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# Bird Responses at Inherent and Induced Edges in the Murray Mallee, South Australia.

## 2. Nest Predation as an Edge Effect

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**Summary:** We assayed nest predation as an edge effect, using artificial ground nests, at inherent (naturally occurring) and induced (human-created) edges in the Murray Mallee, South Australia. Nests were constructed at distances between 0–120 m away from habitat edges. The relative predation rate on nests generally increased close to induced

edges with a significant difference ( $P < 0.05$ ) recorded for two out of five experiments. Predation rate at inherent edges was similar from the edge to the interior, and was lower than that recorded at induced edges. Our results suggest that increased predator numbers, activity or efficiency at locating nests occurred close to the induced edges at our study sites.

Nest predation is believed to have a major impact on the nesting success of birds (Nilsson 1986; Martin 1988; Robinson 1990; Major et al. 1996). Increased levels of predation may occur in fragmented landscapes where potential nest predators are favoured by habitat clearance or modification (Wilcove 1985). This has been cited as a possible reason for the decline of edge-avoiding birds in small habitat fragments in North America (Gates & Gysel 1978; Ambuel & Temple 1983; Wilcove 1985).

To examine the effects of nest predation in fragmented landscapes, many researchers have attempted to determine if the predation rate on either natural or artificial nests increases close to habitat edges when compared to the adjacent interior (e.g. Yahner & Wright 1985; Temple & Cary 1988; Avery et al. 1989; Møller 1989; Yahner 1991; Rudnický & Hunter 1993; Pasitschniak-Arts & Messier 1995). Results from studies such as these have either supported the hypothesis that nest predation increases near edges (e.g. Gates & Gysel 1978; Wilcove et al. 1986; Andr n & Angelstam 1988; Yahner et al. 1989; Gibbs 1991; Burkey 1993; Marini et al. 1995) or found no significant difference between edge and interior predation rates (e.g. Angelstam 1986; Ratti & Reese 1988; Small & Hunter 1988; Yahner 1991; Santos & Telleria 1992). Studies using artificial nests have differed in their methods making it difficult to determine general trends. In a review of nest predation experiments, Paton (1994) argued that the most conclusive studies found an increase in nest predation within 50 m of the edge. He advised that future

research should focus on the first 100-200 m from the edge where increased levels of nest predation are most likely to occur.

In this study, we used artificial ground nests to assay nest predation as an edge effect and examine its potential as an edge-related mechanism influencing the distribution of birds at our study sites (Luck et al. 1999). The aims of our study were to: (1) determine if the relative predation rate on artificial nests changed with increasing distance from a mallee habitat edge; and (2) determine if the relative predation rate on artificial nests differed between induced (human-made) and inherent (naturally occurring) edges.

### Study sites

This study was conducted in the Murray Mallee, South Australia at the same study sites and edges described in Luck et al. (1999). We conducted a total of eight nest predation experiments at the induced and inherent edges at Brookfield, and the induced and inherent edges at Kruger. We also placed nests inside Yookamurra Wildlife Sanctuary, opposite Kruger. The mallee vegetation in Yookamurra is surrounded by an electrified fence that excludes large, introduced mammals (e.g. foxes, cats and dogs). This provided a good opportunity to get an indication of the impact that introduced mammal predators may have on nests on the ground. The edge studied in these experiments was an induced edge created by a dirt road.

## Methods

### Timing of experiments

Pilot experiments were conducted at the induced edge abutting Kruger and Yookamurra from 13–24 April 1996, to test our methods and give an indication of predation rate. Subsequent experiments were conducted at this edge, and at the inherent edge at Kruger, from 6–18 June, and at the inherent edge at Kruger and the induced and inherent edge at Brookfield from 30 July–11 August 1996.

### Nest construction

We constructed artificial ground nests by digging a shallow depression in leaf litter and soil using a small hoe. The nests were approximately 5 cm deep and 15 cm across. Leaf litter was placed in each nest to assist in camouflaging its appearance and to provide a cryptic background for the egg. We standardised the detectability of nests by placing them at the base of mallee eucalypts. Variation in nest size, material and the microhabitat of the nest site may affect the rate of detection by predators (Ratti & Reese 1988). In each nest we placed a single, fresh, commercially produced quail egg. The eggs were cream coloured with varying amounts of brown and black speckling. They had a mean length of 29.3 mm (*s.e.*  $\pm$  0.4 mm) and a mean width of 19.7 mm (*s.e.*  $\pm$  0.2 mm,  $n = 300$ ).

In constructing artificial nests, we attempted to mimic those produced by the Chestnut Quail-thrush *Cinclosoma castanotus*, a ground-nesting bird species that occurred at our study sites. These nests are usually a shallow depression in the ground, lined with leaves, strips of bark and grasses, placed under a low shrub or near a log or tree (MacDonald 1973; Beruldsen 1980). The eggs of this species are approximately 30 mm  $\times$  21 mm in size and usually creamy-white to bluish-grey with brown and grey speckling (Beruldsen 1980). We mimicked this species in an attempt to make the artificial nests less conspicuous. We do not suggest that our results can be extrapolated to infer actual predation rates experienced by this or other ground-nesting bird species at our study sites.

Before being placed in nests, eggs were rinsed with rainwater and air-dried to reduce human scent; we only handled eggs when wearing rubber gloves. When placing eggs in the field, and constructing nests, we wore rubber gloves and rubber boots to further reduce contamination by human scent (following Small & Hunter 1988).

### Nest placement: pilot study

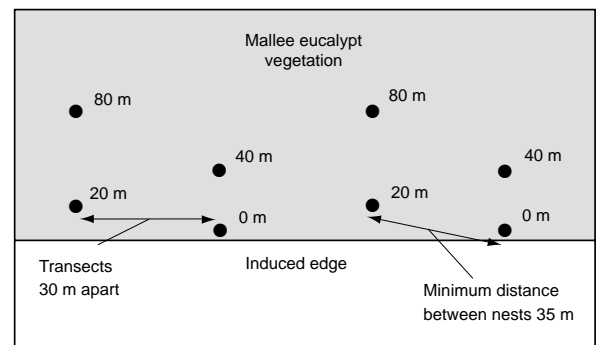
For the pilot study, we constructed a total of 160 nests at the induced edges at Kruger and Yookamurra. Nests were marked using coloured flagging placed 5–20 m away in a recorded compass direction. Flagging had been present throughout the study area for over two months and was not considered a novel feature that might attract predators to nests.

Nests were placed along transects perpendicular to the edge. We established 80 transects at each edge and spaced these a minimum of 30 m apart (a total linear distance of 2370 m). We alternated nest position on each transect to increase the distance between nests to a minimum of 35 m. For example, at Kruger, nests on the first transect were placed at 0 m and 40 m, and on the second transect at 20 m and 80 m from the edge (Fig. 1). This pattern was repeated at Yookamurra and resulted in 40 nests being placed at 0 m, 20 m, 40 m and 80 m at each site. The density of nests was approximately eight per hectare.

Nests were checked after 10 days exposure. This period was consistent with similar nest predation experiments (e.g. Andr n & Angelstam 1988; Small & Hunter 1988). All the nests at a particular edge were checked in one day and at the end of each experiment, eggs and egg fragments were removed and the nests were covered.

### Nest placement: main study

The data obtained from the pilot study indicated that, although predation rate was fairly even up to 80 m from the edge, there was a general trend of decreasing preda-



**Figure 1** Transect design and distance intervals used for nest placement in the pilot study.

tion with increasing distance. To determine if a significant difference occurred further from the edge, we repeated the experiments described above at Kruger and Yookamurra with nests constructed on alternate transects at 0 m and 80 m, and 40 m and 120 m. We also conducted the same experiment at the inherent edge at Kruger to get an indication of the difference in predation rate between induced and inherent edges.

Nests were spaced at equidistant intervals. This had advantages over the pilot study because nests were not clustered near the edge and the minimum distance between nests was increased to 50 m. The density of nests was approximately six per hectare. We repeated the experiment at the inherent edge at Kruger and at the induced and inherent edge at Brookfield. Including the pilot study, three experiments were conducted at induced edges, three at inherent edges and two inside Yookamurra (from an induced edge).

### Data analysis

Predation rate was measured as the number of nests from which an egg was removed or broken. To determine if predation rate differed significantly with distance from the edge, we tested observed versus expected (i.e. an equal proportion of total nests predated at each distance) values at each edge using a  $1 \times n \chi^2$  test (Zar 1996). We tested for differences between predation rate at induced and inherent edges, within a site, using a  $\chi^2 2 \times 4$  contingency table (Zar 1996).

## Results

### Pilot study

At Kruger and Yookamurra, there was no significant difference in predation rate up to a distance of 80 m, however, predation decreased with distance from the edge with a strong trend recorded at Yookamurra (Table 1). At each of the distance points the predation rate was  $\geq 42.5\%$  after 10 days exposure, with the highest rate (85%) being recorded at 0 m, at Kruger.

### Main study

There was a significant difference in predation rate recorded at the induced edge at Kruger ( $P < 0.05$ ) and Yookamurra ( $P < 0.01$ ) with a consistent trend of decreasing predation further from the edge (Table 2). There was no significant difference in predation rate at the Brookfield induced edge up to 120 m, although it did decrease slightly with distance from the edge.

At inherent edges, there was no significant difference in predation rate and no consistent trends with distance from the edge (Table 2). However, the predation rate at inherent edges was generally lower than at induced edges. The significance of this difference was tested by comparing the results from experiments conducted at the same time in the same habitat patch. We compared the predation rate at the induced edge at Kruger with the inherent edge (experiment 1; see Table 2) and at the induced edge at Brookfield with the inherent edge. Although the predation rate at the inherent edges at each site was approximately half that recorded at the induced edges, these differences were not statistically significant.

## Discussion

### Nest predation as an edge effect

In our study, we found that relative predation rates on artificial nests increased close to human-created in-

**Table 1** Results from the pilot artificial nest predation experiments. Table shows number of eggs taken (out of 40) and results of  $\chi^2$  test. Significance levels: n.s. not significant.

	Distance from edge				$\chi^2$
	0 m	20 m	40 m	80 m	
<i>Induced edges</i>					
Kruger	34	27	30	22	2.7 (n.s.)
Yookamurra	33	31	26	17	5.7 (n.s.)

**Table 2** Results from the artificial nest predation experiments. Table shows number of eggs taken (out of 40) and results of  $\chi^2$  test. Significance levels: \* $P < 0.05$ ; \*\* $P < 0.01$ ; n.s. not significant.

	Distance from edge				$\chi^2$
	0 m	40 m	80 m	120 m	
<i>Induced edges</i>					
Kruger	37	34	25	15	10.6 (*)
Yookamurra	36	31	19	12	14.7 (**)
Brookfield	39	30	32	25	3.2 (n.s.)
<i>Inherent edges</i>					
Kruger (exp. 1)	12	14	11	13	0.4 (n.s.)
Kruger (exp. 2)	11	16	18	14	1.8 (n.s.)
Brookfield	18	20	9	17	4.9 (n.s.)

duced edges. Similar results were not recorded at naturally occurring inherent edges suggesting that human-modification of the landscape may lead to an increase in nest predator numbers or activity, or improve their effectiveness at locating nests. This is likely to have an adverse impact on birds that nest close to induced edges. It is also a possible edge mechanism influencing the distribution of birds at our study sites. Luck et al. (1999) showed that ground-nesters like the Chestnut Quail-thrush and Southern Scrub-robin *Drymodes brunneopygia* avoided the induced edges at Kruger and Brookfield, but did not avoid the inherent edges.

Research in North America and Europe suggests that increased nest predation near edges is a result of generalist predators from the surrounding landscape entering vegetation fragments at habitat boundaries (Angelstam 1986; Small & Hunter 1988; Andr n 1992). A number of studies that found an increase in predation near the edge were conducted in habitat fragments surrounded by agricultural land (e.g. Wilcove et al. 1986; Andr n & Angelstam 1988). However, in our study, the induced edges abutted roads rather than open fields, with similar vegetation on both sides of the road. It is possible that predators are attracted to roads because road-kills of suitable prey species represent a reliable and easily obtainable food source.

### Differences between inherent and induced edges

The results of our study suggest that variations in predation of ground nests may be caused by differences in edge type. The overall predation rate for the induced edge experiments (pilot study and main study) was 70%, compared to 35% at inherent edges. It is possible that greater vegetative complexity and shrub cover at inherent edges inhibited predator efficiency at locating nests. We also recorded fewer potential avian predators at inherent edges (Luck et al. 1999). Avian predators such as ravens were more common at induced edges created by land clearance.

The induced edges at our study sites were abrupt, distinct changes between mallee eucalypt vegetation and roadsides. The inherent edges were gradational changes between eucalypt vegetation and open shrubland. Studies by Ratti & Reese (1988) and Suarez et al. (1997) compared predation rates, on real nests, between abrupt and gradational edges. They found that predation rate was lower at gradational edges, and suggested that the complexity of the vegetation at these edges may have reduced predator efficiency. However, a study by Yahner et al. (1989) found no difference between edges.

Equivocal results such as these indicate that more research comparing edge types is required.

### Nest predators

Our study was not designed to accurately identify nest predators. However, by placing nests inside the fenced boundaries of Yookamurra Wildlife Sanctuary we were able to exclude large, introduced mammal predators (e.g. foxes and cats). The absence of these predators had little impact on predation rate. The overall predation rate on nests inside Yookamurra was 64% ( $n = 205$ ), compared to 70% ( $n = 224$ ) for the experiments conducted, at the same edge, in Kruger.

The majority of eggs preyed on inside Yookamurra were completely removed from nests (82.5%  $n = 169$ ) with no signs of nest disturbance (this result was consistent with the induced edges at Kruger and Brookfield). The fate of eggs has been used previously to broadly categorise potential nest predators (Ratti & Reese 1988). Although it has been suggested that mammals (e.g. foxes) are more likely to completely remove eggs from nests leaving behind no signs of disturbance (Ratti & Reese 1988), it has been found that large avian predators (e.g. ravens and crows) also use this method (Andr n 1992). Large avian predators (e.g. Little Raven *Corvus mellori*) were common at the induced edge abutting Kruger and Yookamurra (Luck et al. 1999). However, it is also possible that other native predators (e.g. Bush Rats *Rattus fuscipes*, Sand Monitors *Varanus gouldii* or Grey Currawongs *Strepera versicolor*) were responsible for the nest predation at Yookamurra.

### Conclusion

Although artificial nests are useful in indicating relative predation rate, the results of our study cannot be used as a measure of actual predation experienced by birds nesting in mallee habitat fragments. Artificial nests may be more vulnerable to predators because of nest placement, lack of nest defence by adult birds or attraction to nests by human visitation. Conversely, they may have a lower detectability because adult birds are not flying to or from the nest and there is no bird scent in the vicinity.

We placed a large number of nests at each edge to provide adequate sample sizes for statistical analysis. However, this artificially high level of nest density may have compromised the independence of the predation events (Major & Kendal 1996). Nest density for the pilot study was also highest close to the edge possibly

leading to the higher predation rate recorded (although in the pilot study, there was no significant difference in predation rate with distance from the edge). Given these limitations, we believe that the results obtained for differences in relative predation still have conservation significance. Relative predation rate for the main study was higher close to the edge, and at induced compared to inherent edges, where nest density was the same at each distance point and each edge. Future research is required to examine the nesting success of vulnerable species in fragmented landscapes and explore issues such as the influence of different edge types on predator activity.

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