.57248	Chambers II	S30.95655	E139.23089
Brachina	S31.33281	E138.57044	Chambers II	S30.95803	E139.23885
Brachina	S31.33407	E138.56880	Chambers II	S30.95951	E139.24146
Brachina	S31.33638	E138.56293	Chambers II	S30.95738	E139.24987
Brachina	S31.33921	E138.56589	Weetootla	S30.49637	E139.25245
Brachina	S31.34181	E138.56604	Weetootla	S30.49518	E139.24946
Brachina	S31.34380	E138.55955	Weetootla	S30.48996	E139.24611
Brachina	S31.34130	E138.55370	Weetootla	S30.48775	E139.24319
Brachina	S31.33744	E138.53884	Weetootla	S30.48555	E139.24260
Brachina	S31.33572	E138.53383	Weetootla	S30.48203	E139.23990
Brachina	S31.33534	E138.53703	Weetootla	S30.47883	E139.24173
Brachina	S31.33902	E138.54303	Weetootla	S30.47574	E139.24406
Brachina	S31.33781	E138.54639	Weetootla	S30.47373	E139.24903
Brachina	S31.33887	E138.55213	Weetootla	S30.47147	E139.24924
Chambers I	S30.94278	E139.19566	Weetootla	S30.46820	E139.24954
Chambers I	S30.94561	E139.19896	Weetootla	S30.46647	E139.24804
Chambers I	S30.94727	E139.20279	Weetootla	S30.48445	E139.24052
Chambers I	S30.94696	E139.20509	Willkawillina	S31.26770	E138.87529
Chambers I	S30.94736	E139.20781	Willkawillina	S31.26896	E138.88243
Chambers I	S30.94763	E139.20975	Willkawillina	S31.27248	E138.88022
Chambers I	S30.95097	E139.21344	Willkawillina	S31.28009	E138.88022
Chambers I	S30.94898	E139.21227	Willkawillina	S31.28424	E138.87596
Chambers I	S30.95235	E139.21447	Willkawillina	S31.28669	E138.87654
Chambers I	S30.95244	E139.21834	Willkawillina	S31.29370	E138.87783
Chambers I	S30.95309	E139.22266	Willkawillina	S31.29408	E138.88276
Chambers I	S30.95246	E139.22622	Willkawillina	S31.29861	E138.88328
Parachilna	S31.13260	E138.54105	Willkawillina	S31.29616	E138.88666
Parachilna	S31.13332	E138.53465	Willkawillina	S31.29855	E138.89660
Parachilna	S31.13323	E138.52982	Willkawillina	S31.29760	E138.89910
Parachilna	S31.12784	E138.52373	Willkawillina	S31.30056	E138.90160
Parachilna	S31.12914	E138.51649	Willkawillina	S31.29917	E138.90498
Parachilna	S31.12553	E138.50865	Willkawillina	S31.29785	E138.90874
Parachilna	S31.12710	E138.50644	Willkawillina	S31.29783	E138.89119
Parachilna	S31.12766	E138.50238	Bunyeroo	S31.41644	E138.55394
Parachilna	S31.12948	E138.49810	Bunyeroo	S31.41633	E138.55023
Parachilna	S31.13038	E138.49621	Bunyeroo	S31.41528	E138.54818
Parachilna	S31.13119	E138.49359	Bunyeroo	S31.41623	E138.54623
Parachilna	S31.12636	E138.51423	Bunyeroo	S31.41469	E138.54597
Parachilna	S31.13098	E138.52882	Bunyeroo	S31.41327	E138.54414

Table A 1.2. Questionnaire-based, face-to-face visitor survey discussed in (a) Chapter 2 and (b) Chapter 3 to construct a profile of visitors to the Flinders Ranges and to delineate usage patterns of gorges.

(a) Chapter 2: Visitor profile study

Questions on demography

→ What is your normal residential address?
- Country (if not Australia)
- State (in Australia)

→ How would you describe your travel party (i.e., who is travelling with you) in terms of the biggest unit? For instance, if you are travelling together with your partner but as part of a tour group, select 'tour group' instead of 'adult couple'.
- Unaccompanied
- Adult couple
- Family (parent(s) and child(ren))
- Friends/relatives
- Business associates
- Tour group
- Other (please, specify)

→ How many members are in your travel party?

→ Which of the following age and gender categories do you fit into?
- male
  - 0–20
  - 21–30
  - 31–40
  - 41–50
  - >50
- female
  - 0–20
  - 21–30
  - 31–40
  - 41–50
  - >50

Questions on the trip itinerary and trip preparation

→ Other than this trip, have you ever visited the Flinders Ranges before?
- Yes
- No

→ If yes, which time of the year (state month)?

→ If yes, how many days have you spent there?
- 1–3
- 4–7
- 8–10
- 11–14
- >14

→ Are you planning to visit the Flinders Ranges in the future again?
- Yes
- No
- Maybe

→ If yes, which time of the year (state month)?

→ How many days do you plan to spend in the Flinders Region during your current visit?
- 1–3
- 4–7
- 8–10
- 11–14
- >14

→ What was your main source (specify only 1) of information to prepare for this trip?
- Newspaper/magazine/advertisement
- Brochure at hotel/accommodation
- Guide book
- Travel agent
- Internet (website)
- Radio/TV
- Word-of-mouth
- Clubs/societies
- Visitor information centres
- Previous experience
- Other (please, specify)

Questions on trip incentives

→ Of the following motivations select those that were an important incentive for you to come to the Flinders Ranges (multiple answers).
- Physical exercise
- Relaxation
- Solitude
- Socialising with family/friends/others
- Enjoyment of nature/camping/being outdoors
- Geology/landscape/scenic views
- Educational experience
- Aboriginal heritage and art
- Photography and/or art (paintings, etc.)
- Vegetation/wildflowers
- Wildlife (in general)
- Birds
- Kangaroos and wallabies (e.g., Yellow-footed Rock Wallaby)
- Reptiles
- Other (please, specify)

Questions on activities

→ Estimate the percentage of your daylight hours (from 7:30 am till 5 pm) in the Flinders Ranges that you spend with hiking.

→ Estimate the percentage of your daylight hours (from 7:30 am till 5 pm) in the Flinders Ranges that you spend with scenic driving.

→ How long are the hikes/walks that you plan to do during your trip?
- ≤1 km
- 1 km < x ≤ 3 km
- 3 km < x ≤ 5 km
- 5 km < x ≤ 10 km
- >10 km

→ Would you go camping in a location that can only be reached by foot (i.e., more than 500 m away from your vehicle)?
- Yes
- No

Questions on environmental engagement and tourism impact knowledge

→ Do you support environmental organizations (multiple answers)?
- Via membership in environmental organizations.
- Via donations.
- Via volunteer work.
- I am more active in supporting other 'good causes'.

→ How would you rate the negative influence of tourism on the environment in the Flinders Ranges?
- 1 = Very low
- 2 = Low
- 3 = Medium
- 4 = High
- 5 = Very high

→ What negative impacts do you think tourism can have on the environment in the Flinders Ranges (multiple answers)?

→ How would you rate your knowledge/level of information about tourism impacts on the environment?
- 1 = Very low
- 2 = Low
- 3 = Medium
- 4 = High
- 5 = Very high

(b) Chapter 3: Visitor monitoring study

→ What proportion of your stay will you spend in the gorges of the Flinders Ranges?
- None
- Some (25 %)
- Half
- Most (75%)
- All of it

Note: The rest of the (b)-questions are listed in Table 3.4.

Appendix 2

Table A 2.1. Plant taxa identified at the study sites in Chapter 4 that were not listed (Table 4.2) as indicator species of high or low tourism usage sites next to roads or trails in arid-lands gorges.

Abutilon cryptopetalum
Abutilon leucopetalum
Acacia continua
Acacia ligulata
Acacia salicina
Acacia tetragonophylla
* *Acetosa vesicaria*
Acacia victoriae ssp.
Alectryon oleifolius ssp.
Arthropodium strictum
Boerhavia dominii
Bromus sp.
Callitris glaucophylla
Calotis hispidula
* *Carrichtera annua*
Casuarina pauper
Chamaesyce drummondii
* *Citrullus lanatus*
Commicarpus australis
Cynanchum floribundum
* *Datura leichhardtii*
Dissocarpus paradoxus
* *Dittrichia graveolens*
Dodonaea lobulata
Dodonaea microzyga var.
Dodonaea viscosa ssp.
Enchylaena tomentosa var.
Enneapogon avenaceus
Enneapogon polyphyllus
Eremophila alternifolia
Eremophila longifolia
Eremophila oppositifolia var.
Eucalyptus camaldulensis var.
Eucalyptus socialis
Exocarpos aphyllus
Glycine rubiginosa
Goodenia fascicularis
Goodenia pinnatifida
Gossypium sturtianum var.
Hakea ednieana
Hakea leucoptera ssp.
Heliotropium asperrimum
* *Heliotropium curassavicum*
Hypoxis glabella var.
Ixiochlamys cuneifolia
Juncus sp.
Leiocarpa leptolepis
Lotus cruentus
Lycium australe
Maireana astrotricha
Maireana brevifolia
Maireana pyramidata
Maireana sedifolia
Malvastrum americanum var.
Melaleuca dissitiflora
Melaleuca glomerata
Minuria cunninghamii
Myoporum montanum
* *Nerium oleander*
* *Nicotiana glauca*
Nitraria billardierei
Olearia pimeleoides ssp.
Osteocarpum acropterum var.
Oxalis perennans
* ***Oxalis pes-caprae***
Petalostylis labicheoides
Pimelea microcephala ssp.
Pterocaulon sphacelatum
Ptilotus exaltatus var.
Ptilotus polystachyus var.
* *Ricinus communis*
Salsola kali
* *Schinus molle*
Sclerolaena limbata
Sclerolaena obliquicuspis
Sclerolaena tricuspis
Senecio magnificus
Senna artemisioides nothossp. *artemis.*
Senna artemisioides nothossp. *coriacea*
Sida corrugata var.
Sida cunninghamii
Sida petrophila
* *Sisymbrium erysimoides*
* *Solanum nigrum*
Solanum petrophilum
Solanum sturtianum
Swainsona formosa
Tetragonia tetragonioides
Trachymene glaucifolia
* ***Tribulus terrestris***
Triodia irritans
Wahlenbergia communis
Xanthorrhoea quadrangulata
Zygophyllum aurantiacum ssp.
Zygophyllum prismatothecum

*Non-native species; denoted in bold if 'proclaimed' in South Australia; i.e., landholders are legally obliged to control them (http://www.wmssa.org.au/weeds.htm).

Appendix 3

Table A 3.1. Bird taxa identified at the study sites in Chapter 5 that (according to a chi-square test and subsequent analysis of standardized residuals) showed no significant preference for high or low tourism usage sites ('tolerant' of disturbance) next to (1) roads or (2) trails in arid-lands gorges. Some species were not sighted at either roads or trails, or they were sighted but their counts were not analysed due to low abundance. Also listed is the vertical strata in which a species was viewed in the majority of sightings.

Scientific name	Common name	Strata choice	(1) Next to roads	(2) Next to trails
Acanthagenys rufogularis	Spiny-cheeked Honeyeater	Low trees	Tolerant	Tolerant
Lichenostomus penicillatus	White-plumed Honeyeater	Low trees	Tolerant	Tolerant
Artamus cyanopterus	Dusky Woodswallow	High trees	Tolerant	Tolerant
Todiramphus sanctus	Sacred Kingfisher	High trees	Tolerant	Not tested
Smicrornis brevirostris	Weebill	Low trees	Tolerant	Tolerant
Rhipidura leucophrys	Willie Wagtail	Ground	Tolerant	Tolerant
Hirundo nigricans	Tree Martin	Air, cliff	Tolerant	Tolerant
Egretta novaehollandiae	White-faced Heron	Ground	Tolerant	Not tested
Falco cenchroides	Nankeen (Australian) Kestrel	Air, cliff	Tolerant	Tolerant
Phaps chalcoptera	Common Bronzewing	Ground	Tolerant	Tolerant
Elseyornis melanops	Black-fronted Dotterel	Ground	Tolerant	Not tested
Pomatostomus superciliosus	White-browed Babbler	Ground	Tolerant	Tolerant
Lichenostomus virescens	Singing Honeyeater	Low trees	Tolerant	Tolerant
Colluricincla harmonica	Grey Shrike-thrush	Shrub	Tolerant	Tolerant
Aquila audax	Wedge-tailed Eagle	Low trees	Tolerant	Tolerant
Aphelocephala leucopsis	Southern Whiteface	Shrub	Tolerant	Tolerant
Dacelo novaeguineae	Laughing Kookaburra	High trees	Not tested	Tolerant
Rhipidura fuliginosa	Grey Fantail	Shrub	Not tested	Tolerant
Falco longipennis	Australian Hobby	Air, cliff	Not tested	Not tested
Milvus migrans	Black Kite	Air, cliff	Not tested	Not tested
Chalcites osculans	Black-eared Cuckoo	High trees	Not tested	Not tested
Coracina novaehollandiae	Black-faced Cuckoo-shrike	Low trees	Not tested	Not tested
Accipiter fasciatus	Brown Goshawk	Air, cliff	Not tested	Not tested
Neophema elegans	Elegant Parrot	Low trees	Not tested	Not tested
Hieraaetus morphnoides	Little Eagle	Air, cliff	Not tested	Not tested
Psephotus varius	Mulga Parrot	Shrub	Not tested	Not tested
Cracticus nigrogularis	Pied Butcherbird	Shrub	Not tested	Not tested
Pyrrholaemus brunneus	Redtroath	Shrub	Not tested	Not tested
Cincloramphus mathewsi	Rufous Songlark	Shrub	Not tested	Not tested
Hirundo neoxena	Welcome Swallow	High trees	Not tested	Not tested
Haliastur sphenurus	Whistling Kite	Air, cliff	Not tested	Not tested
Tachybaptus novaehollandiae	Australasian Grebe	Ground	Not tested	Not sighted
Cincloramphus cruralis	Brown Songlark	Shrub	Not tested	Not sighted
Falco peregrinus	Peregrine Falcon	Air, cliff	Not tested	Not sighted
Taeniopygia guttata	Zebra Finch	Shrub	Not tested	Not sighted
Corvus mellori	Little Raven	High trees	Not sighted	Tolerant
Pomatostomus ruficeps	Chestnut-crowned Babbler	Ground	Not sighted	Tolerant
Melithreptus brevirostris	Brown-headed Honeyeater	Low trees	Not sighted	Not tested
Melopsittacus undulatus	Budgerigar	High trees	Not sighted	Not tested
* *Sturnus vulgaris*	Common Starling	Shrub	Not sighted	Not tested
Lichenostomus fuscus	Fuscous Honeyeater	Low trees	Not sighted	Not tested
* *Passer domesticus*	House Sparrow	Shrub	Not sighted	Not tested
Corvus bennetti	Little Crow	High trees	Not sighted	Not tested
Vanellus miles	Masked Lapwing	Ground	Not sighted	Not tested
Lalage tricolor	White-winged Triller	Shrub	Not sighted	Not tested

Note : Species with less than 10 observations ('not tested') were not included in the chi-square test.
*Non-native species.

Appendix 4

Table A 4.1. Questionnaire-based, face-to-face visitor survey in Chapter 7 on past experiences and future preferences for nocturnal observation tours of Australian wildlife.

Questions on demography

→ What is your normal residential address?
- Country (if not Australia)
- State (in Australia)

→ How would you describe your travel party (i.e., who is travelling with you) in terms of the biggest unit? For instance, if you are travelling together with your partner but as part of a tour group, select 'tour group' instead of 'adult couple'.
- Unaccompanied
- Adult couple
- Family (parent(s) and child(ren))
- Friends/relatives
- Business associates
- Tour group
- Other (please, specify)

→ How many members are in your travel party?

→ Which of the following age and gender categories do you fit into?
- male
  - ○ 0–20
  - ○ 21–30
  - ○ 31–40
  - ○ 41–50
  - ○ >50
- female
  - ○ 0–20
  - ○ 21–30
  - ○ 31–40
  - ○ 41–50
  - ○ >50

Questions on previous experience with nocturnal wildlife observation in Australia

→ Have you participated in a nocturnal wildlife observation tour (NWOT) in Australia before?
- Yes, once
- Yes, more than once
- No

In the following: in case of multiple, previous experiences with NWOT in Australia comment only on your most recent experience.

→ Where (country/location/park/organization) did you participate in NWOT?

→ How much did you enjoy it (1-5)?
- 1 = Very little
- 2 = Little
- 3 = Medium
- 4 = High
- 5 = Very highly

→ What animal groups have you encountered during your NWOT experience (multiple answers)?

→ What technical equipment have you used to experience the nocturnal wildlife (multiple answers)?
- Torch/flashlight
- White spotlight
- Red spotlight
- Infrared light with a night vision device
- Thermal imaging system
- Bat detector
- Other technique (please, state)

Questions on preferences for future NWOT experiences in Australia

→ How strong would your interest be for NWOT in Australian arid lands in the future?
- 1 = Very little
- 2 = Little
- 3 = Medium
- 4 = Strong
- 5 = Very strong

→ Do you prefer hiking in a streambed or stationary observation at a water hole or a mix for NWOT?
- Hiking in a streambed
- Stationary observation at water tank
- A mix of the two

→ When should the tour be conducted?
- Around dusk
- Two hours past dusk
- Depending on animal activity
- Doesn't matter
- Early mornings

→ How long should the observation last?
- 30 min
- 1 h
- 1.5 h
- Longer

→ Should there be an introductory talk?
- Yes
- No

→ How long should the introduction be?
- Up to 5 min
- 5–15 min
- More than 15 min

→ What group size would you prefer (state preferred number)?

→ What factors (wildlife and tour features) are important to make your NWOT a satisfying experience (multiple answers)?

→ What wildlife behaviour do you find most interesting (would you like to observe)?
- Body maintenance (feeding, drinking, resting, grooming)
- Social interaction
- Alertness and flight
- General locomotion

→ How high do you rate the negative impact of NWOT on wildlife?
- 1 = Very low
- 2 = Low
- 3 = Medium
- 4 = High
- 5 = Very high