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# Review of the distribution, causes for the decline and recommendations for management of the quokka, *Setonix brachyurus* (Macropodidae: Marsupialia), an endemic macropodid marsupial from south-west Western Australia

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## ABSTRACT

The former and current distribution of the quokka, *Setonix brachyurus*, was mapped from published and all available unpublished records. At the time of European settlement the quokka was widespread and abundant and its distribution encompassed an area of approximately 41 200 km$^2$ of south-west Western Australia inclusive of two offshore islands, Bald Island and Rottnest Island. Historical reports indicated an extensive population decline occurred in the 1930s. The decline continued, with a previously undocumented decline apparent in the period from 1980 to 1992. However, this decline may be an artefact of the time scales used for mapping and may well equate with a previously reported decline for a suite of south-west mammals in the 1970s. By 1992 the quokka's distribution had been reduced to an area of approximately 17 800 km$^2$. An increased awareness of the presence of the quokka on the mainland has resulted in numerous reportings of quokka presence since 1992, has confirmed the existence of several populations at the northern extent of the quokka's known geographic range and indicated the current, 2005, distribution to be similar to that in 1992. However, survey and population estimates at six of these mainland locations from the northern jarrah forest indicated low abundance. There have been no population estimates elsewhere on the mainland. Two populations have been reported from the Swan Coastal Plain, but neither has been confirmed extant.

Predation by the introduced fox, *Vulpes vulpes*, is implicated as a major cause of the quokka's initial decline, while ongoing predation, habitat destruction and modification through altered fire regimes have contributed to the continued decline.

Specific conservation management actions are recommended, namely: (i) Implementing an active adaptive management program in the northern jarrah forest to determine quokka population response to habitat manipulation through the use of fire, fox baiting and pig control; (ii) Surveying the Stirling Range and Green Range populations with emphasis placed on determining population size and population genetic structure; (iii) Surveying the reported occurrences from the Swan Coastal Plain, with emphasis on unambiguously determining presence. If confirmed, priority should be directed to assessing population size and determining the management requirements to ensure persistence of the population; (iv) Surveying southern forest and south coast populations to assess quokka population size, the extent of movement between subpopulations and assessment of the range of habitat types used by quokkas. The latter should be combined with spatial analyses of known extant populations and suitable and potentially suitable habitat; (v) Determining the role of fire in establishing and maintaining preferred habitat of southern forest and south coast populations; and (vi) Establishing a program to assess the potential effects from management operations.

**Keywords**: quokka, *Setonix brachyurus*, distribution, fox predation, fire, adaptive management

## INTRODUCTION

The quokka, *Setonix brachyurus* (Macropodidae: Marsupialia) (Quoy & Gaimard 1830) is a small to medium sized macropodid marsupial, endemic to the mainland of south-west Western Australia and two offshore islands –

Bald Island, east of Albany and Rottnest Island, 20km west of Perth (Fig. 1). Adult males range in weight from 2.7 to 4.2 kg and adult females from 1.6 to 3.5kg (Hayward et al. 2003; Kitchener 1995). The quokka is known to the Aboriginal, or Noongar, people of south-west Western Australia by a range of names including '*Ban-gup*', '*Bungeup*', '*Quak –a*' (Gould 1863; Shortridge 1909), '*kwoka*' and '*bangop*' (Abbott 2001a).

The quokka was the second Australian marsupial recorded by Europeans, the first appears to have been Francis Pelsart's description of the Tammar Wallaby from the Houtman Abrolhos on 1629. The first European record of a quokka is attributed to Samuel Volckertzoon (or Volckersen) who, in 1658, when visiting the then un-named Rottnest Island off the coast near Perth, described the quokka as '*a wild cat resembling a civet-cat but with browner hair*' (Alexander 1914). In 1696 when Willem de Vlamingh visited the island he described the quokka as '*a kind of rat as big as a common cat*' (Alexander 1914). He named the island Rottenest (now Rottnest), meaning rat's nest. The quokka is often erroneously reported by local media as occurring only on Rottnest Island. Its presence on the mainland was described in 1957 as largely unreported (Barker et al. 1957) and it is still widely thought of as only occurring on Rottnest Island.

At the time of European settlement of south-west Western Australia, the mainland distribution of the quokka was thought to extend from the Moore River district 80–100 km north of Perth (Baynes 1979), to areas south and south-east of Perth at locations within the Swan Coastal Plain, the jarrah, *Eucalyptus marginata*, and karri, *E. diversicolor*, forests south-east of Perth, the Cape Leeuwin–Cape Naturaliste region, the south coast and east to the Hunter River east of Bremer Bay (Baynes 1979; Baynes et al. 1975; Glauert 1933; Kitchener 1995; Ride 1970) (Fig. 1). In addition to the Rottnest Island and Bald Island populations, quokkas were reported from Breaksea Island, near Albany (Western Australian Museum records), 'Twin Peak' Island and other off shore islands near Esperance (Shortridge 1909). Subsequent references to the quokka's historic distribution on the mainland, at or prior to the time of European settlement, have included the south coast of Western Australia as far east as Esperance (Shortridge 1909; Troughton 1965).

This inferred former distribution was based on the above reports and location records. All location records were within four biogeographical regions, or bioregions, as identified in the Interim Biogeographical Regionalisation for Australia (IBRA) (Thackway & Cresswell 1995), namely the Swan Coastal Plain, the Jarrah Forest, the Warren and the Esperance Plains bioregions (Fig. 1).

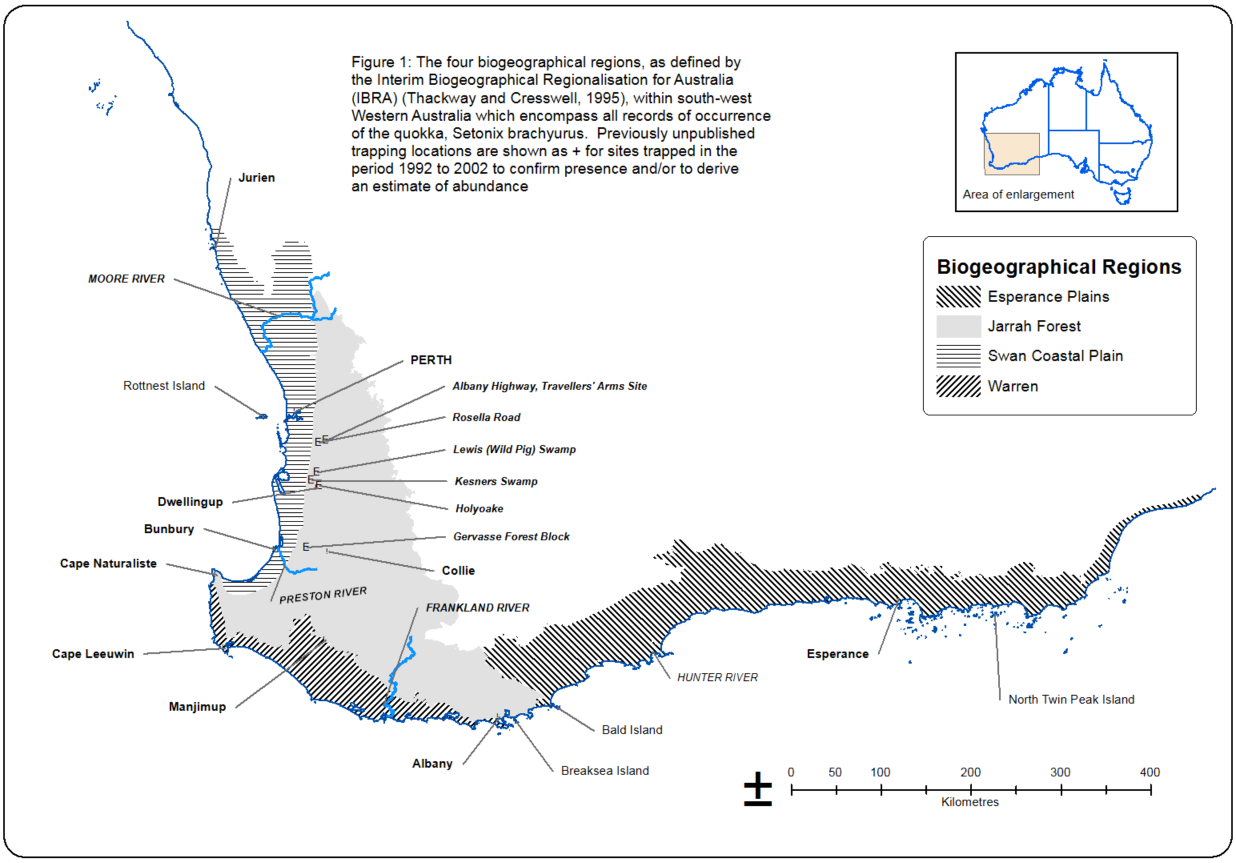


*Figure 1. The four biogeographical regions, as defined by the Interim Biogeographical Regionalisation for Australia (IBRA) (Thackway and Cresswell, 1995), within south-west Western Australia which encompass all records of occurrence of the quokka, Setonix brachyurus. Previously unpublished trapping locations are shown as + for sites trapped in the period 1992 to 2002 to confirm presence and/or to derive an estimate of abundance*

Various authors have expressed concern at the extent of the quokka's decline from this inferred historic distribution and attributed different levels of threat to its conservation status. Clarke (1948) suggested the quokka was almost confined to Rottnest Island. White (1952), although noting there was a misleading impression of rarity on the mainland, conceded the quokka was becoming less abundant there. Loaring (in Serventy et al. 1954) believed quokkas had vanished from their *'gully haunts'* in the Darling Plateau by the 1920s. Sharman (1954) noted the quokka appeared common only on Rottnest and Bald Islands with isolated colonies at some mainland sites.

Barker et al. (1957) cited a 1957 newspaper article which suggested the quokka was extinct on the mainland. That report generated interest in quokka populations, and in the same year, led to the confirmation of the presence of a small colony of quokkas near Byford, immediately south of the Perth metropolitan area (Barker et al. 1957). Hart et al. (1986) and similarly Perry (1973) also noted there was a widely held, yet incorrect, belief the quokka had become extinct on the mainland after the population crash of the 1930s. This collapse of quokka populations on the mainland in the 1930s is widely reported and Ride (1970) recorded, prior to this collapse, that the quokka was common in the south-west and populations were sufficiently abundant for quokka shooting to be a '*familiar sport'*.

Serventy (in Serventy et al. 1954) reported an apparent increase in quokka numbers in the Darling Range and Manjimup areas in the early 1950s. However, this seems to be contradicted by reports from Loaring and Glauert (also reporting in Serventy et al. 1954). Dell (1983) believed Serventy's (1954) reported increase in numbers of the quokka and other species could not be substantiated and was an artefact of an increased awareness by observers. How et al. (1987), when reporting on a vertebrate fauna survey for the area between Busselton and Albany, believed quokka populations had persisted on the mainland but were rapidly diminishing.

In an attempt to quantify the conservation status and causes of decline for a suite of macropod species, Johnson et al. (1989) concluded the quokka had experienced a substantial (85–90%) decline in its geographic range on the mainland. These authors identified the quokka as warranting a high priority for conservation management.

The quokka is currently listed as a *Threatened Species*, in the sub-category Vulnerable, pursuant to the World Conservation Union (IUCN) Red List of Threatened Species (Hilton-Taylor 2000). It is listed nationally as *Threatened Fauna*, in the sub-category Vulnerable, pursuant to the Commonwealth of Australia's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) criteria for Vulnerable. In 1996 it was placed on the Western Australian list of *'fauna which is rare or likely to become extinct'* pursuant to Section 14(2)(ba) of the *Western Australian Wildlife Conservation Act* 1950.

This paper reviews the distribution of the quokka, assesses the probable causes of the species decline and proposes specific conservation management recommendations. The conservation status is reviewed in a forthcoming publication.

# METHODS

## Distribution maps and terminology

Location records for the quokka were obtained from published and unpublished accounts of fossil, subfossil and surface cave deposits, published and unpublished records of distribution/presence, database records of the Western Australian Museum (WAM), database records of the Australian Museum, database records of the Western Australian Department of Environment and Conservation (DEC, formerly the Department of Conservation and Land Management, CALM) (CALM unpublished; Gilfillan unpublished). Additional information on WAM records was supplied by Norah Cooper (pers. comm. to PJdeT)[1] and additional sub-fossil records were obtained from searches of the uncatalogued collection of the Palaeontology and Anthropology Sections of the Western Australian Museum (E. Jefferys pers. comm. to MWH)[2].

Records of presence were provided from our previously unpublished field survey and trapping data from the early 1970s to 2002 with additional detailed data from the period 1992 to 2002 from trapping at six locations within the northern jarrah forest – Gervasse Forest Block, Rosella Road, Albany Highway (Travellers' Arms Site), Holyoake Swamp, Kesners Swamp and Lewis (Wild Pig) Swamp (Fig. 1.). Field survey considered quokkas to be present at a site if confirmed through trapping, recent roadkills or by the presence of scats within characteristic runways in densely vegetated areas considered typical of quokka habitat (see Barker et al. 1957; Christensen et al. 1985; Christensen & Kimber 1975; Dillon 1993; Kitchener 1995; Maxwell et al. 1996; Sinclair 1999). The presence of scats in open areas and away from characteristic runways, was considered insufficient to infer presence (Alacs et al. 2003).

Locations from all sources were mapped using the geographic information system (GIS) software ArcGIS (ESRI 1999-2004). Location records were excluded when they were unable to be validated and/or if not supported by location co-ordinates, or if location co-ordinates could not be determined. The inferred pre-European distribution (inclusive of sub-fossil records) was mapped from these records, as was the distribution at six subsequent times, namely at the time of European settlement, at 1920, 1950, 1980, 1992 and 2005. The inferred distribution at the time of European settlement and at 1920 pre-dates arrival of the fox and the first evidence of fox predation in south-west Western Australia. The 1950 distribution includes records from 1921 to

[1] Norah Cooper: Curator of Mammals, Western Australian Museum, Perth
[2] Elizabeth Jefferys: University of New South Wales

1950. The 1980 distribution includes records from 1951 to 1980. The 1992 distribution includes records from 1981 to 1992. The 2005 distribution is inferred from records post 1992, where populations were verified or where there was no evidence to indicate previously known populations had not persisted. These time frames allow quantitative and visual assessment of the decline from the pre-European distribution. Our use of the term 'pre-European distribution' is synonymous with the term 'original distribution' as used by Baynes (1987). The current (2005) distribution was also mapped to depict density of sighting and location records. Density categories were derived through kernel analysis in ArcGIS. Densities reflect the density of sighting/location records and do not necessarily equate with population densities.

## Areas surveyed, population estimates and survivorship

Estimates of population size were obtained from published accounts and our previously unpublished survey and trapping records at locations within the northern and southern jarrah forests, where the northern jarrah forest is broadly defined as the jarrah, marri and wandoo forests north of the Preston River (Fig. 1). The southern forest is broadly defined as the jarrah, marri, karri, tingle and wandoo forests south of the Preston River, north and west of the Frankland River. The south coast refers to the area east of the Frankland River (Fig. 1).

The Gervasse site (Fig. 1) is subject to an ongoing monitoring program (capture-mark-release-recapture) and capture data were analysed for eleven trapping sessions conducted in June/July 1992, March 1993, June/July 1993, January 1994, August 1994, April 1995, January 1996, January 1997, February 1998, March 1999 and February 2000. To enable comparison with population estimates from five other northern jarrah forest sites (Hayward et al. 2003), estimates of population size from the Gervasse site were derived from the '*death but no immigration*' Jolly-Seber (JS) model using the software interface modified to accommodate unequal time periods between trapping sessions (Barker & McGlinchy 2001).

'*Known to be alive*' (KTBA) estimates were also derived for the Gervasse site, where an animal trapped at trapping session $t_{(n-i)}$, not trapped at $t_{(n)}$ and subsequently trapped at $t_{(n+i)}$ is assumed to be alive at $t_{(n)}$. The number of captures at the other five sites reported from the northern jarrah forest was too low to derive an estimate of, or index to, population size. Where presence was confirmed, data from these sites are reported as the total number of individuals trapped.

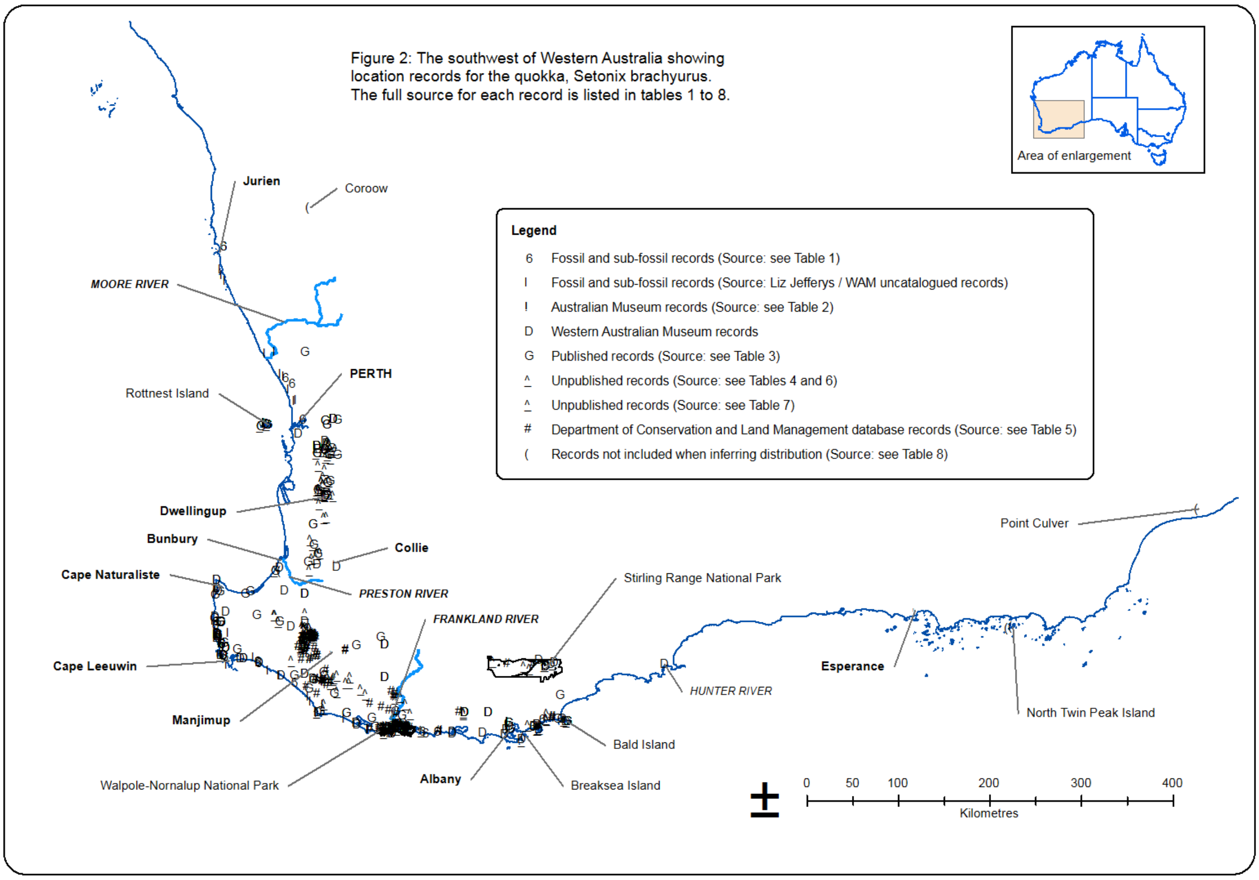


*Figure 2. The southwest of Western Australia showing location records for the quokka,* Setonix brachyurus. *The full source for each record is listed in tables 1 to 8.*

## RESULTS

### Records of occurrence

Fossil and subfossil records are shown in Table 1, Australian Museum records in Table 2, published records in Table 3, unpublished records (from various sources) in Table 4, unpublished records from the Department of Conservation and Land Management databases, now Department of Environment and Conservation (DEC) (CALM unpublished; Gilfillan unpublished) in Table 5. Our previously unpublished location data for extant populations are shown in Tables 6 and 7. All records were mapped and shown in Fig. 2. Data from the Western Australian Museum (Kitchener & Vicker 1981) and additional WAM records (WA Museum database records; pers. comm. from E. Jefferys; pers. comm. from N. Cooper) are presented in mapped form only. Five of the records unable to be validated or unable to be confirmed are shown in Table 8. These records are also mapped in Fig. 2, but excluded when inferring distribution. The population translocated to a predator-proof fenced sanctuary (Karakamia Sanctuary, east of Perth) is also listed in Table 8 and mapped in Fig. 2, but also excluded from inferred distribution, as is the captive colony formerly housed at the University of Western Australia and the location of a failed translocation – the Harry Waring Marsupial Reserve, Jandakot (Short et al. 1992). Two unconfirmed records (Muddy Lake, south of Bunbury and a Water Corporation reserve near Dunsborough) are also listed in Table 8 and mapped in Fig. 2, but excluded from inferred distribution mapping.

### Estimates of population size and survivorship

The '*deaths but no immigration*' Jolly-Seber estimate of population size for Gervasse was 49 ±7.9 and is shown in Table 7, as are results from opportunistic trapping programs initiated to determine presence at five other sites. Known to be alive (KTBA) estimates for the period 1992 to 2000 for the Gervasse population are shown in Table 9.

### DISTRIBUTION

#### *Distribution pre European settlement*

There is no evidence to suggest the quokka has extended its distribution since European settlement and all published and unpublished accounts imply a progressive contraction of this distribution. Therefore, distribution pre-European settlement is inferred from current and historically known location records and from subfossil records and is shown in Fig. 3. The age, i.e. sub-fossil, of the Hasting's Cave deposits east of Jurien Bay (Table 1 and Fig. 2) indicate this to be the northern extent of the

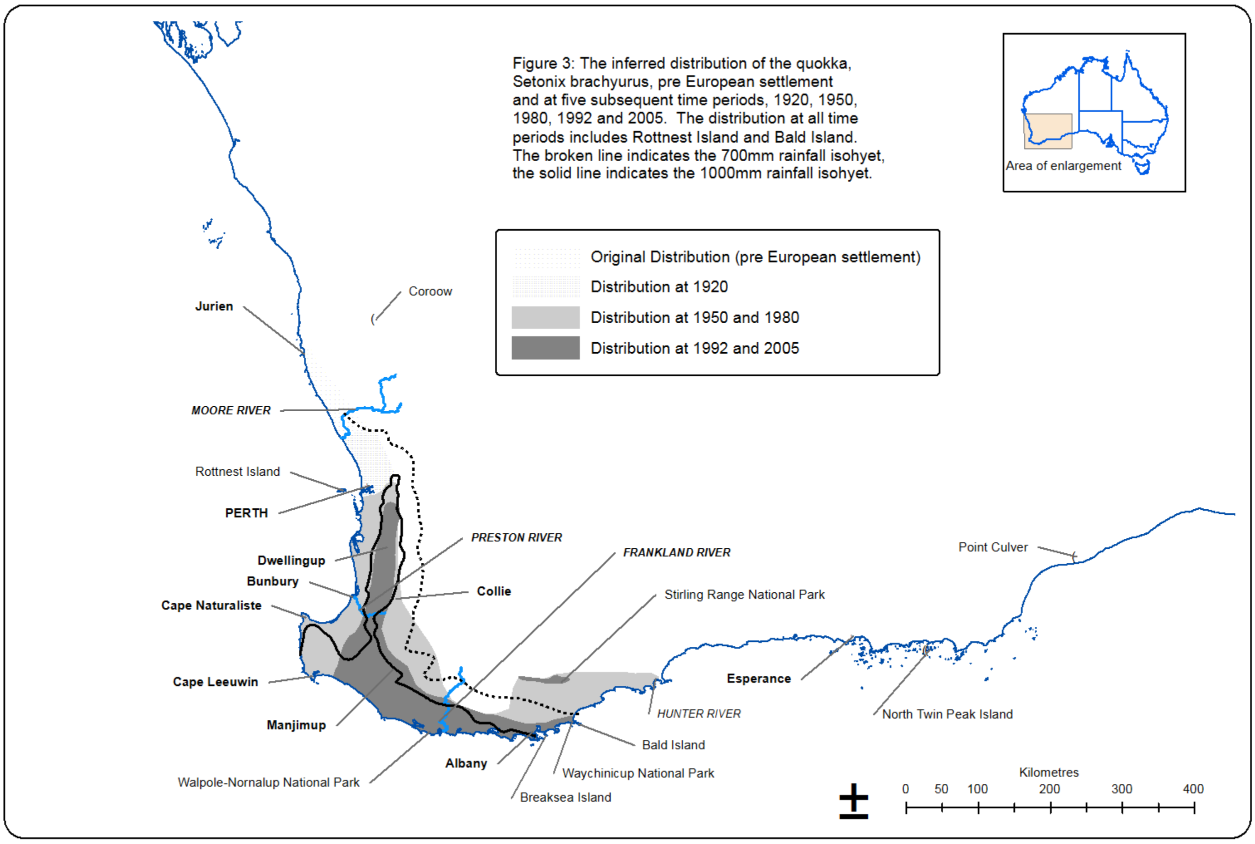


*Figure 3. The inferred distribution of the quokka,* Setonix brachyurus, *pre European settlement and at five subsequent time periods, 1920, 1950, 1980, 1992 and 2005. The distribution at all time periods includes Rottnest Island and Bald Island. The broken line indicates the 700mm rainfall isohyet, the solid line indicates the 1000mm rainfall isohyet.*

quokka's pre-European distribution, as concluded by Baynes (1979). Sub fossil deposits at Yanchep (Merrilees 1965) and the series of deposits from Perth to Jurien Bay (E. Jefferys pers. comm. to MWH) indicate this distribution was continuous. The Hunter River record (Kitchener & Vicker 1981), east of Albany is the eastern most record. Therefore, the inferred pre-European extent of occurrence on the mainland extends from Jurien Bay, southward through the Swan Coastal Plain, the jarrah and karri forest areas, the Leeuwin-Naturaliste region, the south coast and east to the Hunter River, east of Albany. This distribution encompassed an area of approximately 44 300 $km^2$, inclusive of Rottnest Island (15.5 $km^2$) and Bald Island (7.8 $km^2$). This area is exclusive of Breaksea Island, North Twin Peak Island and South Twin Peak Island and exclusive of the south coast, east of the Hunter River, considered by Shortridge (1909) to be within the quokka's original distribution.

The two records from Breaksea Island are from skulls collected by Ian Abbott[3] in 1975 (Kitchener & Vicker 1981). There have been no further records from Breaksea Island and the true origin of these skulls is unclear. The skulls may be sub-fossil specimens representing a natural population which subsequently died out after it became isolated on the Breaksea peninsula when it was separated from the mainland approximately 7 000 years ago (Ian Abbott pers. comm. to PJdeT). Alternatively, explanations (as proposed by Ian Abbott, pers. comm. to PJdeT) include: (i) quokkas still occur on Breaksea Island but have been overlooked; (ii) sealers known to have been operating in the area from the 1790s, and/or Noongar women held captive on the Island, caught quokkas on the mainland and left their remains on Breaksea Island. This is supported by historical records which refer to sealers marooning Noongar women on islands; and (iii) residents on the Island, including a lighthouse keeper present there from 1858, or other visitors, attempted and failed to establish a quokka population on the Island.

Recent work examining the effect of weeds on nesting seabirds has involved considerable time traversing all vegetation types on Breaksea Island and has failed to detect any sign of quokka activity or presence and studies examining sub-fossil remains of seabirds have not identified fossil or subfossil quokka remains (Peter Collins, pers. comm. to PJdeT)[4]. Although quokka remains may have been overlooked (Peter Collins, pers. comm. to PJdeT), there seems to be insufficient evidence to include Breaksea Island within the original distribution of the quokka.

Shortridge (1909) provided the sole reference to quokka presence on *'Twin Peak Island'*, presumably referring to either North Twin Peak Island or South Twin Peak Island in the Recherche Archipelago, off the coast at Esperance. Glauert (in Serventy et al. 1954) described the quokka as plentiful on Rottnest Island and *'some islands off the south coast'*. However, there are no other records of occurrence of the quokka from the islands off Esperance and numerous authors (Abbott & Burbidge 1995; Burbidge 1977; Calaby 1971; Glauert 1933; Maxwell et al. 1996; Sharman 1954; Waring 1956) list the quokka as present on only Rottnest Island and Bald Island. Quokka presence was not recorded on any of the islands in the Recherche group by Serventy (1953), however, the tammar wallaby, *Macropus eugenii*, was recorded as plentiful on Middle Island and North Twin Peak Island. Similarly, Kabay and Start (1976) were unable to confirm presence of quokkas on either North or South Twin Peak Island when they surveyed both islands in 1976. The tammar and quokka do not occur sympatrically on any island and various hypotheses have been forwarded to explain this (see Clarke 1948; Main 1961; Serventy 1951; Serventy 1953). The most parsimonious explanation for the lack of sympatric occurrence is that the small to medium size insular macropod fauna is determined by the climatic conditions at the time of separation from the mainland, with persistence determined by continued availability of suitable habitat. Where islands are small, inter-specific competition operates and one species only will persist. Main (1961) hypothesised an island area in excess of six square miles was necessary to support a single species of small macropod. This hypothesis is consistent with the occurrence of tammars only on Garden Island and quokkas only on Rottnest Island. It is also consistent with the presence of quokkas only on Bald Island.

Given the size of North and South Twin Peak Island and the presence of the tammar on North Twin Peak Island, it is unlikely the quokka also occurred there. The '*Twin Peak Island'* record of Shortridge (1909) therefore appears to be spurious and we believe the record is a reference to the tammar wallaby, presumably from North Twin Peak Island. Thus, we have interpreted the pre-European distribution of the quokka to be exclusive of the islands of the Recherche and exclusive of the south coast, east of the Hunter River. The absence of quokkas from the fossil and sub fossil records from this region is consistent with this inferred distribution.

The inferred pre-historic distribution is not different from the inferred distribution, pre-European settlement. Although abundant in the fossil record dating to the Pleistocene (Balme et al. 1978) (Table 1), the quokka appears to have been restricted to the south-west corner of Australia. The mainland population was presumably split by rising sea levels, with the Rottnest Island population separated between 6 000 and 8 000 years before present (BP) (Churchill 1959). The Bald Island population was separated almost 10 000 years BP (Storr 1965).

Quokka fossil deposits from Devil's Lair were dated to 35 000 years BP (Balme et al. 1978), although more recent techniques suggest an age in excess of 40 000 years (Turney et al. 2001) (Table 1). Balme et al. (1978) concluded quokkas became increasingly abundant from

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32 000 years BP, then showed a slow decline, followed by an increase in abundance. The peak in abundance coincided with a wetter but cooler climate and the period of decline coincided with a period of intense aridity, relative to present conditions. Despite these variations, the quokka was still one of the most abundant species throughout the Devil's Lair deposits (Balme et al. 1978). Balme et al. (1978) concluded the persistence of the quokka throughout this period of climatic variation implies a continuous presence of thickly vegetated watercourses and forest, although the forest species composition may have changed. Importantly, the post-glacial period of aridity experienced in other parts of southern Australia was not as severe in the south-west corner of Australia, thus allowing forest dwelling mammals to persist (Balme et al. 1978).

## Distribution at the time of European settlement

The inferred distribution at the time of European settlement is shown in Fig. 3. Published and unpublished reports (Table 3 and 4) indicate the quokka was locally abundant and the distribution encompassed an area of approximately 41 200 km$^2$. This indicates a relatively minor southern contraction from the pre-European distribution.

With the exception of records north and north-east of Albany, including the Stirling Range National Park, the distribution follows the pattern of rainfall, with records of occurrence confined to areas now receiving an average annual rainfall of 700 mm or more (Fig. 3). Although the distribution is shown as continuous, the Stirling Range and Green Range populations are isolated from all other south coast populations. The Stirling Range population may be in an area of higher rainfall (see climatic influences, below).

## Distribution at 1920

The inferred distribution at 1920 shows no contraction from that at the time of European settlement (Fig. 3).

## Distribution at 1950

The inferred distribution at 1950 is shown in Fig. 3 encompasses an area of occurrence of approximately 37 800 km$^2$ and shows a contraction from that at 1920.

Reports of quokka abundance prior to the mid 1930s contrast to later reports (Tables 3 and 4). Prince (1984) included the quokka amongst the species of kangaroos and wallabies commercially exploited in the first 30 years of the 20th century. Records of the specific number of quokkas harvested were not kept and harvests of the quokka and the tammar wallaby were combined with other small macropods. Potential commercial exploitation of the quokka ceased in 1952, with proclamation of the Fauna Protection Act of 1950 (Prince 1984). As none of these harvests was from Rottnest Island (R.I.T. Prince, pers. comm. to PJdeT)[5], the implication is the quokka was sufficiently abundant on the mainland in the early part of the 20th century to enable it to be commercially exploited. These harvested animals were in addition to the large number of quokkas shot in locally organized *'quokka shoots'* which occurred in the 1940s (Les Wilson, pers. comm. to PJdeT)[6] and it seems the quokka was widespread and abundant prior to the 1930s, albeit in restricted habitat (Gould 1863; Perry 1971; Perry 1973; Shortridge 1909; White 1952). Long-term residents from the Northcliffe area (pers. comm. to PJdeT) reported that in the 1930s, and perhaps into the 1940s, quokkas regularly browsed in pasture well away from areas of restricted creekline habitat. Further evidence indicating the quokka was at high density prior to the decline in the 1930s is provided by the 1933 proclamation of the quokka as 'vermin' pursuant to the Vermin Act, 1918 (Government Gazette of Western Australia 1933).

The subsequent decline is reported anecdotally only. This decline is also only partially reflected by the decline in inferred distribution at 1950 (Fig. 3) which shows only a moderate southward contraction from the inferred distribution at 1920. Populations were still present, or inferred by subsequent *'rediscoveries'* to have been present, as far north as the Perth metropolitan area. No westward contraction in range is apparent and similarly, populations persisted on the Swan Coastal Plain. Although the distribution at 1950 shows only a moderate contraction from 1920, the number of known locations clearly declined and abundance at each also appears to have declined. Quokkas may have persisted as far east as the Hunter River area, east of Albany. However, supportive evidence is provided by one WAM registered specimen record only, collected in 1970 (Kitchener & Vicker 1981). The specimen is a part of a mandible (Norah Cooper, pers. comm. to PJdeT), is undated and may be considerably older than the collection date implies. Thus, the westward contraction may have commenced prior to the collection date of the Hunter River specimen and the eastern extent of the distribution at 1950 (and 1980, see below) may have extended no farther than the Waychinicup Bay/Waychinicup National Park and Green Range area (Fig. 3).

## Distribution at 1980

The inferred distribution at 1980 is shown in Fig. 3 and shows no contraction from that at 1950. However, as for the pattern of decline described at 1950, records indicate the number of known populations had decreased and most published accounts referred to the quokka as rare on the mainland (Table 3).

## Distribution at 1992

The inferred distribution at 1992 is shown in Fig. 3 encompasses an area of approximately 17 800 km$^2$ and

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[6] Les Wilson: long-term resident of the Northcliffe area.

shows a marked contraction from the distribution at 1980. With the exception of a recently reported rediscovery at Muddy Lake, south of Bunbury (Dell & Hyder-Griffiths 2002) (Table 4) and an unconfirmed record from the Dunsborough area (Table 8), the last records from the Swan Coastal Plain are from 1961 from Bibra Lake, at the southern outskirts of the Perth metropolitan area (Kitchener & Vicker 1981) and from 1975 and 1976 from the Bunbury/Muddy Lake area (Table 4) (Hart et al. 1986; Kitchener & Vicker 1981). The last confirmed record from the Cape Leeuwin–Cape Naturaliste area is from 1979 from Wardanup Hill, south of Dunsborough (Kitchener & Vicker 1981).

Populations were present, or inferred as still present by subsequent 'rediscoveries', at Churchman Forest Block, within 10 km of the Perth metropolitan area. Exclusive of Bald Island, the eastern most records are from the Waychinicup National Park area east of Albany and Green Range, northeast of Albany. The Stirling Range population(s) is shown as isolated from other south coast populations and may have been isolated prior to 1992.

## Current distribution

The inferred current distribution is shown in Figs 3 and 4 and is unchanged from 1992.

Trapping in 1995–96 in the Dwellingup and Manjimup areas at sites known to support quokka populations in the 1990s failed to confirm presence at numerous sites (Dillon 1996) (Table 10). With the exception of the unconfirmed records from Muddy Lake and Dunsborough, quokkas are now considered absent from the Swan Coastal Plain. The skull collected at Muddy Lake (Dell & Hyder-Griffiths 2002) in September 2002 has no associated soft tissue and is not aged (Norah Cooper, pers. comm. to PJdeT). Its collection date does not necessarily infer presence of an extant population at the time of collection. Quokka presence is otherwise only inferred at this location by the presence of runways. There is an unconfirmed report of quokka occurrence from a Water Corporation managed reserve in the Dunsborough area and unsubstantiated anecdotal reports of presence in the Cape Leeuwin–Cape Naturaliste area.

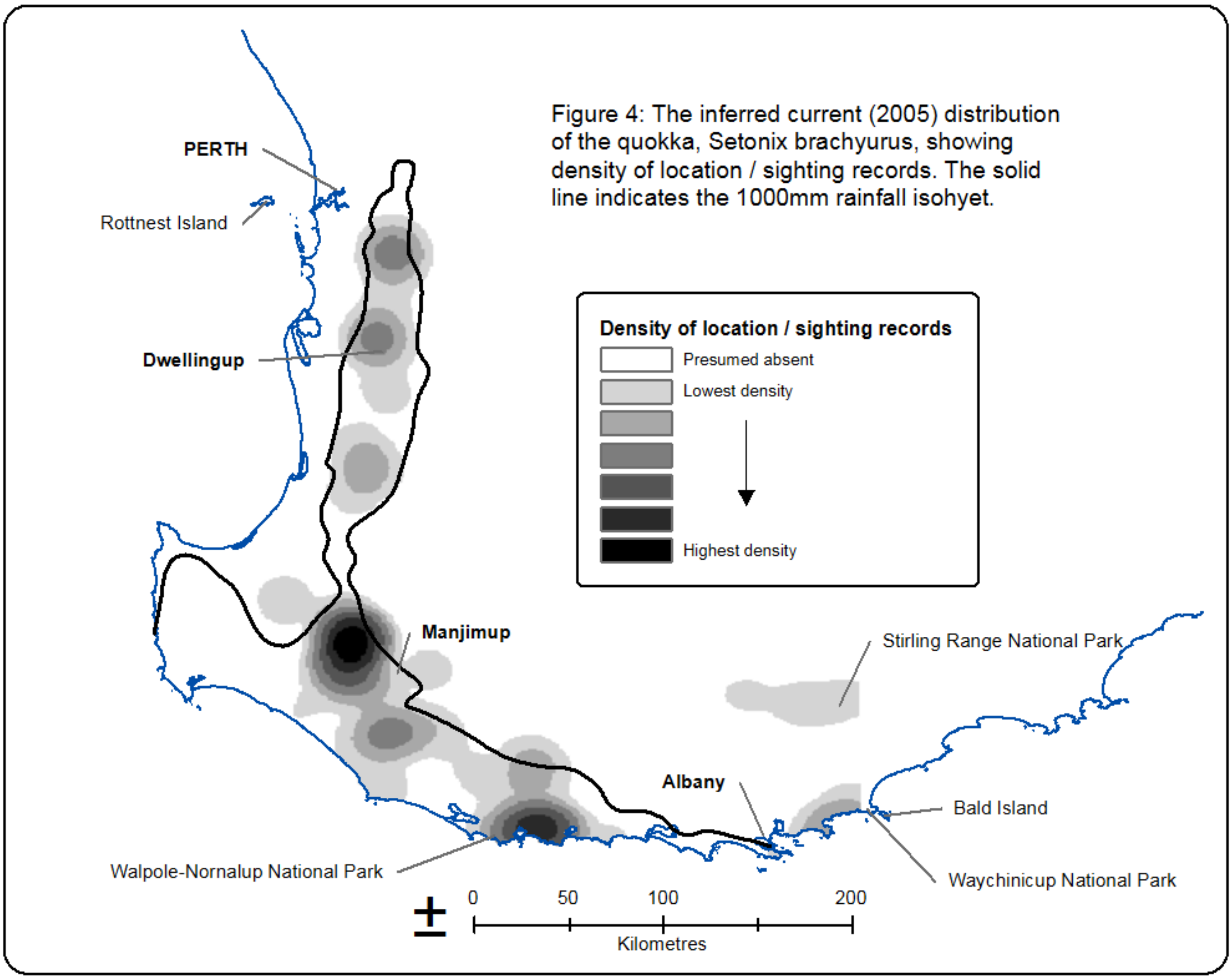


*Figure 4. The inferred current (2005) distribution of the quokka,* Setonix brachyurus, *showing density of location / sighting records. The solid line indicates the 1000mm rainfall isohyet.*

Presence of suitable habitat and anecdotal reports suggest quokkas may also still occur in the lower catchment of the Blackwood River, north-east of Augusta (Roger Hearn, pers. comm. to PJdeT)[7]. Data unavailable for this review and referred to by Liddelow (2006) indicated several populations may occur west of Nannup. The current inferred distribution (Fig. 3) includes these records, however the pattern of these records of occurrence combined with sites also examined by Liddelow (2006) where quokkas were previously known to occur and are considered to no longer occur, suggest this western forest margin may be experiencing the same decline detected in the northern jarrah forest.

The most northerly records from the Darling Plateau are from Churchman Forest Block, approximately 10 km south-east of the Perth metropolitan area (Table 4). The confirmed sites from the northern jarrah forest extend in a narrow band along the Darling Plateau and are bounded by the 1 000 mm annual rainfall isohyet (Fig. 3). There are no confirmed records of extant populations between Collie (Davis Forest Block) and Nannup (Boronia, Gregory and Helms forest blocks) (Table 6, Fig. 3). With the exception of the records from Boronia Forest Block and records east of Nannup (Liddelow 2006), the Nannup population(s) and forest populations farther south are also almost entirely within the 1 000 mm annual rainfall isohyet (Fig. 3). The most easterly mainland records are from the south coast near Waychinicup National Park, east of Albany, from presence inferred by collection of hair from Green Range north-north-east of Albany (J.A. Friend, pers. comm. to PJdeT)[8] and from the Stirling Range National Park, northeast of Albany. As depicted by the inferred distribution at 1992, the Stirling Range and Green Range population(s) appear to be, and may always have been, isolated from other south coast populations.

Figure 4 shows the current inferred distribution based on records of occurrence from 1992 to present. The density gradient depicted (Fig. 4) reflects the density of sighting/location records. It does not necessarily reflect population densities and the nodes of inferred high population density are, to some extent, likely to be an artefact of proximity to townsites and local interest in reporting sightings.

## DISCUSSION

### Distribution and population estimates

The contraction of distribution has been greatest from the northern extent of the geographic range and from the Swan Coastal Plain. The northern-most known extant population is approximately 10 km south-east of Perth. With the exception of the unconfirmed records from Muddy Lake and the Water Corporation reserve near Dunsborough, the quokka is now considered absent from the Swan Coastal Plain and the Cape Leeuwin–Cape Naturaliste area and occurs only as far east as Waychinicup National Park (Figs 2 and 3).

Surveys aimed at determining presence in forest areas since the early 1970s have confirmed quokka populations from the northern (Dwellingup) and southern (Manjimup) forest areas are patchy and discontinuous. The known northern limit of the present distribution was extended in 1995 by discovery of a population near Jarrahdale (Rosella Road) (Tables 6 and 7), in 1996 by re-discovery of a population north-east of Jarrahdale (Albany Highway/Travellers' Arms) (Tables 6 and 7) and in 2001 and 2002 by discovery of populations within Churchman Forest Block, 10 km south-east of the Perth metropolitan area (John Liddington, pers. comm. to PJdeT, Table 4)[9]. Although there are in excess of 40 records of occurrence in the northern jarrah forest post 1992 (Tables 3, 4, 5, 6 and 7), several of these records of occurrence may constitute a single population. Equally importantly, confirmation of presence does not equate with persistence of a population. Figure 4 should therefore be interpreted cautiously, as each sighting/location record does not necessarily reflect a separate population and the density gradient depicted reflects the density of location/sighting records, not population density. Although the nodes which depict highest density in the southern forest, near Manjimup, and the south coast, near Walpole-Nornalup National Park, concur with our observational and unquantified survey data which suggest these areas support the highest density populations (exclusive of Rottenest Island), these nodes also reflect proximity to townsites or areas where there is local interest in reporting sightings. Therefore, the high density nodes are also likely to reflect the level of local survey effort and the level of local interest in reporting sighting records. They should not be seen as quantified estimates of abundance.

Estimates of abundance were available from six sites only, rarely reported more than twenty to thirty individuals and often comprised considerably fewer (Table 3 and 7). The Gervasse population is the only known population shown to support in excess of forty individuals (Table 7). The northern-most sites appear to be at critically low density. The Rosella Road population is thought to be at risk of local extinction (Hayward et al. 2003). The Wild Pig Swamp (Lewis Swamp) site supported quokkas in the early 1990s (Dillon 1993), however despite the evidence of fresh activity, trapping failed to confirm quokka presence when trapped in 1995 (de Tores, Dillon, Tomkinson and Buehrig, Tables 6 and 7) and in 1998–2000 (Hayward et al. 2003). The Holyoake site is thought to be locally extinct (our data and Hayward et al. 2003).

Results from published accounts (Christensen et al.

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1985) and our trapping surveys (Tables 6 and 7) have consistently returned low capture rates from these forest areas. Capture rates of 0.3 (Dillon 1993) and 0.07 to 0.99 (Hayward et al. 2003) quokkas per 100 trap nights for sites in the Dwellingup area and 1.2 per 100 trap nights over three sites north of Dwellingup (Sinclair 1999), are representative of trapping success at these low density sites.

Hayward et al. (2003) believed the northern jarrah forest population formerly constituted a functional metapopulation which is now under threat of collapse. Collapse of this metapopulation, or collapse of the remaining catchment-confined populations, would result in a considerable contraction of the quokkas' distribution. Given the lag time required to detect a decline in a population, we believe there is an urgent need for a coordinated and site-prioritised monitoring program at known quokka sites and appropriate quantitative analyses of monitoring results (see section on management recommendations).

An additional series of surveys has been conducted post collation of the data reported here (Graeme Liddelow[10] and Alan Wright[11], pers. com. to PJdeT) and indicate presence of quokkas at numerous additional locations within the southern forest and northern jarrah forest. However, no data were collected on population size or movement between populations. The likelihood of persistence of these populations is unknown.

## Habitat use

Hayward (unpublished, reported in summary in de Tores et al. 2004) concluded all extant northern jarrah forest populations were associated with creeklines characterised and dominated by the ti-tree, *Taxandria linearifolia* (formerly *Agonis linearifolia*), and further concluded quokka populations from the northern jarrah forest are restricted to areas supporting a structural mosaic of burnt and unburnt vegetation. These findings concur with records from the mid 1970s to 2002 (our records, various unpublished accounts and confirmed sightings).

Hayward (unpublished, reported in summary in de Tores et al. 2004) also examined 66 sites in the northern jarrah forest to assess quokka presence/absence. General Linear Modeling (GLM) and model selection through use of a mixed approach of stepwise removal of variables and the Information-Theoretic approach and Akaike Information Criterion (AIC) (Burnham & Anderson 2002) was used to identify the 'best' model to describe the preferred habitat of the quokka. We do not advocate this mixed approach and recommend use of the Information-Theoretic approach and selection from a set of *a priori* candidate models for any further analyses.

From the mixed approach, three models equally well described the preferred habitat. The explanatory variables of the preferred models were:

(i) the number of 1080 meat baits delivered per hectare (an increased number of baits was correlated with quokka presence);

(ii) the average age of the swamp in terms of years since last burn (there was a positive correlation between years since last burn and quokka presence);

(iii) a habitat factor score (NJF4) (characterised by possessing large areas of *Taxandria* swamp burnt five to nine years previously – positively correlated with quokka presence);

(iv) a habitat factor score (NJF2) (characterized by a high proportion of jarrah – marri open forest and *Taxandria* swamp burnt 15–19 years previously – this variable was negatively correlated with quokka presence); and

(v) increasing distance to anthropogenic disturbance.

Hayward (unpublished, reported in summary in de Tores et al. 2004) concluded these features highlight the importance of a mosaic of age classes within the swamp. This mosaic needs to support early (< 10 years post-fire) and late (long unburnt) seral stages. The intermediate seral stage (15–19 years post fire) is avoided. Therefore, this is a mosaic of specific age classes (young and old) rather than simply a mosaic of mixed age classes. We recommend adopting an active adaptive management program to determine whether conservation management of the quokka can be improved, through the use of fire, to create and maintain this preferred mosaic (see management recommendations section).

The relative importance to the quokka of plant species adapted to different fire intervals also needs to be assessed. For example, species such as *Taxandria linearifolia* will rapidly generate from root stocks and provide a dense cover within one year post a spring fire (Kimber 1974), whereas many other species from riparian zones generate from seed and are adapted to longer intervals between fire (Abbott 1999; Burrows & Wardell-Johnson 2003). Potential conflict with other conservation management priorities must also be addressed. For example, riparian systems supporting quokka populations may also support fire sensitive relictual plant taxa and communities (Burrows & Wardell-Johnson 2003). Therefore, we caution that any imposed fire regime and adaptive management approach should be supported by an appropriate level of monitoring of all species potentially affected by the regime.

Although present in the northern jarrah forest, the habitat occupied there suggests the quokka is not a forest-dwelling species, or more specifically, is not a species of the more open northern jarrah forest. Historic accounts of the appearance of the south-west forests and the pattern of burning by Noongar people in northern jarrah forest have been interpreted by Hallam (1975) as indicating the forests '*comprised tall, straight, mature trees, all frequently scorched but clear of undergrowth and easy to move through*'. If the forest structure was as described by Hallam (1975), it would not have been

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conducive to a contiguous distribution of a species dependent upon swamp and creekline vegetation and may have restricted the quokka to discrete catchments, with minimal dispersal and movement of individuals between catchments.

In southern forest areas, populations appear to be less discrete and the quokka inhabits a broader range of habitats including ti-tree thickets in the upper reaches of creek systems, dense streamside beds of rushes, karri regrowth, ridges supporting karri and tingle, *Eucalyptus guilfoylei* and *E. jacksonii*, forests (Christensen et al. 1985) and occurs widely within forest areas supporting an understorey of spreading sword-sedge, *Lepidosperma effusum*, and *Anarthria scabra* (Greg Freebury, pers. comm. to PJdeT)[12]. Populations from the south coast also appear to be less discrete than the northern jarrah forest populations and occur from Walpole-Nornalup National Park to the Mt Manypeaks area, northeast of Albany (Fig. 3). The extent of mixing (dispersal, immigration and emigration) between sub-populations from the southern forest and the extent of mixing between sub-populations from the south coast areas is not known.

## Population genetics – the northern jarrah forest metapopulation

Hayward et al. (2003) hypothesised the northern jarrah forest formerly supported a metapopulation which is now in a state of 'terminal collapse'. Conversely, results from a study on the genetic structure (Alacs 2001) of the same populations revealed these northern jarrah forest populations showed no evidence of mixing. The latter study suggests these populations may never have constituted a single metapopulation. However, the two findings are not mutually exclusive. Alacs (2001) and Hayward et al. (2003) examined the same geographically separated populations (different catchments) from within the northern jarrah forest. We hypothesise there may have been mixing (gene flow) within catchments, but little or no mixing between catchments. Each catchment may have constituted a functional metapopulation.

Historical evidence from the Swan Coastal Plain is consistent with this hypothesis and suggests the populations from the Coastal Plain were discrete and confined to individual swamps and/or catchments or sub-catchments. We further hypothesise the populations from the northern jarrah forest, although confined to catchments or sub-catchments, mixed with populations from the same catchment on the Swan Coastal Plain. Hence metapopulations may have existed, but under this scenario, each catchment or subcatchment would have supported a metapopulation. With progressive fragmentation of suitable habitat in the jarrah forest and on the coastal plain (draining of swamps and increased distances between suitable habitat patches), movement between habitat fragments would have been less frequent and eventually ceased.

## Factors influencing decline of the quokka

Numerous studies have attempted to determine the causes of the widespread decline in Australia's mammalian fauna since European settlement (see for example Burbidge & McKenzie 1989; Calaby & Grigg 1989; Calver & Dell 1998a; Calver & Dell 1998b; Morton 1990; Recher & Lim 1990; Short et al. 2002; Short & Calaby 2001; Smith & Quinn 1996; Wilson & Friend 1999). These reviews have been selective and addressed some, but not all of the plausible causes for decline. In a comprehensive analysis, Abbott (2001b) reviewed the role of fifteen possible causes for the decline of the bilby, *Macrotis lagotis.* His conclusion concurred with Watts (1969) i.e. that the fox was *'the necessary and sufficient factor associated with regional declines'* of the bilby.

Different studies have attributed the decline in distribution and abundance of the quokka to specific, but varying causes. A marked decline of the quokka was recorded during the 1930s (White 1952). Christensen (1978; Christensen 1980b) presented evidence for a decline in a range of mammal species from south-west Western Australia in the period from 1973 to 1978 and believed this decline was the result of an increased level of predation by foxes. Christensen (1978) further suggested this increase in fox predation coincided with a cessation of widespread 1080 baiting for rabbits, which in turn led to a reduction of secondary poisoning of foxes. King et al. (1981) concurred with this belief. The phenomenon of secondary poisoning of foxes was subsequently demonstrated by Algar and Kinnear (1996). Our data suggest a period of marked decline in the extent of occurrence between 1980 and 1992 (Fig. 3). However, this period of decline may be an artefact of the time periods used for mapping. The mapped decline may reflect the decline identified by Christensen (1978).

A widespread decline of many species, particularly in more arid areas, was recorded in the 1880s (Shortridge 1909). However, Shortridge (1909) also noted the mammals of the south-west, to as far north as the Moore River, had not *'disappeared in the same extraordinary way'*. Burbidge and McKenzie (1989) attributed the modern (post 1900) decline of Western Australia's non-volant terrestrial, critical weight range (35 g–5.5 kg) mammalian fauna to environmental changes since European settlement. They believed these changes reduced available productivity by diverting resources to humans and introduced species and reduced vegetative cover through grazing and altered fire regimes. Critical weight range mammals suffered the greatest declines due to their limited mobility and relatively high metabolic requirements (Burbidge & McKenzie 1989). They further identified factors likely to ameliorate susceptibility to decline and believed critical weight range mammal species with the ability to use, or with a requirement for rockpiles were afforded additional protection. Kinnear et al. (1988) had previously identified the predation

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refuge value of rockpiles and subsequently (Kinnear et al. 1998) provided more empirical evidence for this. Burbidge and McKenzie (1989) believed species using burrows, sheltering in hollow logs or to some extent, those with an arboreal habit, would also be afforded protection from predation. We believe the quokka, with a requirement for a vegetation mosaic which includes areas difficult to penetrate, represents a further group of critical weight range mammal fauna benefiting from use of a predation refuge, analogous to the rock wallaby use of rockpiles. However, we caution that although refuges may provide temporal respite from predation, long-term persistence of predation may still lead to local and regional extinctions, despite the presence of refuges.

Burbidge and McKenzie (1989) claimed the arid zone fauna were most at risk and fauna from the mesic zone were somewhat buffered from the changes which resulted in reduced resource availability. The more mesic south-west Western Australian environment may have buffered the fauna from this initial decline. Recent research suggests fauna from mesic areas are no longer secure (Woinarski et al. 2001). Mesic areas may have more available environmental productivity and may tolerate longer periods of the various disturbances responsible for the decline observed in arid areas. However, continued depletion of environmental resources and a reduction in refugia may be contributing to a more modern decline. The decline of the quokka is consistent with this pattern, with the distribution contracting from the more arid northern and west coast areas, while populations from the more mesic southern forest and south coast areas have persisted (Figs 3 and 4).

## Predation by the dingo, European red fox and feral cat and interaction with other species

Three eutherian predators, the dingo, *Canis lupus dingo*, the European red fox, *Vulpes vulpes,* and the cat, *Felis catus,* have been introduced to Australia since the arrival of humans. These eutherian predators acted on a predator-naïve marsupial prey which had not interacted with medium-sized cursorial predators for the preceding 20 000 to 30 000 years (Johnson et al. 1989).

## The Dingo

The dingo was introduced to Australia by Asian seafarers approximately 3 500 to 4 000 years ago (Corbett 1995b). Where present, the primary prey of the dingo is usually medium sized mammals (Corbett 1995a) and large macropods (Corbett & Newsome 1987). However, dingoes will prey upon a wide range of species (Corbett & Newsome 1987; Newsome et al. 1983; Robertshaw & Harden 1985; Thomson 1992; Whitehouse 1977) and the preferred prey in any particular area appears to be determined not only by prey abundance, but by prey availability (Corbett 1995a; Corbett & Newsome 1987; Vernes et al. 2001). In north-west Western Australia, Thomson (1992) found large prey items, mostly kangaroos, featured prominently, with smaller prey items taken less often. Taking smaller prey was associated with a breakdown of dingo packs and an increase in the number of solitary dingoes (Thomson 1992).

In south-west Western Australia, the quokka was common prior to the 1930s and may have been an occasional prey item for the dingo, although the quokka's preference for densely-vegetated habitat may have offered refuge from predation. However, the established presence of the dingo within the region prior to the modern decline of the quokka, implies dingo predation was not the major cause of that decline. Our own observations indicate dingoes are now exceedingly rare in the jarrah forest and are thus unlikely to be generating predation pressure of any consequence on quokka populations. Historically, the dingo is believed to have had little major impact on the majority of Australian fauna with the exception of the Thylacine, *Thylacinus cynocephalus*, and the Tasmanian devil, *Sarcophilus harrisii*, (see Corbett 1995b; Jones 1995; Rounsevell & Mooney 1995).

The impact of the dingo on Australian native fauna may have been minimised through competitive inhibition by the sympatric mesopredator, humans. Similarly, dingoes may exhibit an indirect effect as a mesopredator (Newsome 2001). Dingoes are thought to prey on the European red fox and the feral cat where they occur sympatrically in the Nullarbor region of Western Australia (Marsack & Campbell 1990), however Marsack and Campbell (1990) implied the evidence for this was circumstantial. Thomson (1992), as part of an extensive study in north-west Western Australia, found the feral cat was present as a prey item only once, and the fox was not present at all in the stomach contents from a sample of 95 dingoes. Newsome et al. (1983) recorded the fox and the cat present in 1.6 and 0.3 percent respectively from the stomach contents of 530 dingoes in a trapping and dietary analysis study in south-eastern Australia. The lack of any other comprehensive data supporting the assertion of intraguild predation suggests dingoes are more likely to competitively inhibit foxes and cats than prey directly on them.

## The European red fox

The red fox was introduced to eastern Australia in the late 1860s to 1870s (Rolls 1969; Troughton 1965) and had spread to the south-west of Western Australia by the early 1930s (Gooding 1955; Jarman 1986; King & Smith 1985; Long 1988). The arrival of the fox in south-west Western Australia coincides with the reported decline of the quokka (White 1952) and numerous small to medium size terrestrial native mammals from mainland Australia (Burbidge & McKenzie 1989; Daubney et al. undated; Friend 1990; Jenkins 1974; Richards & Short 1996). Numerous authors have suggested the fox was responsible for this fauna decline, see for example the review by Abbott (2001b). Although it is only relatively recently that the fox has been empirically linked to the suppression of native mammal populations (see Kinnear et al. 1988; Kinnear et al. 1998), it seems very likely foxes were responsible for the initial decline of the quokka on the mainland and have contributed to its continued decline. The abundance of quokkas on Rottnest Island in the absence of foxes (Dunnet 1963; Holsworth 1964; Holsworth 1967; Kitchener 1970; Shield 1959) is consistent with this hypothesis. Further evidence of the effect of foxes on quokkas comes from a series of reintroductions, and ultimate failure, of nearly 700 Rottnest Island quokkas between 1972 and 1983 to a fenced, but not fox-proof, enclosure at Jandakot, near Perth (Short et al. 1992) (Table 8). By 1988 only nine quokkas remained in the 254 ha enclosure. The low survivorship was attributed to predation by foxes and feral cats (Short et al. 1992).

The fox is now generally accepted as a significant predator of medium size terrestrial native Australian mammals. Recognition has been at a national and state level, as demonstrated by the Commonwealth of Australia's *Threat Abatement Plan for Predation by the European Red Fox* (Biodiversity Group Environment Australia 1999) and two recently published state plans for control of the red fox – the *Victorian Pest Management. A framework for Action. Fox Management Strategy* (DNRE 2002) and the *New South Wales Threat Abatement Plan for Predation by the Red Fox* (Vulpes vulpes) (NSW NPWS 2001). Fauna management programs in Western Australia have recognised the importance of fox control and the Western Australian Department of Environment and Conservation (DEC) has implemented a broad scale fox control and fauna recovery program, *Western Shield*. The program is focused on recovery of threatened fauna through effective fox control and translocation of threatened fauna species in the presence of fox control.

The predecessor to *Western Shield* was Operation Foxglove, a large scale experimental 1080 baiting program within the northern jarrah forest of south-west Western Australia (de Tores 1999). The areas baited within the 550 000 ha study area of Operation Foxglove, combined with local baiting at the Gervasse site, include or abutted all but one of the known extant occurrences of the quokka in the northern jarrah forest. The Foxglove baiting program commenced in 1994 and, despite the fact that quokka populations have not shown an increase in abundance since this baiting program commenced (Hayward et al. 2003), we hypothesise the quokka has persisted in the northern jarrah forest as a result of this baiting and further believe effective long term conservation of the quokka requires implementing and maintaining fox control programs (see management recommendations).

## The feral cat

Aborigines from the desert regions of central Australia and central Western Australia believe cats to have either always been present or to have arrived *'from the west'* (Burbidge & McKenzie 1989). Although far from claiming the assertion as definitive, Gaynor (2000) believed this arrival from the west may have been a result of cats escaping from Dutch shipwrecks off the west coast of Australia. Dickman (1996) noted cats could have been introduced to north-western Australia as early as the 16$^{th}$ Century. However, Abbott (2002), from a detailed search of historical records, concluded cats were not present on mainland Australia prior to European settlement. Abbott (2002) presented a compelling argument and conceptual model to support his belief that cats spread from multiple points of introduction at coastal locations in the period 1824 to 1886. Abbott (2002) and others before him (see Morton 1990) also argued there is insufficient evidence to support the assertion that cats were responsible for any mammal extinctions from arid Australia. However, there is general consensus in the literature (see Dickman 1996) to suggest the cat has contributed to the decline of many species. Although there is some empirical evidence correlating the presence of cats with extinctions of critical weight range mammals from islands (Burbidge & Manly 2002) and empirical evidence indicating predation by feral cats led to reduced population sizes of small native vertebrates (Risbey et al. 2000), we caution against inferring a causal relationship between cat predation and fauna extinctions on the mainland generally, and between cat predation and quokka decline specifically.

Abbott (2002), citing Catling , Coman (1991) and Dickman (1996) noted the optimal prey size for cats was approximately 200g. The weight of adult quokkas ranges from 1.6 to 3.5kg for females and 2.7 to 4.2 kg for males (Hayward et al. 2003; Kitchener 1995), which suggests if cats prey on quokkas, predation may be restricted to juveniles, or will favour predation of juveniles. Circumstantial evidence suggests feral cats prey on the young of bridled nailtail wallabies, *Onychogalea fraenata*, (Horsup & Evans 1993) and the brush-tailed rock-wallaby, *Petrogale penicillata*, (Short et al. 1992). More convincing evidence was presented implicating the cat as a significant predator of juvenile and adult allied rock-wallabies, *Petrogale assimilis*, (Spencer 1991). All three species are larger than the quokka (Eldridge & Close 1995; Evans & Gordon 1995; Prince 1995), suggesting cats may well prey on juvenile and/or adult quokkas.

Cats have also been identified as predators of several species of Australian mammals with adult body weights greater than 200 g. For example, cats were responsible for between 25 and 32% of predation events of adult woylies, *Bettongia penicillata*, at translocation release sites in the northern jarrah forest (de Tores 1999) and responsible for predation of adult brushtail possums, *Trichosurus vulpecula*, in the same study (de Tores, Himbeck, MacArthur, Maxwell, White and Rosier, unpublished radio telemetry data). Cats have also been reported as preying on adult rufous hare-wallabies, *Lagorchestes hirsutus*, (Gibson et al. 1994), the burrowing bettong, *Bettongia lesueur,* (Christensen & Burrows 1994), the numbat, *Myrmecobius fasciatus*, (Friend & Thomas 1994) and the western ringtail possum (de Tores 2005). Short et al. (1992) concluded cat predation contributed to the failure of a translocation of the banded hare-wallaby, *Lagostrophus fasciatus*. The above suggests cats prey on a suite of native mammal fauna, inclusive of species larger than 200g and have the potential to prey on quokkas. Short et al. (1992) further concluded direct predation by foxes and cats was a more plausible explanation, than overgrazing by rabbits and other macropods, for the failure of the quokka translocations to Jandakot in the 1970s.

However, the failure of the Jandakot translocations and the suspicion that cat predation contributed to those failures are insufficient to conclude cat predation was responsible for the initial and continued decline of quokka populations on the mainland. Equally confounding is the co-existence of cats and quokkas on Rottnest Island with no discernable reduction in quokka abundance. Similarly confounding is the presence of cats in Tasmania with no discernable reduction in quokka-size prey species.

Molsher (1999) concluded, from an experimental study at Lake Burrendong, New South Wales, interspecific competition between foxes and cats was the most likely mechanism limiting feral cats. Interspecific competition between cats and foxes was also thought to be a possible explanation for the observed increase in cat numbers when fox density was experimentally reduced at Heirisson Prong, north-west Western Australia (Risbey et al. 2000). Such a response (mesopredator release) is a potential outcome of DEC's large-scale fox control and fauna recovery program, *Western Shield*. However, the lack of records of cat predation from Rottnest Island and the absence of evidence to support the assertion that the cat was responsible for other mammal extinctions (Abbott 2002), suggests cats are unlikely to be solely or primarily responsible for the widespread decline of the quokka.

## Other predators and interactions

Other predators are unlikely to have been responsible for the decline in quokka populations. Nocturnal birds of prey are reported to have been responsible for fossil deposits from several cave sites (see Table 1 – owl accumulated fossil deposits). Two owl species from the south-west of Western Australia, the barking owl, *Ninox connivens*, and the masked owl, *Tyto novaehollandiae*, have been recorded taking prey as large as young rabbits (Schodde & Tidemann 1982), so could presumably prey on juvenile or sub-adult quokkas. Although Johnstone (cited as a pers. comm. by Abbott 1999) regarded the barking owl as a species favouring swamps and edges of rivers, it is not a forest species (Abbott 1999) and was not recorded at any of the seventy forest sites surveyed by Liddelow et al. (2002). The masked owl is infrequently recorded in forest (Abbott 1999) and is more common in woodland or at the interface of agricultural land and forest (Liddelow et al. 2002). Therefore, neither species is likely to have been responsible for the decline of the quokka, particularly within forest areas. The presence of quokka bones recovered from a wedge-tail eagle's eyrie on Bald Island (Storr 1965) indicates the quokka may be an occasional prey item of the wedge-tail eagle. However, we caution against inferring presence of a prey species in the diet of a predator equates with a predation induced decline of the detected prey species. The quokka's diurnal use of densely vegetated swamps within forest areas on the mainland (Christensen et al. 1985; Storr 1964b; White 1952), use of Spreading Sword-sedge, *Lepidosperma effusum*, and *Anarthria scabra* habitat within other forest areas and use of heath habitat on the south coast further minimises the risk of predation by eagles.

Large predatory snakes, e.g. the carpet python, *Morelia spilota*, and to a lesser extent goannas, *Varanus* spp., are able to prey upon species such as the southern brown bandicoot, *Isoodon obesulus*, the common brushtail possum, *Trichosurus vulpecula* , the brush-tailed bettong, *Bettongia penicillata*, (de Tores, Himbeck, MacArthur, Maxwell, White and Rosier, unpublished radio telemetry data), the western ringtail possum, *Pseudocheirus occidentalis*, (de Tores 2005) and the tammar wallaby, *Macropus eugenii*, (David Pearson, pers. comm. to MWH)[13] and may also pose a predation threat to sub-adult quokkas. However, these predators have co-existed with the quokka in the south-west of Western Australia throughout the quokkas existence and there is no evidence to suggest they initiated the decline in quokka abundance. The co-existence of high density populations of the carpet python and the tammar wallaby on Garden Island is consistent with this hypothesis.

The feral pig, *Sus scrofa*, an introduced opportunistic omnivore, is present in forest areas of south-west Western Australia and most climatic regions in Australia (Pavlov 1995). In addition to the commercial health risks posed, where investigated, pigs have been found to pose a significant environmental and management problem (Pavlov et al. 1992). Ecological damage associated with pig activity (rooting) in wet tropical forests in Queensland was shown to vary with forest type, with wet sclerophyll forest sites showing the greatest disturbance (Laurance & Harrington 1997). Our observations (MJD in particular) have confirmed the presence of pigs at numerous quokka sites and, although not supported by any quantitative data, there appears to be a trend of increasing occurrence of pig activity and pig abundance at quokka sites in the south-west forests (MJD, personal observations; Graeme Liddelow, pers. comm. to PJdeT). Non-target captures of quokkas at sites trapped for pig control purposes (see records by Liddington and Staines in Table 4 for the years 2001 and 2002) may indicate an overlap of quokka and pig preferred habitat within the south-west forests. The relatively sedentary nature of pigs (Caley 1997; Saunders & Kay 1996) and the potential for pigs to significantly disturb quokka habitat by creating large openings and easier access for foxes, may pose an additional threat to the conservation status of the quokka.

## Climatic influences

The mainland quokka populations appear to have been historically limited to areas of the south-west of Western

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Australia with an annual average rainfall in excess of 700 mm. The current distribution of the quokka closely follows the limit of the 1 000 mm rainfall isohyet and, for all but the eastern extent of the distribution near the Stirling Range National Park, appears to be limited to areas with an annual average rainfall of 700 mm. or more (Figs 3 and 4). This may reflect the quokka's relatively high water requirements (Main & Yadav 1971).

Populations in the vicinity of Stirling Range and Green Range appear to be isolated from all other south coast populations and also appear to be within a lower rainfall zone (Figs 3 and 4). The locations of rainfall recording stations provided by the Australian Bureau of Meteorology (BoM) indicate stations are located to the north and south of the Stirling Range, with no stations in the immediate vicinity of the known extant quokka populations. The Stirling Range may be in a pocket of higher, orographically generated rainfall, not detected by the BoM rainfall recording stations and not reflected in the pattern of rainfall isohyets. This hypothesis is supported by the presence of an isolated population of the red flowering gum, *Corymbia ficifolia*, (Brown et al. 1998) and the occurrence several wet region bird species (Ian Abbott, pers. comm. to PJdeT) in the Stirling Range. The *Corymbia ficifolia* population is 100 km north of its main distribution and the species is thought to be a relic from a past wetter climate (Brown et al. 1998). Further evidence of this orographic effect was provided by Courtney (1993) who prepared a rainfall isohyet map depicting the highest peaks of the Stirling Range as receiving more than 700mm of rainfall annually. The Stirling Range quokka population(s) may have been traditionally isolated or may represent a remnant of a once contiguous population. In either case, the status and security of these isolated populations and the isolated occurrence at Green Range warrant further investigation.

The Rottnest Island population suffers seasonal mortality over summer and this has been attributed indirectly to dehydration (Barker 1961; Holsworth 1964; Main et al. 1959; Packer 1968; Storr 1964b). Nonetheless, quokkas persisted in the fossil record from south-west Western Australia throughout periods of significant climatic variation from warm and wet to glacial aridity. Cook (1960) suggested climate change was the cause of the modern decline of the quokka. There seems to be insufficient evidence to attribute climate change alone as the major cause of the decline of the quokka since the 1930s. However, Balme et al. noted the persistence of the quokka in the fossil record through periods of aridity may have been because the south-west corner of Australia did not experience the extremes in aridity experienced by other parts of southern Australia. Therefore, the consequences of increasing aridity associated with current patterns of climate change should be seen as a potential threat to the continued persistence of the quokka.

## European colonisation and development

Reports from naturalists in the early 1900s indicated the quokka was common prior to and until the 1930s (Gould 1863; Shortridge 1909; White 1952) and, with very few exceptions, most reports suggest quokkas were restricted to specific habitats (see Holsworth 1967; Storr 1964b). Much of the coastal heath and shrubland habitats in the south-west of Western Australia where quokkas once occurred (Shortridge 1909; White 1952) have been cleared for urban development. The coastal plain, from north of Perth to Busselton (Fig. 1) has few remaining pockets of undisturbed vegetation and the remaining fragments are small and easily invaded by introduced predators. The areas known to have historically supported quokka populations from the Swan Coastal Plain were swamps or low lying seasonally waterlogged areas. These coastal plain swamps have been progressively drained, with very few retaining their original drainage patterns. Similarly, the upper reaches of many creek systems in the forested areas of the Darling Range have been cleared for agriculture, dammed to supply water to Perth or split from connecting habitat by roads to such an extent that the remaining quokka habitat is highly fragmented and in places may be too small to support viable populations.

Other factors associated with European colonisation may have similarly affected the quokka. Calver and Dell (1998b) believed all mammal species from the south-west forests of Western Australia historically had a wider distribution and suggested the extant mammal fauna may be resilient to changes in forest structure. However, they cautioned this resilience may not be the case and emphasised the importance of experimentally demonstrating that there are no direct and indirect links between forestry practices and declines in distribution and abundance on the suite of resident native fauna from the south-west of Western Australia. Increases in predation rates (Wayne et al. 2000), increases in the area of edge affected habitat (Wilson & Friend 1999), increases in interpatch distances (Hayward et al. 2003) and increases in roading disturbance (Calver & Dell 1998a) may be indirect effects from management of the jarrah forest. The effect of these activities on quokka populations has not been quantified. Roading and other disturbances associated with mining and harvesting, resulting in removal of habitat and alteration of drainage patterns, also have the potential to contribute to increases in interpatch distances. Construction of logging access roads in 2001–2002 in Nairn Forest Block in the southern forest region of south-west Western Australia has been implicated as an example of the detrimental effects from harvesting and the associated roading activities. Post commencement of roading there was an observed increase in the number of reported quokka roadkills. A minimum of 10 quokka roadkills was reported by a single observer within a six month period in close proximity to, and coinciding with roading activity at Nairn Forest Block (John Austin, pers. comm. to PJdeT)[14]. However, there are alternative and equally plausible explanations

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for this increase in observed roadkills. Quokkas may have been attracted to areas of new growth resulting from recent burns of roadside verges. This explanation is also consistent with the quokkas' preference for a vegetation mosaic which includes recently burnt areas (de Tores et al. 2004). Nonetheless, this uncertainty highlights the need to identity the cause of the large number of roadkills and to quantify the direct and indirect effects from anthropogenic disturbance.

## *Fire*

The Noongar people have occupied the south-west corner of Australia for at least the last 40 000 years (Balme et al. 1978; Merrilees et al. 1973) and possibly longer (Turney et al. 2001). In the period prior to European settlement, the Noongar people of the south-west are thought to have burnt the jarrah forest, with low intensity fires, with a minimum fire interval of two to three years in the moist to high rainfall areas, and two to five years in the forest areas with lower annual rainfall and lower fuel accumulation rates (Burrows et al. 1995). Burrows et al. (1995) concluded this pattern of burning would have led to a vegetation mosaic which would have included patches of unburnt forest, with most patches *'being less than 6 years since last fire'* (see also Wilson & Friend 1999). Riparian environments may have experienced longer intervals between fires (Abbott 2000; Burrows & Friend 1998).

Ward et al. (2001) (see also Ward & Sneeuwjagt 1999) believed examining fire scars on grass trees, *Xanthorrhoea* spp., provided a more sensitive technique for determining fire history. From examination of grass trees, Ward et al. (2001) believed Noongar burning, or the pre-European frequency of burning in the jarrah forest, was once every three to four years. Lamont et al. (2003) cautioned that the susceptibility of grass trees to fire, and therefore their ability to reflect fire history, depends on their location in the landscape. Burrows and Wardell-Johnson (2003) further cautioned against interpreting historic patterns of fire on a regional scale on the basis of patterns observed among individual grass trees. The findings of Ward et al. (2001) suggested a shorter interval between fires than concluded by Burrows et al. (1995). However, both studies indicated the frequency of burning in forest areas of south-west Western Australia has changed from the frequency used by the Noongar people. Ward and Sneeuwjagt (1999) further implied these changes also apply to coastal areas. Abbott (2003) suggested the interval between fires set by the Noongar people in coastal areas may have been as short as two to four years.

Alterations to fire regimes following European settlement have been implicated with declines in fauna abundance and range (see review by Wilson & Friend 1999). Burrows et al. (1995) believed three distinct fire regime periods or eras could be defined for the forests of south-west Western Australia post European settlement, namely (i) the first European era (1855–1920) where there was a cessation of Noongar burning practices which led to longer intervals between fires and more intense fires; (ii) the second European era (1920–1965) when forestry practices adopted a policy of fire exclusion. Burning was restricted to strategic buffers and fire suppression purposes. Much of the forest remained unburnt and large high intensity wildfires occurred, fuelled by logging debris and naturally occurring high fuel loads; (iii) the third European era (1965–1995) where fuel reduction burning was based on a six to ten year rotation. Although fire frequency for this period was comparable to the pre-European regimes, fire intensity was higher, fuelled primarily by logging debris (Burrows et al. 1995). Towards the end of this third era, and from 1962 in particular, the area burnt by prescribed fire greatly increased (Lachie McCaw[15] pers. comm. to PJdeT and unpublished data). This was a reflection of the then Forest Department's expanded program of broad-scale burning which commenced after 1954 (McCaw et al. 2005; Wallace 1966).

Although this third 'era' encompasses the period 1980 to 1992, i.e. the period within which our data indicate a large contraction in the distribution of the quokka, no direct causal relationship can be drawn, particularly as the areas of greatest quokka decline are outside forest areas subject to this fire regime. Fire regimes in forest areas post 1995 have been similar to the third European era described by Burrows et al. (1995). Discussions with Departmental operational staff involved in prescription burning, combined with the reported reduction in the extent of the area burnt annually in the south-west of Western Australia, indicated a trend of progressively decreasing prescribed-burn fire frequency in the south-west. The 1998–99 prescribed burn program achieved less than 50% of the planned prescribed burning program and was the lowest achieved since 1961 (CALM 1999). The areas *'prescription burnt'* in the south-west forest regions in 1999–2000, 2000–2001 and 2001–2002 were 134 308, 87 866 and 74 739 ha. respectively (CALM 2000; CALM 2001; CALM 2002). From 2002 on this trend of decreasing area burnt annually has been reversed, with 144 835 ha burnt as part of prescribed burns in 2002–2003 and 192 119 ha in 2003–2004 (CALM 2003; CALM 2004). We caution that increasing the area *'prescription burnt'* alone does not equate with burning to provide the preferred habitat mosaic. Our personal observations (PJdeT) suggest broad scale burning has a tendency to use natural barriers as fire boundaries. The *Taxandria linearifolia* creeklines often act as such natural barriers and the long term effect has been to encroach upon these barriers and progressively reduce the size and extent of the *T. linearifolia* creeklines. This type of encroachment does not equate with providing the burn conducive to maintaining the preferred habitat of the quokka. However, effective use of prescribed burns does provide the opportunity to use fire to create the quokka's preferred habitat mosaic as described by

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Hayward (2002) and Hayward (unpublished, reported in summary in de Tores et al. 2004).

The finding by Hayward (unpublished, reported in summary in de Tores et al. 2004) is only partly consistent with findings from a small-scale study (Christensen & Kimber 1975) specifically examining the effect of fire on the quokka in forest sites near Dwellingup in the 1970s. Christensen and Kimber (1975) concluded quokkas returned to swamps to forage almost immediately after a burn, showed an influx of new individuals (i.e. previously un-trapped animals) and became resident 18 months after the fire. There appeared to be no resident quokka population where vegetative cover was entirely removed by the fire (Christensen & Kimber 1975). An older (unburnt for 15 years) site trapped in that study led the authors to conclude quokkas desert sites unburnt for 15 years and have a preference for a spatial mosaic or patchy burn which provide areas of refuge and areas of foraging habitat (Christensen & Kimber 1975). Hayward (unpublished, reported in summary in de Tores et al. 2004) came to a different conclusion and suggested this 15 to 19 year post-fire component of the mosaic did not represent the upper fuel age of the quokkas preferred mosaic. Hayward (unpublished, reported in summary in de Tores et al. 2004) showed this component of the mosaic was negatively correlated with quokka presence (avoided by quokkas) and the preferred mosaic included an additional component which was long unburnt (see section on habitat use). We therefore suggest a burning regime which will create and maintain the mosaic identified by Hayward (unpublished, reported in summary in de Tores et al. 2004) is required in the northern jarrah forest. This would necessitate different burning regimes from those currently used at quokka sites in the northern jarrah forest (see section on management recommendations).

Small, scattered populations are also likely to be susceptible to stochastic events such as wildfires which may result in localised and more extensive extinctions. Kirke (1983) reported quokkas fleeing from wildfires at Green Range, north of Albany. Similarly, in the Northcliffe area, quokkas observed in large numbers in the 1940s and earlier, and known to feed in paddocks away from vegetated creeklines, were reported as last seen in number at this location when fleeing from a fire in the 1940s (Laurie Wilson, pers. comm. to PJdeT)[16]. Numerous quokkas were also observed in an open paddock after fleeing a wildfire in the Allen Road/Hilltop Road area in Walpole-Nornalup National Park, circa 1987 (John Asher, pers. comm. to PJdeT)[17]. Quokkas are now reported to have repopulated this area and are thought to be in large numbers (Greg Freebury, pers. comm. to PJdeT).

The only known record of occurrence from Karnet Forest Block, west of Jarrahdale, is from quokkas observed fleeing a fire in 1991 (unpublished records from A.N. Start, Table 4). A high-intensity wildfire burnt a large portion of the Stirling Range National Park in November 2000 (pers. obs. of MWH) and numerous quokka deaths were reported. A similar fire in the Stirling Range National Park in 1991 was thought to have been equally damaging to quokkas. However, quokkas were reported to have repopulated burnt areas in subsequent years (Sinclair 1999). A large number of quokka deaths was also recorded as a result of a wildfire in the Nuyts Wilderness area, near Walpole in 2001 (Middleton 2001). Quokkas have subsequently been detected in unburnt patches within the boundary of the Nuyts fire and quokka presence has been inferred at three locations immediately outside the burn boundary. Presence was inferred by detection of scats within typical quokka runways in dense patches of Spreading Sword-sedge, *Lepidosperma effusum*, and *Anarthria scabra* (Greg Freebury, pers. comm. to PJdeT). With the exception of the program established to monitor recovery from the Nuyts fire, the extent of documenting any recovery from these stochastic events has been largely anecdotal.

The quokka appears to be capable of persisting in a fire-prone environment and the absence of low intensity fire from many sites may be a contributing factor to the collapse of the northern jarrah forest metapopulation as described by Hayward et al. (2003). However, there is sufficient evidence from the northern jarrah forest to suggest quokka populations there are dependent on the presence of a structural mosaic which incorporates areas burnt within the previous nine years, but also has a large overall fuel age (i.e. must also include areas long unburnt) (Hayward, unpublished, reported in summary in de Tores et al. 2004).

Further support for the requirement of a mosaic, and not simply a requirement for the presence of fire within the past nine years, is provided by the results from surveys in 1995–1996 (Dillon 1996). From 28 northern and southern forest locations previously known to support quokka populations, nine no longer supported quokkas and seven of these nine sites had been burnt within the previous 10 years (Table 10) (Dillon 1996). Although these areas provide the component of the mosaic which has been burnt within the last 9 to 10 years, they may no longer support areas of long unburnt habitat.

A fire regime of low intensity burns and with a frequency comparable to the third European era of Burrows et al. (1995) may be appropriate to generate the vegetation mosaic preferred by the quokka. However, no single fire regime will benefit all taxa. Of particular concern is the threat to the Noisy Scrub-bird, *Atrichornis clamosus*. The noisy scrub-bird has a preferred habitat of densely vegetated creekline and gully vegetation (Abbott 1999; Burbidge 2003). A too frequent burning regime of creeklines where it and the quokka are sympatric may compromise noisy scrub-bird habitat and *'even a mild fire can render an area unsuitable for many years'* (Burbidge 2003). Although the only known locations where extant populations of the noisy scrub-bird and quokka occur sympatrically are at Two Peoples

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Bay, on the south coast, the noisy scrub-bird has recently been translocated to sites within the northern jarrah forest where quokkas may also occur. Therefore, there is the potential for conflicting fire management requirements at these translocation release sites.

There are also indirect detrimental effects from fire. Christensen (1980a) recorded increases in the predation rate on the brush-tailed bettong following fire. This type of indirect effect may also result in localised increased predation risk for other mammal populations. Kinnear et al. (Kinnear et al. 1988) suggested this type of indirect threat may increase the risk of localised extinctions.

## Hunting by Aboriginal people

Gardner (1957), citing John Lort Stokes, referred to observations of Aboriginal people burning the bush for the purpose of catching snakes, lizards and wallabies. These prey were speared as they fled the burning vegetation. Gould (1863) and Evans (undated) were more specific and noted quokkas were eaten by Aboriginal people. Evans (undated) noted the Aboriginal people from the Northcliffe area supplemented their diet with quokka, kangaroo and marron. Gould (1863) noted quokkas were killed in great numbers at the end of the season by Aboriginal people. Gould's (1863) description of Aboriginal people burning the bush to flush out their prey is consistent with Gardner's (1957) description. The end of the season referred to by Gould (1863) is no doubt a reference to the end of summer, as Meagher (1974), citing numerous historical records, noted towards the end of summer, Aboriginal people set fire to the bush to drive the wallabies from their retreats. Green (1989) referred to use of fire at Bald Head in January (mid summer) to '*burn off the land for wallaby*' and the January reference of '*brought home … three wallaby from Bald Head where the Aborigines had fired the land to hunt*' indicates burning for this purpose was not restricted to the end of the summer season. At other times of the year dogs were used to drive out prey (Meagher 1974).

Although Aboriginal people may have been responsible for exterminating some island populations of macropods (Abbott 1980), there is no evidence to suggest Aboriginal hunting of the quokka contributed to the species' decline.

## Disease

Reports from studies of colonies of captive quokkas show the susceptibility of the species to disease (see Bradshaw 1991). Anecdotal accounts in 1967 suggested a fatal herpes epidemic transmitted by a handler affected a captive quokka colony (Burnet 1968). *Salmonella* infections are common in the Rottnest Island and Bald Island quokka populations but far less so on the mainland (Hart 1977; Hart et al. 1986). Hart (1981) found captured mainland quokkas died within 24 hours of exposure to bags in which Rottnest Island quokkas had been held. These deaths were attributed to infections from *Salmonella meunchen*. Hart (1981) hypothesised these deaths may have been the result of cross infection from use of the Rottenest Island bags, but conceded *S. meunchen* may have been present at an undetectably low level in the mainland quokka population and became lethal only when the animals were stressed through trapping.

Barker et al. (1957) recorded the presence of the parasite *Ixodes australiensis* in mainland populations of the quokka and several other parasites and diseases have been isolated from quokkas.

Mass mortality of quokkas was reported from the Northcliffe area where swamps were reportedly '*full of quokka bodies*' in the early 1920s (George Gardner cited as a pers. comm. by How et al. 1987). How et al. (1987) attributed this to disease. Similarly, there are records of an epidemic within the quokka population in the Warren River area, near Manjimup in 1921 (Aldrich 1921; Lane-Poole 1921; Weston 1921). Unexplained quokka deaths were also reported from Crown reserves in the vicinity of Yallingup in 1933 (Aldrich 1933). Other references (Cook 1960; Perry 1973; Waring 1956; White 1952) also indicated mass deaths occurred as a result of disease in the 1930s. Mass deaths have recently been attributed to surplus killing by foxes (Short et al. 2002).

The decline in arid zone mammals of the late 1800s noted by Shortridge (1909) and reported from the Nullarbor Plain (Richards & Short 1996), has been suggested to be a result of a *'strange virus'* which Richards and Short (1996) suggest, albeit based on anecdotal accounts, may have been the protozoan parasitic disease toxoplasmosis, passed on from feral cats. Toxoplasmosis was first recorded in the Rottnest Island quokkas in 1961 (Gibb et al. 1966) and has been reported in other marsupials including the eastern barred bandicoot, *Perameles gunnii*, (Lenghaus et al. 1990), the western ringtail possum, *Pseudocheirus occidentalis*, (de Tores 2005) and the chuditch, *Dasyurus geoffroii*, (Haigh et al. 1994). Berdoy et al. (2000) noted toxoplasmosis may alter the behaviour of its intermediate hosts and increase its susceptibility to predation.

White (1952) believed fox predation, competition with rabbits, destruction of habitat through clearing and bushfires were supplementary to disease as the causal factor for the quokkas' virtual disappearance on the mainland. Despite the references to quokkas dying from disease in the 1920s (Aldrich 1921; Lane-Poole 1921; Weston 1921) and the 1930s (Cook 1960; Perry 1973; Waring 1956; White 1952), the persistence of quokkas on Rottnest Island and Bald Island during these periods suggests disease was not the major contributor to their decline, or alternatively, if disease was responsible for the decline on the mainland, it did not have the same effect on, or did not reach, Rottnest Island or Bald Island. It was during this period of decline on the mainland in the 1930s when the quokka was no doubt at high density on Rottnest Island, as it was in this period when it was first referred to as a pest on Rottnest Island (Storr 1963).

Although White (1952) believed a decline caused by predation, competition and habitat destruction was supplementary to that caused by disease and Cook (1960) linked the decline of the quokka with disease, Recher and Lim (1990) considered disease to be a contributing, not causal, factor to the decline of the Australia's mammal fauna. Johnson et al. (1989) discounted disease as a factor associated with the decline of critical weight range macropods altogether. Dickman (1992) noted there was no evidence to indicate widespread disease as the cause of the decline of mammals within Australasia. We concur with these authors and suggest there is insufficient evidence to conclude disease alone was the cause of the decline of the quokka. However, we caution against trivializing the potential effects from disease. The 1826 King George's Sound record of Quoy and Giamard noted the quokka specimen described '*was recently dead when we found it, probably from disease*' (Alexander 1916). If disease was the cause of death, it is reasonable to hypothesise disease was brought to King George's Sound by Europeans. Although the Rottnest Island population appears to be secure, its possible exposure to disease as a result of human contact should be seen as a potential threat. Introduction of a disease, or a single catastrophic event, could result in a chance extinction of this insular population.

## Management recommendations

### *The northern jarrah forest*

We recommend an active adaptive management approach for conservation management of the quokka within the northern jarrah forest. The active adaptive management approach requires implementing an agreed experimental approach (i.e. agreed to by all stakeholders), whereby a set of models and management actions have been formulated and appropriate monitoring protocols established. We believe monitoring should be focused on examining the response of the quokka to a variety of management practices.

Quantified data has shown the northern jarrah forest populations are at low density. Despite the presence of fox baiting, these populations have not responded and predation is still potentially limiting population response. Based on the rapid rate of fox re-invasion of the northern jarrah forest post aerial baiting events (de Tores 1999), the lower probability of survivorship of the woylie, *Bettongia penicillata*, in treatments baited four times per year compared with six times per year, and the significantly lower levels of survivorship in areas abutting agricultural land (de Tores 1999), we recommend the active adaptive management program incorporates an assessment of the effectiveness of an increased frequency of 1080 baiting.

The northern jarrah forest populations are highly fragmented, the populations are not mixing and the preferred habitat within the *Taxandria* swamps is a complex mosaic of recently burnt and long unburnt areas. An additional requirement of the preferred mosaic is to have a minimal area burnt 15 to 19 years previously. The preferred spatial configuration of these seral stages is not known – specifically, the relative proportion of each required seral stage is not known and the upper limit of 'time since last fire' , i.e. the maximum period of time without fire within the long unburnt component of the mosaic, is not known. Fire management practices which selectively burn long unburnt components of the mosaic may be detrimental to the long-term conservation of quokkas in the northern jarrah forest. This practice has the potential to increase fragmentation of quokka habitat by removing a component of the preferred mosaic. This practice should not be seen as a method for creation of quokka habitat, and, at best, constitutes a program more akin to a trial and error approach than an adaptive management program.

Therefore, we recommend the active adaptive management program should assign high priority to spatial analyses of existing, historic and potential quokka sites in the northern jarrah forest, with the objective of stratifying the existing *Taxandria* mosaic (with strata based on the number of years post fire) and determining whether any of these swamps can be better managed through the use of fire. Under this scenario, fire would be used to create the preferred mosaic. We also recommend monitoring should incorporate genetic analyses to test the northern jarrah forest metapopulation hypothesis. We further advocate any monitoring program associated with quokka conservation needs to incorporate a component to enable quantitative assessment of pig damage to quokka habitat. Although we advocate use of conventional trapping techniques to determine quokka abundance, we caution against the overuse of invasive trapping and strongly recommend use of alternative methods where applicable. These methods include molecular techniques (Alacs et al. 2003). We also recommend development of techniques to quantify abundance based on the extent of activity in quokka-like runways. Currently assessment of activity in runways can measure activity levels only and should not be extrapolated to infer abundance. Further development of the technique adopted by Hayward et al. (2005) is recommended.

The active adaptive management program should specify quantifiable conservation outcomes. Such measurable long-term conservation outcomes include determining:

- the number of known extant quokka sites where the preferred structural mosaic has been established through the use of fire;
- the number of new sites where the preferred structural mosaic has been created through the use of fire;
- the number of sites where quokka populations remain stable or show an increase in abundance (as measured through survival analyses and population estimates, respectively);
- the number of sites currently thought to be supporting potentially suitable habitat, where quokka presence has not been detected/confirmed, and where, post habitat manipulation, quokka presence is confirmed and a population established;

- the number of sites where population mixing has been confirmed (i.e. sites where animals have been known to disperse to and where the source site is still viable [the source sites can be identified through the use of molecular techniques, and population viability can be determined by conventional monitoring [trapping] and population modeling]).

### The Swan Coastal Plain

High priority is recommended to unambiguously determine quokka presence at Muddy Lake and the water authority reserve near Dunsborough. If presence is confirmed, we recommend a monitoring program be implemented to ensure any trend of increase or decrease in population can be detected. The requirement for introduced predator control and habitat manipulation should also be assessed. Minimal data were available on quokka presence elsewhere on the Swan Coastal Plain. We recommend a review of the former known locations from the Swan Coastal Plain (historically these were swamps), assessment of quokka presence at these sites and examination of the effects from draining these swamps. If appropriate, and where possible, the conservation value of re-instating former drainage patterns should be examined.

### The southern forest and south coast

The dearth of information on the size of each population/ sub-population from the southern forest and south coast areas should be addressed. We recommend an initial approach of confirming presence, through trapping, at sites where quokkas are thought to occur. We further recommend undertaking spatial analysis of these extant populations and locations of known and potentially suitable habitat in conjunction with a survey and monitoring program to assess population size. The extent of dispersal/immigration/emigration between habitat patches should be quantified to determine whether the sub-populations constitute a functional metapopulation, discrete sub-populations or a panmictic population. This process would enable populations of high conservation value to be identified, where conservation value is assessed in terms of the population's strategic value locally, regionally and globally as determined by its geographic location, demographics, genetic structure and importance as a source population for re-stocking other populations/ subpopulations.

As a matter of urgency, we recommend a more rigorous and strategic approach be implemented to assess the potential effect from timber harvesting and associated operational activities. Assessment should identify the extent of quokka habitat to be modified, destroyed or retained by each proposed operation, the size of the population(s) affected by the proposed operation, the conservation significance of the population, the potential for dispersal, numbers likely to disperse and dispersal patterns, availability of suitable habitat within dispersal distances, population size within areas of suitable habitat within dispersal distance and the potential effect on these populations.

We recommend investigation of the population(s) from the Stirling Range to assess the security of these populations. Survey is recommended to assess population size, habitat used and the security of this habitat from stochastic events, in particular from wildfire. We also recommend examination of the genetic structure to determine whether the Stirling Range and Green Range population(s) was, or is still, contiguous with other south coast populations.

## CONCLUSION

The distribution of the quokka appears to have been traditionally limited by climate and by rainfall in particular. Reduction in availability of suitable habitat, in conjunction with predation and changed fire regimes, appear to have limited this distribution, or more specifically has further confined the quokka to specific habitats within the limits of its geographic range.

For the quokka, like numerous other native mammal species, the arrival of Europeans to Australia coincided with a slow but continual decline in abundance and range (Fig. 3). From 1900 in particular, the increasing human population in the south-west of Western Australia resulted in anthropogenic disturbances including vegetation clearance, logging, mining, hunting and changed fire regimes. Introduced predators have been implicated in 40% of historic extinctions (Caughley & Gunn 1996) and it seems likely that predation pressure from the introduced red fox, in conjunction with continued habitat alteration through fire exclusion and colonisation, further compromised the conservation status of the quokka.

However, the quokka, like many Australian native mammals (Wilson & Friend 1999) appears to be resilient to individual disturbance factors but also appears to be increasingly susceptible to the cumulative effect of multiple factors. None of these factors has occurred in isolation. Many commenced more or less in synchrony with the arrival of the fox (Recher & Lim 1990) and all continue to operate.

Although there is considerable agreement that multiple factors combined to contribute to the decline, there is also considerable disagreement as to the ultimate cause of the decline of critical weight range mammals since European arrival (see Burbidge & McKenzie 1989; Lunney et al. 2001; Morton 1990; Recher & Lim 1990; Short et al. 2002; Short & Calaby 2001; Smith & Quinn 1996; Wilson & Friend 1999). Abbott (2001b) concluded the fox was the primary agent responsible for the decline of the bilby. However, a single explanatory hypothesis to account for past and continuing declines is unlikely to be applicable to all species and it would seem logical that each species is affected to a differing degree by each factor. Similarly, the relative importance of any factor will vary spatially for each species. Kinnear et al. (2002) proposed two hypotheses, niche loss/damage and predation, to account for the initial and continued decline of Australia's critical weight range mammal fauna. The hypotheses are not necessarily mutually exclusive (Kinnear et al. 2002). There is a wealth of evidence linking two factors to the decline of the quokka; predation and a loss of the quokkas' preferred habitat mosaic. The latter equates with the niche loss/damage hypothesis proposed by Kinnear et al. (2002). We believe the two hypotheses, niche loss/damage and predation, when acting in concert, are sufficient to account for the pattern of decline of the quokka.

Islands, although not immune from disturbance factors, often act as refuges for threatened species largely because the factors responsible for the decline on the mainland are often absent from islands (Dickman 1992). The quokka population on Rottnest Island may provide clues to the significance of the various disturbance factors which led to its decline on the mainland. Compared to the mainland, the Rottnest Island population has a higher susceptibility to disease (*Salmonella*) (Hart et al. 1986), encounters seasonal aridity leading to summer mortality (Hodgkin & Sheard 1959; Shield 1964) and a period of anoestrus (Shield 1964). Rottnest Island and mainland south-west Western Australia have experienced the effects of development and have been subject to extensive habitat fragmentation. The success of the quokka population on Rottnest Island, despite these disturbances, suggests the species is quite resilient. With respect to disturbance factors, the most significant difference between Rottnest Island and the south-west mainland appears to be the presence of the fox on the mainland. Recent interesting advances in our understanding of the effect of the fox on native fauna reinforce this conclusion. The predation efficiency of foxes combined with the inadequate anti-predator defences of a predator-naïve fauna may lead to *'high and unsustainable'* levels of predation (Short et al. 2002). Short et al. (2002) concluded this is the case for the Australian mammal fauna which has evolved in relative isolation since the break-up of Gondwana 50-60 million years BP (Heatwole 1987). Short et al. (2002) further concluded surplus killing may be an outward sign of this mismatch and provided case studies to support their assertion that the declines of many prey species, and in particular those species with limited refugia, may be a result of surplus killing by foxes.

The hypothesis that species with little or no refuge would have suffered most from this predation (Short et al. 2002) is consistent with the pattern of decline of critical weight range mammals in the arid zone described by Burbidge and McKenzie (1989). The quokka is now restricted to areas of refuge (islands and dense vegetation on the mainland). The presence of this latter refuge seems likely to have been the sole factor staving off extinction resulting from fox predation and the combined effects of altered fire regimes and habitat loss.

With the continued depletion of resources (nutrients, water, refuge), which have previously buffered the fauna decline in the more mesic areas of the mainland (Recher & Lim 1990; Woinarski et al. 2001), the buffering capability may be in the process of being compromised. Further extinctions may result (Recher & Lim 1990; Woinarski et al. 2001) and the assumption that critical weight range mammals in mesic areas are secure (Burbidge & McKenzie 1989) may no longer be valid.

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Table 1

Fossil and sub-fossil records of *Setonix brachyurus*. The site names are listed in a north to south latitudinal cline and are mapped in Figure 2. Bolding and an asterisk indicate the deposits at that site are considered to be part of the original (modern) mammal fauna as noted by the source for the record or as inferred by the age of the deposit. Bolding only indicates a more subjective assessment of age, where deposits were implied as part of the original (modern) mammal fauna. The abbreviation BP means before present.

| Site name | Location | Description | Comment | Age | Source | Comment on *Setonix* record |
|---|---|---|---|---|---|---|
| **Hastings Cave / Drovers Cave *** | 8 km north east of Jurien, approx 210 km north of Perth | Described by (Lundelius 1957; Lundelius 1960) as entrance formed by collapse of roof. Cave formed from arches developing (coherence) over dissolved aeolian calcarenite (Baynes 1979). | Hastings Cave / Drover's Cave listed by (Lundelius 1957) as representative of Jurien Bay caves. Bone deposits were concentrated near cave mouth (Lundelius 1957) and thought to be derived from owl pellets. Concurs with Baynes (1979). Fragmentation of bones of larger mammals considered to be indicative of mammalian predator accumulation (Baynes 1979), with a minor contribution as a result of human occupation. | 5 900 ± 140 years BP (Lundelius 1960), however Lundelius (1957) reported top most foot of surface deposits to represent fauna prior to effect of introduced species. Also listed presence of rabbits and house mouse and interpreted this as indicating younger deposits. Baynes (1979) listed ages (Hastings Cave) as 400 ± 70 years BP at a depth of 10 mm to 11 400 ± 200 years BP at 2.98m. | Baynes (1979)<br><br>Lundelius (1960)<br><br>Merrilees (1968) | Listed from 1 layer only, mammal occurrences were from deposits considered to less than 1,000 years old and considered to be part of the original fauna<br><br>Lower levels only<br><br>Merrilees noted the only records of *Setonix* from the Moore River – Dongara region are from lower parts of Hastings Cave deposit. However, Jefferys (pers comm. to MWH) subsequently listed *Setonix* occurrence at Echidna Cave (Dongara), an un-named cave near the northern boundary of Nambung National Park, House Cave (Moore – Dongara river area), Greensand Cliffs (Gingin) and McIntyre Gully (Gingin) |
| **Yanchep *** | North of Perth | A complete quokka skeleton recovered in 1965 registered with the WAM as part of the fossil collection. | | The skull was penetrated by a small iron stake implanted during the animal's life time, thereby inferring persistence of quokkas in Perth area in modern times | (Merrilees 1965) | Skeleton with iron rod through skull |
| Orchestra Shell Cave | Wanneroo, North of Perth. Location noted as approx 16km south of Yanchep cave described by Lundelius (1957) | 4 stratigraphic levels, progressive faunal impoverishment towards top. | Lair, deposits presumed to be accumulated by *Sarcophilus*. | not specified | Archer (1974b) | Lower two levels |
| Murray Cave | Approximately 40km north of Perth | Considered to represent a carnivore's accumulation, typical of *Sarcophilus* | | 3 090 ± 90 years BP. Contains youngest dated occurrence (from charcoal at 1–7cm depth) of thylacine | (Archer 1974a) | |
| **Rainbow Cave *** | 1 km inland, 1.5km south of the mouth of the Margaret river, south-west Western Australia | Collapsed limestone cave, 30m deep, 15m wide | | Lilley (1993) aged at 340 ± 45 years BP at depth of 5–10cm; 790 ± 50 years BP at depth of 25–30cm; 8340 ± 45 years BP at depth of 35–40cm; 4150 ± 70 years BP at depth of 70–75cm; and a second age of 1030 ± 50 | Lilley (1993) | At depths of 10,15, 25, 35, 50 and 75cm. Deposits above 30cm are therefore presumably from the modern fauna |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | years BP was determined at depth of 25–30cm | | |
| Mammoth Cave | Margaret River area, south west Western Australia | Was the first cave in Western Australia to yield fossil vertebrate remains & described by Glauert (1948). Originally recognised as having two stratigraphic units: a yellow-red sand layer above coarse red sand. Both layers capped with travertine (Lundelius 1960). Remnants of a previously longer tunnel in calcareous aeolianites | Deposits considered by Glauert (1948) to be water lain. Merrilees (1968) considered deposits were more consistent with talus and not water transported as suggested by Glauert | Lundelius (1960) dated deposits from the upper sand layer as greater than 37 000 years BP. Merrilees (1968) dated upper parts of deposit as 31,000 years BP | Glauert (1948)<br>Cook (1963)<br>Merrilees (1968)<br>Lundelius (1960) | |
| Margaret River caves | | not described | Glauert (1926) referred to collections from 'certain caves near the Margaret River in the extreme South-West'. Location taken nominally here as Mammoth Cave | Pleistocene | Glauert (1926) | |
| Harley's Cave | Cape Leeuwin – Cape Naturaliste region, south west Western Australia | not described | Listed by Merrilees (1968) as representative of specimens collected by Lowry (1967) from surface litter from caves in Cape Leeuwin–Cape Naturaliste region. However, no indication of these collections being made by Lowry (1967) who discussed geomorphology | Listed as fauna characteristic of the region for some hundred to a few thousand years prior to European settlement | Merrilees (1968) | |
| Lake Cave | Margaret River area, south west Western Australia | not described | | not given | Glauert (1948) | |
| **Devil's Lair, or Nannup Cave of Lundelius (1960; 1966) and Cook (1960). *** | South west of Witchcliffe, south west Western Australia | Small cave in aeolian calcarenite. Travertine floor over red clayey sands thought to be washed in. Deposits described from two levels: immediately below travertine floor; and at depth of 4 feet. | Deposits considered (Lundelius 1960) to be a result of *Sarcophilus*, hence the name Devil's Lair. Dortch and Merrilees (1971) described as artefacts and food remains presumably left as a result of Aboriginal use of the cave. Some remains may have been left by *Sarcophilus*. Baynes et al. (1975) considered upper layers may have been accumulated by humans and believed *Sarcophilus* was responsible for subsequently 'working over' the deposits. | Surficial layers described as recent as 320 years BP. Other deposits extending to 35,160 years BP Balme et al. (1978). Lundelius (1960) dated the upper level 8,500 ± 160 years BP, with deposits at 4 feet as 12,175 ± 275 years BP Dortch and Merrilees (1973) listed uppermost stratigraphic unit to be less than 12,000 years old, with other major stratigraphic units as 19,000 – 25,000 years old and the bottom deposit more than 31,000 years old. Subsequent dating techniques supported these dates for upper layers and indicated lower levels may be in excess of 40,000 years old (Turney et al. 2001). | Dortch and Merrilees (1971)<br>Dortch and Merrilees (1973)<br>Lundelius (1966)<br>Balme et al. (1978)<br>Baynes et al. (1975)<br>Lundelius (1960)<br>Cook (1960) | <br><br><br>Represented consistently throughout deposit (all ages)<br>Deposits considered to be part of the modern fauna (occurring in the area immediately pre European arrival)<br>Both levels<br> |

**Table 1** (cont.)

| Site name | Location | Description | Comment | Age | Source | Comment on *Setonix* record |
|---|---|---|---|---|---|---|
| Strong's Cave, or Strongs' Cave of Cook (1963) | 7 miles south of Mammoth Cave | As for Mammoth Cave has a complex development history. Main deposits in entrance chamber. Has talus slope undermined by stream action & central portion of talus collapsing. Material washed and transported by stream and then mixed with sedimentary deposits | | Central portion of talus slope has more recent, young deposits, but excavations from stream bed considered older, but younger than Mammoth Cave. Some of Mammoth Cave deposits not present in Strong's Cave also imply Strong's Cave deposits may be younger | Cook (1963)<br>Merrilees (1968) | Teeth only |
| **Two small un-named caves (Cave 1 and Cave 3)** | Near Turner Brook, Augusta | Surface/sub-surface cave deposits within 8cm of surface (Cave 1) and 13cm of surface (Cave 3) | Deposits included unworn *Sarcophilus* teeth with poorly formed roots. Interpreted as juvenile animals. This, combined with known geographic range of medium size owl species and the inaccessibility of caves, suggests deposits a result of owl predation. | 430 ± 160 BP based on radio carbon dated hair from Cave 1. Cave 3 may be older. Neither cave had deposits of the introduced mammals (house mouse, black rat or rabbit), all of which may have arrived post accumulation of deposits | Archer and Baynes (1972) | Present in Cave 3 only |
| Bride's Cave | Margaret River area, south west Western Australia | not described | | not given | Glauert (1948) | |
| Skull Cave | Cape Leeuwin region of south west Western Australia | Comprised of a large main chamber with partially collapsed roof and a smaller chamber leading from western part of main chamber. Both chambers partially filled with sandy sediments, possibly washed in | May have functioned as a pit trap with additional deposits resulting from use by owls | Upper layer (21–28cm) aged at 2,900 ± 80 years BP Intermediate layer (100–115cm) 7,875 ± 100 years BP. Depth of 190cm considered late Pleistocene | Porter (1979) | Present at depths to 170cm |
| Scott River | Coastal dunes south of the Scott River | Exposed fossil soils and surface deposits from mobile-partly stabilised sand dunes | | not given, presence of fox and rabbit remains imply deposit is mix of fossil and modern animal remains | Butler (1969) | |
| **Scott River Area *** | Between Ledge Point and Black Point | Bones collected from sand dunes | collected in period 12 March 1976 to 22 March 1976 | not dated, presumably sub fossil or recent. Presence of rabbit remains with other specimens implies these are recent (part of the modern fauna) | Kabay and Start (1976) | Presumably sub fossil or recent |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Warren River / Donnelly River area** | Described as bounded by the Warren and Donnelly rivers, the south coast and Vasse Highway. Bone material from Yeagerup Sand Dunes | Specimens collected from sand dunes | collected in period 27 to 31 May 1976 | not dated, presumably sub fossil or recent | Kabay and Start (1976) | Presumably sub fossil or recent |
| **Norman's Beach / Plantagenet** | Sand blowout south of Plantagenet location 4348 and 1 km east of Norman's Beach | described only as bone(s) collected | collected in period 15 to 20 August 1976 | not dated, presumably sub fossil or recent | Kabay and Start (1976) | Presumably sub fossil or recent |
| **Walpole** | Described as coastal sand blow out, Walpole area | Species listed as obtained in sand dunes | collected in period 15 to 20 August 1976 | not dated, however the presence of rabbit and fox remains with other specimens collected implies these are recent deposits (part of the modern fauna) | Kabay and Start (1976) | Presumably sub fossil or recent |
| **Two Peoples Bay Nature Reserve** | East of Albany | Species listed as obtained in sand dunes | collected in period 23 April 1976 to 5 May 1976 and 15 to 20 August 1976 | not dated, presumably sub fossil or recent. Presence of rabbit remains with other specimens implies these are recent (part of the modern fauna) | Kabay and Start (1976) | Presumably sub fossil or recent |
| **Plantagenet** | Sand dunes, south of Plantagenet Location 4130 | described only as bone(s) collected | collected in period 15 to 20 August 1976 | not dated, presumably sub fossil or recent | Kabay and Start (1976) | Presumably sub fossil or recent |
| **William Bay National Park** | | Species listed as material picked up in sand dunes | collected in period 4 to 10 February 1976 | not dated, presumably sub fossil or recent | Kabay and Start (1976) | Presumably sub fossil or recent |
| **Boat Harbour** | Sand blowout at Boat Harbour east of Reserve 7723 | described only as bone(s) collected | collected in period 15 to 20 August 1976 | not dated, presumably sub fossil or recent | Kabay and Start (1976) | Presumably sub fossil or recent |

Table 2

Australian Museum records of the quokka, *Setonix brachyurus*. Additional records by Masters lacking location records are not shown.

| Year of collection | Location | Collector | Form of specimens | Comments | Australian Museum Registration number |
|---|---|---|---|---|---|
| Undated | Rottnest Island | | brain in Formalin | | M 18429 |
| Undated | Rottnest Island | G. P. Whitley-Staff | skull and mandibles | Shown as G. P. Whitney-Staff in Australian Museum database | S 1936 |
| Undated | Rottnest Island | G. P. Whitley-Staff | skull only | Shown as G. P. Whitney-Staff in Australian Museum database | S 1937 |
| Undated | Rottnest Island | G. P. Whitley-Staff | skull, odd mandible | Shown as G. P. Whitney-Staff in Australian Museum database | S 1938 |
| Undated | Rottnest Island | Taronga Park Trust | skin | | M 7994 |
| Undated | Rottnest Island | Taronga Park Zoo | skin skull | | M 8177 |
| 1866 | King George's Sound | Masters | mount | Year of collection nominally shown here as 1866, as Masters is known to have collected in King George's Sound area from Jan to April 1866 (Abbott 1999; Glauert 1950) and Sept 1868 to April 1869 (Glauert 1950), however this record not listed by Krefft (1867; 1869). No co-ordinates listed, co-ordinates for Albany used, however Masters known to have collected as far north as the Pallinup River (Salt River) (Glauert 1950) and the Stirling Range (Abbott 1999) | P 1048 |
| 1866 | King George's Sound | Masters | mount | See comment for record P 1048 | P 1049 |
| 1866 | King George's Sound | Masters | spirit | See comment for record P 1048 | P 1060 |
| 1866 | King George's Sound | Masters | spirit | See comment for record P 1048 | P 1061 |
| 1866 | King George's Sound | Masters | spirit | See comment for record P 1048 | P 1062 |
| 1920 | Nornalup near Denmark | A. S. Le Souef | skin skull | Year of collection not listed. Nominally listed here 1920 as Le Souef known to have collected in Porongurup area in 1920 (Abbott 1999). Co-ordinates map to Southern Ocean, directly south of Nornalup Inlet and Walpole, corrected to map near Nornalup | M 4212 |
| 1920 | Nornalup, near Denmark | A. S. Le Souef | skull only | No co-ordinates with this record, corrected co-ordinates for Le Souef record (M 4212) used. Other comments for record M 4212 apply. | S 1799 |
| 1920 | Nornalup, near Denmark | A. S. Le Souef | skull only | No co-ordinates with this record, corrected co-ordinates for Le Souef record (M 4212) used. Other comments for record M 4212 apply. | S 1800 |
| 1921 | King River, 10 miles from Albany | E. Le G. Troughton J. Wright | skin skull | Shown as LE G. Troughton in Australian Museum database | M 3083 |
| 1921 | King River, 10 miles from Albany | E. Le G. Troughton J. Wright | skin skull | Shown as LE G. Troughton in Australian Museum database | M 3084 |
| 1921 | King River, 10 miles from Albany | E. Le G. Troughton J. Wright | | Shown as LE G. Troughton in Australian Museum database | M 3085 |

| | | | | | |
|---|---|---|---|---|---|
| 1921 | King River, 10 miles from Albany | E. Le G. Troughton J. Wright | skin skull | Shown as LE G. Troughton in Australian Museum database | M 3086 |
| 1921 | Princess Royal Bay, Albany | E. Le G. Troughton J. Wright | skin skull | Shown as LE G. Troughton in Australian Museum database. Co-ordinates (35 deg 3 min South and 117 deg 53min East) map to within Princess Royal Harbour, corrected to map to map on Princess Royal Harbour foreshore near Albany townsite | M 3087 |
| 1935 | Rottnest Island | S. Larnach | spirit | | M 18214 |
| 1935 | Rottnest Island | S. Larnach | spirit | | M 18215 |
| 1935 | Rottnest Island | S. Larnach | spirit | | M 18216 |
| 1935 | Rottnest Island | S. Larnach | spirit | | M 18217 |
| 1935 | Rottnest Island | S. Larnach | spirit | | M 18218 |
| 1935 | Rottnest Island | S. Larnach | spirit | | M 18219 |
| 1961 | Rottnest Island | Taronga Park | skin skull | | M 9056 |
| 1987 | edge of Lake Bagdad, Rottnest Island | Gavin Gattenby | skeleton | | M 18626 |
| 1997 | Rottnest Island | E. Dovey | skull | | M 33146 |

Table 3

Published records of occurrence of the quokka, *Setonix brachyurus*. Records are listed chronologically.

| Year of record | Location or Site name | Source | Comment |
|---|---|---|---|
| 1658 | Rottnest Island | Samuel Volckersen (Volckertzoon), cited by (Alexander 1914) Glauert (1950) | Considered the first record of quokka sighting by a European and only the second record of a marsupial from Australia by a European |
| 1696 | Rottnest Island | Willem de Vlamingh, cited by (Alexander 1914) Glauert (1950) | Mistook the quokka on Rottnest island for ' … A kind of rat as big as a common cat … ' |
| 1801 | Rottnest Island | M. Freycinet,, cited by Alexander (1916) | M. Freycinet, observed a quadruped 'which the old Dutch navigators actually mistook for a rat' |
| 1826 | King George's Sound | Records of Quoy and Gaimard as cited by Alexander (1916) | Reported the new species, the specimen described as recently dead and ... 'probably from disease' |
| 1829 | King George's Sound | Scott Nind, cited by (Alexander 1916) and Glauert (1950) | Scott Nind, medical officer at the King George's Sound penal settlement recorded the presence of the quokka |
| 1829 | Rottnest Island | Dr T.B. Wilson, cited by Alexander (1918) | Dr T.B. Wilson, visitor to the Swan River Settlement, when visiting Rottnest Island recorded 'the dogs caught two wallabi' |
| 1830 | King George Sound | Walton (1988) | The type specimen of Quoy and Gaimard |
| 1837 | Swan River, Perth | George Gray, cited by | Glauert (1950) reported Gray's list of species from the Swan River. The list included the quokka Kitchener et al. (1978) |
| | | Glauert (1950) | noted Gray's reference to 'Swan River' may have included the Darling Range & the York & Avon River valleys. Nominally mapped as Piesse Brook |
| 1842 | Coastal areas | Gilbert, cited by Gould (1863) | Gilbert found the quokka abundant in all the swampy tracts which 'skirt nearly the whole of Western Australia at a short distance from the sea'. Presumably this was referring to the south west of WA only. Gilbert was known to have visited WA and collected from this area in 1839–1840 and 1842–1843 Abbott (1999). Date nominally listed here as 1842 and locations nominally shown as Albany and Margaret River area |
| 1905 | Bald Island | Shortridge (1909) | see note 1, below |
| 1905 | Rottnest Island | Shortridge (1909) | see note 1, below |
| 1905 | Margaret River, Burnside | Shortridge (1909) | see note 1, below |
| 1905 | Busselton, Yallingup | Shortridge (1909) | see note 1, below |
| 1905 | Albany, King River | Shortridge (1909) | see note 1, below |
| 1905 | Albany, King River | Thomas (1906) | Descriptions of collections made by Shortridge. Listed as collected during end of 1904 and during 1905. Nominally listed here as 1905 and mapped as same location as Shortridge (1909) for King River |

| | | | |
|---|---|---|---|
| 1905 | Albany, Big Grove, King George's Sound | Thomas (1906) | Descriptions of collections made by Shortridge. Listed as collected during end of 1904 and during 1905. Nominally listed here as 1905 and nominally mapped as the between Albany and King River |
| 1907 | Margaret River area | W. H. Loaring, cited by White (1952) | Quokkas recorded as very numerous 1907–1910. Location nominally mapped as creekline in forested area, immediately west of Margaret River |
| 1912 | Irwin Inlet – Mt Frankland area | Diaries of S.W. Jackson, cited by Abbott (1998) | Jackson's diaries for 1912–1913 record '*caught a wallaby in trap*' and sleeping under sword grass here (Deep River) interpreted by Abbott as referring to quokkas. Nominally shown as 1912 and nominally mapped as Deep River. |
| 1919 | Lower Blackwood Valley | Perry (1971) | Recorded the quokka as numerous and frequently seen in the Lower Blackwood valley. Approximate location only |
| 1920 | Margaret River | Hoy, cited by Short and Calaby (2001) | From collections by Charles Hoy, 1919–1922. Hoy collected 9 specimens from the Margaret River area in 1920. With the exception of *Trichosurus vulpecula*, he described none of the collected mammals as plentiful. The quokka was described as seldom seen (due to nocturnal habits). Location nominally mapped as immediately northwest of Margaret River |
| 1920 | Un-named cave near Gingin | Roe (1971) | Roe (1971) recorded this location as a fossil/subfossil record and noted long term residents were aware quokkas (along with boodies, *Bettongia lesueur*, and bilbies, *Macrotis lagotis*) were present in the district until arrival of the fox |
| 1920 | Bickley, Darling Scarp, now considered a suburb of Perth | W. H. Loaring, cited by White (1952) | Noted as particularly plentiful in the early 1920s with extensive runways in thick scrub bordering streams |
| 1920 | Darling Range, Piesse Brook- Bickley | W.H. Loaring in Serventy et al. (1954) | The quokka described to have 'vanished from its gully haunts … 30 years ago'. This record is nominally shown as present here 30 years earlier (1920) and location mapped as Piesse Brook (Piesse Gully) |
| 1922 | Yarloop, Logue Brook, Darling Range between Perth and Harvey | White (1952) | Recorded as numerous in low tangled scrub when author was a schoolboy and still plentiful until 1926 when he left school. Approximate location only, nominally mapped as upper catchment of Logue Brook and date nominally shown 1922 |
| 1929 | Busselton | White (1952) | Recorded as 'in great numbers', location approximate |
| 1929 | Cape Leeuwin – Cape Naturaliste | White (1952) | Recorded as 'in great numbers', location approximate |
| 1920s/ 1930s | Helena River, near Mundaring | Perry (1973) | Recorded as abundant in dense low cover along creeks and river courses from valley of Helena River eastwards. Location identified as Greystones pine plantation which was planted by Dick Perry in the 1920s/1930s and record assumed to be from the 1920s to 1930s (Ian Abbott, pers. com. to PJdeT). |
| 1930 | Northcliffe area | Daubney et al. (undated) | Discussions between one of us (PJdeT) and local landholders plus reports in Daubney et al. (undated) indicate the quokka was considerably more abundant in the Northcliffe area prior to the arrival of the fox. Gladys Buckingham, school teacher in Northcliffe, recalled of the 1930s 'every swamp was a maze of tracks and tunnels of wallabies, quokkas, bandicoots …' (Daubney et al. undated). Location approximate and mapped as immediately east of Northcliffe townsite, date here nominally listed as 1930 |
| 1931 | Vasse Estuary, near Busselton | White (1952) | Quokkas 'in numbers' in low scrub between coastal dunes, location approximate |
| 1932 | Pine plantations, Pemberton | Stewart (1936) | Recorded as responsible for damage to pine plantations within karri forest areas and recorded grazing up to 2 kms from swamps. Location mapped here nominally as pine plantations, immediately east of Pemberton |
| 1932 | Rottnest Island | Storr (1963) | Storr cited H.T.Pearse, as the first reference (1932) to the large number of quokkas on Rottnest Island being regarded as a pest |

Table 3 (cont.)

| Year of record | Location or Site name | Source | Comment |
|---|---|---|---|
| 1933 | Comments on general distribution | Glauert (1933) | Published to indicate the present range (in 1933) of marsupial fauna in Western Australia and as an update to the distributions described by Shortridge (1909). Described distribution of the quokka as extending from Moore River to the south coast and inclusive of Rottnest Island and Bald Island. No reference to the presence on the islands off Esperance as suggested by Shortridge. Described as abundant in suitable swampy localities. Nominally mapped here as Albany and Dwellingup, Holyoake |
| 1933 | Bickley, Darling Scarp, now considered a suburb of Perth | W. H. Loaring, cited by White (1952) | Quokkas still present in gullies in 1933–34 |
| 1933 | Margaret River area | W. H. Loaring, cited by White (1952) | Quokkas reported as far less plentiful than previously recorded in 1907–10. Location nominally mapped as for 1907–1910 and as creekline in forested area, immediately west of Margaret River |
| 1933 | Canal Rocks, near Yallingup | White (1952) | Recorded as particularly numerous in 1933, still present 4 years later, less noticeable within a few years |
| 1954 | Manjimup, Perup area | A.D. Jones in Serventy et al. (1954) | Recognised the area bounded by the Tone and Perup rivers, northward to latitude 34 degrees 12 minutes South was rich in marsupials. Date nominally listed here as 1954 and location mapped as within the Perup Forest, and between Tone & Perup rivers, northeast of Manjimup |
| 1954 | Manjimup, Morallup | A.D. Jones in Serventy et al. (1954) | Record reported to A.D. Jones (in Serventy et al. 1954) as a sighting 10 miles north of Mordallup. Presumably this is a reference to Morallup, which places this record approximately 23km northeast of Manjimup. Date nominally listed here as 1954 |
| 1954 | Comments on general distribution | L. Glauert in Serventy et al. (1954) | Described as plentiful on Rottnest Island and 'some islands off the south coast' and in swampy country in the lower south west. Nominally mapped here as Albany and the Broke Inlet (D'Entrecasteaux) areas, the latter as mapped by Christensen et al. (1985) |
| 1954 | Comments on general distribution (cont) from L. Glauert in Seventy et al. (1954) | L. Glauert in Serventy et al. (1954) | Described as no longer present in the valleys of the Darling Range. Presumably the 'islands' reference is referring to Bald Island, but this may also be a reference to the islands of Esperance which were otherwise referred to only by Shortridge (1909). |
| 1954 | Yarloop, Darling Range between Perth and Harvey | Serventy et al. (1954) | Serventy noted quokkas seen occasionally, with plenty of signs in all swamps. Nominally recorded as 1954. Exact location unclear, nominally mapped as Logue Brook area and the same location as White (1952). Serventy's report appears to contradict the reports of Glauert and Loaring, both also in Serventy et al. (1954), who believed quokkas had vanished from gully haunts of the Darling Range 30 years previously. However, the area referred to by Serventy et al. (1954) is 100km South of the section of Darling Range Loaring and Glauert may have been referring to. |
| 1954 | Manjimup, near Broke Inlet turnoff | Serventy et al. (1954) | Recorded as first record for 10 years. Nominally recorded as 1954, exact location unclear. Possibly referring to the 'Broke Inlet turn-off' from the South Western Highway (Manjimup-Walpole Highway), mapped at this location |
| 1954 | Toolbrunup, Stirling Ranges | Sharman (1954) | Examined quokka chromosome number and urogenital system and compared with related species. Noted quokkas formerly widely distributed, now common only on Rottnest and Bald islands. Noted a skull collected from Stirling Ranges. Location nominally shown as Bluff Knoll, Stirling Range. |

| | | | |
|---|---|---|---|
| 1955 | Walpole | J.A. Rate, cited by Barker et al. (1957) | Capture of an immature quokka. Approximate location only, nominally mapped as within Walpole-Nornalup National Park |
| 1956 | Rottnest Island | Dunnet (1963) | Examined quokka sub populations at Bagdad and Serpentine soaks at eastern/central area of Rottnest Island in the period 1954–1958. Nominally listed here as 1956, see also Dunnet (1962). Estimates of population size were variable and differed between and within sampling periods. Dunnet cautioned these estimates were also subject to bias |
| 1956 | Albany Highway, near Travellers' Arms (southeast of Perth) | R. Aitken, cited by Barker et al. (1957) | Two roadkill records. Location approximate only and identified from map in Sadleir (1959). See 1966 record by Kent Williams (Table 4) and 1996 record by de Tores, Dillon, Tomkinson and Buehrig (Table 6) |
| 1956 | Rottnest Island | Shield (1959) | 450 quokkas sampled in 1956–57 as part of study assessing whether quokka population was limited by environmental/ physiological factors. No estimate of the size of the Rottnest population |
| 1956 | Rottnest Island | Waring (1956) | Noted quokkas known from two off-shore islands only (Rottnest and Bald) and considered the only mainland population to be 'a remnant population in Karri forest' in the south-west. Referred to the Rottnest population as consisting of 'perhaps 5,000 individuals'. |
| 1957 | Byford, Manjedal Brook on the southeast edge of the Perth metropolitan area | Barker et al. (1957) | Three quokkas trapped in the period 8 May to 6 June 1957. Trapping survey initiated in response to a newspaper article which suggested quokkas had become extinct on the mainland. |
| 1958 | Rottnest Island | Herrick (1961) | Examined adrenal function of the quokka and included animals collected from Rottnest Island (Summer 1958) and observations from two sites on Rottnest |
| 1958 | Manjedal Brook, north of Jarrahdale | Storr (1964b) | Study of quokka habitat, no estimates of population size. Presumably the site(s) used by Sadleir (1959) and Barker et al. (1957) |
| 1958 | Rottnest Island | Storr (1964a) | Nutritional study, 511 quokkas caught over unspecified number of monthly visits in 1958. No estimate of population size |
| 1959 | Rottnest Island | Holsworth (1967) | Examined home range and territory use in the period 1954 to 1964. Nominally shown here as 1959. No estimate of population size, however showed variation in the number of individual animals caught from 38 in 1960 to 813 in 1963 |
| 1959 | Bald Island | Storr (1965) | Recorded quokkas as abundant, occurring from sea level to the peak, but density varied greatly |
| 1959 | Waychinicup | Storr (1965) | None trapped or snared, abundant evidence in 'swampy valleys draining into the lower Waychinicup'. Exact location not given, mapped as approximate location only. |
| 1963 | Rottnest Island | Packer (1965) | Observational study in 1963, no estimate of population size |
| 1967 | Rottnest Island | Nicholls (1971) | Caught and monitored 27 quokkas from West End of Rottnest Island to determine home range and movements, 1967–1968. No estimate of population/sub-population size |
| 1969 | Rottnest Island | Kitchener (1973) | Recorded an average of 53 resident quokkas at the Barkers Swamp study site, with average density of 1 quokka per 0.06ha and noted this was considerably greater than the average of 1 quokka per 0.4 – 1.2ha recorded by Main and Yadav (1971). The localised high density at Barkers Swamp was considered to reflect the localised high quality site and the high density was maintained by 'recruitment of considerable number of quokkas into the local population' |
| 1970 | Rottnest Island | Kitchener (1972) | Reported on observed behaviours, interactions and dominance of sub population at Barkers Swamp. Sub population estimated by direct count during nocturnal observations. However, subpopulation estimate not reported |

Table 3 (cont.)

| Year of record | Location or Site name | Source | Comment |
|---|---|---|---|
| 1970 | Darling Range, close to Perth | Ride (1970) | Recorded as rare on the mainland, known only from a few swampy valleys in the Darling Range. Nominally shown here as Dwellingup (Holyoake) where known to occur in the 1970s |
| 1971 | Comments on general distribution | Calaby (1971) | Calaby noted the quokka was known from a few swampy areas on the mainland and was still common on Rottnest and Bald islands. Nominally mapped as Dwellingup, Holyoake |
| 1971 | Rottnest Island | Main and Yadav (1971) | Reviewed the conservation information for macropods from Barrow Island and compared this to other islands. Gave an estimate of quokka population density for Rottnest Island as ranging from 1 quokka per 1.2ha to 1 per 0.4ha. However, no data supplied to show how these values were derived and density may have been determined on basis of the entire island being occupied. Date nominally shown here as 1971 |
| 1971 | Bald Island | Main and Yadav (1971) | Gave an estimate of quokka population size at Bald Island as ranging from 600–1900 quokkas (if entire island was occupied). Qualified, in recognition not all of the island was occupied, to give an upper estimate of 600. Date nominally listed here as 1971 |
| 1971 | Dwellingup | Schmidt and Mason (1973) | Recorded a suite of mammal species in forest near Dwellingup in 1971 and concluded populations were concentrated in swamps and other areas of dense vegetation. Quokkas included in list of species recorded, no site details, nominally mapped here as Holyoake |
| 1972 | Dwellingup, Wrens Road Swamp (east) | Christensen and Kimber (1975) | Population trapped (1972–74) before and after a partial burn. Trap success rate increased after the burn. Indices to abundance imply moderate size population, however no estimate of population size. Date assumed to be 1972, see Christensen (undated) in table of unpublished records |
| 1972 | Albany Highway, southeast of Perth | Crabb (1973) | Roadkill, near the '27 mile peg on Albany Highway' |
| 1974 | Dwellingup, Duncans Road Swamp | Christensen and Kimber (1975) | Population trapped 1972–74. This site unburnt, cf Wrens Road. Trap success comparable to post burn capture success at Wrens Road. Indices to abundance imply a moderate size population, no estimate of population size. Date nominally shown as 1974 |
| 1975 | Karri, northwest of Northcliffe | Christensen et al. (1985) | Listed and mapped by Christensen et al. (1985) as Survey Area L, Karri. See note 2, below |
| 1975 | Yeagarup, between the Donnelly and Warren rivers | Christensen et al. (1985) | Listed and mapped by Christensen et al. (1985) as Survey Area A, Yeagarup . See note 2, below |
| 1975 | Mitchell, north northwest of Walpole | Christensen et al. (1985) | Listed and mapped by Christensen et al. (1985) as Survey Area I, Mitchell. See note 2, below |
| 1975 | Soho, northeast of Walpole | Christensen et al. (1985) | Listed and mapped by Christensen et al. (1985) as Survey Area H, Soho. See note 2, below |
| 1975 | Boranup, south of Margaret River | Christensen et al. (1985) | Listed and mapped by Christensen et al. (1985) as Survey Area D, Boranup. See note 2, below |

| | | | |
|---|---|---|---|
| 1975 | Giants, between Nornalup Inlet and Irwin Inlet, east of Nornalup | Christensen et al. (1985) | Listed and mapped by Christensen et al. (1985) as Survey Area O, Giants. See note 2, below |
| 1975 | Dombakup, west northwest of Northcliffe | Christensen et al. (1985) | One of two sites listed and mapped by Christensen et al. (1985) as Survey Area C, Dombakup. See note 2, below |
| 1975 | Woolbales, southeast of Broke Inlet | Christensen et al. (1985) | Listed and mapped by Christensen et al. (1985) as Survey Area B, Woolbales. See note 2, below |
| 1975 | Dombakup, west of Broke Inlet (D'Entrecasteaux National Park) | Christensen et al. (1985) | One of two sites listed and mapped by Christensen et al. (1985) as Survey Area C, Dombakup. See note 2, below |
| 1975 | Sunklands, south-southeast of Busselton | Christensen et al. (1985) | Listed and mapped by Christensen et al. (1985) as Survey Area E, Sunklands. See note 2, below |
| 1976 | Nannup, Mowen/Stoats Road Crossing | Hart et al. (1986) | Trapped as part of comparative study of *Salmonella* infection. Implied to be at low density |
| 1976 | Muddy Lake, south of Bunbury | Hart et al. (1986) | Trapped as part of comparative study of *Salmonella* infection. Implied to be at low density |
| 1976 | Dwellingup, Holyoake | Hart et al. (1986) | Reported high trap yield (10 animals from 100 trap nights) using elaborate traps comprised of fence lines and enclosures, where multiple trap nights assumed for each trap |
| 1976 | Byford | Hart et al. (1986) | Trapped as part of comparative study of *Salmonella* infection. Implied to be at low density. Presumably same site as trapped by Barker et al. (1957) and Sadleir (1959) |
| 1977 | Dwellingup, Holyoake | Hart et al. (1986) | Reported high trap yield (27 animals from 204 trap nights) using elaborate traps comprised of fence lines and enclosures, where multiple trap nights assumed for each trap |
| 1980 | Bald island | Hart et al. (1986) | 14 quokkas caught from a single one-night trip. No estimate of abundance reported, however population level reported to fluctuate as a result of summer starvation |
| 1983 | Darling Scarp | Dell (1983) | This publication produced to update the Western Australian Museum mammal records with recent observations and review the literature. The quokka was listed as one of several species to have declined. Nominally mapped here as Dwellingup, Urbrae Forest Block |
| 1983 | Green Range, 60km northeast of Albany | Kirke (1983) | Quokkas reported as fleeing from burning bushland. Skeleton subsequently collected. The only record at this location prior to this was from Pearce (1969), see 1969 entry in Table 4, Unpublished Records. |
| 1985 | Waychinicup Inlet, east of Albany | Hart et al. (1986) | Trapped as part of comparative study of *Salmonella* infection. Population implied to be at low density |
| 1985 | Pt D'Entrecasteaux | How et al. (1987) | Survey conducted in the period March 1985, October to November 1985 and January to February 1986. Nominally shown here as 1985. Quokka reported from only 1 of 10 locations surveyed. This record of presence implied by How et al. (1987) to be questionable. Location approximate only |

Table 3 (cont.)

| Year of record | Location or Site name | Source | Comment |
|---|---|---|---|
| 1985 | Pemberton and Dwellingup | Mead et al. (1985) | Animals collected from mainland (Dwellingup and Pemberton) and islands for laboratory assessment of tolerance to 1080. Sample size not specified and no estimate of population size at collection point. Date nominally shown here as 1985. Location mapped nominally as state forest, immediately east of Pemberton and Dwellingup (Holyoake) |
| 1985 | Bald Island | Mead et al. (1985) | Animals collected for laboratory assessment of tolerance to 1080. Sample size not specified and no estimate of population size at collection point. Date nominally shown here as 1985 |
| 1985 | Rottnest Island | Mead et al. (1985) | Animals collected for laboratory assessment of tolerance to 1080. Sample size not specified and no estimate of population size at collection point. Date nominally shown here as 1985 |
| 2000 | Collie, Victor Road, Hamilton Forest Block | Hayward et al.(2003) | Trapped over the period 1998–2000. Population estimated to be 9 +/- 1 (Jolly-Seber mark-recapture derived estimates) |
| 2000 | Collie/Harvey, Hadfield Forest Block | Hayward et al.(2003) | Trapped over the period 1998–2000. Population estimated to be 29 +/- 5 (Jolly-Seber mark-recapture derived estimates) |
| 2000 | Dwellingup, Kesners Swamp, Turner Forest Block | Hayward et al.(2003) | Trapped over the period 1998–2000. Population estimated to be 36 +/- 6 (Jolly-Seber mark-recapture derived estimates) |
| 2000 | Jarrahdale, Chandler Road Site, Chandler Forest Block | Hayward et al.(2003) | Trapped over the period 1998–2000. Population estimated to be 10 (Jolly-Seber mark-recapture derived estimates) |
| 2000 | Jarrahdale, Rosella Road, Gordon Forest Block | Hayward et al.(2003) | Trapped over the period 1998–2000. No population estimate, only one animal trapped |

Notes:

1. Shortridge collected 38 specimens and described the quokka as plentiful among coastal thickets and swamps of the south west, not extending inland. The distribution was recorded as extending from the Moore River in the north, and mapped to include the south coast as far east as Esperance. The eastern extent appears to be based of reports from Twin Peak & other islands off Esperance. This is the only report of quokka occurrence from the islands off Esperance and no collections have been documented from these islands. Shortridge's record is assumed to be referring to tammars, see text.
2. Christensen et al. (1985) from surveys 1970–1982 noted the quokka as widespread and locally common. Estimates of population size were not provided and locations are approximate and remapped from map on p4 of Christensen et al. (1985). Date nominally shown as 1975

Table 4

Unpublished records of occurrence of the quokka, *Setonix brachyurus*. Records are listed chronologically.

| Year of record | Location or Site name | Source | Comment |
|---|---|---|---|
| 1940 | Northcliffe, Bashford Road area, 10km east of Northcliffe | L. Wilson (personal communication to PJdeT) | Quokkas observed in large numbers in 1940s and earlier and known to feed in paddocks away from vegetated creeklines. Reported as 'last seen in number when fleeing from fire' in the 1940s. Location approximate and shown nominally as 1940 |
| 1958 | Rottnest Island | Sadleir (1959) | Conducted a trapping program at the Byford/Manjedal Swamp site on the mainland and Rottnest Island to examine physiological differences between the two populations |
| 1958 | Byford, Manjedal Swamp/Brook | Sadleir (1959) | Trapped at Manjedal Swamp in April – May and September – October 1958. Six quokkas only caught, all in the April – May period |
| 1962 | Rottnest Island | Holsworth (1964) | Trapped in period May 1961 to May 1963 and incorporated data from 1954 to 1961 and from December 1963 to April 1964. Nominally shown here as 1962. Population estimates were derived for 4 areas within the West End only. Each area was comprised of several group territories. Population estimates were described by Holsworth as stable for the period 1955 to 1963, however data indicates large variations in abundance. |
| 1965 | Travellers' Arms, Albany Highway, south-east of the Perth metropolitan area | Kent Williams (pers. comm. to PJdeT) | Quokkas successfully trapped in 1965 at swamp on the opposite side of Albany highway from the Travellers' Arms Hotel. Subsequent trapping in the same year, post fire was unable to confirm continued presence. See record for 1996 (Table 6) when presence at this location was re-confirmed |
| 1969 | Two Peoples Bay Nature Reserve, near CSIRO hut | Bannister (1970) | Reported carcass found in 1969 by N. Robinson, in thick scrub at bottom of a shallow gully, near CSIRO hut. Old evidence and no indication of recent activity when surveyed by Bannister (1970). Location mapped here is approximate |
| 1969 | Rottnest Island | Kitchener (1970) | Estimated a mean monthly population size from a study area comprised of 48 quadrats, each 12m x 12m at Barkers Swamp, near the centre/eastern end of the Island. Estimates derived from data collected in the period December 1967 to December 1969. Listed here as 1969. Estimates were from direct observations and included permanent and temporary residents, recruits and transients. Mean monthly estimate was approximately 45 adults and 13 juveniles within the Barkers Swamp study site. |
| 1969 | Green Range, 50 miles (30km) northeast of Albany | Pearce (1969) | Local landholder recorded the presence of small kangaroos. Subsequent investigation by WA Department of Fisheries Fauna Warden detected spoor consistent with quokka. Drawing of spoor provided in Departmental file – we have presumed this to be a quokka. Presence recorded here in 1983, see 1983 entry in Table 3. |
| 1970 | Two Peoples Bay Nature Reserve, near weather station above CSIRO hut | Bannister (1970) | Unable to confirm by trapping, presence inferred by runs and scats detected in thickly vegetated gullies, near weather station above CSIRO hut. Location mapped here is approximate |
| 1970 | Two Peoples Bay Nature Reserve, south-west of Pt Gardner | Bannister (1970) | Unable to confirm by trapping, presence inferred by runs and scats detected in thickly vegetated gullies, bottom of valley, south-west of Pt Gardner |
| 1970 | Two Peoples Bay Nature Reserve, Moates Lagoon | Bannister (1970) | Unable to confirm by trapping, presence inferred by runs and scats detected in thickly vegetated gullies, thick swampy areas at west end of Moates Lagoon |

Table 4 (cont.)

| Year of record | Location or Site name | Source | Comment |
|---|---|---|---|
| 1972 | Dwellingup, Wrens Road Swamp (west), Urbrae Forest Block | Christensen (undated) | Trapping program before (August to November 1972) and after (12 to 21 December 1972) a low intensity burn of 60% of quokka habitat within the swamp. No estimates of density, however a total of 22 individuals trapped. |
| 1972 | Dwellingup, Wrens Road Swamp (east), White Forest Block | Christensen (undated) | Trapping program before (August to November 1972) and after (12 to 21 December 1972) a low intensity burn of 60% of quokka habitat within the swamp. No estimates of density, however a total of 22 individuals trapped. |
| 1975 | Denbarker, 5km east of Denbarker Road bridge over Mitchell River | Kabay and Start (1976), note 1, below | 150 cage trap nights and 180 snare trap nights over 9 nights (28–30 July 1975 and 11–20 August 1975). Six quokkas trapped or snared |
| 1975 | Mount Manypeaks, North of Mount Manypeaks | Kabay and Start (1976), note 1, below | 130 cage trap nights over three nights plus 60 snare trap nights over three nights (5–7 July 1975). One quokka only seen, runways and scats found |
| 1975 | Two Peoples Bay, Mt Gardner | Kabay and Start (1976), note 1, below | 180 cage trap nights over 4 nights (1–8 July 1975). No quokka captures, but presence inferred by presence of scats and runways in gullies and in dense heath bordering gullies |
| 1975 | Nannup, Mowen Road creek crossing, east of its junction with Stoats Road | Kabay and Start (1976), note 1, below | Surveyed June 1975 with 50 cage trap nights and 10 snare trap nights over one night (in period 6–17 June 1975). Three quokkas trapped, scats and runways present |
| 1976 | Bald Island | Kabay and Start (1976), note 1, below | 360 cage trap nights over three nights (29 May – 3 June 1976). One quokka trapped, large number seen and a number of skulls collected |
| 1976 | Two Peoples Bay, 'Robinson's Gully' | Kabay and Start (1976), note 1, below | 360 cage trap nights over 4–9 nights at a range of locations (13 April – 2 May 1976). Two juvenile quokkas trapped at 'Robinson's Gully'. Approximate location only mapped here |
| 1976 | Bunbury, Muddy Lake, 11km South of Bunbury | Kabay and Start (1976), note 1, below | 150 cage trap nights over three nights June 1975 (10–12 June 1975). Quokka skeletal material recovered, runways and scats common. No live animals trapped in June 1975, but were seen subsequently (4 Feb 1976) by these investigators. Co-ordinates corrected to plot to location of Muddy Lake |
| 1977 | Dwellingup, Holyoake | Hart (1977) | Trapped 10 individual quokkas over the period 6–11 November 1976 and 27 over the period 17–24 March 1977 |
| 1979 | Jandakot | Austin (1979) | Estimated population size of a translocated, fenced population, where 393 quokkas ex Rottnest Island had been released in the period 1972–1978. Population estimated to be approximately 84 animals in 1979. Translocated population subsequently shown to have failed to persist |
| 1982 | Jarrahdale (Mundilup Forest Block) | D. Giles (personal communication to PJdeT) | Record of roadkill(s) reported from the early 1980s (nominally 1982) by local landholder. Reported to Doug Giles, Department of Conservation and Land Management, Jarrahdale |
| 1986 | Stirling Range National Park – Bluff Knoll (1986–1991) | A.N. Start, note 2 below | Confirmed records of presence (sightings) by Allan Rose in the period from 1986 to 1991. Nominally listed and mapped here as 1986, see also record for 1991 |

| | | | |
|---|---|---|---|
| 1988 | Walpole-Nornalup National Park, Nuyts Wilderness | K. Gillen, note 2 below | Records of scats and runways (east of Mt Hopkins, Karri Hill Gully east of Crystal Lake and south of Deep River) over the period June 1986 to June 1988. Nominally shown here as 1988 and mapped at east of Crystal Lake |
| 1988 | Mount Manypeaks area | K. Gillen, note 2, below | Several records of quokka scats and runways noted in period September 1987 to September 1989. Mapped location is approximate only and listed as 1988 |
| 1989 | Mount Frankland National Park, Middle Road | A.N. Start, note 2 below | Incidental sighting by Andrew Morton. Sighting of one animal only |
| 1989 | Two Peoples Bay Nature Reserve, Mt Gardner area | K. Gillen, note 2 below | Multiple records of quokka scats and runways noted in period June 1985 to July 1991. Three confirmed sightings in July 1988 (Lower Robinson's Gully/Coffin Gully), July 1989 (Coffin Gully) and July 1990 (Robinson's Gully/Coffin Gully) |
| 1989 | Bald Island | K. Gillen, note 2 below | Record of scats and subsequent quokka sighting on rocks near western shore |
| 1991 | Stirling Range National Park, Success Ridge Track | Smith, R. | Carcass recorded by Bob Smith (CALM Manjimup), via Lachie McCaw (CALM Manjimup). Quokka thought to be displaced as a result of fire |
| 1991 | Nannup, Lewana Plantation | A.N. Start, note 2 below | Carcass of juvenile fox-killed quokka collected in pine plantation. Approximate mapping of location only. No details of source population |
| 1991 | Stirling Range National Park - Bluff Knoll (1986–1991) | A.N. Start, note 2 below | Confirmed records of presence (sightings) by Allan Rose in the period from 1986 to 1991. Nominally listed here as 1991, see also 1986 record above. Area burnt in April 1991 and only one record at this location since (see 1991 record below). Presence otherwise suggested by scats, see 1995 record of Barrett (1996). |
| 1991 | Stirling Range National Park - Bluff Knoll (1991) | A.N. Start, note 2 below | Carcass (bones only) collected by Allan Rose. Presumed killed as a result of fire |
| 1991 | Jarrahdale, Rosella Road, Gordon Forest Block | A.N. Start, note 2 below | Presence reported from scat only. Subsequently trapped to confirm presence in 1995 (previously unpublished results, see Table 9) and to estimate population size 1998–2000 (Hayward et al. 2003) |
| 1991 | Jarrahdale, Karnet Forest Block | A.N. Start, note 2 below | Sighted by Grant Pronk when flushed from vegetation as escaping bushfire |
| 1992 | Walpole, Roe Forest Block | A.N. Start, note 2 below | Known for one roadkill carcass recorded by Phil Durell |
| 1994 | Mt Manypeaks | K. Gillen, note 2 below | Reported as dead sub-adult male |
| 1994 | Two Peoples Bay Nature Reserve | (Sinclair 1999) | None caught during Sinclair's survey period. Subsequently caught (by WA Dept of Conservation and Land Management staff) from December 1994 onwards from several different locations. Location co-ordinates here are therefore approximate |
| 1995 | Stirling Range National Park - Ellen Peak | Barrett (1996) | Presence indicated by detection of hair (hair tube). Fresh scats and runways also observed by Sinclair (1999). |
| 1995 | Stirling Range National Park - Toolbrunup Peak | Barrett (1996) | Presence indicated by detection of scats |
| 1995 | Stirling Range National Park - Bluff Knoll | Barrett (1996) | Presence indicated by detection of scats from southern slopes and cascade area |

Table 4 (cont.)

| Year of record | Location or Site name | Source | Comment |
|---|---|---|---|
| 1995 | Mount Manypeaks Nature Reserve | Barrett (1996) | Presence indicated by detection of hair (hair tube) |
| 1995 | Stirling Range National Park - Hume Peak | Barrett (1996) | Presence indicated by detection of scats |
| 1996 | Pemberton, Poole Forest Block (second site) | G. Liddelow, note 3 below | Approximate date. Abundance rated as 1 (low) on scale of 1–3 for extent of visible activity (scats within runways, extent of runways and spoor) |
| 1996 | Pemberton, Tinkers Brook, Sutton Forest Block | G. Liddelow, note 3 below | Approximate date. Abundance rated as 1 (low) on scale of 1–3 for extent of visible activity (scats within runways, extent of runways and spoor) |
| 1996 | Pemberton, Poole Forest Block | G. Liddelow, note 3 below | Approximate date. Abundance rated as 1 (low) on scale of 1–3 for extent of visible activity (scats within runways, extent of runways and spoor) |
| 1996 | Jarrahdale, Chandler Road Orchard | D. Giles (personal communication to PJdeT) | Known from one sighted individual. Presumable contiguous and/or from Chandler Road population |
| 1996 | Stirling Range National Park, Chester Pass Road | Sinclair (1999) | Noted as a single dead animal found on Chester Pass Road in 1996. Date provided and location given to Mark Roddy, Park Ranger, as opposite Toll Peak car park, Chester Pass Road |
| 1997 | Jarrahdale, Gordon Forest Block | P. Batt Giles (personal communication to PJdeT) | Identified from extensive runways, may be continuos with the Rosella Road population |
| 1998 | Two Peoples Bay Nature Reserve, Mt Gardner area | Friend and Butler (nominally 1998) | Incidental, non-target capture of quokkas at 3 sites at Two Peoples Bay Nature Reserve when monitoring/surveying for Gilbert's potoroo. Sites were East Firebreak, Lower Firebreak & West 6. Mapped here as 1 location, near Mt Gardner |
| 1999 | Two Peoples Bay Nature Reserve, Mt Gardner area | Friend and Butler (nominally 1999) | Incidental, non-target capture of quokkas at 4 sites at Two Peoples Bay Nature Reserve when monitoring/surveying for Gilbert's potoroo. Sites were East Firebreak, Lower Firebreak, North Firebreak & Hakea. Mapped here as 1 location, near Mt Gardner |
| 2001 | Perth water supply catchment, Churchman Forest Block | J. Liddington (personal communication to PJdeT) | One individual quokka trapped as a non-target incidental capture when trapping for pigs. First reported capture from this site |
| 2001 | Perth water supply catchment, water catchment exclusion within Churchman Forest Block | J. Liddington (personal communication to PJdeT) | Quokka caught as a non-target incidental capture when trapping for pigs. Second capture from this section of catchment |
| 2002 | Perth water supply catchment, Churchman Forest Block (second site) | J. Liddington (personal communication to PJdeT) | Quokka caught as a non-target incidental capture when trapping for pigs. Third capture from this section of catchment |

| | | | |
|---|---|---|---|
| 2002 | Perth water supply catchment, Churchman Forest Block (third site) | J. Liddington (personal communication to PJdeT) | Confirmed roadkill. Fourth record within 12–15 months from this section of catchment |
| 2002 | Northcliffe, Nairn Forest Block | M. Sheehan (personal communication to PJdeT) | Roadside sighting of live quokkas and several confirmed roadkill records. Roadkills appear to be associated with disturbance resulting from roading activity, prior to timber harvesting |
| 2002 | Dwellingup, Urbrae Forest Block | R. Staines (personal communication to PJdeT) | Three quokkas trapped and one carcass found in period 21 February to 11 March 2002. Trapped quokkas were non-target incidental captures when trapping for pigs. Within 3.5km of sub catchment where Christensen (undated) trapped in 1972 |
| 2002 | Dwellingup, Kyabram Brook, Park Forest Block | R. Staines (personal communication to PJdeT) | Within Alcoa's Willowdale mine site. Trapped as a non-target incidental capture when trapping for pigs. Known at this site from one capture only |
| 2002 | Quarrum Nature Reserve, east of Walpole | G. Freebury (personal communication to PJdeT) | Quokka presence confidently inferred by detection of scats in characteristic quokka runways |
| 2002 | Peak Forest Block, North of Walpole | G. Freebury (personal communication to PJdeT) | Quokka presence confidently inferred by detection of scats in characteristic quokka runways |
| 2002 | Muddy Lake, south of Bunbury | (Dell & Hyder-Griffiths 2002) | The authors reported 'road kill specimens had been collected recently' and 'carcasses had been brought … in … up until about two years ago'. A skull collected form the site on 25 September 2002 has been confirmed as a quokka (WAM record M54132), however the skull is not aged (Norah Cooper, pers. comm. to PJdeT) and quokka presence is otherwise only inferred from presence of runways |
| 2003 | Dwellingup (Banksiadale Forest Block) - within Alcoa's Huntly Mine Site mining envelope | M. Burt (personal communication to PJdeT) | Roadkill. Carcass reported to Merv Burt, Dwellingup. Carcass confirmed at swamp site, not collected |
| 2003 | Del Park Road, Dwellingup (Turner/Marrinup Forest Block) | M. Burt (personal communication to PJdeT) | Roadkill. Carcass reported and collected by Merv Burt, Dwellingup. Decomposed carcass collected |
| 2003 | Bighill Brook (Nairn Forest Block) | M. Sheehan (personal communication to PJdeT) | Roadkill, Wheatley Coast Road, 300m Northcliffe side of Bighill Brook |
| 2003 | Nannup (Boronia Forest Block) | G. Voigt (personal communication to PJdeT) | Characteristic quokka runways identified and confirmed as quokka by G. Liddelow, Department of Conservation and Land Management. Identified prior to proposed silvicultural burn |
| 2003 | Nannup (Nelson Forest Block) | M. Maxwell (personal communication to PJdeT) | Department of Conservation and Land Management Blackwood District record no 70, nocturnal sighting |
| 2003 | Nannup (Beaton Forest Block) | M. Maxwell (personal communication to PJdeT) | Department of Conservation and Land Management Blackwood District record no 74. Dead, presumably a roadkill |
| 2003 | Nannup (Gregory Forest Block) | M. Maxwell (personal communication to PJdeT) | Department of Conservation and Land Management Blackwood District record no 76. Dead, presumably a roadkill |

Table 4 (cont.)

| Year of record | Location or Site name | Source | Comment |
|---|---|---|---|
| 2003 | Mt Chudalup, Windy Harbour Road | M. Sheehan (personal communication to PJdeT) | Two quokkas, night sighting, eastern side of road near 'waterpoint' at Mt Chudalup monadnock |
| 2003 | Karri Gully, Dalgarup Forest, Brockman highway, between Nannup and Bridgetown | K. Redman (personal communication to PJdeT) | Three separate road kill records on Brockman Highway, between Nannup and Bridgetown, all within the first half of 2003 |
| 2003 | Salmon Beach Road, off Windy Harbour Road | M. Sheehan (personal communication to PJdeT) | Four separate sightings over three weeks on roadside in coastal heath/stunted peppermint, near pump shed |
| 2003 | Jarrahdale, Frollet Plantation (between Mundlimup and Cobiac forest blocks) | D. Giles (personal communication to PJdeT) | Four quokkas sighted fleeing a burn |
| 2003 | Northcliffe, Wheatley Coast Road | P. Sargison (personal communication to PJdeT) | One sub-adult male roadkill, 200–300m south of Orchid Road, on eastern side of Wheatley Coast Road. Carcass retained for collection by Department of Conservation and Land Management staff |
| 2003 | Nannup/Bridgetown, Brockman Highway | K. Redman (personal communication to PJdeT) | One adult male road kill. Half way between Nannup and Bridgetown – 400m W of Jarrah Park |
| 2003 | Green Range | J.A. Friend (personal communication to PJdeT) | Hair sample collected when surveying (hair tubes) for Gilbert's Potoroo. |

Notes:

1 Kabay and Start (1976) Sought information from the public, from field staff from relevant government agencies and carried out biological survey to detect the presence of Gilbert's potoroo, *Potorous tridactylus gilbertii*, (*now P. gilbertii*) and the broad faced potoroo, *P. platyops*, in the period April 1975 to October 1976. Quokka presence was also recorded at numerous sites investigated.

2. Unpublished database records of A.N. Start, Western Australian Department of Conservation and Land Management.

3. Unpublished records from incidental sightings and opportunistic trapping by G. Liddelow, Western Australian Department of Conservation and Land Management

Table 5

Records of occurrence of the quokka, *Setonix brachyurus*, extracted from unpublished Department of Conservation and Land Management databases (CALM unpublished; Gilfillan unpublished). Original source for most records was Departmental operational district staff. Records are predominantly from incidental and opportunistic sightings. Records are listed chronologically.

| Date of record | Location | Comment |
|---|---|---|
| 1987 | Pemberton, Brockman National Park, near Pemberton-Northcliffe Road | carcass – 3 animals |
| 1992 | William Bay National Park | Information forwarded by Greg Freebury, WA Department of Conservation and Land Management. Date is estimate. Diurnal sighting of 1 individual |
| 1993 | Pemberton, Brockman National Park | roadkill |
| 1994 | Manjimup, Lewin Forest Block, Davidson Road / Pine Creek gully system | No other details |
| 1994 | Manjimup, Lewin Forest Block. Davidson Road / Pine Creek gully system | |
| 1994 | Manjimup, 7 Day Road / Court Rd | No other details |
| 1994 | Manjimup | |
| 1995 | Manjimup, Lewin Forest Block, Junction Davidson & Easter Rd | No other details |
| 1995 | Manjimup, Andrew Forest Block | No other details |
| 1995 | Manjimup, Lewin Forest Block, junction of Davidson and Easter roads | No other details |
| 1995 | Manjimup, Lewin Forest Block, junction of Davidson and Easter roads | |
| 1995 | Manjimup, Lewin Forest Block, junction Davidson and Easter roads | |
| 1995 | Manjimup, Andrew Forest Block | |
| 1996 | Walpole-Nornalup National Park, Cemetery Road Reserve 31362 | |
| 1996 | Walpole-Nornalup National Park, Monastery Road, 1.5 km from South Coast Highway | |
| 1996 | Walpole-Nornalup National Park, South Coast Highway, 0.5 km west of Gully Road | |
| 1996 | Walpole-Nornalup National Park, near Spike Road Reserve 31362 | |
| 1996 | Walpole-Nornalup National Park, Frankland River, near Monastery Landing | |
| 1996 | Walpole-Nornalup National Park, Cemetery Road Reserve 31362 | |
| 1996 | Walpole-Nornalup National Park, Allen Road, 0.5 km from Hilltop Road | |
| 1996 | Walpole-Nornalup National Park, Pool Road | |
| 1996 | Walpole-Nornalup National Park, eastern boundary of Reserve 31362 | |
| 1996 | Walpole, Valley of the Giants, Valley of the Giants Road | |
| 1996 | Walpole, Loc. 10190, 1 km northwest of junction of Jones Road and Hilltop Road | |
| 1996 | Walpole, Valley of the Giants, Bohall Road, 2.5 km from South Coast Highway | |
| 1996 | Walpole, Valley of the Giants, I km along track running southeast of Pedro firebreak | |

Table 5 (cont.)

| Date of record | Location | Comment |
|---|---|---|
| 1996 | Walpole, Valley of the Giants, northern end of Twin Creek Road | |
| 1996 | Walpole, Valley of the Giants, Court Road, 1 km from South Coast Hwy | |
| 1996 | Walpole, Valley of the Giants, South Coast Highway, 250 m west of Conspicuous Beach Road. | |
| 1996 | Walpole, 1.5 km northwest of junction of Jones Road and Hilltop Road | |
| 1996 | Walpole, Valley of the Giants, Valley of the Giants Road | |
| 1996 | Walpole-Nornalup National Park, Monastery Road, 0.5 km west of Zig Zag Road | |
| 1996 | Walpole, Valley of the Giants, Valley of the Giants Road | |
| 1996 | Walpole, Valley of the Giants, Rate Road 3.3 km north of South Coast Hwy | |
| 1996 | Pemberton, Brockman NP, adjacent to farmland | Diurnal sighting of 2 quokka disturbed by and escaping from machine (dozer) disturbance |
| 1996 | Walpole, Valley of the Giants, South Coast Hwy, 1.1 km east of Conspicuous Beach Road | |
| 1996 | Frankland, Ford Road 3 km from Talbot Road | |
| 1996 | Walpole Inlet, near Collier Creek, eastern edge | |
| 1996 | Nornalup, Nornalup Bridge, South Coast Highway. | |
| 1996 | Manjimup, Solai Forest Block, Solai Rd HC6395 | No other details |
| 1996 | Walpole, Valley of the Giants, South Coast Highway, 1km south of 28 Mile Road | |
| 1996 | Manjimup, Yardup Forest Block, 1km North along Edwards Road from Perup Road | Database records indicate two different sightings, same day. The source is identified for one sighting only and is possibly a duplicate record. The Yardup record(s), combined with the 1954 record by A.D. Jones in Serventy et al. (1954) represent the only quokka records from the Perup forest. |
| 1996 | Manjimup, Lewin Forest Block, Easter & Eastwin roads | No other details |
| 1996 | Manjimup, Nelson Forest Block, Bibbulmun Track approx 500m south of Willow Springs | No other details |
| 1996 | Walpole, Valley of the Giants, near South Coast Highway, 2 km west of Nut Road | |
| 1996 | Manjimup, Solai Forest Block, Solai Road | |
| 1996 | Manjimup, Yardup Forest Block, 1km north along Edwards Road from Perup Road | No other details |
| 1996 | Roe, first creek system west of Claude Road, on Roe Road. (near Mt. Roe) | |
| 1996 | D'Entrecasteaux National Park, Mandalay Beach Road, near beach | |
| 1996 | Walpole-Nornalup National Park, Tinglewood Road, 1.5 km from South Coast Highway | |
| 1996 | Manjimup, Nelson Forest Block, Bibbulmun Track approx 500m south of Willow Springs | |
| 1996 | Walpole, Keystone Rd. 1.5 km north of South Coast Highway | |

| Date of record | Location | Comment |
|---|---|---|
| 1996 | Manjimup, Easter Forest Block, Easter and Eastwin roads | |
| 1996 | Walpole-Nornalup National Park, Shelleys Beach | |
| 1996 | Walpole-Nornalup National Park, South Coast Highway, 0.75 km west of Tinglewood Road | |
| 1996 | Walpole-Nornalup National Park, walking track between Sealers Cove and Circus Beach | |
| 1996 | Walpole-Nornalup National Park, gully north-northwest of Circus Beach | |
| 1996 | Walpole-Nornalup National Park, 1 km northwest of Circus Beach | |
| 1996 | Walpole, Rest Point Road, 1 km from South Coast Highway | |
| 1996 | Denbarker, Denmark- Mt. Barker Road, near Mitchell River Bridge | |
| 1997 | Manjimup, Netic Forest Block, Pool Road | |
| 1997 | Walpole, Approximately 200m east of the junction of Tree Top Walk Road and Valley of the Giants Road on Valley of the Giants Road | Roadkill |
| 1997 | Pemberton, D'Entrecasteaux National Park, near Landslide Road in aerial burn area DC16 | diurnal sighting of 1 adult quokka |
| 1997 | Walpole, Valley of the Giants Road approximately 200m west of the Tree Top Walk turn-off | Roadkill, carcass identified |
| 1997 | Manjimup, Graphite Forest Block, Austin Road | |
| 1997 | Manjimup, Andrew Forest Block, Top Road | |
| 1997 | Manjimup, Netic Forest Block, Netic quokka exclusion (WHAT IS THIS) | |
| 1997 | Manjimup, Netic Forest Block, Pool Road | |
| 1997 | Manjimup, Netic Forest Block, junction of Sexton and Parky Roads | |
| 1997 | Manjimup, Netic Forest Block, Sexton Road | |
| 1997 | Manjimup, Netic Forest Block, Kanny Road | |
| 1997 | Manjimup, Andrew Forest Block, Dalberg Road waterpoint – 2.5 km west of Austin Road | |
| 1997 | Pemberton, D'Entrecasteaux National Park | Roadkill on Salmon Beach Road 1km from Windy Harbour. Definite signs of quokka activity in 4year old heath north of road |
| 1997 | Manjimup, Mack Forest Block, Well Road | No other details |
| 1997 | Manjimup, Netic Forest Block, Kanny / Parky Roads | |
| 1997 | Pemberton, Crowea Forest Block, McAlpine Road waterpoint | Presence inferred by signs (scats, runways) |
| 1997 | Walpole, Walpole-Nornalup National Park, walk trail from town to Coalmine Beach | Diurnal sighting of one individual, crossing walk trail |
| 1997 | Manjimup, Solai Forest Block, Monk / Solai Roads | |
| 1997 | Pemberton, Crowea Forest Block, thick ti-tree between coupes on Crowea Road | Presence inferred by signs (scats, runways) |
| 1997 | Pemberton, Crowea Forest Block | Diurnal sighting |
| 1997 | Pemberton, Crowea Forest Block, track crossing Orchid Rd, 1.1km from Crowea Road | |
| 1997 | Pemberton, Crowea Forest Block, south-west corner 1984 regen on south side of road | Presence inferred by signs (scats, runways) |

Table 5 (cont.)

| Date of record | Location | Comment |
|---|---|---|
| 1997 | Pemberton, Crowea Forest Block, McAlpine Road, water point near Hawkins Road and Dan Road | Presence inferred by signs (scats, runways) |
| 1997 | Pemberton, Crowea Forest Block, Rowney Road north of Crowea Rd | Presence inferred by signs (scats, runways) |
| 1997 | Pemberton, Crowea Forest Block, Karri/Marri gully 1.9km from Wheatley Coast Road | |
| 1997 | Pemberton, Crowea Forest Block, track crossing Cederman Road 400m from Wheatley Coast Road. Karri/Marri regrowth | |
| 1997 | Walpole, Wye Forest Block | Presence inferred by signs (spoor) |
| 1997 | Manjimup, Mack Forest Block, Mt Mack Road / Tom Road intersection | |
| 1997 | Manjimup, Netic Forest Block, Pool Road | No other details |
| 1997 | Walpole, Rocky Forest Block | No detail, presumably a sighting |
| 1997 | Walpole, Rocky Forest Block | Old (not fresh) evidence in unburnt gully |
| 1997 | Walpole, Sharpe Forest Block | Presumably determined by evidence of activity, at creek in Sharpe Block (North of Sharpe 6), flows into the Deep River |
| 1997 | Manjimup, Solai Forest Block, Monk / Solai Roads | No other details |
| 1997 | Manjimup, Andrew Forest Block, Top Road | No other details |
| 1997 | Manjimup, Graphite Forest Block, Austin Road | No other details |
| 1997 | Manjimup, Graphite Forest Block, Cow Brook – Davidson Road | No other details |
| 1997 | Manjimup, Gordon Forest Block, Mobil Road | No other details |
| 1997 | Manjimup, Andrew Forest Block, Dalberg Road waterpoint – 2.5 km | No other details |
| | west of Austin Road | |
| 1997 | Manjimup, Mack Forest Block, McNab Well | No other details |
| 1997 | Manjimup, Netic Forest Block, Penny Road | No other details |
| 1997 | Manjimup, Netic Forest Block, Kanny Road | No other details |
| 1997 | Manjimup, Netic Forest Block, Kanny / Parky Roads | No other details |
| 1997 | Manjimup, Netic Forest Block, Junction of Sexton and Parky Roads | No other details |
| 1997 | Manjimup, Netic Forest Block, Pool Road | No other details |
| 1997 | Manjimup, Netic Forest Block | No other details |
| 1997 | Manjimup, Mack Forest Block, Mt Mack Road / Tom Road intersection | No other details |
| 1997 | Walpole, Rocky Forest Block | Recorded as gully crossing road, presumably presence inferred by evidence of activity |
| 1997 | Manjimup, Mack Forest Block, McNab Well | |
| 1997 | Manjimup, Gordon Forest Block, Mobil Road | |
| 1997 | Manjimup, Netic Forest Block, Penny Road | |
| 1997 | Manjimup, Graphite Forest Block, Cow Brook – Davidson Road | |
| 1997 | Manjimup, Netic Forest Block, Sexton Road | No other details |

| Date of record | Location | Comment |
|---|---|---|
| 1997 | Walpole, Ford Road approximately 2.0km south west from the corner of Ford and Collis roads | diurnal sighting of 1 quokka crossing road |
| 1997 | Walpole, approximately 200m west of the Conspicuous Beach turn-off on the South Coast Highway (northern verge) | Roadkill |
| 1997 | Manjimup, Mack Forest Block, Well Road | |
| 1998 | Walpole, Walpole-Nornalup National Park, Valley of the Giants old carpark | diurnal sighting of 1 quokka crossing carpark |
| 1998 | Walpole, Walpole-Nornalup National Park, Valley of the Giants Road, approximately 500m south of Howe Road | night sighting of adult quokka crossing road |
| 1998 | Walpole, 100m west on Beardmore and Thomson roads | diurnal sighting of 1 quokka crossing road |
| 1998 | Walpole, approximately 400m west of the Jack Rate Lookout on the South West Highway | nocturnal sighting of 1 quokka at roadside |
| 1999 | Walpole, South Coast Highway approximately 3.5km east of Walpole | Roadkill 1 adult |
| 1999 | Walpole, Jones Road, 1km south of Clarke Road | Nocturnal sighting of 3 quokkas, at least 1 adult. Runways present in vegetation |
| 1999 | Manjimup, Beavis Forest Block, Beavis 8 | diurnal sighting of 2 quokkas |
| 1999 | Manjimup, Lewin Forest Block, Pine Creek Road, 1.3 km from Davidson Road | Carcass |
| 1999 | Walpole, Walpole-Nornalup National Park, 100m west of Nornalup Bridge | Roadkill, carcass identified |
| 1999 | Manjimup, 220 metres east of Boundary Road on Willow Spring Road | identified from carcass |
| 1999 | Manjimup, Andrew Forest Block | diurnal sighting of 2 quokkas |
| 1999 | Manjimup, near intersection Penny Road and Willow Spring Road | diurnal sighting of 1 quokka |
| 1999 | Stirling Range National Park, Pyungoorup Peak | Carcass forwarded to Western Australian Museum |
| 1999 | Two Peoples Bay Nature Reserve, on access track to research quarters | Nocturnal sighting of 1 quokka |
| 1999 | Walpole, South West Highway, approximately 400m west of the Jack Rate Lookout and approximately 700m east of Tinglewood Road | Roadkill 1 adult |
| 2000 | Waychinicup National Park | carcass |
| 2000 | Two Peoples Bay Nature Reserve, Little Beach Road, start of slashed firebreak to south of road | Nocturnal sighting of 1 quokka |
| 2000 | Two Peoples Bay Nature Reserve, approximately 2–300 m from start of Little Beach Road | Nocturnal sighting of 2 quokkas |
| 2000 | Waychinicup National Park, Waychinicup Road, just north of creek crossing | carcass |
| 2000 | Manjimup, Nelsons Location 9466 Jones Rd, Yanmah / Glenoran area | day sighting of 3 individuals, feeding on household scraps |
| 2000 | Waychinicup National Park, campsite | Nocturnal sighting of 2 quokkas |
| 2000 | Two Peoples Bay Nature Reserve, Little Beach Road, start of slashed firebreak to south of road | carcass |
| 2000 | Manjimup, Beavis Forest Block | |
| 2000 | Manjimup, Donnelly Mill Road | nocturnal sighting of 1 quokka |
| 2000 | Manjimup | |
| 2000 | Manjimup, 100m South of Palings Road and Coronation Road | Carcass |

Table 5 (cont.)

| Date of record | Location | Comment |
|---|---|---|
| 2000 | Manjimup, 1km east along Telephone Road from Coronation Road | Carcass |
| 2000 | Manjimup | one individual sighted running from road to scrub |
| 2001 | Walpole, 1/2 way between Deep River and Crystal Springs on South Western Highway | carcass |
| 2001 | Walpole, Crystal Springs, Coalmine Beach turnoff on South Coast Highway, approximately 3km east of Walpole | Carcass |
| 2001 | Stirling Range National Park, Mt. James Road | capture of 1 quokka during Western Shield monitoring |
| 2001 | Dwellingup, Del Park Road, south of Alcoa minesite | Roadkill 1 adult |

Table 6

Previously unpublished records of occurrence of the quokka, *Setonix brachyurus*, held by the authors. Records are from opportunistic sightings and trapping programs implemented to determine presence. Records are listed chronologically.

| Year of record | Location or Site name | Source | Comment |
|---|---|---|---|
| 1971 | Dwellingup, Lewis (Wild Pig) Swamp | Dillon (1993) see note 1, below | Reported on the 1971 survey of the wetter western creek systems in vicinity of Dwellingup. A total of 52 quokkas caught at 6 sites. Population density estimates of 1 animal per 2 ha in swamps unburnt for 5–10 years. Locations nominally mapped as Lewis and Holyoake swamps |
| 1971 | Dwellingup, Holyoake | Dillon (1993) see note 1, below | As above |
| 1988 | Dwellingup, Alcoa's Huntly Mine Site envelope | Dillon (1993) see note 1, below | Four of 5 sites inspected in 1988 showed evidence of quokka activity. Nominally mapped as Lewis Swamp, within mine site envelope. No estimates of population size |
| 1992 | Dwellingup, Holyoake | Dillon (1993) see note 1, below | 15 of 30 swamps surveyed in vicinity of Dwellingup in 1992 showed evidence of quokka activity. Three of these were then trapped unsuccessfully (fence funnel trap), subsequently one quokka only was trapped (wire cage trap) at the Holyoake site only. |
| 1992 | Collie/Mornington, Hadfield Forest Block | R. Brazell, note 2 below | Population presumed to be contiguous with population trapped and population size reported by Hayward et al. (2003) |
| 1992 | Collie/Mornington, Gervasse Forest Block | R. Brazell, note 2 below | This site known to support a relatively large population. Population estimate reported in this study (see Table 7) |
| 1992 | Collie/Mornington, Hamilton Forest Block | R. Brazell, note 2 below | 3 quokkas trapped when site trapped to determine presence in 1992. Population presumably contiguous with the population trapped by Hayward et al. (2003) |
| 1992 | Collie/Mornington, Victor Road Site, Hamilton Forest Block | R. Brazell, note 2 below | This site known to support a relatively large population. Population presumably contiguous with the population trapped by Hayward et al. (2003) |
| 1992 | Collie/Mornington, Hadfield Forest Block | R. Brazell, note 2 below | This site known to support a quokka population – population estimate reported by Hayward et al (2002). Other incidental quokka reportings and opportunistic trapping from Hadfield Forest Block presumed to be contiguous with this population |
| 1995 | Pemberton, Chudalup Forest Block | Dillon (1996), note 3 below | Presence indicated, abundance rated at 1 on scale of 0 (absence) to 3 (relatively abundant). Abundance considered comparable with survey in 1978–79 |
| 1995 | Manjimup, Andrew Forest Block (second site) | Dillon (1996), note 3 below | Presence indicated, abundance rated at 2 on scale of 0 (absence) to 3 (relatively abundant). Unknown if abundance has changed since survey in 1978–79 |
| 1995 | Manjimup, Lindsay Forest Block | Dillon (1996), note 3 below | Presence indicated. Abundance rated at 1 on scale of 0 (absence) to 3 (relatively abundant) and considered to be reduced from previous survey in 1978–79. Logging operations close to swamp. |
| 1995 | Nannup, Mack Forest Block | Dillon (1996), note 3 below | Presumably contiguous with the Andrew Forest Block (third site) record. Presence indicated, abundance rated at 1 on scale of 0 (absence) to 3 (relatively abundant). Abundance considered comparable with survey in 1992–93 |

Table 6 (cont.)

| Year of record | Location or Site name | Source | Comment |
|---|---|---|---|
| 1995 | Walpole, Weld Forest Block | Dillon (1996), note 3 below | Presence indicated, abundance rated at 1 on scale of 0 (absence) to 3 (relatively abundant). Abundance considered comparable with survey in 1978–79 |
| 1995 | Walpole-Nornalup National Park (Hilltop Road or formerly Hilltop Forest Block) | Dillon (1996), note 3 below | Presence indicated, abundance rated at 2 on scale of 0 (absence) to 3 (relatively abundant). Abundance considered comparable with survey in 1978–79. Was burnt in wildfire in 1987, quokkas seen dispersing at time of fire |
| 1995 | Walpole, Crossing Forest Block | Dillon (1996), note 3 below | Presence indicated, abundance rated at 1 on scale of 0 (absence) to 3 (relatively abundant). Abundance considered comparable with survey in 1978–79 |
| 1995 | Walpole, Giants Forest Block | Dillon (1996), note 3 below | Presence indicated, abundance rated at 1 on scale of 0 (absence) to 3 (relatively abundant). Abundance considered comparable with survey in 1978–79 |
| 1995 | Nannup, Gregory Forest Block | Dillon (1996), note 3 below | Presence indicated, abundance rated at 1 on scale of 0 (absence) to 3 (relatively abundant). Abundance considered comparable with survey in 1992–93. Site is long unburnt |
| 1995 | Nannup, Beaton Forest Block | Dillon (1996), note 3 below | Presence indicated, abundance rated at 1 on scale of 0 (absence) to 3 (relatively abundant). Abundance considered comparable with survey in 1992–93 |
| 1995 | Nannup, Beaton Forest Block (third site) | Dillon (1996), note 3 below | Presence indicated, abundance rated at 1 on scale of 0 (absence) to 3 (relatively abundant). Abundance considered comparable with survey in 1992–93 |
| 1995 | Manjimup, Andrew Forest Block (third site) | Dillon (1996), note 3 below | Presumably contiguous with the Mack Forest Block record. Presence indicated. Abundance rated at 2 on scale of 0 (absence) to 3 (relatively abundant) and considered to be comparable with previous survey in 1978–79. Site disturbed by construction of newly dug water point. |
| 1995 | Nannup, Helms Forest Block | Dillon (1996), note 3 below | Presence indicated, abundance rated at 1 on scale of 0 (absence) to 3 (relatively abundant). Abundance considered reduced from survey in 1975. swamp patch burnt in 1994 (1 year prior to this assessment) |
| 1995 | Nannup, Beaton Forest Block (second site) | Dillon (1996), note 3 below | Presence indicated, abundance rated at 1 on scale of 0 (absence) to 3 (relatively abundant). Unable to determine if change in abundance from previous survey |
| 1995 | Nannup, Beaton Forest Block (fifth site) | Dillon (1996), note 3 below | Presence indicated, abundance rated at 1 on scale of 0 (absence) to 3 (relatively abundant). Unable to determine if abundance has changed since previous survey |
| 1995 | Manjimup, Andrew Forest Block | Dillon (1996), note 3 below | Presence indicated, abundance rated at 2 on scale of 0 (absence) to 3 (relatively abundant). Unknown if abundance has changed since survey in 1978–79 |
| 1995 | Nannup, Beaton Forest Block (fourth site) | Dillon (1996), note 3 below | Presence indicated, abundance rated at 2 on scale of 0 (absence) to 3 (relatively abundant). Unable to determine if abundance changed from previous survey |
| 1995 | Nannup, Gregory Forest Block (second site) | Dillon (1996), note 3 below | Presence indicated, abundance rated at 1 on scale of 0 (absence) to 3 (relatively abundant). unable to determine if abundance has changed since last survey. runways appear unused, old scat only detected |

| | | | |
|---|---|---|---|
| 1995 | Dwellingup, Kesners Swamp, Marrinup Forest Block | P. de Tores, M. Dillon, A. Tomkinson and R. Buehrig, note 4 below | Known to support a population in the 1970s, population presence confirmed through trapping in February to March 1995. Population size estimated by Hayward (2003) |
| 1995 | Dwellingup, Lewis (Wild Pig) Swamp, Wilson Forest Block | P. de Tores, M. Dillon, A. Tomkinson and R. Buehrig, note 4 below | Showed signs of fresh activity in 1995, presence unable to be confirmed by trapping. Presence also unable to be confirmed in 2000 by Hayward et al. (2003) and this location may no longer supports a population |
| 1995 | Dwellingup, Holyoake Forest Block | P. de Tores, M. Dillon, A. Tomkinson and R. Buehrig, note 4 below | Showed evidence of activity in 1995, however, by 2000 considered to no longer support a population |
| 1995 | Jarrahdale, Rosella Road, Gordon Forest Block | P. de Tores, M. Dillon, A. Tomkinson and R. Buehrig, note 4 below | Trapped to confirm presence. Seven capture events of 4 quokkas, April 1995 |
| 1996 | Manjimup, Storry Forest Block | Dillon (1996), note 3 below | Presence indicated, abundance rated at 1 on scale of 0 (absence) to 3 (relatively abundant). Unable to determine if abundance has changed since last survey |
| 1996 | Nannup, Netic Forest Block | Dillon (1996), note 3 below | Presence indicated, abundance rated at 2 on scale of 0 (absence) to 3 (relatively abundant). Unable to determine if abundance has changed since previous survey. fresh tracks and activity beyond swamp area |
| 1996 | Nannup, Nelson Forest Block | Dillon (1996), note 3 below | Presence indicated, abundance rated at 1 on scale of 0 (absence) to 3 (relatively abundant). Unable to determine if abundance has changed since previous survey. appears 6–10 years since last (patchy) burn |
| 1996 | Jarrahdale, Chandler Road, Chandler Forest Block | P. de Tores, M. Dillon, A. Tomkinson and R. Buehrig, note 4 below | Known to support a population -population estimate reported by Hayward et al. (2003) |
| 1996 | Jarrahdale, Albany Highway Site. (Travellers' Arms site). | P. de Tores, M. Dillon, A. Tomkinson and R. Buehrig, note 4 below | Population reported from a roadkill in 1996 and subsequent follow up trapping (in the same year) confirmed presence. This site presumed to be the Travellers' Arms site referred to in 1956 by R. Aitken, cited by Barker et al. (1957) (Table 3) and trapped by Kent Williams in 1966 (Table 4) |
| 1996 | Collie/ Mornington Road, Hamilton Forest Block | R. Brazell, note 2 below | Known from 1 roadkill, source population not confirmed |
| 2000 | Collie, Davis Forest Block | M. Hayward, note 5 below | Presence inferred by detection of scats within runways |
| 2000 | Dwellingup, Marrinup Forest Block | M. Hayward, note 5 below | Presence inferred by detection of scats within runways |
| 2000 | Dwellingup, Federal Forest Block | M. Hayward, note 5 below | Presence inferred by detection of scats within runways |
| 2000 | Pemberton, Dickson Road | M. Hayward, note 5 below | Presence inferred by detection of scats within runways |
| 2000 | Dwellingup, Finlay Brook, Wilson Forest Block | M. Hayward, note 5 below | Presence inferred by detection of scats within runways. Spoor subsequently observed by de Tores and Dillon |
| 2000 | Dwellingup, Clinton Forest Block | M. Hayward, note 5 below | Presence inferred by detection of scats within runways. |
| 2000 | Dwellingup, Alcoa Conveyor Belt | M. Hayward, note 5 below | Presence inferred by detection of scats within runways. |
| 2000 | Dwellingup, South Dandalup Dam | M. Hayward, note 5 below | Presence inferred by detection of scats within runways. Also known previously from incidental sightings. Population may be contiguous with population at Kesners Swamp and the Conveyor Belt Site |

Table 6 (cont.)

| Year of record | Location or Site name | Source | Comment |
|---|---|---|---|
| 2000 | Dwellingup, Keats Forest Block | M. Hayward, note 5 below | Presence inferred by detection of scats within runways. |
| 2000 | Dwellingup, Turner Forest Block | P. de Tores, note 4 below | Incidental sighting in May 2000, subsequent additional incidental sighting reported in October 2000 and roadkill (carcass collected by M. Maxwell and C. Trethowan) in December 2000. Also subsequently considered by Hayward to support a quokka population |

Notes:

1. Dillon (1993) reported on a 1971 survey of creek systems in the wetter western creek systems in vicinity of Dwellingup, a 1988 survey within Alcoa's Huntly mine site envelope near Dwellingup and 1992 broadscale survey to determine presence in swamps near Dwellingup
2. Unpublished records from incidental sightings and opportunistic trapping by R.I. Brazell, Western Australian Department of Conservation and Land Management.
3. Dillon (1996) report on survey of sites surveyed from 1995 –1996, where presence was confirmed through trapping, or indicated by scats observed within runways and other fresh signs of activity – scats alone not considered sufficient to confirm presence.
4. Unpublished records from incidental sightings, trapping programs initiated to determine presence and opportunistic trapping by P. J. de Tores, M. J. Dillon, A. Tomkinson and R. Buehrig, Western Australian Department of Conservation and Land Management.
5. Results from unpublished field survey conducted by M. W. Hayward between September 1998 and September 2000 where a range of potential locations were examined for evidence of quokka presence. With the exception of the South Dandalup Dam site, the sites listed were previous not known to support quokkas.

Table 7

Previously unpublished trapping records for the quokka, *Setonix brachyurus*, from sites in the northern jarrah forest of south-west Western Australia

| **Site name** | **Year(s) trapped** | **Purpose of trapping program** | **Method of analysis** | **Result** |
|---|---|---|---|---|
| Gervasse Forest Block, near Collie | 1992 to 2000 | Long-term monitoring of abundance and survivorship | Abundance estimates derived from the *'deaths and no immigration'* Jolly-Seber model Survivorship estimates derived from the Program MARK Cormack-Jolly-Seber model | Population estimate of 49.21 ±7.85 individuals |
| Rosella Road, near Jarrahdale | April 1995 | Opportunistic trapping to determine presence only Subsequently trapped by Hayward et al. (2003) to derive population estimates | Listing of total number of captured individuals | 7 captures of 4 quokkas |
| Albany Highway, southeast of the Perth metropolitan area. This location is presumed to be the Travelers' Arms site referred to by Barker et al. (1957) (Table 3) and Williams in 1966 (Table 4) | 1996 | Opportunistic trapping to determine presence only | Listing of total number of captured individuals | 1 capture of an adult male |
| Holyoake, Dwellingup | August 1995 | Opportunistic trapping to determine presence only | N/A | No captures, no evidence of recent presence. Old runways and no fresh scats |
| Lewis (Wild Pig) Swamp, Dwellingup | August 1995 | Opportunistic trapping to determine presence only | N/A | No captures, some evidence of recent activity in runways |
| Kesners Swamp, Dwellingup | February to June 1995 | Opportunistic trapping to determine presence only Subsequently trapped by Hayward et al. (2003) to derive population estimates | Listing of total number of captured individuals | 22 captures of 10 quokkas |

Table 8

Location records for the quokka, *Setonix brachyurus*, excluded from maps used to infer distribution and excluded from estimates of extent of occurrence. Records listed and/or the location described were either unable to be confirmed, or were from captive colonies/sanctuaries

| Location | Year of record | Source of record | Comment |
|---|---|---|---|
| North Twin Peak Island | 1905 | Shortridge (1909) | Shortridge included 'Twin Peak' island as a known site for the quokka. Unclear if this was a reference to North Twin Peak Island or South Twin Peak Island. Quokkas have not been recorded from either island by any other author and the record is considered to be a tammar wallaby, see comments in text |
| South Twin Peak Island<br>Point Culver | 1905 | Shortridge (1909)<br>Western Australian Museum records. WAM registration number 024346 | Comments for the North Twin Peak Island, above apply.<br>Identification confirmed as a quokka in 1982 by D.J. Kitchener (WA Museum) (Norah Cooper pers. comm. to PJdeT). The record is outside the known historic range and the range as determined by the fossil record and is therefore considered spurious. No additional location details available and no date of collection or any other details. Accuracy of location therefore considered insufficient to include within inferred distribution. |
| Coorow | 1949 | Western Australian Museum records. WAM registration number 002781 | Validity of record questioned by Nora Cooper (WA Museum). Remains were collected from a cave in 1949, subsequently destroyed and unable to be verified (Norah Cooper pers. comm. to PJdeT). |
| Breaksea Island | 1975 | Western Australian Museum records. WAM registration number 002781 | See comments in text. |
| Department of Zoology, University of Western Australia | 1958 and 1959 | Western Australian Museum records. WAM registration numbers 003365 and 003618 | Specimen presumed to be from the captive colony held at the University of Western Australia, ex Rottnest Island |
| Karakamia Sanctuary, Chidlow, east of Perth | 1998 | Smitz (1998) | Four quokkas originally sourced from mainland locations and released within a predator proof fenced sanctuary. Three quokkas released in 1996, two of which were originally sourced from the Gervasse population, near Collie and held by the 'Big Swamp Wildlife Park', Bunbury. The third was a captive bred young of the first two. The fourth animal sourced from the Rosella Road site and released in 1997. One death has been recorded and at least 1 young has been produced, population size unknown at May 2002 |
| Harry Waring Marsupial Reserve, Jandakot | 1979 | Austin (1979) | Population sourced from Rottnest Island and released at the fenced Harry Waring Marsupial Reserve. The colony failed to persist. |
| Muddy Lake, south of Bunbury | 2002 | Dell and Hyder-Griffiths (2002) | Unconfirmed record – See listing in Table 4 |
| Water Corporation reserve, Dunsborough | 2004 | Jim Lane (pers. comm. to PJdeT) | Unconfirmed record |

Table 9

Known To Be Alive (KTBA) estimates for the quokka, *Setonix brachyurus*, at the Gervasse Forest Block site, for the period 1992 to 2002.

| Month and Year of trapping | KTBA estimate |
|---|---|
| June/July 1992 | First trapping session, no KTBA estimate available |
| March 1993 | 14 |
| June/July 1993 | 20 |
| January 1994 | 22 |
| August 1994 | 20 |
| April 1995 | 19 |
| January 1996 | 15 |
| January 1997 | 12 |
| February 1998 | 12 |
| March 1999 | 11 |
| February 2000 | Last trapping session, no KTBA estimate available |

Table 10

Locations previously known to support populations of the quokka, *Setonix brachyurus*, re-surveyed in the period 1995–1996 by Dillon (1996) and found to show no evidence of presence or where presence was unable to be confirmed.

| Location | Year of last known record | Comment |
|---|---|---|
| Netic Forest Block, Manjimup | 1978–79 | 0 to 2 years since last burnt. Quokkas subsequently reported from other locations within this and neighbouring forest block (see Table 5) |
| Shannon, Walpole | 1978–79 | 0 to 2 years since last burnt, swamp vegetation completely burnt. Quokkas subsequently reported from other locations within Shannon River area (see Table 5) |
| Giants Forest Block, Walpole | 1978–79 | Very heavy litter layer and 11 years or more since last burn. Previously known from a roadkill only at this site. Quokkas subsequently reported from other locations within this forest block (see Tables 5 and 6) |
| Walpole-Nornalup National Park (Hilltop Road area), Walpole | 1978–79 | Very heavy litter layer and 11 years or more since last burn. No recent evidence of activity. Quokkas subsequently reported from other locations within this vicinity and may be at high density (see text and Tables 5 and 6) |
| Sheepwash Forest Block, Denmark | 1978–79 | 6 to 10 years since last burn. No sign of recent activity |
| Farmland area, Bunbury | 1976 | No evidence of activity, habitat now water logged. Location determined on basis of incorrect geographic co-ordinates for Muddy Lake listed by Kabay and Start (1976) |
| Urbrae Forest Block, Dwellingup | 1988 | 11 years or more since last burn. Quokkas subsequently reported from other locations within this forest block (see Table 6) |
| Holyoake, Dwellingup | 1992 | 3 to 5 years since last burn. Subsequently trapped more intensively (August 1995) (Table 7) with no evidence of quokka activity or presence |
| Inglehope Forest Block, Dwellingup | 1972–73 | 6 to 10 years since last burn. No sign of activity when surveyed by Dillon (1996) nor when surveyed by Hayward (2002) in 1999–2000. |