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Resources Management Board

Kowari monitoring in Sturt's Stony Desert, South Australia

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Cover image: A Kowari on typical gibber pavement habitat. Photo by Nathan Beerkens (Arid Recovery).

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LANDHOLDER SUMMARY

The Kowari is a small carnivorous marsupial that has declined significantly since European settlement and is now restricted to only a handful of sites on pastoral leases in the north-east of South Australia and south-western Queensland. Kowaris are the largest surviving marsupial predator inhabiting gibber pavement country, where they live in burrows dug into scattered sand mounds. Kowaris feed on a variety of insects and other invertebrates (including grasshoppers and spiders), lizards, small mammals and birds that live on the gibber, sand mounds and run-on country.

In May 2018, areas previously surveyed were revisited on Clifton Hills, Pandie Pandie and Cordillo Downs pastoral leases to assess the health and coverage of Kowari populations. Sites were trapped with metal box traps baited with dog food and fish oil. Sand mounds were assessed to determine their ability to provide effective burrow sites at various distances from waterpoints, and spotlighting was done to provide information on species not entering traps. Kowaris were detected on both Clifton Hills and Pandie Pandie stations, but not on Cordillo Downs. We found that sand mounds were less disturbed and Kowaris were more likely to be captured in areas that are further from waterpoints.

A number of surveys on Clifton Hills and Pandie Pandie since 1999 show that Kowari persist on the gibber flats within 40 km of the shared boundary, with more than 10 fold fluctuations in numbers depending on seasonal trends. This makes the population vulnerable to impacts related to increased stock and predator numbers associated with new waterpoint placements, primarily from shelter site loss as sand mounds become deflated through trampling by stock. Sand mounds are vital for Kowaris to create burrow systems for shelter, whilst perennial grass and forb cover provides sand mound stability and food resources for invertebrate species and other animals upon which the Kowari depends on for food.

The vulnerability of these populations has been highlighted by the apparent loss of populations on neighbouring stations, where the Kowari occupied smaller isolated areas of favoured gibber with sand mound habitat.

This report not only summarises the results of survey effort in 2018, but also highlights the historic known Kowari distribution, important habitat features and what to take into account when planning future waterpoint developments.



INTRODUCTION

The Kowari (*Dasyuroides byrnei*) is listed as Vulnerable under national and state (South Australia and Queensland) legislation due to the considerable decline in its range since European settlement. Historical records indicated that the range of Kowaris has decreased significantly since the mid-1800s and, despite the earliest records of Kowaris coming from the west of the Simpson Desert, there have been no Kowaris recorded there since 1901.

Monitoring of the Kowari population in Sturt's Stony Desert has been ongoing for over a decade, following extensive surveys and research on this rare marsupial predator in the 1990s. Monitoring surveys during this period have included approximately 40 sites between the Cooper Crossing and the Queensland border, with focus around two trapping grids near Koonchera Dune on Clifton Hills station, where Kowari numbers and other parameters have been compared at different grazing intensities.

Kowari numbers have fluctuated from high capture rates in 2009 and 2013 to extremely low captures in 2007 during a drought and in 2012 following an exceptionally wet period. Declines in 2012 may have been attributed to either competition for traps with super-abundant long-haired rats (*Rattus villosissimus*) or increases in predation possibly from adult rats as well as larger predators that respond to super-abundant rats.

The purpose of the 2018 monitoring survey was to determine the status of the Kowari at known refuge areas on Clifton Hills and Pandie Pandie, and to revisit areas on Cordillo Downs in which Kowaris had previously been known to occur but had not been seriously sampled in over a decade. Assessments of the quality of sand mounds at a range of sites were also undertaken, as previous research has identified sand mounds as being a critical shelter resource for Kowari survival, as favoured locations for shelter and breeding burrows.



METHODS

Trapping

Trapping surveys were carried out at 11 sites on Clifton Hills, Pandie Pandie and Cordillo Downs stations between 23-31 May 2018 (Table 1 and Figure 1). Metal box (Elliott) traps (Figure 2) baited with dog biscuits and fish oil were set from a vehicle at a spacing of 100 m. The Clifton Hills trap sites consisted of 5 lines, set 1 km apart, each with 40 traps spaced at 100 m intervals (~4 km x 4 km grid with 200 traps in total covering ~16 km²). In all other areas, traps were set in single lines of 100 traps spaced at 100m intervals covering ~10 km each. In most cases, existing trap sites were revisited, while two new trap transects were set up on Pandie Pandie and Cordillo Downs. The Clifton Hills trapping grids were trapped for four nights, while other trap sites were trapped for two nights, except for the Cadelga sites on Cordillo Downs which were trapped for one night.

Table 1. Summary of trap sites and trap effort during the 2018 survey.

Property	Trap site	Description	Dates	Trap nights
Clifton Hills	PAN Grid	4km x 5km trapping grid, on south-east side of Pandieburra Bore	23-26 May	800
	WAL Grid*	4km x 5km trapping grid in Gap Paddock – northern end of Walker’s Crossing access route	23-26 May	780
Clifton Hills/ Pandie Pandie	PPBARR#	10km trap transect from south of Barr 1 tank on Pandie Pandie into Clifton Hills	27-28 May	200
Pandie Pandie	PPPOT6^	12.6km trap transect on west side of Pothole Dune	27-28 May	246
	PPKOCH	10km trap transect east-west along Kochalana Tank track	27-28 May	200
Cordillo Downs	CAD1	10km trap transect north-west of Cadelga Ruin	29 May	104
	CAD2	10km trap transect south of Cadelga Ruin	29 May	94
	CAD3*	10km trap transect south-west of Cadelga Ruin	29 May	100
	KP00101	10km trap transect north of Kachumba Waterhole	30-31 May	200
	KO05401	7.7km trap transect north of Kachumba Waterhole	30-31 May	154
	KP3*	10km trap transect north of Kachumba Waterhole	30-31 May	200

*only 180 traps were set on WAL Grid on first night of trapping.

^only part of trap transect trapped during current survey.

#new trap transect established during current survey.



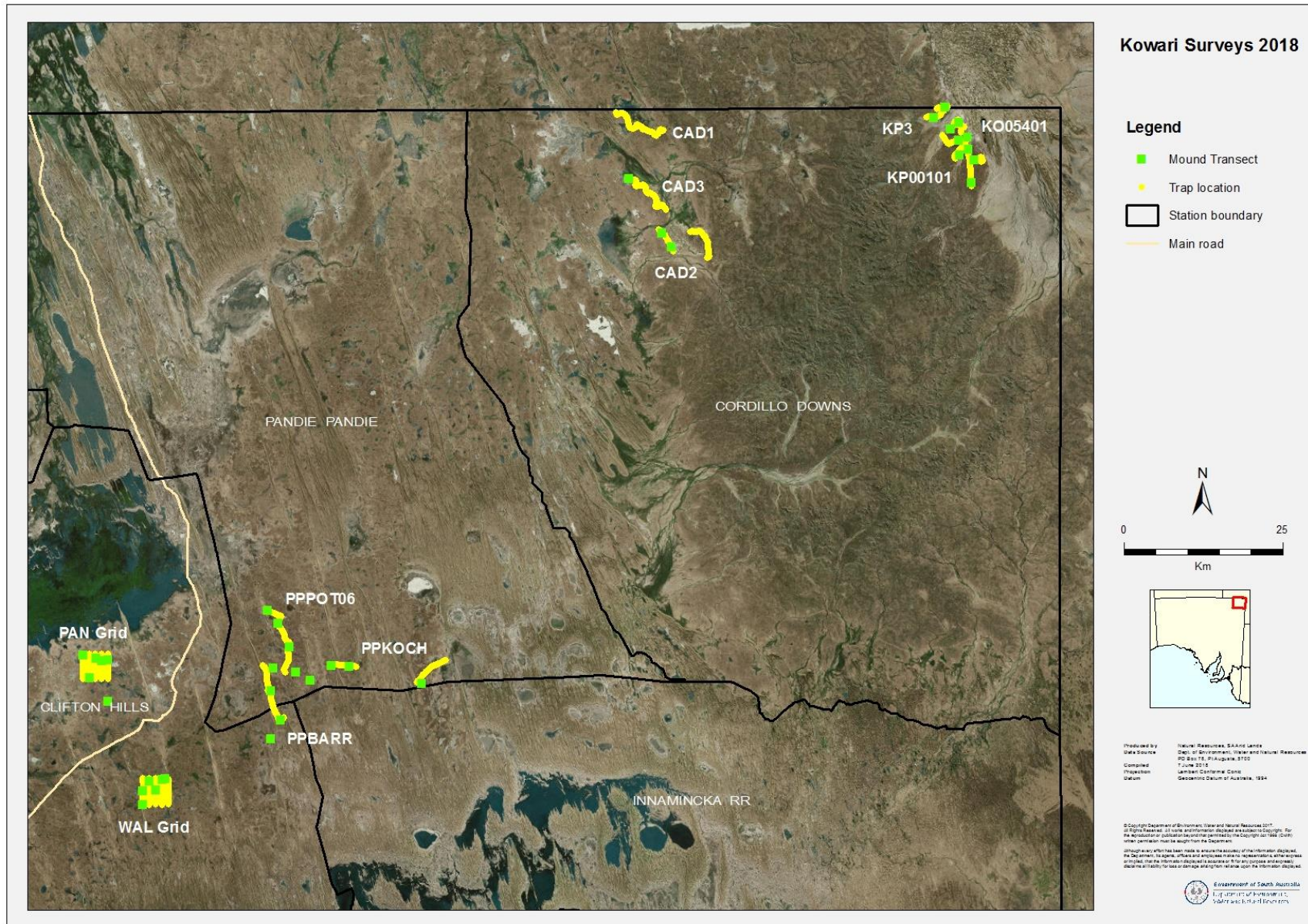


Figure 1. The location of trap sites visited in 2018. The location of mound assessment sites is also shown. Site labels refer to sites in Table 1.





Figure 2. An Elliott trap set in typical Kowari habitat on a pavement gibber plain.

Weather conditions during the survey were generally warm, with mild overnight minima of between 7-14 °C (Table 2). Several days were windy and overcast, however windy conditions generally eased overnight. Rainfall in the months preceding the survey was minimal, however floodwaters from Queensland had flowed through the north-east channels of the Diamantina and Warburton Rivers.

Table 2. Summary of weather conditions during the survey. Taken from the nearest recording station at Birdsville. Dir = direction, Spd = speed (km/h), RH = relative humidity (%).

Date	Day	Temp (°C)		Max wind gust		9am				3pm			
		Min	Max	Dir	Spd	Temp	RH	Dir	Spd	Temp	RH	Dir	Spd
23/05/18	Wed	13.7	31.3	S	30	20.1	34	NNE	7	30.5	16	WSW	13
24/05/18	Thu	14.2	24.7	SSE	33	16.6	44	SE	17	24.1	23	S	17
25/05/18	Fri	8.1	25.2	S	35	13	58	S	11	24.8	26	SSW	17
26/05/18	Sat	8.9	25.3	ESE	22	13.5	59	S	13	24.2	28	ESE	13
27/05/18	Sun	10.2	28.3	SE	20	16	51	Calm		27.2	21	N	7
28/05/18	Mon	11.5	25.3	SSW	46	15.8	43	SSW	17	24.6	27	SW	26
29/05/18	Tue	7.5	22.1	ESE	31	11.7	59	S	11	21.5	30	SSE	19
30/05/18	Wed	7.3	22	SE	33	12.8	61	S	13	21.5	35	S	22
31/05/18	Thu	7.6	21.2	SSE	46	11.9	59	SSE	22	20.4	36	SSE	28






Habitat assessments

A rapid assessment of sand mound profile and height developed by Brandle and Canty (2008) was repeated during the current survey. Several previously surveyed sites were revisited, as well as a number of new sites. The location of the mound assessment survey sites is shown in Figure 1. At each site, sand mound profile and height was recorded, as well as other parameters relating to gibber cover and size, cover of hard depressions, sand spreads, sand mounds and trees/shrubs greater than 40 cm in height. These parameters were split into different cover classes (Table 3). At each site, ideally >30 mounds are categorised into a height and profile matrix (Table 4), however this was not always possible where mounds were very sparse.

Table 3. Cover classes for each habitat parameter assessed at sand mound assessment sites.

Parameter	Cover classes
Gibber pavement cover	1= <5%; 2=5-25%; 3=25-50%; 4=50-75%; 5= >75%
Cover of gibber in preferred size range (1-50mm)	1= <50%, 2=50-75%, 3=75-90%, 4=>90%
Hard depression cover	1= <5%; 2=5-25%; 3=25-50%; 4=50-75%; 5= >75%
Sand mound cover	1= <5%; 2=5-25%; 3=25-50%; 4=50-75%; 5= >75%
Sand spread cover	1= <5%; 2=5-25%; 3=25-50%; 4=50-75%; 5= >75%
Cover of trees and shrubs >40cm high	1= 0, 2= <5%, 3= >5%

Table 4. Profile and height classes used to categorise each sand mound.

Profiles	Height classes
Type 1 – flat or irregular 	1 = <10cm 2 = 10-25cm
Type 2 – convex edge 	3 = 25-40cm 4 = 40-60cm
Type 3 – concave edge 	

Data analysis

The rapid assessment tally data was totalled for each profile and height class and then transformed to proportional data for comparison between properties, sites where Kowaris were captured (during this survey) and waterpoint distances.

A mound assessment site was considered to be in close proximity to a Kowari capture if it was ≤ 500 m from a trap location at which a Kowari was captured.



Mound assessment sites were categorised into waterpoint distance classes by nearest distance to a permanent waterpoint; near = 0-3 km, medium = 3.1-7 km, far-remote = > 7.1 km. These distances take fencelines into account, but do not account for ephemeral waterpoints (e.g. waterholes) and so some sites may in fact be closer to water depending on seasonal conditions.

Spotlighting and searching

Opportunistic spotlighting was carried out from a vehicle on Cordillo Downs. Spotlighting was also undertaken on foot on Clifton Hills and Pandie Pandie stations. Care was taken to not spotlight along trap transects in case capture rates were affected. Spotlighting was conducted for a minimum of one hour in adjacent areas of suitable habitat.

Tracks, scats and other sign (such as burrows) of Kowari was searched for in suitable habitat, particularly on sand mounds and other sandy areas.



RESULTS

Trapping

Kowaris

Trap effort is summarised in Table 5 and totals 3078 trap nights across the 11 sampled sites. A total of 24 individual Kowaris were captured (Table 5); 15 on Clifton Hills Station and nine on Pandie Pandie Station (Figure 3). No Kowaris were captured on Cordillo Downs Station despite a trap effort of 852 trap nights across six transects. The PPBARR trap transect south of Barr2 Tank on Pandie Pandie and into Clifton Hills was trapped for the first time and yielded one Kowari capture. Kowari trap success was comparable to the dry June 2003 session and the much wetter June 2011 trapping session, during which a plague of long-haired rats monopolised traps (Table 6).

The age structure of Kowaris was diverse, with several sub-adult animals (Figure 4) captured weighing between 60-80 g, suggesting a late breeding event during 2017. The remainder of Kowaris captured were adults, with the majority of females showing non-developed pouches, however one female was found to have three small joeys present in her pouch, suggesting mating had occurred in April/May, based on their gestation period of 35 days (Meißner and Ganslößer 1985). A total of 12 female Kowaris were captured ranging from 63-109 g, and 12 male Kowaris ranging from 68-152 g in weight. The majority (83%) of males were adults weighing >80 g while 58% of females were sub-adults weighing <80 g.

Table 5. Summary of captures from all sites during the survey. The total number of individuals captured is displayed, with the number including same session recaptures shown in brackets. % trap success refers to individuals only (excludes same session recaptures).

Property	Site	No. of nights trapped	Trap nights (# traps x # nights set)	Total Kowaris # individuals (total captures)	Total other species # individuals (total captures)	% trap success (# individuals / # trap nights)
Clifton Hills	PAN Grid	4	800	9(9)	1(1)	1.3
	WAL Grid	4	780	5(5)	1(1)	0.8
Clifton Hills/ Pandie Pandie	PPBARR	2	200	1(1)*	0	0.5
Pandie Pandie	PPPOT6	2	246	5(6)	0	2.0
	PPKOCH	2	200	4(5)	0	2.0
Cordillo Downs	CAD1	1	104	0	0	0
	CAD2	1	94	0	0	0
	CAD3	1	100	0	2(2)	2.0
	KP00101	2	200	0	0	0
	KO05401	2	154	0	0	0
	KP3*	2	200	0	0	0
		Total	3078	24(26)	4(4)	0.9

*Kowari captured on Clifton Hills.



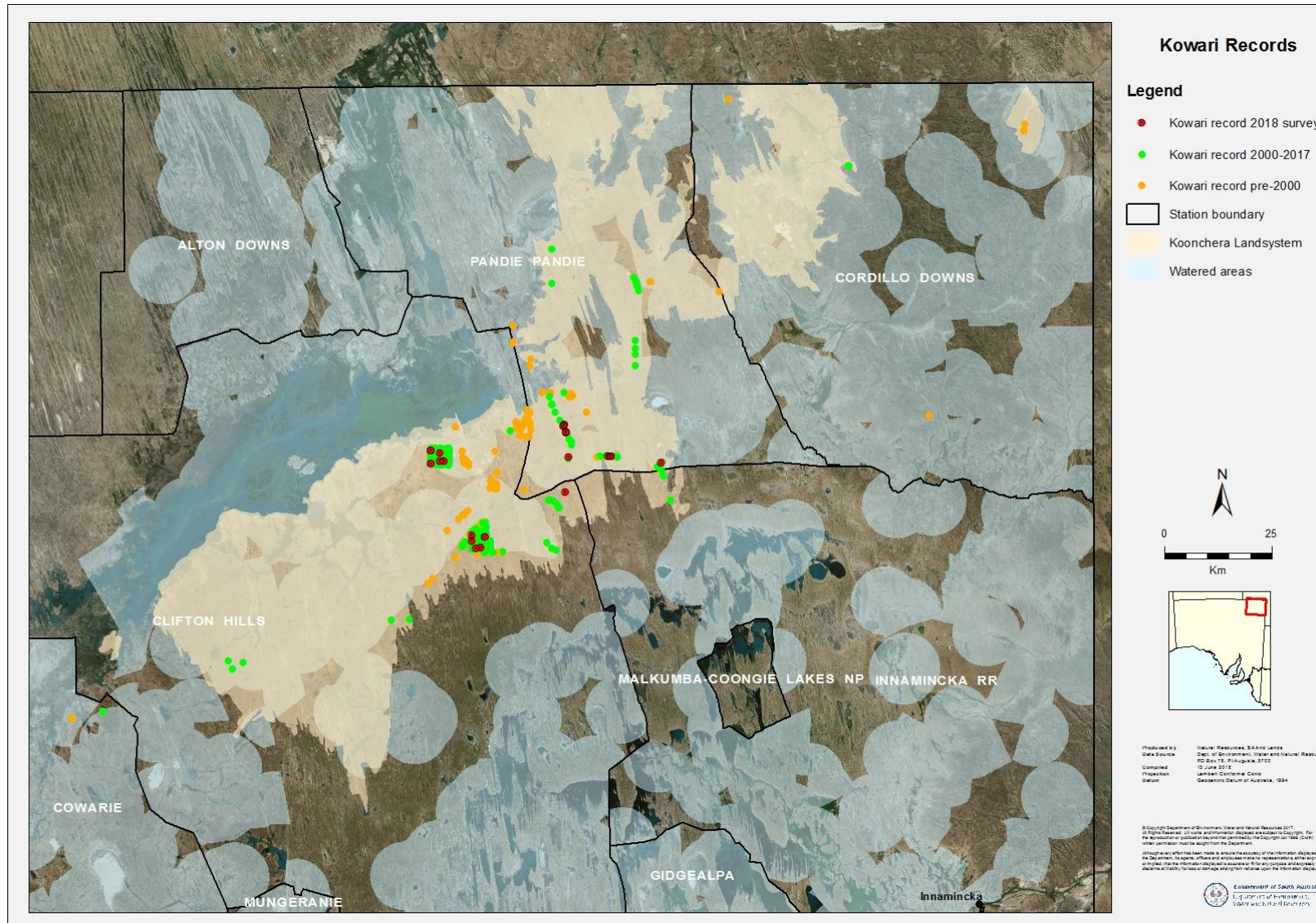


Figure 3. Location of Kowaris recorded during the 2018 survey (red dots). The location of previous Kowari records is also shown. The beige shaded Koonchera land system supports favoured Kowari habitat. Watered areas are derived from an 8 km radius around natural and artificial surface water. Please note that whilst the watered area is an underestimate as not all waters are plotted, some waters are not permanent.



Table 6. Comparison of Kowari capture rates and number of individuals at WAL and PAN trapping grids on Clifton Hills over the past 19 years. The total number of individuals captured is displayed, with the total number of captures (including recaptures) shown in brackets and percentage trap success (of kowari individuals) underneath.

Site	Total individuals (total captures) % trap success of individuals													
	Aug 1999	Oct 2000	May 2001	Aug 2001	April 2002	Mar 2003	Jun 2003	Mar 2006	Dec 2007	May 2009	Jun 2011	Apr 2013	Sep 2015	May 2018
WAL Grid	39 3.3%	30(32) 3.8%	37(50) 4.6%	42(54) 4.5%	36(67) 5.0%	11(16) 1.5%	4(4) 0.5%	6(6) 0.8%	4(4) 1.3%	9(16) 1.3%	2(2) 0.5%	27(29) 7.5%	2(2) 0.5%	5(5) 0.6%
Trap effort	1200*	800	800	940^	720	720	720	720	330#	720	360**	360	360	780
PAN Grid	-	-	25(30) 3.1%	-	19(29) 2.4%	3(4) 0.4%	4(6) 0.5%	7(13) 0.9%	-	35(44) 4.4%	3(3) 1%	19(21) 4.8%	-	9(9) 1.1%
Trap effort	-	-	800	-	800	800	800	800	-	800	300**	400	-	800

* no grids established. WAL site trap effort 1200 trap nights (400 traps x 3 nights set in long lines)

^ 50m x 50m sub-grid within WAL GRID established. WAL site trap effort 940 trap nights (100 x 1 night + 380 x 3 nights)

opportunistic trapping over 2 nights on WAL grid only. Areas of best Kowari habitat targeted on western side of grid.

** opportunistic trapping over 2 nights on grids only – run-on/swampy areas not trapped (to avoid excessive Plague Rat captures and inaccessible wet areas) and extra traps set in gibber pavement areas between grid lines.





Figure 4. A sub-adult male Kowari caught on Pandie Pandie Station.

Other small mammal species

Numbers of other small mammals were well down on previous trapping sessions prior to 2010-12 (Table 7). Captures included two Fawn Hopping-mouse (*Notomys cervinus*) (one on the PAN Grid and one on the CAD3 trap transect on Cordillo Downs), one Kultarr (*Antechinomys laniger*) (Figure 5) trapped on the WAL Grid, and one Central Short-tailed Mouse (*Leggadina forresti*) trapped on Cordillo Downs.

Table 7. Summary of all small mammals captured during Kowari surveys since 2000 at the PAN and WAL trapping grids on Clifton Hills. Totals are pooled between the two grids, with the percentage trap success in brackets below (and include all captures, including same session recaptures).

Species	Trapping Session (trap effort)										
	2000 (1400)*	May 2001 (1600)	Aug * 2001 (940)	Apr 2002 (1600)	Mar 2003 (1520)	June 2003 (1520)	Mar 2006 (1520)	May 2009 (1520)	June 2011 (660)**	Apr 2013 (760)**	May 2015 (1580)
Kowari <i>Dasyercus byrnei</i>	32 (3.6%)	80 (5.0%)	54* (5.74%)	96 (6.0%)	20 (1.3%)	10 (0.65%)	19 (1.25%)	60 (3.9%)	5 (0.9%)	50 (6.57%)	14 (0.89%)
Kultarr <i>Antechinomys laniger</i>	0	22 (1.4%)	6 (0.6%)	4 (0.3%)	46 (3%)	21 (1.3%)	22 (1.37%)	14 (0.92%)	0	0	1 (0.06%)
Stripe-faced Dunnart <i>Sminthopsis macroura</i>	0	0	0	0	0	0	1 (0.06%)	2 (0.13%)	0	0	0
Fawn Hopping-mouse <i>Notomys cervinus</i> (Endangered SA)	17 (1.2%)	0	0	1 (0.06%)	1 (0.07%)	2 (0.13%)	6 (0.37%)	6 (0.39%)	0	1 (0.13%)	1 (0.06%)
Sandy Inland Mouse <i>Pseudomys hermannsburgensis</i>	7 (0.5%)	0	0	0	0	0	0	0	0	0	0
Desert Mouse <i>Pseudomys desertor</i>	0	0	0	1 (0.06%)	0	0	0	0	0	0	0
Forrest's Mouse <i>Leggadina forresti</i>	1 (0.07%)	1 (0.06%)	0	0	0	0	0	0	0	0	0
House Mouse <i>Mus musculus</i> (Introduced)	0	1 (0.06%)	0	0	1 (0.07%)	0	0	0	0	0	0
Plague Rat <i>Rattus villosissimus</i>	0	1 (0.06%)	0	0	0	0	0	0	192 (29.1%)	2 (0.26%)	0

*WAL Grid trapped only

**Trapping over 2 nights compared to 4 in previous years.





Figure 5. The single kultarr captured during the survey, on the WAL Grid on Clifton Hills Station.

Spotlighting and searching

No Kowaris were detected during spotlighting. One small mammal was detected near WAL Grid on 23rd May but could not be identified. Three Fawn Hopping-mice (*Notomys cervinus*) (Figure 6) were detected while spotlighting on Cordillo Downs, as well as one feral cat (*Felis catus*) and one dingo (*Canis lupis*). Hopping-mouse tracks were also observed around a trap site on the KP3 trap transect on Cordillo Downs.

A potential Kowari burrow (Figure 7) was detected while searching at mound assessment site PVT3 on the PAN Grid; approximately 500 m north of where a Kowari was captured. The burrow was approximately 7-8 cm high and wide and was located on a sand mound under a Cottonbush (*Maireana aphylla*) plant. No fresh scats were detected at the burrow. Reasonably fresh Kowari scats were detected on a sand mound at mound assessment site PAND38. No other sign of Kowaris were detected during the survey.

A fresh burrow (Figure 8) and scats were detected at a trap site on the CAD2 trap transect on Cordillo Downs. The burrow was approximately 6 cm high and wide. Unfortunately, no animals were trapped at the site, however fresh scats and tracks were detected around the trap when checked in the morning. It is unclear which species was responsible for the burrow, scats and tracks.





Figure 6. A Fawn Hopping-mouse (*Notomys cervinus*) spotlighted on the gibber near KP00101 trap transect on Cordillo Downs. Photo by Hamish Longbottom.



Figure 7. A possible Kowari burrow detected on a sand mound on the PAN trapping grid.



Figure 8. A burrow recorded next to a trap site on the CAD2 trap transect on Cordillo Downs.



Habitat assessments

A total of 37 mound assessment sites were surveyed in 2018. A full list of sites and associated data is provided in Appendix 1.

Relationship with Kowari occurrence

Seven of the 37 mound assessment sites were in close proximity (i.e. within 500 m) to where a Kowari was captured. Sites in close proximity to where Kowaris were captured tended to have a higher percentage of concave (Type 3) and convex (Type 2) mounds compared to sites where Kowaris were not detected (Figure 9). Mounds were also higher at sites where Kowaris were captured, with more than 6% of mounds greater than 40 cm in height and 25% of mounds greater than 25 cm in height (Figure 10). No difference in other habitat parameters were observed between sites where a Kowari was captured and those where Kowaris were not captured (Figure 11).

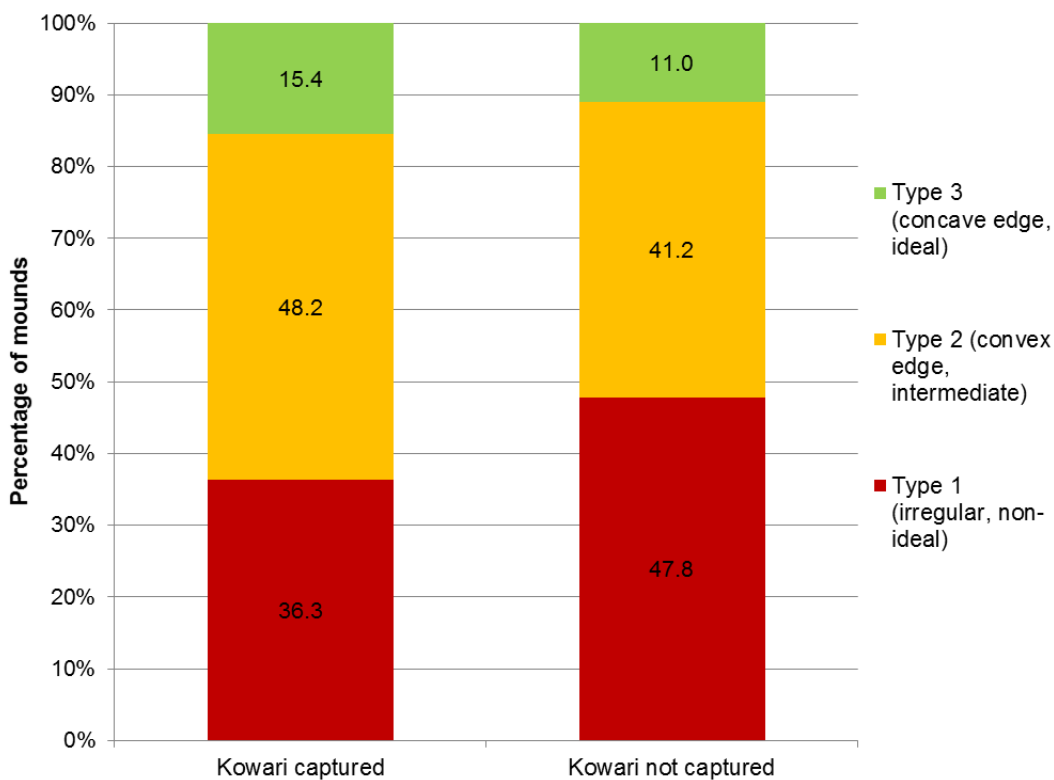


Figure 9. The percentage of mounds in each profile category for sites where Kowaris were captured (n=7) versus sites where Kowaris were not captured (n=37).



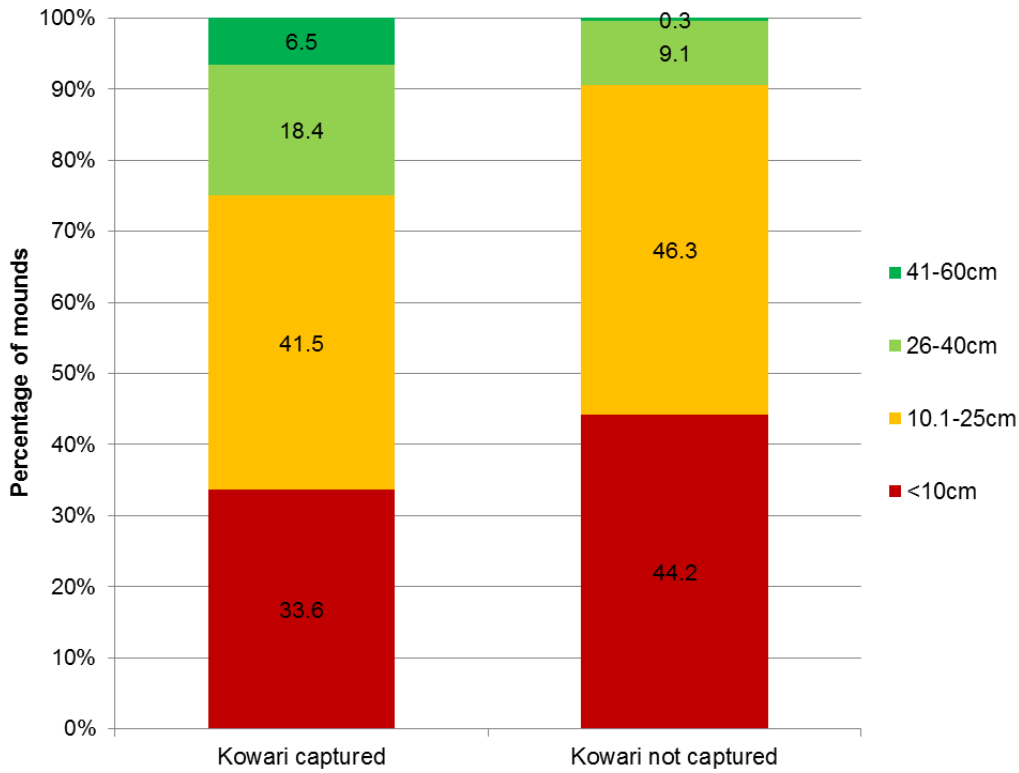


Figure 10. The percentage of mounds in each height category for sites where Kowaris were captured (n=7) versus sites where Kowaris were not captured (n=37).

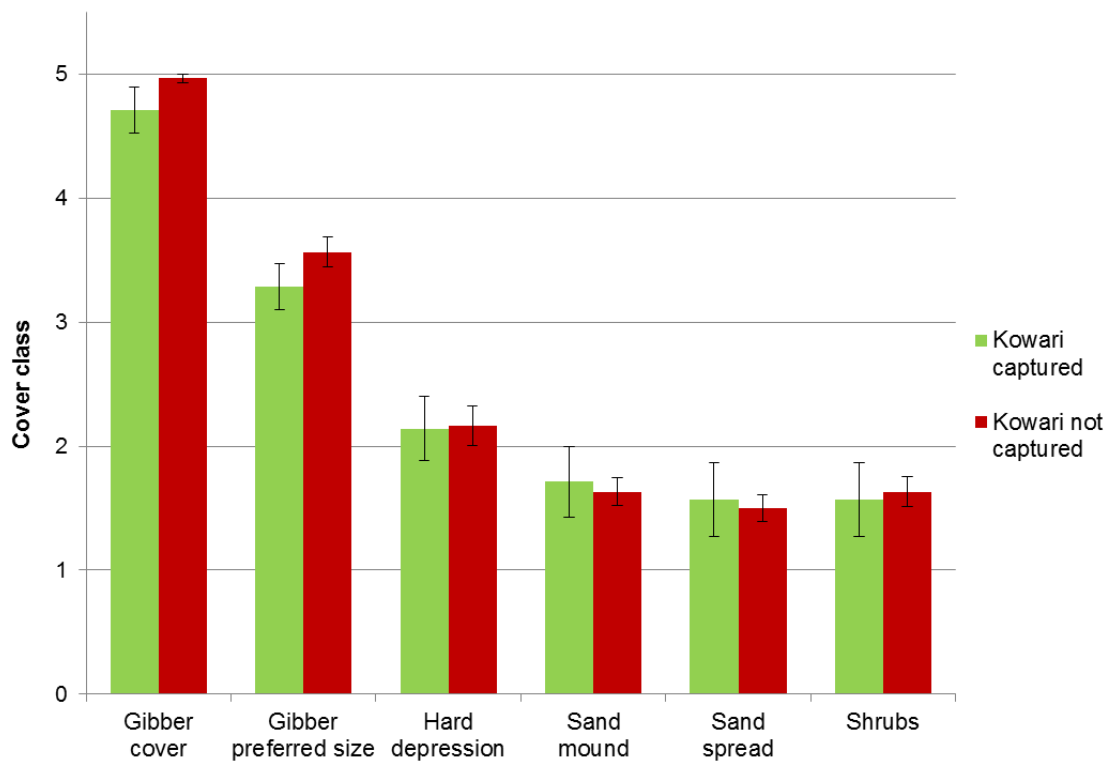


Figure 11. The average cover class for each habitat parameter for sites where Kowaris were captured (n=7) versus sites where Kowaris were not captured (n=37).



Differences between properties

Differences in the profile and height of sand mounds were observed between properties and between the two trapping grids on Clifton Hills. Sites on the WAL Grid on Clifton Hills tended to have a much higher proportion of concave (Type 3) and convex (Type 2) mounds compared to the PAN Grid and sites on Pandie Pandie and Cordillo Downs (Figure 12). Mounds were also higher at sites on the WAL Grid compared to the PAN Grid and other properties, with more than 20 % of mounds greater than 25 cm in height (Figure 13). Sites on the WAL Grid and Cordillo Downs had a higher cover of gibber in the preferred size range (1-50 mm) compared to the PAN Grid and sites on Pandie Pandie and Cordillo Downs (Figure 14).

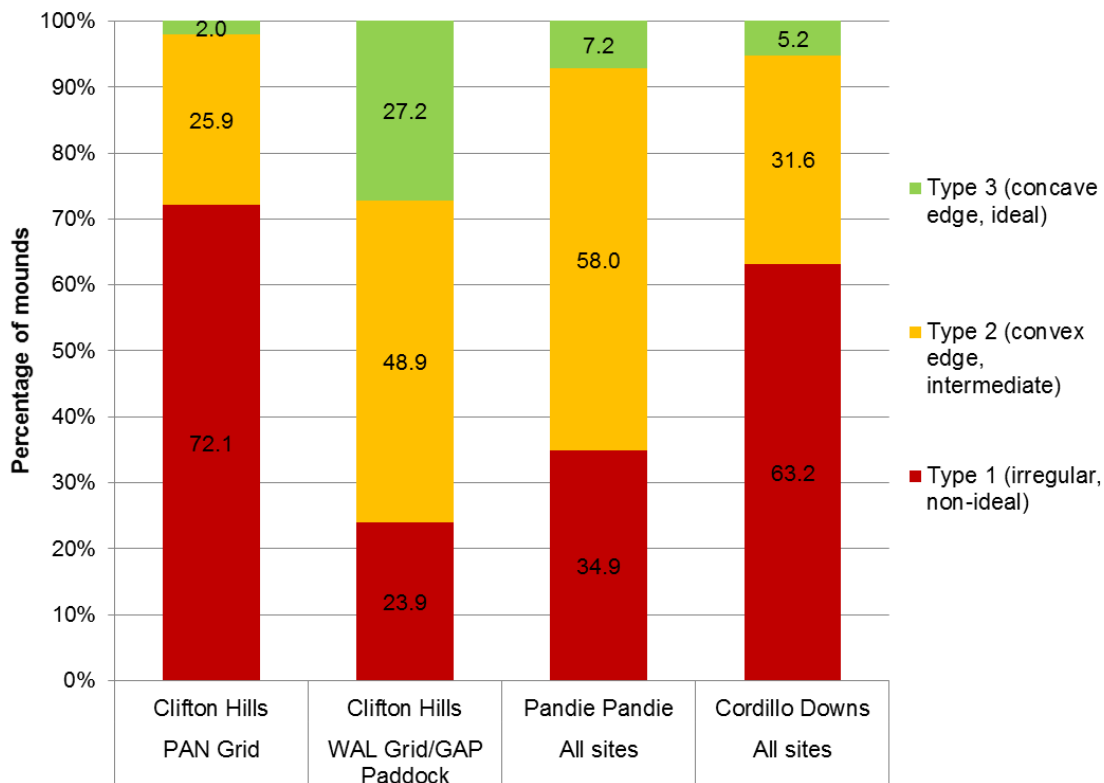


Figure 12. Percentage of mounds in each profile category for each property. GAP Paddock refers to mound assessment sites near the southern end of the PPBARR trap transect on Clifton Hills.



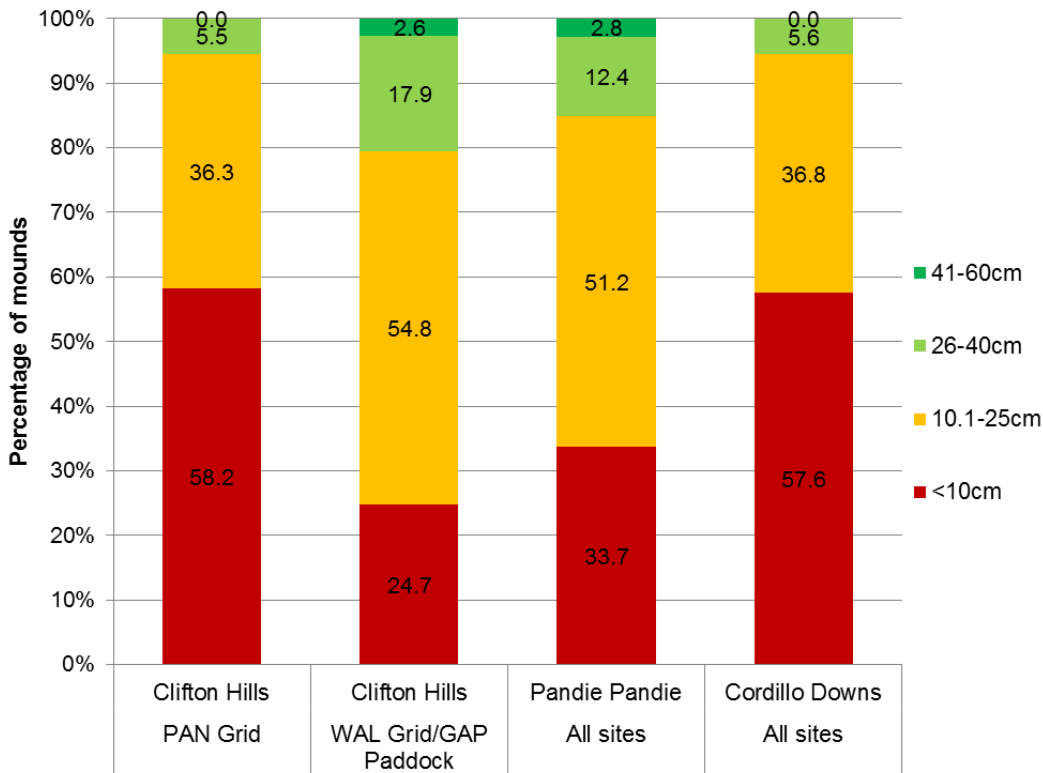


Figure 13. Percentage of mounds in each height category for each property. GAP Paddock refers to mound assessment sites near the southern end of the PPBARR trap transect on Clifton Hills.

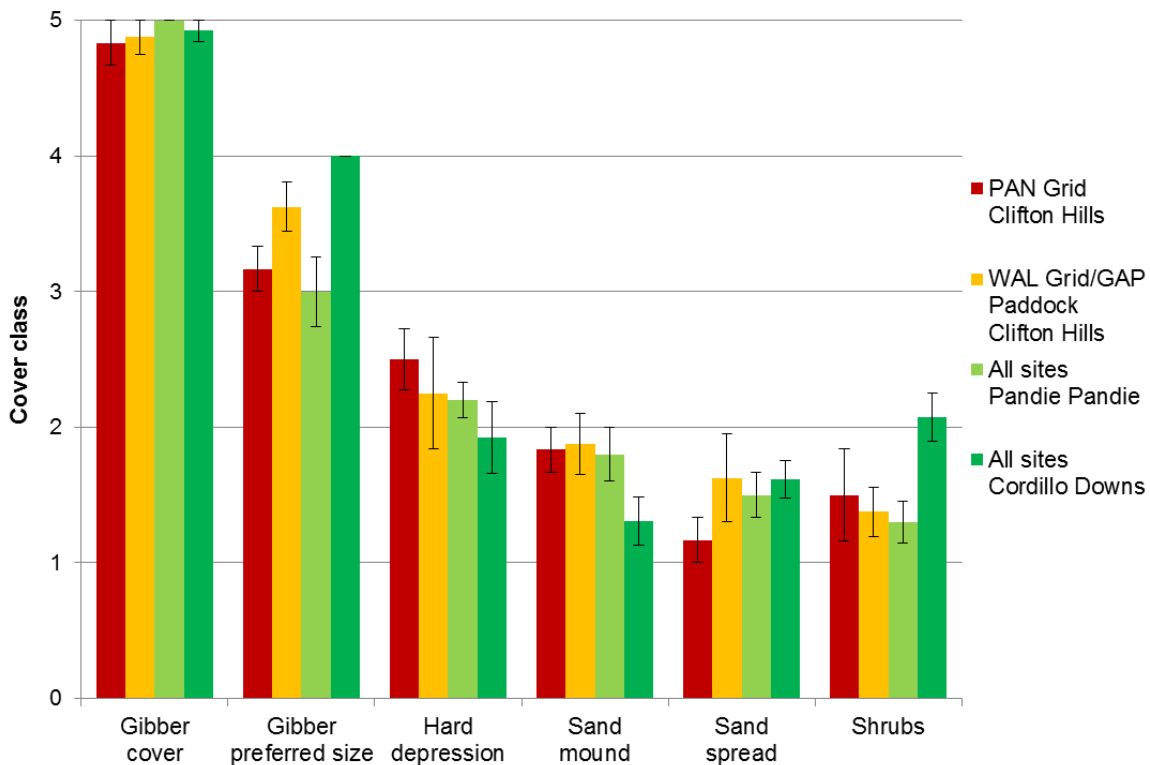


Figure 14. The average cover class for each habitat parameter for sites on each property. GAP Paddock refers to mound assessment sites near the southern end of the PPBARR trap transect on Clifton Hills.



Relationship with distance to permanent water

A higher proportion of sites in close proximity to Kowari captures were further from permanent waterpoints than sites remote from Kowari captures, with only one of the seven sites (14.3 %) in close proximity to Kowari captures close to a permanent waterpoint compared to 10 of the 30 sites (33.3 %) where Kowaris were not captured (Figure 15). However, this trend was not statistically significant at $\alpha = 0.05$. Sites that were further from waterpoints tended to have a much higher proportion of concave (Type 3) and convex (Type 2) mounds compared to sites near waterpoints (Figure 16). Mounds were also higher at sites that were further from waterpoints, with more than 20 % of mounds greater than 25 cm in height at sites more than 7 km from permanent waterpoints (Figure 17).

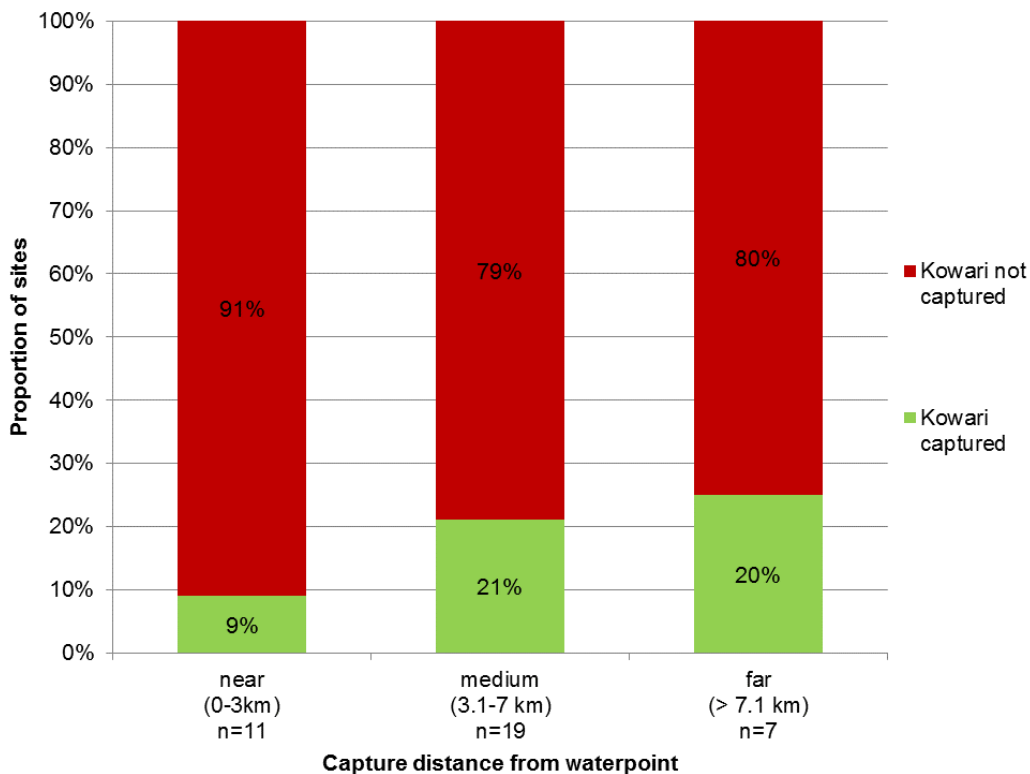


Figure 15. The proportion of sites in relation to distance to permanent waterpoints for sites where Kowaris were captured (n=7) versus sites where Kowaris were not captured (n=30).



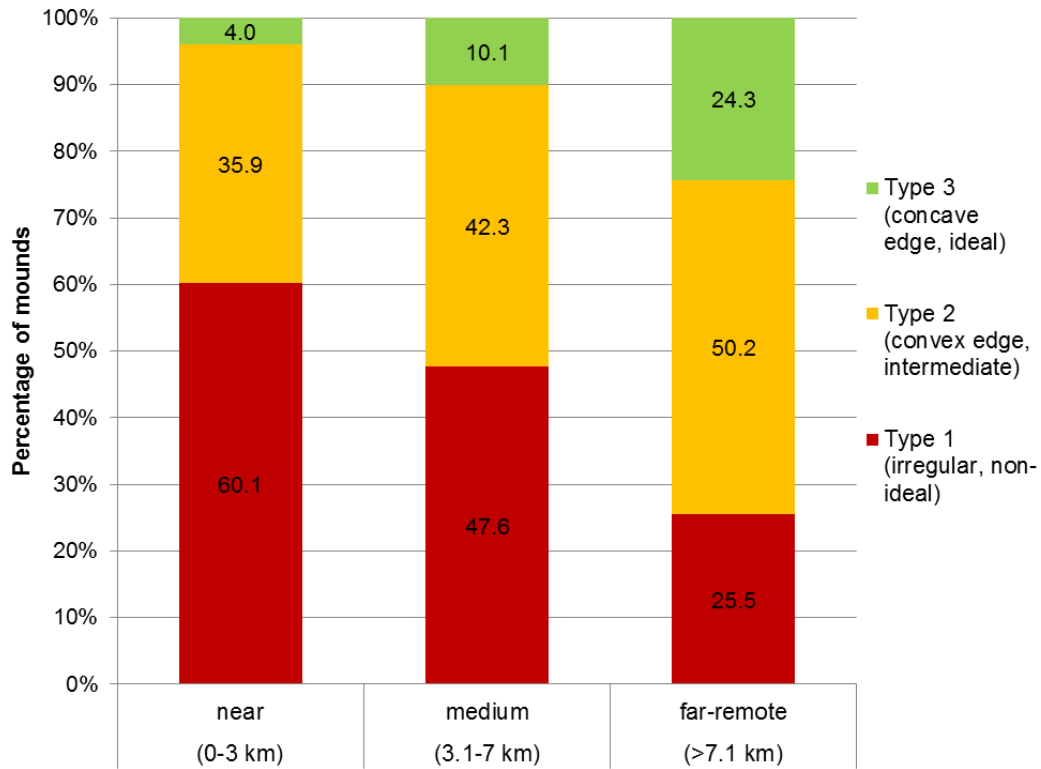


Figure 16. The percentage of mounds in each profile category in relation to distance to permanent waterpoints.

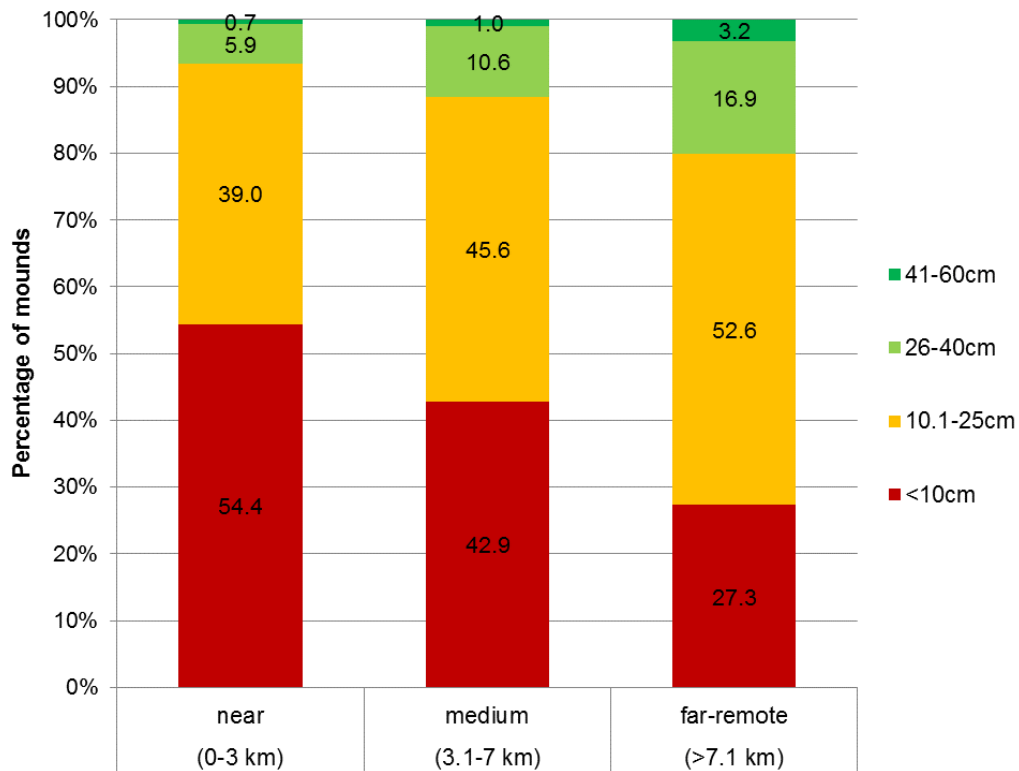


Figure 17. The percentage of mounds in each height category in relation to distance to permanent waterpoints.



The impact of cattle grazing was evident at several sites, with pugging and poor quality (flat or irregular) mounds recorded where cattle usage was obvious (i.e. closer to waterpoints) compared to areas where cattle usage was not as evident (Figures 15 and 16). While vegetation cover on sand mounds was not specifically recorded, it was noted that many sand mounds on Cordillo Downs had reasonable vegetation cover, although they were dominated by Button-grass (*Dactyloctenium radulans*) and very little, if any, other species.



Figure 18. A degraded and unproductive sand mound on the PAN Grid (L) in contrast to the more intact and better vegetated sand mounds on the WAL Grid (R) on Clifton Hills.



Figure 19. A sand mound with cattle pugging evident on the PAN Grid on Clifton Hills.





Figure 20. Sand mounds on Cordillo Downs dominated by Button-grass (*Dactyloctenium radulans*).



DISCUSSION

Dry conditions preceding the survey are likely to have led to relatively low Kowari captures during this survey. Previous work has indicated that even at very low densities Kowari should be detected along 10 km transects through suitable habitat with 100 traps at capture rates below 2 %. The results of this survey show the Kowari is persisting in South Australia but is restricted to a limited area of gibber plains on Clifton Hills and Pandie Pandie Stations. The absence of Kowari captures or sign on Cordillo Downs supports earlier work (Pedler *et al.* 2011, 2013 and Read and Moseby 2015) suggesting that Kowaris have not expanded their range following exceptional rainfall, unlike several other desert mammals (Pedler *et al.* 2017).

Previous surveys have usually recorded much higher captures on the WAL Grid compared to the PAN Grid near Pandieburra Bore, presumably because sand mounds at the WAL Grid are less disturbed by cattle and can therefore support a higher number of Kowaris. However, during this survey, a slightly higher number of Kowaris were captured on the PAN Grid compared to the WAL Grid. This result is comparable to the results of a 2009 survey, when 35 individuals were captured on the PAN Grid compared to nine on the WAL Grid. While conditions were dry at the time of the 2018 and 2009 surveys, it is possible that the higher captures on the PAN Grid relate to proximity to Goyder Lagoon, which was flooded at the time of both surveys and likely to support more Kowari prey, i.e. insects and other small animals.

The low number of other small mammals captured compared to some previous years could be due to a number of factors. The trapping methods are somewhat targeted towards Kowaris (particularly the spacing of traps and bait used) and are less effective at catching small rodents and other dasyurids. During this survey, trapping was only carried out for one or two nights at sites on Pandie Pandie and Cordillo Downs Stations. Most other small mammal species are more likely to be captured as they become less wary of the traps on subsequent nights. However, capture rates were also low on the trapping grids on nights three and four. The low number of small mammals were detected during spotlighting surveys is normal. Whilst total captures were low, recaptures of animals on subsequent nights was lower than is usual for Kowaris, but consistent with other “dry” trips. A possible explanation may be the need to forage in different sectors of their territories (not intercepted by traplines) on subsequent nights because of the dry conditions. Lack of recaptures reduces the ability to estimate population density, however given previous results it is likely that the lack of captures reflects actual low abundance of small mammal species due to dry conditions and reduced resources.

Sand mound assessments, from this survey and previous surveys, support observations that more dense populations of Kowaris exist in areas with a greater proportion of the less disturbed convex (Type 3) mounds greater than 25 cm in height. Also, fewer Kowaris were captured in areas where mounds were in poorer condition. Kowaris appear to consistently persist in areas more than 3 km from permanent waterpoints and where mounds are in less disturbed condition. However, a slightly higher Kowari occupancy of habitats on the PAN Grid, where fewer sand mounds exist and mounds are of poorer quality compared to those on the WAL Grid, indicate that sand mounds are not necessarily the only driver of Kowari abundance, as suggested by Moseby and Read (2015). The nature and condition of gibber pavement, as well as the presence of fertile gilgais and patches that concentrate water and nutrients to support perennial vegetation, seem to also be important in



providing burrowing substrate and food resources for Kowaris (Pedler *et al.* 2011, Moseby and Read 2015).

While sand mounds on Cordillo Downs generally had good vegetation cover, they were dominated by Button-grass, a short lived ephemeral grass that is not indicative of sand-mound condition and is unlikely to stabilise sand mounds and provide for sustained invertebrate and vertebrate prey for Kowaris. The extent of high quality Kowari habitat on Cordillo Downs is limited by geomorphology, occurring as isolated patches when compared to the Clifton Hills/Pandie Pandie area (Figure 3). It is probable that when localised extinctions happen, the recolonisation required to maintain a population has not occurred. This lack of population expansion following good seasons has also been noted across other parts of the former Kowari distribution in South Australia, particularly along the southern half of Sturt Stony Desert.

Conclusions and recommendations

Kowaris appear to be persisting at core sites on Clifton Hills and Pandie Pandie Stations, however low captures and the species' restricted range suggest the species' vulnerable rating is justified and may require re-evaluation, given apparent ongoing decline over the last two decades. Possible causes of decline have been investigated, particularly the impact of large herbivores on sand mound quality which has been linked to mound destabilisation. Grazing management and placement of new waterpoints needs to be sensitive to important habitat features such as sand mounds for the species to survive on pastoral managed lands. To date no evidence has been collected around the role of predators which have mostly been undetectable in areas with reliable Kowari populations.

Answers to the following questions are needed to improve Kowari prospects:

1. Kowari populations have a high reproductive capacity. What is the species' dispersal strategy and what limits dispersal across the variety of habitats encountered?
2. What role do predators play in regulating existing populations – do they limit dispersal and/or the establishment of new populations? If so, which predators?
3. What grazing regimes/strategies are most compatible with Kowari conservation?
4. Can apparently suitable habitat across the species' former distribution again support self-sustaining populations?
 - Is there a role for assisted dispersal to maintain Kowaris across their former range by re-populating areas that suffer localised extinctions?

There is a role for the wider NRM and research community to partner with landholders to find answers to these questions and test potential solutions.



ACKNOWLEDGEMENTS

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Figure 21. The survey team (L:R): Rob Brandle, Hamish Longbottom, Kath Tuft, Tali Moyle, Cat Lynch, Amanda McLean, Billy La Marca, Alison Skinner and Nathan Beerkens.



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APPENDICES

Appendix 1. Mound assessment sites surveyed during the 2018 survey. All cover cases relate to five categories as follows: 1 = <5%, 2 = 5-25%, 3 = 25-50%, 4 = 50-75%, 5 = >75%, except 'Gibber preferred size' variable which has four classes and measures the proportion of apparent gibber pavement within the 1-5cm size range: 1 = <50%, 2 = 50-75%, 3 = 75-90%, 4 = >90%.

Transect ID	Zone	Easting	Northing	Kowari captured	Gibber cover class	Gibber preferred size cover	Hard depression cover	Sand mound cover	Sand spread cover	Trees/Shrubs >40cm	Type 1 - Irregular				Type 2 - Convex				Type 3 - Concave			
											<10 cm	10-25 cm	26-40 cm	41-60 cm	<10 cm	10-25 cm	26-40 cm	41-60 cm	<10 cm	10-25 cm	26-40 cm	41-60 cm
PAND38	54	347015	7035298	N	5	4	1	2	2	1	18	14	0	0	0	3	0	0	0	0	0	0
PANM1	54	349989	7031690	N	5	3	2	2	2	1	14	6	0	0	0	9	0	0	0	1	1	0
PVT1	54	345984	7038859	N	5	3	3	2	1	1	38	6	0	0	1	6	2	0	0	0	0	0
PVT2	54	349990	7038097	Y	5	3	3	2	1	1	17	4	0	0	0	3	4	0	0	0	0	0
PVT3	54	348020	7038397	N	5	3	3	1	1	1	8	0	0	0	0	3	0	0	0	0	0	0
PVT4	54	349005	7038006	Y	4	3	2	2	1	3	20	0	0	0	1	18	2	0	0	0	2	0
WALE40	54	355496	7015523	N	5	4	2	2	1	2	5	12	0	0	8	22	8	0	1	28	10	0
WALB01	54	358988	7019534	N	5	4	3	2	1	1	16	4	0	0	1	25	3	1	0	1	1	0
WALC18	54	357498	7017794	N	5	4	4	2	1	2	13	1	0	0	11	22	1	0	0	7	0	0
WALD04	54	356448	7019235	N	5	4	2	2	1	2	13	8	0	0	14	30	6	0	0	26	17	1
WALE20	54	355490	7017611	N	5	3	1	2	1	1	4	7	0	0	3	32	11	1	0	9	20	7
WVT1	54	358494	7019494	Y	4	4	3	3	1	2	6	6	0	0	4	19	2	0	0	5	6	0
Kowari Reserve 1	54	377181	7028748	Y	5	3	1	1	3	1	9	3	0	0	3	12	9	6	0	4	4	0
Kowari Reserve 2	54	375596	7025738	N	5	2	3	2	1	2	33	7	0	0	7	38	2	0	1	9	10	0
Bank 1 Tank	54	381900	7034977	N	5	4	2	2	1	2	12	0	0	0	3	42	8	0	0	1	1	0
Bank 1 Tank 2	54	379539	7036187	N	5	2	3	1	2	1	2	12	0	0	0	31	5	0	0	5	2	0



Transect ID	Zone	Easting	Northing	Kowari captured	Gibber cover class	Gibber preferred size cover	Hard depression cover	Sand mound cover	Sand spread cover	Trees/Shrubs >40cm	Type 1 - Irregular				Type 2 - Convex				Type 3 - Concave			
											<10 cm	10-25 cm	26-40 cm	41-60 cm	<10 cm	10-25 cm	26-40 cm	41-60 cm	<10 cm	10-25 cm	26-40 cm	41-60 cm
Barr 2 Tank	54	375971	7036873	N	5	3	2	2	1	1	15	1	0	0	0	0	0	0	0	0	0	0
KOCH01	54	385128	7037218	N	5	4	2	2	1	1	9	0	0	0	9	35	0	0	0	2	1	0
KOCH25	54	387913	7037101	N	5	4	2	2	1	1	16	0	0	0	3	27	5	0	0	4	3	0
KOCH45	54	399322	7034362	Y	5	4	2	2	2	2	29	4	0	0	1	21	3	2	0	1	0	0
POT 6	54	378589	7040120	Y	5	3	2	1	1	1	17	0	0	0	2	4	0	0	0	1	0	0
Pothole4	54	376793	7043827	N	5	3	2	3	2	1	8	2	0	0	1	12	8	6	0	0	3	2
Pothole5	54	375150	7045825	Y	5	3	2	1	2	1	14	4	0	0	2	13	7	2	0	4	4	2
PPCMP	54	375650	7033300	N	5	2	2	2	2	2	19	11	0	0	7	20	12	0	0	0	0	0
CAD2_32	54	438699	7102661	N	5	3	3	1	3	1	30	8	0	0	0	0	0	0	0	0	0	0
CAD2_7	54	437199	7104783	N	5	4	2	1	2	2	52	24	0	0	1	13	2	0	0	0	0	0
CAD3_1975	54	432057	7113269	N	5	4	1	1	2	2	6	3	0	0	2	10	0	0	0	4	0	0
Kachumba far	54	484000	7122000	N	5	4	1	2	2	2	19	5	0	0	2	36	10	0	0	8	7	0
Kachumba far 2	54	482672	7121014	N	5	4	2	1	1	1	34	5	0	0	0	0	0	0	0	0	0	0
Kachumba near	54	484043	7116995	N	5	4	1	1	2	2	34	12	0	0	1	23	3	0	0	0	0	0
Kachumba near 2	54	485346	7119791	N	5	4	2	1	2	3	33	18	0	0	0	21	1	0	0	2	0	0
KO05401_107	54	486374	7116200	N	5	4	3	1	2	2	19	0	0	0	2	4	0	0	0	2	0	0
KP00101_07	54	485955	7112610	N	5	4	4	1	1	1	29	0	0	0	0	2	0	0	0	0	0	0
KP00101_57	54	485439	7117919	N	5	4	1	1	1	2	8	0	0	0	12	2	0	0	0	0	0	0
KP3_1987	54	483990	7119226	N	5	4	2	1	1	2	42	13	0	0	11	1	0	0	0	0	0	0
KP3_33	54	480036	7122873	N	5	4	1	1	2	3	58	7	0	0	11	9	0	0	0	2	0	0
KP3_67	54	481828	7124450	N	4	4	3	3	2	3	29	11	0	0	20	37	14	0	0	9	7	0

