

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The former and current distribution of the quokka, *Setonix brachyurus*, was mapped from published and all available unpublished records.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 km² 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 km². 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 Tamar 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).

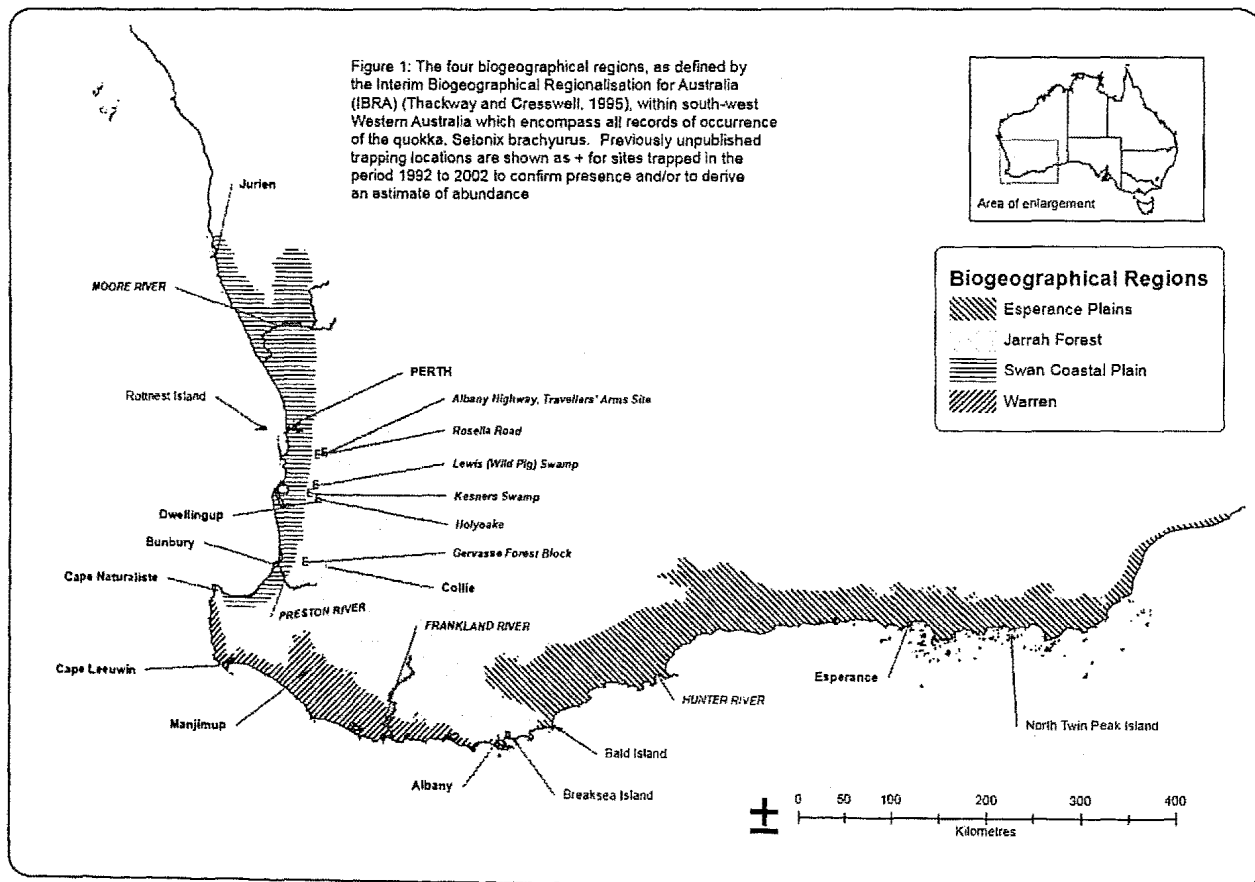


Figure 1. The four biogeographical regions, as defined by the Interim Biogeographical Regionalisation for Australia (IBRA) (Thackway and Cresswell, 1995), within south-west Western Australia which encompass all records of occurrence of the quokka, *Setonix brachyurus*. Previously unpublished trapping 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 Rottneest 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 Rottneest 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 $t_{(n-1)}$, 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.

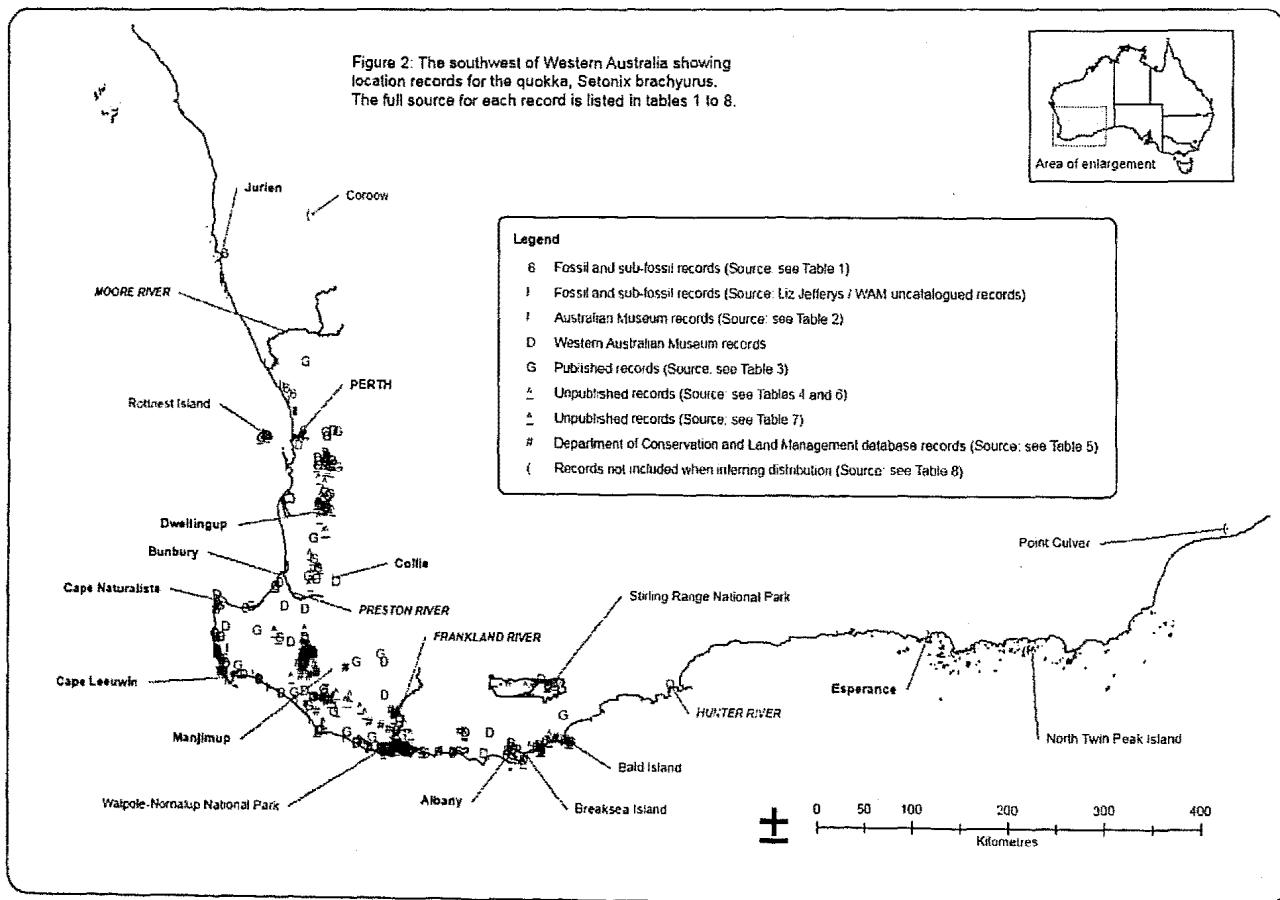


Figure 2. The southwest of Western Australia showing location records for the quokka, *Setonix brachyurus*. The full source for each record is listed in tables 1 to 8.

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

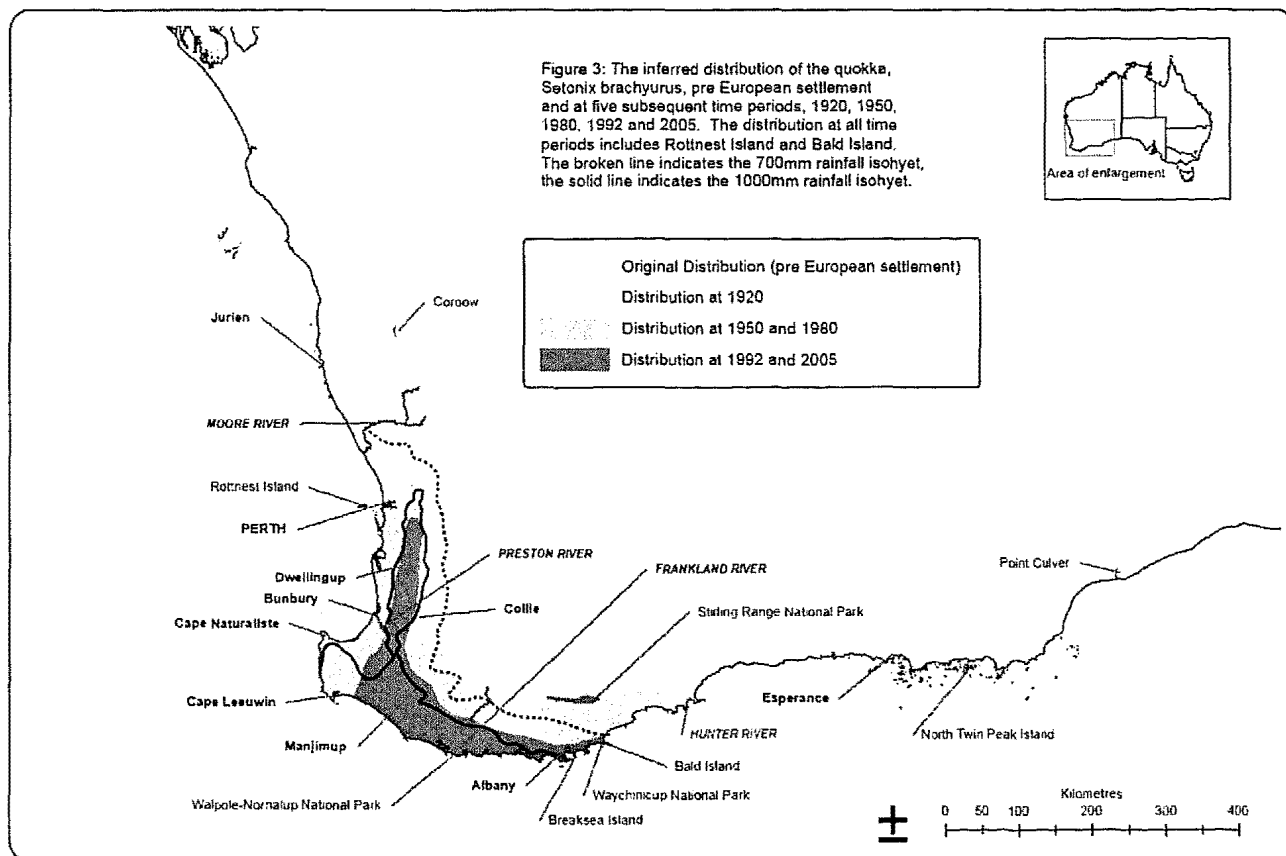


Figure 3. The inferred distribution of the quokka, *Setonix brachyurus*, pre European settlement and at five subsequent time periods, 1920, 1950, 1980, 1992 and 2005. The distribution at all time periods includes Rottnest Island and Bald Island. The broken line indicates the 700mm rainfall isohyet, the 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 km², inclusive of Rottneest Island (15.5 km²) and Bald Island (7.8 km²). 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 Abbott³ 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 Rottneest 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 Rottneest 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 Rottneest 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 Rottneest 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

³ Ian Abbott: Science Advisor and Senior Principal Research Scientist, Western Australian Department of Environment and Conservation, Science Division, Kensington

⁴ Peter Collins: Fauna Conservation Officer, Western Australian Department of Environment and Conservation, South Coast Region, Albany

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 km². 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 km² 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 tamar 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 Rottneest 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 km² and

⁵ R.I.T. (Bob) Prince: Senior Research Scientist, Western Australian Department of Environment and Conservation, Science Division, Woodvale

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 Wardenup 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 PJdT). 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.

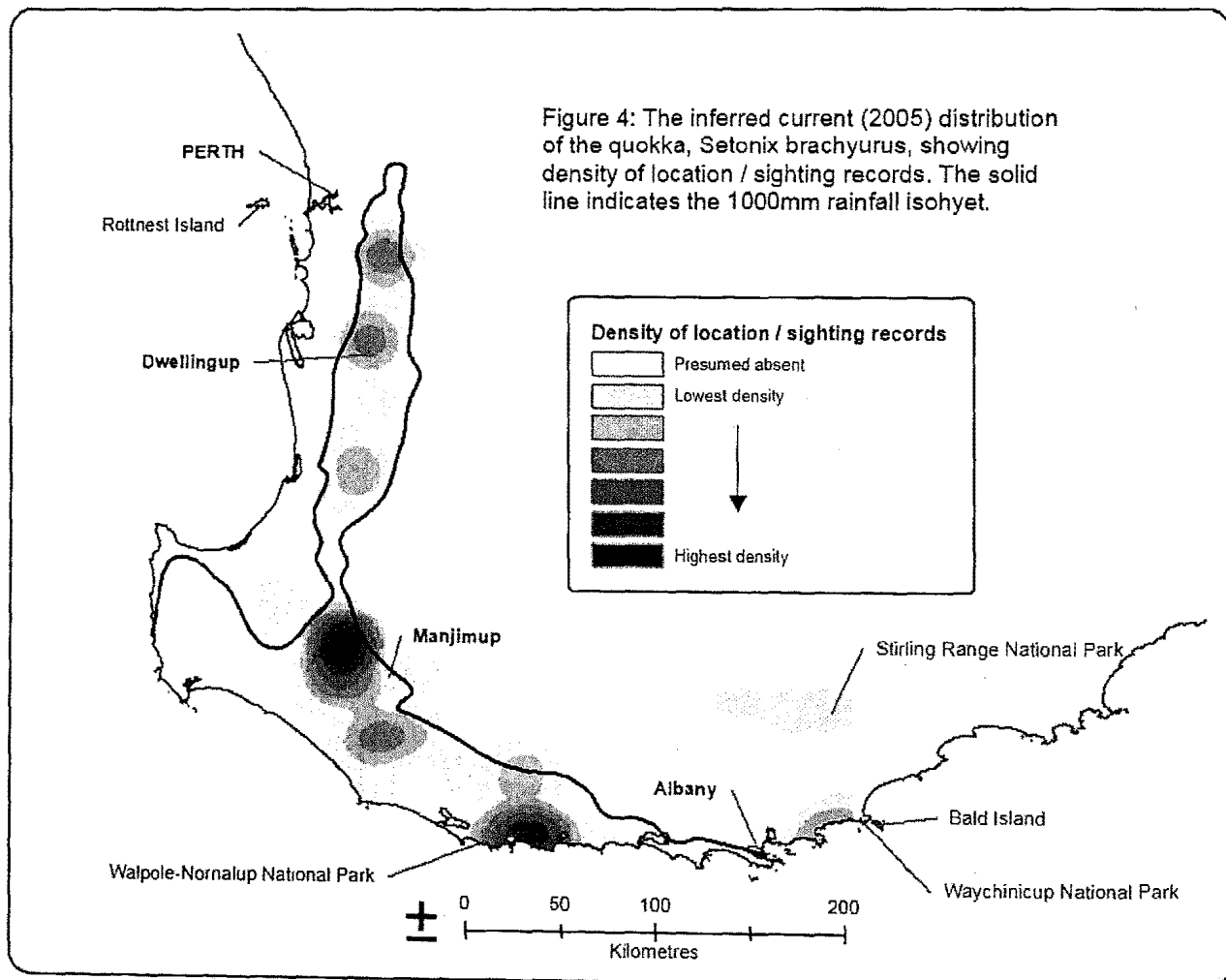


Figure 4. The inferred current (2005) distribution of the quokka, *Setonix brachyurus*, showing density of location / sighting records. The solid line indicates the 1000mm rainfall isohyet.

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 Liddelow¹⁰ and Alan Wright¹¹, pers. com. to PJdT) 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 Torres *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 Torres *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 Torres *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 (Shorridge 1909). However, Shorridge (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 harrisi*, (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 Rottneest 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 Rottneest 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 16th 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, *Isodon 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 Rottneest 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

¹⁴ John Austin: Long-term local resident, Northcliffe, Western Australia

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 identify 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 McCaw¹⁵ 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

¹⁵ Lachie McCaw: Senior Research Scientist, Western Australian Department of Environment and Conservation, Science Division, Manjimup

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

¹⁶ Laurie Wilson: Long-term local resident, Northcliffe, Western Australia

¹⁷ John Asher: Environmental Officer, Western Australian Department of Environment and Conservation, Nature Conservation Division, Bunbury

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 muenchen*. Hart (1981) hypothesised these deaths may have been the result of cross infection

from use of the Rottnest Island bags, but conceded *S. muenchen* 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 geoffroyi*, (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 Rottneest 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 Rottneest 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). Rottneest 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 Rottneest Island, despite these disturbances, suggests the species is quite resilient. With respect to disturbance factors, the most significant difference between Rottneest 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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REFERENCES

- Abbott I (1980). Aboriginal man as an exterminator of kangaroo and wallaby populations on islands round Australia. *Oecologia* 44:347-354.

- Abbott I (1998). Avifauna of the Irwin Inlet-Broke Inlet-Mt Frankland region of south-west Western Australia, 1912-1913. *CALMScience* 2(4):373-386.
- Abbott I (1999). The avifauna of the forests of south-west Western Australia: changes in species composition, distribution, and abundance following anthropogenic disturbance. *CALMScience Supplement* 5:1-175.
- Abbott I (2000). Impact of agricultural development and changed fire regimes on species composition of the avifauna in the Denmark region of south-west Western Australia, 1889-1999. *CALMScience* 3(3):279-308.
- Abbott I (2001a). Aboriginal names of mammal species in south-west Western Australia. *CALMScience* 3(4):433-486.
- Abbott I (2001b). The Bilby *Macrotis lagotis* (Marsupialia: Peramelidae) in south-western Australia: original range limits, subsequent decline, and presumed regional extinction. *Records of the Western Australian Museum* 20:271-305.
- Abbott I (2002). Origin and spread of the cat, *Felis catus*, on mainland Australia, with a discussion of the magnitude of its early impact on native fauna. *Wildlife Research* 29(1):51-74.
- Abbott I. (2003). Aboriginal fire regimes in south-west Western Australia: evidence from historical documents. In: *Fire in Ecosystems of south-west Western Australia: impacts and management*. (I Abbott & N Burrows, Eds). Backhuys Publishing, Leiden, the Netherlands. Perth, Western Australia, pp. 119-146.
- Abbott I, Burbidge AA (1995). The occurrence of mammal species on the islands of Australia: a summary of existing knowledge. *CALMScience* 1(3):259-324.
- Alacs E, Aplers D, de Tores PJ *et al.* (2003). Identifying the presence of quokkas (*Setonix brachyurus*) and other macropods using cytochrome *b* analyses from faeces. *Wildlife Research* 30(1):41-47.
- Alacs EA (2001). Conservation genetics of the Quokka, *Setonix brachyurus*. Honours thesis. Veterinary Biology. Murdoch University. Perth, Western Australia
- Aldrich J (1921). File note dated 9 May 1921 in Western Australian Government State Records Office Archives: 56/21 AN 108 Acc 477. Game Act - Diseases among Quaggas (Wallabies) in South West.
- Aldrich J (1933). File note dated 9 September 1933 in Western Australian Government State Records Office Archives: 56/21 AN 108 Acc 477. Game Act - Diseases among Quaggas (Wallabies) in South West.
- Alexander WB (1914). The history of zoology in Western Australia. Part I. - Discoveries in the 17th Century. *The Journal of the Natural History and Science Society of Western Australia* 5:49-64.
- Alexander WB (1916). History of zoology in Western Australia. Part II. - 1797-1829. *Journal and Proceedings of the Royal Society of Western Australia* 1:83-149.
- Alexander WB (1918). History of zoology in Western Australia. Part 3. - 1829-1840. *Journal and Proceedings of the Royal Society of Western Australia* III:37-69.
- Algar D, Kinnear JE (1996). Secondary poisoning of foxes following a routine 1080 rabbit-baiting campaign in the Western Australian wheatbelt. *CALMScience* 2(2):149-152.
- Archer M (1974a). New information about the quaternary distribution of the Thylacine (Marsupialia, Thylacinidae) in Australia. *Journal of the Royal Society of Western Australia* 57(2):43-50.
- Archer M (1974b). Excavations in the Orchestra Shell Cave, Wanneroo, Western Australia. *Archaeology and Physical Anthropology in Oceania* 9(2):156-162.
- Archer M, Baynes A (1972). Prehistoric mammal faunas from two small caves in the extreme south-west of Western Australia. *Journal of the Royal Society of Western Australia* 55(3):80-90.
- Austin C (1979). The Well-Being of the Jandakot Quokka Population. Population Analysis. Thesis submitted in partial fulfillment of Bachelor of Science (Honours). Zoology Department. University of Western Australia. Perth. Western Australia. Perth
- Balme J, Merrilees D, Porter JK (1978). Late Quaternary mammal remains, spanning about 30 000 years, from excavations in Devil's Lair, Western Australia. *Journal of the Royal Society of Western Australia* 61(2):33-65.
- Bannister JL (1970). Report on Biological Survey, Two Peoples Bay Nature Reserve (No. 27956) February 3 to 17, 1970. Unpublished Report for the Western Australian Museum. Perth, Western Australia.
- Barker R, McGlinchy A. (2001). M-R-I. Mark Recapture Interface for Programs Capture and Jolly. Version 2. Landcare Research. Manaaki Whenua. New Zealand. <http://www.landcareresearch.co.nz>
- Barker S (1961). Studies on marsupial nutrition. III. The copper-molybdenum-inorganic sulphate interaction in the Rottneest quokka, *Setonix brachyurus* (Quoy & Gaimard). *Australian Journal of Biological Science* 14:646-658.
- Barker S, Main AR, Sadleir RM (1957). Recent capture of the quokka (*Setonix brachyurus*) on the mainland. *The Western Australian Naturalist* 6:53-55.
- Barrett S (1996). A Biological Survey of Mountains in Southern Western Australia. Unpublished report prepared for the Western Australian Department of Conservation and Land Management and the Australian Nature Conservation Agency.
- Baynes A (1979). The Analysis of a Late Quaternary Mammal Fauna from Hastings Cave, Jurien. PhD Thesis. University of Western Australia. Perth
- Baynes A. (1987). The original mammal fauna of the Nullarbor and southern peripheral regions: evidence from skeletal remains in the superficial cave deposits. In: *A Biological Survey of the Nullarbor Region South and Western Australia in 1984*. (NL McKenzie & AC Robinson, Eds). South Australian Department of Environment and Planning. Adelaide, pp. 139-152.
- Baynes A, Merrilees D, Porter JK (1975). Mammal remains from the upper levels of a late Pleistocene

- deposit in Devil's Lair, Western Australia. *Journal of the Royal Society of Western Australia* 58(4):97–126.
- Berday M, Webster JP, MacDonald DW (2000). Fatal attraction in rats infected with *Toxoplasma gondii*. *Proceedings of the Royal Society of London (Series B)* 267:1591–1594.
- Biodiversity Group Environment Australia (1999). Threat Abatement Plan for Predation by the European Red Fox. Environment Australia under the Natural Heritage Trust. Canberra, ACT, Australia.
- Bradshaw SD. (1991). *Rottneest Quokka Workshop. An inquiry into the current status of the quokka, held in the Rottneest Research Station on 9–10 March, 1991*. Unpublished report prepared for the Rottneest Island Research Committee.
- Brown KL, Hickman EJ, Lally TR (1998). Discovery of the red flowering *Corymbia ficifolia* in the Stirling Range. *The Western Australian Naturalist* 22(1):23–24.
- Burbidge AA (Ed.) (1977). *The Status of Kangaroos and Wallabies in Australia. Report of the Working Group on Macropod Habitat of the Standing Committee of the Council of Nature Conservation Ministers*. Department of Environment, Housing and Community Development. Australian Government Publishing Service, Canberra.
- Burbidge AA, McKenzie NL (1989). Patterns in the modern decline of Western Australia's vertebrate fauna: causes and conservation implications. *Biological Conservation* 50:143–198.
- Burbidge AA, Manly BFJ (2002). Mammal extinctions on Australian islands: causes and conservation implications. *Journal of Biogeography* 29:465–473.
- Burbidge AH. (2003). Birds and fire in the Mediterranean climate of south-west Western Australia. In: *Fire in Ecosystems of south-west Western Australia: impacts and management*. (I AbbottN Burrows, Eds). Backhuys Publishing, Leiden, the Netherlands. Perth, Western Australia, pp. 321–348.
- Burnet SM (1968). *Changing Patterns: an atypical autobiography*. Sun Books. Melbourne.
- Burnham KP, Anderson DR (2002). *Model Selection and Multimodel Inference. A Practical Information-Theoretic Approach*. Second Edition. Springer-Verlag. New York.
- Burrows N, Wardell-Johnson G. (2003). Fire and plant interactions in forested ecosystems of south-west Australia. In: *Fire in Ecosystems of south-west Western Australia: impacts and management*. (I AbbottN Burrows, Eds). Backhuys Publishing, Leiden, the Netherlands. Perth, Western Australia, pp. 225–268.
- Burrows ND, Friend GR. (1998). Biological indicators of appropriate fire regimes in southwest Australian ecosystems. In: *Fire in Ecosystem Management: Shifting the Paradigm from Suppression to Prescription*. (TL PrudenLA Brennan, Eds). Proceedings of the Tall Timbers Fire Ecology Conference No. 20. Tall Timbers Research Station, Tallahassee, Florida. 413–421.
- Burrows ND, Ward B, Robinson AD (1995). Jarrah forest fire history from stem analysis and anthropological evidence. *Australian Forestry* 58(1):7–16.
- Butler WH (1969). Remains of *Sarcophilus* the 'Tasmanian' Devil (Marsupialia, Dasyuridae) from coastal dunes south of Scott River, Western Australia. *The Western Australian Naturalist* 11(4):87–88.
- Calaby JH (1971). The current status of the Australian macropodidae. *Australian Journal of Zoology* 16(1):17–28.
- Calaby JH, Grigg GC. (1989). Changes in macropod communities and populations in the past 200 years, and the future. In: *Kangaroos, Wallabies and Rat-Kangaroos*. Vol. 2 (G Grigg, P JarmanI Hume, Eds). Surrey Beatty & Sons Pty Limited. Chipping Norton, New South Wales, pp. 813–820.
- Caley P (1997). Movements, activity patterns and habitat use of feral pigs (*Sus scrofa*) in a tropical habitat. *Wildlife Research* 24(1):77–88.
- CALM (1999). Department of Conservation and Land Management Annual Report 1998–1999. Perth, Western Australia.
- CALM (2000). Department of Conservation and Land Management Annual Report 1999–2000. Perth, Western Australia.
- CALM (2001). Department of Conservation and Land Management Annual Report 2000–2001. Perth, Western Australia.
- CALM (2002). Department of Conservation and Land Management Annual Report 2001–2002. Perth, Western Australia.
- CALM (2003). Department of Conservation and Land Management Annual Report 2002–2003. Perth, Western Australia.
- CALM (2004). Department of Conservation and Land Management Annual Report 2003–2004. Perth, Western Australia.
- CALM. (unpublished). Unpublished Department of Conservation and Land Management database records of fauna occurrence in Western Australia.
- Calver MC, Dell J (1998a). Conservation status of mammals and birds in the southwestern Australian forests. II. Are there unstudied, indirect or long-term links between forestry practices and species decline and extinction? *Pacific Conservation Biology* 4:315–325.
- Calver MC, Dell J (1998b). Conservation status of mammals and birds in the southwestern Australian forests. I. Is there evidence of direct links between forestry practices and species decline and extinction? *Pacific Conservation Biology* 4:296–314.
- Catling PC (1988). Similarities and contrasts in the diets of foxes, *Vulpes vulpes*, and Cats, *Felis catus*, relative to fluctuating prey populations and drought. *Australian Wildlife Research* 15:307–317.
- Caughley G, Gunn A (1996). *Conservation biology in theory and practice*. Blackwell Science. Carlton.

- Christensen P (1978). The introduced european red fox (*Vulpes vulpes*): a serious threat to native mammals of the south-west. Forests Department of Western Australia. Perth. November 1978.
- Christensen P, Burrows N. (1994). Project desert dreaming: experimental reintroduction of mammals to the Gibson Desert, Western Australia. In: *Reintroduction Biology of Australian and New Zealand Fauna*. (M Serena, Ed.). Surrey Beatty and Sons. Sydney, pp. 199–207.
- Christensen P, Annelis A, Liddelow G et al. (1985). Vertebrate fauna in the southern forests of Western Australia: a survey. Bulletin 94. Forests Department of Western Australia. Perth. 1985.
- Christensen PE (undated). Effect of Prescribed Burning on One Population of Quokka (*Setonix brachyurus*). Local Expt. 117. Unpublished report for the Forests Department of Western Australia.
- Christensen PE, Kimber PC. (1975). Effects of prescribed burning on the flora and fauna of south-west Australian forests. In: *Managing Terrestrial Ecosystems*. Brisbane. (J Kikkawa HA Nix, Eds). Ecological Society of Australia. Proceedings of the Ecological Society of Australia, Vol 9: 85–106.
- Christensen PES (1980a). The biology of *Bettongia penicillata* Gray, 1837, and *Macropus eugenii* (Desmarest, 1817) in relation to fire. Bulletin 91. Forests Department of Western Australia. Perth. 1980.
- Christensen PES (1980b). A sad day for native fauna. *Forest Focus* 23:3–12.
- Churchill DM (1959). Late Quarternery eustatic changes in the Swan River District. *Journal of the Royal Society of Western Australia* 42:53–55.
- Clarke JR (1948). Anatomy of the Quokka. Part 1. – External morphology and large intestine. *Journal of the Royal Society of Western Australia* 33:59–150.
- Coman BJ. (1991). The ecology and control of feral cats in Australia. In: *The Impact of Cats on Native Wildlife*. (C Potter, Ed.). National Endangered Species Program, Australian National Parks and Wildlife Service, Canberra. 70–74.
- Cook DL (1960). Some mammal remains found in caves near Margaret River. *The Western Australian Naturalist* 7(4):107–108.
- Cook DL (1963). The fossil vertebrate fauna of Strong's Cave, Boranup, Western Australia. *The Western Australian Naturalist* 8(7):153–162.
- Corbett LK (1995a). *The Dingo in Australia and Asia*. University of New South Wales Press. Sydney.
- Corbett LK. (1995b). Dingo, *Canis lupus dingo*. In: *The Mammals of Australia*. (R Strahan, Ed.). Reed Books. Sydney, pp. 696–698.
- Corbett LK, Newsome AE (1987). The feeding ecology of the dingo. III. Dietary relationships with widely fluctuating prey populations in arid Australia: an hypothesis of alternation of predation. *Oecologia* 74:215–227.
- Courtney J. (1993). Climate. In: *Mountains of Mystery. A Natural History Of The Striling Range*. (C Thomson, G Hall G Friend, Eds). Western Australian Department of Conservation and Land Management. Perth, Western Australia.
- Crabb D (1973). Quokka on the Albany Highway. *The Western Australian Naturalist* 12(6):141.
- Daubney ME, Gardner G, Moore EM et al. (Eds.) (undated). *Northcliffe Remembers*. Northcliffe Pioneer Museum, Northcliffe, Western Australia.
- de Tores P (1999). 1997–1998 Report to Environment Australia National Feral Animal Control Program ISF06638. Control and Ecology of the Red Fox in Western Australia – Prey Response to 1080 Baiting Over Large Areas. Unpublished report prepared for Environment Australia, National Feral Animal Control Program. ISF06638. Department of Conservation and Land Management. Perth.
- de Tores P (2005). A proposal for translocation of the western ringtail possum, *Pseudocheirus occidentalis*, an arboreal marsupial endemic to the south-west of Western Australia. Unpublished report prepared for the Western Australian Department of Conservation and Land Management. Perth, Western Australia.
- de Tores PJ, Hayward MW, Rosier SM (2004). The western ringtail possum, *Pseudocheirus occidentalis*, and the quokka, *Setonix brachyurus*, case studies: *Western Shield* review – February 2003. *Conservation Science Western Australia* 5(2):235–257.
- Dell J. (1983). The Importance of the Darling Scarp to Fauna. In: *Scarp Symposium. A one day symposium to review land use and conflicts on the Darling Scarp*. Perth. Western Australian Institute of Technology. WAIT Environmental Studies Group. Report No. 10:
- Dell J, Hyder-Griffiths B (2002). A Preliminary Assessment of the Faunal Values of the Muddy Lakes Portion of the South Bunbury to Capel Coastal Corridor. Unpublished Draft Report. Department of Environmental Protection.
- Dickman CR. (1992). Conservation of Mammals in the Australasian Region: the Importance of Islands. In: *Australia and the Global Environmental Crisis*. (JN Coles JM Drew, Eds). Academy Press. Canberra, pp. 175–214.
- Dickman CR (1996). *Overview of the impacts of feral cats on Australian native fauna*. Australian Nature Conservation Agency. Canberra.
- Dillon M (1993). Summary of Studies Involving the Mainland Quokka in the Dwellingup District Since the Early 1970s. Unpublished Report for the Department of Conservation and Land Management. Perth, Western Australia.
- Dillon MJ (1996). Summary of all Sites Assessed for Quokka Abundance. Unpublished report prepared for the Western Australian Department of Conservation and Land Management. Perth. Western Australia.
- DNRE (2002). *Victorian Pest Management. A*

- framework for Action. *Fox Management Strategy*. The State of Victoria, Department of Natural Resources and Environment.
- Dortch C, Merrilees D (1971). A Salvage Excavation in Devil's Lair, Western Australia. *Journal of the Royal Society of Western Australia* 54(4):103–113.
- Dortch CE, Merrilees D (1973). Human occupation of Devil's Lair, Western Australia during the Pleistocene. *Archaeology & Physical Anthropology in Oceania* VIII(2):89–115.
- Dunnet GM (1962). A population study of the quokka, *Setonix brachyurus* Quoy and Gaimard (Marsupialia). II. Habitat, movements, breeding and growth. *CSIRO Wildlife Research* 7(1):13–32.
- Dunnet GM (1963). A population study of the quokka, *Setonix brachyurus* Quoy and Gaimard (Marsupialia). III. The estimation of population parameters by means of the recapture technique. *CSIRO Wildlife Research* 8:78–117.
- Eldridge MDB, Close RL. (1995). Allied rock-wallaby, *Petrogale assimilis*. In: *The Mammals of Australia*. (R Strahan, Ed.). Reed Books. Sydney, pp. 365–366.
- ESRI. (1999–2004). *ArcGIS 9*. Environmental Systems Research Institute, Inc.
- Evans HD (undated). *Pioneering in the Karri Country*. Pemberton-Northcliffe Tourist Bureau.
- Evans M, Gordon G. (1995). Bridled Nailtail Wallaby, *Onychogalea fraenata*. In: *The Mammals of Australia*. (R Strahan, Ed.). Reed Books. Sydney, pp. 356–358.
- Friend JA (1990). The Numbat *Myrmecobius fasciatus* (Myrmecobiidae): history of decline and potential for recovery. *Proceedings of the Ecological Society of Australia* 16:369–377.
- Friend JA, Thomas ND. (1994). Reintroduction and the numbat recovery programme. In: *Reintroduction Biology of Australian and New Zealand Fauna*. (M Serena, Ed.). Surrey Beatty and Sons. Sydney, pp. 189–198.
- Friend JA, Butler T (nominally 1998). Gilbert's Potoroo Recovery Team Annual Report 1998. Unpublished report for the Western Australian Department of Conservation and Land Management. Albany, Western Australia.
- Friend JA, Butler T (nominally 1999). Gilbert's Potoroo Recovery Team Annual Report 1999. Unpublished report for the Western Australian Department of Conservation and Land Management. Albany, Western Australia.
- Gardner CA (1957). The fire factor in relation to the vegetation of Western Australia. *The Western Australian Naturalist* 5(7):166–173.
- Gaynor A (2000). Report on the history of the arrival of the feral cat population in Western Australia. *CALMScience* 3(2):149–179.
- Gibb DGA, Kakulas BA, Perrett DH et al. (1966). Toxoplasmosis in the Rottneest quokka (*Setonix brachyurus*). *Australian Journal of Experimental Biology and Medical Science* 44:665–672.
- Gibson DF, Lundie-Jenkins G, Langford DG et al. (1994). Predation by Feral Cats, *Felis catus*, on the Rufous Hare-wallaby, *Lagorchestes hirsutus*, in the Tanami Desert. *Australian Mammalogy* 17:103–108.
- Gillfillan S. (unpublished). Unpublished database records of fauna occurrence from the south coast region of Western Australia.
- Glauert L (1926). A List of Western Australian Fossils. *Geological Survey of Western Australia Bulletin* 88:36–71.
- Glauert L (1933). The distribution of the marsupials in Western Australia. *Journal of the Royal Society of Western Australia* 19:17–32.
- Glauert L (1948). The cave fossils of the south-west. *The Western Australian Naturalist* 1:100–104.
- Glauert L (1950). The development of our knowledge of the marsupials of Western Australia. *Journal of the Royal Society of Western Australia*:115–134.
- Gooding CD (1955). The vermin bonus system in Western Australia. Part 1 – The distribution of payments. *The Journal of Agriculture of Western Australia* 4(4):433–449.
- Gould J (1863). *The Mammals of Australia*. Volume II. The author. 26 Charlotte Street, Bedford Square, London.
- Government Gazette of Western Australia. (1933). *The Vermin Act, 1918. Proclamation*. Perth, Western Australia.
- Green N. (1989). *Aborigines of the Albany Region 1821–1898. The Bicentennial Dictionary of Western Australians. Volume VI*. The University of Western Australia Press, Perth, Western Australia.
- Haigh SA, Gaynor WT, Morris KD. (1994). A health monitoring program for captive, wild and translocated chuditch (*Dasyurus geoffroii*). In: *Proceedings of the 1994 Conference of the Australian Association of Veterinary Conservation Biologists*. Canberra. (AW English GR Phelps, Eds). Australian Association of Veterinary Conservation Biologists. 52–66.
- Hallam SJ (1975). *Fire and Hearth a study of Aboriginal usage and European usurpation in south-western Australia*. Australian Institute of Aboriginal Studies. Canberra.
- Hart R (1977). Report on trapping program and assessment of health of quokkas at Holyoake Site, near Dwellingup. Unpublished report.
- Hart RP (1981). The ecology of Salmonella in a wild marsupial, the Quokka (*Setonix brachyurus*). PhD thesis. Department of Zoology. University of Western Australia. Perth
- Hart RP, Bradshaw SD, Iveson JB (1986). *Salmonella* infections and animal condition in the mainland and Bald Island populations of the quokka (*Setonix brachyurus*: Marsupialia). *Journal of the Royal Society of Western Australia* 69(1):7–11.
- Hayward MW (2002). The ecology of the quokka (*Setonix brachyurus*) (Macropodidae: Marsupialia) in the northern jarrah forest of Australia. PhD thesis.

- School of Biological, Earth and Environmental Science. University of New South Wales. Sydney
- Hayward MW, de Tores PJ, Dillon MJ et al. (2003). Local population structure of a naturally occurring metapopulation of the quokka (*Setonix brachyurus* Macropodidae: Marsupialia). *Biological Conservation* 110:343–355.
- Hayward MW, de Tores PJ, Dillon MJ et al. (2005). Using faecal pellet counts along transects to estimate quokka (*Setonix brachyurus*) population density. *Wildlife Research* 32(6):503–507.
- Heatwole H. (1987). Major components and distribution of the terrestrial fauna. In: *Fauna of Australia. General Articles*. Vol. 1A (GR DyneDW Walton, Eds). Australian Government Publishing Service. Canberra, pp. 101–135.
- Herrick EH (1961). Some preliminary experiments on adrenal function during seasonal stresses in a wild marsupial (*Setonix brachyurus*). *Journal of the Royal Society of Western Australia* 44(2):61–64.
- Hilton-Taylor C. (2000). *2000 IUCN Red List of Threatened Species*. IUCN, Gland, Switzerland and Cambridge, UK.
- Hodgkin EP, Sheard K (1959). Rottneest Island: the Rottneest Biological Station and recent scientific research. 42(3):65–95.
- Holsworth WN (1964). Marsupial Behaviour with special reference to Population Homeostasis in the Quokkas on the West End of Rottneest Island. PhD Thesis. Department of Zoology. University of Western Australia. Perth, Western Australia
- Holsworth WN (1967). Population dynamics of the quokka, *Setonix brachyurus*, on the west end of Rottneest I., Western Australia. I. Habitat and distribution of the quokka. *Australian Journal of Zoology* 15:29–46.
- Horsup A, Evans M (1993). Predation by feral cats, *Felis catus*, on an endangered marsupial, the bridled nailtail wallaby, *Onychogalea franenata*. *Australian Mammalogy* 16(1):83–84.
- How RA, Dell J, Humphreys WF (1987). The ground vertebrate fauna of coastal areas between Busselton and Albany, Western Australia. *Records of the Western Australian Museum* 13(4):553–574.
- Jarman P. (1986). The red fox – an exotic, large predator. In: *The ecology of exotic animals and plants: some Australian case histories*. (RL Kitching, Ed.). John Wiley and Sons. Brisbane, pp. 45–61.
- Jenkins CFH (1974). The decline of the Dalgite (*Macrotis lagotis*) and other wild life in the Avon Valley. *The Western Australian Naturalist* 12(8):169–172.
- Johnson KA, Burbidge AA, McKenzie NL. (1989). Australian Macropodoidea: Status, causes of decline and future research and management. In: *Kangaroos, Wallabies and Rat-Kangaroos*. Vol. 2 (G Grigg, P Jarman I Hume, Eds). Surrey Beatty & Sons Pty Limited. Chipping Norton, New South Wales, pp. 641–657.
- Jones M. (1995). Tasmanina Devil, *Sarcophilus harrisi*. In: *The Mammals of Australia*. (R Strahan, Ed.). Reed Books. Sydney, pp. 82–84.
- Kabay ED, Start AN (1976). Results of the Search for the Potoroo in South West and South Coast of Western Australia 1975/76. Unpublished report prepared for the Western Australian Department of Fisheries and Wildlife. Perth, Western Australia.
- Kimber PC. (1974). Some effects of prescribed burning on jarrah forest birds. In: *3rd Fire Ecology Symposium*. Monash University, Melbourne. 49–57.
- King DR, Smith LA (1985). The distribution of the European red fox (*Vulpes vulpes*) in Western Australia. *Records of the Western Australian Museum* 12(2):197–205.
- King DR, Oliver AJ, Mead RJ (1981). *Bettongia* and fluoroacetate: a role for 1080 in fauna management. *Australian Wildlife Research* 8:529–536.
- Kinnear JE, Onus ML, Bromilow RN (1988). Fox control and rock-wallaby population dynamics. *Australian Wildlife Research* 15:435–450.
- Kinnear JE, Onus ML, Sumner NR (1998). Fox Control and rock-wallaby population dynamics – II. An update. *Wildlife Research* 25(1):81–88.
- Kinnear JE, Sumner NR, Onus ML (2002). The red fox in Australia – an exotic predator turned biocontrol agent. *Biological Conservation* 108:335–359.
- Kirke A (1983). Quokka, *Setonix brachyurus*, at Green Range. *The Western Australian Naturalist* 15(6):146.
- Kitchener DJ (1970). Aspects of the Response of the Quokka to Environmental Stress. PhD Thesis. University of Western Australia. Perth, Western Australia
- Kitchener DJ (1972). The importance of shelter to the quokka, *Setonix brachyurus* (Marsupialia), on Rottneest Island. *Australian Journal of Zoology* 20:281–299.
- Kitchener DJ (1973). Notes on home range and movement in two small macropods, the potoroo (*Potorous apicalis*) and the quokka (*Setonix brachyurus*). *Mammalia* 37:231–240.
- Kitchener DJ. (1995). Quokka, *Setonix brachyurus*. In: *The Mammals of Australia*. (R Strahan, Ed.). Reed Books. Sydney, pp. 401–403.
- Kitchener DJ, Vicker E (1981). *Catalogue of modern mammals in the Western Australian Museum 1895 to 1981*. Western Australian Museum. Perth.
- Kitchener DJ, Chapman A, Barron G. (1978). Mammals of the Northern Swan Coastal Plain. In: *Faunal Studies of the Northern Swan Coastal Plain. A Consideration of Past and Future Changes*. The Western Australian Museum, for the Department of Conservation and Environment. Perth, Western Australia.
- Kreffit G (1867). List of specimens collected by Mr George Masters, Assistant Curator, during the year 1866. Annual Report. Australian Museum. pp: 6–7.
- Kreffit G (1869). Specimens collected by Mr George Masters, Assistant Curator, in Western Australia. Annual Report. Australian Museum. pp: 7–8.

- Lamont BB, Ward DJ, Eldridge J et al. (2003). Believing the Balga: a new method for gauging the fire history of vegetation using grass trees. In: *Fire in Ecosystems of south-west Western Australia: impacts and management*. (I Abbott N Burrows, Eds). Backhuys Publishing, Leiden, the Netherlands. Perth, Western Australia, pp. 147–169.
- Lane-Poole CE (1921). File note dated 17 May 1921 in Western Australian Government State Records Office Archives: 56/21 AN 108 Acc 477. Game Act – Diseases among Quaggas (Wallabies) in South West.
- Laurance WF, Harrington GN (1997). Ecological associations of feeding sites of feral pigs in the Queensland wet tropics. *Wildlife Research* 24(5):579–590.
- Lenghaus C, Obendorf DL, Wright FH. (1990). Veterinary aspects of *Perameles gunnii* biology with special reference to species conservation. In: *Management and Conservation of Small Populations. Proceedings of a conference held in Melbourne, Australia. September 26–27, 1989*. (TW Clark JH Seebeck, Eds). Chicago Zoological Society. Brookfield, Illinois.
- Liddelow GL (2006). Rapid survey of quokka (*Setonix brachyurus*) in the southern forests. In Annual Research Activity Report. July 2005 – June 2006. Science Division. Discovering the nature of WA. Department of Conservation and Land Management. Perth, Western Australia. pp: 71–72.
- Liddelow GL, Wheeler IB, Kavanagh RP. (2002). Owls in the Southwest Forests of Western Australia. In: *Ecology and Conservation of Owls*. (I Newton, R Kavanagh, J Olsen et al., Eds). CSIRO. Melbourne, pp. 233–241.
- Lilley I (1993). Recent research in southwestern Western Australia: a summary of initial findings. *Australian Archaeology* 39:34–41.
- Long JL (1988). Introduced birds and mammals in Western Australia. Technical Series 1 (2nd Edn). Agricultural Protection Board, Perth, Western Australia.
- Lowry DC. (1967). *Geological Survey of Western Australia*. Bureau of Mineral Resources, Geology and Geophysics, Perth, Western Australia.
- Lundelius E (1957). Additions to knowledge of the ranges of Western Australian mammals. *The Western Australian Naturalist* 5:173–182.
- Lundelius EL (1960). Post Pleistocene Faunal Succession in Western Australia and its Climatic Interpretation. Report of the International Geological Congress. XXI Session. Part IV Chronology and Climatology of the Quaternary. Norden. 1960. pp: 142–153.
- Lundelius EL (1966). Marsupial carnivore dens in Australian caves. *Studies in Speleology* 1(4):174–181.
- Lunney D, Matthews A, Grigg J (2001). The diet of *Antechinus agilis* and *A. swainsonii* in unlogged and regenerating sites in Mumbula State Forest, south-eastern New South Wales. *Wildlife Research* 28(5):459–464.
- Main AR (1961). The occurrence of macropodidae on islands and its climatic and ecological implications. *Journal of the Royal Society of Western Australia* 44(3):84–89.
- Main AR, Yadav M (1971). Conservation of macropods in reserves in Western Australia. *Biological Conservation* 3(2):123–133.
- Main AR, Shield JW, Waring H. (1959). Recent studies on marsupial ecology. In: *Biogeography and Ecology in Australia*. (RL Keast, RL Crocker, CS Christian, Eds). The Hague, Netherlands, pp. 315–331.
- Marsack P, Campbell G (1990). Feeding behaviour and diet of dingoes in the Nullarbor Region, Western Australia. *Australian Wildlife Research* 17:349–357.
- Maxwell S, Burbidge AA, Morris K (Eds.) (1996). *The 1996 Action Plan For Australian Marsupials and Monotremes*. Endangered Species Program. Project Number 500. Wildlife Australia, Canberra, ACT.
- McCaw L, Hamilton T, Rumley C. (2005). Application of fire history records to contemporary management issues in south-west Australian forests. In: *A forest conscienceness: proceedings 6th National Conference of the Australian Forest History Society Inc, 12–17 September 2004*. Augusta, Western Australia. (M Calver, H Bigler-Cole, G Bolton et al., Eds). Millpress, Rotterdam.
- Mead RJ, Twigg LE, King DR et al. (1985). The tolerance to fluoroacetate of geographically separated populations of the quokka (*Setonix brachyurus*). *Australian Journal of Zoology* 21(6):503–511.
- Meagher SJ (1974). The food resources of the aborigines of the south-west of Western Australia. *Records of the Western Australian Museum* 3:14–65.
- Merrilees D (1965). Quokka at Yanchep in historic time. *The Western Australian Naturalist* 10(1):18.
- Merrilees D (1968). Man the destroyer: late Quaternary changes in the Australian marsupial fauna. *Journal of the Royal Society of Western Australia* 51(1):1–24.
- Merrilees D, Dix WC, Hallam SJ et al. (1973). Aboriginal man in southwest Australia. *Journal of the Royal Society of Western Australia* 56:44–55.
- Middleton E (2001). Nuyts Wilderness Wildfire Impact Report. 7–11 March 2001, Walpole, Western Australia. Unpublished report prepared for the Department of Conservation and Land Management, Perth, Western Australia.
- Molsher RL (1999). The ecology of feral cats, *Felis catus*, in the open forest in New South Wales: interactions with food resources and foxes. PhD Thesis. School of Biological Sciences. University of Sydney. Sydney
- Morton SR. (1990). The impact of European settlement on the vertebrate animals of arid Australia: a conceptual model. In: *Australian Ecosystems: 200 years of Utilization, Degradation and Reconstruction*. Geraldton, Western Australia. (DA Saunders, AJM Hopkins RA How, Eds). Ecological Society of Australia. Proceedings of the Ecological Society of Australia, Vol 16: 201–213.
- Newsome AE. (2001). The biology and ecology of the dingo. In: *A Symposium on the Dingo*. (CR Dickman,

- D Lunney, Eds). Royal Zoological Society of New South Wales. Mosman, New South Wales, pp. 20–33.
- Newsome AE, Corbett LK, Catling PC et al. (1983). The feeding ecology of the dingo. I. Stomach contents from trapping in southeastern Australia, and the non-target wildlife also caught in dingo traps. *Australian Wildlife Research* 10:477–486.
- Nicholls DG (1971). Daily and seasonal movements of the quokka, *Setonix brachyurus* (Marsupialia), on Rottnest Island. *Australian Journal of Zoology* 19:215–226.
- NSW NPWS (2001). *Threat Abatement Plan for Predation by the red fox (Vulpes vulpes)*. NSW National Parks and Wildlife Service. Hurstville, Sydney.
- Packer WC (1965). Environmental influences on daily and seasonal activity in *Setonix brachyurus* (Quoy and Gaimard) (Marsupialia). *Animal Behaviour* 13:270–283.
- Packer WC (1968). Eosinophils and population density in the marsupial *Setonix*. *Journal of Mammalogy* 49(1):124–126.
- Pavlov PM. (1995). Pig, *Sus scrofa*. In: *The Mammals of Australia*. (R Strahan, Ed.). Reed Books. Sydney, pp. 698–699.
- Pavlov PM, Crome FHJ, Moore LA (1992). Feral pigs, rainforest conservation and exotic disease in north Queensland. *Wildlife Research* 19(2):179–194.
- Pearce AT (1969). File note dated 24 February 1969 in Western Australian Government State Records Office Archives: 65/50 Acc 477. Folio 120. F.C. Act – Identification of Fauna – General File.
- Perry DH (1971). Observations of a young naturalist in the Lower Blackwood Valley in the year 1919. *The Western Australian Naturalist* 12(2):46–47.
- Perry DH (1973). Some notes on the decline and subsequent recovery of mammal populations in the south-west. *The Western Australian Naturalist* 12(6):128–130.
- Porter JK (1979). Vertebrate remains from a stratified Holocene deposit in Skull Cave, Western Australia, and a review of their significance. *Journal of the Royal Society of Western Australia* 61(4):109–117.
- Prince RIT (1984). Exploitation of Kangaroos and Wallabies in Western Australia I. A Review to 1970, with special reference on Red and Western Grey Kangaroos. Wildlife Research Bulletin Number 13 Western Australia. Department of Fisheries and Wildlife, Perth, Western Australia.
- Prince RIT. (1995). Banded hare-wallaby, *Lagostrophus fasciatus*. In: *The Mammals of Australia*. (R Strahan, Ed.). Reed Books. Sydney, pp. 406–408.
- Recher HF, Lim L. (1990). A review of current ideas of the extinction, conservation and management of Australia's terrestrial vertebrate fauna. In: *Australian Ecosystems: 200 years of Utilization, Degradation and Reconstruction*. Geraldton, Western Australia. (DA Saunders, AJM Hopkins RA How, Eds). Ecological Society of Australia. Proceedings of the Ecological Society of Australia, Vol.16: 287–301.
- Richards JD, Short J (1996). History of the disappearance of native fauna from the Nullarbor Plain through the eyes of long term resident Amy Crocker. *The Western Australian Naturalist* 21(2):89–96.
- Ride WDL (1970). *A Guide to the Native Mammals of Australia*. Oxford University Press. Melbourne.
- Risbey DA, Calver MC, Short JC et al. (2000). The impact of cats and foxes on the small vertebrate fauna of Heirisson Prong, Western Australia. *Wildlife Research* 27(3):223–236.
- Robertshaw JD, Harden RH (1985). The ecology of the dingo in north-eastern New South Wales III. Analysis of macropod bone fragments found in dingo scats. *Australian Wildlife Research* 12:163–171.
- Roe R (1971). Trial excavation in a small cave, Gingin. *The Western Australian Naturalist* 11:183–184.
- Rolls EC (1969). *They All Ran Wild: The enthralling story of pests on the land in Australia*. Angus and Robertson Ltd. Sydney.
- Rounsevell DE, Mooney N. (1995). Thylacine, *Thylacinus cynocephalus*. In: *The Mammals of Australia*. (R Strahan, Ed.). Reed Books. Sydney, pp. 164–165.
- Sadleir RMFS (1959). Comparative Aspects of the Ecology and Physiology of Rottnest and Byford Populations of the Quokka (*Setonix brachyurus* Quoy and Gaimard). Honours thesis. University of Western Australia. Perth. Western Australia
- Saunders G, Kay B (1996). Movements and home ranges of feral pigs (*Sus scrofa*) in Kosciusko National Park, New South Wales. *Wildlife Research* 23(6):711–720.
- Schmidt W, Mason M (1973). Fire and fauna in the northern jarrah forest of Western Australia. *The Western Australian Naturalist* 12(6):162–164.
- Schodde R, Tidemann SC (Eds.) (1982). *The Reader's Digest Complete Book of Australian Birds*. Reader's Digest Services Pty Ltd, Sydney.
- Serventy DL (1951). Inter-specific competition on small islands. *The Western Australian Naturalist* 3(1):59–60.
- Serventy DL, Glauert L, Carnaby IC et al. (1954). The recent increase of the rarer native mammals. *The Western Australian Naturalist* 4:128–141.
- Serventy VN (1953). The archipelago of the Recherche. 4. Mammals. *Australian Geographical Society Report* 1:40–48.
- Sharman GB (1954). The relationships of the quokka (*Setonix brachyurus*). *The Western Australian Naturalist* 4:159–168.
- Shield JW (1959). Rottnest Island: the Rottnest Biological Station and recent scientific research. 15. – Rottnest field studies concerned with the Quokka. *Journal of the Royal Society of Western Australia* 42(3):76–82.
- Shield JW (1964). A breeding season difference in two populations of the Australian macropod marsupial (*Setonix brachyurus*). *Journal of Mammalogy* 45(4):616–625.
- Short J, Kinnear JE, Robley A (2002). Surplus killing

- by introduced predators in Australia – evidence for ineffective anti-predator adaptations in native prey species? *Biological Conservation* 103:283–301.
- Short J, Bradshaw SD, Giles J et al. (1992). Reintroduction of macropods (Marsupialia: Macropodoidea) in Australia – a review. *Biological Conservation* 62:189–204.
- Short JC, Calaby JH (2001). The status of Australian mammals in 1922 – collections and field notes of museum collector Charles Hoy. *Australian Zoologist* 31(4):533–562.
- Shortridge GC (1909). An account of the geographical distribution of marsupials and monotremes of south-western Australia having special reference to the specimens collected during the Balston Expedition of 1904–1907. *Proceedings of the Zoological Society (London)* 1909:803–848.
- Sinclair EA (1999). Genetic variation in two endangered marsupials, the quokka, *Setonix brachyurus*, and Gilbert's potoroo, *Potorous gilbertii*. PhD thesis. University of Western Australia. Perth, Western Australia
- Smith AP, Quinn DG (1996). Patterns and causes of extinction and decline in Australian conilurine rodents. *Biological Conservation* 77:243–267.
- Smitz A (1998). Progress report on fate of quokkas translocated to Karakamia Sanctuary, east of Perth. Unpublished report for Karakamia Sanctuary for the Department of Conservation and Land Management, Perth Western Australia.
- Spencer PBS (1991). Evidence of predation by a feral cat *Felis catus* (Carnivora: Felidae) on an isolated rock-wallaby colony in tropical Queensland. *Australian Mammalogy* 14:143–144.
- Stewart DWR (1936). Notes on marsupial damage in pine plantations. *Australian Forestry* 1(2):41–42.
- Storr GM (1963). Some factors inducing change in the vegetation of Rottneest Island. *The Western Australian Naturalist* 9(1):15–22.
- Storr GM (1964a). Studies on marsupial nutrition. IV. Diet of the quokka, *Setonix brachyurus* (Quoy & Gaimard), on Rottneest Island, Western Australia. *Australian Journal of Biological Science* 17(2):469–481.
- Storr GM (1964b). The environment of the quokka (*Setonix brachyurus*) in the Darling Range, Western Australia. *Journal of the Royal Society of Western Australia* 47(1):1–2.
- Storr GM (1965). Notes on Bald Island and the adjacent mainland. *The Western Australian Naturalist* 9(8):187–196.
- Thackway R, Cresswell ID (Eds.) (1995). *An Interim Biogeographical Regionalisation for Australia: a Framework for Setting Priorities in the National Reserves Cooperative Program. Version 4.0*. Australian Nature Conservation Agency, Canberra.
- Thomas O (1906). On mammals collected in South-west Australia for Mr. W. E. Balston. *Proceedings of the Zoological Society of London* 1906:468–478.
- Thomson PC (1992). The behavioural ecology of dingoes in north-western Australia. III. Hunting and feeding behaviour, and diet. *Wildlife Research* 19(5):531–542.
- Troughton E (1965). *Furred Animals of Australia*. Angus and Robertson. Sydney, London, Melbourne.
- Turney CSM, Bird MI, Fifield LK et al. (2001). Early human occupation at Devil's Lair, southwestern Australia 50,000 years ago. *Quaternary Research* 55:3–13.
- Vernes K, Dennis A, Winter J (2001). Mammalian diet and broad hunting strategy of the dingo (*Canis familiaris dingo*) in the wet tropical rain forests of northeastern Australia. *Biotropica* 33(2):339–345.
- Wallace WR (1966). Fire in the jarrah forest. *Journal of the Royal Society of Western Australia* 49(2):33–44.
- Walton DW (Ed.) (1988). *Zoological catalogue of Australia. 5 Mammalia*. AGPS, Canberra.
- Ward D, Sneeuwjagt R (1999). Believing the balga. A time capsule of fire management. *Landscape* 14(3):10–16.
- Ward DJ, Lamont BB, Burrows CL (2001). Grassfires reveal contrasting fire regimes in eucalypt forests before and after European settlement in southwestern Australia. *Forest Ecology and Management* 150:323–329.
- Waring H (1956). Marsupial studies in Western Australia. *The Australian Journal of Science* 18:66–73.
- Watts CHS (1969). Distribution and habits of the rabbit bandicoot. *Transactions of the Royal Society of South Australia* 93:135–141.
- Wayne A, Ward C, Rooney J et al. (2000). The immediate impacts of timber harvesting and associated activities on the Ngwayir (*Pseudocheirus occidentalis*) in the Jarrah forest of Kingston State Forest Block. Progress Report December 2000. Unpublished report prepared for the Western Australian Department of Conservation and Land Management.
- Weston LN (1921). File note dated 18 March 1921 in Western Australian Government State Records Office Archives: 56/21 AN 108 Acc 477. Game Act – Diseases among Quaggas (Wallabies) in South West.
- White SR (1952). The occurrence of the quokka in the south-west. *The Western Australian Naturalist* 3(5):101–103.
- Whitehouse SJO (1977). The diet of the Dingo in Western Australia. *Australian Wildlife Research* 4:145–150.
- Wilson BA, Friend GR (1999). Responses of Australian mammals to disturbance factors. *Australian Mammalogy* 21(1):87–105.
- Woinarski JCZ, Milne DJ, Wanganeen G (2001). Changes in mammal populations in relatively intact landscapes of Kakadu National Park, Northern Territory, Australia. *Austral Ecology* 26:360–370.

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 <i>Setonix</i> 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) Lundelius (1960) 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 Lower levels only Merrilees noted the only records of <i>Setonix</i> from the Moore River – Dongara region are from lower parts of Hastings Cave deposit. However, Jefferys (pers comm. to MWH) subsequently listed <i>Setonix</i> 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 <i>Sarcophilus</i> .	not specified	Archer (1974b)	Lower two levels
Murray Cave	Approximately 40km north of Perth	Considered to represent a carnivore's accumulation, typical of <i>Sarcophilus</i>		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) Cook (1963) Merrilees (1968) 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 <i>Sarcophilus</i> , 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 <i>Sarcophilus</i> . Baynes et al. (1975) considered upper layers may have been accumulated by humans and believed <i>Sarcophilus</i> 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) Dortch and Merrilees (1973) Lundelius (1966) Balme et al. (1978) Represented consistently throughout deposit (all ages) Baynes et al. (1975) Deposits considered to be part of the modern fauna (occurring in the area immediately pre European arrival) Lundelius (1960) Both levels Cook (1960)

Table 1 (cont.)

Site name	Location	Description	Comment	Age	Source	Comment on <i>Setonix</i> 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) 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 <i>Sarcophilus</i> 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	Rottneest Island		brain in Formalin		M 18429
Undated	Rottneest Island	G. P. Whitley-Staff	skull and mandibles	Shown as G. P. Whitney-Staff in Australian Museum database	S 1936
Undated	Rottneest Island	G. P. Whitley-Staff	skull only	Shown as G. P. Whitney-Staff in Australian Museum database	S 1937
Undated	Rottneest Island	G. P. Whitley-Staff	skull, odd mandible	Shown as G. P. Whitney-Staff in Australian Museum database	S 1938
Undated	Rottneest Island	Taronga Park Trust	skin		M 7994
Undated	Rottneest 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	Rottneest Island	Samuel Voickersen (Volckertsoon), 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	Rottneest Island	Willem de Vlamingh, cited by (Alexander 1914) Glauert (1950)	Mistook the quokka on Rottneest island for '... A kind of rat as big as a common cat ...'
1801	Rottneest 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	Rottneest Island	Dr T.B. Wilson, cited by Alexander (1918)	Dr T.B. Wilson, visitor to the Swan River Settlement, when visiting Rottneest 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)	Glauert (1950) reported Gray's list of species from the Swan River. The list included the quokka Kitchener et al. (1978) 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	Rottneest 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 ' <i>caught a wallaby in trap</i> ' 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 <i>Trichosurus vulpecula</i> , 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, <i>Bettongia lesueur</i> , and bilbies, <i>Macrotis lagotis</i>) 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 Serventy 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 <i>Salmonella</i> infection. Implied to be at low density
1976	Muddy Lake, south of Bunbury	Hart et al. (1986)	Trapped as part of comparative study of <i>Salmonella</i> 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 <i>Salmonella</i> 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	Waychincup Inlet, east of Albany	Hart et al. (1986)	Trapped as part of comparative study of <i>Salmonella</i> 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	Rottneest 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 tammar, 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 P.JdeT)	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 P.JdeT)	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 Rottneest 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 continuous 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, Naim 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 from 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 (Naim 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, Dalgarp 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, 1 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 west of Austin Road	No other details
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 tamar wallaby, see comments in text
South Twin Peak Island Point Culver	1905	Shortridge (1909) Western Australian Museum records. WAM registration number 024346	Comments for the North Twin Peak Island, above apply. 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)
Urbae 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.