The effect of fire on the habitat use of the Black-eared Miner *Manorina melanotis*

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In 2006, a widespread fire in the Bookmark Biosphere Reserve, South Australia, consumed over one-third of the old growth mallee considered to be the prime habitat of the endangered Black-eared Miner *Manorina melanotis*. Since 2008, the species has been observed foraging and breeding in the fire-altered area. To verify whether food resources can explain the Black-eared Miners' presence in habitat consisting of early seral stages, we examined if a link could be found between the foraging behaviour of the Black-eared Miner and its invertebrate food resources.

Foraging behaviour of Black-eared Miners was sampled opportunistically using focal observations. All potential invertebrate food resources were sampled using micro-pitfalls, malaise traps, beating trays, sweep nets and active searches. Black-eared Miners devoted significantly more time to foraging in long unburned (hereafter referred to as unburned) rather than in recently burned habitat. No differences in invertebrate abundance, species richness or diversity were found between burned and unburned habitats. However, differences in community composition between habitats were found. Lerp, which is a sugary protective covering of particular insect larvae, is an important food source for the Black-eared Miners, and was found more in the unburned natural habitat.

We found that Black-eared miners may be more adaptable than previously thought when it comes to utilization of burned habitat. Still, this study reaffirms the importance of unburned habitat for Black-eared Miners.

Key words: mallee, lerp, species diversity, invertebrate communities, foraging behaviour, prey abundance, fire mosaic, fire management

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Fire can have profound effects on biological communities and species diversity. These effects are often complex (e.g. Perry *et al.* 2011) and are dependent on the many and varied aspects of a fire outbreak, such as its intensity and time since fire (Smucker *et al.* 2005). In some cases it can increase a species' abundance or attract new species, temporarily increasing species diversity (Kotliar *et al.* 2002, Moretti *et al.* 2002, Vandvik *et al.* 2005). Fire can also have a negative effect on species diversity (Clarke 2008, Driscoll *et al.* 2010) or reduce species richness (Willcox & Giuliano 2011).

Mallee habitat in southern Australia is prone to wildfires that can cover thousands of hectares (Noble & Vines 1993). In 2006, a widespread fire burnt 118,000 hectares in the Bookmark Biosphere Reserve, South Australia, and removed over one third of the old growth mallee considered prime habitat for the Black-eared Miner *Manorina melanotis* (Baker-Gabb 2001, Clarke *et al.* 2008).

The Black-eared Miner (Figure 1), an endangered species, is a native Australian colonial honeyeater, approximately 20 cm in length, which formerly occurred

Figure 1. A Black-eared Miner in malee habitat (photo GVS).

throughout the Murray Mallee region in Victoria, New South Wales and South Australia but is now absent from much of its former range (Baker-Gabb 2001, Clarke *et al.* 2001). Its only remaining stronghold lies within the Bookmark Biosphere Reserve (formally known as the Riverland Biosphere; Clarke *et al.* 2005, 2008). The fire in 2006 was presumed to be disastrous for the Black-eared Miner population because of its supposed need for mallee vegetation that has not been affected by fire for at least 45 years (Starks 1987, McLaughlin 1992a, Muir *et al.* 1999, Baker-Gabb 2001, 2007, Clarke *et al.* 2005). An initial estimation of colony numbers in the Bookmark Biosphere Reserve indeed showed a steep decline after the fire (2002: 501 colonies (Clarke *et al.* 2005); 2007: 187 colonies (Clarke *et al.* 2008)). Interestingly enough, with effect from 2008 many (15) colonies were found foraging and even breeding in and around the 2006 fire-damaged area (C. Hedger, pers. obs.). This kind of behaviour has been observed on previous occasions (Starks 1987, Silveira 1995) but until now was con-sidered to be an exception rather than the rule (Clarke *et al.* 2005). Woinarski & Recher (1997) noted that the

observed increase in invertebrate abundance in post-fire regenerating eucalypt vegetation could lead to increased abundances of some bird species. Changes in the availability of their food resources might explain why the Black-eared Miner would utilize the fire-damaged area.

On account of this, we aimed to verify in this study whether, in fact, food resources could be an explana-tion for the observed increase in Black-eared Miner presence in the burned habitat. Therefore, we decided to assess whether a relationship could be found between the abundance, species richness or diversity of food resources and the foraging behaviour of the Black-eared Miner.

METHODS[1]

The study area was located in Birds Australia (now BirdLife Australia) Gluepot Reserve, Calperum Station and along the border of Taylorville Station, which are all part of the Bookmark Biosphere Reserve in South Australia, Australia (Figure 2).

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[1]For a more detailed description please refer to the supplementary material.

Data were collected from 5 May to 28 June 2011, in late autumn to early winter, a period during which the Black-eared Miner had not yet been studied intensively. The data collection was carried out after an exceptionally long period of rain (BOM 2011). We simultaneously focused on the Black-eared Miners' behaviour, in both the burned and the unburned areas (Figure 3), and compared the food resources in those locations. Black-eared Miner foraging behaviour was sampled opportunistically using focal observations at nine locations (colonies situated along the border of burned and unburned habitat). Availability of potential food resources for the Black-eared Miners was assessed in 12 locations (each containing part of the burned and unburned habitats) using micro-pitfalls, malaise traps, beating trays, sweep nets and active searches (see Figure 4).

Foraging behaviour

The Black-eared Miners were followed opportunistically on foot during the morning from 8:00 to 11:00 Australian Central Standard Time on three consecutive days per colony. The first Black-eared Miner to be spotted was followed until it disappeared from view. When possible, other birds from the group were subsequently observed (one at a time) until all birds moved out of sight. Black-eared Miners were not colour-banded, making individual identification impossible. Individuals were possibly observed several times on different locations and days, which we assume not to represent a problem in comparing behaviour between habitats. Observations were done with binoculars to increase the distance between birds and observers to avoid influencing behaviour as much as possible.

The specific behaviour of every bird observed was recorded (duration in seconds), divided into gleaning (foraging in trees, shrubs or on the ground), hawking (catching invertebrates during flight), feeding young and being fed (see also Moysey 1997). All non-foraging behaviour was classified as flying or sitting (see also Moysey 1997). For each behaviour observed, we recorded the bird's position: habitat type (burned or unburned), height (above or below 2 m) and location (stem, branch, foliage, shrub, soil, leaf litter or air).

At 08:00 and 11:00 every morning, the temperature, relative humidity and cloud density were recorded (in five categories of equal proportion) as these parameters can influence avian behaviour (Archard *et al.* 2006, Jones & Dawkins 2010). The age of each bird followed (classified into adult or juvenile) was also noted because we assumed that behavioural aspects (type and duration) correlate with age. Juveniles were defined as begging birds that did not forage on their own but were fed.
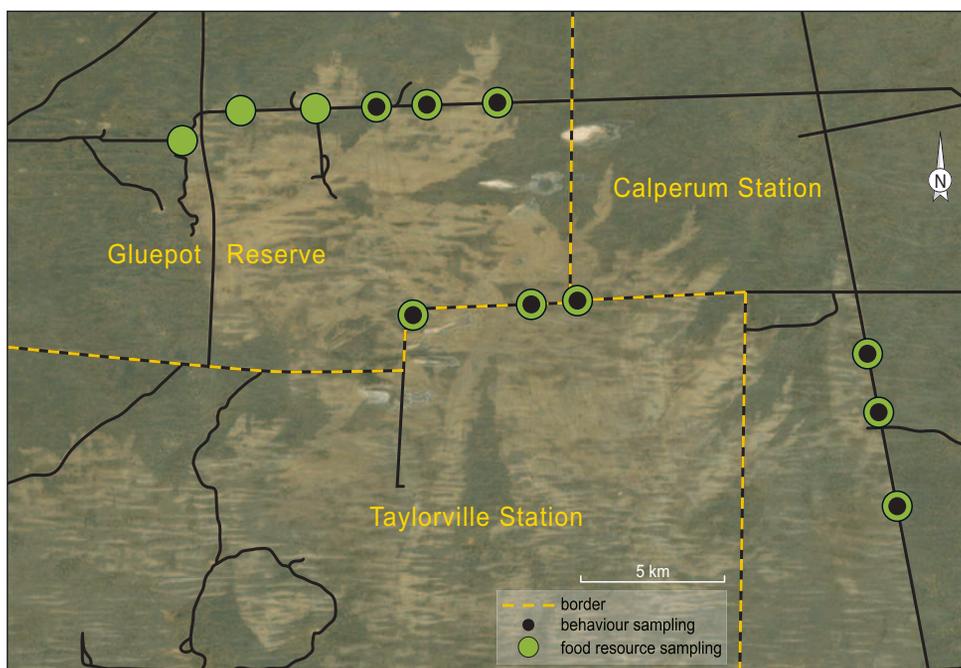

Figure 2. Fire map of the study area in Bookmark Biosphere Reserve with sampling areas along the roads. The dark parts of the map are unburned; the light parts are burned habitat.

Figure 3. Malee habitat in Bookmark Biosphere Reserver. (A) Recently burned and (B) unburned habitat. (photos GVS)

Food resource sampling

Food resource sampling grids were placed on twelve sites, each in an area containing at least transects of 130 m of burned and 130 m of unburned habitat (required for the layout of the sampling grid; see Figure 4). Pitfall and malaise trap sampling took place in the same week as the behavioural observations, with sweeping, beating, active search and lerp (the sugary protective covering of many Australian psyllids (Psyllidae); Paton 1980) counting (number of cocoons visible per tree), employed on one of the three days the colony in question was observed.

Each food resource sampling grid (see Figure 4) contained five quadrangular pitfall grids, each consisting of four micro pitfalls, in the burned and five pitfall grids in the unburned habitat to collect invertebrates occurring on open ground and in low vegetation (Sutherland 2006). Per habitat a malaise trap was used to sample flying insects and four different sampling stations were put in place for passive sweeping, active sweeping, beating and active searches to catch all possible invertebrates which could serve as food for the Black-eared Miners. The quantity of lerp on the leaves of *Eucalyptus* spp. trees was estimated by counting the number visible on each tree in the passive sweeping quadrangle.

Temperature, relative humidity and presence/ absence of rain were recorded at each of the four sampling stations per grid (see Figure 4) immediately before and after employing the standardized combination of sampling methods.
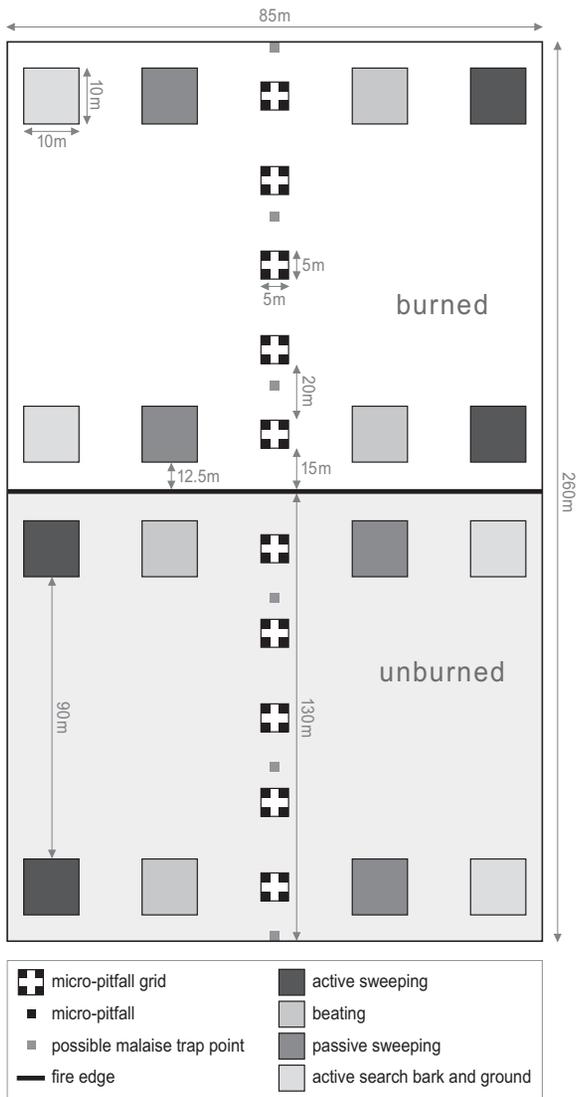
Figure 4. Food resource sampling grid layout. Distance between pitfall quadrates centre to centre was 25 m, each containing four pitfalls at every corner. Malaise traps (two per area, one in burned one in unburned) were set up at equal distance from the fire border: 30 m, 60 m or 90 m. In order to avoid bias we always used the quadrate (10×10 m) to the left of the pitfalls (facing away from the fire border) for passive sweeping and the quadrate on the right for beating. Two additional 10×10 m quadrates were laid out with their edge at a distance of 10 m of the nearest edge of the first quadrates. In the second left quadrate active search on bark and ground was employed with active search by sweeping undertaken in the second right quadrate. To minimize sampling bias, each researcher specialized in their own sampling methods (e.g. beating and active sweeping) throughout the data collection period.

Data preparation

The percentage of time spent on each type of behaviour was calculated for each observation of a bird. Individual birds that were seen in both the burned and the unburned habitats were excluded from the database ($n = 22$). Only observations lasting more than 60 s were included in the analysis ($n = 181$, mean observation time 195 s ± 274 SD).

We sorted all collected invertebrate samples into recognizable taxonomic units. Because of habitat inconsistency with the GIS fire-history-map, six pitfalls and five food resource sampling stations for beating, net sweeping and active searches were discarded (and also their counterparts in the alternative habitat). Results of six other pitfall grids and one malaise trap were discarded due to severe disturbance in the field (seven pitfalls were removed by foxes; one malaise trap was blown down by the wind).

Abundance, species richness, number of orders and Simpson's diversity D were calculated per sampling location and for the different combinations of sampling methods. A comparison was made per taxonomic order to determine which species occurred exclusively in burned, unburned or both habitats. Based on that, the Jaccard similarity index was calculated (per order). As ants (Formicidae) were by far the most abundant group numerically, they were treated separately from other Hymenoptera species in all calculations.

Data analysis

Data were tested for normality and homogeneity of variances and where appropriate were transformed to meet these assumptions. Behavioural observations were transformed with arcsine square-root, whereas data on invertebrates were log-transformed after adding 1. In all General Linear Models (GLM) the following predictor variables were included if statistically significant: temperature (at the beginning/end of the observation), humidity (at the beginning/end of the observation), cloud density (at the beginning/end of the observation), age of bird (juvenile/adult). Because of the correlation between variables, the temperature recordings at the beginning and end of the observation, humidity and cloud density were not included simultaneously.

In order to test whether there were differences between the burned and unburned habitats in the amount of time spent on a specific type of behaviour we constructed a Univariate GLM (forward selection, threshold $P \leq 0.05$) for each type of behaviour. To test whether invertebrate occurrence (abundance, richness, Jaccard similarity index and Simpson's diversity) was

different between habitats (burned/unburned) or with increasing distance from the fire border, repeated measures GLMs were used. The initial within-subject factors for the repeated measures GLM were habitat, distance from fire border and their interaction.

In order to test whether there was a difference in lerp abundance between the burned and unburned habitats, a repeated measures GLM was used. The initial within-subject factors for this test were habitat, distance from fire border and their interaction. In order to test whether gleaning was dependent on invertebrate occurrence (abundance, richness or diversity) or lerp abundance, in particular, we used a linear regression analysis.

We used IBM SPSS v. 19 for all statistical analyses. Results were considered significant if $P \leq 0.05$. Means are presented ± one standard error unless otherwise mentioned.

RESULTS

Behaviour

Although colony observations always commenced on the fire border, there were over seven times as many observations in the unburned habitat ($n = 160$) compared with the burned habitat ($n = 21$). Behavioural observations included in the analysis (>60 s) lasted on average 195 ± 23 s (ranging from 61 to 2593, $n = 160$) in the unburned habitat and 205 ± 37 s in the burned habitat (ranging from 62 to 711, $n = 21$).

Temperature, cloud coverage and rain did not influence foraging behaviour ($P > 0.05$). Black-eared Miners spent more than twice as much time 'sitting' in the burned compared to the unburned habitat ($F_{1,177} = 57.5$, $P < 0.001$) and more than four times as much time 'gleaning' in unburned habitat rather than the

Table 1. Black-eared Miner behaviour in burned and unburned habitat. Behaviour is expressed as a percentage of the total observation time. [*]$P < 0.001$.

Behaviour	Unburned habitat ($n = 160$) mean ± SE (%)	Burned habitat ($n = 21$) mean ± SE (%)
Sitting[*]	35.11 ± 2.45	78.44 ± 5.53
Gleaning[*]	59.93 ± 2.53	13.90 ± 5.43
Flying	3.89 ± 0.64	7.61 ± 1.80
Hawking	0.08 ± 0.05	0.00 ± 0.00
Being fed	0.37 ± 0.11	0.00 ± 0.00
Feeding young	0.62 ± 0.31	0.04 ± 0.04

burned habitat ($F_{1,177} = 57.2$, $P < 0.001$; Table 1). Part of the variance in 'sitting' was explained by bird age ($F_{1,177} = 31.0$, $P < 0.001$) and for 'gleaning' part of the variance was explained by humidity ($F_{1,177} = 7.20$, $P < 0.01$) as well as bird age ($F_{1,177} = 31.0$, $P < 0.001$). In both habitats the birds appeared to glean predominantly between loose hanging bark (on the tree trunk) and among the foliage, and mainly above 2 m in height (Table 2). Other types of behaviour were not found to be significantly different between habitats (Table 1).

Food resources

In the unburned sampling sites ($n = 30$), we collected 2506 invertebrate specimens belonging to 225 species, resulting in an average Simpson diversity index (1/D) of 1.88 ± 0.88. In the burned sites ($n = 30$) we found 3431 invertebrates, 182 invertebrate species, and an average Simpson diversity index (1/D) of 1.67 ± 0.48. No statistical differences were found for species abundance, richness or diversity between habitats or with increasing distance from the fire border when the results of all food resource sampling methods were combined.

We did, however, find a difference in the composition of the invertebrate community between the burned and the unburned habitats (Table 3), with many species

Table 2. Vertical foraging location distribution shown as the height at which birds were observed per habitat. Note that a bird can express a certain behaviour several times and n does therefore not equal number of birds observed. $n = $ the number of times the behaviour was observed.

	Height < 2 m		Height > 2 m	
	Mean (sec)	n	Mean (sec)	n
Unburned habitat				
Ground - soil	12	96		n/a
Ground - leaf litter	31	8		n/a
Shrub	15	19		0
Bark - stem	18	139	18	387
Bark - branch	15	3	6	11
Foliage	18	35	24	359
Air		0	5	3
Burned habitat				
Ground - soil	22	6		n/a
Ground - leaf litter		0		n/a
Shrub	14	6	53	2
Bark - stem	8	7	14	57
Bark - branch		0	9	3
Foliage	9	2	24	7
Air		0		0

being detected exclusively in burned (87 species) or unburned habitat (130 species). The Jaccard similarity index (JSI), representing the total species overlap between burned and unburned habitat, was low (0.304), with ants (Formicidae) having the biggest overlap (JSI = 0.511) whereas Coleoptera and Mantodea assemblages had relatively little overlap (JSI < 0.183; Table 3).

Besides differences in invertebrate communities, more lerp (number of cocoons) was present ($F_{1,11} = 6.58$, $P = 0.026$) in the unburned habitat (14.04 ± 4.45) compared to the burned habitat (2.21 ± 1.01).

Gleaning dependency on food resources
No significant linear relationship was found between the amount of time spent on gleaning and the invertebrate abundance ($F_{1,13} = 1.15$, $P = 0.28$), species richness ($F_{1,13} = 1.16$, $P = 0.28$), species diversity ($F_{1,13} = 1.01$, $P = 0.34$) or lerp ($F_{1,13} = 0.25$, $P = 0.81$) for each of the nine locations where both behaviour was observed and food resources were sampled.

DISCUSSION

We investigated the influence that fire had on food resources of the Black-eared Miner and whether this translates into differences in their foraging behaviour in fire-damaged areas versus habitat long unaffected by fire. Based on personal observations from 2008 onwards that many (15) colonies were found foraging and even breeding throughout the 2006 fire-damaged area and its surroundings, the birds were expected to be found often in the fire-damaged habitat and spend a substantial amount of time foraging there. However, our study did not show this and is consistent with earlier studies (Clarke *et al.* 2005). Although colony observations always commenced on the fire border, more than seven times as many observations were made in the long unaffected rather than in the fire-damaged habitat, implying that the colonies we followed spent substantially more time in the unburned habitat. This, together with the fact that foraging mainly took place in the area long unaffected by fire (here, 60% of time was spent on

Table 3. Total number of invertebrates and invertebrate species richness in burned, unburned or in both habitats. Species are given per order, only Formicidae is given separately because of the extent of the family. Species exclusively means that number (%) of species was only found in that habitat. JSI is Jaccard similarity index, 1 being completely similar, 0 being completely dissimilar between burned and unburned habitat. *Hym. = Hymenoptera.

Order	Total		Unburned		Burned		Both	JSI
	Individuals	Species	Individuals	Species exclusively	Individuals	Species exclusively	Species	
Hymformicidae*	4988	47	1993	14 (30%)	2995	9 (19%)	24 (51%)	0.511
Hym. others*	143	33	98	14 (42%)	45	8 (24%)	11 (33%)	0.333
Araneae	167	55	65	25 (45%)	102	19 (35%)	11 (20%)	0.200
Diptera	185	37	98	15 (41%)	87	8 (22%)	14 (38%)	0.378
Lepidoptera	99	34	44	12 (35%)	55	12 (35%)	10 (29%)	0.294
Coleoptera	117	31	58	16 (52%)	59	10 (32%)	5 (16%)	0.161
Orthoptera	115	23	74	8 (35%)	41	6 (26%)	9 (39%)	0.391
Hemiptera	32	16	26	11 (69%)	6	1 (6%)	4 (25%)	0.250
Mantodea	38	11	27	5 (45%)	11	4 (36%)	2 (18%)	0.182
Blattaria	27	10	7	3 (30%)	20	4 (40%)	3 (30%)	0.300
Scorpiones	4	3	1	0 (0%)	3	2 (67%)	1 (33%)	0.333
Odonata	3	3	3	3 (100%)	0	0 (0%)	0 (0%)	0.000
Thysanura	2	2	1	1 (50%)	1	1 (50%)	0 (0%)	0.000
Phasmatodea	4	2	1	1 (50%)	3	1 (50%)	0 (0%)	0.000
Isopoda	8	1	7	0 (0%)	1	0 (0%)	1 (100%)	1.000
Neuroptera	1	1	1	1 (100%)	0	0 (0%)	0 (0%)	0.000
Embioptera	1	1	0	0 (0%)	1	1 (100%)	0 (0%)	0.000
Chilopoda	2	1	2	1 (100%)	0	0 (0%)	0 (0%)	0.000
Diplopoda	1	1	0	0 (0%)	1	1 (100%)	0 (0%)	0.000
Total	**5937**	**312**	**2506**	**130 (42%)**	**3431**	**87 (28%)**	**95 (30%)**	**0.304**

foraging versus 14% in fire-damaged area), confirms the findings of Clarke *et al.* (2005) that Black-eared Miners display a distinct preference for mallee habitats that have not been damaged by fire for at least 45 years.

This preference does not seem to have been influenced by the overall invertebrate availability: no significant differences were discovered in abundance, species richness or diversity between the fire-damaged and the unaffected habitats. The fact that this study was carried out five years after the fire and after an exceptional long period of rain may have resulted in any initial overall differences in invertebrate species richness and abundance having dissipated. Studies by Pryke & Samways (2012) and Abbott *et al.* (2003) initially found a lower post-fire invertebrate species richness; abundance either increased or decreased (Pryke & Samways 2012) or remained the same (Abbott *et al.* 2003). Both studies revealed that invertebrate communities rapidly recovered subsequent to fire (see also Moretti *et al.* 2006). Moretti *et al.* (2006) found no change whatsoever in the overall invertebrate species richness or abundance after a single fire, although the different taxa showed a large variation in response. The composition of the invertebrate community in our study differed strongly between fire-damaged and unaffected habitats, as was also the case in several other studies (Swengel 2001, Moretti *et al.* 2006, Beaumont *et al.* 2012, Pryke & Samways 2012).

Although Black-eared Miners are known to forage on a wide variety of invertebrate orders (Barker & Vestjens 1984, Higgins *et al.* 2001), it is unknown which invertebrates are eaten the most. They do mainly forage by gleaning and probing the loose and hanging bark of mallee eucalyptus trees (McLaughlin 1992a, 1992b, Higgins *et al.* 2001). The fact that the birds spent significantly more time foraging in unburned habitat could be explained by its vegetation attributes (e.g. stem diameter (Clarke *et al.* 2010, Luck *et al.* 1999) and decorticating bark abundance (Haslem *et al.* 2011)) which are diminished in burned habitat and influence invertebrate occurrence (see e.g. Majer *et al.* 2003).

The fact that lerp was more abundant in the unburned habitat might also explain why the birds spent significantly more time foraging in this type of habitat, because lerp is an important energy source for honeyeaters (Paton 1980) such as the Black-eared Miner (McLaughlin 1990). Lerp only occurs on eucalyptus leaves (Phillips 1992). Canopy cover is dependent on time-since-fire, showing a rapid increase for the first 35 years after a fire, then continuing to increase at a lower rate for many years thereafter (Haslem *et al.* 2011). Lerp occurrence is therefore likely to increase with time-since-fire, adding to the importance of areas older than 35 years post-fire for Black-eared Miners.

We did not find evidence of higher invertebrate abundance in the unburned habitat of a colony's territory. However, the fact that we were unable to get samples above two metres in height, and the fact that most foliage grows above this height in the unburned areas, implies that invertebrates dependent on foliage could well have been under-investigated in these habitats. For the same reason, the difference in lerp densities between the two habitats may be greater than this study has revealed. Although no direct relation could be found between the observed foraging behaviour and the amount of food resources, this could well prove to be different if these resources (lerp as well as invertebrates) were to be sampled above a height of 2 m, in favour of the unburned habitat. After all, most foraging behaviour was observed to take place above a height of 2 m. The lack of vegetation above 2 m in burned areas might then explain the preference for unburned habitat. Though care was taken not to disturb the birds by keeping sufficient distance, it is possible that observers influenced birds, causing them to forage higher in trees and possibly in the unburned area which provides better cover.

We found that Black-eared Miners may be more adaptable than previously thought when it comes to utilization of burned habitat. This was also found to be the case with the highly endangered Eastern Bristlebird *Dasyornis brachypterus*, with birds reoccupying many burned sites within two years despite fire being considered a major threat to the species (Lindenmayer *et al.* 2011). This null-response, with bird species seemingly little affected by fire, was the reaction most observed in the thirty bird species studied by Watson *et al.* (2012) in the Murray Mallee, with many other species negatively affected at first but recolonizing the burned habitat as time progressed. The personal observations concerning the Black-eared Miners occupying the burned areas since 2008 tentatively suggest that a similar scenario is possible for this species. However, we do need to emphasize the fact that the fire in 2006 left many unburned patches, which may have had a positive influence on the recovery of the Black-eared Miners in the area as these patches could serve as refuges during and immediately after the fire (see also Lindenmayer *et al.* 2011).

The importance of the old growth mallee habitat for this species is emphasized yet again in this study, with

Black-eared Miners seemingly able to use burned areas opportunistically but preferring old growth. This appears to be the case with many other bird species in the Murray Mallee. Practically all species observed were affected by fire when it occurred in habitat which had not been burned for at least 20 years (Watson *et al.* 2012). The fact that some species are less frequently observed in habitats which have not been affected by fire for over 50 years does stipulate the dynamic nature of the fire mosaic pattern in the mallee ecosystem (Watson *et al.* 2012). Long-term fire management plans in the mallee habitat are of paramount importance to ensure the conservation of many threatened species such as the Black-eared Miner. However, which specific fire management is most beneficial requires very careful assessment.

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SAMENVATTING

Een grootschalige brand in het Zuid-Australisch natuurreservaat 'Bookmark Biosphere Reserve' verwoestte in 2006 meer dan één derde van het habitat van de bedreigde Zwartoor-Honingeter *Manorina melanotis*. Sinds 2008 werd echter geobserveerd dat deze vogelsoort ook foerageert en broedt in habitat dat door het vuur is aangetast. Met dit onderzoek wilden wij achterhalen of de beschikbare voedselbronnen de aanwezigheid van de Zwartoor-Honingeters in verbrand habitat kon verklaren. We hebben onderzocht of er een relatie bestond tussen het foerageer gedrag van de Zwartoor-Honingeter en de aanwezige ongewervelde voedselbronnen zoals spinnen en insecten.

Het foerageergedrag van de vogels werd opportunistisch gesampled: de eerste vogel die werd gespot, werd gevolgd tot deze uit het zicht verdwenen was waarna de volgende werd geobserveerd. In de gebieden waar de vogels geobserveerd waren, werden monsters genomen van alle potentiële voedselbronnen.

Zwartoor-Honingeters spendeerden significant meer tijd aan foerageren in onverbrand habitat ten opzichte van recent verbrand habitat. Er werden geen verschillen gevonden tussen verbrand en onverbrand habitat in de hoeveelheid ongewervelde dieren die er voorkwamen, noch in de soortenrijkdom (hoeveelheid soorten) of de diversiteit van de ongewervelden. Wel werden er verschillen gevonden in welke soort ongewervelde dieren er aanwezig waren in de habitatten. In onverbrand habitat was er ook meer 'lerp' (de suikerachtige cocon van insecten) aanwezig, wat een belangrijke voedselbron voor de vogels is.

Uit ons onderzoek komt naar voren dat de Zwartoor-Honingeter flexibeler is dan men voorheen dacht met betrekking tot het gebruik van verbrand habitat. Deze studie bevestigt wel opnieuw dat onverbrand habitat heel belangrijk is voor de Zwartoor-Honingeter.

APPENDIX

Selection of study sites

Using sighting reports (data from Department of Environment and Natural Resources (DENR) of South Australia 2010) a Black-eared Miner distribution map was created using ArcMap (ESRI v. 9.3.1) creating a buffer of 800 m around the sightings (based on the maximum recorded foraging distance during the breeding season (Baker-Gabb 2001), and later confirmed to be the maximum distance within which observations were made), overlaid by a fire history map of 2006. Only sightings including both burned (in 2006) and unburned (more than 45 years) habitat within the buffer were selected and preference was given to Black-eared Miner sightings along or near roads (dirt tracks) for practical purposes. For all sites, the unburned habitat had not seen fire for over 45 years, while all burned habitat was incinerated in 2006. Using call-playback we visually verified whether Black-eared Miners still occurred at or near the chosen sites.

To get additional study sites, we opportunistically searched for Black-eared Miner presence, using call-playback on locations not mentioned in the DENR sighting reports but where fire borders were along or crossed roads. Once a new sighting of two or more Black-eared Miners was recorded, searching recommenced after a distance of 1200 m to exclude possible overlap between Black-eared Miner colonies.

Coordinates of every sighting were recorded using a GPS. A selection of twelve study sites was made based on distance between potential sites (to exclude overlap of colony territories a distance of 1200 m was used) and group size. On nine sites we studied foraging behaviour and on 12 sites we sampled food resources (see Figure 2). Per week, three sites were visited.

Food resource sampling

The fire border between the two habitats was primarily a road. When no road was present ($n = 2$) an additional distance of 2.5 m on either side of the fire border was implemented to retain a similar distance between the sampling grids in burned and unburned habitat as sites containing a road. In two cases, low fire intensity had resulted in a fine scale mosaic of burned and unburned habitat. These areas were excluded and the sampling grid was laid out once the habitat was homogenous, increasing the distance between the two habitats.

Micro pitfalls (60 mm diameter, 100 mm deep with roof) were set up so that the rim of the trap was level with the ground. In order to kill specimens falling into the pitfall, 60 ml propylene glycol was added to each trap. A 'roof' (blackened CD) was used to reduce catching of and/or attractiveness to small and large vertebrates (Forrest & Hirst 2004). A gap of about 20 mm was left between roof and ground level to limit passage to invertebrates. Using four pitfalls in a quadrat rather than one pitfall was expected to increase the number of invertebrates caught and reduce any differences in capture results due to different microclimates present (Shattuck 1999).

At the three food resource sampling grids laid out simultaneously per week, two malaise traps (to collect flying invertebrates; Sutherland 2006) were set up at an equal distance at both sides from the fire border (30 m, 80 m and 130 m respectively) with a possible invertebrate gradient with increasing distance to the fire border in mind. The collection chamber of each malaise trap (containing 300 ml propylene glycol) was pointed towards the sun (Forrest & Hirst 2004), facing north. In order to control for differences in malaise trap height, malaise traps of similar size were set up in each sampling site. All malaise and pitfall traps were operated for six consecutive days per sampling grid.

Whilst the pitfalls and malaise traps were in operation, each sampling grid was visited for one afternoon starting at 11:45 h to sample for invertebrates, as many species supposed to be food for Black-eared Miners were unlikely to be captured in micro pitfalls or malaise traps. Passive sweeping (to collect invertebrates on open ground and low vegetation; Sutherland 2006), beating (to collect invertebrates in low foliage of trees and shrubs; Sutherland 2006) and active search (to include invertebrates that generally escape capture by other methods) were employed towards this end. The expectation was that by choosing the extreme ends of the food resource sampling grid for these sampling methods an edge effect from the burned area into the unburned area and vice versa could be observed if present. Passive sweeping (with a net of 38 cm diameter) was done by walking and sweeping the complete 10×10 m quadrat (see Figure 4) systematically, sampling all vegetation up to a height of c. 50 cm. During active sweeping the researcher actively searched for a total of 10 min for flying and hopping invertebrates within the designated quadrat (see Figure 4) and attempted to capture them with the sweeping net. In another quadrat, beating trays (0.8×0.8 m) were placed under trees and shrubs > 50 cm and < 2 m and a branch or the foliage was tapped sharply with a stick three times (Forrest & Hirst 2004). All (parts of) live and dead trees and shrubs within the quadrat were sampled. Active search involved looking for inverte-

brates on the stem and underneath/below loose bark of trees whilst another researcher simultaneously searched for invertebrates on the ground. Both took place within the designated quadrat and lasted 10 min. Active search was also used to sample lerp (the sugary protective covering of many Australian psyllids; Paton 1980), and active sweeping to catch flying and hopping invertebrates undersampled by other methods.

Data preparation
Invertebrates were preserved in methylated spirits (70%) and stored in glass vials until sorted and counted. Invertebrates caught in the four pitfalls were taken together to represent the capture of that pitfall quadrat. All invertebrates below 5 mm were discarded, unless they formed an equivalent mass. Ten or more individuals of the same species > 1 mm < 5 mm were considered to form an equivalent mass and were included in the database. Less than ten specimens < 5 mm were assumed to be of little value to Black-eared Miners, and we presumed that specimens < 1 mm were energetically not profitable and too difficult for birds to find and capture. We identified all invertebrate specimens at morphospecies level.

Per sampling location (pitfall quadrat, malaise trap or combined sampling station for beat/sweep/active search – see Figure 4, $n = 174$) and for the different combinations ($n = 72$) of sampling grid ($n = 12$), habitat ($n = 2$) and method ($n = 3$) as well as for all sampling grid by habitat combinations ($n = 24$) abundance, number of species and orders present were calculated as well as the Simpson's diversity D – one of the most meaningful and robust diversity measures available (Lande 1996, Magurran 2004) – expressed as 1/D (the most widely used form; Magurran 2004).

Data analysis
To test if invertebrates (abundance, richness, Jaccard similarity index and Simpson's diversity) were dependent on habitat or distance from the fire border, a GLM (repeated measures) was constructed. We also tested the interaction between habitat and distance from the fire border. The within-subject factors for the GLM repeated measures started with habitat, distance and their interaction as factors. A forward selection (variable was included in the model at $P \leq 0.05$) was used on the covariates, several weather measurements (e.g. temperature at different times) and vegetation communities (twelve types). Variables were not used in the model simultaneously when they were correlated (e.g. temperature 9:00 AM minimum and humidity 9:00 AM, Pearson correlation: $P \leq 0.05$).