Western Shield Monitoring Results: Mammals — trapping transects and camera monitoring to December 2023



Images: Numbats (courtesy: D Thomson), Red fox and White-tailed Dunnart (DBCA)

July 2024

Prepared by Michelle Drew

GOVERNMENT OF WESTERN AUSTRALIA
Department of Biodiversity, Conservation and Attractions
PARKS AND WILDLIFE SERVICE
western shield

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Contents

Acknowledgements

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Executive Summary

Western Shield (WS) aims to recover and sustain wild populations of Western Australian native fauna through broadscale introduced predator management. To support this, fauna populations and introduced predators are monitored to determine the efficacy of WS management practices. Monitoring results are presented below on four native mammal species — koomal (*Trichosurus vulpecula hypoleucus*), woylie (*Bettongia pencillata*), chuditch (*Dasyurus geoffroii*) and quenda (*Isoodon obesulus*), for the period 1996 to 2023. In addition, preliminary information on two additional species, quokka (*Setonix brachyurus*) and black-flanked rock-wallaby (BFRW: *Petrogale lateralis lateralis*) are provided along with summaries of introduced predator activity at targeted sites.

A total of 32 sites were monitored for native fauna using Western Shield mark-recapture methods in 2023. Of these, 29 sites were monitored using WS cage trapping methods[1], and three sites using Thomas traps targeting black-flanked rock-wallaby or quokka. Of the 29 sites monitored using cages in 2023, four of these sites are outside of the WS footprint acting as reference sites in long-term analysis. Targeted camera monitoring (occupancy) or point count monitoring was also conducted at 27 sites for predators and one site for quokkas[2].

The relative abundance of woylies increased at eight of the ten monitored populations of the species with occupancy improving in the period 2021 to 2023. There is an increasing trend in occupancy for chuditch (2022-2023) after several years of decline (2019 – 2022). Relative abundance of this species in standard WS monitoring continues to be too low to effectively monitor this species using these standardised methods. However, chuditch specific monitoring has been effective at providing density estimates to assist in the provision of data to the Threatened Species Scientific Committee (TSSC) for a review of the conservation status of the species. This monitoring has also facilitated the ongoing provision of chuditch to Taronga Zoo for the captive breeding program. It is recommended that chuditch specific monitoring continue to enable efficient assessment of the species conservation status and the efficacy of different baiting regimes in a range of ecosystems.

Koomal are the most frequently captured Critical Weight Range (CWR)[3] species in WS trapping. Occupancy of the species declined rapidly from 2021 to 2022 with some recovery in 2023. It is probable that declines are being driven by multiple processes, and it is unlikely directly linked with fox or feral cat activity. However, under the Forest Management Plan 2024 – 2033 and Feral Cat Strategy 2023 – 2028 Western Shield has been able to increase the frequency of baiting across a large portion of the Western Shield baiting footprint. It is hoped this will help to alleviate pressure on koomal and other sensitive species.

Quenda occupancy continues to rise across the monitoring sites (2021 to 2023), contrasting with the declining trend from 1996 – 2020. However, the relative abundance of the species continues to remain very low using WS methods. Low captures of the species using WS cage monitoring limit accurate estimates of the species density and it will be important to consider alternative monitoring methods to determine trends at the population level.

Quokka monitoring is largely conducted under district programs. Only one site has collected long-term mark-recapture monitoring as part of Western Shield. This population continues to show positive trends, with abundance increasing in recent years.

[1] Noting that although they use WS methods some sites are monitored under district programming.

[2] Districts have indicated that additional sites were monitored however the details were not available for this report.

[3] Critical weight range – mammals in the weigh range of 35g to 5500 g

Monitoring of black-flanked rock-wallabies (BFRW) indicates positive population trends with either increasing relative abundance or point counts across most sites, including the recently enhanced population at Kalbarri National Park. However, the population at Cape le Grand continues to maintain low levels of activity compared to the peak recorded in 2015 — 2016. The introduction of Eradicat® at Cape Le Grand in 2024 will help to address the impact of feral cats on this species. Consideration should be given to implementing additional management of feral predators at the site to ensure adequate protection of the remaining BFRW. This could include more frequent ground baiting or targeted trapping and shooting of feral species.

Higher rainfall in 2021 and 2022 is likely to have contributed to increasing occupancy and relative abundance of quenda, chuditch, woylies, and quokka. Koomal have not responded as quickly, this is likely a result of the longevity and slower reproductive output of the species compared to species that are shorter lived and have a high reproductive output such as woylie, chuditch, quenda and quokka.

Information gathered from predator monitoring sites continues to indicate that fox activity is suppressed in baited areas compared with non-baited control sites. This is evident at sites with regular baiting throughout the year, emphasising the importance of the maintenance of regular ground baiting transects at sites, particularly those with low frequency aerial baiting (i.e., less than 6 events/annum). Data from this monitoring has provided justification for increasing fox baiting across the Forest Management Plan area and the adoption of Eradicat® baiting at multiple locations across the Western Shield footprint.

Camera and track monitoring has indicated that feral cat activity has increased substantially across multiple baiting cells in the period 2021-2022. This is particularly evident, but not limited to, monitored sites in DBCA's Pilbara, Wheatbelt and South Coast regions. It is recommended that additional feral predator management actions be implemented where possible and consideration made to increase the capacity of additional feral predator mitigation strategies across the state.

Recommendations

1. Chuditch specific monitoring continue and be expanded to help define the species current range, enable efficient assessment of the species conservation status and the efficacy of different baiting regimes in a range of ecosystems.
2. Implement consistent quokka monitoring across their distribution. Consistent reportable monitoring will enable DBCA to more effectively monitor and manage this species.
3. Additional feral predator management actions be implemented at sites where monitoring has indicated feral cat activity has increased. This includes Cape Range, Cape le Grand, Dragon Rocks and Dryandra.
4. Undertake a risk assessment and develop action plans relevant to each DBCA district that provides alternative management actions for implementation if the prescribed baiting/predator management cannot be delivered and/or if predator activity rates continue to rise. The action plans should provide trigger points for when alternative actions should be implemented, how and when these actions would be implemented and responsibilities for each action.

Introduction

Western Shield (WS) aims to promote wild populations of Western Australian native fauna that are threatened by red foxes and feral cats through broadscale introduced predator management. The program primarily manages foxes and feral cats through the landscape scale deployment of toxic baits. In some circumstances, baiting is complemented with other introduced predator control actions such as trapping and/or fencing to provide additional protection to vulnerable species. Translocations (i.e., wild to wild and captive to wild) may also occur to augment the conservation efforts for some species.

To assess the effectiveness of introduced predator management, WS monitors both native and introduced fauna populations (Figure 1). This monitoring assumes that if WS management is effective, populations of native mammal species sensitive to feral cat and/or fox predation will be maintained or improved at these sites provided no other threatening process is impacting the monitored species.

Western Shield native species monitoring targets four native mammal species (primary species). These are koomal (*Trichosurus vulpecula hypoleucus*), the critically endangered woylie (*Bettongia pencillata*), the vulnerable chuditch (*Dasyurus geoffroii*) and the Priority 4 quenda (*Isoodon obesulus*). These species are medium-sized mammals that are known to respond positively to introduced predator management and can be captured easily using simple cage trapping techniques. State level summaries are presented for each species for the period 1996 to 2023 and include WS data and district programs that employ WS cage monitoring methods. Where possible, additional data collected from other DBCA projects that monitor quokka (*Setonix brachyurus,* vulnerable) or black-flanked rock-wallabies (*Petrogale lateralis lateralis*, endangered) have been included to provide information on the response of native species to management in areas where the four primary species are either sparse or absent.

Commencing in 2015, camera monitoring has been implemented across a broad range of habitats. Where available, results from camera monitoring have been presented providing information on threatened species, foxes and feral cats. This data will be vital in providing more comprehensive information on species distribution and the activity of feral predators relative to different baiting regimes in the long-term.

Unless otherwise stated, information presented in this report is based on raw data. Updates to the 2017 population modelling will be conducted at the end of 2024. The modelling will assist in understanding the significance of population fluctuations of the four primary species and will incorporate explanatory variables (e.g., fire, temperature, vegetation health, habitat fragmentation, rainfall, etc) as these covariates may impact on the trajectory of populations of native fauna.

State summary: Distribution and relative abundance of key species in the south of the state

Standard WS monitoring uses cage traps lured with universal bait (i.e., peanut butter mix with oats and sardines). Cages are set every 200 m along unsealed tracks and typically set for four nights. Trap effort varies at each location (see Appendix 1 for details for each site). All data presented below has been standardised relative to trap effort to enable effective comparison between sites. A total of 29 sites were monitored using cage traps in 2023 (Figure 1 and Figure 2). This trap effort continues to be lower than the minimum of 36 recommended in the Western Shield Monitoring Plan (Department of Biodiversity, Conservation and Attractions 2021). Four of the 29 cage monitored sites in 2023 are control sites (i.e., outside of the WS management area) — Nambung, Pardelup, Porongorups, and Stene, providing information on fauna populations in areas with no active DBCA fox or feral cat management.

Camera monitoring for predators involves the use of automated wildlife cameras set to take three images per trigger. Camera locations are chosen using a random point generator for each site with a minimum distance of 1.5 km between each point (for details on camera monitoring methods see Drew (2018). The number of cameras at each location varies according to district capacity or project (see Appendix 1 for details). Data collected from predator cameras provides information on the effectiveness of different bait prescriptions. In addition, targeted camera monitoring has been used at several sites to monitor for threatened species. Cameras at these sites are placed in habitat areas most likely to support the target species. Sites with active camera monitoring in 2023 are highlighted in Figure 1, noting that some sites are monitored through district or third-party programs (e.g., Project Numbat, Numbat Taskforce, etc.). Modelling has not been completed for camera data and all figures on fox and feral cat activity are based on raw camera detections.

Occupancy modelling (presence/absence) using the unmarked program (Fiske and Chandler 2011) in R (R Core Team 2020) was used to model long term trends for the four primary WS species across 43 of the most frequently monitored sites (cage monitoring only: 1996 to 2022). The sites included in the analyses and methods used are provided in Appendix 3.

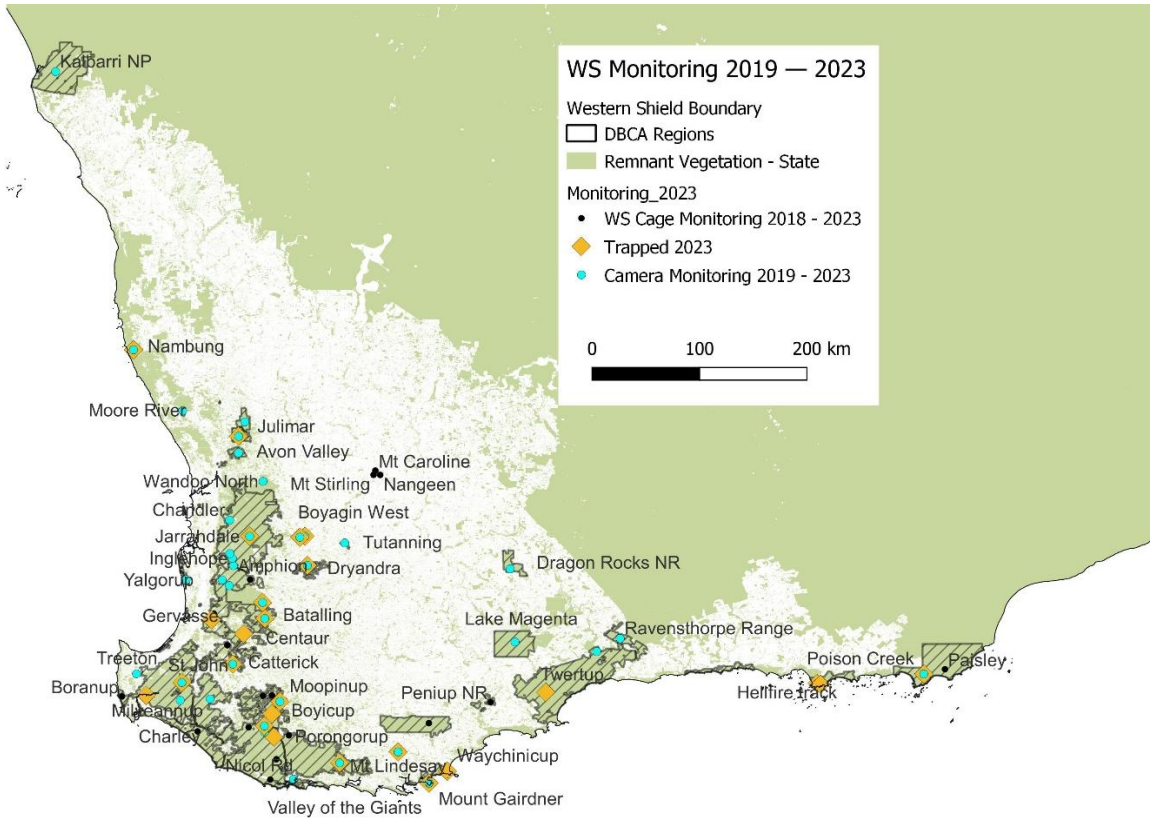

Figure 1: Map indicating the distribution of monitoring sites across the south of the state. Sites marked with an orange diamond were monitored with cage traps in 2023, black dots are sites that have been monitored at least once in the last five years and light blue dots indicate active camera monitoring in 2023. Note some of the sites indicated are not official WS sites but use the same or very similar methods. Monitoring at Kalbarri, Mt Caroline, Mt Stirling, and Nangeen use Thomas traps, trapping at Gervasse uses both cage and Thomas traps.

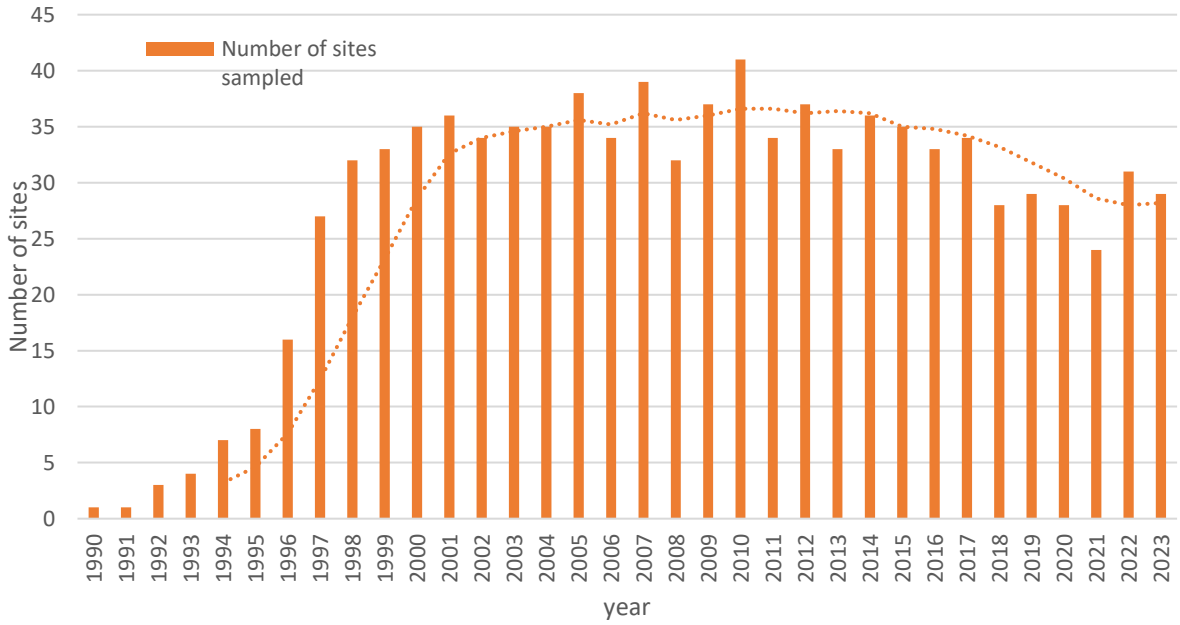

Figure 2: Number of sites monitored using WS standard cage monitoring methods each year. The dotted line represents the average number of sites monitored every five years.

Woylie

Woylie occupancy

Using standard WS cage trapping, a total of 10 sites recorded woylies in 2023, while 11 sites detected woylies when including both cage and camera monitoring. Fifteen sites detected the species in the five-year period 2019 — 2023 (Figure 3). Woylie occupancy[4] declined in the period 2013 – 2020, but has improved 2021 to 2023 (Figure 4).

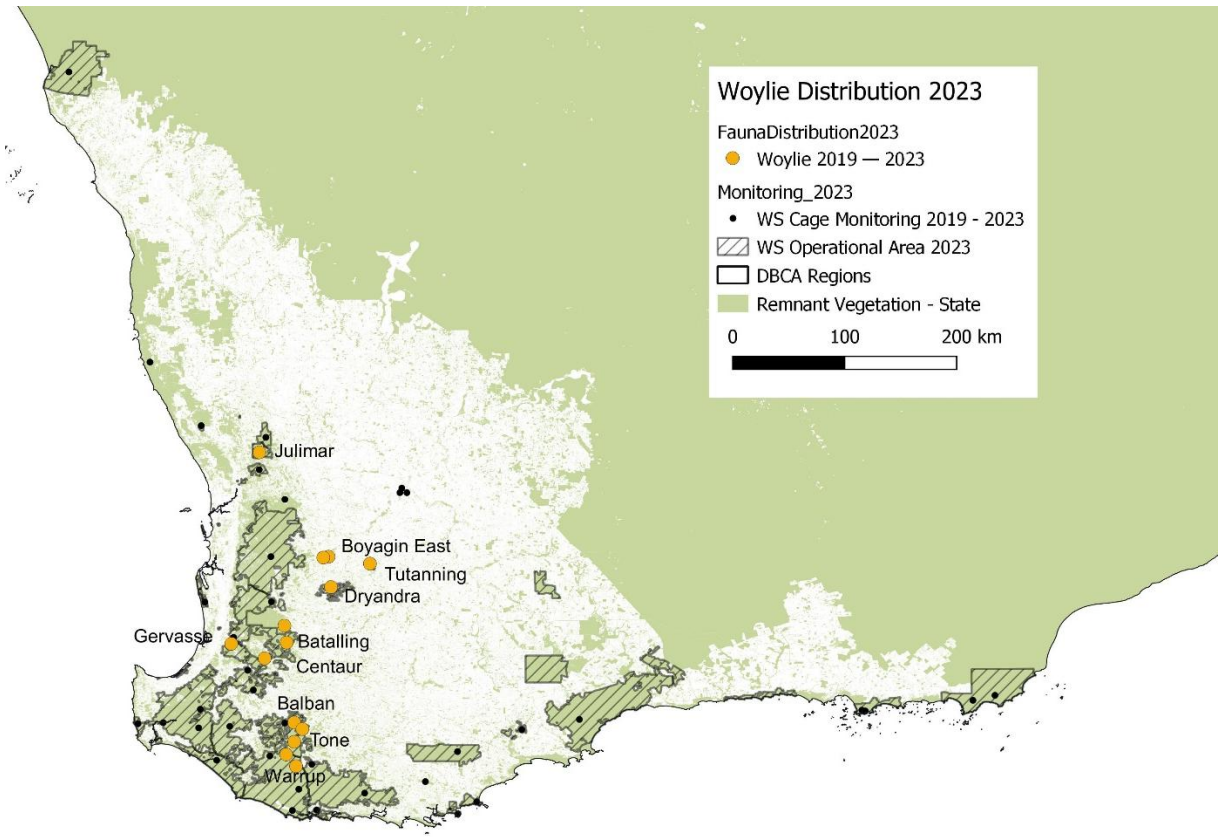

Figure 3: Sites where woylies were captured in cage trapping or noted on camera monitoring 2019 – 2023 (orange dots). Black dots indicate sites that were monitored at least once between 2019 and 2023 using WS cage monitoring methods.

[4] Occupancy modelling using the "unmarked" package: Models for data from unmarked animals in R with up to four visits per secondary survey and up to two per primary survey for each site each year.

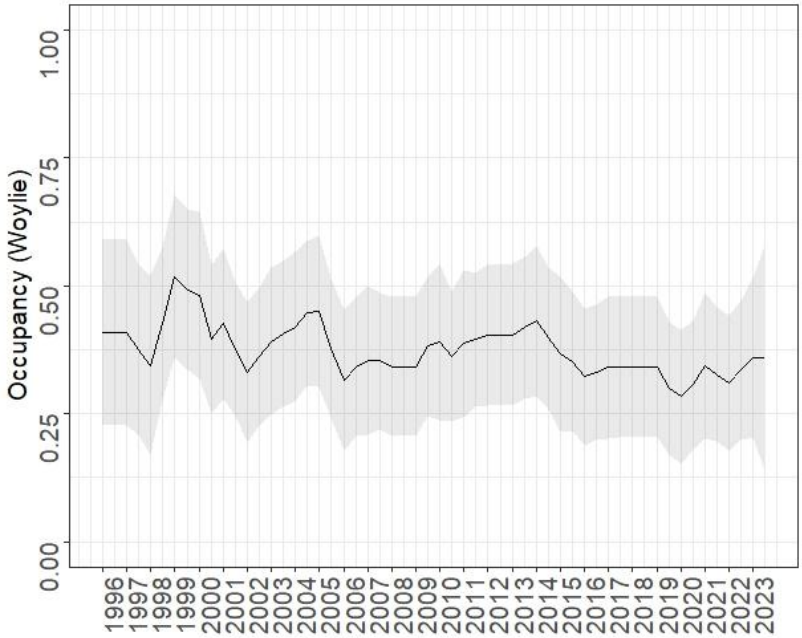

Figure 4: Modelled occupancy of woylies based on cage monitoring at WS monitoring sites (N = 43) 1996 – 2023 (x-axis = Year). Grey area is the 95% confidence bound, the larger the bounds the lower the confidence in the data. Larger confidence bounds usually reflect periods of lower trap effort.

Woylie populations

Average daily capture rates of woylies in 2023 increased at eight of the ten WS cage monitored sites with woylies present (Figure 6). This suggests that local conditions are promoting increased recruitment and or reduced mortality at most sites. Higher than average rainfall in Western Australia in 2021 (i.e. 9% above the 1961-1990 average, Figure 5: BOM 2022) may have promoted higher reproductive output in this species in some locations.

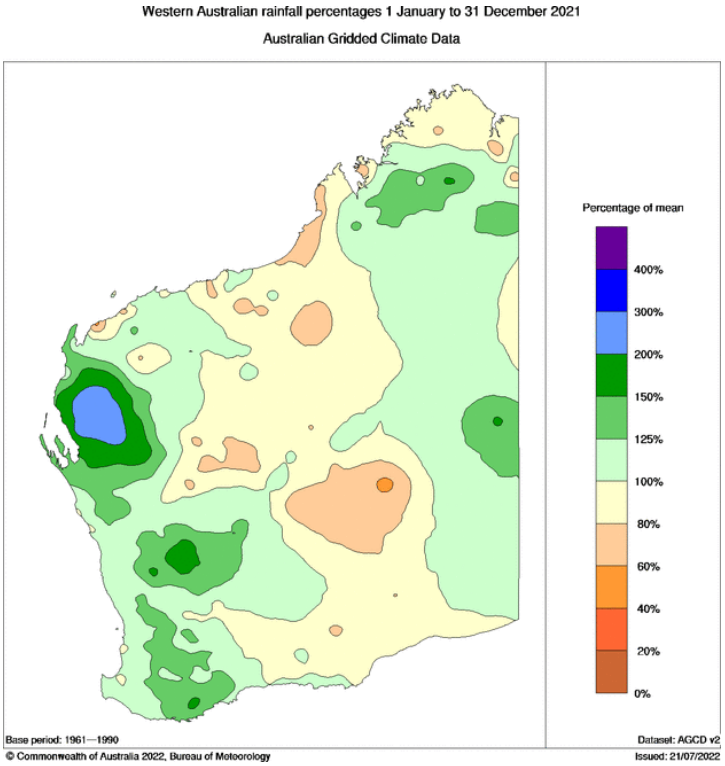

Figure 5: Map of Western Australia annual rainfall percentage anomaly in 2021 relative to mean rainfall 1961 — 1990 (BOM 2022)

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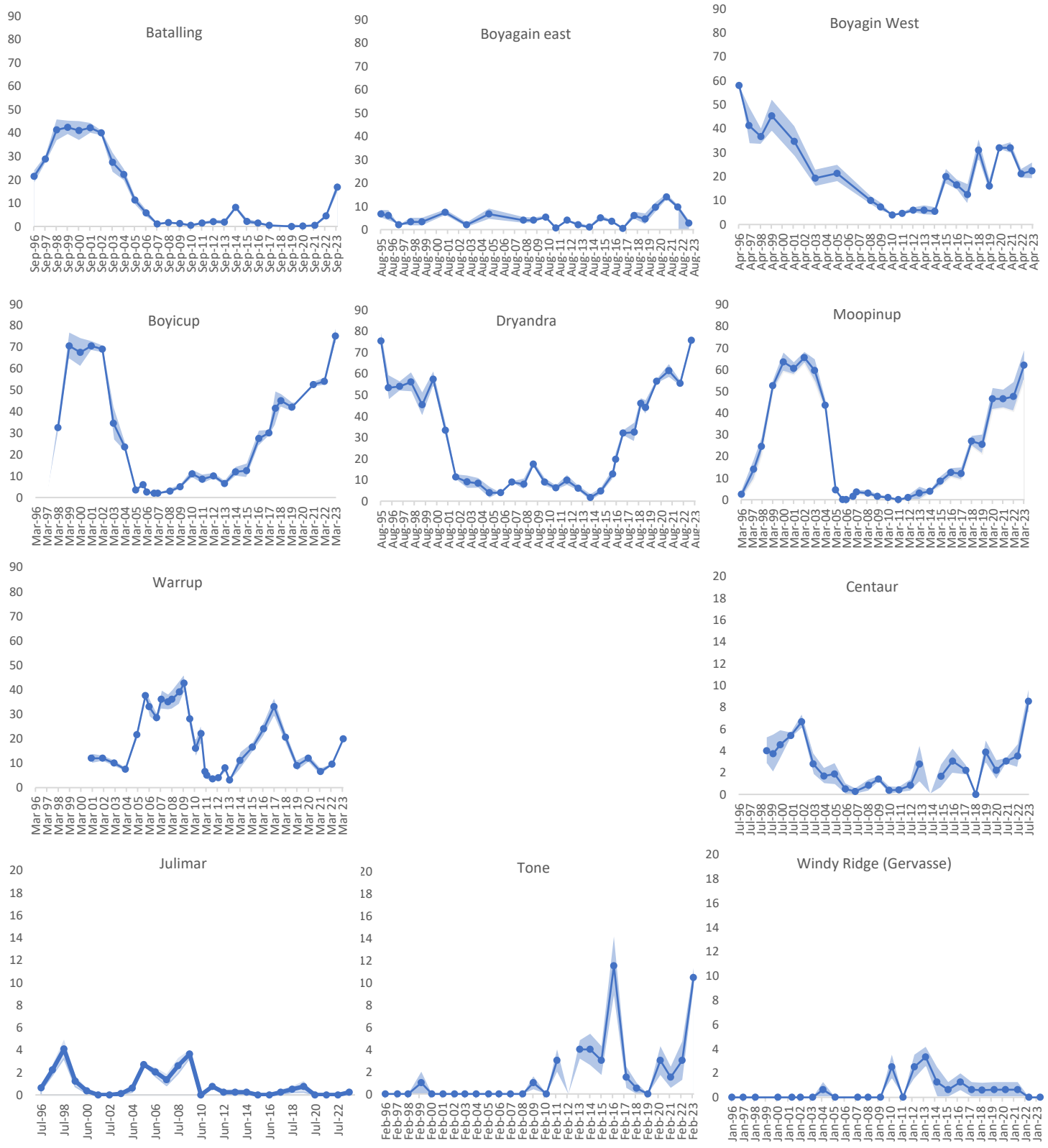

Figure 6: Average daily capture rates of woylies at key woylie sites in the south-west of WA. Blue shading indicates the standard error. Note: the scale is adjusted for high and low capture sites and care should be taken when comparing figures. Boyagin East to Warrup are high capture sites, Centaur to Windy Ridge, low capture sites.

Chuditch

Overall, there has been an increasing trend in the number of sites where chuditch have been detected (occupancy) in cages (1996 – 2019). However, from 2019 occupancy (WS standard cage trapping) declined (Figure 7). This decline stabilised in 2021-2022 with an upward trend in 2023.

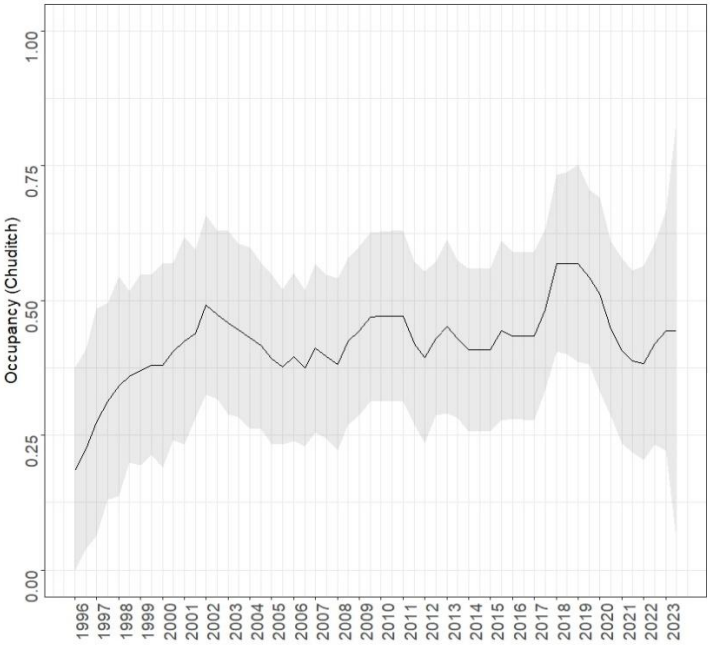

Figure 7: Modelled occupancy of chuditch at WS cage monitoring sites (N=43) 1996 – 2023 (x-axis=Year). The grey area is the 95% confidence bound, the larger the bounds the lower the confidence in the data — this usually reflects periods of lower trap effort.

A total of 15 sites recorded chuditch using WS cage methods in 2023. Chuditch were also detected at Avon Valley National Park, Kalbarri National Park, Lake Magenta, Mt Lindesay, Tutanning and Dragon Rocks on cameras, bringing the total number of sites recording the species using standard WS cage and predator monitoring in 2023 to 21 locations. In the period 2018 – 2023 chuditch have been recorded on camera and/or in WS cages at 29 locations (Figure 8) — this excludes the data from targeted chuditch monitoring sites which use different methods. The relative abundance of chuditch captured at a site level using WS methods remains low (Figure 9).

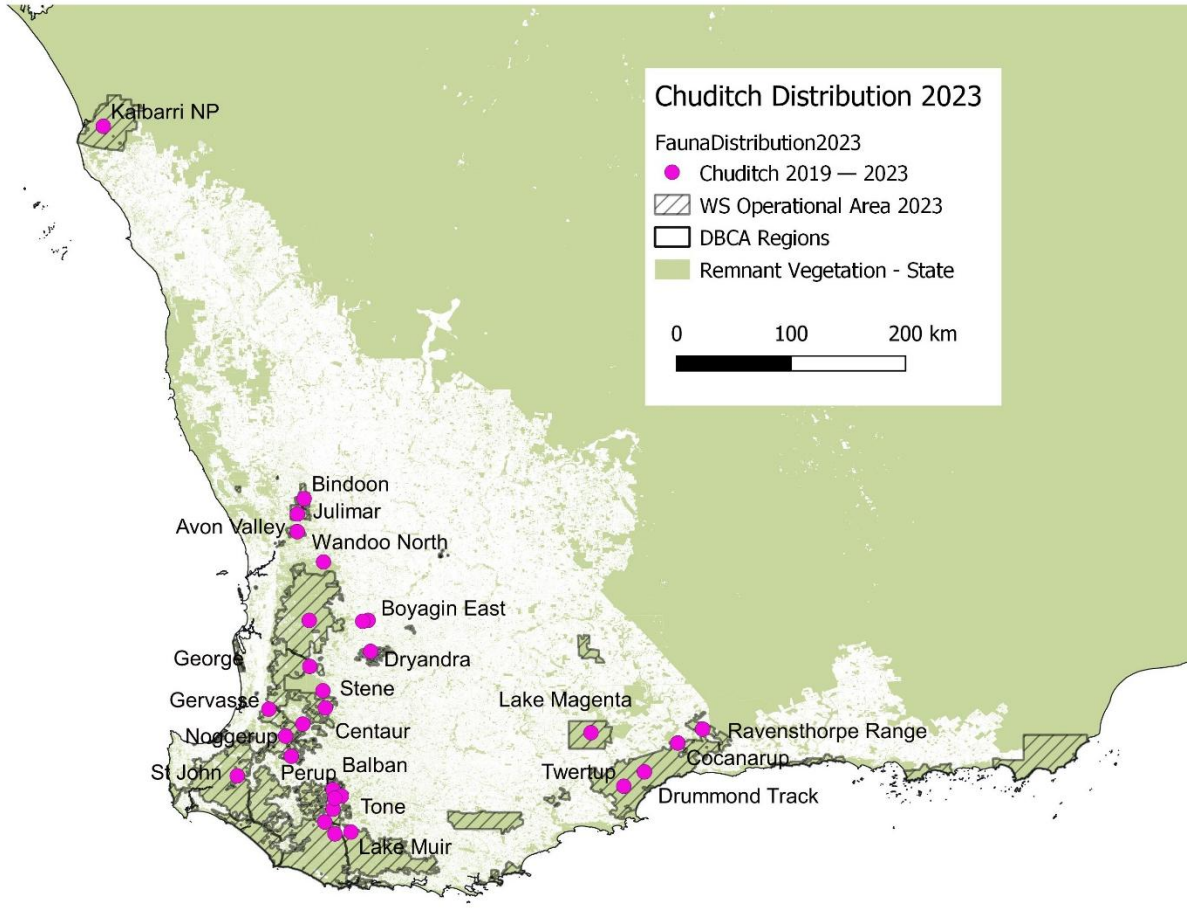

Figure 8: Sites where chuditch were captured in cage trapping or detected on camera monitoring 2019 – 2023 (pink dots) using standard WS methods and chuditch specific monitoring (i.e. Cocanarup, Lake Magenta, Kalbarri and Ravensthorpe, see Chuditch specific monitoring for further details).

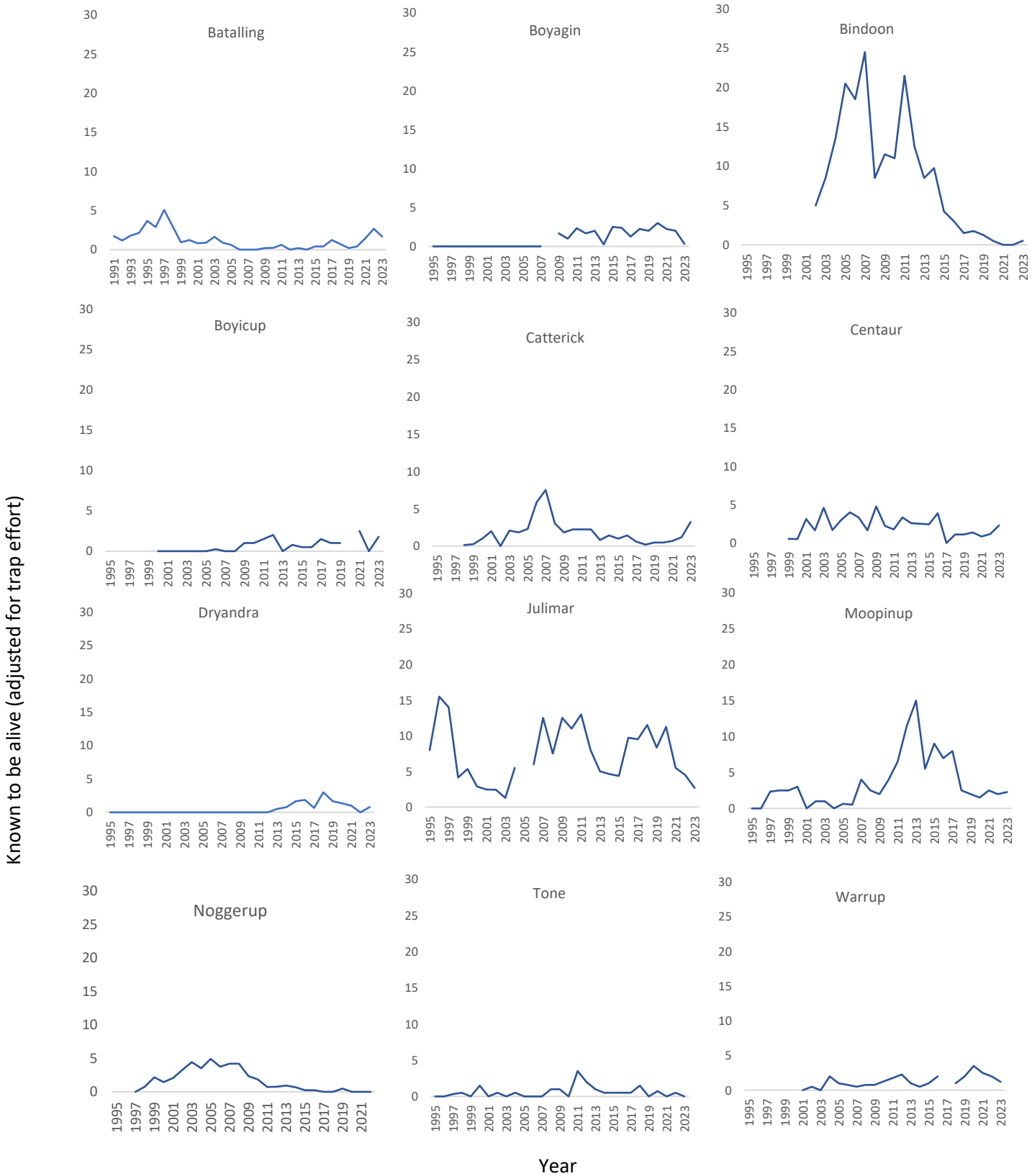

Figure 9: Known to be alive (KTBA) adjusted for trap effort (y-axis) of chuditch across WS and district monitoring sites, where chuditch are regularly captured. X-axis = year. Note that the number of animals recorded in each year will be adjusted based on captures in subsequent trapping events. Noggerup was not monitored in 2022 or 2023. This data excludes chuditch specific monitoring.

Chuditch specific monitoring

Funding received through DBCA Regional Priorities, Alcoa Foundation, and Taronga Zoo was used to continue chuditch specific monitoring in 2023. This is a collaborative project between Biodiversity and Conservation Science, Conservation and Ecosystem Management and Regional and Fire Management Services (2020 – 2023). This project was initially implemented with the aim of understanding the trajectory of populations of this threatened species across its currently known distribution. This information will be used to determine if the species conservation status requires review (2024) and if additional threat management will be required to protect this species.

In 2023, chuditch specific monitoring was conducted by DBCA at 9 sites. Additional data were collected at three sites by Australian Wildlife Conservancy as part of a translocation and the data was shared with DBCA (Figure 10). Cage traps were lured with chicken and cages were set every 500 m along unpaved tracks near or along WS transects. Trapping was conducted March to July 2023.

Chuditch were captured at 11 of the 12 sites surveyed using cages. No chuditch were captured at Dragon Rocks. Lake Magenta, Jarrahdale and Ravensthorpe all captured less than 10 individuals. Dryandra yielded the highest chuditch captures with 59 individuals captured over 362 trap nights. Avon Valley recorded 57 over 458 trap nights. Tone-Perup and Batalling recorded 49 and 48 respectively over 470 and 365 trap nights (Figure 11). Dragon Rocks, Lake Magenta and Ravensthorpe were relatively recently established, and some had not been monitored for fauna in recent years. Repeated surveys may result in an increased capture rate at these sites due to trap habituation.

Camera monitoring was established in 2023 at Helena and Aurora Ranges, Peak Charles and Lake Magenta. Chuditch specific cage monitoring will be repeated in 2024 at all the 2023 sites and will include the addition of sites in the northern jarrah forest, wheatbelt and in the Frankland district.

Information gathered from this project has assisted in the establishment of a captive breeding population at Taronga Zoo which has successfully bred 37 chuditch. These animals have now been released to augment newly established populations at Mt Gibson in WA and at Arid Recovery and Gammon Ranges in South Australia between 2022 and 2023. Sixteen juveniles will also be released at Wild Deserts in NSW in April 2024. A total of 12 chuditch were harvested from WA populations in 2022 and 2023.

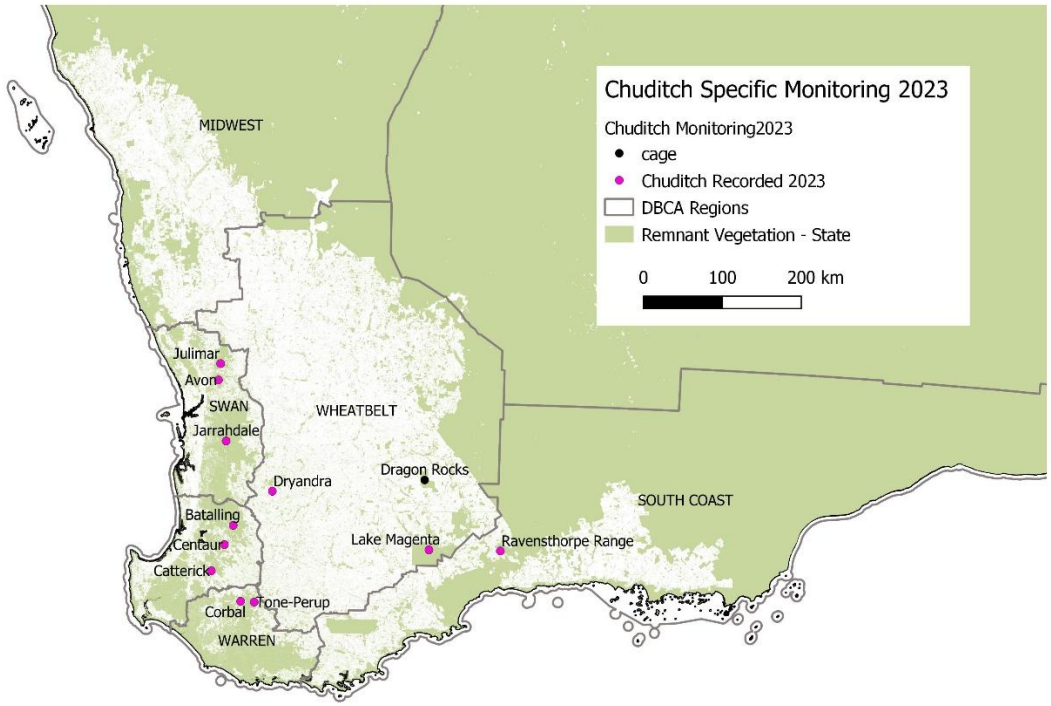

Figure 10: Location of chuditch specific monitoring sites surveyed in 2023, pink dots indicate sites where chuditch were detected.

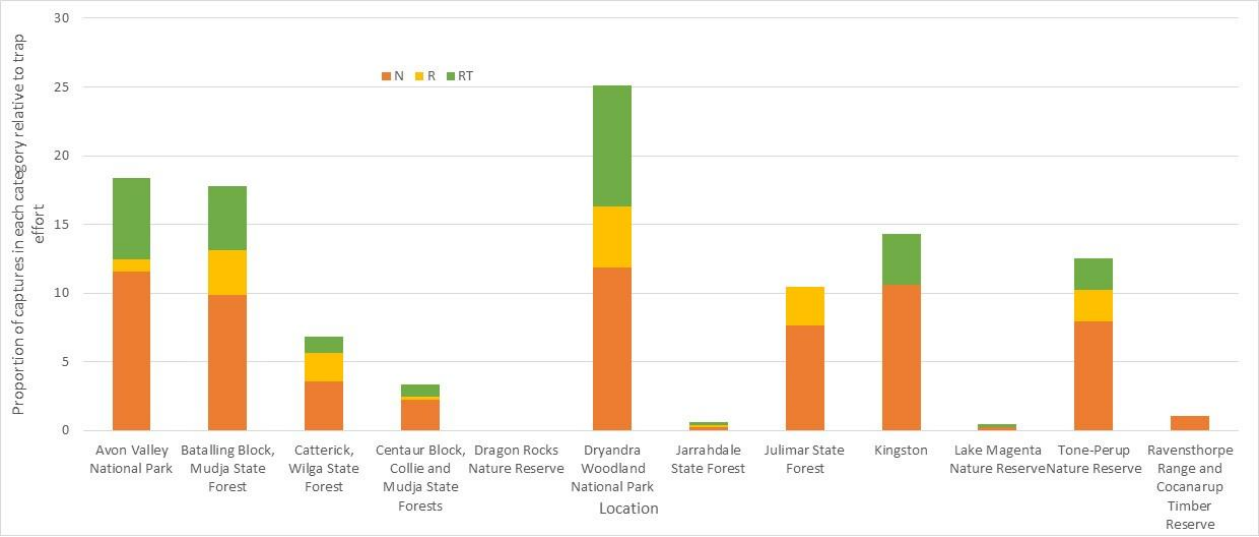

Figure 11: Number of chuditch captured in each location in 2023, adjusted for trap effort. New (N) = never been captured, Recapture (R)= captured in a previous-session and Retrap (RT) = retrapped same-session.

Koomal

Koomal continue to be the most frequently captured medium-sized marsupial in WS cage trap monitoring. This species is not currently listed as threatened in Western Australia however it is monitored by Western Shield as an indicator species for the efficacy of fox baiting as the high capture rates across multiple sites enables effective comparisons between monitoring sites (spatial) and overtime at the same site

(temporal). Koomal responded quickly to predator management shortly after the commencement of Western Shield however between 2006 and 2013 occupancy of this species steadily declined (Figure 12). There has been some recovery in the period 2014 to 2021 but a rapid decline in 2021 – 2022 has resulted in occupancy remaining relatively low. It is important to note that these declines are likely a consequence of multiple processes. Fox management has remained consistent or increased at all the reported sites.

Extended periods of below average rainfall were experienced across a large portion of the forest area 2004 to 2011. This resulted in annual streamflow decline of 12 – 50 % in the northern jarrah forest compared to 1975 – 2003 (Conservation Commission of Western Australia, 2012), this reduction in rainfall has driven declines in forest density (Croton et al, 2014) and likely has implications for the availability of food and shelter resources for this omnivorous species. Climate change has been implicated in the decline in the crown health and increased mortality of wandoo (Dalmaris et al 2015). This is likely to have long-term implications for a species that prefers dens in older standing wandoo trees (> 131 years old: Abbott and Whitford, 2001).

A detailed analyses will be conducted at the end of 2024 to assist in determining the most likely cause of reduced occupancy of koomal.

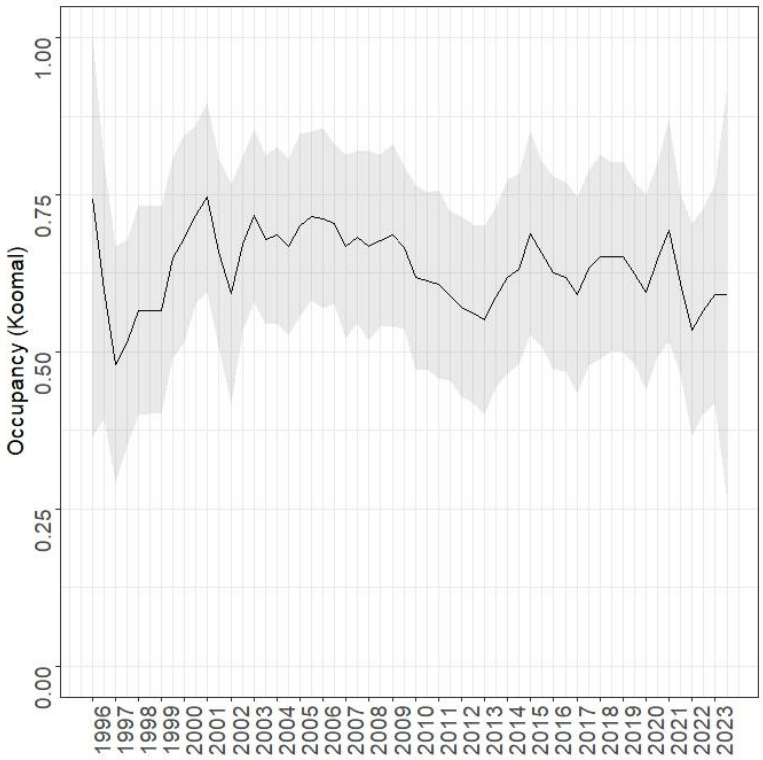

Figure 12: Modelled occupancy of koomal based on cage monitoring at WS monitoring sites (N = 43) 1996 – 2023 (x-axis = Year). Grey area is the 95% confidence bound, the larger the bounds the lower the confidence in the data — this usually reflects periods of lower trap effort. Note that in 1996 only a single site was monitored.

Koomal were detected at 16 cage monitored sites and on cameras at five additional sites within the WS management area and at four of the non-baited reference sites bringing the total numbers of sites the species was detected in 2023 to 25 locations (Note: camera data is not currently included in the occupancy data). Analysis of the camera monitoring indicates that although koomal persist at sites without active cat or fox management, koomal detections are often significantly lower at these sites compared to baited areas (Figure 14).

Koomal relative abundance

The number of captures of koomal increased across several of the lower performing sites in 2023, with Batalling, Boyicup, Catterick and Warrup recording slightly higher numbers when compared to 2022 (Figure 15). Lower than anticipated captures continue to be observed at Dryandra and Moopinup. As noted in the 2022 report, lower captures at some sites are likely linked to the high capture rates of

woylies, which has resulted in fewer traps being available for koomal (Figure 16). Data indicates that once woylie captures start to exceed 35 – 40% of captures, koomal capture rates start to decline. Camera monitoring at Dryandra has suggested that koomal detections although variable over time have not declined in the period 2015 – 2023 (Figure 17). It is likely that the downward trend in cage capture rates at Dryandra does not reflect a true decline in the species abundance.

In contrast, sites such as Tone, St Johns and Stirling Ranges (last monitored in 2022) continue to demonstrate poor recovery. Batalling and Tone camera monitoring suggests that koomal numbers have declined 2020 to 2023 (Figure 14 and Figure 18). Koomal are a long-lived species with a relatively slow reproductive rate (maximum annual population growth $r_m = 0.77$) when compared to chuditch ($r_m = 1.21$), quenda ($r_m = 2.02$) or woylies ($r_m = 1.9$: Hone et al 2010). As such it is anticipated that there is lag time between environmental perturbations that impact recruitment and our ability to observe a response. Shannon (Tone) and Sunklands (St Johns) will receive an increase fox management commencing 2023/2024, with both locations to be baited six times a year at a density of 5 baits/km^2, while Eradicat® will be integrated into the existing fox baiting program for the Stirlings. All changes in the baiting prescriptions from 2021 onwards are outlined in Table 6 of Appendix 2.

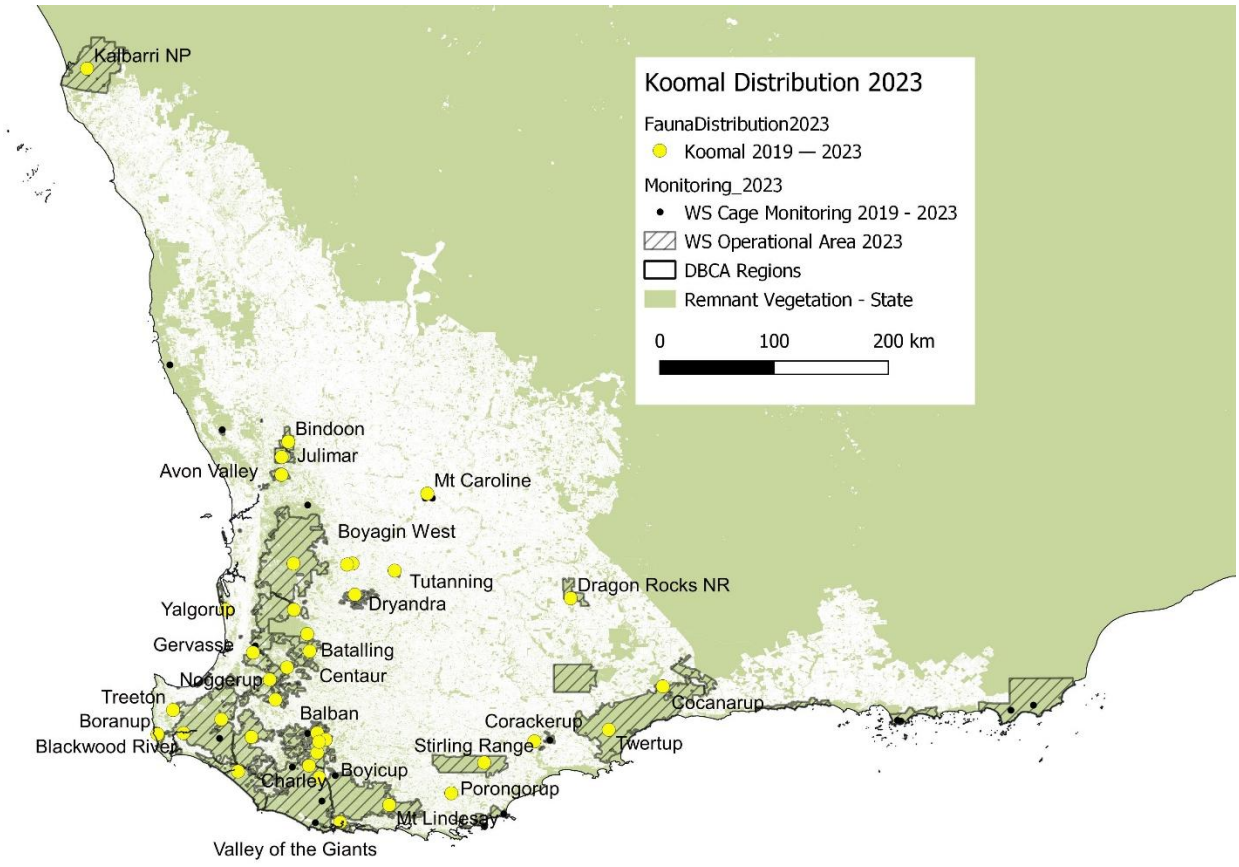

Figure 13: Sites where koomal were captured in cage trapping or detected on camera monitoring 2019 – 2023 (yellow dots). Black dots indicate sites that were monitored at least once between 2019 and 2023 using WS cage monitoring methods.

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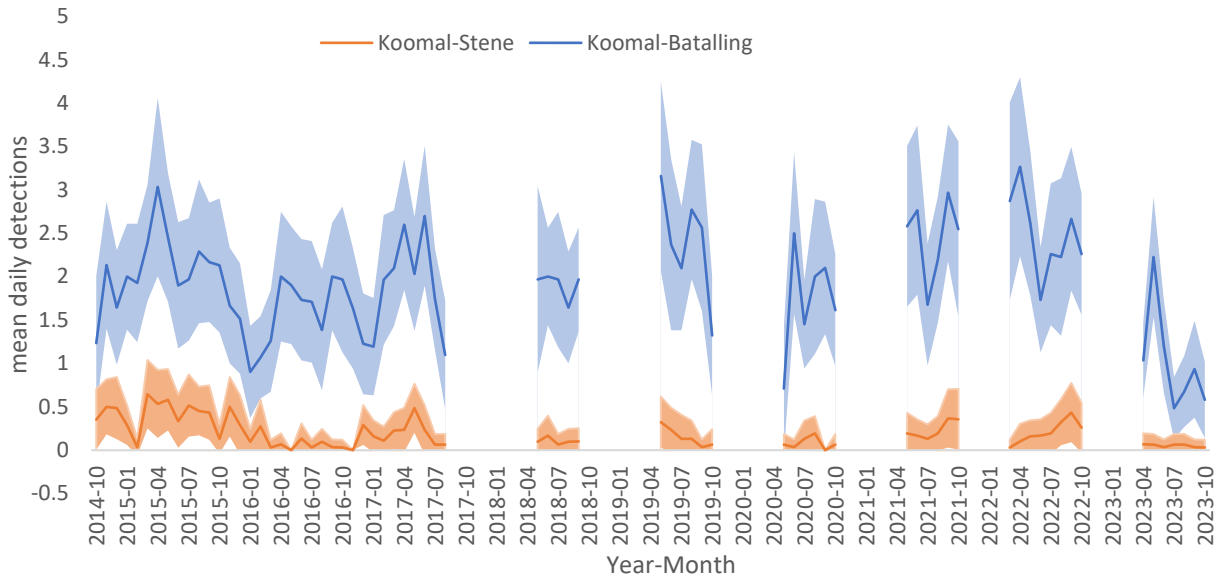

Figure 14: Mean monthly detections of koomal on camera at Batalling (4 x aerial Probait events/annum) and Stene (no current fox or feral cat management). Note that in 2023 Stene cameras were compromised by a prescribed burn and over 50% of the cameras were not operational in the 2023 season.

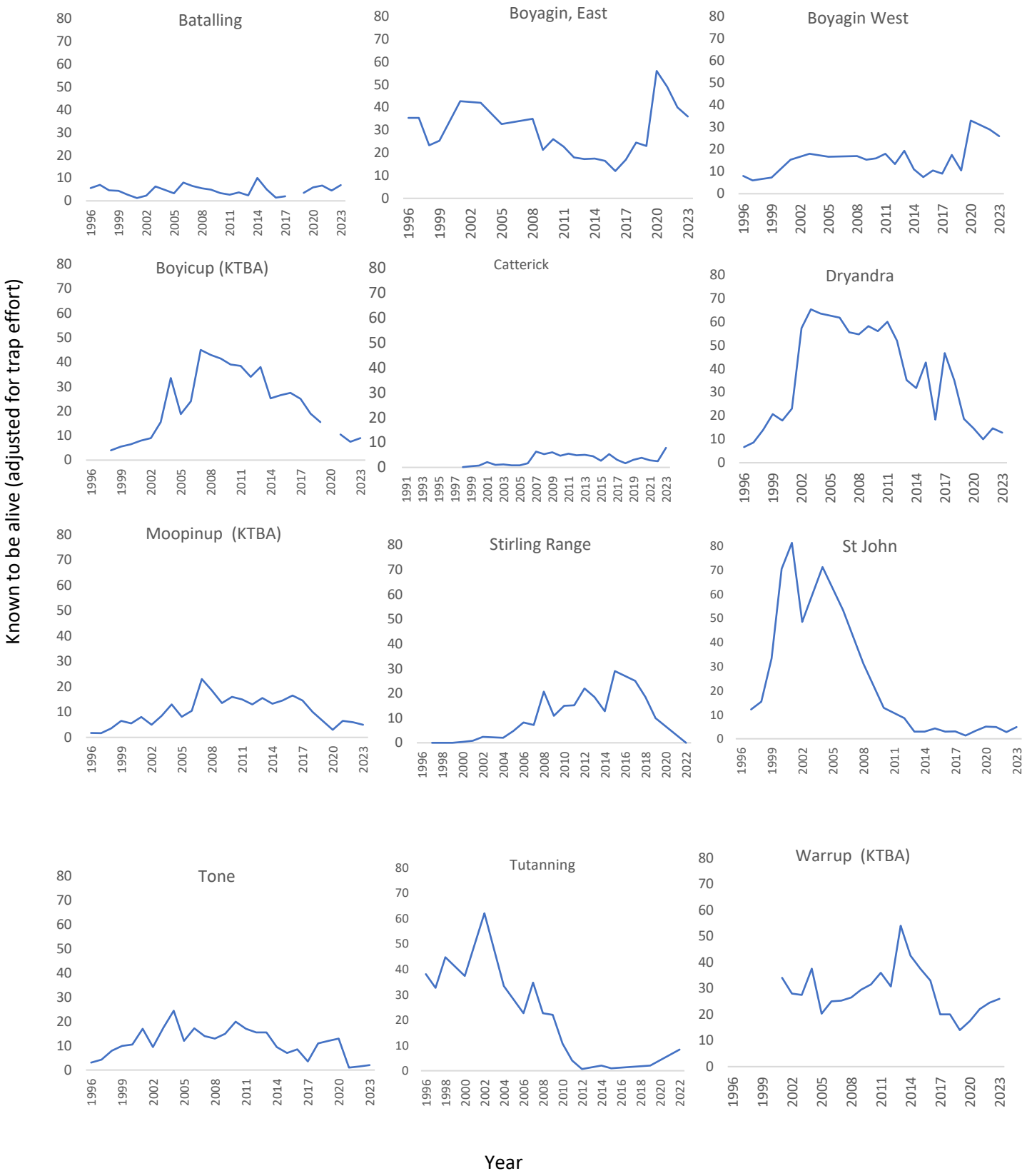

Figure 15: KTBA (adjusted for trap effort; y-axis) for koomal at selected WS sites (x-axis = year). Note only 12 sites with the highest captures are included. Stirling Ranges and Tutanning are rotational sites and were not monitored in 2023.

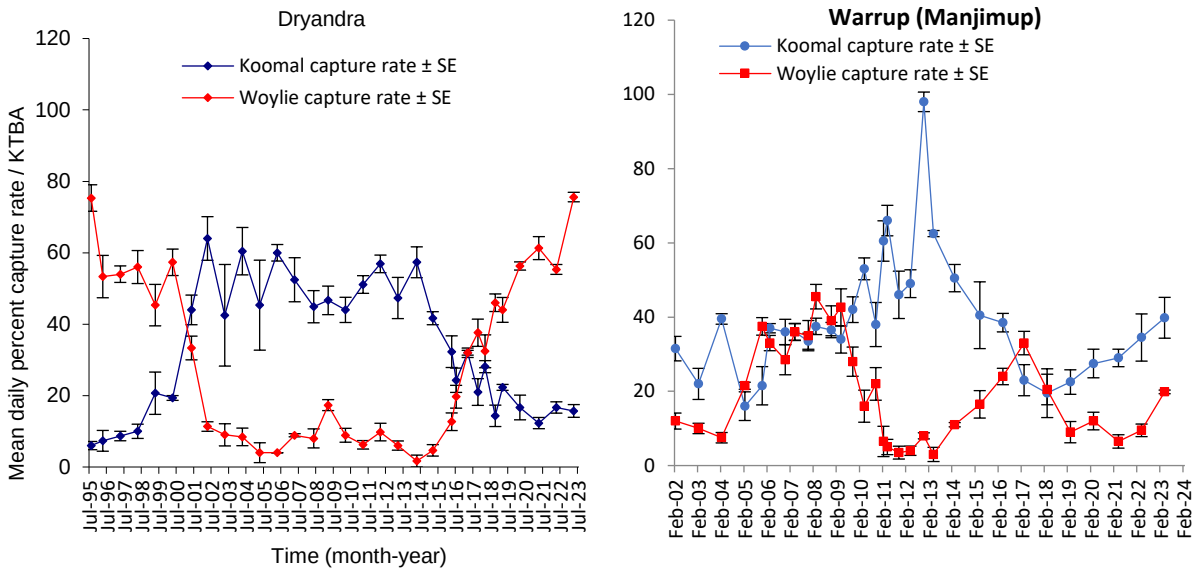

Figure 16: Changes in captures of koomal relative to captures of woylies at Dryandra main block and Warrup (Manjiump cell). Error bars = standard error.

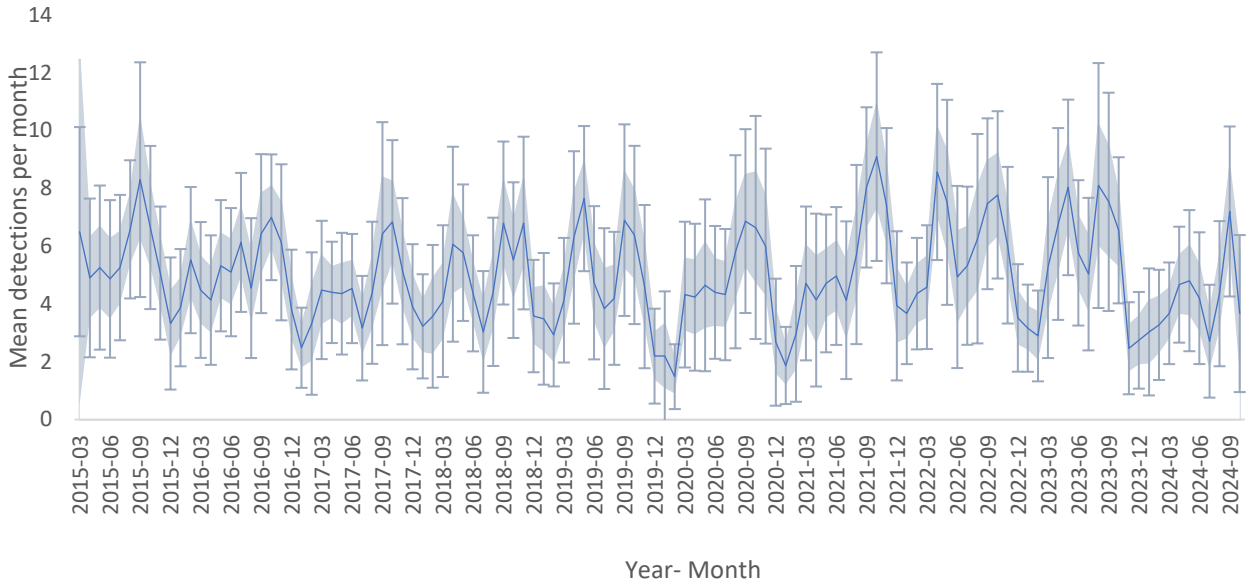

Figure 17: Mean daily detections of koomal at Dryandra 2014 – 2023.

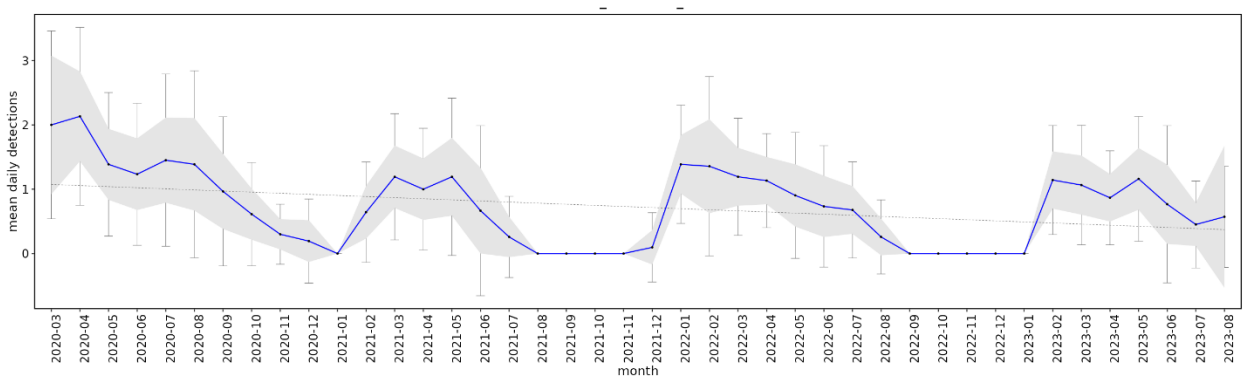

Figure 18: Mean daily detections of koomal at Tone (Manjimup) 2020 — 2023

Quenda

Quenda occupancy

Quenda occupancy between 1996 and 2020 was highly variable but on average occupancy declined (Figure 19). However, from 2021 there has been a substantial increase in occupancy (Figure 19). The reproductive output in the species is strongly linked to increasing photoperiod and rainfall, with litter sizes often reduced in drought periods (Copley et al. 1990). Successful recruitment has been linked to the quality of the habitat and food supply, with dense understorey habitat and supply of subterranean food resources important for successful recruitment and dispersal (Department of Environment and Conservation (NSW) 2006), both of which are linked to rainfall and the local fire regime. Rainfall in 2021 was 9% above the 1961 to 1990 average (BOM 2022, Figure 5) and may have promoted increased reproductive output in this species and expansion of suitable habitat. Detailed analyses will be conducted at the end of 2024 to help understand the possible determinates of variations in quenda occupancy across the south-west of WA.

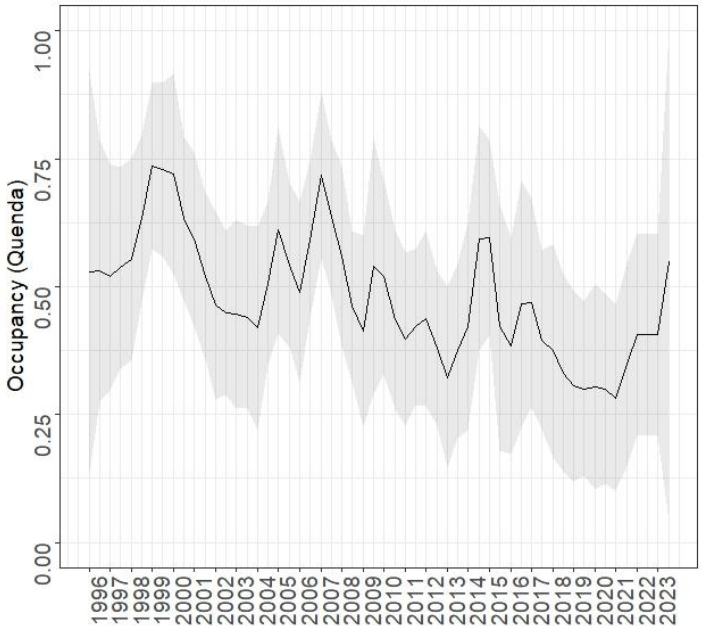

Figure 19: Modelled occupancy of quenda based on cage monitoring at WS monitoring sites over time (N=43). Grey area is the 95% confidence bound, the larger the bounds the lower the confidence in the data — this usually reflects periods of lower trap effort. Note that in 1996 only a single site was monitored.

In addition to the 13 sites where quenda were captured in cages or Thomas traps, camera monitoring also identified quenda at five baited sites and four non-baited control sites, bringing the total number of sites with quenda present to 21 and a total of 30 locations using suitable trapping methods over the five year period 2019 — 2023 (Figure 20).

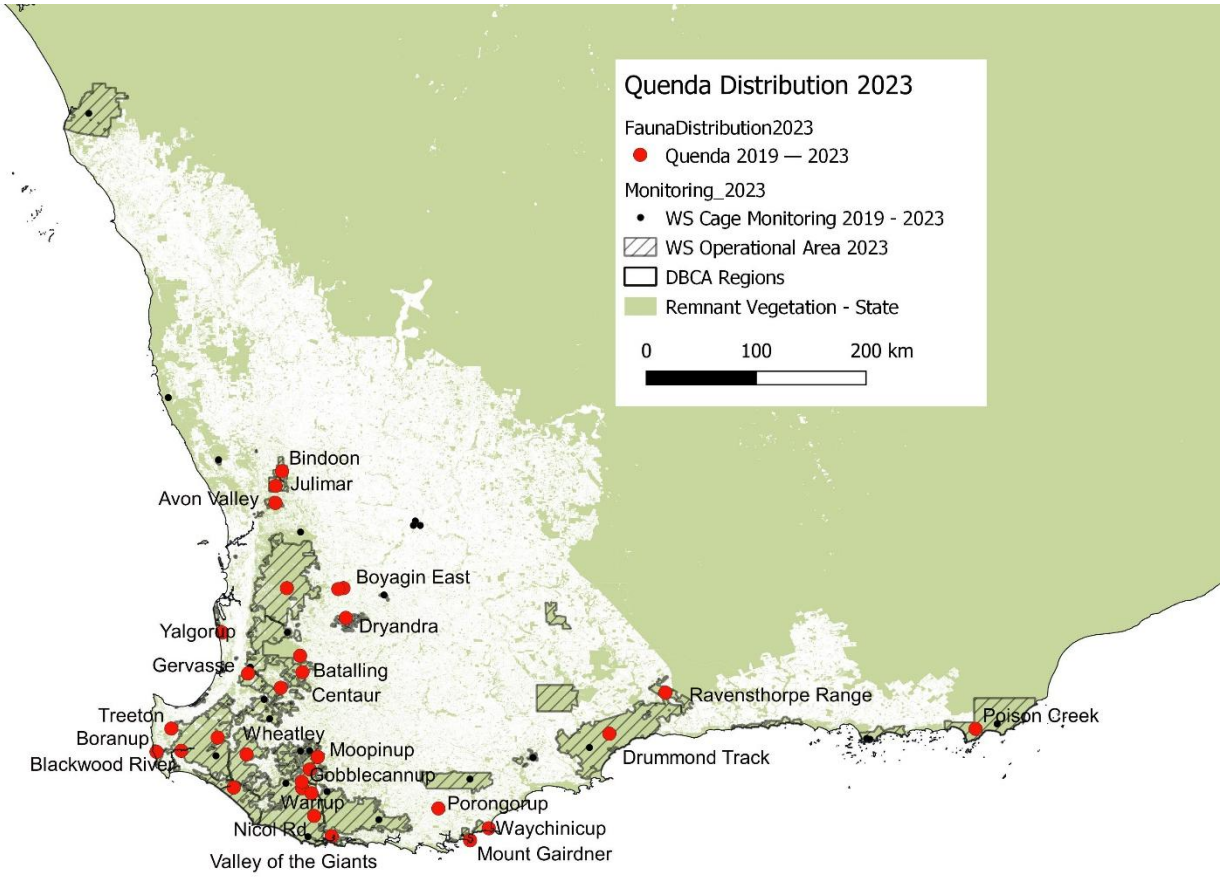

Figure 20: Sites where quenda were recorded in cage trapping using WS methods, quokka monitoring or camera monitoring 2019 – 2023 (red dots). Black dots indicate sites that were monitored at least once between 2019 and 2023 using WS cage monitoring methods.

Quenda populations

The relative abundance of quenda at monitored sites has remained low and annual response is still highly variable (Figure 21). At a single site, Quokka Swamp, where there was a change in lure using in Thomas traps from 2019, capture rates of quenda increased substantially from 2019 to 2023. It is possible that the change in bait has improved the quenda detection at Quokka Swamp compared to other sites, which continue to use universal bait. This suggests that to adequately sample this species for population size assessment more species-specific monitoring may be necessary.

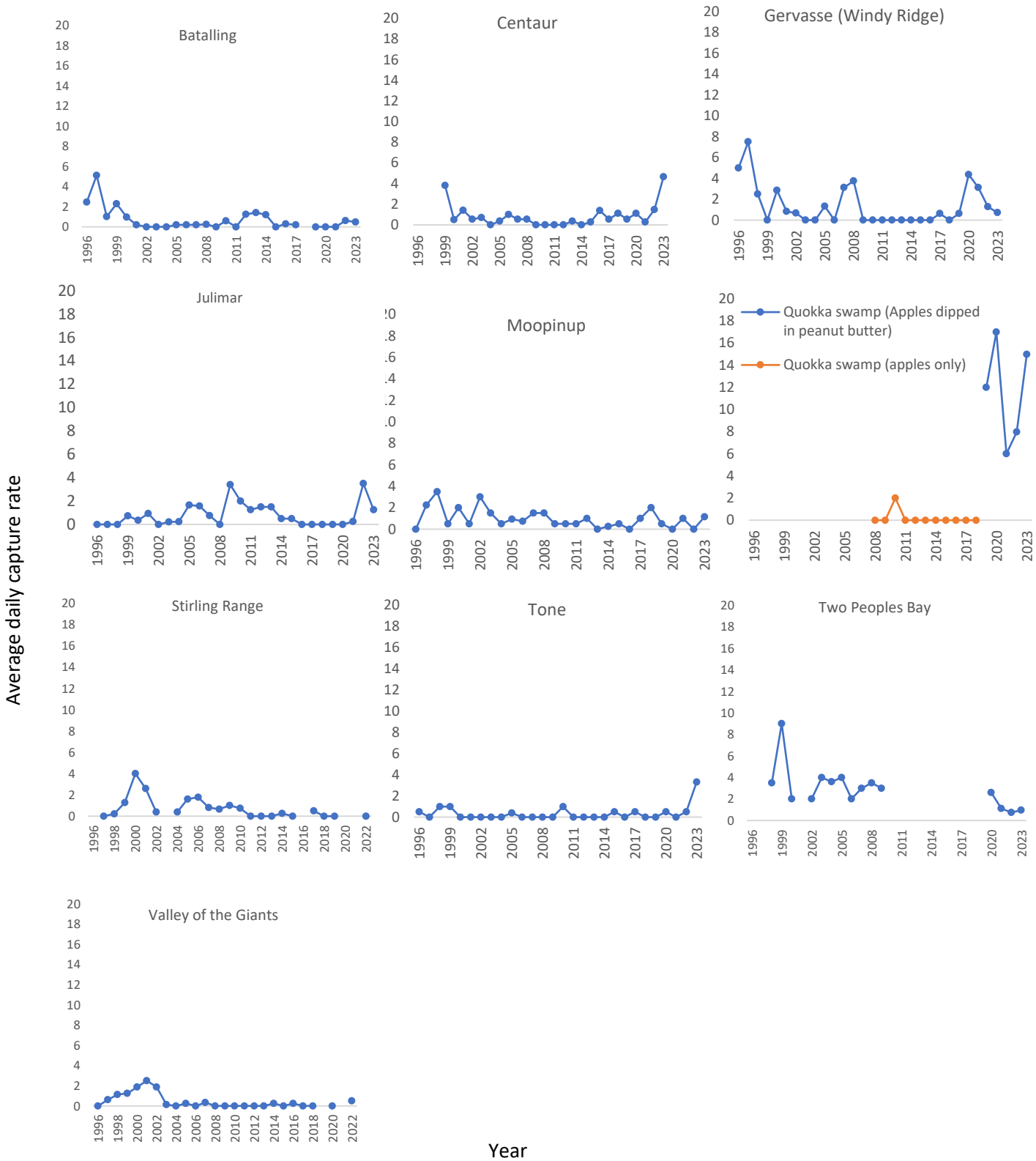

Figure 21:Average daily capture rates at selected sites with frequent captures of quenda across the south-west of Western Australia. Quokka Swamp uses Thomas traps baited with apples rather than cages and in 2019 implemented a change of bait (blue line) to better target quokkas, this may have also increased quenda captures. Stirling Ranges and Valley of the Giants are rotational sites and were not monitored in 2023.

Quokka

Quokka occupancy

Quokkas are known to be sparsely distributed throughout the forest area. Data is usually collected as part of planning for prescribed burns or other management activities and to date has only been implemented as a WS activity in three districts. Ideally standardised monitoring should be implemented across the quokka's mainland range. Below is a summary of data provided through the quokka recovery team, together with any quokka records from WS or district predator monitoring. It is noted that some sites may have conducted targeted quokka monitoring which have not been reported. Camera monitoring identified quokka at eight locations in 2023 (Table 1). Notably the record at Mt Lindesay is the most eastern record for Frankland District since 1975.

In addition to the eight camera locations, quokka were also captured at a single mark-recapture monitoring site in 2023 (Quokka Swamp). The species was recorded on camera or in trapping at 17 locations between 2019 and 2023 (Figure 22).

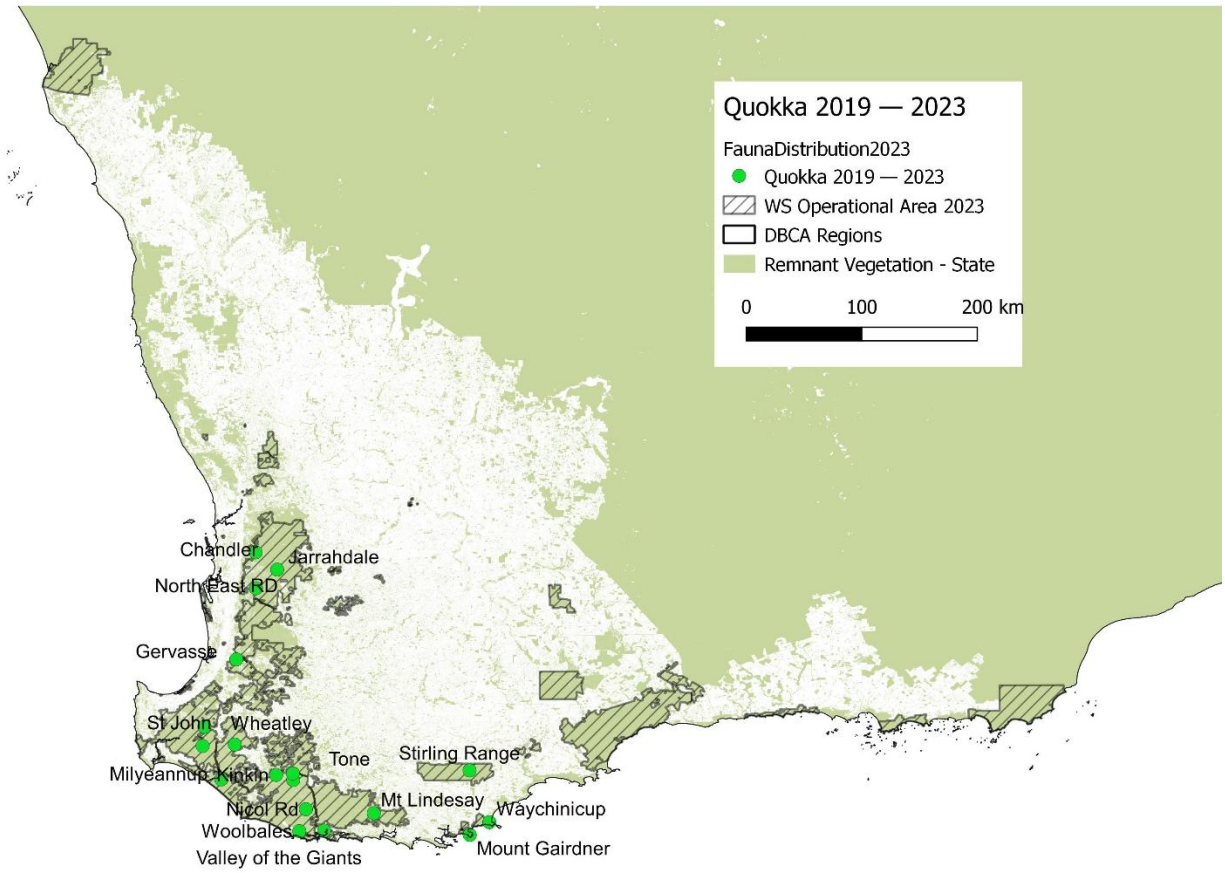

Figure 22: Sites where quokka were captured in traps or on camera 2019 – 2023 (green dots). Monitoring for quokka is limited and generally targeted to likely habitats. Ad hoc monitoring is associated with known disturbance events, such as prescribed burns.

Table 1: Summary of quokka records using camera monitoring or scat surveys in the south-west of WA in 2022 — 2023.

WS cell	Location (monitoring type)	Number of cameras active (trap nights/survey locations)	Monitoring Period	Number cameras/locations recording quokkas
D'encastreau	Charley	50		5
Denbarker	Mt Lindesay (targeted)	15 (680)	16/6/2023 – 20/10/2023	10
Donnelly	Wheatley (targeted)	50	Apr-23	6
Donnelly	Scat surveys	23	Feb-23	1
Manjimup	Scat surveys	1	Feb-23	1
Perth Hills	Amphion	1	2023	**0**
Perth Hills	Hollyoak — North east Rd (ad hoc)	7 (462)	21/2/2022 – 27/04/2022	2
Perth Hills	Inglehope (ad hoc)	1		0
Perth Hills	Jarrahdale (predator cameras)	20 (836)	01/01/2023 – 17/2/2023	2
Perth Hills	Serpentine pipehead dam	1	2022	0
Perth Hills	Tumlo	3 (369)	14/01/2022 – 18/5/2022	0
Shannon	Gobblecannup (targeted)	50	February 2022	7
Shannon	Tone (predator)	10 (870)	2/2/2023 – 12/08/2023	7
Shannon	Scat surveys	26	Jan-Mar 2023	8
Stirlings	Bluff knoll	tbc	2021	tbc
Sunklands	Milyeannup (targeted)	10 (700)	4/3/2021 – 13/5/2021	5
Sunklands	St Johns (predator)	15 (3074)	9/6/2023 — 15/11/2023	5
Two Peoples Bay	TPB	30	1/1/2023 – 11/5/2023	23
Walpole	Valley of the Giants	10 (410)	17/5/2022 – 27/06/2022	4
Waychinicup	Waychinicup	40	Jan-23	14

tbc= to be confirmed. Note: scat surveys need to record fresh scats with medium or high confidence to be noted as quokka's present

Quokka populations

Results from targeted quokka trapping at Gervasse suggests that from the mid-1990s to 2014 there was a general decline in the relative abundance of quokkas at this location, however in recent years the population appears to have increased (Figure 23), noting there was a change in the lure from apples only to apples dipped in peanut butter from 2019.

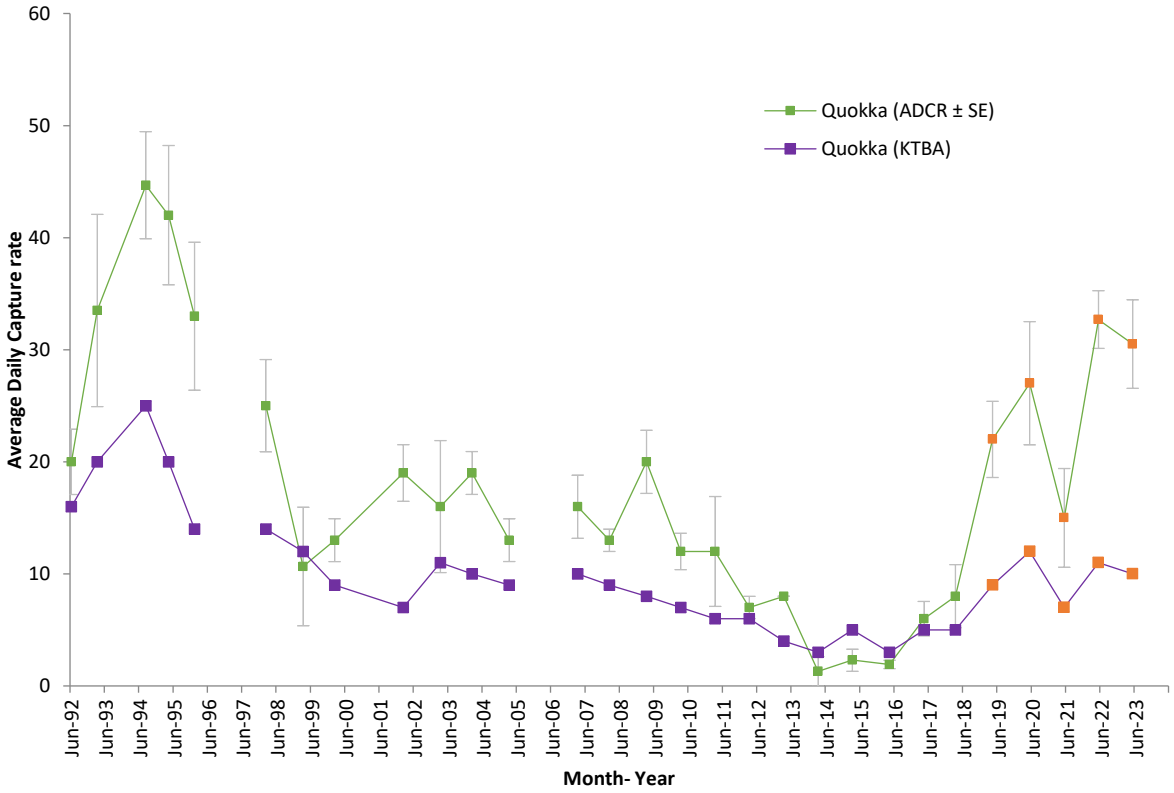

Figure 23: Average daily capture rate (ADCR) or relative abundance of quokkas (green line) and known to be alive (KTBA: purple line) at Gervasse (Quokka swamp), Wellington National Park. Error bars = standard error. Note a change in bait from apples to apples dipped in peanut butter commencing in 2019 (denoted by orange markers).

Black-flanked rock-wallaby (*Petrogale lateralis lateralis)*

Populations of black-flanked rock-wallaby (BFRW) are currently monitored under various district programs across Western Australia. Monitoring at the Cape Range cell (Pilbara), Central Wheatbelt sites (Wheatbelt), Avon Valley National Park (Perth Hills) and Kalbarri National Park (Midwest) is conducted using both cameras and Thomas traps (Table 2). Camera monitoring has also been established at Durba Hills and the Calverts in the Pilbara, and at Cape Le Grand and Salisbury Island (South Coast).

It is highly likely that populations at Avon and Walyunga are either extinct or functionally extinct. Monitoring at Avon Valley National Park has only recorded a single animal in the period 2017 – 2022 with no records in 2023. No animals have been recorded at Walyunga in recent years (Table 2).

Physical evidence of overgrazing and poor body condition of animals together with population modelling suggests the fenced population at Nangeen is at or close to carrying capacity with an estimated 120 – 170 individuals in 2021 (Figure 25: Povh et al., 2023). It is likely that number has increased and the population is at or beyond the carrying capacity of the site.

The Kalbarri population was last monitored using traps in 2022 (Table 2) and will be monitored again in 2025. Camera monitoring is ongoing and indicates that there has been continued breeding, with additional scat and visual surveys suggesting the population continues to expand the area they are using in the gorge.

Populations at Cape Range are either increasing or relatively stable (Figure 26 and Figure 27). Notably, camera monitoring at Cape Le Grand has indicated a reduction in BFRW activity from 2017 (

Figure 28). More recent data suggest that the population has stabilised in the period 2017 to 2023 with data in late 2023 suggesting that activity may be increasing (Figure 28). A total of 32 BFRW were translocated to Cape Le Grand between 2003 and 2004.

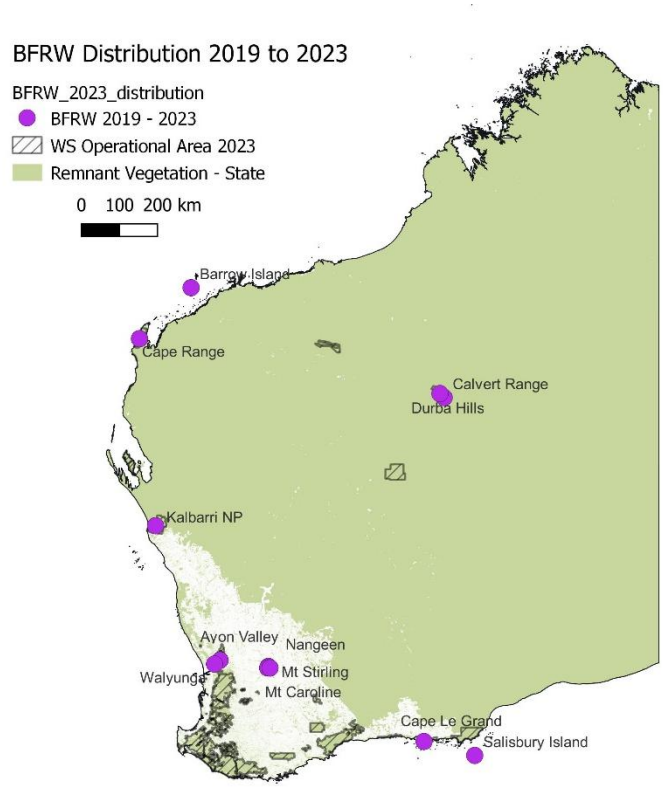

Figure 24: Sites where black-flanked rock-wallabies were recorded during targeted monitoring 2019 – 2023 (purple dots) on DBCA managed lands. Note that monitoring for black-flanked rock-wallabies is targeted to known habitats.

Table 2: Summary of recent BFRW monitoring at sites with active predator management.

Location	*Monitoring type*	*Years*	*Summary*
Avon Valley	Camera	2023	No individuals recorded.
Barrow Island	Sight surveys	2023	18 individuals noted in 2023 (only 4 of the 33 locations surveyed).
Cape Le Grand	Cameras	2015-2023	Camera monitoring indicates decline in activity since 2015 to 2017 (Figure 28). Activity stablised in recent years.
Cape Range	Thomas traps	2018 2018&2022	ManduMandu estimated 61 individuals[5] Pilgonoman estimated 106 animals[5]
	Point Counts	2010-2024 2019 2019	Yardi Creek – point counts (Figure 27) Ex-Ningaloo (not baited) UCL north of Exmouth (not baited)
Durba Hills (translocated population)	Cameras *Thomas*	2019-2021	26 cameras were deployed in 2019. Closure of remote communities due to COVID prevented 2020 check. Some cameras were still active in 2021 resulting in 898 camera-trap nights. Cameras were serviced in June 2021. Camera images in 2021 contained male and female rock-wallabies. There were also images of females with pouch young and young-at-heel. Classifications still to be finalised. Trapping in August 2021 captured 7 individuals.
Kalbarri	Cameras and Thomas	2020 — 2022	2020 (Thomas): 12 individuals KTBA at Hawks Head, six of the seven females had pouch young. 1 male at Z-Bend. Camera image analysis still to be completed. 2022 (Thomas): 44 individuals. Many females carrying pouch young (total of 307 trap nights including Fourways, Hawks Head, Z-bend and skywalk). Scheduled to be trapped in 2025
Mt Caroline	Thomas	2021	Trap success rates indicates the population is increasing. Scheduled to be trapped in 2024.
Mt Stirling	Thomas	2023	Six individuals in 2023 reduced from nine in 2018.
Nangeen	Thomas	2022	See Figure 25, population stabilising, but likely close to carrying capacity. Estimated to be 120 – 170 individuals.
Sales/Gundaring	Thomas	2023	45 individuals KTBA, population increasing.

[5] (Clausen pers. Com. Lincoln-Peterson Population Estimate for mark re-sight)

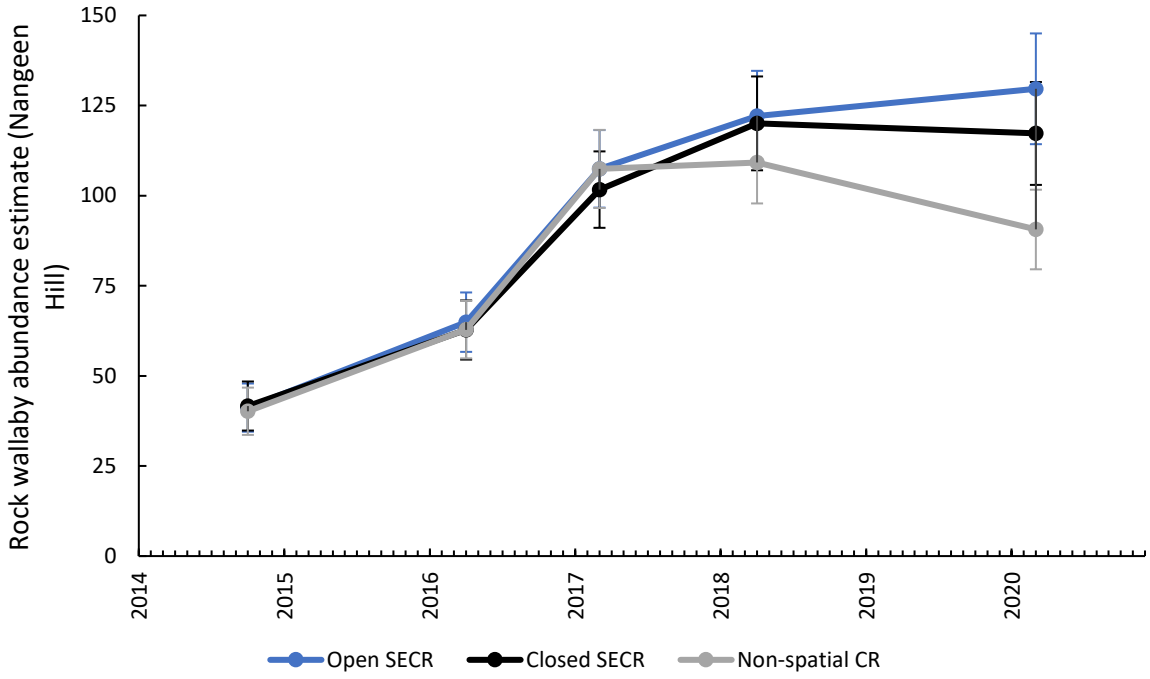

Figure 25: Estimates of abundance of Black-flanked rock wallabies at Nangeen Hill using both non-spatial and spatial capture recapture methods. Spatially explicit capture recapture (SECR) was conducted assuming both an open population and a closed population. Density estimates calculated by SECR were used to estimate abundance using a 50m buffer area around trap sites to capture their refuges and expected foraging distance. (K. Nilsson).

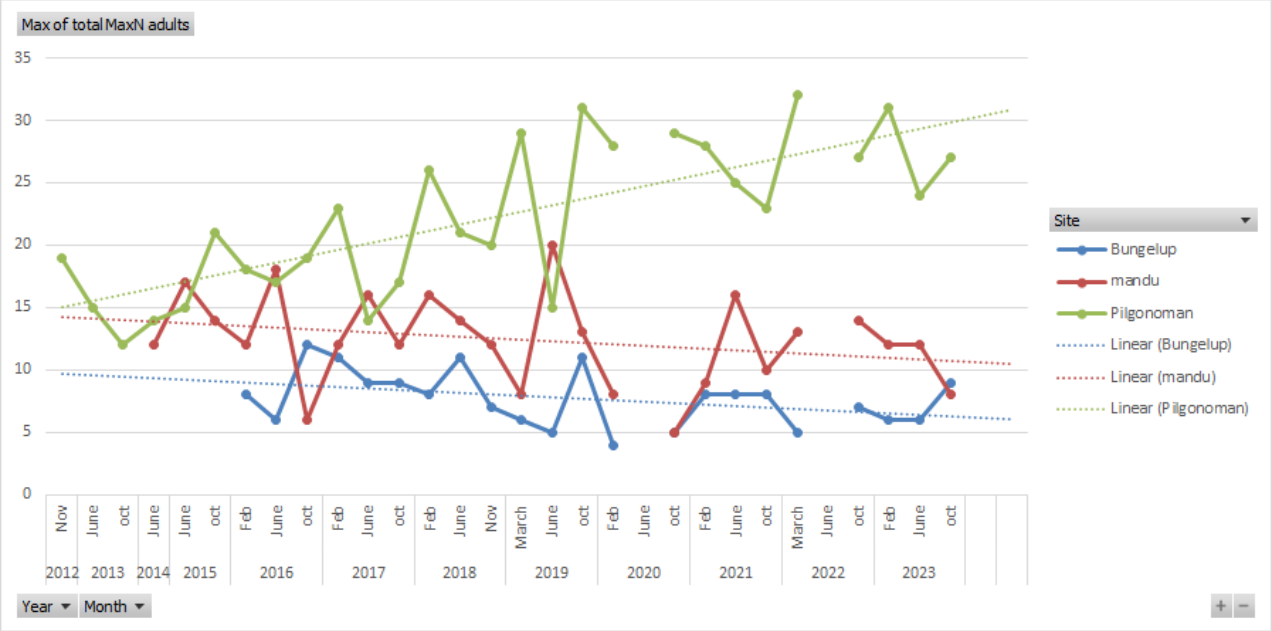

Figure 26. Population estimates of BFRW at Cape Range National Park.

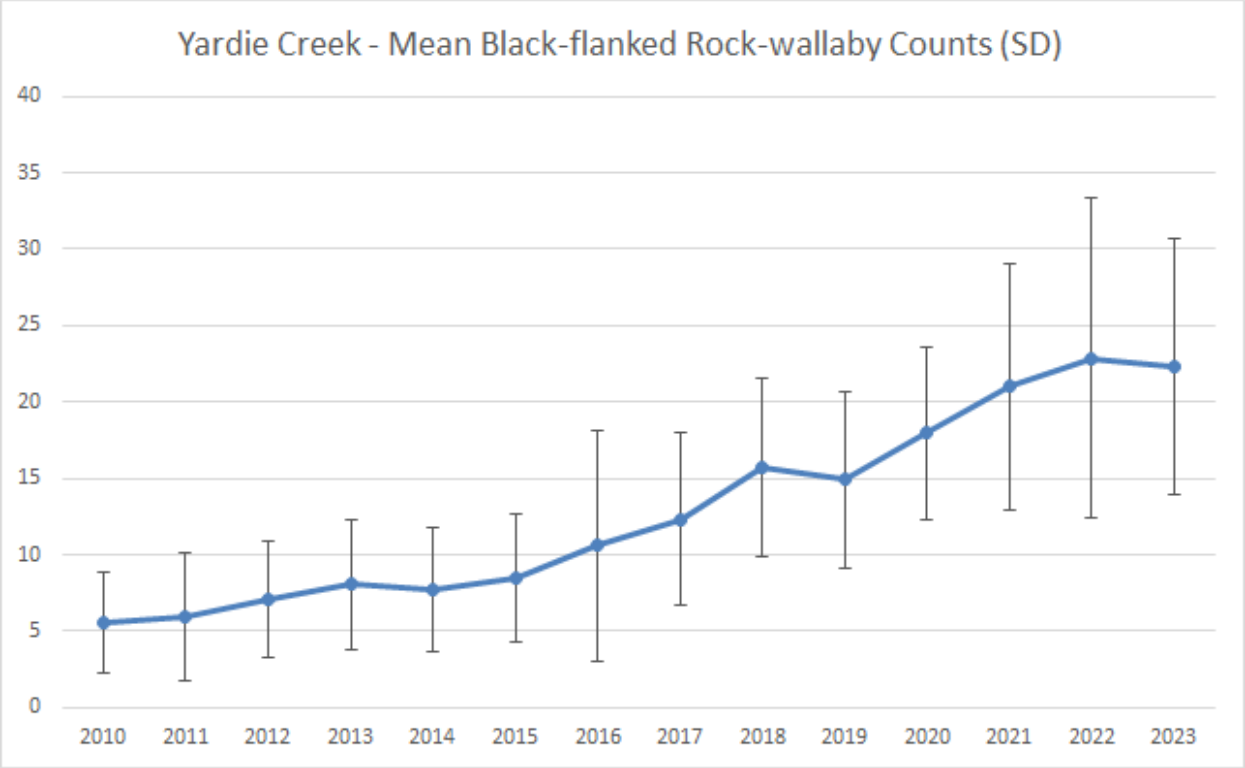

Figure 27: Mean of BFRW counts at Yardie Creek (Error bars = ±standard deviation).

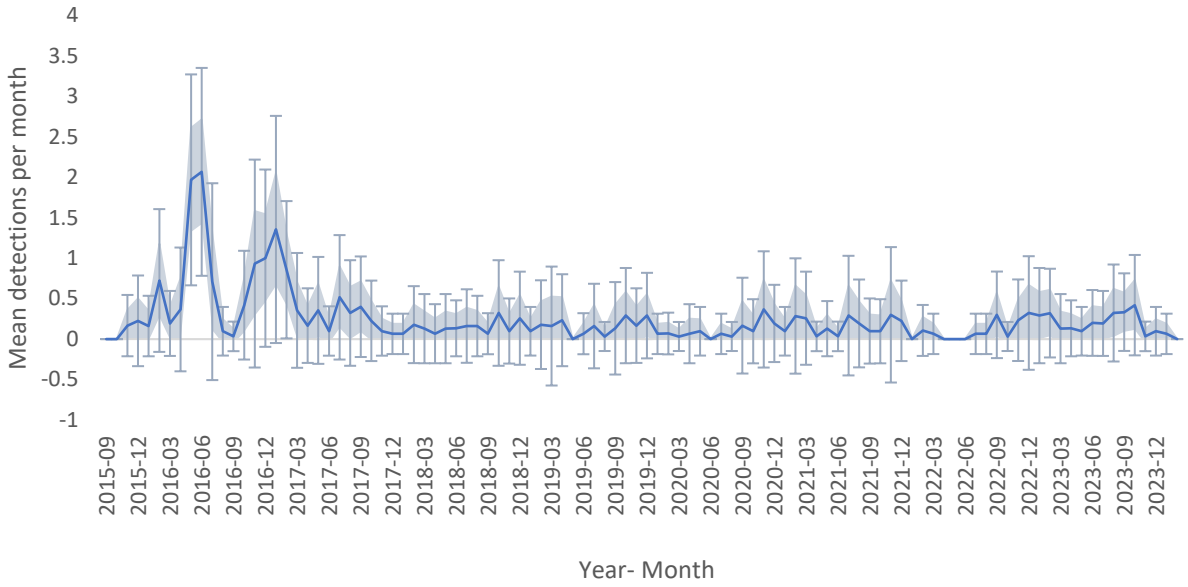

Figure 28: Mean daily detections of BFRW at Cape Le Grand National Park 2015 – 2023.

Fox and feral cat management

A summary of the aerial and ground baiting for each WS cell is provided in Appendix 2. A large portion of the WS baiting cells received increased baiting in 2023 due to increased funding available through the FMP, the Feral Cat Strategy and external sponsorship provided by the Alcoa Foundation (Appendix 2;Table 4 and Table 5).

Except for Julimar and Bindoon, all WS cells within the Forest Management Plan area received six aerial deliveries of Probait in 2023. Dragon Rocks received an increase in Probait aerial deliveries in 2022/2023 and its first Eradicat® baiting in autumn 2023 with several other cells in the Wheatbelt and Southcoast scheduled to receive Eradicat® in autumn 2024 (Appendix 2,Table 6). Eradicat® will also be trialled in parts of the northern jarrah forest in autumn 2024.

In the 2022/2023 period, lack of access to baiting transects due to rainfall and/or lack of 1080 trained staff reduced ground baiting delivery to below the prescription at 29% of reported cells.

Predator monitoring

Predator monitoring[6] was conducted at 19 baited sites and seven reference sites (i.e., areas with no predator management) in 2023 (see Appendix 1 for level of effort at each site in 2023). Figure 29 provides a summary of the fox detections (i.e., number detections summed across each site per month, 24-hour quiet period/number trap nights each month and averaged across the sampling period) at baited and reference sites for sites with long term monitoring. The number of detections/trap nights is used as an indication of the level of fox or feral cat activity at the site.

[6] Predator monitoring uses automated wildlife cameras randomly deployed across a portion of a cell with a minimum distance of 1.5 km between cameras at most sites. Cameras are set according to the methods defined in the Western Shield Camera Trap Monitoring Protocols (Drew 2018). Cape Range uses cameras and track counts, however, only track counts have been analysed for 2023.

Based on camera detections, fox activity is on average higher at sites with no fox management and on average higher at sandplain sites and woodland sites compared to that recorded in the jarrah forest sites (Figure 29). Variation in activity between ecosystems may be a result of reduced detectability of foxes in forest environments or that foxes are more prevalent outside the forest areas. A more detailed analysis will be completed in late 2024 incorporating potential explanatory variables to improve our understanding of fox activity drivers and facilitate more targeted management.

Feral cats

On average, feral cats are detected less frequently than foxes in all habitat types (Figure 29 and

Figure 30). It is unclear if this is a result of cryptic behaviour, their smaller size, or because they are less common compared to foxes. To help understand our ability to monitor feral cats using current methods, in 2023 nine feral cats were radio collared across Avon Valley National Park (AVNP) and Walyunga National Park (WNP) as part of a collaborative research project with BCS and Western Shield, and sponsored by Alcoa, South32 and Newmont. This research identified that our current monitoring methods using randomly placed cameras are not sufficient at effectively monitoring feral cats in the northern jarrah forest. Camera arrays that target high use areas such as river lines and tracks almost tripled detection rates of feral cats in forest environments (*Figure 31* and *Figure 32*).

Cameras will be deployed along targeted habitats in AVNP and WNP in 2024 prior to Eradicat® baiting and a revision of camera deployment protocols will occur in 2024/2025 across forested sites to maximise our understanding of feral cat activity with the aim of improving bait efficacy. Implications of using a different camera array will then be assessed to determine if this method can produce data suitable for analyses.

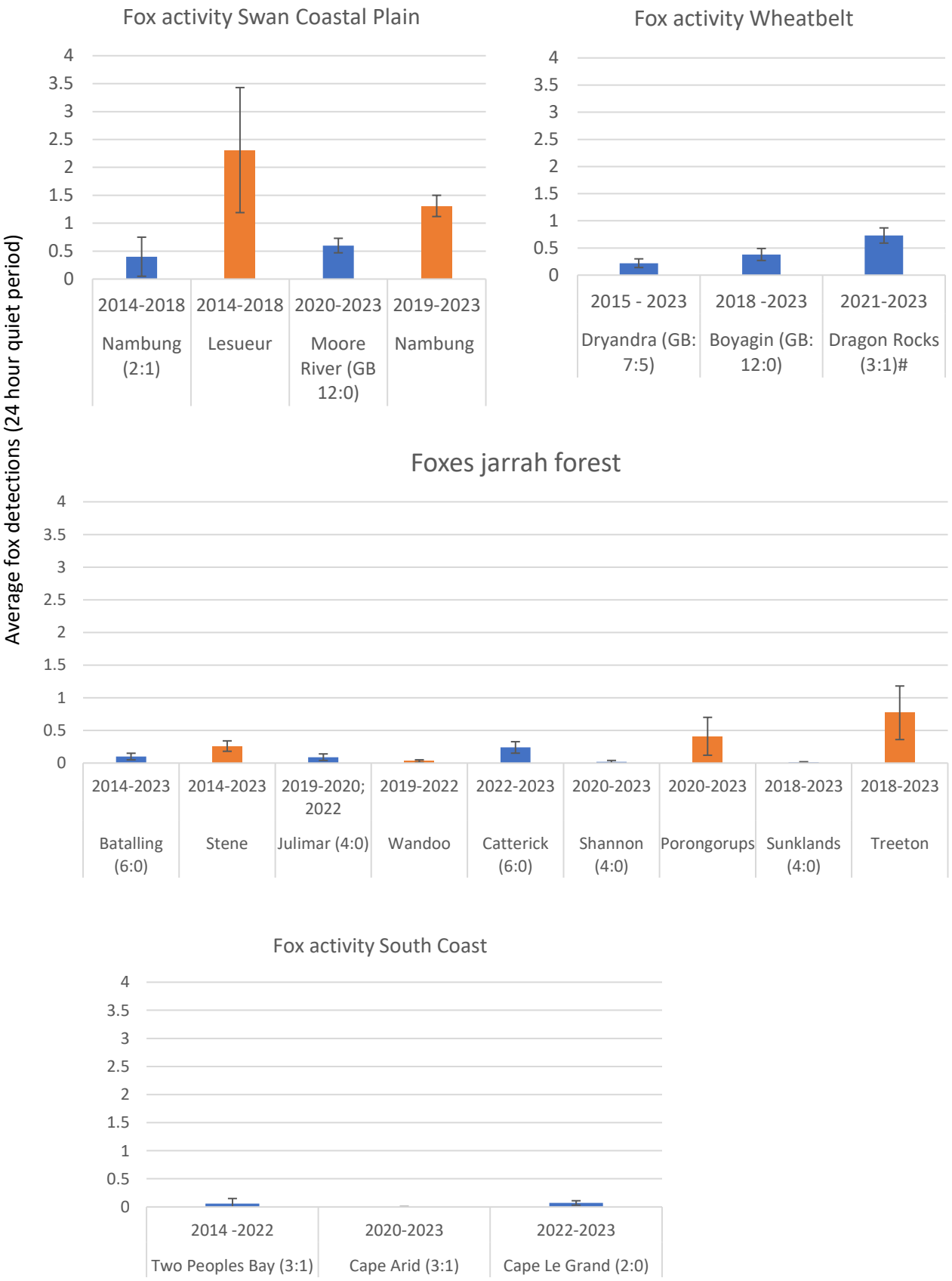

Figure 29: Fox activity detected on camera within each ecosystem. Years represent the period cameras were active. Data in parenthesis are aerial Probait:Eradicat® prescription frequency in the 2022/2023 financial year (GB = ground bait only). Blue bars are sites with active fox management, orange bars are sites with no active fox management. #commenced Eradicat® in March 2023.

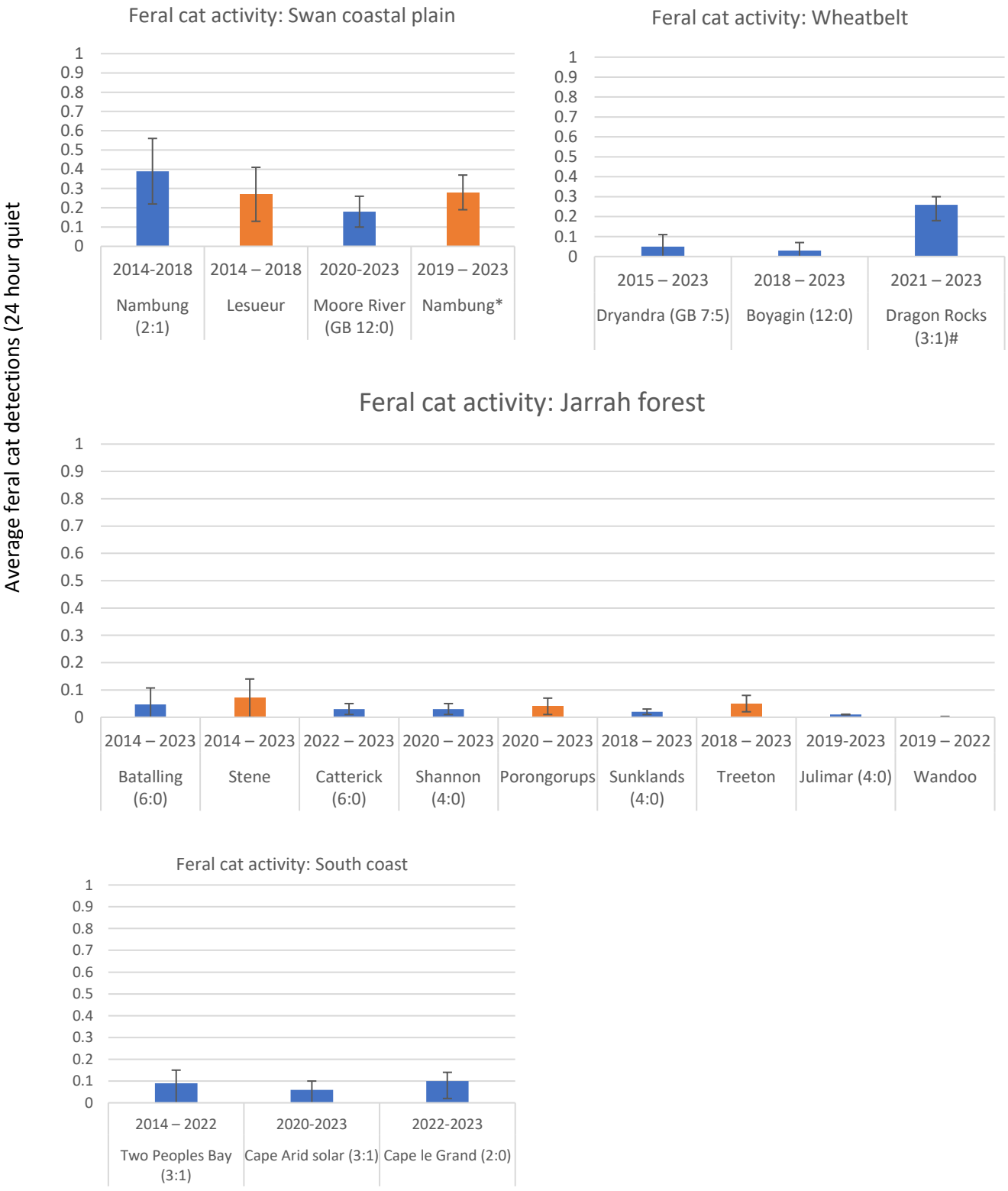

Figure 30: Feral cat activity detected on camera within each ecosystem. Years represent the period cameras were active and data in parenthesis are Probait:Eradicat® (GB= ground bait only) prescription frequency in the 2022/2023 financial year. Blue bars are sites with active fox management, orange sites with no active fox management. #commenced Eradicat® in March 2023.

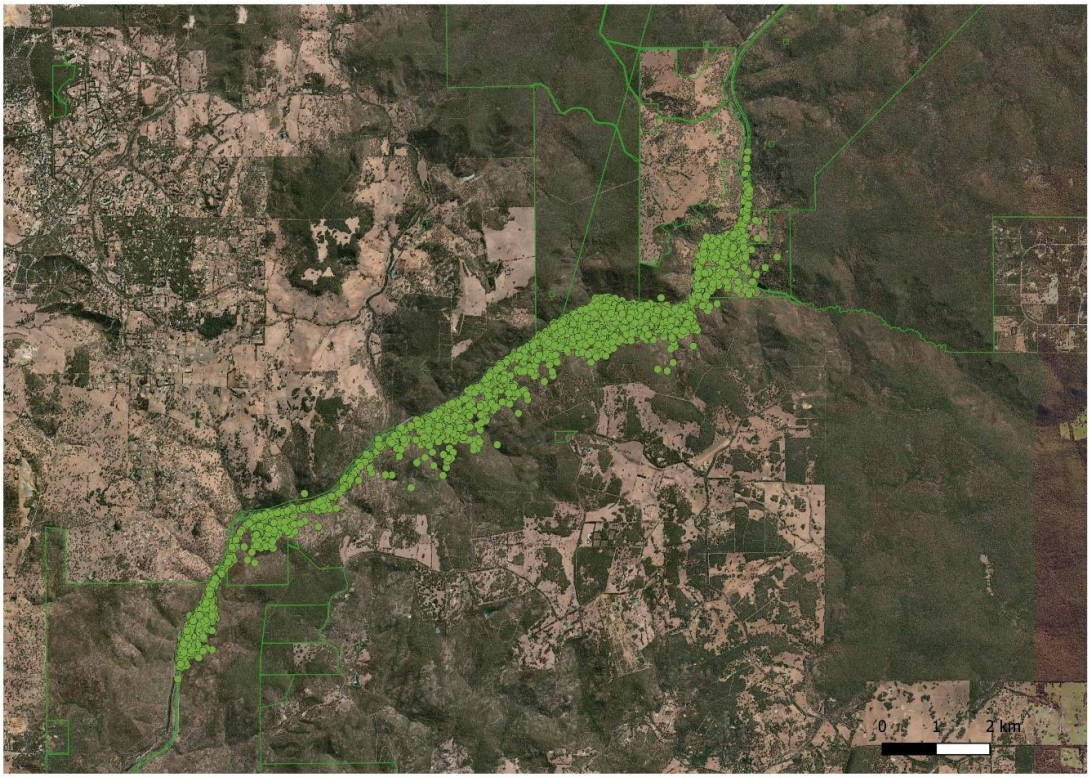

Figure 31: Movements of a feral cat in the Avon Valley. Green dots indicate hourly fixes of the feral cat. The cat was highly focussed on the river line and nearby habitats.

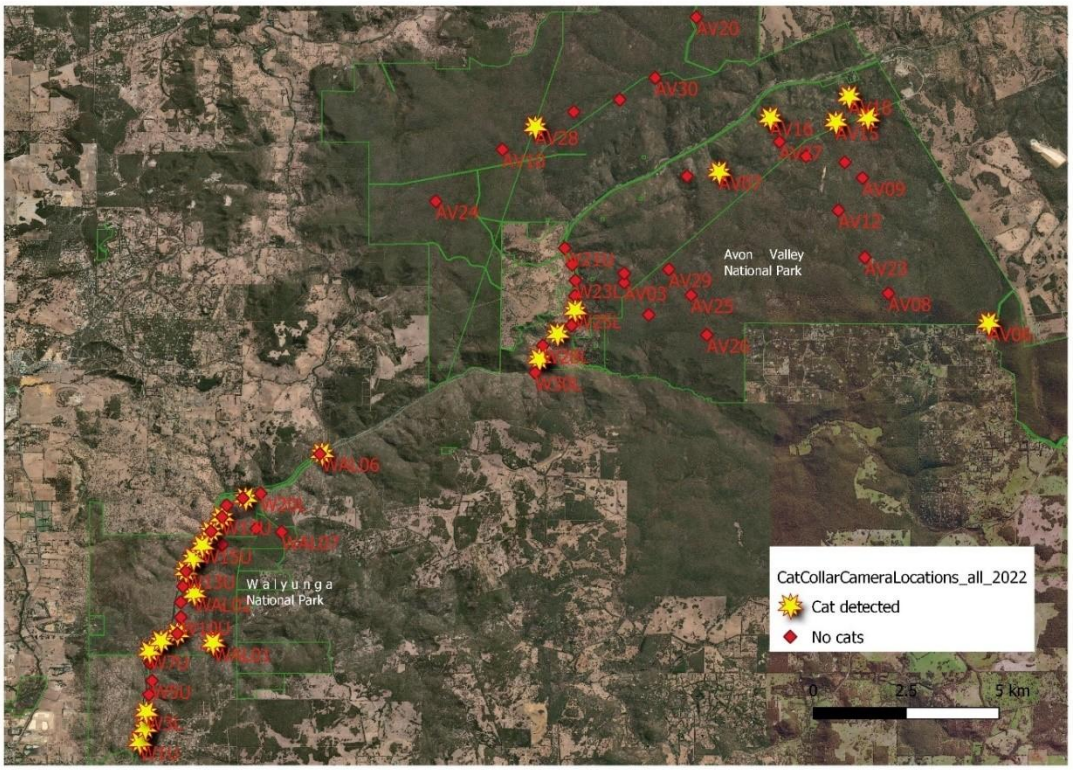

Figure 32: Location of cameras (red dots). Yellow stars indicate cameras that detected a feral cat. Green lines indicate boundaries of DBCA managed land.

Swan Coastal Plain

Predator monitoring continued at Moore River and Nambung in 2023. Camera data indicates that regular ground baiting helps to suppress fox activity and in periods where ground baiting is not completed fox activity rises (Figure 33). Fox activity continues to increase at Nambung which has not been baited since 2018.

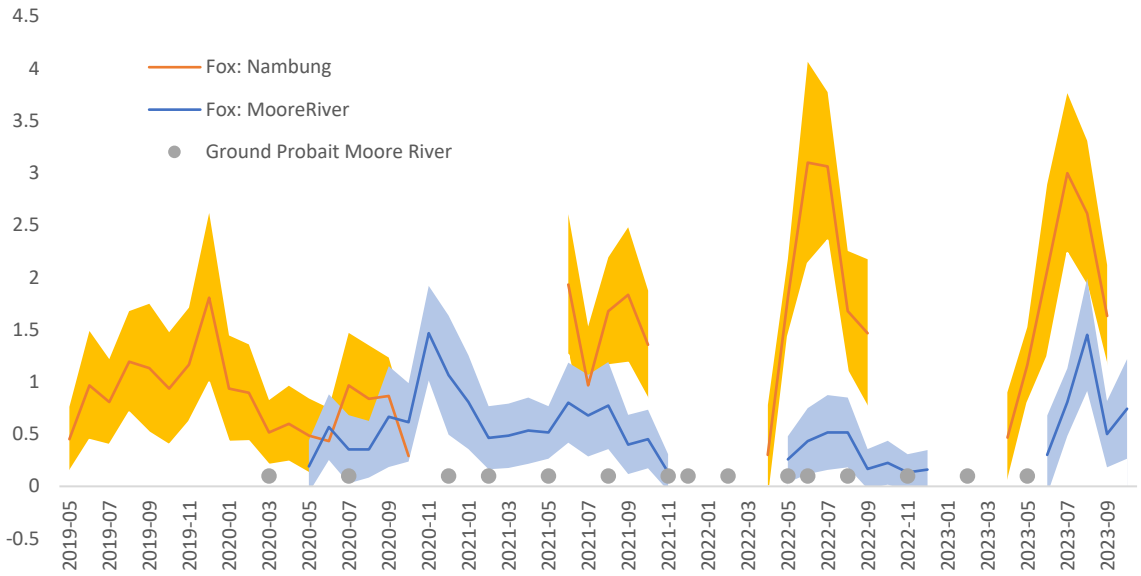

Figure 33: Fox detections at non-baited site (Nambung: orange line) and a ground baited site (Moore River: blue line). Blue dots indicate the month Probaits were delivered to Moore River (Prescription: 12 x ground Probait events/annum). Shading represents the 95% confidence interval.

Feral cat activity tends to be higher on the Swan Coastal Plain compared to that recorded in the jarrah forest, woodland sites or on the south coast (**Error! Reference source not found.**). There have been improved outcomes for native species at sites where there is a high intensity feral cat management (e.g. Dryandra, Figure 6). Cat management has not been implemented at Moore River and consequently feral cat activity at the site is similar to that recorded at Nambung National Park after the cessation of all introduced predator management (Figure 34). Additional analyses will be conducted to examine the impact of Eradicat® deployment frequency on feral cat activity in 2023 with the aim of determining the most effective management regime for different environments.

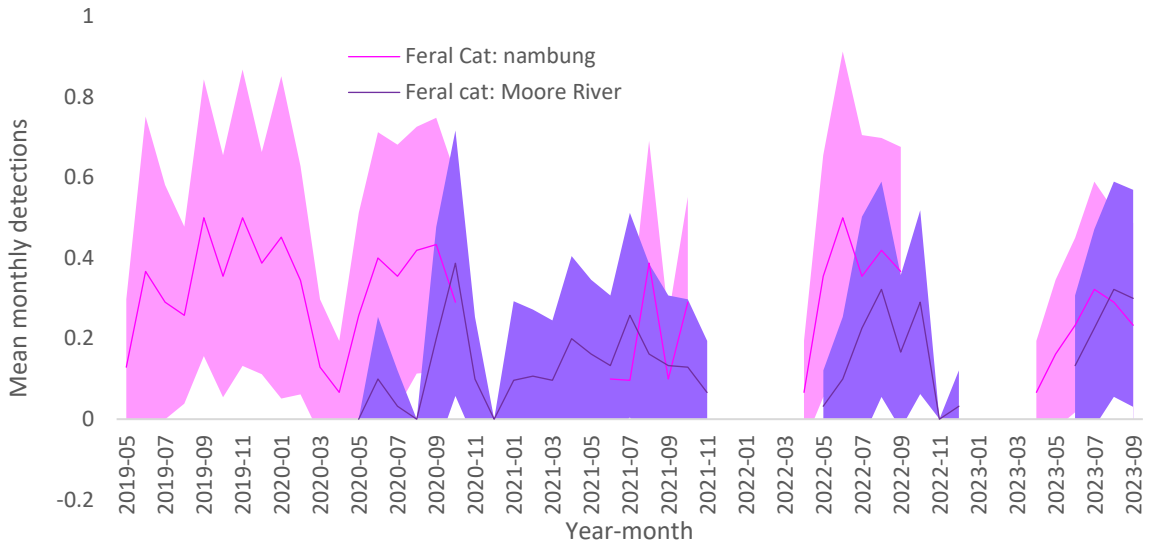

Figure 34: Feral cat detections at Nambung (no predator management since 2018) and at Moore River (12 x ground Probait events/annum). Shading represents the 95% confidence interval.

Jarrah Forest

Long-term predator monitoring at baited and non-baited areas in the jarrah forest shows fox activity is on average higher in the non-baited areas compared to areas with some fox management (Figure 35 and Figure 36). However, temporal fox activity is highly variable and in recent years fox activity has declined in the non-baited reference site Stene (Figure 35), this however is complicated by the loss of data for some of the cameras in Stene due to fire. Of note is the almost complete absence of foxes at St Johns (Sunklands cell), with only five independent detections of foxes in the period 2018 – 2022 (Figure 36). In comparison the detections in the control site (Treeton) were significantly higher with over 500 independent detections in the same period.

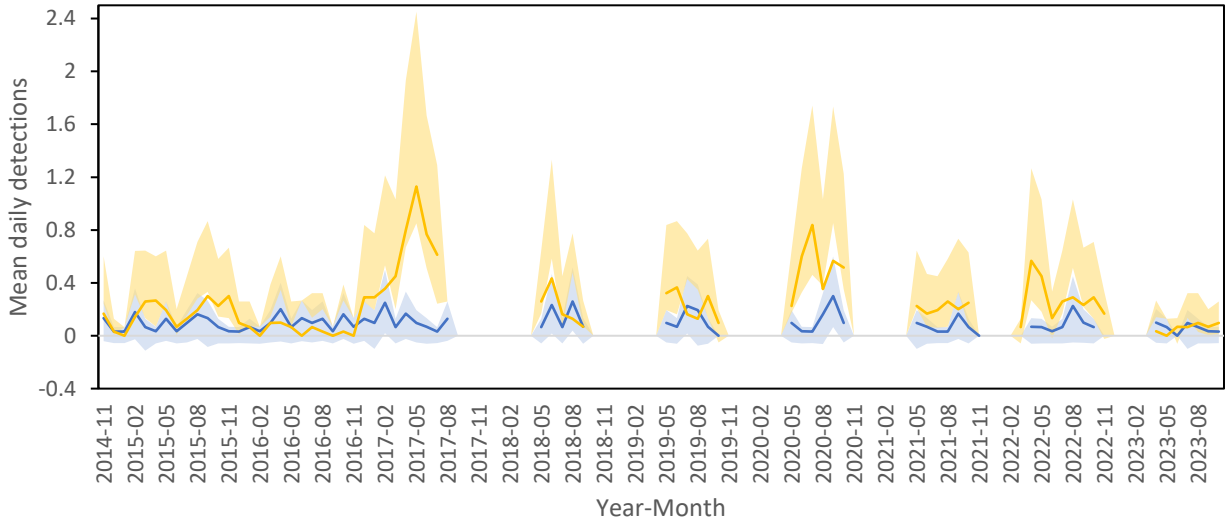

Figure 35: Fox detections on camera at a baited site (Batalling: blue line, 4 x aerial Probait events/annum 1996-2005; 2016-2021, 6 x aerial Probait events/annum 2006-2009; 2012-2015 and 2021 onwards) and non-baited reference site (Stene: yellow line) 2014 – 2023. Shading represents the 95% confidence interval. Note there was a bushfire in Stene in January 2016 which destroyed over 50% of the available cameras and affected detections in 2016 and in 2023 over 50% of the cameras were removed for prescribed burning in Stene resulting in less than half the cameras operational for the 2023 deployment period.

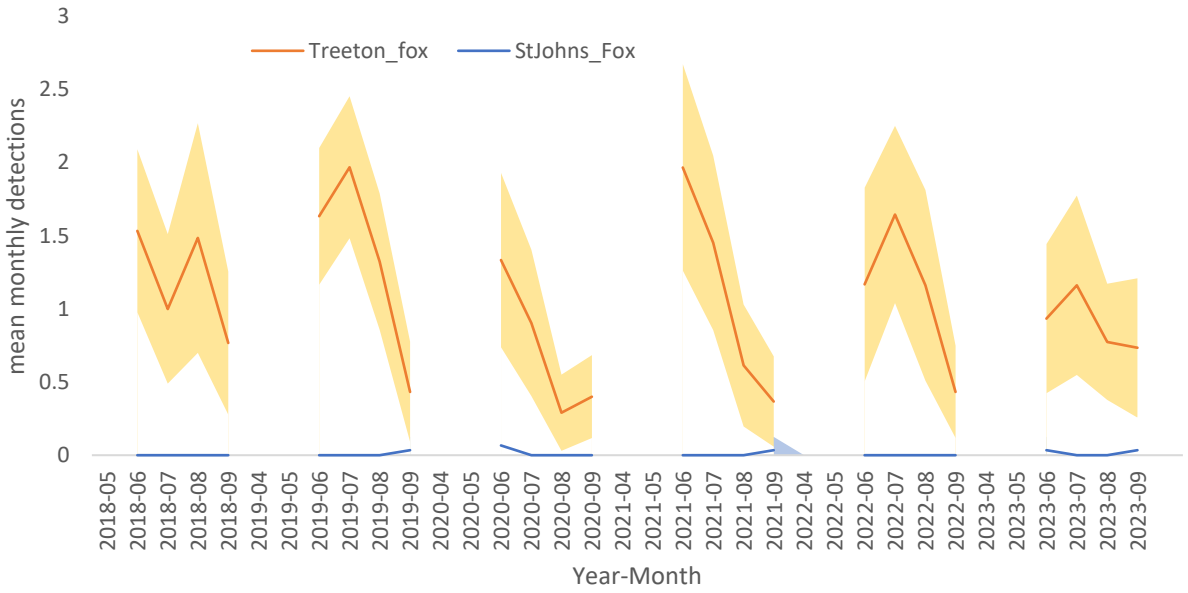

Figure 36: Fox detections on camera at a baited site (St Johns — Sunklands: blue line, 2 x aerial Probait events/annum, increased to 4 Probait deliveries in 2023) and non-baited reference site (Treeton: orange line) 2018 – 2023. Shading represents the 95% confidence interval.

Despite the absence of feral cat management in the northern jarrah forest, most monitored sites had low detections of feral cats (Figure 37). As identified previously, this is likely a result of their more cryptic nature in forest environments. Deployment arrays for feral cats will be reassessed in 2024 — 2025 in line with new information for the northern jarrah forest with additional camera arrays established to faciliate improved feral cat detection in forest environments.

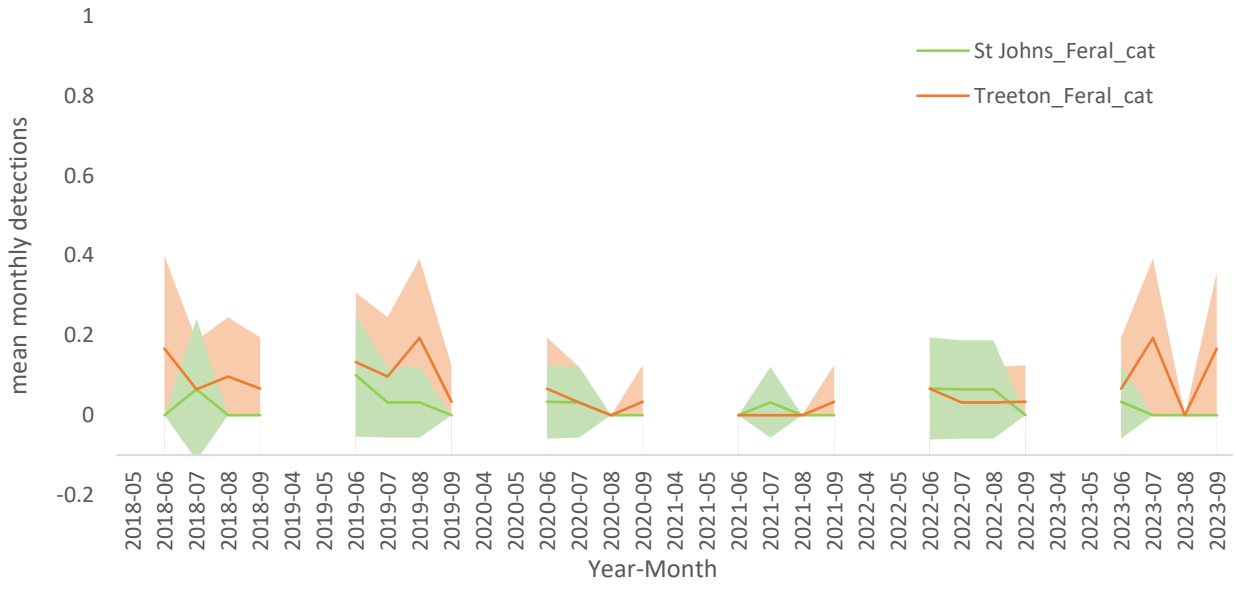

Figure 37: Feral cat detections at St Johns (Sunklands: 2 x aerial Probait events/annum, increased to 4 Probait deliveries in 2023) and at Treeton (no predator management). Shading represents the 95% confidence interval.

Wheatbelt woodlands

Both fox and feral cat detections appear to have increased slightly at Dryandra in 2022 and 2023, however the activity of both species is still very low compared with average detections on swan coastal plain sites (

Figure 30) or Dragon Rocks (Figure 39). Comparison of this data to woylie detections on camera (Figure 41) suggests that even though fox and feral cat activity appears to be increasing at Dryandra this has not had a significant impact on the activity of woylies at this point. Suppression activities such as fox and feral cat baiting and neighbour management are likely maintaining fox and feral cat numbers at levels that still enable populations of sensitive species to increase, however consideration should be made to increase management to manage numbers of predators before levels increase further.

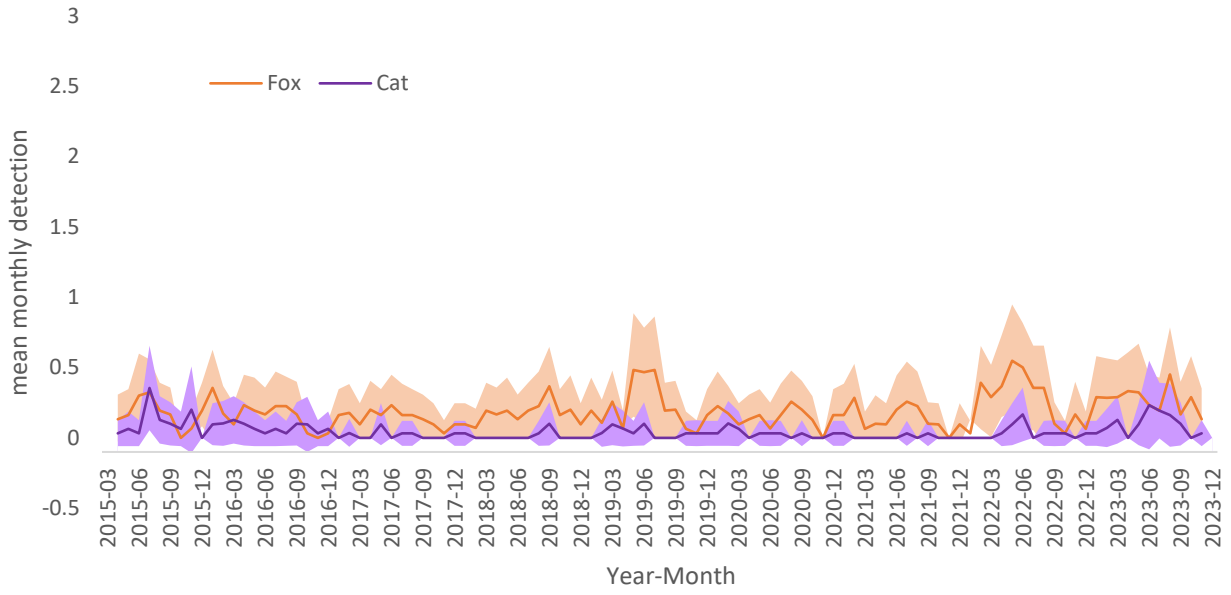

Figure 38: Fox (orange) and feral cat (purple) detections at Dryandra (blue line: ground baited 7 x Probait events plus 5 x Eradicat® events/annum). Shading represents the 95% confidence interval.

Fox and feral cat activity continues to increase at Dragon Rocks (*Figure 39*). The above average rainfall from 2021 to 2023 (*Figure 40*) has likely promoted increases in populations of both predator species. It is anticipated with the integration of Eradicat® into the baiting prescription from March 2023 and the increase of fox baiting from 2 deployments per annum to three, fox and feral cat numbers will be managed to levels which will enable populations of threatened species to increase.

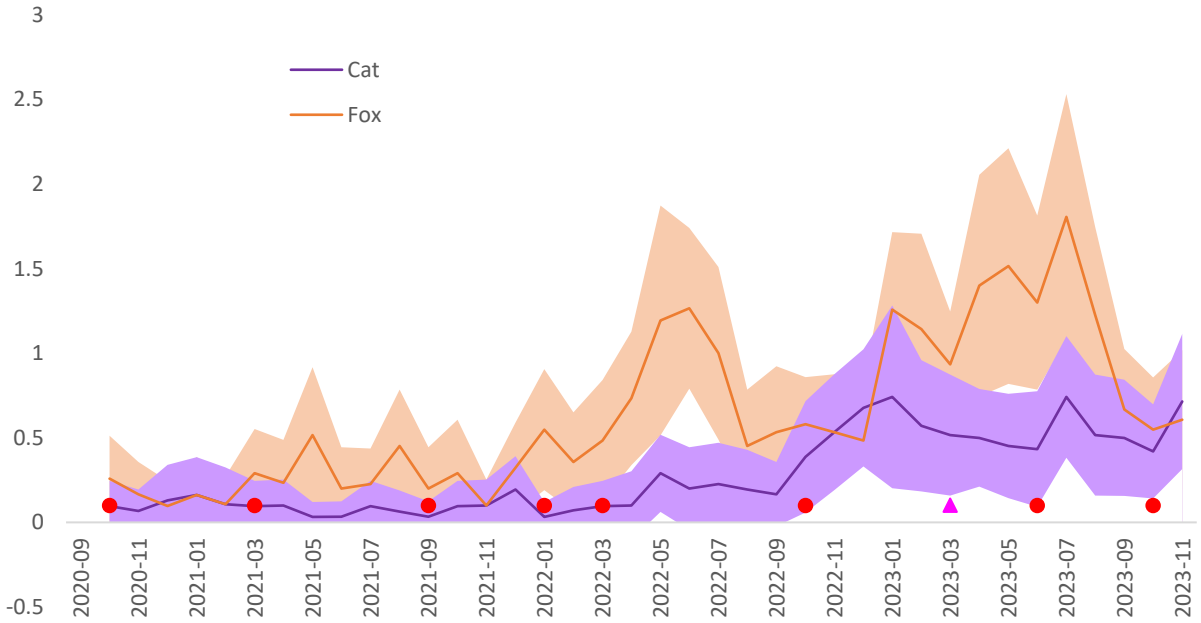

Figure 39: Fox (orange) and cat (purple) detections at Dragon Rocks (aerial baited x 2 Probait events (red dots) plus 6 x ground Probait events/annum, Aerial bait increased to 3 x Probait events/annum in 2021-2022 and in 2023 the site was baited with Eradicat® (pink triangle)). Shading represents the 95% confidence interval. Data courtesy of Mark Cowan.

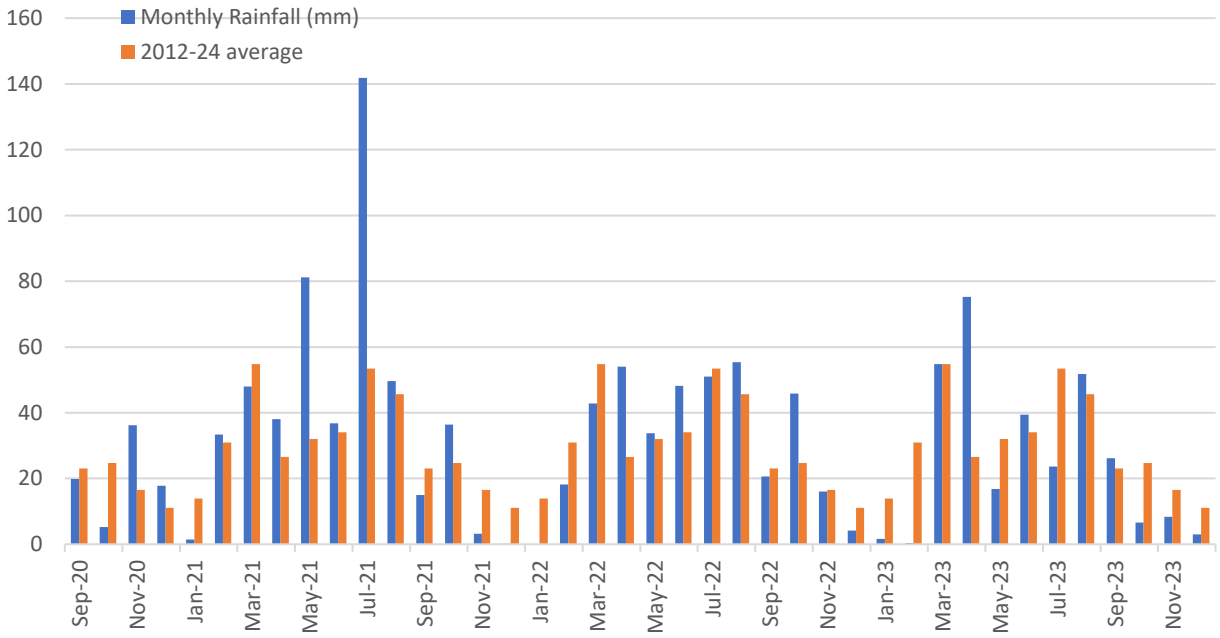

Figure 40: Monthly rainfall at Dragon Rocks compared to the average for each month (2012-2023)

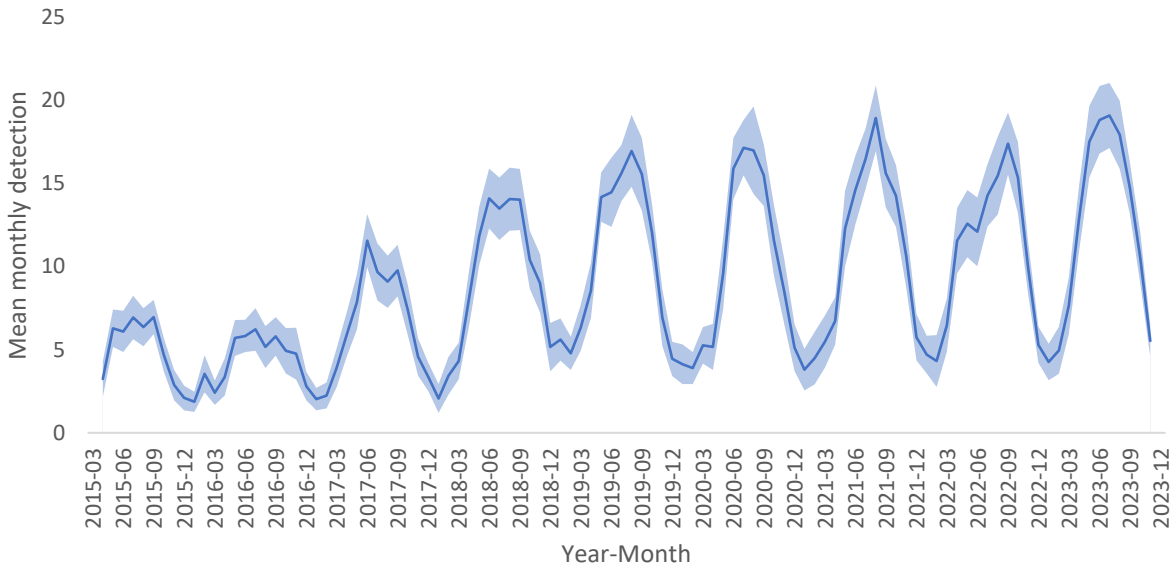

Figure 41: Woylie detections at Dryandra on remote cameras. Shading represents the 95% confidence interval.

South Coast

Predator monitoring at Cape Arid National Park (CANP) indicates very low fox activity (Figure 42) compared to all other ecosystems (Figure 29 and

Figure 30). Eradicat® has been integrated with Probait at this site since 2011 with initial monitoring undertaken as a research project (Algar et al., 2011, Comer et al., 2020). Results suggest that the efficacy of Eradicat and post bait feral cat trapping was variable, with a significant decrease in cat activity detected 2013 and in 2018. The research identified that an integrated approach of baiting and trapping was essential to provide sustained suppression of feral cat activity in south-coast reserves (Comer et al 2020). Feral cat trapping continues to be conducted by staff in the South Coast Region at selected reserves (Table 3). This provides additional ongoing protection to a range of threatened species within the reserves. The ongoing feral cat and fox suppression activities (i.e. aerial and ground baiting combined with trapping and shooting programs) conducted at several south coast sites is providing substantial protection to a range of threatened taxa in this region. Camera based predator monitoring has continued in CANP (Figure 42) and continues to demonstrate the value of an integrated approach.

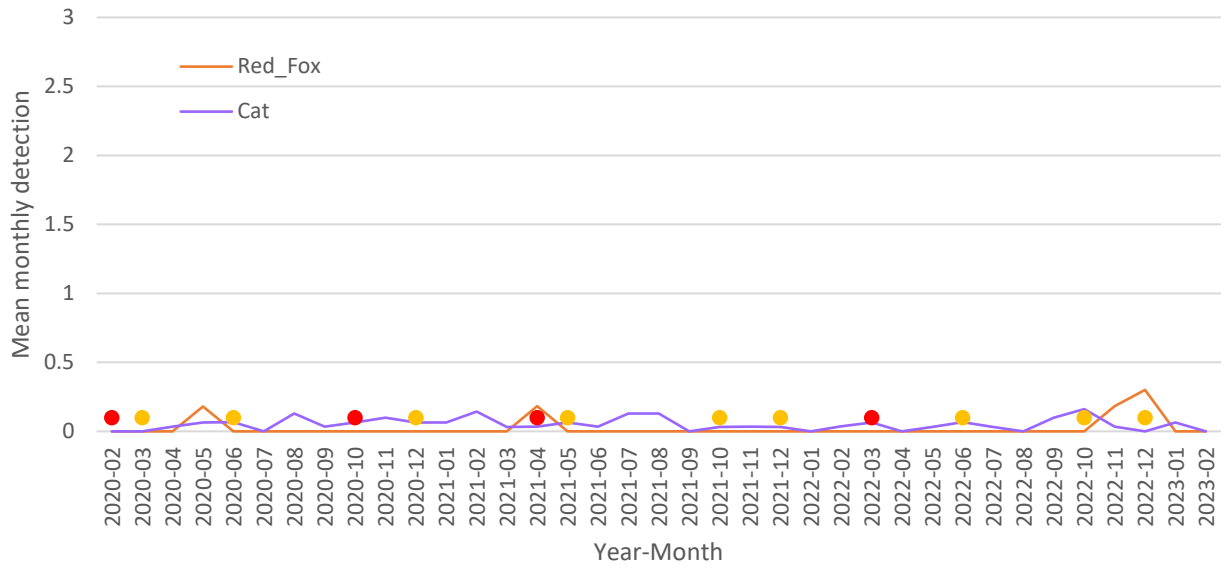

Figure 42: Fox and feral cat detections at Cape Arid National Park (3 x Probait: 1 x Eradicat® events/annum). Dots indicate the month Probait (yellow dots) or Eradicat® (red dots) was aerially delivered to the site.

Table 3: Summary of feral cat and fox removals from each location in the South Coast Region.

Location	Year	Number feral cats removed	Number foxes removed
Angove	2020	5	3
Peniup	2020	1	0
Two Peoples Bay	2020	7	0
Angove	2021	8	3
Peniup	2021	No trapping, too wet	No trapping, too wet
Two Peoples Bay	2021	2	0
Corackerup	2022	4	2
Peniup	2022	9	1
Two Peoples Bay	2022	1	0
Angove	2023	3	2
Peniup	2023	9	0

Pilbara

Monitoring at Cape Range National Park demonstrates that there are very few foxes relative to other predators in the landscape. Feral cats continue to be detected at the site and activity appears to be increasing, with annual track counts suggesting a substantial increase in cat activity since 2021 (Figure 43). Examination of annual rainfall data suggests that increased rainfall in the last few years may have increased the activity of both feral cats and dingoes at Cape Range (Figure 43). Increased effort may need to be implemented to manage the change in feral cat numbers. This might include increasing ground baiting effort particularly around sensitive populations, such as the black-flanked rock-wallaby and turtle nesting areas and increasing trapping or shooting programs.

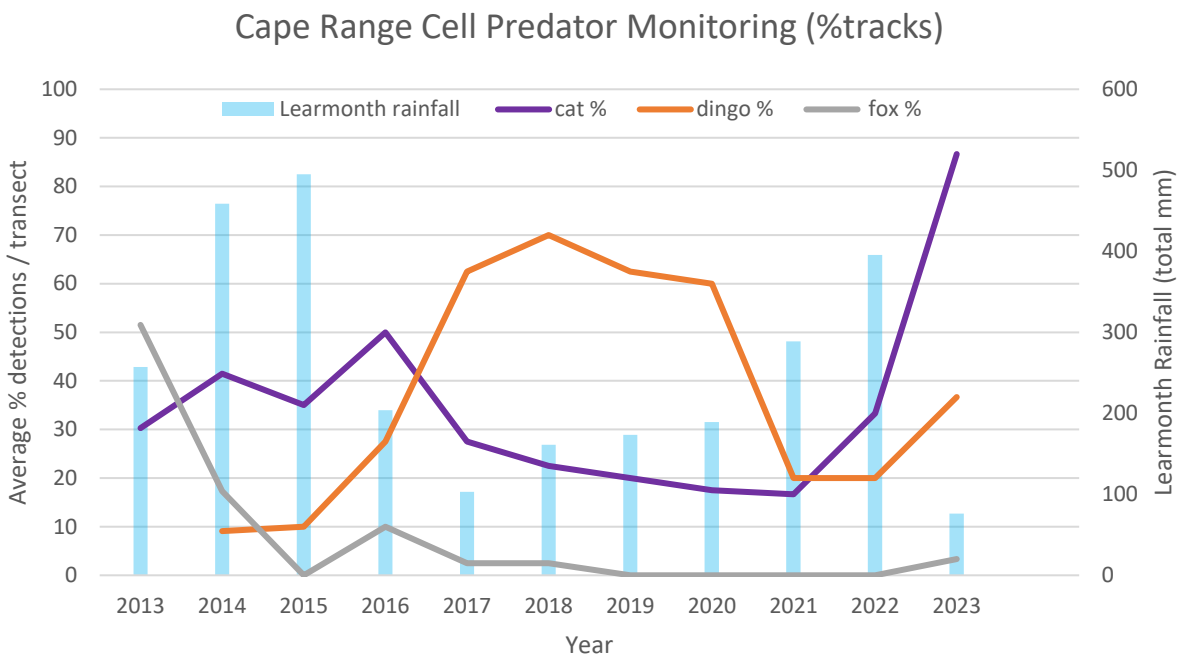

Figure 43: Average percentage activity of foxes, dingoes and feral cats using track counts relative to rainfall (BOM station: Learmonth) at Cape Range.

Adaptive management

Increased funding from Alcoa Foundation, the Forest Management Plan and Feral Cat Strategy, has enabled Western Shield to increase the level of fox and feral cat management across a substantial portion of the WS baiting footprint (Figure 44). Details of the change in prescriptions within each financial year are provided in Appendix 2 Table 8. This funding has also facilitated increased monitoring for chuditch and red-tailed phascogales, assisted with the roll out of implementing Western Shield monitoring at Jarrahdale and the monitoring at two reference sites (i.e. Stene and Dunn Rock) in 2023. Monitoring at these sites will assist in providing more complete information on the efficacy of different prescriptions in different ecosystems and facilitated improved adaptive management.

A review of the monitoring plan is scheduled to occur at the end of 2024. This will include a detailed analysis of the data collected to the end of 2024 including data from predator cameras and native species monitoring. Modelling will incorporate potential explanatory variables to improve our understanding of the drivers of fox and feral cat activity. This will provide insights on the effectiveness of our management and facilitate more targeted management. Modelling that incorporates the predictive impacts of varying baiting regimes is planned to be explored.

This review will also enable us to consider if sufficient data is being collected to assess the efficacy of current baiting prescriptions across all ecosystems and if the data collected is sufficient for effective adaptive management.

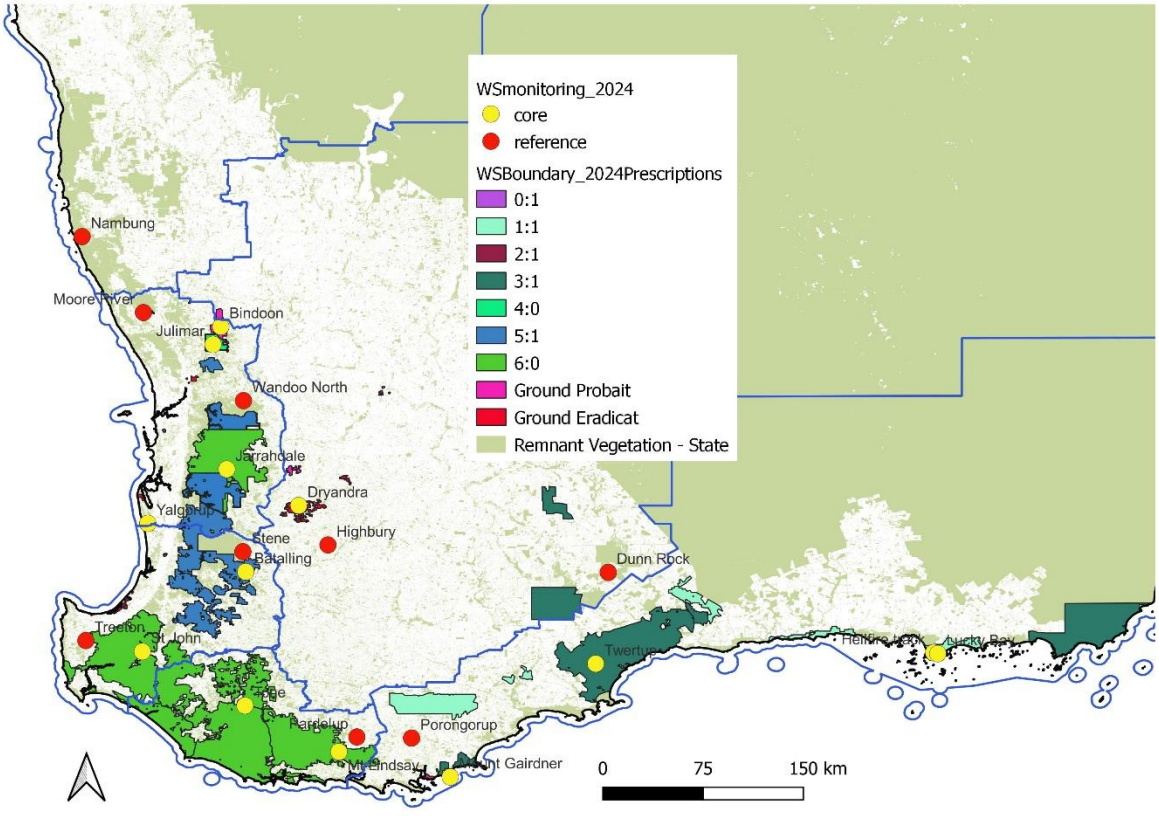

Figure 44: Western Shield core and reference monitoring sites adjusted to meet changes in predator management across the WS baiting footprint relative to 2023/2024 WS baiting prescriptions. Note that monitoring commenced at Dunn Rock (paired with Fitzgerald River National Park — Twertup), and Pardelup (paired with Mt Lindesay) in 2023.

Discussion

Feral predator baiting can have a substantial impact on feral predator activity (Thomson, et al 2000, Comer et al, 2020) and is one of the most cost-effective ways to manage feral predators across large areas of land. However, that impact can be short lived. Gwinn and Drew (unpublished) identified that feral cats could recover to pre-baiting levels within four months of baiting and foxes within 3 months on the Swan coastal plain. Doherty and Algar (2015), Comer et al (2020) and Doherty et al (2022) all identified that the efficacy of Eradicat® in reducing feral cat activity can be highly variable both between locations and between years at the same location (baiting cell). Baiting effectiveness can be influenced by multiple factors including the availability of alternative food sources, non-target uptake of baits, bait density and frequency, surrounding landscapes and/or by seasonal climatic conditions. High rainfall years can enhance ecosystem productivity including promoting recruitment and migration of feral predators and their food sources, whilst limiting the capacity to deliver both ground and aerial baits.

Frequency of baiting is important in environments with a high potential migration rate of feral predators (Gwinn and Drew, unpublish). Increasing the frequency of aerial baiting is a simple way to minimise feral predator migration and recruitment. However, as noted above the efficacy of baiting can be impacted by a range of ecological processes and current label requirements of Eradicat®, set by the Australian Pesticides and Veterinary Medicines Authority (APVMA), limit aerial delivery of baits to a single event per year.

Given the number of processes that can impact on the efficacy of feral predator baiting, feral predator management should be multifaceted to provide the best outcomes and may need to be modified to meet the changing requirements of an area. Supplementary ground baiting, trapping, shooting, neighbour engagement and Felixer® are all tools that should be considered as part of the management program. Implementation of a variety of control methods has been successful in providing exceptional levels of predator control in some locations and enabled the persistence of some of Western Australia's most vulnerable species (e.g. numbats and woylies at Dryandra Woodland National Park; and Gilbert's Potoroo, western ground parrot and other threatened species in reserves in the South Coast Region).

Camera and track monitoring conducted between 2021 to 2023 by Western Shield, districts and affiliated programs has indicated that feral cat activity, and in some instances fox activity, has increased substantially across multiple baiting cells. This has most likely been driven by high rainfall experienced in 2021. This is particularly evident, but not limited to, monitored sites in DBCA's Pilbara, Wheatbelt and South Coast regions. It is recommended that additional feral predator management actions be implemented where possible in these areas and consideration made to increase the capacity of additional feral predator mitigation strategies across the state.

Funding under the *Feral Cat Strategy 2023-2028* has enabled the integration of an annual aerial bait delivery of Eradicat® into the existing predator management programs in 2023/2024 at several sites in the DBCA's Wheatbelt and South Coast regions (see Appendix 2, Table 6). Funding under the *Forest Management Plan 2024-2033* has enabled an increase in the frequency of aerial delivery of Probait® to six times per year across much of the forested areas in the south-west of the state. Ground baiting programs including Eradicat® have also been implemented to provide more frequent protection to native species for a multitude of sites. However, in the 2022/2023 period, lack of access to ground baiting transects due to rainfall and/or lack of 1080 trained staff reduced ground baiting delivery to below the prescription at 29% of reported cells. With predator numbers increasing at many sites, lower frequency ground baiting represents a potential risk to multiple native species.

Consideration needs to be given to developing mitigation strategies to maximise feral predator management actions at all sites and improve conservation outcomes for threatened species long-term.

This risk assessment could consider alternative management options should weather, staffing issues or other factors prevent delivery of ground or aerial baits. This will also be a great opportunity to consider implementing additional long-term actions that can provide ongoing mitigation of the risks of feral predators to native species.

Ideally, risk assessments should be done for each baiting cell to ensure the most effective approaches for each area. However, at a minimum, an overarching risk assessment and action plan should be established at a district level to ensure mitigating strategies can be enacted in a timely manner to minimise any risks to sensitive native fauna.

Actions that could be used to mitigate risks include but are not limited to:

- Modify the timing of baiting to minimise the risk of rainfall interrupting delivery.
- Implement or expand neighbour engagement particularly in baiting areas that have a large and complex perimeter.
    - Engage with neighbours and encourage management of foxes and cats on their properties. This could include farm site carcass management, desexing of cats, trapping and shooting programs.
    - Management of rabbits.
- Increase the number of 1080 trained staff in regions to increase capacity to deliver ground baiting at the recommended frequency.
    - If availability of trained staff is a problem, please notify the Western Shield Operations Officer immediately — there may be capacity to provide a 1080 trained staff member to deliver ground baiting.
- If site conditions prevent ground bait deliveries, implement a trapping or shooting program in accessible areas, including the bait cell perimeter.
- Focus ground baiting around predator sensitive fauna populations.
- Implement a post-aerial baiting shooting and trapping program to remove foxes and feral cats as an ongoing management action.

Ideally, some or all these actions can become part of the long-term management plan for feral cats and foxes in each district where capacity allows.

Glossary

Activity: number of days where a species was detected on a camera in a month or number trap nights each month. The number of detections or trap nights is used as an indication of the level of activity of that species at the site.

Detection probability (p): derived from occupancy modelling and provides a metric of how likely you will detect a species if it is present at a site.

Occupancy (ψ): the probability of a species occurring within a site during the sampling session.

Occupancy Model: a model used to account for imperfect detection of a species in surveys and to predict the probability of the true presence or absence of a species at a site. This is done by quantifying the uncertainty in detection (detection probability) of a species at a site using the available data.

Appendix 1: Trap effort per site 2023

Cell/Area	Site_transect	# WS cages: trap nights	Elliotts: trap nights	Thomas traps: trap nights	# Predator cameras (trap nights)	Chuditch specific cages: #trap nights	Targeted camera monitoring (trap nights)	Comments/next monitoring session
Avon	Avon Valley	0	0	0		458	0	Research program (2022-2023) District cage trapping due 2025
Manjimup	Balban	0	0	0	0	240	0	
Lane Poole	Batalling	420	0	0	45 (11051)	365	0	Next scheduled 2024
Julimar	Bindoon	382	0	0	28 (TBC)	0	0	Cameras set on tethered baits stations. Scheduled 2024
Sunklands	Blackwood River	295	0	0	0	0	0	Scheduled 2026
Boranup	Boranup	173	0	0	0	0	0	Scheduled 2026
Boyagin	Boyagin East	167	0	0	0	0	0	Scheduled 2024
Boyagin	BoyaginWest	166	0	0	10930	0	0	Cameras: Project Numbat. Cages Scheduled 2024
Manjimup	Boyicup	168	0	0	0	0	0	Scheduled 2024
Burrup	Burrup	0	0	0	TBC	0	0	
Calvert Range	Calvert Range	0	0	0	Track counts	0	0	
Cape le Grand	Cape le Grand	0	0	0	6590	0	0	Scheduled 2025
Cape Range	Cape Range	0	0	0	67(4500) +track counts	0	0	BFRW:cameras and point counts
Wellington	Catterick	217	0	0	5015	481	0	Scheduled in 2024
Wellington	Centaur	217	0	0	0	444	0	Scheduled in 2024
Manjimup	Chariup	0	0	0	0	0	0	monitored every 3- 5 years
D'Entrecasteaux	Charley	0	0	0	0	0	10	linear cameras
Fitzgerald	Cocanarup	0	0	0	0	236	10 (51)	Scheduled in 2024
Manjimup	Corbal	0	0	0	0	378	0	District monitored every 3- 5 years. AWC completed chuditch monitoring 2023
Dragon Rocks	Dragon Rocks NR	0	0	0	49 (17000)	452	0	Chuditch monitoring scheduled 2024
Dryandra	Dryandra	254	0	0	30(TBC)	362	0	Chuditch monitoring conducted by AWC in 2023
Dunn Rock	Dunn Rock				30 (TBC)			Reference site, established in November 2023, Trapping scheduled 2024
Durba Hills	Durba Hills	0	0	?	26(TBC)	0	0	
Manjimup	Dwalgan	0	0	0	0	0	0	Monitored every 5 years

Cell/Area	Site_transect	# WS cages: trap nights	Elliotts: trap nights	Thomas traps: trap nights	# Predator cameras (trap nights)	Chuditch specific cages: #trap nights	Targeted camera monitoring (trap nights)	Comments/next monitoring session
Lane Poole	George	0	0	0	0	0	0	Monitored by district program, every 3 years
Wellington	Gervasse/Quokka swamp	142	0	100	0	0	0	Scheduled in 2024
Shannon	Gobblecannup	0	0	0	0	0	50 (TBC)	
Gundaring/Sales	Gundaring	165	0	0	0	0	0	Scheduled 2026
Helena Aurora	Helena Aurora	0	0	0	0	0	30 (TBC)	Chuditch cameras (30 cameras lured deployed in 2023)
Cape Le Grand	Hellfire track/Lucky Bay	163	0	0	22 (4194) to June2023	0	9 (2722)	
Perth Hills	Hills Forest	0	0	0	0	0	0	Part of Nearer to nature
Walpole	Hilltop	0	0	0	0	0	0	
Perth Hills	Hollyoak	0	0	0	0	0	0	quokka monitoring
Perth Hills	Jarrahdale	399	0	0	26 (836)	481	0	predator cameras BCS
Jaurdi	Jaurdi	0	0	0	0	0	0	No planned monitoring in 2023
Julimar	Julimar	378	0	0	1444	294	0	chuditch monitoring conducted by AWC
Kalbarri	Kalbarri NP	0	0	0	30 (TBC)0	0	0	BFRW due to be monitored in 2025
Denbarker	Lake Muir (Myalgelup)	0	0	0	0	0	0	
Nambung	Lancelin DTA	0	0	0	0	0	0	No longer monitored
Sunklands	Milyeannup	0	0	0	0	0	0	targeted quokka cameras not set in 2023
Fitzgerald	Moir Track	0	0	0	0	0	0	
Manjimup	Moopinup	175	0	0	15 (1652)	241	0	Predator cameras set by district, Scheduled for 2024
Moore River	Moore River NR	200	0	0	20 (3215)	0	0	Scheduled for 2024
Mt Caroline	Mt Caroline	0	0	0	0	0	0	Scheduled for 2024
Denbarker	Mt Lindesay	370	384	0	1672	0	10	
Mt Stirling	Mt Stirling	0	0	112	0	0	0	
Nambung	Nambung NP	200	0	0	30 (4695)	0	0	reference site
Nangeen	Nangeen	0	0	0	0	0	0	
Shannon	Nicol Rd	0	0	0	0	0	0	
Wellington	Noggerup	0	0	0	0	0	0	Scheduled 2024
Cape Arid	Paisley	0	0	0	0	0	0	

Cell/Area	Site_transect	# WS cages: trap nights	Elliotts: trap nights	Thomas traps: trap nights	# Predator cameras (trap nights)	Chuditch specific cages: #trap nights	Targeted camera monitoring (trap nights)	Comments/next monitoring session
Denmark SF	Pardelup	358	378	0	1558	0	0	reference site to commence 2023
Peak Charles	Peak Charles	0	0	0	0	0	0	No further plans to monitor this site
Peniup	Peniup NR	174	190	0	0	0	0	
Cape Arid	Poison Creek	247	129	0	0	0	0	
Porongorup	Porongorup	187	0	0	20 (2711)	0	0	Schedules for 2024
Ravensthorpe	Ravensthorpe	0	0	0	0	234	0	chuditch monitoring, funding dependent
Sunklands	St John	411	432	0	20 (3074)	0	0	Scheduled 2024
Gundaring/Sales	Sales	0	0	0	0	0	0	
Stene	Stene	380	0	0	45 (3773)	0	0	not baited, cameras removed for fires limited trap nights in 2023
Stirling	Stirling Range	0	0	0	0	0	0	
Shannon	Tone SF	181	0	0	15 (2631)	0	0	Scheduled 2024
Treeton SF	Treeton	0	0	0	20 (3380)	0	0	reference site, cage monitoring to commence 2024
Perth Hills	Tumlo	0	0	0	0	0	0	Quokka monitoring
Tutanning	Tutanning	0	0	0	30 (TBC)	0	0	Scheduled for WS trapping in 2025
Fitzgerald	Twertup	174	0	0	0	0	0	
Two Peoples Bay	Two Peoples Bay NR	103	0	0	15 (TBC)	0	0	
Walpole	Valley of the Giants	0	0	0	0	0	10 (TBC)	linear cameras (not lured)
Manjimup	Warrup	166	0	0	0	0	0	
Manypeak	Waychinicup	186	0	0	0	0	0	
Donnelly	Wheatley	0	0	0	0	0	50	
Perth Hills	Wandoo North	0	0	0	15 (1316)	0	0	
Shannon	Woolbales	0	0	0	0	0	0	
Yalgorup	Yalgorup	0	0	0	20	0	0	Schedules for 2024

Note the following sites have been removed: Alexander UCL – this was removed as it was not a feasible site

Appendix 2: Fox and Feral cat management in each Western Shield cell or area.

Table 4: Square kilometres subject to aerial baiting December 2022 to November 2023 in each Western Shield cell. Standard delivery of aerial Probait® is at a density of five Probait® per square kilometre/event while Eradicat® is delivered at 50 baits per square kilometre/event.

Region	Cell Name	Date aerial baiting commenced	Frequency aerial baiting /annum (2023/2024)	bait type	Dec 2022 - Feb 2023	2023 Mar-May	2023 Jun - Aug	2023 Sep-Nov	Total
SOUTH COAST	Angove	Nov-96	4	Probait	29.78	29.78	29.78	29.78	119.12
SWAN	Avon	Jun-99	6	Probait	102.47	204.94	102.47	204.94	614.82
SOUTH WEST	Boranup	Mar-05	6	Probait		64.81	64.81	129.62	259.24
PILBARA	Burrup	Oct-1997 (Probait) change to Eradicat Jun-2021	1	Eradicat®			23.34		23.34
GOLDFIELDS (PILBARA)	Calverts	Mar-03	1	Eradicat®			198.02		198.02
SOUTH COAST	Cape Arid	Mar-11 (2016)	1	Eradicat®		2021.69			2021.69
SOUTH COAST	Cape Arid	Dec-96	3	Probait	2021.69		2021.69	2021.69	6065.07
SOUTH COAST	Cape le Grand	Dec-96	2	Probait		290.15		290.15	580.30
PILBARA	Cape Range	Aug-14	1	Eradicat®			966.99		966.99
WHEATBELT	Corackerup	Apr-21	1	Eradicat®		28.59			28.59
WHEATBELT	Corackerup	Sep-96	1	Probait				28.59	28.59
WARREN	Denbarker	Nov-96	6	Probait	2095.41	2095.41		4190.82	8381.64
WARREN	D'entrecasteaux	Oct-97	6	Probait		738.92		1477.84	2216.76
WARREN	Donnelly	Oct-97	6	Probait		996.5		1993	2989.5
WHEATBELT	Dragon Rocks	Mar-23	1	Eradicat®		238.45			238.45
WHEATBELT	Dragon Rocks	May-96	3	Probait	238.45		238.45	238.45	715.35
PILBARA	Durba Hills	Jul-07	1	Eradicat®			288.81		288.81
SOUTH COAST	Fitzgerald	Drummond 2010, Twertup 2013, Moir 2013 + 2016 only	1	Eradicat®		1247.58			1247.58
SOUTH COAST	Fitzgerald	Oct-96	3	Probait	3597.01	2593.89	3597.01	3597.01	13384.92
PILBARA	Fortescue Marsh	Aug-12	1	Eradicat®			642.97		642.97
WARREN	Irwin	Dec-96	6	Probait		44.01		88.02	132.03
SWAN	Julimar	Jul-92	4	Probait	178.43	178.43	178.43	178.43	713.72
MIDWEST	Kalbarri	Nov-96	2	Probait		1662.44			1662.44

Region	Cell Name	Date aerial baiting commenced	Frequency aerial baiting /annum (2023/2024)	bait type	Dec 2022 - Feb 2023	2023 Mar-May	2023 Jun - Aug	2023 Sep-Nov	Total
MIDWEST	Kalbarri Eurardy	Kalbarri: Aug -16, Eurady 2023	1	Eradicat®			1841.09		1841.09
MIDWEST	Kalbarri Eurardy	Eurady 2023	2	Probait				1842	1842
WHEATBELT	Lake Magenta	May-96	3	Probait	946.5	946.5	946.5	946.5	3786
SWAN/SOUTH WEST	Lane Poole	Jun-Apr-94	5	Probait	1535.24	3070.48	1535.24	3070.48	9211.44
GOLDFIELDS	Matuwa	Jul-04		Eradicat®			2225.74		2225.74
WARREN	Manjimup	Nov-96		Probait	817.3	817.31	817.31	1634.62	4086.54
SOUTH COAST	Manypeaks	Feb-12	1	Eradicat®		107.05			107.05
SOUTH COAST	Manypeaks	Nov-96	3	Probait	107.05		107.05	107.05	321.15
SOUTH COAST	Peniup	Apr-21	1	Eradicat®		36.3			36.3
SOUTH COAST	Peniup	Sep-96	1	Probait				36.3	36.3
MIDWEST	Peron	Mar-02	1	Eradicat®			985.28		985.28
SWAN	Perth Hills	Apr-94	6	Probait	3246.96	6493.92	3246.96	6493.92	19481.76
SOUTH COAST	Ravensthorpe	Sep-97(?)	1	Probait		265.39		265.39	530.78
SOUTH WEST	Scott	Mar-98	6	Probait		8.37		16.74	25.11
WARREN	Shannon	Nov-96	6	Probait	2717.52	2717.52		5432.08	10867.12
SOUTH COAST	Stirlings Range (High)	Nov-96	1	Probait		283.02		283.02	566.04
SOUTH COAST	Stirlings Range (Low)	Nov-96	1	Probait		675.13		674.96	1350.09
SOUTH COAST	Stokes	Dec-96	1	Probait		189.7		189.7	379.4
SOUTH WEST	Sunklands	Jul-97	6	Probait		2467.83		4935.66	7403.49
SOUTH COAST	Two Peoples Bay	Feb-12	1	Eradicat®		30.1			30.1
SOUTH COAST	Two Peoples Bay	Nov-96	3	Probait	30.1		30.1	30.1	90.3
WARREN	Walpole	Dec-96	6	Probait		52.99		105.98	158.97
SOUTH WEST	Wellington	Apr-94 to Oct 96	5	Probait	823.98	1647.96	823.98	1647.96	4943.88

1. Lane Poole ext. cell extends across Perth Hills and Wellington Districts. The area defined here includes the area subject to baiting in both districts. 2. Sites that received additional Probait delivery as part of Alcoa Foundation sponsorship. Additional baits are deployed in spring and autumn increasing the area baited in those two seasons. 3. Increase from two annual aerial Probait deliveries to four annual Probait deliveries in response to a significant bushfire at Boranup in the summer of 2021/2022.

Table 5: Number of baits deployed for ground baiting in each treatment area July 2022 to June 2023. Ground delivery of Probait is one bait every 200 m of track while Eradicat is delivered at one bait per 100 m of track.

GB transect	District	Bait type	Planned frequency	2022 Jul	2022 Aug	2022 Sep	2022 Oct	2022 Nov	2022 Dec	2023 Jan	2023 Feb	2023 Mar	2023 Apr	2023 May	2023 Jun	2022/ 2023 Total
Avon	Perth Hills	Probait	4	258	0	0	239	0	0	237	0	216	239	0	0	1189
Avon	Perth Hills	Eradicat	4	0	0	0	0	0	0	0	0	0	0	476	0	476
Benger	Wellington	Probait	12	9	0	0	0	0	0	9	9	0	32	0	0	59
Bindoon	Perth Hills	Probait	8	251	0	150	172	225	0	214	204	0	249	0	465	1930
Boranup	Blackwood	Probait	12	231	165	225	204	226	222	225	207	222	230	223	219	2599
Buller NR	Swan	Probait		Not reported												
Cape Arid	Esperance	Eradicat	3	0	0	0	0	0	0	0	1350	0	0	0	0	1350
Cape Arid	Esperance	Probait	4	0	0	0	0	0	0	0	0	725	0	630	0	1355
Cape Le Grand	Esperance	Probait	4	0	0	0	0	0	0	0	0	0	0	443	0	443
Corackerup	Albany	Eradicat	5	0	0	0	0	0	0	0	0	501	0	480	0	981
Corackerup	Albany	Probait	7	0	175	0	0	0	234	247	244	0	250	0	0	1150
Creery Wetlands NR	Swan	Probait	8	Not reported												
Denbarker	Donnelly	Probait	4	0	0	332	0	0	0	362	0	0	362	0	314	1370
Denbarker	Frankland	Probait	4	0	0	0	73	73	0	73	0	73	0	73	0	365
D'Entrecasteaux	Donnelly	Probait	0	0	0	170	103	0	0	267	0	422	0	0	373	1335
Donnelly	Donnelly	Probait	0	0	0	635	0	0	0	665	0	667	0	0	547	2514
Ellen Brook NR	Swan	Probait	4	Not reported												
Fitzgerald River	Albany	Eradicat	1	0	0	184	0	0	0	0	0	800	0	0	0	984
Fitzgerald River	Albany	Probait	3	190	0	903	0	0	958	0	0	566	0	0	0	2617

GB transect	District	Bait type	Planned frequency	2022 Jul	2022 Aug	2022 Sep	2022 Oct	2022 Nov	2022 Dec	2023 Jan	2023 Feb	2023 Mar	2023 Apr	2023 May	2023 Jun	2022/ 2023 Total
Gull Rock	Albany	Probait	4	0	0	0	80	0	0	105	0	0	78	0	0	263
Irwin	Frankland	Probait	6	0	9	0	26	26	0	26	0	0	26	0	0	113
Julimar	Perth Hills	Probait	8	299	0	0	228	0	0	267	346	0	270	263	0	1673
Kalbarri	Midwest	Eradicat	3	0	5050	0	0	5000	0	0	0	0	5300	0	0	15350
Kalbarri	Midwest	Probait	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Lake McLarty NR	Swan	Probait		Not reported												
Lane Poole ext	Wellington	Probait	7	314	314	314	314	314	314	314	314	314	314	0	0	3140
Lane Poole ext	Wellington	Eradicat	5	0	0	0	0	0	0	0	0	0	0	0	600	600
Lane Poole*	Perth Hills	Probait	6	250	0	215	0	258	0	425	0	432	0	434	0	2014
Locke NR	Blackwood	Probait	12	13	8	7	6	8	18	27	29	29	0	27	22	194
Manjimup	Donnelly	Probait	12	670	600	1955	1508	600	1085	2378	600	2863	600	600	2823	16282
Manypeaks	Albany	Eradicat	5	700	0	924	0	0	0	0	0	700	700	0	0	3024
Manypeaks	Albany	Probait	7	0	248	0	0	355	355	277	400	0	0	355	0	1990
Mogumber NR / Lake Wannamal NR	Swan	Probait	12	0	0	0	0	0	0	0	0	0	0	58	0	58
Moore River NR	Swan	Probait	6	0	58	0	0	58	0	0	58	0	0	58	0	232
Muddy Lakes	Wellington	Probait	7	0	0	0	0	9	0	9	9	0	9	0	0	36
Nine Mile Lake NR	Swan	Probait		Not reported												
Peniup	Albany	Eradicat	5	0	0	500	0	0	0	0	0	544	0	520	0	1564
Peniup	Albany	Probait	7	140	129	0	0	0	275	273	278	0	275	0	0	1370
Perth Hills	Perth Hills	Probait	12	648	667	1549	1691	1261	1694	1693	2193	1192	794	1687	0	15069

GB transect	District	Bait type	Planned frequency	2022 Jul	2022 Aug	2022 Sep	2022 Oct	2022 Nov	2022 Dec	2023 Jan	2023 Feb	2023 Mar	2023 Apr	2023 May	2023 Jun	2022/ 2023 Total
Ravensthorpe	Albany	Probait	4	0	0	1041	0	0	1232	0	0	418	0	0	1135	3826
Scott NP	Blackwood	Probait	12	36	37	36	37	87	76	109	110	105	114	36	79	862
Shannon	Donnelly	Probait	4	0	0	1085	350	0	0	1413	0	1329	0	0	1037	5214
Shannon	Frankland	Probait	4	0	154	0	0	146	146	0	146	0	146	0	146	884
Stirling Range	Albany	Probait	4	2000	0	0	710	0	0	1985	0	0	1180	0	0	5875
Stokes	Esperance	Probait	4	429	0	478	0	0	0	625	0	0	0	702	0	2234
Sunklands	Blackwood	Probait	12	173	220	187	199	167	0	166	200	174	185	177	173	2021
Thomsons Lake NR	Swan	Probait	2	Not reported												
Tuart Forest	Blackwood	Probait	12	202	188	212	209	171	110	212	211	212	214	0	145	2086
Twin Swamps NR	Swan	Probait	4	Not reported												
Two Peoples Bay	Albany	Eradicat	5	0	0	370	294	0	0	0	0	0	0	0	0	664
Two Peoples Bay	Albany	Probait	7	185	169	61	0	143	185	0	0	0	0	0	0	743
Walpole	Frankland	Probait	6	516	0	121	0	256	0	256	0	256	0	121	0	1526
Walyunga	Perth Hills	Probait	9	103	0	0	0	156	0	156	140	11	147	136	0	849
Water Corp Angove	Albany	Probait	4	0	0	0	200	0	0	200	0	0	200	0	0	600
Wellington	Wellington	Probait	7	200	200	200	65	110	430	235	235	235	208	0	0	2118
Wellington	Wellington	Eradicat	5	0	0	0	0	0	0	0	0	0	0	0	350	350
Yalgorup NP	Swan	Probait	6	Not reported												

Table 6: Summary of changes in fox and feral cat baiting prescriptions from 2021 to 2024. Prescriptions Aerial Probait: Aerial Eradicat: Ground Probait: Ground Eradicat

Site	FY: 2021-2022	2022-2023	2023-2024
Angove Water Reserve	4:0:4:0	4:0:4:0	4:0:4:0
Avon	4:0:8:0	6:0:4:4	5:1:4:4
Batemans Bay	0:0:3:3	0:0:3:3	0:0:3:3
Benger Swamp Nature Reserve	0:0:12:0	0:0:12:0	0:0:12:0
Bindoon	0:0:8:0	0:0:8:0	0:0:4:4
Boddington	4:0:0:0	4:0:0:0	6:0:0:0
Boranup	2:0:12:0	2:0:12:0	6:0:7:5
Boyagin	0:0:12:0	0:0:12:0	0:0:12:0
Burrup	1:1:3:2	1:1:3:2	1:1:3:2
Calvert Range	0:1:0:2	0:1:0:2	0:1:0:2
Cape Arid	3:1:4:3	3:1:4:3	3:1:4:3
Cape Le Grand	2:0:4:0	2:0:4:0	1:1:4:4
Cape Range	0:1:0:6	0:1:0:6	0:1:0:6
Corackerup	1:1:7:5	1:1:7:5	1:1:7:5
Creery Wetlands & Channel Island Nature Reserves	0:0:8:0	0:0:8:0	0:0:8:0
Denbarker	3:0:4:0	3:0:4:0	6:0:2:2
D'Entrecasteaux	2:0:0:0	2:0:0:0	6:0:0:0
Donnelly	2:0:0:0	2:0:0:0	6:0:0:0
Dragon Rocks	2:0:8:0	3:1:4:4	3:1:4:4
Dryandra	0:0:7:5	0:0:7:5	0:0:7:5
Durba Hills	0:1:0:0	0:1:0:0	0:1:0:0
Ellenbrook	0:0:4:0	0:0:4:0	0:0:4:0
Fitzgerald	4:1:3:1	3:1:3:1	3:1:2:2
Five Mile Beach	0:0:3:3	0:0:3:3	0:0:0:0
Fortescue Marsh	0:1:0:1	0:1:0:1	0:1:0:1
Garden Island	0:0:0:0	0:0:0:0	0:0:8:0
Gull Rock	0:0:4:0	0:0:4:0	0:0:4:0
Gundaring Nature Reserve	0:0:26:0	0:0:26:0	0:0:26:0
Harold Holt	0:0:3:3	0:0:0:0	0:0:3:3
Irwin	2:6:0:0	2:0:6:0	6:0:3:3
Jane's Bay	0:0:3:3	0:0:3:3	0:0:3:3
Julimar	4:0:8:0	4:0:8:0	4:0:8:0
Kalbarri	2:1:1:3	2:1:1:3	2:1:1:3
Eurardy	0:0:0:0	0:0:0:0	2:1:0:0
Lake Magenta	4:0:4:0	4:0:4:0	3:1:2:2
Lane Poole	4:0:12:0	6:0:7:5	5:1:7:5
Locke Nature Reserve	0:0:12:0	0:0:12:0	0:0:7:5
Matuwa Kurrara Kurrara (formerly Lorna Glen)	0:1:0:2	0:1:0:2	0:1:0:2
Manjimup	4:0:12:0	4:0:12:0	6:0:7:5
Manypeaks	3:1:7:5	3:1:7:5	3:1:7:5
Mogumber Nature Reserve	0:0:12:0	0:0:12:0	0:0:12:0
Moore River National Park	0:0:0:0	0:0:0:0	0:0:0:0
Moore River Nature Reserve	0:0:12:0	0:0:12:0	0:0:12:0

Site	FY: 2021-2022	2022-2023	2023-2024
Mt Caroline Nature Reserve	0:0:26:0	0:0:26:0	0:0:26:0
Mt Stirling Nature Reserve	0:0:26:0	0:0:26:0	0:0:26:0
Nambung	0:0:0:0	0:0:0:0	0:0:0:0
Nangeen Hill Nature Reserve	0:0:26:0	0:0:26:0	0:0:26:0
Peniup	1:1:7:5	1:1:7:5	1:1:7:5
Peron	0:1:0:5	0:1:0:5	0:1:0:5
Perth Hills*(1773 km^2)	4:0:12:0	6:0:7:5	6:0:7:5
Perth Hills Cat (1475 km^2)	4:0:12:0	6:0:7:5	5:1:7:5
Ravensthorpe Range	2:0:4:0	2:0:4:0	1:1:2:2
Sales Rock	0:0:26:0	0:0:26:0	0:0:26:0
Scott	2:0:12:0	2:0:12:0	6:0:7:5
Shannon	3:0:4:0	3:0:4:0	6:0:2:2
Stirlings	2:0:4:0	2:0:4:0	1:1:2:2
Stokes	2:0:4:0	2:0:4:0	1:1:2:2
Sunklands	2:0:12:0	2:0:12:0	6:0:7:5
Thomson's Lake Nature Reserve	0:0:2:0	0:0:2:0	0:0:2:0
Tuart Forest	0:0:12:0	0:0:12:0	0:0:7:5
Tutanning Nature Reserve	0:0:12:2	0:0:12:2	0:0:12:2
Twin Swamps Nature Reserve	0:0:4:0	0:0:4:0	0:0:4:0
Two Peoples Bay	3:1:7:5	3:1:7:5	3:1:7:5
Walpole	2:0:6:0	2:0:6:0	6:0:4:2
Wellington	4:0:12:0	6:0:7:5	5:1:7:5
Yalgorup National Park	0:0:6:0	0:0:6:0	0:0:4:2
Walyunga (south)	0:0:9:0	0:0:9:0	0:0:4:0
Walyunga (north)	0:0:12:0	0:0:12:0	0:0:7:0

* A portion of the cell is subject to Eradicat as a trial in autumn 2024.

Appendix 3: Occupancy modelling

Methods

Occupancy modelling (i.e. presence/absence) using the unmarked program (Fiske and Chandler 2011) in R (R Core Team 2020) was used to model long term trends for the four primary Western Shield species across 43 of the most frequently monitored sites (cage monitoring only) in the period 1992 to 2023.

Noongar seasons were used to delineate the primary periods. However, surveys were not always conducted at consistent times during the year and as a result, there was considerable variability in whether a site was monitored in any one of the six Noongar seasons in any given calendar year. Based upon the monitoring regime, we were able to model two primary periods for each site within each calendar year. However, the season of monitoring varied from one site to another and from one calendar year to another. Each site was repeat (or secondary) surveyed over a maximum of four days (max n = 43, average n = 31.5); noting that we were comfortable assuming that the occupancy status did not change over the secondary survey period.

The unmarked single species multi-season modelling function (colext) was applied with the initial occupancy parameter modelled without a covariate. The colonisation and extinction parameters were allowed to vary as a function of primary period and the detection parameter was modelled as a function of the approximated Noongar season (i.e., Birak, Bunuru, Djeran, Makuru, Djilba, Kambarang[7]). Our logic was that detection status was most likely to be driven by the actual season whereas occupancy was most likely to be driven by other factors (such as initial occupancy, management treatment, etc). We only used a small number of well justified biologically sensible covariates and as such, did not utilise any model comparison approaches (Royle et al. 2014).

The 'goodness-of-fit' of each model was assessed with the generic parametric bootstrapping function 'parboot' in unmarked as described by Fiske and Chandler (2011). Graphs were generated with ggplot2 (Wickham 2016).

Sites included in analyses

Avon Valley, Balban, Batalling, Bindoon, Blackwood River, Boranup, Boyagin EAST, Boyagin WEST, Boyicup, Camelar, Cape Arid, Cape Le Grand, Catterick, Centaur, Corackerup, Drummond Track, Dryandra, Dwalgan, George Block, Gervasse, Julimar, Lake Magenta, Lake Muir, Milyeannup, Moir Track, Moopinup, Mount Gairdner, Mt Lindesay, Nicol Rd, Noggerup, Peniup, Porongorup, St John, Stirling Range, Tone, Tutanning, Twertup, Valley of the Giants, Warrup, Waychinicup, Wellington National Park, Woolbales, Yalgorup

[7] Noongar seasons are defined by weather patterns and ecological changes and hence are not specifically defined by the Gregorian calendar, however for the purposes of detection modelling they were defined by: Birak = Dec-Jan; Bunuru = Feb-Mar; Djeran = Apr-May; Makuru =Jun-Jul; Djilba =Aug-Sep; Kambarang = Oct-Nov (https://www.noongarculture.org.au/food/).

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