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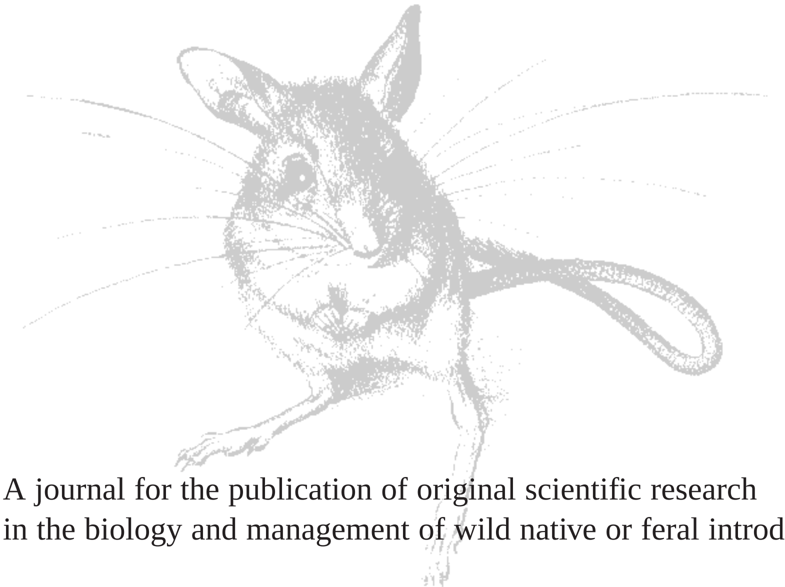

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Application of an Ultralight Aircraft to Aerial Surveys of Kangaroos on Grazing Properties

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Abstract

A Drifter ultralight aircraft was used as a platform for line-transect aerial surveys of three species of kangaroo in the sheep rangelands south-east of Blackall and north of Longreach in central-western Queensland in winter 1993 and 1994. Favourable comparisons between the results of ultralight surveys and those made from a helicopter flying the same transects and foot surveys along another set of transects, all within a few days of the ultralight survey, confirmed the expectation we had that an ultralight would be a satisfactory and much cheaper vehicle for conducting aerial surveys of kangaroos. The comparisons are even more favourable when data for the three species surveyed are combined, pointing to a problem in species identification and underlining the importance of using only experienced observers for aerial survey of kangaroos, whatever the platform. The use of an ultralight aircraft could have particular value where a comparatively small area, such as an individual sheep or cattle property, is under consideration. In this paper, we present the numerical comparisons, along with an evaluation of the practicability of using this type of aircraft. We also describe a possible future scenario in which an accreditation process could see approved kangaroo surveyors undertaking property assessments by ultralight, under contract to graziers or other interested parties.

Introduction

The aim of the project was to assess the suitability of an ultralight aircraft as a platform for aerial survey of kangaroos at a local scale, such as that of individual grazing properties.

The idea of using an ultralight to survey kangaroos arose from contact with biologists in the Pantanal in Brazil, who are using one to survey caiman and other wildlife. Low air speed and good visibility are desirable features in an aerial survey platform and, for this reason, helicopters are being used in Queensland for kangaroo surveys in blocks of 5000–11 000 km^2. Line transects flown by helicopters have been shown to provide accurate density estimates of mule deer (White *et al*. 1989) and feral pig carcasses (Hone 1988). Helicopters are, however, very expensive. An ultralight aircraft combines low airspeed and good visibility at a small fraction of the cost of a helicopter. On present rates, the charter rate for an ultralight would probably be A\$60–80 h^{-1}, including the pilot, compared with A\$300–350 for a helicopter (and A\$180–200 h^{-1} for a suitable fixed-wing aircraft).

The introduction of a helicopter by Clancy *et al*. (in press) for aerial surveys, carried out by the Queensland Department of Environment (QDoE), has enabled the application of a line-transect rather than a strip-transect method of assessment of population density. Aerial surveys for kangaroos have been undertaken for many years from fixed-wing aircraft flying at 250 ft (76 m) above ground and 100 kn (187 km h^{-1}), with strip-transect methodology (Caughley *et al*. 1976; Grigg 1979; Southwell 1989). This is considered satisfactory for obtaining estimates of red kangaroos (*Macropus rufus*) in open country and in light cover, and as an index of trends in population densities over wide geographic areas from year to year. For eastern grey kangaroos (*Macropus giganteus*), western grey kangaroos (*M. fuliginosus*) and common wallaroos (*M. robustus*), however, the conventional methodology is much less than perfect (Hill *et al*. 1985, 1987; Short and Hone 1988; Southwell 1989; Pople *et al*. 1993). Sightability for these species is

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low and variable, leading to large random errors and a poor index of trends in population size. The problem is particularly pronounced for all four species in heavily timbered country.

Accordingly, a helicopter has been applied in a series of experiments by Clancy *et al.* (in press) with line-transect rather than strip-transect methods. In the latter, the observers count all the individuals they see in a single strip, usually 200 m wide, on each side of the aircraft. Correction factors are applied, to account for that proportion of animals believed to have been missed (Caughley 1977), and densities are calculated and scaled up to the total survey area to determine an estimate of total numbers.

In the line-transect method, however, observers count individuals sighted in each of a series of parallel strips, demarcated by a grid positioned between the viewer and the ground. More animals are seen in the closer strips, fewer further out and, indeed, the method has as one of its assumptions that animals on the line of the transect itself are not overlooked. The shape of the curve of numbers seen plotted against distance from the line is the basis of calculations that lead to an estimate of density in the total area viewed. This can then be scaled up to the whole survey area, as before. Comprehensive descriptions of line-transect methods can be found in Burnham *et al.* (1980) and Buckland *et al.* (1993).

Results obtained with the helicopter are encouraging (Clancy 1995), being very similar to data obtained by Pople (unpublished data) in foot surveys along some of the same line transects, foot surveys having already been established as an accurate survey method (Southwell 1994). An additional outcome of the helicopter method is that it will allow the derivation of revised correction factors by which the accuracy of strip-transect surveys from fixed-wing aircraft (for larger areas) will be able to be improved. This could be achieved in a study similar to that described here.

The potential value of using an ultralight instead of a helicopter has an additional attraction, that of bringing the cost of undertaking aerial survey of kangaroos within the reach of individual landholders, many of whom already employ such machines for mustering sheep.

The authors believe that, with growing interest in harvesting kangaroos for profit to landholders, rather than solely as pest destruction, the time is coming when graziers may wish to assess kangaroo numbers on their own properties. Using a helicopter for this would be quite suitable, but expensive, whereas use of an ultralight aircraft would bring the cost down considerably.

Against this background, therefore, we used an ultralight aircraft to count kangaroos by a line-transect method over the same lines flown by a helicopter, and those walked, in two areas of central-western Queensland in 1993 and 1994. The idea was to assess this type of platform as a cheap alternative to the use of a helicopter, the hypothesis being that, because the chosen ultralight mimicked the visibility, speed and height characteristics of the helicopter survey method, there should be no difference between them apart from what could be a consequence of having only a single observer.

Methods

Large-scale Comparisons: Ultralight Compared with Helicopter

Surveys were flown by both helicopter and ultralight across two survey blocks in central-western Queensland (Fig. 1). Longreach block is approximately 5000 km^2 and dominated by open tussock grasslands of Mitchell grasses (*Astrebla* spp.), with some areas of low open *Acacia* woodland with a lower stratum of tussock grasses. There are high densities of red kangaroos and lower densities of both eastern grey kangaroos and common wallaroos within the block. Blackall block is approximately 7500 km^2 and dominated by open tussock grasslands, low open *Acacia* woodlands with a lower stratum of tussock grasses, and low open and low *Acacia* woodland, both with no significant lower stratum. Red kangaroos, eastern grey kangaroos and common wallaroos occur at high densities in the block.

Parallel east–west transects, 10 km apart, were flown across each of the survey blocks. Each transect was divided into two survey lines each approximately 40 km long and separated by a 10-km interval that was not surveyed. A further five parallel 40-km lines were flown on the southern section of the Blackall block. The exact distances were determined by a global positioning system (GPS) receiver. Identical transects were flown by both the ultralight and the helicopter, again enabling a direct comparison of the two techniques.

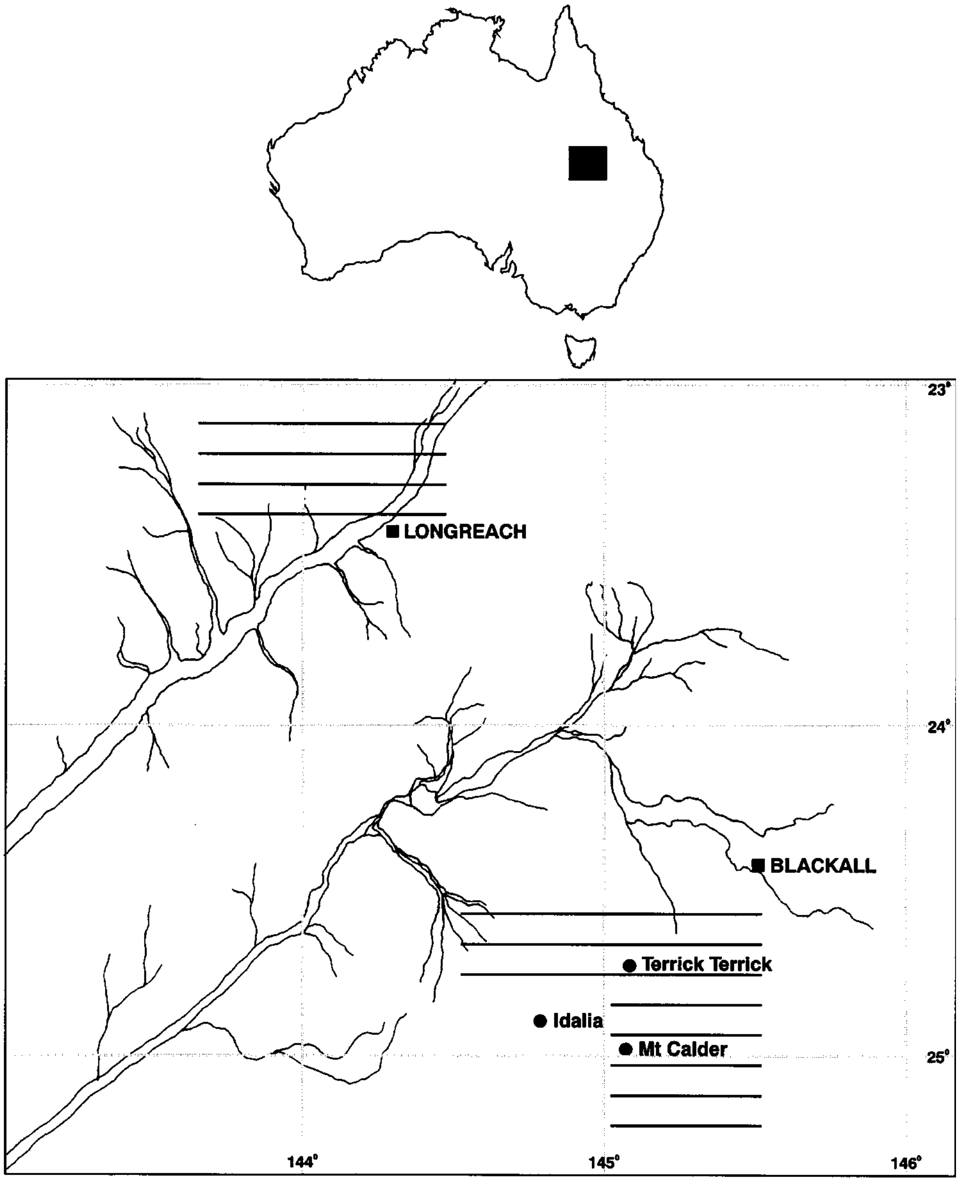

Fig. 1. Location of transect lines flown in the large-scale surveys of Longreach and Blackall survey blocks. Major drainage lines of the Thomson (Longreach) and Barcoo (Blackall) Rivers are also shown. Fine-scale surveys were flown on three properties located within the Blackall survey block.

An attraction of these survey blocks was that the vegetation cover represents most of the range in cover experienced in semi-arid Australia, where most aerial surveys of kangaroos are performed. Additionally, the two blocks provided a contrast of relatively heterogeneous (Blackall) and relatively homogeneous (Longreach) vegetation cover.

Fine-scale Comparisons: Ultralight Compared with Ground Survey

At a finer scale, ground and ultralight surveys were conducted within the Blackall survey block on Idalia National Park and two nearby sheep-grazing properties, Mt Calder and Terrick Terrick. These properties feature high densities of red kangaroos and common wallaroos, and low densities of eastern grey kangaroos. The survey areas were approximately 70, 150 and 120 km^2, respectively. At each site, vegetation ranges from grassland to brigalow (*Acacia harpophylla*) and gidgee (*A. cambagei*) woodland, with some areas of dense regrowth and fallen timber. The result is a mosaic of vegetative cover types, making sightability of kangaroos highly variable. Topography is flat to slightly undulating. These features were also characteristic of the whole Blackall survey block (see above).

On each of the three properties, eight 5-km foot transects were placed systematically, without regard to any particular compass direction, to allow easy access to start and end points. These transects were grouped into four pairs, with each pair being approximately parallel and 1 km apart. Identical transects were traversed both by ultralight and on foot, enabling a direct comparison of the two techniques.

Surveys by Ultralight

Ultralight surveys were conducted with a two-seater Drifter ultralight aircraft (Austflight Aviation, Boonah, Queensland), in which the two seats are in tandem, not side by side (Fig. 2). All observations were made by the observer, seated behind the pilot. To allow more complete and more comfortable viewing of the ground directly below, we removed the wheel spats and packed up the back of the rear seat, which otherwise reclines too far. Sightings of kangaroos were recorded in 25-m distance classes up to 125-m perpendicular to the transect line with a micro-cassette recorder. Distance classes on each side of the aircraft were delineated with a grid made by stretching plastic tape between the wire struts at measured intervals (Fig. 3). Placement of the tapes was determined by flying at survey height past markers on the ground at a known distance apart. We used the row of cone markers at an aerodrome as a reference line, and placed white markers at measured distances from that. As there was only one observer, counting could be conducted out one side only. This was always the southern side on east–west transects, as this provided the best visibility. Beard was the observer throughout the study. She has been a calibrated kangaroo counter since 1979 and has more than 1000 h of aerial survey experience. All transect lines were flown twice to increase sample size, with at least 24 h between repeats. (See Results for more details of the applicability of this type of aircraft to aerial survey.)

Transects across the two survey blocks were typically 40 km (22 nautical miles) long and were flown with reference to a GPS receiver (Garmin GPS 100) that, in addition to directional guidance, also provided a continuous readout of ground speed, distance to run to the end of a line, and time to run (Fig. 4). The aircraft was flown at 250 ft (76 m) above ground (judged by experience and with reference to the aircraft's pressure altimeter) and as close to 50 kn (93 km h^{-1}) airspeed as wind conditions at any time allowed. Counting was

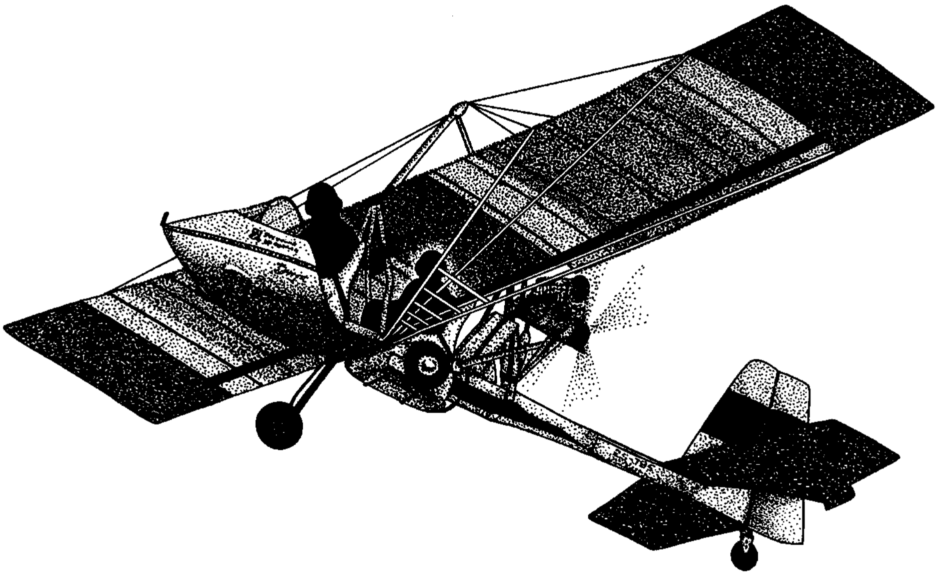

Fig. 2. Kangaroo's-eye view of the Drifter ultralight. Note the observer seated behind the pilot.

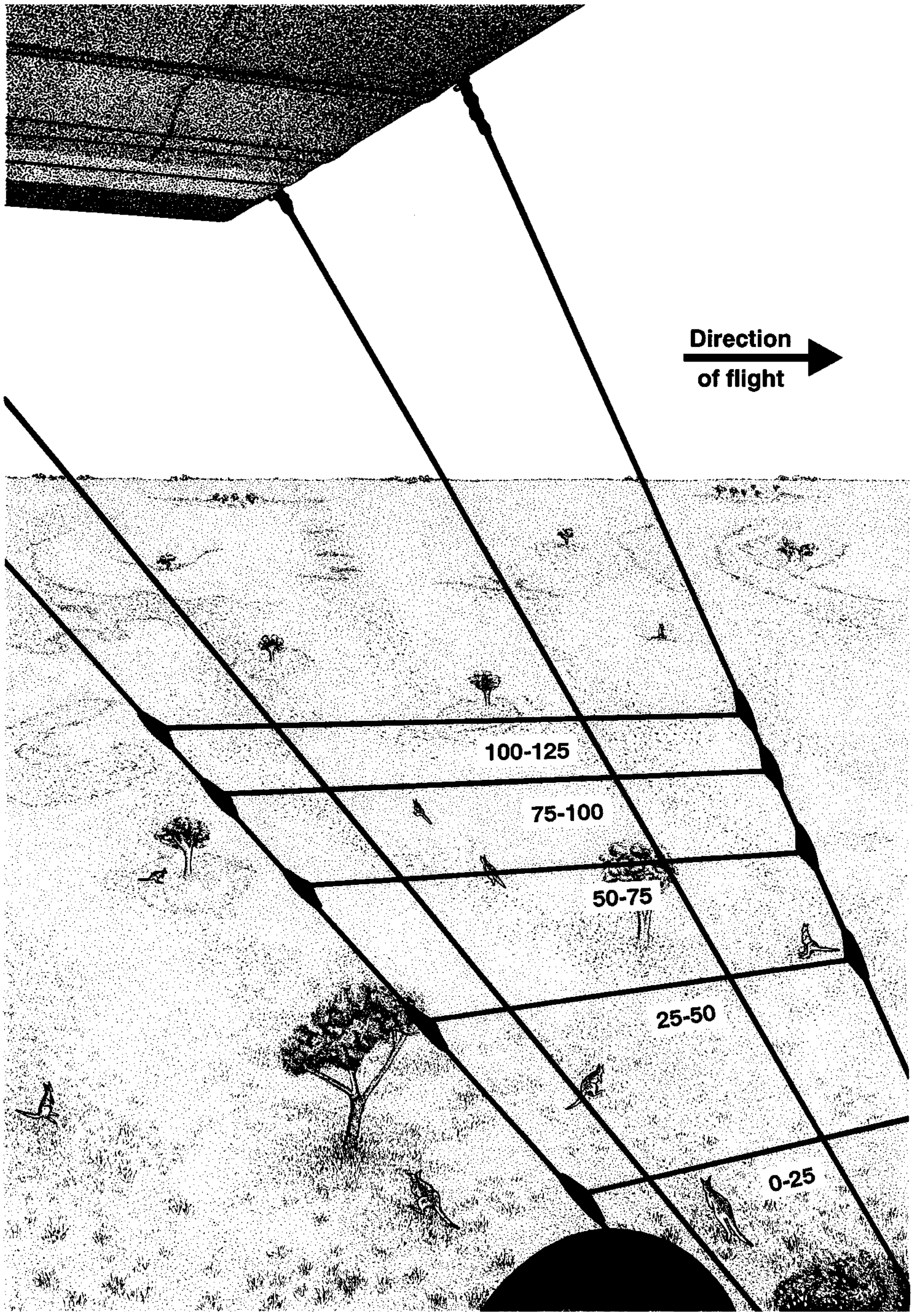

Fig. 3. Observer's-eye view. The observer sits behind the pilot and views the ground, looking down and slightly ahead of the aircraft, through a grid of plastic strips tied to the wire struts. These strips delineate 25-m distance classes up to 125 m out from the line of the transect. Observations of the numbers of kangaroos in each distance class, identified to species, are spoken into a cassette recorder for later transcription and analysis.

Fig. 4. Pilot's-eye view. Navigation and the marking of sampling segments along the transect are effected with reference to a global positioning system receiver (in this case a Garmin GPS 100).

continuous in 5 nautical mile units separated by 0·5 nautical mile rest breaks. The observer concentrated particularly on the innermost strip, trying not to miss any animals. The outer strips were scanned only briefly when the observer was confident that no animals were being missed on the inner strips. An alternative method would have been to scan each strip with the same effort, but this would reduce the probability of seeing an animal on the line. Line-transect theory is built on the assumption that all animals on the line are seen (Buckland *et al.* 1993).

Surveys were conducted within 4 h of sunrise and 3 h of sunset during late May and early June 1993 and 1994.

Surveys by Helicopter

A Bell 47 KH4 helicopter was flown at 200 ft (61 m) above ground and at 50 kn (93 km h^{-1}) with the doors removed. Two rear-seat observers counted out either side of the helicopter, each surveying one-half of a transect line. Sightings of kangaroos were recorded in 25-m distance classes up to 125 m perpendicular to the transect line with a micro-cassette recorder. Distance classes were delineated with tape on an aluminium pole that was placed underneath the observers and extended out from the helicopter. Positioning of the tape on the pole was determined by prior calibration with distances marked on the ground. Observers counted continuously in 5-min units separated by 30-s breaks. Unit distances were determined by a GPS receiver. The scanning pattern of observers was identical to that used in the ultralight.

Surveys were also conducted within 4 h of sunrise and 3 h of sunset within two weeks of the ultralight surveys.

Surveys on Foot

Ground surveys were conducted on foot by following a compass bearing along marked transects. Observers used micro-cassette recorders to record the radial distance and sighting angle of each macropod observed. Perpendicular distances were then calculated from these data. Distances were measured with a rangefinder and angles were measured with a prismatic compass. When a group of animals was sighted, attempts were made to measure angles and distances to each individual. However, if the animals moved off before this could be done, angles and distances for the extremes of the group were recorded and values for the remaining animals interpolated. Transects commenced 1–2 h after sunrise and were walked in pairs (i.e. 10 km), taking 3–4·5 h to complete.

For every survey period, ground counts were always conducted within two weeks of the ultralight counts.

Data Analysis

Initially, histograms of the data were examined for evidence of heaping, evasive movement prior to detection and, for ground surveys, appropriate truncation levels. For ground surveys, up to 10% of data were truncated.

Helicopter, ultralight and ground counts were all analysed with the computer program DISTANCE (Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University, Fort Collins, USA). Following the recommendations of Buckland *et al*. (1993), five models were considered in the analysis. Each model comprises a key function and may be adjusted with a series expansion containing one or more parameters. The models were a uniform or hazard-rate key function with either a cosine or a polynomial series expansion, and a half-normal key function with a Hermite polynomial. The number of adjustment terms was determined through a sequential addition of up to five terms (the default). The model with the lowest value for Akaike’s Information Criterion (AIC) was generally selected. However, models with unrealistic spikes at zero distance, rather than a distinct ‘shoulder’ near the line, were disregarded. As data from aerial surveys were collected in broad distance categories, little manipulation of the grouping intervals was possible. Ground-survey data were analysed ungrouped as suggested for macropods by Southwell and Weaver (1993). However, some data were analysed in grouped form also, in an attempt to reduce the effect of heaping or a spurious spike in the data (Buckland *et al*. 1993). Several different grouping intervals were examined.

Buckland *et al*. (1993) suggested a sample size of at least 60–80 sightings for adequate estimation of density. Where sample sizes fall below this value, some caution is needed in interpreting the results. No estimates were determined for samples of fewer than 30 sightings, forcing some data from the fine-scale surveys on the Blackall properties to be pooled, either across years or properties or both, to provide an adequate sample size. Pooling was similarly required across some transect lines on the large-scale surveys.

Density estimates (D) were determined as

$$D = [n \times f(0)] / 2L \tag{1}$$

where n is the number of sightings, $f(0)$ is the probability density function of the perpendicular density data at zero distance from the transect line and L (km) is the total length of the survey transect (Buckland *et al*. 1993). Variance estimates for property and survey-block densities were calculated as

$$\mathrm{var}(D) = D^2([\mathrm{CV}(n)]^2 + \{\mathrm{CV}[f(0)]\}^2) \tag{2}$$

where $\mathrm{CV}(n)$ is the coefficient of variation for the number of sightings across transect lines and $\mathrm{CV}[f(0)]$ is the coefficient of variation of the probability density function of the perpendicular density data at zero distance (Buckland *et al*. 1993).

Data were analysed as individual sightings rather than clusters. However, for animals that aggregate, individual sightings are unlikely to be independent. This does not appear to introduce any bias in density estimation for macropods, where group sizes are relatively small (Southwell and Weaver 1993). The use of individual sightings may overestimate the true variance (Buckland *et al.* 1993), but has the advantage of a larger sample size.

Comparisons of survey methods were made initially by one-, two- and three-factor repeated-measures ANOVA (Winer *et al.* 1991), performed by the SAS statistical package (SAS Institute Inc., Cary, North Carolina, USA). Analyses were conducted separately for each species with either transect lines within survey blocks or property as the basic sample unit. Survey block and year, both with two levels, were used as fixed factors, while survey method was the repeated factor. All density estimates were $\log_{10}$-transformed.

Survey methods were compared also by calculating the percent relative bias (PRB) for each survey for each species:

$$\mathrm{PRB} = 100(D_\mathrm{u} - D_\mathrm{g})/D_\mathrm{g} \qquad (3)$$

where D_u is density estimated from the ultralight and D_g is density estimated from ground or helicopter surveys. The calculations were made at the level of a survey block or property. The term ‘bias’ is used tentatively here, as it implies the ground- or helicopter-survey density estimates are equivalent to true densities.

Further comparisons between ultralight and ground counts were made by means of regression analysis. Data were first scrutinised for outliers and non-linear trends from leverage values and standardised residuals. Simple linear regressions were fitted:

$$D_\mathrm{u} = \mathrm{b}D_\mathrm{g} + \mathrm{c}. \qquad (4)$$

If the intercept c did not differ significantly from zero, the line was refitted and constrained to pass through the origin. Tests of b = 1 were also conducted.

Detection histograms generated from the ultralight surveys for each of the three species on the survey blocks were compared by log–linear modelling (Manly 1992; Crawley 1993). This was performed with the GLIM statistical package (NAG Ltd, Oxford, UK). A hierarchical approach was used with higher-order interactions being removed from the model if they were not significant at the conservative 1% level. Species, block, year and distance class were used as factors.

Results

Aeronautical Considerations

Logistics of survey with a Drifter ultralight aircraft

The Drifter carries two people, seated in tandem, which allows the observer, behind the pilot, to always choose to look to the side giving better visibility. This is almost invariably the southern side for winter surveys at these latitudes, so we decided to have the observer always look south. The survey method relies upon the aircraft being flown at constant height above terrain (76 m in our case). We did not use a radar altimeter to confirm height, although one could be fitted in future developments. Fifty knots (93 km h^{-1}) is a comfortable cruising speed for the Drifter and is not difficult to maintain as a ground speed in nil-wind conditions. One limitation of the Drifter is its narrow airspeed envelope, comfortably 40–55 kn unless one wishes to be loitering near stall speed. Winds were such during our survey periods that it was common for ground speed to be 5 kn too fast or too slow and, on occasions, there were larger discrepancies. The same problems beset any other fixed-wing platform, although to a lesser extent. A Cessna 182, for example, has a ‘comfortable’ speed envelope of 75–120 kn. The most important consideration in either strip- or line-transect sampling, however, is knowing the distance flown during counting, a task made easier by the use of a GPS receiver. Use of only timed units, as is common in broad-scale fixed-wing aerial surveys (Caughley and Grigg 1981), would have required ground speed to be constant and known. Whether the line-transect method is less sensitive than the strip-transect method to aircraft ground speed is yet to be tested.

The comparatively low cruising speed of the Drifter, 50 kn, is a strength for enhancing viewing while on transect, but provides a limitation during transport flights. Combined with an endurance of about 3·5 h, it dictates that fuel and a suitable landing strip must be available reasonably close to the survey area. A helicopter of the type likely to be chosen for aerial survey would have a similar endurance and an air speed of about 75 kn. A Cessna 182 has a cruising air speed of 120 kn and an endurance up to 6 h. The low air speed of an ultralight makes flight times very susceptible to even quite moderate winds and, therefore, there is a special need for conservative flight planning.

Other considerations, too, demand conservative planning. Surveys are done in winter, so the crew is exposed for long periods (3–3·5 h) to the cold wind. We wore protective clothing including helmets, goggles, fur-lined boots and gloves.

From an aeronautical point of view, Grigg found the Drifter to be docile, strong, tolerant and easy to fly. It carries a good load and in 1993, when we conducted the work without a ground-support vehicle, we carried all personal effects on the trip from near Brisbane to the survey areas and return, as well as all survey requirements and a container of emergency fuel.

The aircraft we used was set up specially for the operation. The Garmin GPS 100 receiver was fitted centrally and within easy reach of the pilot (Fig. 4), with its antenna mounted on a BNC-connector protruding from the most anterior point of the fibreglass pod. A pilot–passenger communications system is standard on the Drifter, but we modified it to include the ability to use a tape recorder for data collection. In practice, this meant that Beard and Grigg could communicate (which is essential, as the survey segments are dictated by reference to the GPS receiver, and visual contact for signalling is difficult to achieve), Beard could record data as required (heard by Grigg in the front) and Grigg could make and receive radio calls without data collection being interrupted. The only other significant modification was that, in 1994, we had a trim-tab fitted to the elevator, which was a significant improvement because it removed the need to provide continuous gentle back pressure on the control stick in our fully loaded configuration.

Survey Results and Comparison between Methods

Comparison of ultralight and ground estimates

For ground surveys, the shapes of the histograms of perpendicular distances included small spikes at zero distance, broad shoulders and peaks in sighting frequencies a short distance (<30 m) from zero. This suggests, but does not prove, that there was negligible reactive movement of animals prior to being observed. Grouping data made little difference to the shape of the fitted model and resulting density estimate. As a result, all estimates were based on ungrouped data. Density estimates from both ground and ultralight surveys on the three properties are shown in Table 1. Coefficients of variation for densities estimated on both survey blocks and properties ranged between 15 and 30%, reflecting the non-uniform dispersion of macropods across both survey blocks and properties.

Comparison of the two survey methods by a repeated-measures ANOVA resulted in no significant difference in density estimates for red kangaroos ($F_{1,5} = 0{\cdot}08$, $P > 0{\cdot}5$). For red kangaroos, a regression analysis resulted in a model with an intercept not significantly different from zero ($t_4 = 0{\cdot}19$, $P > 0{\cdot}8$) and a regression coefficient [b = 0·96 ± 0·18 (s.e.)] that did not differ from b = 1 ($F_{1,5} = 0{\cdot}05$, $P > 0{\cdot}8$) when the line was constrained to pass through the origin ($r^2 = 0{\cdot}82$). PRB averaged 2·4 ± 16·5.

A regression analysis of the wallaroo data also resulted in a model with an intercept not significantly different from zero ($t_2 = -1{\cdot}67$, $P > 0{\cdot}2$). With the line constrained through the origin ($r^2 = 0{\cdot}99$), the regression coefficient (b = 0·27 ± 0·01) differed significantly from b = 1 ($F_{1,3} = 6049{\cdot}1$, $P < 0{\cdot}001$). PRB averaged –76·0 ± 1·8.

Comparison of ultralight and helicopter estimates

Density estimates from both aerial survey platforms are shown in Table 2. For red kangaroos, a repeated-measures analysis revealed a marginally significant difference between the two methods ($F_{1,26} = 4{\cdot}4$, $P = 0{\cdot}045$). There were no block or year main effects, nor any interactions. For eastern grey kangaroos, there was a significant block × year interaction ($F_{1,22} = 4{\cdot}7$,

Table 1. Estimates of macropod density with associated sample sizes (*n*) for ultralight and ground surveys of the Blackall properties, and the percent relative bias (PRB)

Species: RK, red kangaroo; W, wallaroo; EGK, eastern grey kangaroo. Sample sizes for ground surveys are those after truncation

Property	Year	Species	Density from ultralight survey (kangaroos km^{-2})	*n*	Density from ground survey (kangaroos km^{-2})	*n*	PRB
Idalia	1993	RK	10·0	46	18·1	139	–44·6
Idalia	1994	RK	13·6	73	11·9	86	14·0
Mt Calder	1993	RK	15·1	64	15·4	113	–1·9
Mt Calder	1994	RK	14·2	142	25·2	115	–43·6
Terrick Terrick	1993	RK	37·3	195	25·7	159	45·2
Terrick Terrick	1994	RK	10·7	88	7·4	54	45·3
Terrick Terrick	1993	W	21·0	105	76·1	576	–72·4
Terrick Terrick	1994	W	21·5	137	82·0	447	–73·7
Idalia	Both	W	4·6	38	23·4	190	–80·3
Mt Calder	Both	W	2·9	39	13·1	123	–77·6
All properties	Both	EGK	2·4	60	1·4	79	73·7

Table 2. Estimates of macropod density and associated sample sizes (*n*) for aerial surveys of the Blackall and Longreach survey blocks, and the percent relative bias (PRB)

Species: RK, red kangaroo; EGK, eastern grey kangaroo; W, wallaroo

Survey block	Year	Species	Density from ultralight survey (kangaroos km^{-2})	*n*	Density from helicopter survey (kangaroos km^{-2})	*n*	PRB
Blackall	1993	RK	16·6	1114	13·5	764	23·0
Blackall	1994	RK	20·0	1192	10·8	681	84·5
Longreach	1993	RK	13·9	664	15·2	688	–8·6
Longreach	1994	RK	13·9	654	14·4	828	–3·5
Blackall	1993	EGK	11·5	785	18·7	1170	–38·7
Blackall	1994	EGK	7·4	566	14·7	701	–49·5
Longreach	1993	EGK	4·4	188	4·1	315	6·8
Longreach	1994	EGK	6·9	331	6·6	311	4·4
Blackall	1993	W	10·3	565	10·2	575	–4·1
Blackall	1993	W	10·9	572	8·9	361	22·6
Longreach	1993	W	2·9	124	3·2	108	–8·2
Longreach	1994	W	4·4	172	3·5	165	25·4

$P < 0·05$) and a significant method × block interaction ($F_{1,22} = 5·47$, $P < 0·05$). For wallaroos, density estimates on transect lines could be calculated on only the Blackall survey block. Here, there were no significant differences between the two survey methods, nor a year main effect or any interaction.

The PRBs for red and eastern grey kangaroos were inversely related on the Blackall survey block. This suggests that there may have been some misidentification of the two species by observers in either the helicopter or the ultralight or both. This is unlikely to have been a problem on the Longreach survey block, where the vegetation is more open and the macropod density is lower. Here, the density estimates of red and eastern grey kangaroos from the two methods were in concordance. The PRBs for wallaroos suggested a reasonably consistent agreement between the two survey methods.

If misidentifications are contributing to discrepancies between the two methods, this can be examined by comparing combined densities in each year and in each survey block. Data were reanalysed for the three species pooled. The resulting density estimates (Table 3) show clearly that most of the discrepancies disappear, reinforcing the conclusion that misidentifications are likely to be a larger source of error than differences between the survey platforms. Indeed, presented in this way, the results indicate a striking concordance between the two methods.

Table 3. Estimates of macropod density, three species combined, in 1993 and 1994 in each of the survey blocks

Survey block	Year	Density from ultralight survey (kangaroos km^{-2})		Density from helicopter survey (kangaroos km^{-2})	
		Mean	s.e.	Mean	s.e.
Blackall	1993	37·3	4·1	43·2	5·5
Blackall	1994	39·5	4·0	34·7	4·4
Longreach	1993	21·8	5·1	24·9	5·9
Longreach	1994	26·1	2·8	23·9	7·8

Detection histograms

Log–linear modelling of the detection histograms from the ultralight surveys resulted in the minimal adequate model shown in Table 4. The model was a poor fit according to log-likelihood statistics ($\chi^2_{28} = 52{\cdot}2$, $P < 0{\cdot}01$). However, the addition of any higher-order interaction terms was non-significant at the 1% level. Furthermore, fewer than 5% of standardised residuals were outside the range of –2 to 2 and then only marginally so. Each parameter estimate in Table 4 refers to the transformed value of the response variable (in this case, kangaroo numbers) relative to a ‘reference cell’, which is represented by the lowest level of each factor, such as the 0–25-m distance class. Interpretation of the minimal adequate model centres upon factor interactions. From the main effects, it is trivial to know that there were more animals seen on the Blackall survey block. These differences may simply reflect different sample sizes. What is of interest is how the number of animals sighted in each distance class differs between the species, survey blocks and years. A significant interaction between distance class and any of these factors suggests that the pattern described by the main effects needs to be modified. Therefore, the estimates in Table 4 that are of interest are those that involve the distance categories. The number of sightings clearly declined monotonically from the line. The decline was steepest for wallaroos and most gradual for eastern grey kangaroos. A greater proportion of sightings were made in the furthest distance categories in 1994 and at Longreach.

Discussion

As a platform for aerial survey of red and eastern grey kangaroos, it is quite clear that an ultralight aircraft such as the Drifter can be used to return survey results with a high level of accuracy, and that it would be very suitable for use in surveys to estimate the density of kangaroos on individual properties. It is as good as a helicopter, but much cheaper. Assuming that ground counts approximated true density, then wallaroo density was consistently underestimated. A negative bias of the same order has been found also for helicopter surveys of wallaroos (Clancy *et al.* in press). However, the consistency of this bias in all studies suggests that a correction factor of 2–3 should adequately monitor wallaroo numbers. Comparisons of ground and helicopter surveys suggest that this bias is greater at low densities (Clancy *et al.* in press).

Table 4. Parameter estimates and associated standard errors for the minimal adequate model from a log–linear model comparing detection histograms across survey blocks, species [eastern grey kangaroo (‘grey’) and wallaroo], years and distance classes

Parameter descriptions represent factor levels and interactions. Only significant estimates are shown (i.e. │(estimate)/(s.e.)│ > 2). Estimates are relative to the number of red kangaroos seen in the 0–25-m distance category at Blackall in 1993

Estimate	s.e.	Parameter
6·01	0·04	Constant
–0·39	0·06	Grey
–0·49	0·06	Wallaroo
–0·60	0·06	Longreach
–0·19	0·06	Distance (50 m)
–0·67	0·06	Distance (75 m)
–1·22	0·08	Distance (100 m)
–2·37	0·11	Distance (125 m)
–0·92	0·09	Grey × Longreach
–0·98	0·11	Wallaroo × Longreach
–0·40	0·07	Grey × 1994
0·18	0·08	Grey × distance (75 m)
–0·25	0·08	Wallaroo × distance (50 m)
–0·21	0·09	Wallaroo × distance (75 m)
–0·70	0·12	Wallaroo × distance (100 m)
–0·56	0·16	Wallaroo × distance (125 m)
0·57	0·11	Longreach × distance (125 m)
0·21	0·08	1994 × distance (100 m)
0·69	0·11	1994 × distance (125 m)
0·97	0·13	Grey × Longreach × 1994
0·40	0·15	Wallaroo × Longreach × 1994

Other potential applications exist for ultralights, such as a research tool for the determination of correction factors for aerial survey, and for other aspects of wildlife research. A trial of the aircraft for radio-tracking echidnas in an area between Stanthorpe and Texas in south-eastern Queensland showed it to be quite satisfactory. With some further modification, such as mounting fixed antennae, we are confident that it could be of great value for such work where regular airborne tracking is required for a study within a relatively limited area. Also there is potentially a wide range of applications in general surveillance work in national parks, in inland areas particularly.

The sightability curves generated on these aerial surveys certainly make biological sense. Detection functions were steepest for the more cryptic species, wallaroos, and flattest for the more gregarious species, eastern grey kangaroos. In more open country, at Longreach, the detection function was also flatter. The differences between years is not clear, but sightability of kangaroos is known to vary seasonally, with temperature being an important influence (Bayliss and Giles 1985; Hill *et al.* 1985; Caughley 1989). Red kangaroos are also known to feed in more open areas during drier times (Newsome 1965). It is this sensitivity to varying sightability that makes line-transect methods so attractive.

That said, in future use for kangaroo surveys, it may be that a better method would be to employ strip-transect rather than line-transect methods. In any aerial kangaroo survey, the scanning method adopted by the observer is crucial to the accuracy of the technique. If all strips are scanned equally then it is likely that animals will be missed in the innermost strip, thereby violating the most critical assumption for line transects and leading to an underestimation of density. This is certainly true for line-transect surveys of kangaroos from conventional fixed-wing aircraft (Pople *et al.* 1993). Unfortunately, scanning each strip equally seems to be a more comfortable method of observation than concentrating on the innermost strip. However, scanning each strip equally is used in strip-transect sampling, and other aspects of data collection and analysis are also much simpler for strip-transect sampling than for line-transect sampling. Wider application of ultralights as a survey platform may therefore be easier to implement with strip rather than line transects. Correction factors could be developed for line transects or, if three-seat ultralights were available, double counting (Southwell 1989).

The importance of having well-qualified observers cannot be overlooked, particularly for strip transects. Differences in visibility bias between observers on aerial surveys of kangaroos have been well recognised (e.g. Short and Bayliss 1985); however, problems with species misidentification have been thought to be only minor (Caughley 1989). The results presented in Tables 2 and 3 suggest otherwise. We feel a growing concern about the need for better recognition of the importance of training observers for aerial survey, and will be writing about it elsewhere. Over the years, we have adopted quite strict training procedures before using an observer's data. In general, in our conventional fixed-wing aircraft and strip-transect sampling, we do not use data gained by a trainee until there are favourable comparisons with the data gained by a trained, experienced observer viewing the same strip. Our experience is that this often takes 8–10 survey sessions, and we are reluctant to use their data until they have about 50 h survey time. Also we know from considerable experience that not all people will be suitable: motion sickness and an inability to concentrate for extended periods will exclude many, probably most, people from becoming calibrated observers.

We can foresee a time when graziers could be hiring accredited kangaroo surveyors to make an assessment of the kangaroo densities on a particular property or group of properties, with a view to applying for a particular harvest quota for the area. This, of course, anticipates a time when kangaroos are regarded as a resource for graziers, rather than a pest, and much has been written elsewhere about the prospects of that development (Grigg 1987, 1989, 1995). If the technique is to be used in this fashion, by operators other than wildlife authorities, there will need to be some system of observer and pilot training and accreditation, perhaps by a State or Federal wildlife agency. Suitable aircraft are already in use within the sheep rangelands as replacements for helicopters in mustering operations, and the opportunity may be there for appropriate operators to extend their mustering operations into wildlife surveys.

It should be noted that present Civil Aviation Safety Regulations prohibit the commercial use of ultralight aircraft in this way. Our operation was quite legal because it was non-commercial. Future use by commercial operators will depend upon changes to Civil Aviation Authority regulations, which seem to be continually under review as ultralights are becoming more reliable and more common.

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References

Bayliss, P., and Giles, J. (1985). Factors affecting the visibility of kangaroos counted during aerial surveys. *Journal of Wildlife Management* **49**, 686–692.

Buckland, S. T., Anderson, D. R., Burnham, K. P., and Laake, J. L. (1993). 'Distance Sampling.' (Chapman and Hall: London.)

Burnham, K. P., Anderson, D. R., and Laake, J. L. (1980). Estimation of density from line transect sampling of biological populations. *Wildlife Monographs* **72**, 1–202.

Caughley, G. (1977). ‘Analysis of Vertebrate Populations.’ (Wiley and Sons: London.)

Caughley, G. (1989). Repeatability of aerial surveys. Unpublished report to Australian National Parks and Wildlife Service, Canberra.

Caughley, G., and Grigg, G. C. (1981). Surveys of the distribution and density of kangaroos in the pastoral zone of South Australia and their bearing on the feasibility of aerial survey in large and remote areas. *Australian Wildlife Research* **8**, 1–11.

Caughley, G., Sinclair, R., and Scott-Kemmis, D. (1976). Experiments in aerial survey. *Journal of Wildlife Management* **40**, 290–300.

Clancy, T. F. (1995). Techniques for broad scale monitoring of the abundance of kangaroos in the mulgalands. In ‘Ecological Research and Management in the Mulgalands’. (Eds M. J. Page and T. S. Beutel.) pp. 31–36. (University of Queensland: Brisbane.)

Clancy, T. F., Pople, A. R., and Gibson, L. A. (in press). Comparison of helicopter line transects with walked line transects for estimating densities of kangaroos. *Wildlife Research* **23**.

Crawley, M. J. (1993). ‘Glim for Ecologists.’ (Blackwell Scientific Publications: London.)

Grigg, G. C. (1979). Aeronautical aspects of aerial survey. In ‘Aerial Surveys of Fauna Populations’. Australian National Parks and Wildlife Service Special Publication No. 1.

Grigg, G. C. (1987). Kangaroos—a better economic base for our marginal grazing lands? *Australian Zoologist* **24**, 73–80.

Grigg, G. C. (1989). Kangaroo harvesting and the conservation of arid and semi-arid rangelands. *Conservation Biology* **3**, 194–197.

Grigg, G. C. (1995). Kangaroo harvesting for conservation of rangelands, kangaroos and graziers. In ‘Sustainable Use of Wildlife for Conservation’. (Eds G. C. Grigg, P. T. Hale and D. Lunney.) pp. 161–165. (Centre for Conservation Biology, The University of Queensland: Brisbane.)

Hill, G. J. E., Barnes, A., and Wilson, G. R. (1985). Time of day and aerial counts of grey kangaroos. *Journal of Wildlife Management* **49**, 843–849.

Hill, G. J. E., Barnes, A., and Wilson, G. R. (1987). The effect of drought on kangaroo populations: a comment. *Journal of Wildlife Management* **51**, 602–603.

Hone, J. (1988). A test of the accuracy of line and strip transect estimators in aerial survey. *Australian Wildlife Research* **15**, 493–497.

Manly, B. F. J. (1992). ‘The Design and Analysis of Research Studies.’ (Cambridge University Press: Cambridge.)

Newsome, A. E. (1965). The distribution of red kangaroos, *Megaleia rufa* (Desmarest), about sources of persistent food and water in central Australia. *Australian Journal of Zoology* **13**, 289–299.

Pople, T., Cairns, S., Clancy, T., Grigg, G., and Beard, L. (1993). Accuracy of kangaroo surveys in Queensland using fixed-wing aircraft. Unpublished report to the Australian National Parks and Wildlife Service, Canberra.

Short, J., and Bayliss, P. (1985). Bias in aerial survey estimates of kangaroos. *Journal of Applied Ecology* **23**, 559–571.

Short, J., and Hone, J. (1988). Calibrating aerial surveys of kangaroos by comparison with drive counts. *Australian Wildlife Research* **15**, 277–284.

Southwell, C. (1989). Techniques for monitoring the abundance of kangaroo and wallaby populations. In ‘Kangaroos, Wallabies and Rat-kangaroos’. (Eds G. Grigg, P. Jarman and I. Hume.) pp. 659–693. (Surrey Beatty and Sons: Sydney.)

Southwell, C. (1994). Evaluation of walked line transect counts for estimating macropod density. *Journal of Wildlife Management* **58**, 348–356.

Southwell, C., and Weaver, K. (1993). Evaluation of analytical procedures for density estimation from line-transect data: data grouping, data truncation and the unit of analysis. *Wildlife Research* **20**, 433–444.

White, G. C., Bartmann, R. M., Carpenter, L. H., and Garrot, R. A. (1989). Evaluation of aerial line transects for estimating mule deer densities. *Journal of Wildlife Management* **53**, 625–635.

Winer, B. J., Brown, D. R., and Michels, K. M. (1991). ‘Statistical Principles in Experimental Design.’ 3rd Edn. (McGraw-Hill: New York.)

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