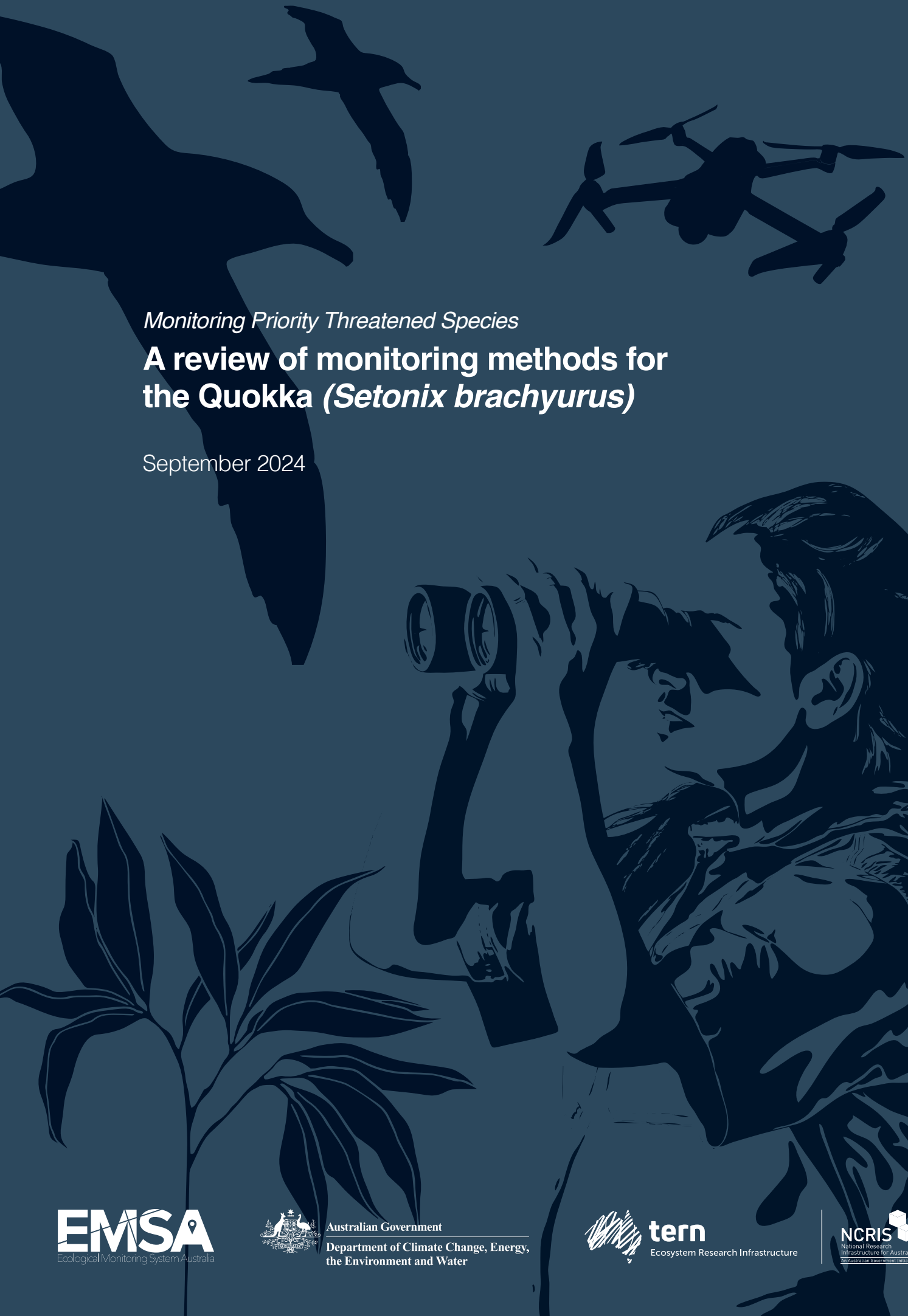

Monitoring Priority Threatened Species

A review of monitoring methods for the Quokka *(Setonix brachyurus)*

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We acknowledge the Traditional Custodians of Australia and their continuing connection to land and sea, waters, environment and community. We pay our respects to the Traditional Custodians of the lands we live and work on, their culture, and their Elders past and present.

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About

This literature review collates information on one of the 110 priority threatened species identified in the *Threatened Species Action Plan 2022-2032* and has been reviewed by invited practitioners experienced in monitoring the species.

The *Survey Guidelines for Monitoring Threatened Species* project, a collaboration of the Department of Climate Change, Energy, the Environment, and Water (DCCEEW) and the Terrestrial Ecosystem Research Network (TERN), aims to improve our knowledge of threatened species by enhancing accessibility and sharing of quality scientific threatened species data. By developing best practice field survey guidelines and recommendations, practitioners will be better equipped to conduct standardised, repeatable surveys.

By identifying the monitoring methods typically implemented by practitioners, documenting and assessing the techniques known to work, and identifying opportunities to standardise the methods, we can move towards ensuring all monitoring is species-appropriate, comparable between practitioners and populations, and repeatable over time. Further, together with consistent terminology, guidelines, instructions, and data collection, we can refine efforts and resources to measure and share information. Data collected using robust, standardised methods will improve our knowledge of threatened species and underpin threatened species recovery at scale. This project is essential to establishing monitoring protocols and data repositories to enhance the accessibility and sharing of threatened species data.

TERN has prepared the literature reviews for the Department of Climate Change, Energy, the Environment, and Water. For further information, please visit the EMSA Threatened Species Survey Guidelines website. Additional information, particularly monitoring methods and techniques not included that should be considered, can be brought to the author's attention by emailing tern@adelaide.edu.au for consideration for future updates.

Contents

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1 Background

1.1 Species name

The Quokka *(Setonix brachyurus)* (Quoy and Gaimard, 1830) is known to the Aboriginal Noonga people of south-west Western Australia by a range of names, including *Ban-gup*, *Bungeup*, *Quak-a*, *Kwoka* and *Bangop* (DEC 2013).

1.2 Conservation status

The Quokka is listed as Vulnerable under the *Environmental Protection and Biodiversity Conservation Act 1999* (Cth). The International Union for Conservation of Nature's (IUCN) Red List of threatened species, lists the species as Vulnerable, citing a small area of occupancy and a small and fragmented population that is continuing to decline(Burbidge & Woinarski 2020). Table 1 identifies the species conservation status under Commonwealth, state, and IUCN listings.

Table 1. National, international and state conservation status for the Quokka.

Jurisdiction	Conservation status	Legislation
Commonwealth	Vulnerable	*Environment Protection and Biodiversity Conservation Act 1999*
Western Australia	Vulnerable	*Biodiversity Conservation Act 2016*
IUCN	Vulnerable	IUCN Red List of Threatened Species

1.3 Summary of data held in the Threatened Species Index

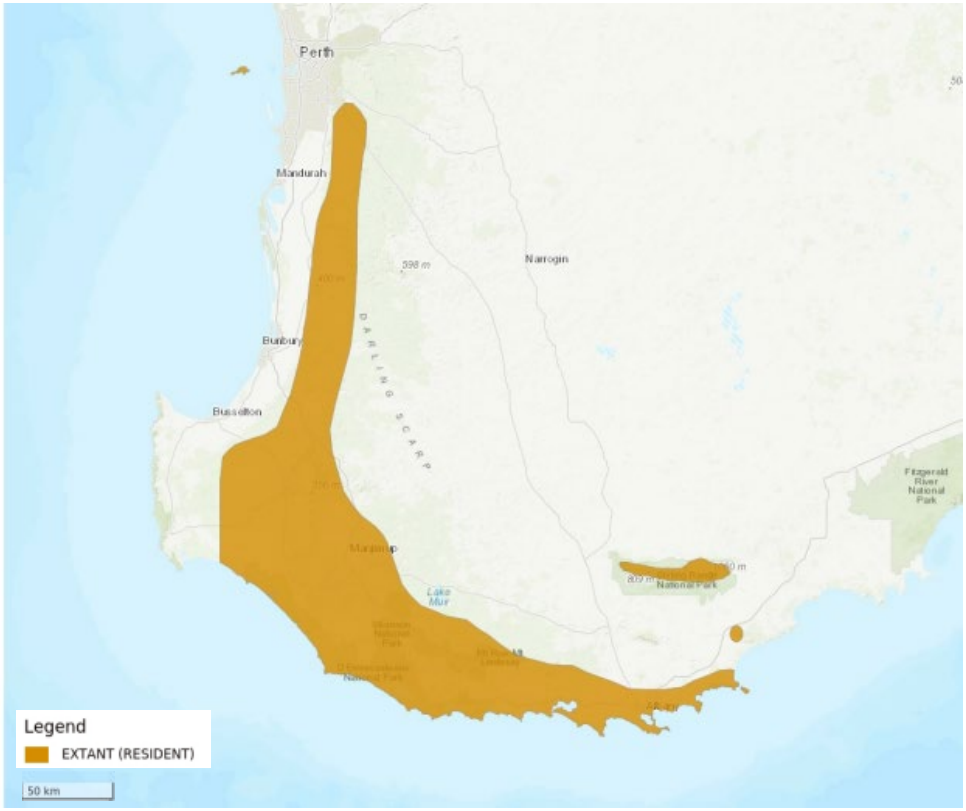
The Threatened Species Index (TSX) provides reliable and robust measures of change in the relative abundance of Australia's threatened and near-threatened species at national, state and regional levels. Understanding these changes in species populations is crucial for monitoring Australia's conservation progress and allows users to measure and report on the benefits of conservation investments, and to justify and design targeted management responses. Currently, the index is restricted to birds, plants and mammals, with new groups to be added in the near future.

The TSX does not hold data on the Quokka. More information on the TSX, including how to contribute threatened species monitoring data to the index, can be found on the TSX website.

1.4 Distribution and abundance

The Quokka is a small wallaby species endemic to the south-west of Western Australia. Before European settlement, the Quokka had a distribution from Jurien Bay (~200 km north of Perth) to the Hunter River (~200 km east of Albany), covering approximately 41,200 km^2 (de Tores et al. 2007), where the species was widespread and abundant throughout its range (de Tores et al. 2007; DEC 2013). A significant population decline occurred in the 1930s (DEC 2013) with the introduction of the Red Fox (*Vulpes vulpes*) to the region. In 1933, the Quokka were declared vermin (Government Gazzette of Western Australia 1933) and regularly hunted and poisoned (Prince 1984; Ride 1970). Since then, continued predation, habitat destruction and modification via altered fire regimes have significantly reduced their range and abundance (de Tores et al. 2007; DEC 2004; Hayward 2002). Their distribution is now estimated to have been reduced to an area of approximately 17,800 km^2 (de Tores et al. 2007) (Figure 1.).

Figure 1. Distribution of Quokka in the south-western Western Australia



Source: IUCN (International Union for Conservation of Nature)

Quokka populations on the mainland persist in the northern Jarrah Forest region, between Perth and Collie (Dundas et al. 2018; Hayward et al. 2003), the Muddy Lakes area on the Swan Coastal Plain (Sinclair & Hyder 2009), the southern Jarrah-Karri Forests between Nannup and Denmark, and in reserves on the south coast such as Torndirrup National Park, Two Peoples Bay Nature Reserve, and the Stirling Range National Park (de Tores et al. 2007; Sinclair & Hyder 2009; Spencer et al. 2019). Their distribution can be patchy and discontinuous (de Tores et al. 2007), with a number of sub-populations occurring within these locations (Sinclair 2001; Spencer et al. 2019). There are also two significant island populations of Quokka from which they are best known - Rottnest Island (20 km west of Perth) and Bald Island (east of Albany).

Rottnest Island is considered the population stronghold, with numbers that peak around 1200 during the breeding season but then decline in the summer (Phillips 2016). Recent population monitoring has not occurred for the Bald Island population, however, previous records suggest a significant population of 200-600 individuals (Main & Yadav 1971). On the mainland in the northern Jarrah Forests region, sub-populations range between 5-36 adults (Dundas et al. 2018; Hayward et al. 2003), and, in 2003, it was estimated that the total population in the region may be as few as 150 individuals (Hayward et al. 2003). Such small populations without genetic mixing are vulnerable to genetic problems such as inbreeding and loss of heterozygosity (Caughley 1994). Other mainland populations have not been surveyed for their abundance specifically, and there is no indication that any mainland populations persist in numbers greater than 50 (DEC 2013). Extrapolating population dynamics from island populations to mainland populations would be inappropriate as the two areas have vast environmental and ecological differences (Hayward 2002).

1.5 Habitat requirements

The Quokka's range is naturally limited by climate, particularly rainfall (de Tores et al. 2007). Mainland populations are restricted to dense riparian vegetation in high rainfall zones (Bain 2015; de Tores et al. 2007; Gibson et al. 2010) that receive more than 600-1000 mm annual rainfall (de Tores et al. 2007).

Quokkas are found in various vegetation types, from heathlands to shrublands on both the mainland and on Rottnest and Bald Island (Storr 1963a, 1963b, 1965). They require habitat that provides a mosaic of vegetation in different seral stages from young vegetation to long unburnt (Bain 2015; Hayward et al. 2005b), however, the understanding of habitat features that are critical to their survival is variable across their range.

In the northern Jarrah Forests, their habitat is primarily *Taxandria linearifolia* swamp shrublands (Hayward et al. 2005b), and they prefer the broad, flat upper reaches of creek systems with understorey that is sufficiently thick and complex to provide refuge from predation (Hayward et al. 2003). Quokkas consume new growth of plants in a habitat that has been recently (within 10 years) burnt (Bain 2015; Dundas et al. 2018; Hayward 2005) and is in the early seral stages of succession. In the northern Jarrah Forests, habitat preference are driven by time since fire, adjacent vegetation age (>25 years) and the presence of predators (Hayward 2005). In the southern Forests, Quokkas occupy a more diverse range of forest and wetland habitats (Bain 2015; de Tores et al. 2007) with permanent water. In the south, they most commonly occupy they occupy Jarrah (*Eucalyptus marginata*), Marri (*Corymbia calophylla*), Karri (*E. diversicolor*) or Tingle (*E. jacksonii* or *E. guilfoylei*) forests and riparian habitats with a sedge dominated understorey. In this area Quokkas occupy habitat where the vegetation is more complex than in the northern extent of their range, and they choose areas based on vegetation complexity, the presence of woody debris and habitat patchiness (Bain 2015).

The species naturally exists in small meta-populations (Hayward et al. 2003). When the vegetation structure matures and opens up in a functioning meta-population, the population will migrate to new, younger habitat patches. Individuals will occasionally mate with Quokkas in adjacent populations, providing genetic mixing (Hanski & Gilpin 2008; Hayward et al. 2003). In the northern Jarrah Forests, these populations do not mix and are in a state of collapse (Hayward et al. 2003). In the southern Forests populations, greater habitat connectivity allows Quokkas to move more freely between habitat patches, creating a functioning metapopulation (Bain 2015).

Specific information regarding critical habitat in other sub-populations such as those on Rottnest and Bald Islands has not been documented (DEC 2013).

1.6 Biology and Ecology

The Quokka is a medium sized (Hayward et al. 2003; Kitchener 1995) macropodid marsupial. They are sexually dimorphic (Dunnet 1962; Sinclair 1998), with adult males weighing an average of 3.7 kg with an average head-body length of 487 mm, which is significantly larger than that of females, which weigh an average of 2.7 kg and have an average head-body of 468 mm (Dundas et al. 2018; Hayward 2002).

Female Quokkas are polyestrous (they ovulate more than once in each breeding season) and may breed throughout the year with a gestation period of 27 days (Sharman 1955a). Quokkas also undergo embryotic diapause, allowing them to suspend the development of an embryo temporarily. If the first pouch young dies, the second embryo will resume development and be born 24-27 days later (Sharman 1955b). At birth, quokkas weigh around 0.4 g. They leave the pouch between 175 and 195 days old, and maturity is reached at around 389 days in males and 254 days in females (Sharman 1955a, 1955b; Shield & Woolley 1960). Juveniles will then begin breeding at about one year to 18 months old (Shield 1968). They can live up to 14 years in captivity and more than 10 years in the wild (DEC 2013).

The ecology and behaviour of Quokkas have been extensively studied for the Rottnest Island population (Bakker & Main 1980; Dunnet 1962; Phillips 2016; Sinclair 1998; Storr 1963a, 1963b).

However, there is no rationale for extrapolating many of these factors to mainland populations (Hayward 2002). On Rottnest and Bald Islands, breeding occurs only once per year, and most young are born between mid-February and the end of April (Shield 1968), whereas on the mainland, Quokkas breed throughout the year (Hayward et al. 2003).

Quokkas are mostly nocturnal and primarily herbivorous browsers. They consume mostly leaves and stems (Hayward et al. 2005b). On Rottnest Island, however, they show omnivorous feeding habits, consuming food scavenged from tourists (Phillips 2016). They have also been recorded feeding on small reptiles, such as the legless lizard (*Lialis burtonis*), molluscs and introduced snail (*Helix pisana*) (Phillips 2016). It has been suggested that this behaviour may occur in response to inadequate food availability, particularly during summer (Erickson 1951; Phillips 2016). In the northern Jarrah Forests there appears to be seasonal and between site variation in dietary intake (Hayward et al. 2005b), and localised extinctions in this region have been attributed to reduced dietary diversity and lack of availability of recently burnt habitat to provide for the Quokka's dietary needs (DEC 2013).

Quokkas, like some other macropods, can store fat in their tails to cope with seasonal food availability (Bakker & Main 1980; Hayward 2002; Sinclair 1998). Tail circumference can be used to indicate the condition of a Quokka during monitoring.

1.7 Threats

Threatening processes for this species include predation by the introduced Red Fox (*Vulpes vulpes*) and the Feral Cat (*Felis catus*), habitat destruction, habitat modification via altered fire regimes and roadkill. This species is also impacted by phytophthora dieback within their habitat, altered hydrological regimes, climate change and disease (de Tores et al. 2007; DEC 2013; Hayward 2002).

Since introducing foxes to the south-west of Western Australia, they have been considered the major cause for the decline of Quokka populations on the mainland (de Tores et al. 2007; DEC 2013). The construction of roads throughout Western Australia's south-west has facilitated Red Fox dispersal throughout the Quokka's range. Quokkas have been documented expelling pouch young when pursued by predators, a survival mechanism that can negatively affect population growth in the long term (Hayward et al. 2005a).

Mainland populations are limited to areas with an average rainfall of greater than 600 mm, and it is suggested that this reflects the Quokka's relatively high water requirements (Main & Yadav 1971). This means Quokka populations may be susceptible to decline caused by changes in drying climate conditions. On Rottnest Island, the population has limited permanent water availability and suffers significant seasonal mortality over the summer, attributed indirectly to dehydration (Barker 1961; de Tores et al. 2007; Storr 1963a). Due to lower population sizes, mainland populations do not have the resilience to withstand this kind of mortality with increasing aridity.

2 Existing monitoring

2.1 Overview of monitoring methods

In mainland populations, Quokkas are considered a 'cryptic macropod' (Bain et al. 2014) and experience trap-shyness (Hayward et al. 2003). Rapid sign-based surveys of appropriate habitat are often conducted in the lead-up to more intensive monitoring to inform where efforts should be concentrated (Bain et al. 2014; Sinclair & Hyder 2009). Indicators of presence in these surveys include:

- scats (Quokka or predators such as the red fox)
- runnels (tracks or tunnels in the thick undergrowth that form from repeated use by Quokkas)
- hair
- skeletal remains
- tracks.

Monitoring for the Quokka commonly focuses on:

- occurrence
- population abundance
- range
- habitat condition monitoring.

2.2 Monitoring resources

Key resources with information for monitoring the Quokka include:

- *Quokka (Setonix brachyurus) Recovery Plan* (DEC 2013)
  - Long-term objective to at least maintain the current distribution and abundance with existing conservation measures including:
    - adoption of a rapid assessment technique to assess sites for signs of Quokka presence (Bain et al. 2014).
  - Recovery Actions include:
    - developing protocols for monitoring, reporting and detecting new Quokka occurrences.
    - identify and establish key sites for routine monitoring to investigate population demographics and genetics of the Quokka's geographic range.
- *Population Monitoring of an endemic macropod, the Quokka (Setonix brachyurus) in the northern jarrah forest Western Australia* (Dundas et al. 2018):
  - discusses the need for standardised methods for comparative population studies across species range.
  - documents trapping protocols used for annual monitoring in the Northern Jarrah Forests region.
  - includes six nights of pre-feeding before trapping.
  - Includes (?) adapted protocols to reduce stress on frequently captured animals, particularly mothers with non-captured joeys on foot.
  - outlines standard measurements taken in trapping surveys.

- *Survey Guidelines for Australia's threatened mammals*; Guidelines for detecting mammals listed as threatened under the Environmental Protection and Biodiversity Conservation Act 1999 (DSEWPC 2011)
  - provides guidelines for survey methods to detect the presence of threatened mammal species (does not offer survey guidelines to assess abundance).
  - prescribes method guides based on mammals of similar bodyweight and habit.
  - survey effort is not specific to each species, but a generalised methodology is provided for each mammal group.
  - recommends the following survey techniques for detection of the Quokka in areas up to 5 ha:
    - daytime searches for signs of activity including 'runnels', tracks and scats.
    - daytime searches for presence in areas up to 5 ha that should be implemented before live trapping.
    - genetic analysis may be necessary to identify and distinguish between species' scats.
- *Overcoming the challenges of measuring the abundance of a cryptic macropoda: is a qualitive approach good enough* (Bain et al. 2014):
  - looks at conventional methods for population estimation to calibrate a rapid survey technique for the Quokka.
  - Identifies rapid survey techniques to be effective at determining presence of quokkas but result in an over estimation of population size because of inaccurate assumptions about occupancy and relative abundance of animals.
  - Identifies an alternative survey method based on fresh fecal pellets that provides a reliable and practical measure of population abundance.
  - outlines mark-recapture techniques and faecal pellet count techniques.

2.3 Survey methods

2.3.1 Sign-based surveys

Sign-based searches are often conducted before trapping to determine the presence of Quokkas in an area and to inform where trapping efforts should be concentrated (Bain et al. 2014; Sinclair & Hyder 2009). Searches are focussed on 'runnels' – tracks or tunnels in the thick undergrowth that form from Quokkas' repeated use. Skeletal material and hair also collected as signs of presence (Sinclair & Hyder 2009); however, scats and sand pads were the most common signs used to detect Quokka presence. Table 2 summarises sign-based survey methods typically used for monitoring Quokkas.

Faecal pellet counts

Indirect methods such as faecal pellet counts can be practical and reliable techniques for estimating population abundance (Bain et al. 2014) and have been used extensively used to study the relative or actual abundance of a wide range of small to medium-sized mammalian species (Allen et al. 1996; Buckland et al. 2001; Hayward et al. 2003; Johnson & Jarman 1987) including macropodids such as the Swamp Wallaby (Floyd 1980), Red Necked Pademelon (Vernes 1999), the Parma Wallaby (Read & Fox 1991), the Red Necked Wallaby and the Eastern Grey Kangaroo (Johnson & Jarman 1987). Faecal pellet counts are a rapid and inexpensive survey option, and for this species take less than 10% of the time of trap-based mark-recapture surveys (Bain et al. 2014).

Scat identification can be difficult when multiple macropodid species are present (Hayward et al. 2005c; Sinclair & Hyder 2009) however, scat counts can be combined with species confirmation via

DNA analysis (Alacs et al. 2003; Sinclair & Hyder 2009) to provide confidence in findings. Other small to medium-sized macropodids in the same region as Quokkas, with similar, difficult-to-differentiate scats, include the Western Brush Wallaby, the Tamar Wallaby, the Woylie and the Western Grey Kangaroo (DSEWPC 2011). Scats should be collected within a day of deposit to be viable for DNA analysis. Red Fox scats may also be collected and analysed to determine if Quokka is being preyed upon as an indicator of presence (Sinclair & Hyder 2009). Lack of scat detection and variation in pellet deposition and decay are potential sources of error using faecal pellet counts a tool to estimate abundance (Buckland et al. 2001; Bulinski & McArthur 2000; Hayward et al. 2005c; Read & Fox 1991).

Advantages of faecal pellet count over mark-recapture methods for estimators of population size include: reduced labour intensity, cost-effectiveness, they can be used for rapid assessment over large areas, and they cause minimal disturbance or injury to animals that is often associated with trapping (Hayward et al. 2005c).

Sand Pads

Tracks can be an unreliable indicator of Quokkas presence because they are often undetectable due to dense vegetation and lack of exposed suitable substrate (Bain et al. 2014) within their habitat. Strategic placement of sand pads within runnels, introducing sand (rather than raking the existing substrate) with or without bait (Mawson & Orell 2001) may overcome this substrate limitation. Introduced sand must be used with caution as it has the potential to introduce the plant pathogen *Phytopthora cinnamonmi* (Bain et al. 2014) and must be treated before being introduced to a site.

Table 2. Methods overview of key studies using sign-based surveys.

Survey type	Study design	Survey effort	Location	Reference
Faecal pellet count	▪ On ground searches concentrated on runnels. ▪ Fresh scats identified (three pellets at a time, soft and greenish in colour). ▪ DNA analysis using RT-PCR methods to confirm ▪ European fox scat was also collected and analysed to determine if Quokka was being preyed upon. ▪ Skeletal remains and carcasses were also collected during these searches	▪ Three separate visits between February and March	Muddy Lakes wetland and adjacent area	(Sinclair & Hyder 2009)
Sand pads	▪ Small pads (~0.5 x 0.5 m) at the vicinity of two runway exits ▪ Larger pads (~2 x 1 m) on vehicle access track	▪ Monitored and refreshed every morning between 14-19 March 2008 ▪ No Quokka tracks identified	Muddy Lakes wetland and adjacent area	(Sinclair & Hyder 2009)
Faecal pellet count	▪ Transects 30-50 m from swamp edge to centre of swamp ▪ Searched runnels within transects for scats. ▪ Only pellets in the immediate vicinity of the observer were counted ▪ Only fresh pellets counted ▪ The same observer undertook all transects	▪ Conducted in mid-late winter ▪ Nine sites ▪ Minimum of ten transects per site ▪ Eight sites surveyed with areas between 2.6 and 15.3 ha (average = 9.3 ha)	Northern half of the Jarrah forest biogeographical zone of south western Australia	(Hayward et al. 2005c)
Faecal pellet count	▪ Liddelow rapid survey consists of field observations of the apparent level of Quokka activity – runnels, faecal pellets, tracks and incidental sightings. ▪ Where Quokka activity was identified, observations were used to derive a qualitive and relative estimate of Quokka abundance which was rated subjectively as low, med or high.	▪ 137 habitats between Manjimp and Walpole were surveyed for Quokkas using Liddelow rapid survey technique ▪ Initial surveys were typically less than 30 mins	Suitable habitat between Manjimp and Walpole in the Jarrah forest biogeographical zone of south western Australia	(Bain et al. 2014)

	▪ Runnel counts, track counts and faecal pellet counts were undertaken at each site 10 days before trapping. ▪ Eight transects each 240 m long ▪ Visited each morning for 10 consecutive days ▪ Fresh faecal pellets were counted and collected (to avoid repeat counting on different days)	▪ Each of the rapid survey elements when applied at transect level took 3 hrs per site. ▪ From these initial surveys a subset of 12 study sites were then selected for mark-recapture surveys on the basis relative-abundance categories including 4 at each low med and high.

2.3.2 Live capture

Live capture surveys occur in habitats most suited to Quokkas, such as creek lines and swamps (Bain et al. 2014; de Tores et al. 2007; Gibson et al. 2010; Sinclair & Hyder 2009). Live trapping is not considered necessary at the first stage of a detection survey (DSEWPC 2011). Sign-based searches are often conducted before trapping to determine the presence of Quokkas in an area and to inform where trapping efforts should be concentrated (Bain et al. 2014; Sinclair & Hyder 2009). Table 3 summarises sign-based survey methods typically used for monitoring Quokka's.

On the mainland, Quokkas typically experience 'trap shyness' and therefore have low capture probability (Hayward et al. 2003). To address this, it is recommended that live capture surveys are preceded by a period of pre-baiting/free-feeding in the week before surveys (Bain et al. 2014; Dundas et al. 2018; Hayward et al. 2003). Baits for Quokkas include apple, apple juice and the standard oat/peanut butter mix.

For ethical reasons, trapping should not occur during the hot summer months (DSEWPC 2011; Dundas et al. 2018). Dundas et al. (2018) adapted their mark-recapture study from consecutive nights of monitoring to non-consecutive nights (four nights over eight days) to reduce the impact of trapping on animals, especially frequently captured Quokkas and mothers with non-captured joeys at foot (identified by lactation).

Open population estimates are thought to require a minimum of three primary trapping periods (e.g. years/seasons/months/weeks), each containing five secondary sampling periods (e.g. days/hours) depending on the target species (Pollock 1982). Standard measurements of captured Quokkas include: weight, sex, pes length, reproductive status and tail circumference (a measure of condition (Bakker & Main 1980).

Table 3. Methods overview of key studies using live trapping surveys.

Survey type	Study design	Survey effort	Location	Reference
Cat/possum traps (0.3x0.3x0.7 m) Collapsible hessian traps (0.3x0.45x0.8m)	▪ Trap lines were set near creek lines where scats and 'runnels' were found, indicating Quokka activity. ▪ Bait were apple, peanut butter and apple juice ▪ Six Sheffield cage traps (22 x 22 x 55 cm) and four Elliott traps (9 x 10 x 33 cm) were baited and monitored for a total of 96 trap-nights to provide information on other mammal species using the wetlands. No Quokkas were captured	▪ The area was pre-baited for five days and monitored for a further five days (60 trap nights)	Muddy Lakes wetland and adjacent area	(Sinclair & Hyder 2009)
Wire traps with treadle trigger (0.3x0.3x0.8 m)	▪ Remote cameras showed that Quokkas moved around traps during daylight hours therefore traps were opened before dusk and left open overnight then checked and closed at dawn.	▪ One to five trapping sessions occurred at 14 sites in autumn, winter and spring in 2010, autumn and winter in 2011	Northern jarrah forests, Darling Range, WA	(Dundas et al. 2018)

Survey type	Study design	Survey effort	Location	Reference
	▪ Traplines set where there was visual evidence of Quokka presence (fresh scats and used runnels) ▪ Ten traps set ~20 m apart along creek lines ▪ Each trapping session was preceded by 6 nights of pre-feeding ▪ Weight, sex, left pes length (excluding nail), head length, circumference of tail (measure of condition (Bakker & Main 1980)) were all measured. Animals classified as pouch young, sub adult or adult. ▪ Sites had one of three levels of fox baiting treatment pre-survey: monthly hand baiting, seasonal aerial baiting or no baiting	(not during summer for ethical reasons)		
Large wire cage traps (0.9x0.45x0.45 m) Small wire cage traps (0.6x0.2x0.2 m)	▪ Two sizes of traps were used to reduce non-target captures in the large traps and minimise unequal catchability of individual Quokkas ▪ Pre-baiting for period of six to seven days prior to trapping, ▪ Trap stations situated every 50-100 m along creek lines in the swamp areas and between 30 and 80 m outside the swamp. ▪ Traps baited with apples and peanut butter, rolled oats, honey and pilchards. ▪ Captured animals sedated for 30-60 minutes to allow for measurement to be taken. ▪ Weight, sex, pes length, tail circumference (a measure of condition (Bakker & Main 1980)) measurements and reproductive status recorded. ▪ TROVAN1 transponder microchip fitted under the skin of captured Quokka. The hole resulting from the ear tissue sample taken for genetic analysis served as a secondary mark to ensure that no marks were missed or lost.	▪ Eight sites surveyed with areas between 2.6 and 15.3 ha (average = 9.3 ha) over eight days	Northern half of the Jarrah Forest biogeographical zone of south western Australia	(Hayward et al. 2003)
'Thomas' soft wall traps made with shade cloth stretched over a wire frame (0.45x 0.45x0.8 m)	▪ An initial Liddelow rapid survey identified 12 sites for mark recapture study ▪ Population estimates from the rapid survey and faecal pellet counts were compared to mark recapture technique. ▪ Trapping 'webs' as opposed to trapping grids used ▪ 65 traps set 30 m apart ▪ Traps were modified to allow non-target species Rattus fuscipes to escape and trigger plate adjusted so rats would not set off traps. ▪ Captured Quokkas weighed, ear tagged, pes measurements pouch condition and presence of pouch young also recorded. ▪ Faecal pellet counts were found to be an effective technique for measuring Quokka population.	▪ 12 sites surveyed ▪ 65 traps ▪ Three days of pre-baiting ▪ Average density of 14.1 traps per ha	Suitable habitat between Manjimp and Walpole in the Jarrah Forest biogeographical zone of south western Australia	(Bain et al. 2014)

2.3.3 Other survey methods

Other monitoring methods that have been used but have not been widely implemented include:

- camera trapping (Dundas et al. 2018) – in conjunction with live trapping
- Spotlighting (Sinclair & Hyder 2009) – in conjunction with other methods.

3 Key agencies and organisations involved in the species research and recovery

Key agencies, organisations or individuals identified as having been previously or currently actively involved in monitoring Quokka include:

- Matt Hayward, University of Newcastle
- Paul de Tores, University of NSW
- Karlene Bain, Python Ecological Services.

4 Survey guideline recommendations gathered from the literature

This literature review of monitoring methods for the Quokka has identified some key points that must be addressed when developing species-specific survey guidelines. These points include:

- Presence can be determined by sign-based surveys, usually focusing on scats associated with 'runnels' in thick vegetation. In areas where multiple macropod species are present DNA analysis may be used to confirm that the scats are from Quokka.
- Faecal pellet counts are an effective, rapid, inexpensive survey option for estimating population abundance. For Quokka, it takes less than 10 % of the time that trap-based mark-recapture surveys do (Bain et al. 2014).
- Sign-based surveys should be conducted to inform the location of mark-recapture studies, allowing biological and population data to be collected.
- Capture mark-recapture studies may also be used for estimating population abundance. Quokkas are trap-shy and require 5-7 nights of pre-baiting or free feeding before trapping surveys are undertaken. To avoid causing distress to feeding joeys and mothers, it is recommended that surveys should be undertaken on non-consecutive trap nights.

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