# The western ringtail possum, *Pseudocheirus occidentalis*, and the quokka, *Setonix brachyurus*, case studies: *Western Shield* review—February 2003

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## ABSTRACT

Case studies are presented for the western ringtail possum, *Pseudocheirus occidentalis*, and the quokka, *Setonix brachyurus*. The ringtail case study summarises information from a recent review of the species' distribution and conservation status, collates information on ringtail populations within the areas covered by the Department of Conservation and Land Management's (CALM) fauna recovery program, *Western Shield*, and draws extensively on the recent findings from translocation programs. Critical to the case study is the finding that (i) monitoring of the response to fox control programs is poor, or non-existent, at all known sites, with the exception of research specific translocation sites. This may reflect the difficulty in censusing and monitoring this species; and (ii) translocation success has not been demonstrated at any translocation release site and the primary translocation site, Leschenault Peninsula Conservation Park, has suffered a significant population decline. Hypotheses are proposed to explain this decline and, in the absence of demonstrated translocation success, critical components for monitoring western ringtail possum translocations are recommended. Monitoring protocols are also recommended for other extant populations within the species' geographic range.

The quokka case study also summarises information from a recent review of the species' distribution and conservation status and collates information on quokka populations within the areas covered by *Western Shield*. The case study also draws extensively on the findings from recent research from the northern jarrah forest. As for the ringtail case study, the quokka case study found monitoring is non-existent or poor, or *ad hoc* at best, at all known sites, with the exception of research specific sites within the northern jarrah forest. Consistent with recently published research findings, intervention management is recommended at these northern jarrah forest sites. An active adaptive management framework, using fire as a tool to create the preferred structural habitat mosaic, is recommended.

Both case studies highlight the need to review data collection, collation, analyses and reporting processes to ensure data are collected in a manner to allow objective analyses and scrutiny. Under this proposed scenario, any conservation gains can be quantified and documented. Conversely, in circumstances where desired outcomes have not been met, the failure to meet set goals can be identified and mechanisms can be implemented to improve conservation management.

## INTRODUCTION

### Background and overview

The western ringtail possum, *Pseudocheirus occidentalis*, and the quokka, *Setonix brachyurus*, are within the suite of mammal species considered at risk of predation by the introduced red fox, *Vulpes vulpes*. Both species have shown a contraction in geographic range and abundance since the arrival of the fox in south-west Western Australia and the fox has been implicated as a contributing factor to their decline (de Tores *et al.* 1998; de Tores *et al.* in review; de Tores, unpublished; Hayward *et al.* 2003).

The original *Western Shield* proposal (Burbidge *et al.* 1995) identified the western ringtail possum as a species likely to benefit from broad scale fox control and further implied the quokka, and a suite of other small to medium sized mammals, would also benefit from fox control. With the commencement of *Western Shield*, many operational baiting programs have been implemented and the native fauna response to fox control has been monitored. However, with the exception of site specific research programs, there has been no monitoring of western ringtail possum or quokka population response to fox control.

Fox baiting has been in place at Leschenault Peninsula Conservation Park as part of a translocation release program for the western ringtail possum since the early 1990s and predates *Western Shield*. Similarly, other fox baiting programs have been in place at sites where the western ringtail possum and the quokka are known to occur, although these programs were not specifically designed or implemented to conserve either species.

The western ringtail possum site specific research has been associated with translocation release programs of rehabilitated orphaned and/or injured possums and possums displaced as a result of vegetation clearing and habitat modification or habitat loss at development sites. Monitoring of these populations has recently raised several issues of concern (de Tores and Rosier, unpublished-a; de Tores *et al.* unpublished-a; de Tores *et al.* unpublished-b). Similarly, site specific research investigating the ecology of the quokka in the northern jarrah forest has identified issues of concern for conservation management of the quokka (see Hayward, 2002; Hayward *et al.* 2003; Hayward *et al.* 2004).

The case studies below summarise much of the recent published and unpublished findings and propose specific recommendations relevant to *Western Shield* and conservation management of both species.

## Terms of reference for the case studies

Specific terms of reference for the case studies were to:

i) outline the distribution, changes in status over time and probable causes of change for each species
ii) identify the components of *Western Shield* being used in the management of each species (e.g. predator control, translocation) and the populations being managed
iii) identify all the people (and their roles) involved in the management of each species
iv) describe or tabulate the implementation of *Western Shield* actions with respect to each managed population and the process for modifying prescriptions
v) in consultation with key people from each involved Region, assess the efficacy of the implementation of *Western Shield* actions and decision making procedures.

## The components of *Western Shield*, the people involved, populations monitored and actions implemented in relation to the western ringtail possum and the quokka

Table 1 identifies the components of *Western Shield* relevant to the western ringtail possum and the quokka. Information was provided by CALM regional, district and Science Division staff.

The lack of information on population size and population response to fox control at the locations listed in Table 1 reflects the difficulty of undertaking population studies on both species. The western ringtail possum is not amenable to conventional trapping techniques and capture-mark-release-recapture (termed 'mark-recapture') methods for estimating population size are not appropriate. Alternative techniques are labour intensive, costly and require training of survey personnel to ensure data collection techniques are consistent and comparable between locations.

The quokka occurs in densely vegetated creeklines over much of its range (Christensen *et al.* 1985; de Tores *et al.* in review; Hayward, 2002; Hayward *et al.* 2004). Conventional trapping in this habitat is physically difficult, labour intensive and has the potential to 'open up' the vegetation and expose resident quokka populations to increased risk from fox predation (de Tores *et al.* in review). Conventional trapping techniques can, and have been used to, estimate quokka population abundance (see for example Hayward *et al.* 2003). However, with the exception of the study by Hayward *et al.* (2003), quokka trapping has usually been undertaken in an *ad hoc* manner and the data has provided information on presence only, or at best has provided indices to abundance. These indices are not necessarily comparable across sites. Alternative techniques are currently being investigated, see for example Alacs *et al.* (2003), where extraction of DNA from epithelial tissue sloughed with faecal pellets was used to confirm species presence. Similarly, Hayward *et al.* (unpublished-b) used faecal pellet counts to derive estimates of quokka abundance. Importantly, this technique was validated by comparison with densities derived from mark-recapture techniques.

The sites listed in Table 1 indicate there is only one *Western Shield* monitoring site (quokkas at D'Entrecasteaux, Nuyts Wilderness) where there has been a response to fox control, albeit only inferred. This response has been inferred by detection of faecal pellets at baited sites of unburnt vegetation immediately outside the boundary of a recent wildfire. Population size has not been quantified and there are no pre fire data on abundance. There are no other *Western Shield* monitoring sites where the western ringtail possum or the quokka has been shown to respond to fox control. Anecdotal accounts (often reported in the media) of increases in abundance of the western ringtail possum and quokka as a result of *Western Shield* baiting are not supported by quantified data. Similarly, records of occurrence have not been shown to equate with persistence of populations.

The lack of a detectable response to fox control should be interpreted cautiously. It should not be seen as indicating an absence of response, but a reflection of the difficulty of deriving reliable estimates of abundance for the western ringtail possum and the quokka.

However, the findings from monitoring the quokka and the western ringtail possum at other sites, i.e. sites monitored intensively as part of specific programs, concluded the quokka has shown no response to baiting in the northern jarrah forest (Hayward, 2002; Hayward *et al.* 2003) and translocation of the western ringtail possum at four sites could not be considered successful, despite the presence of baiting for fox control (de Tores, unpublished; de Tores and Rosier, unpublished-a; de Tores

Table 1

*Western Shield* monitoring sites where the western ringtail possum and the quokka are known or are thought to be present. Additional sites listed are those where information on density/abundance/presence is known or inferred from monitoring and where fox baiting is carried out.

| DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT REGION | SITES CURRENTLY BAITED AND KNOWN TO SUPPORT POPULATIONS OF THE WESTERN RINGTAIL POSSUM OR QUOKKA | SPECIES PRESENT | BAITING REGIME | TYPE OF MONITORING IN PLACE AND RESULTS FROM MONITORING | SOURCE OF INFORMATION |
|---|---|---|---|---|---|
| Swan | Lane Poole Reserve and Keats Forest Block (within the northern jarrah forest) | **western ringtail possum**<br>A translocation site. Released animals were rehabilitated possums sourced primarily from wildlife carers in Busselton/Bunbury and surrounding area. | Within the 6 baitings per year treatment of Operation Foxglove | Radio telemetry monitoring was undertaken as part of a student project (Curtin University, Honours project). Indicators of success of the translocation included confirmation of breeding. However, there were no data to indicate young survived to independence and no evidence to suggest released possums survived beyond the first few months post release. Results from Millen (1997) and follow up monitoring indicated a high level of mortality, attributed to predation by the chuditch, *Dasyurus geoffroii*. Translocation cannot yet be deemed successful.<br>Monitoring commenced in July 1996 and ceased in April 2000 with the absence of funds and the death of the last remaining radio collared possum. | Millen (1997); de Tores and Rosier (unpublished data) |
| | Northern Jarrah Forest | **quokka**<br>Seven sites monitored over a 2-year period 2000-2001 | Within the 2 and 4 baitings per year treatment of Operation Foxglove with additional monthly baiting in the immediate vicinity of each 'quokka swamp' | Trapping and radio-telemetry to estimate abundance and survivorship, respectively. Additional details provide in the quokka case study, this paper. | Hayward *et al.* (2003) |
| | Northern Jarrah Forest | **quokka**<br>Scattered populations, known from incidental sightings, road kills and non-target captures when trapping for feral pig control | Within the 2 and 4 baitings per year treatment of Operation Foxglove. | No formal monitoring carried out by *Western Shield*. Quokka populations are thought to be extinct at two of these sites. | de Tores *et al.* (in review) |
| | Karakamia Sanctuary (privately owned wildlife sanctuary) | **western ringtail possum**<br>A translocation site, possums sourced primarily from wildlife carers and more recently from development sites in Busselton / Bunbury. | Permanent barrier baiting along a predator proof fence line | Radio-telemetry and spotlight monitoring. Translocation success is yet to be confirmed. Data to indicate success include:<br>• survivorship for over 4 years post release; and<br>• confirmed recruitment.<br>However, there is no evidence to show recruits have survived to independence or sexual maturity and dispersal patterns are unknown. | Smitz (2001) |
| | Karakamia Sanctuary | **quokka**<br>A translocation release site. Three quokkas released in 1996 ex Big Swamp Wildlife Park, Bunbury and originally sourced from mainland sites. An additional orphaned young from the northern jarrah forest was subsequently released as a juvenile/sub-adult in 1998. | as above | Monitored by opportunistic observations. Chance sightings have indicated recruitment of at least one individual. | Smitz (2001) |

Table 1 (continued)

| DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT REGION | SITES CURRENTLY BAITED AND KNOWN TO SUPPORT POPULATIONS OF THE WESTERN RINGTAIL POSSUM OR QUOKKA | SPECIES PRESENT | BAITING REGIME | TYPE OF MONITORING IN PLACE AND RESULTS FROM MONITORING | SOURCE OF INFORMATION |
|---|---|---|---|---|---|
| Swan (cont.) | Yalgorup National Park | **western ringtail possum**<br>A translocation site. Released animals were sourced from development sites where habitat had been destroyed | Monthly | Radio-telemetry and spotlighting to assess survivorship and density estimates, respectively. Results and additional details are provided in the western ringtail possum case study, this paper. | de Tores and Rosier (unpublished-a) |
| South West | Leschenault Peninsula Conservation Park | **western ringtail possum**<br>A translocation site. Released animals sourced from wildlife carers in Busselton/Bunbury | Monthly, see western ringtail possum case study and appendix 1 this paper for details | Radio-telemetry and spotlighting to assess survivorship and density estimates, respectively. Results and additional details are provided in the western ringtail possum case study, this paper. | de Tores *et al.* (unpublished-b) |
| | Harvey River, Water Corporation Managed estate | **western ringtail possum** | Unclear, baiting appears to have occurred between 1999 and December 2002. Intensity and frequency is also unclear | Presence confirmed in 1997 and estimated to be at very low density.<br>Consultant (B. Jones) commissioned to monitor for the Water Corporation. Unpublished reports indicate the western ringtail possum population in the Harvey River Valley is in 'terminal decline' with one breeding pair thought to be present. Consultant has been retained to monitor this population and three unspecified forest populations and habitat until 2010-2011, fund management by the Dept of CALM. This work was implemented outside the recovery team endorsement process. | de Tores and Rosier (1997)<br>Jones and Northover (2001) |
| | Ludlow Tuart Forest and other sites in the south west region | **western ringtail possum** | ? | The western ringtail possum is known to occur within the Ludlow and Abba River areas, north of Busselton. Sites known to have been previously baited, no additional information provided by regional staff. | |
| Warren | Manjimup, Perup Forest | **western ringtail possum** | 4 baitings per year, commenced in 1992 for protection of six species of rare fauna | High density populations detected from *ad hoc* spotlighting. The declines observed in the nearby Kingston Block have not been observed at Perup. | Ian Wilson (pers. comm.) [i]<br>Adrian Wayne and John Rooney (pers. comm.) [i] |
| | Manjimup, Kingston Block | **western ringtail possum** | 4 baitings per year, commenced in 1992 for protection of six species of rare fauna | Annual spotlighting carried out as part of a research program 1997-2002 has detected a decline in the number of sightings per transect. Decline interpreted to be in response to timber harvesting.<br>*Ad hoc* spotlighting by District staff has provided results consistent with research findings. | Adrian Wayne and John Rooney (pers. comm.) [i]<br>Wayne *et al.* (2001a)<br>Ian Wilson (pers. comm.) [i] |
| | Donnelly, Netic Block | **quokka** | 4 baitings per year, commenced 1992 | *Ad hoc* trapping with low capture success. No response detected. | Ian Wilson (pers. comm.) [i] |
| | Donnelly, Giblet/Court Block | **quokka** | 4 baitings per year, commenced 2000 | Baiting commenced to ameliorate effect of disturbance from roading. No monitoring of response. | Ian Wilson (pers. comm.) [i] |

Table 1 (continued)

| DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT REGION | SITES CURRENTLY BAITED AND KNOWN TO SUPPORT POPULATIONS OF THE WESTERN RINGTAIL POSSUM OR QUOKKA | SPECIES PRESENT | BAITING REGIME | TYPE OF MONITORING IN PLACE AND RESULTS FROM MONITORING | SOURCE OF INFORMATION |
|---|---|---|---|---|---|
| | Shannon, Crowea Block | **quokka** | 4 baitings per year, commenced 1999 | Baiting commenced to ameliorate effect of disturbance from roading. *Ad hoc* trapping with low capture success. No response detected. | Ian Wilson (pers. comm.) [i] |
| Warren (cont.) | Shannon, Kinkin/Dordagup area | **quokka** | 4 baitings per year, commenced 1998 | Baiting commenced to ameliorate effect of disturbance from roading and fire. No response detected. | Ian Wilson (pers. comm.) [i] |
| | D'Entrecasteaux, Dombakup Block | **quokka** | 4 baitings per year, commenced 1999 | Baiting commenced to ameliorate effect of disturbance from roading. *Ad hoc* trapping with low capture success. No response detected. | Ian Wilson (pers. comm.) [i] |
| South Coast | D'Entrecasteaux - Nuyts Wilderness | **quokka** | Monthly baiting | A large number of quokka deaths recorded as a result of an intense wildfire in the Nuyts Wilderness area in 2001. Quokka presence has subsequently been detected in unburnt patches within the boundary of the Nuyts fire - presence inferred by detection of scats within typical quokka runways at three locations immediately outside the burn boundary. A program (detection of scats) has been implemented to monitor recovery/response post fire. | Greg Freebury (pers comm.) [i]<br>Middleton (2001) |
| | D'Entrecasteaux - 'Woolbales Block' | **?** | 6 baitings per year | Annual trapping carried out since March 1997 for the suite of small to medium size mammals. No formal monitoring program in place for the quokka. | Greg Freebury (pers comm.) [i] |
| | Walpole Nornalup National Park - 'Hilltop Area' | **quokka** | 6 baitings per year | Annual trapping carried out since May 1997 for the suite of small to medium size mammals as part of *Western Shield*. No formal monitoring program in place for the quokka, however quokka presence inferred at sites supporting suitable habitat of spreading sword-sedge, *Lepidosperma effusum*, and *Anarthria scabra.* | Greg Freebury (pers comm.) [i] |
| | Walpole Nornalup National Park - Giants Block | **quokka** | 6 baitings per year | Bi-annual trapping carried out since November 1996 for the suite of small to medium size mammals as part of *Western Shield*. No formal monitoring program in place for the quokka, however quokka presence inferred at sites supporting suitable of habitat of spreading sword-sedge, *Lepidosperma effusum*, and *Anarthria scabra.* | Greg Freebury (pers comm.) [i] |
| | Walpole Nornalup National Park - Mt Clare area | **quokka** | 6 baitings per year | Annual trapping carried out since 1997 for the suite of small to medium size mammals as part of *Western Shield*. No formal monitoring program in place for the quokka, however quokka presence inferred at sites supporting suitable habitat of spreading sword-sedge, *Lepidosperma effusum*, and *Anarthria scabra.* | Greg Freebury (pers comm.) [i] |
| | Mehniup Hill Nature Reserve | ? | 6 baitings per year | | Greg Freebury (pers comm.) [i] |
| | William Bay National Park | **western ringtail possum** | 6 baitings per year | No formal monitoring program in place for the western ringtail possum. | Greg Freebury (pers comm.) [i] |

Table 1 (continued)

| DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT REGION | SITES CURRENTLY BAITED AND KNOWN TO SUPPORT POPULATIONS OF THE WESTERN RINGTAIL POSSUM OR QUOKKA | SPECIES PRESENT | BAITING REGIME | TYPE OF MONITORING IN PLACE AND RESULTS FROM MONITORING | SOURCE OF INFORMATION |
|---|---|---|---|---|---|
| | West Cape Howe National Park, 25km West of Albany | **western ringtail possum** | 4 baitings per year | Western ringtail possum known to be present, no *Western Shield* monitoring or western ringtail possum specific monitoring in place. | Peter Collins (pers. comm.) [i] |
| South Coast (cont.) | Gull Rock National Park, 14km East of Albany | **western ringtail possum** | 4 baitings per year | Western ringtail possum known to be present, no *Western Shield* monitoring or western ringtail possum specific monitoring in place. | Peter Collins (pers. comm.) [i] |
| | Porongurups National Park, 30km North of Albany | **western ringtail possum** | 4 baitings per year | Standard *Western Shield* monitoring - 5km transects with 50 wire cage and 50 Elliott traps monitored in Spring and Autumn. No specific western ringtail possum monitoring and presence of western ringtail possum is known from one (possibly more) opportunistic sighting only. | Peter Collins (pers. comm.) [i] Jim Shugg (pers. comm.) [i] |
| | Waychinicup - Mt Manypeaks-Normans inlet, 35-50km East North-East of Albany | **western ringtail possum** | 4 baitings per year | Standard *Western Shield* monitoring - 5km transects with 50 wire cage and 50 Elliott traps monitored in Spring and Autumn. No specific western ringtail possum monitoring however the western ringtail possum is regularly sighted by field staff. | Peter Collins (pers. comm.) [i] |
| | Angove Water Reserve, 26km North-East of Albany | **western ringtail possum** | 4 baitings per year | This site is monitored for noisy scrub-bird and western bristle-bird, no specific monitoring for the western ringtail possum, however the western ringtail possum is regularly sighted by field staff. There is recent evidence of recolonisation (fresh scats and animals sighted) of area burnt in 2000. | Peter Collins (pers. comm.) [i] |
| | Two Peoples Bay Nature Reserve, 28 km East North-East of Albany | **western ringtail possum** | 4 baitings per year | This site is monitored for Gilberts potoroo, noisy scrub-bird and western bristle-bird, no specific monitoring for the western ringtail possum. | Peter Collins (pers. comm.) [i] |
| | Two Peoples Bay Nature Reserve, 28 km East North-East of Albany | **quokka** | 4 baitings per year | This site is monitored for Gilberts potoroo, noisy scrub-bird and western bristle-bird, no specific monitoring for the quokka, however, quokkas are regularly caught as non target species in trapping programs for Gilbert's potoroo. The quokka is considered to be in relatively high density and may be responding to fox control. | J. A. (Tony) Friend (pers. comm.) [i] |

(i) List of pople referred to in Table 1 through a personal communication (pers. comm.) with the first author. Listed in citation order from Table 1.

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|---|---|
| Ian Wilson: | Western Australian Department of Conservation and Land Management, District Nature Conservation Co-ordinator, Manjimup. |
| Adrian Wayne: | Western Australian Department of Conservation and Land Management, Forest Ecologist, Science Division, Manjimup |
| John Rooney: | Western Australian Department of Conservation and Land Management, Technical Officer, Science Division, Manjimup |
| Greg Freebury: | Western Australian Department of Conservation and Land Management, South Coast Region, Albany |
| Peter Collins: | Western Australian Department of Conservation and Land Management, Fauna Conservation Officer, Albany |
| Jim Shugg: | Former employee of Western Australian Department of Conservation and Land Management, Pemberton |
| J.A. (Tony) Friend: | Western Australian Department of Conservation and Land Management, Principal Research Scientist, Science Division, Albany |

*et al.* unpublished-b; Millen, 1997; Smitz, 2000; Smitz, 2001).

These issues are discussed in the following case studies.

## Case Study 1: The western ringtail possum, *Pseudocheirus occidentalis*

### Distribution

The distribution and conservation status of the western ringtail possum was recently reviewed and is detailed in de Tores (unpublished). In summary, the review concluded the western ringtail possum continues to meet the World Conservation Union (IUCN) criteria for a Threatened species in the category Vulnerable. The known extant geographic range of the western ringtail possum was shown to be larger (in terms of extent of occurrence) than inferred by Jones *et al.* (1994). However, this extension of geographic range was attributed to a greater awareness of the western ringtail possum and an increase in the number of known records of occurrence. It was not seen as an indication of recovery or partial recovery of the species. The known extant geographic range was extended by confirmation of records of occurrence in jarrah, *Eucalyptus marginata*, and jarrah/marri, *Corymbia calophylla*, forest near Collie and riverine stands of peppermint, *Agonis flexuosa*, near the Harvey River, east of Harvey.

The review emphasised confirmation of presence should not be equated with long term persistence of populations/subpopulations. The Collie and Harvey River populations were identified as at risk. Threats to these populations include fox predation and habitat modification.

Additional populations considered at risk were at the northern extent of the species range (exclusive of translocated populations) near Bunbury, populations within the greater Busselton area and populations within jarrah/marri forest near Manjimup. Threats to the Bunbury and Busselton populations were identified as habitat fragmentation and population fragmentation associated with urban development. Threats to the Manjimup populations were identified as timber harvesting and burning operations, see also Wayne *et al.* (2000) and Wayne *et al.* (2001b). However, many of the known western ringtail possum populations in the Manjimup area are outside areas available for logging and are within the extensive reserve system (Neil Burrows, CALM, pers. comm.). The forest populations near Manjimup are currently the subject of a research program investigating the ecology of, and quantifying the threats to, the western ringtail possum (Adrian Wayne, CALM, pers. comm.).

The ongoing requirement to clear land for housing and for industry in the greater Busselton area will continue to result in habitat loss and displacement of resident populations of the western ringtail possum. There will be a continued need for land use planners and wildlife managers to address this issue (de Tores, unpublished). Proponents of development projects have traditionally adopted a strategy whereby the issue of western ringtail possum conservation is addressed through translocation. This issue is relevant to, and discussed in, the case study.

### Background

The western ringtail possum case study is based on, and extracts information from, previous reports, publications and a suite of publications in preparation. The response of the western ringtail possum and the response of *in situ* resident populations of the common brushtail possum, *Trichosurus vulpecula*, at western ringtail possum translocation release sites are specifically addressed in the case study. Details on survivorship, habitat use by individual radio-collared animals, breeding success, dispersal, home range, capture and handling/sedation are given in the background summary only and detailed in a series of manuscript currently in preparation [de Tores (unpublished), de Tores *et al.* (unpublished-b), de Tores and Rosier (unpublished-a), de Tores and Rosier (unpublished-b), de Tores *et al.* (unpublished-c) and de Tores and Rosier (unpublished-c).]

The translocation release sites referred to in the case study are within Leschenault Peninsula Conservation Park and Yalgorup National Park. Both reserves are currently baited for fox control and fall within the *Western Shield* fauna recovery program.

### Western ringtail possum translocations to Leschenault Peninsula Conservation Park

#### *Background and objectives*

Leschenault Peninsula Conservation Park is located immediately north of Bunbury and approximately 160 km south of Perth.

Prior to the first release at Leschenault in 1991, injured and/or orphaned possums passed on to wildlife carers for rehabilitation and possums displaced by habitat destruction from the Busselton area, were released in an *ad hoc* manner at the discretion of wildlife carers. Translocation release site selection was determined by wildlife carers and there was no assessment of the fate of released animals.

A pilot study by Jones (1991) followed the progress of rehabilitated western ringtail possums released at Locke Nature Reserve, Busselton. Five western ringtail possums were fitted with radio-collars and released. Within six weeks, four were dead and the condition of the retrieved carcasses indicated the cause of death was fox predation. In August-September 1991, Leschenault Peninsula Conservation Park was identified as a more appropriate release site. Site selection was on the basis of presence of extensive stands of suitable habitat, i.e. presence of peppermint, *Agonis flexuosa*, the preferred diet of the western ringtail possum, and tuart, *Eucalyptus* *gomphocephala*, known to provide suitable tree hollows. Tuart and peppermint woodland and forest are known to support high density western ringtail possum populations in the greater Busselton area.

Leschenault Peninsula Conservation Park is within secure conservation estate. It is an 11km long, narrow peninsula highly suitable to baiting. It is bounded by the Indian Ocean and Leschenault estuary, with a narrow, 600m wide, isthmus providing the only opportunity for re-invasion by foxes.

Leschenault is north of the northern most known coastal occurrence of the western ringtail possum, but within the species' former geographic range. If successful, the release program would result in an extension of the species current range and establish a new population within secure conservation estate. It would also provide wildlife carers with the opportunity to contribute to a program with positive conservation outcomes.

1080 baiting commenced in September 1991 and a 4-weekly baiting regime (13 baiting sessions per year) was implemented, using the existing roading network for vehicle delivery of baits. The standard 4.5mg 1080 dried meat baits were used and approximately 100 –115 baits were distributed at each baiting event.

The first release of eight rehabilitated possums was in September 1991. All released possums were sourced from wildlife carers. Subsequent release dates were largely determined by wildlife carers, with a total of 106 rehabilitated western ringtail possums released over the period 1991 to 1997.

Monitoring protocols for released animals, criteria used to determine success and results from monitoring are detailed in de Tores *et al.* (unpublished-b). In summary, released possums establish regular use of dreys and tree hollows. Home range estimates were comparable to reports in the literature and unpublished information on home range for the western ringtail possum and the common ringtail possum, *Pseudocheirus peregrinus.* Females were shown to produce young, the sex ratio of young was not significantly different from parity and dispersal patterns of young were consistent with that expected from the literature, i.e. female young stayed within the natal range and male young dispersed. Recruits to the population were also shown to breed successfully.

Spotlight transects were conducted in 1996, 1997 and 1998 and results (summarised below) confirmed the western ringtail possum population progressively increased.

The translocation was deemed to be successful, subject to follow-up spotlight monitoring confirming the population level had been sustained or increased and subject to the outcome of proposed genetic analyses. Specific issues proposed for the genetic analyses include assessment of the effective population size and examining whether breeding is restricted to a limited number of individuals (de Tores *et al.* unpublished-b).

Follow up spotlighting was carried out in 2002 and identified a decline in density of the western ringtail possum (density estimates are detailed below). The number of sightings fell from 77 in 1996, 75 in 1997 and 100 in 1998, to 2 in 2002. The corresponding number of common brushtail possum sightings was 89 in 1996, 119 in 1997, 102 in 1998 and 114 in 2002.

The cause of the decline in western ringtail possum density is unclear. Possible explanations include competition with the common brushtail possum, increased predation by cats, foxes or pythons, prey switching (rabbit numbers have been significantly reduced and may no longer be as prevalent in the diet of introduced and native predators), effects from drought, presence of disease (toxoplasmosis has been confirmed in the ringtail population at Yalgorup), unsuitable habitat or a combination of these possible causes.

However, the most parsimonious explanation for the decline is an increase in the level of fox predation as a result of changes to the 1080 baiting regime. Appendix 1 details the history of 1080 baiting, post 1997 at Leschenault. The baiting history shows there was a 3 month period (31/12/1998 to 24/3/1999 - corresponding with a known peak period in fox dispersal) where 2 consecutive monthly baitings were missed and an additional 2 months in the period 26/5/99 to 18/12/99 where monthly baiting was not carried out (5 baitings only carried out in this 7 month period).

Monthly baiting also appears to have been missed in June 1998, April 2000, August 2000, February 2001, August 2001, November and December 2001 and March 2002. All of the missed baitings are between the 1998 and 2002 spotlight surveys. The multiple months when baiting was not carried out may have been sufficient to result in temporary increases in fox numbers and cause the decline in the western ringtail possum population.

Other changes to the baiting regime at Leschenault have also been implemented. Specifically, fewer baits are now delivered at each baiting session and baits are now buried. These changes further confound interpretation of the cause of the decline in western ringtail possum density. These changes in protocol alone may account for an increase in fox numbers, as bait uptake by foxes is reduced when baits are buried (Thomson and Kok, 2002). A switch to buried baits at rock wallaby sites was also shown to result in an increase in predation (Kinnear, CALM, pers. comm.).

The hypothesis that the missed baiting events and changes to the baiting regime were responsible for an increase level of predation and subsequent decline in density of the western ringtail possum is not mutually exclusive of any other factor, or combination of factors, contributing to the decline.

The sections below address the methodology used to derive the estimates of density for the western ringtail possum and the common brushtail possum. The alternative hypothesis that competition with the common brushtail possum was responsible for the decline in western ringtail possum density is discussed.

## *Methodology*

**Release dates, radio-telemetry monitoring and home range estimates**

All released animals were fitted with a reflective ear tag and implanted with a Trovan® passive transponder to provide a unique identifier. Breeding status/condition was assessed and standard morphometrics were recorded and are detailed in de Tores *et al.* (unpublished-b).

A subset of all released animals was radio-collared and monitored to determine survivorship, home range and habitat use. Initially, conventional single stage radio transmitters with loop aerials (Biotel, South Australia) were used. These were subsequently replaced with two stage transmitters with movement sensitive (mortality) circuitry (AVM, USA; and Biotrack UK) with a 2-hour period of inactivity required to trigger mortality mode. Further details of radio-collars used, history of use and development of a breakaway collar for use on subadult and juvenile western ringtail possums is given in de Tores *et al.* (unpublished-b) and de Tores and Rosier (unpublished-b).

Home range data collected included nocturnal and diurnal location records to determine core range (diurnal locations only) and home range inclusive of nocturnal foraging area (diurnal and nocturnal locations combined). All estimates were derived using the Harmonic Mean Analysis option (Dixon and Chapman, 1980) of RangesV/6 software (Kenward *et al.* 2003; Kenward and Hodder, undated). Home range results are reported for 95% isopleths in de Tores *et al.* (unpublished-b), as is the rationale for use of Harmonic Mean Analysis.

**Distance sampling model selection and density estimates for the western ringtail possum and the common brushtail possum**

Density estimates were derived annually from spotlighting data for 1996, 1997, 1998 for the western ringtail possum and 1996, 1997, 1998 and 2002 for resident populations of the common brushtail possum.

Two vehicle driven spotlighting transects were established and each was spotlighted for six to nine consecutive nights from mid March to early June each year. Two operators (one driver and one spotter) were required on each occasion. Spotlighting personnel varied minimally, with the same person (PdeT) present at each spotlighting event. Full details of equipment and description and justification of methodology are provided in de Tores *et al.* (unpublished-b).

Density estimates were derived using DISTANCE Sampling protocols (Buckland *et al.* 2001) and the Line Transect option of the software DISTANCE 4.0 (Thomas *et al.* 2002).

Model selection in DISTANCE is based on the Information-Theoretic approach and Akaike Information Criteria (AIC). A series of *a priori* candidate models was compared and the preferred model determined on the basis of AIC values and differences in AIC values (delta (Ä)AIC) (Buckland *et al.* 2001). Models with a ÄAIC of less than 2 are considered to be equally well supported by the data (Buckland *et al.* 2001; Burnham and Anderson, 2002).

**Distance sampling to determine habitat use of the common brushtail possum**

Habitat categories were delineated on the basis of the floristic and structural vegetation units identified by Trudgen (1984). Trudgen's (1984) mapped vegetation units were provided digitally by CALM's Information Management Branch and modified, post ground-truthing, to reflect structural and successional changes post 1984. Habitat units were then mapped in the Geographic Information System (GIS), Arcview. A GPS location record (post processed differential GPS) was recorded for each sighting record in 2002. The ArcView GIS extension XTools was used to identify the habitat unit in which each spotlighting sighting record occurred.

## Results

**Model selection and density estimates for the western ringtail possum**

Estimates of density (from 252 sighting records) from the preferred model are shown in Table 2 and show increasing western ringtail possum density from 1996-1998. Two sightings only were recorded for the same annual sampling effort in 2002 and therefore no density estimates were derived for 2002.

**Model selection and density estimates for the common brushtail possum**

Estimates of density (from 424 sighting records) from the preferred model are shown in Table 3 and show increasing common brushtail possum density from 1996-1998 and 2002.

**Model selection and habitat use of the common brushtail possum**

Density estimates per stratum are shown in Table 4. Table 5 lists the habitat units derived from Trudgen (1984), modified to reflect structural changes post 1984 and used as strata in the preferred model. Common brushtail possum density estimates varied by an order of magnitude between the two highest density strata (stratum 3, 92 records; stratum 2, 19 records).

## Western ringtail possum translocations to Yalgorup National Park

## *Background and objectives*

Releases commenced in July 1995 in response to the management requirement to relocate possums displaced as a result of habitat modification/removal at development sites in the greater Busselton and Bunbury area. Yalgorup National Park was identified as an appropriate release location as it supported suitable habitat and, if successful, the translocations would result in a further extension of

TABLE 2

Output from the preferred model from DISTANCE, stratified by year, to estimate western ringtail possum density at Leschenault Peninsula Conservation Park 1996–1998.

| STRATUM (YEAR) | DENSITY ESTIMATE (NO/HA) | %CV | DF | 95% CONFIDENCE INTERVAL |
|---|---|---|---|---|
| Stratum: 1996 | 0.28390 | 19.67 | 25.78 | 0.19018 - 0.42379 |
| Stratum: 1997 | 0.30220 | 16.01 | 29.67 | 0.21834 - 0.41825 |
| Stratum: 1998 | 0.45915 | 13.46 | 30.08 | 0.34927 - 0.60359 |

TABLE 3

Output from the preferred model from DISTANCE, stratified by year, to estimate common brushtail possum density at Leschenault Peninsula Conservation Park 1996 – 1998 and 2002.

| STRATUM (YEAR) | DENSITY ESTIMATE (NO/HA) | %CV | DF | 95% CONFIDENCE INTERVAL |
|---|---|---|---|---|
| Stratum: 1996 | 0.24317 | 18.14 | 31.16 | 0.16850 - 0.35094 |
| Stratum: 1997 | 0.36774 | 15.02 | 37.45 | 0.27176 - 0.49761 |
| Stratum: 1998 | 0.36461 | 13.71 | 45.06 | 0.27699 - 0.47993 |
| Stratum: 2002 | 0.38963 | 13.56 | 47.07 | 0.29695 - 0.51123 |

Table 4

Output from the preferred model from DISTANCE, stratified by habitat category, to estimate common brushtail possum density at Leschenault Peninsula Conservation Park, 2002. Descriptions of habitat categories are given in Table 5.

| STRATUM (YEAR) | DENSITY ESTIMATE (NO/HA) | %CV | DF | 95% CONFIDENCE INTERVAL |
|---|---|---|---|---|
| Stratum 1: | 0.0009 | 101.26 | 12.00 | 0.0001 - 0.0056 |
| Stratum 2: | 0.0616 | 31.41 | 21.91 | 0.0326 - 0.11632 |
| Stratum 3: | 0.17545 | 14.03 | 27.59 | 0.1318 - 0.23359 |
| Stratum 4: | 0.0089 | 86.55 | 5.48 | 0.0014 - 0.0577 |

TABLE 5

Habitat categories in which common brushtail possum sightings were recorded during the 2002 spotlight transects at Leschenault Peninsula Conservation Park.

| DESCRIPTION OF HABITAT UNIT | HABITAT STRATUM |
|---|---|
| Low shrubland, low open shrubland, high open shrubland to high shrubland, closed heath | 1 |
| *Agonis flexuosa* (peppermint) woodland of low open forest to low closed forest, inclusive of areas with *Eucalyptus gomphocepha* (tuart) overstorey and/or tuart emergents. | 2 |
| *Eucalyptus gomphocephala* woodland with relatively sparse *Agonis flexuosa* understorey | 3 |
| Beach, mobile dunes, poorly stabilised areas disturbed by waste disposal | 4 |

the geographic range of the western ringtail possum and establish populations in secure conservation estate. The translocations were also carried out under the belief the Leschenault translocations had been successful.

A total of 142 western ringtail possums was caught and relocated from six development sites in period July 1995 to September 2001. Releases were at two sites within Yalgorup National Park, White Hill and Preston Beach. Fox baiting was initiated at both sites prior to the first release and a monthly baiting regime has been maintained. All released possums were sourced directly from development sites, prior to or during site clearing. In each case, a contribution to funding for capture, relocation and monitoring was provided by the development proponent.

## Methodology

**Release dates, radio-telemetry monitoring and home range estimates**

The timing of release of western ringtail possums was largely determined by the site clearing requirements of the development proponents responsible for funding the relocation and monitoring of the displaced possums. Protocols for recording standard morphometrics, assessing breeding condition, radio-collaring and release were similar to the protocols adopted for the Leschenault releases and are detailed in de Tores and Rosier (unpublished-a).

Monitoring of survivorship, home range and habitat use is similar to that described for Leschenault. However, use of differential GPS enabled sub-metre accuracy of diurnal and nocturnal location records and detailed analysis of habitat use. Additional data were also collected on den tree, tree hollow and diurnal rest site use and are described in de Tores and Rosier (unpublished-a).

**DISTANCE sampling model selection and density estimates**

One walked spotlight transect of approximately 1.4 km was established at each release site. Spotlighting was carried out over 14 consecutive nights in March/April 2002 and density estimates for the western ringtail possum and resident populations of the common brushtail possum were derived using the DISTANCE sampling protocols (Buckland *et al.* 2001) as described for Leschenault. Post processed differential GPS locations were recorded for each sighting.

**DISTANCE sampling to determine habitat use of the western ringtail possum and the common brushtail possum**

Aerial Photograph Interpretation (API), using 1 : 20 000 stereo paired aerial photographs and a stereoscopic viewer, was used to identify and delineate vegetation units. Vegetation units were ground-truthed and unit boundaries digitised on geo-referenced aerial photographs using the GIS software ArcView (ESRI, 1992-2000). Vegetation units were subsequently grouped into habitat units. The ArcView GIS extension XTools was used to identify the habitat unit in which each spotlighting sighting record occurred.

## Results

**Criteria for success**

As for the Leschenault translocations, the following criteria for success have been met:

- Released possums established regular use of dreys and tree hollows
- Home range estimates were comparable to reports in the literature and unpublished information on home range for the western ringtail possum and are comparable to home range estimates from Leschenault
- Females have been shown to produce young and the sex ratio of young was not significantly different from parity
- Dispersal patterns of young were consistent with that expected from the literature, i.e. female young stayed within the natal range and male young dispersed
- Recruits to the population were also shown to breed successfully.

Success criteria yet to be established are:

- Confirmation the population has increased and can be sustained
- Maintenance of genetic diversity and confirmation that breeding is not restricted to a limited number of individuals.

**Model selection and density estimates for the western ringtail possum and the common brushtail possum**

The density estimates for the western ringtail possum and common brushtail possum at each site are given in Table 6 and Table 7, respectively.

**Habitat use of the western ringtail possum and the common brushtail possum**

Density estimates per stratum (habitat category) for the western ringtail possum and common brushtail possum are shown in Table 8 and 9 respectively and were derived from the preferred models, stratified by habitat category. Table 10 lists the habitat categories derived from grouping the API defined vegetation units. Western ringtail possum density estimates were higher in stratum 5 and common brushtail possum estimates were higher in stratum 6.

## Discussion

### Density estimates, habitat use and distance sampling

The output from the preferred model to estimate western ringtail possum density at Leschenault (Table 2) showed a pattern of progressively increasing density for 1996-1998. Similarly, the common brushtail possum showed a pattern of increasing density from 1996–2002 (Table 3). However, the net increase in density of the common brushtail possum in the period 1998–2002 (the period when the western ringtail possum density declined) was 0.025 individuals/ha. The implication is that this very small increase in common brushtail possum density is unlikely to result in an increase in the level of interspecies competition and is unlikely to have resulted in the decline in western ringtail possum density.

The output from the preferred models to estimate western ringtail possum and common brushtail possum densities, stratified by habitat stratum, at Leschenault and Yalgorup (Tables 4, 8 & 9) show a clear pattern of habitat partitioning at Yalgorup. The western ringtail possum showed a preference for habitat stratum 5 (dense *Agonis* understorey) and the common brushtail possum showed a preference for habitat stratum 6 (sparse *Agonis* understorey). Data were insufficient to enable the same analysis for Leschenault (i.e. only two western ringtail possum sightings from 2002), however, the common brushtail possum showed a preference for habitat stratum 3 (*Eucalyptus gomphocephala* woodland with sparse *Agonis* understorey). This habitat unit is analogous with the habitat unit preferred by the common brushtail possum at Yalgorup and suggests habitat partitioning may also have occurred at Leschenault. Under this scenario, i.e. habitat partitioning and a very small net increase in common brushtail possum density, it would seem unlikely competition between the two species was responsible for the decline of the western ringtail possum at Leschenault. In a study examining habitat use of the two sympatric possum species, Jones and Hillcox (1995) also found the relative abundance of the two species was largely

TABLE 6

Output from the preferred model from DISTANCE, stratified by site, to estimate density of the western ringtail possum at each translocation release site within Yalgorup National Park. Estimates from 2002 spotlighting data.

| STRATUM (YEAR) | DENSITY ESTIMATE (NO/HA) | %CV | DF | 95% CONFIDENCE INTERVAL |
|---|---|---|---|---|
| Stratum: Preston Beach | 1.0378 | 34.52 | 20.89 | 0.51637 - 2.0857 |
| Stratum: White Hill | 0.69214 | 24.41 | 34.17 | 0.42455 - 1.1284 |

TABLE 7

Output from the preferred model from DISTANCE, stratified by site to estimate density of the common brushtail possum at each site within Yalgorup National Park. Estimates from 2002 spotlighting data.

| STRATUM (YEAR) | DENSITY ESTIMATE (NO/HA) | %CV | DF | 95% CONFIDENCE INTERVAL |
|---|---|---|---|---|
| Stratum: Preston Beach | 0.53213 | 39.70 | 40.41 | 0.24566 - 1.1527 |
| Stratum: White Hill | 0.62306 | 46.78 | 46.30 | 0.25453 - 1.5252 |

TABLE 8

Output from the preferred model, stratified by habitat category, to estimate density of the western ringtail possum at Yalgorup National Park. Descriptions of habitat strata are given in Table 10.

| STRATUM (YEAR) | DENSITY ESTIMATE (NO/HA) | %CV | DF | 95% CONFIDENCE INTERVAL |
|---|---|---|---|---|
| Stratum: 5 | 0.60605 | 37.08 | 72.89 | 0.2964 - 1.2394 |
| Stratum: 6 | 0.17677 | 39.14 | 30.47 | 0.0818 - 0.38200 |

Table 9

Output from the preferred model, stratified by habitat category, to estimate density of the common brushtail possum at Yalgorup National Park. Descriptions of habitat strata are given in Table 10.

| STRATUM (YEAR) | DENSITY ESTIMATE (NO/HA) | %CV | DF | 95% CONFIDENCE INTERVAL |
|---|---|---|---|---|
| Stratum: 5 | 0.0809 | 24.45 | 35.78 | 0.0496 - 0.13190 |
| Stratum: 6 | 0.1772 | 17.03 | 17.03 | 0.1262 - 0.24887 |
| Stratum: 7 | 0.0231 | 64.95 | 28.11 | 0.0069 - 0.0779 |

TABLE 10

Habitat units within which western ringtail possum and common brushtail possum sightings were recorded during the 2002 spotlight transects at Yalgorup National Park, see text. See also de Tores and Rosier (unpublished-a) for details of the vegetation categories.

| DESCRIPTION OF HABITAT UNIT | HABITAT STRATUM |
|---|---|
| *Eucalyptus gomphocephala* woodland/open woodland to 25m with dense *Agonis flexuosa* understorey. | 5 |
| *Eucalyptus gomphocepha* woodland/open woodland to 25m with sparse *Agonis flexuosa* understorey. | 6 |
| *Eucalyptus gomphocephala* woodland/open woodland to 25m with absence of *Agonis flexuosa* in the understorey. | 7 |

determined by floristics. The western ringtail possum was more abundant in areas with more peppermint and the common brushtail possum was more abundant in areas with more tuart.

This further suggests factors other than competition with the common brushtail possum may have been responsible for the decline in western ringtail possum density.

**Changes to the baiting regime and the statutory responsibilities for recording locations where 1080 baits are laid**

It is unclear if changes to the baiting regime were responsible for the decline in western ringtail possum density at Leschenault. However, it remains the most parsimonious explanation. In the absence of experimental controls, the cause of the decline is unlikely to be unequivocally explained. Re-instating the 4-weekly baiting regime is recommended if further western ringtail possum releases are proposed at the Leschenault release site. This will require resolution of the conflict between management for conservation and management for visitor use (see below).

Similarly, the variation in detail of the record keeping for 1080 bait delivery made it difficult to interpret exactly how many baits were distributed at Leschenault at each baiting event. This further confounds identification of a cause and effect relationship between the number of baits delivered monthly and the decline of the western ringtail possum population.

**Conflict between conservation management and management for visitor use**

The decision to amend the baiting regime at Leschenault was primarily in response to the findings from a risk assessment which identified a potential risk to park users and domestic pets brought into the Park (R. Armstrong, CALM, pers. comm.). The operational application of several other 1080 baiting programs using conventional dried meat baits has also recently been amended as a result of similar risk analyses. As was the case at Leschenault, risk assessment at other sites has resulted in reductions to the frequency and intensity of baiting programs and the method of laying baits has changed to a buried bait delivery system. The latter imposes additional costs to baiting programs and has been shown to result in a reduced uptake of dried meat baits (Thomson and Kok, 2002).

When preparing, implementing and reviewing existing and proposed 1080 baiting programs, managers of conservation estate are expected to address the conflict between management for conservation purposes through the use of 1080 and management for visitor use. This is often done in the absence of information on community values and community expectations.

It is recommended that CALM implements a program to assess community attitudes to, and expectations from, its use of 1080 baiting for fox control. This will allow assessment of public expectation of a state government agency with the primary objective of nature conservation and the potentially conflicting, secondary objective of fulfilling the demand for public use, notwithstanding the latter's requirement to be consistent with the primary objective. Assessment of community attitudes and expectations will ultimately assist the Department with refining philosophies and improving strategies for baiting conservation estate and thereby reduce conflict between management objectives.

**Translocation as a management tool and the importance of monitoring**

Translocation is now widely accepted as a management tool for re-establishing species throughout their former range and in habitats from which they have become extinct. However, it should not be seen as a panacea for resolving all issues associated with fauna range contractions and regional extinctions (de Tores *et al.* unpublished-b). In the case of the western ringtail possum, translocation is yet to be shown to be an effective management tool. The potential for the translocations at Leschenault to succeed appears to have been compromised by changes to the baiting regime. Re-instating the former baiting regime and initiating further releases should be supported by research to assess the interaction between the suite of resident and introduced predators, the long term interaction between the western ringtail possum and the common brushtail possum and the importance of site specific habitat factors (de Tores *et al.* unpublished-b). The fate of the Yalgorup translocations is also yet to be determined (de Tores and Rosier, unpublished-a). Further translocation of the western ringtail possum (i.e. translocation to additional sites) is not recommended until the outcome of translocations to Leschenault and Yalgorup is known and there is a clear understanding of the factors influencing translocation success/failure.

To achieve this, monitoring needs to be focussed to ensure translocation outcomes can be assessed against specific criteria for success. Equally important is the need to specify the criteria for failure. Planning for translocation programs must also ensure resources are sufficient to enable monitoring to be effective. This may necessitate reducing the number of sites monitored or increasing the resources committed to monitoring.

If translocation can be established as a viable management strategy for the western ringtail possum, monitoring effort and intensity may be able to be relaxed. However, in the absence of demonstrated success, critical components of monitoring western ringtail possum translocation outcomes include:

- determining the fate of released possums—we recommend radio telemetry, ideally incorporating mortality circuitry and new advances, such as contact telemetry, as they become applicable for small to medium size arboreal marsupials. Analytical techniques focussing on survivorship are recommended, such as the known fate model from Program MARK (White, 2001)

- determining the fate of recruits to the population—we recommend use of breakaway collars for this purpose (de Tores and Rosier, unpublished-b) to ensure this age class is monitored and the survivorship and dispersal patterns determined
- estimating population changes through quantifiable measures – we recommend changes to population size should be assessed through the use of techniques which quantify these changes and don't simply report spotlight count data. Recommended techniques include DISTANCE Sampling (Thomas *et al.* 2002)
- assessing the effectiveness of predator control – this involves monitoring fox, cat and other predators to determine the effectiveness of introduced predator control and ideally should incorporate an assessment of the extent of interactions between predators. Monitoring should address the issues of mesopredator release and intraguild predation (Polis *et al.* 1989).

The *Western Shield* program in general appears to have little focus on monitoring fox populations. Monitoring of fox (and where appropriate, cat) populations is strongly recommended. This monitoring should assess fox and cat presence at treatment (baited) sites and control (unbaited) sites with the objectives of assessing whether the baiting program has achieved set targets of predator density reduction, and if met, determining if this has resulted in biodiversity conservation gains, as measured against the criteria for translocation success or by increases in native fauna abundance and survivorship.

Monitoring western ringtail possum response to fox control at locations other than specific translocation and other research sites has been poorly addressed by the *Western Shield* program. We recommend implementing a program to identify the sites of high conservation value to the western ringtail possum. We further recommend initiating a structured monitoring program at selected sites representative of the range of habitats occupied by the western ringtail possum. This monitoring program should assess western ringtail possum population changes and responses to fox control and the impact of other management practices and disturbance regimes. We advocate use of monitoring and analytical techniques with strong mathematical foundations (e.g. DISTANCE Sampling and the Information-Theoretic approach) and caution against use of simple spotlight count techniques and scat count techniques without appropriate validation of these techniques. We particularly caution against use of either of the latter two techniques where justification for the use of one is based on correlation with the other unvalidated method.

## CASE STUDY 2: THE QUOKKA, *SETONIX BRACHYURUS*

### Distribution

The distribution and conservation status of the quokka was recently reviewed by de Tores *et al.* (in review). The quokka was shown to have suffered a decline in geographic range in the 1930s, coinciding with the arrival of the fox in south-west Western Australia. A further decline appears to have occurred in the period 1980 to 1992, however, the latter may be an artefact of the IUCN methodology for assessing range contraction. Predation by the introduced red fox was implicated as a major cause of the initial decline, while ongoing predation, habitat destruction and modification through altered fire regimes appear to have contributed to the continued decline.

An increased awareness of the presence of the quokka on the mainland has resulted in numerous records of occurrence since 1992, has confirmed the existence of several populations at the northern extent of the quokka's known geographic range and indicated the current extent of occurrence to be similar to that in 1992. However, censuses at six locations in the northern jarrah forest (Hayward *et al.* 2003) indicated low abundance and only one population has persisted on the Swan Coastal Plain. Persistence of this population needs to be verified.

The review (de Tores *et al.* in review) emphasised the need for urgent management attention at sites in the northern jarrah forest, where Hayward *et al.* (2003) concluded the few remaining small populations constitute the terminal remnants of a collapsing metapopulation. The review further recommended:

> '…management of the quokka should adopt an adaptive management approach, under which research and monitoring is focused on examining the response of the quokka to a variety of management practices including habitat manipulation through the use of fire, fox baiting and pig control.'

Further, the review identified emphasis should initially be placed on the most vulnerable populations – those in the northern jarrah forest and the Stirling Range.

The Stirling Range population(s) are geographically isolated from other south coast populations and 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 was recognised as warranting further investigation.

The review also identified the lack of quantitative data on quokka populations from southern forest and south coast regions. Recommendations for southern forest and south coast areas included the requirement for:

> '…surveying to assess quokka population size, the extent of immigration and emigration and assessment of the range of habitat types used by quokkas'. The review further recommended 'this be combined with spatial analyses of known extant populations and suitable and potentially suitable habitat. The role of fire in establishing and maintaining preferred habitat should be determined and a program to assess the potential effects from management operations should be implemented.'

The review concluded the quokka continues to meet the IUCN criteria for listing as a Threatened species in the category Vulnerable.

## Background

The quokka case study is based on recent publications and a suite of publications in review and in preparation. The case study has extracted information from these manuscripts, and has placed emphasis on the quantitative analyses from the northern jarrah forest carried out by Hayward (2002) and reported in Hayward *et al.* (2003), Hayward *et al.* (2004), Hayward *et al.* (unpublished-a), Hayward *et al.* (in review-b) and Hayward *et al.* (in review-a).

## Quokka population structure in the northern jarrah forest

Results from mark-recapture studies at northern jarrah forest sites previously known to support populations of the quokka confirmed low density at six sites. Density and abundance estimates were derived by Hayward *et al.* (2003) for four of the seven sites trapped and at an additional site (Gervasse, near Collie) by de Tores *et al.* (in review). Where appropriate, the Jolly-Seber model of 'death but no immigration' was used. Abundance estimates for these five sites are shown in Table 11. A sixth site, Rosella Road, is also listed, however, only one individual was trapped and data were therefore insufficient to derive abundance estimates. No captures were recorded at an additional two sites where the quokka is now thought to be locally extinct (Hayward *et al.* 2003)

With the exception of Victor Road, all sites are baited as part of *Western Shield* or Operation Foxglove (a broadscale 1080 baiting program in the northern jarrah forest of south-west Western Australia – the predecessor to *Western Shield*). Victor Road had the highest proportion of juveniles and pouch young and therefore has the greatest propensity to increase. Hayward *et al.* (2003) believed the low population density at the unbaited Victor Road site reflected a low level of recruitment following weaning. The Hadfield Site, which ranked second in its propensity to increase (i.e. showed a high proportion of juveniles and pouch young), showed a relatively high density and abundance. This may reflect the quokkas ability to increase in abundance in the presence of fox control. However, despite the six year baiting program, quokka populations in the northern jarrah forest have not shown a pattern of increase in response to fox control (Hayward *et al.* 2003).

Hayward *et al.* (2003) concluded the absence of a detectable response to fox control may reflect on-going predation, despite the presence of baiting programs, and may also reflect the absence of the quokka's specific habitat requirement for a mosaic of seral stages within the *Agonis linearifolia* swamps.

## Habitat requirements

Habitat use by the quokka was investigated in a study of 58 radio collared quokkas at the northern jarrah forest sites (Hayward *et al.* in review-a). Quokkas were found to be largely restricted to *Agonis* swamps. Quokkas were shown to prefer early seral stage *Agonis* swamp habitat, burnt within the previous ten years, where this seral stage was part of a mosaic including older age classes (Hayward *et al.* in review-a).

The presence or absence of quokka populations at 66 sites in the northern jarrah forest was further investigated. General Linear Modeling (GLM) with stepwise removal of variables identified a preferred model to describe the quokkas' preferred mosaic.

The explanatory variables of the preferred model were:

- the number of 1080 meat baits delivered per hectare
- the average age of the swamp (calculated as the area of each swamp habitat unit at a site multiplied by the average number of years post fire of that unit and then divided by the total area of swamp to obtain an average number of years post fire)
- a habitat factor score (NJF4, characterised by possessing large areas of *Agonis* swamp burnt five to nine years previously).

The preferred model (Model 11, Table 12) therefore indicated that, in addition to the requirement for fox control, quokkas are more likely to be present at swamps which support young (five to nine year) post-fire successional stages and long average ages since fire. Further use of model selection (the Information-Theoretic approach, and specifically Akaike Information Criteria, or AIC) (Burnham and Anderson, 2002) identified two other models which were equally well supported by the data. All models examined are shown in Table 12. The variables used in the modeling process are described in Table 13.

TABLE 11

Estimates of quokka abundance at sites from the northern jarrah forest. Estimates derived from the Jolly-Seber model of death but no immigration, with the exception of Rosella Road, where only 1 individual was trapped.

| SITE | ESTIMATE OF ABUNDANCE | SOURCE |
|---|---|---|
| Chandler Road | 10 ± 0 | Hayward *et al.* 2003 |
| Hadfield | 29 ± 5 | Hayward *et al.* 2003 |
| Kesners | 36 ± 6 | Hayward *et al.* 2003 |
| Rosella Road | no estimate | Hayward *et al.* 2003 |
| Victor Road | 9 ± 1 | Hayward *et al.* 2003 |
| Gervasse | 49 ± 4 | de Tores *et al.* in review |

TABLE 12

Model selection statistics for the presence/absence of quokka populations at 66 sites from the northern jarrah forest of south-west Western Australia. The models are numbered sequentially from the null model. The statistic for the Akaike Information Criterion (AIC), the difference in AIC values (delta (△) AIC) and the Akaike weights are also shown. Models with a lower AIC are deemed to best fit the data (Burnham and Anderson, 2002). Models with a △AIC of less than two have substantial support while those with a △AIC greater than seven have no support (Burnham and Anderson, 2002). Akaike weights provide a weight of evidence in favour of each model and reflect the probability that the model is the Kullback-Leibler best model for the data (Burnham and Anderson, 2001). The model variables are described in Table 13. See also the text comments noting this process is a hybrid between conventional GLM and the Information-Theoretic approach.

| MODEL | AIC | DAIC | AKAIKE WEIGHTS |
|---|---|---|---|
| 1. Null model Pres/Abs ~ Slope + Distance to forest edge + Length of Swamp + Baits + Age + Mosaic + Distance to disturbance + Rainfall + NJF1 + NJF2 + NJF3 + NJF4 + NJF5 | 72.6195 | 12.8377 | 0.0001 |
| 2. Null model with NJF1 deleted | 70.9039 | 11.1221 | 0.0009 |
| 3. Model 2 with Mosaic deleted | 69.4129 | 9.6311 | 0.0022 |
| 4. Model 3 with Slope deleted | 67.9952 | 8.2134 | 0.0047 |
| 5. Model 4 with Rainfall deleted | 66.7131 | 6.9313 | 0.0095 |
| 6. Model 5 with Distance to forest edge deleted | 65.3131 | 5.5313 | 0.0181 |
| 7. Model 6 with NJF3 deleted | 63.9917 | 4.2099 | 0.0364 |
| 8. Model 7 with Swamp length deleted | 62.0052 | 2.2234 | 0.0705 |
| 9. Model 8 with NJF5 deleted | 61.5839 | 1.8021 | 0.1903 |
| 10. Model 9 with Distance to disturbance deleted | 60.3629 | 0.5811 | 0.2349 |
| **11. Model 10 with NJF2 deleted** | **59.7818** | **0** | **0.4325** |

Models 9 and 10 equally well describe the data (△AIC < 2.0 in both cases). Given habitat Factor NJF2 (a high proportion of jarrah-marri open forest and 15–19 year post-fire *Agonis* swamp) was negatively correlated with quokka abundance (Hayward *et al.* in review-b), the additional explanatory variables determining quokka abundance are:

- absence/reduction of NJF2 (Model 10) (i.e. absence of a high proportion of jarrah - marri open forest and 15–19 year post-fire *Agonis* swamp )
- increasing distance to disturbance (Model 9).

*Note: the model selection process presented is a hybrid between conventional GLM and the Information-Theoretic approach as described by Burnham and Anderson (2002). A more rigorous application of the Information-Theoretic approach, reviewing a more comprehensive set of a priori candidate models is given in Hayward et al. (in review-b)*

Habitat features have previously been associated with the persistence of quokka populations. Quokkas were thought to exhibit a preference for a mosaic of freshly burnt (< 10 years) and long unburnt areas (Christensen and Kimber, 1975; Hayward *et al.* 2003). The NJF4 variable relates to the presence of large areas of *Agonis* swamp shrubland burnt between five and nine years previously. When this variable is viewed with the other explanatory variable of the preferred model, i.e. the average age of the swamp, further weight is added to Christensen and Kimber's (1975) earlier hypothesis.

These features, combined with the additional explanatory variable from Model 10, highlight the importance of a mosaic of age classes within the swamp with early (< 10 years post-fire) and late (large values for average age of the swamp) seral stages as important for quokka presence. The intermediate seral stage is avoided. This is a mosaic of specific age classes (young and old) rather than simply a mosaic of mixed age classes.

## GENERAL DISCUSSION AND RECOMMENDATIONS IN RELATION TO THE FURTHER IMPLEMENTATION OF *WESTERN SHIELD*

### The importance of habitat and habitat management

Fox predation has contributed to the decline of a suite of species, including the western ringtail possum and the quokka. However, fauna declines are unlikely to be the result of a single dimensional causal factor, such as predation (de Tores *et al.* unpublished-b). In the case of the quokka in particular, fox control alone will be insufficient to ensure its effective long term conservation. There is a clear requirement for habitat management.

Specific recommendations are detailed in Hayward *et al.* (2003), (Hayward, 2002), de Tores *et al.* (in review), Hayward *et al.* (in review-a) and Hayward *et al.* (unpublished-c) for management of quokka populations in the northern jarrah forest and include:

- the use of fire to create and maintain a mosaic of specific age classes;
- the use of fire to ensure suitable habitat is available for dispersing quokkas; and
- adoption of a landscape approach to habitat management for the quokka to ensure interpatch distances are short and patches of suitable habitat are within dispersal range.

TABLE13

Variables used in modeling the occurrence (presence/absence) of the quokka at 66 locations within the northern jarrah forest of south-west Western Australia. Correlated variables excluded from analyses are marked with an asterisk. Table modified from Hayward *et al*. (in review-b)

| VARIABLE NAME | DESCRIPTION |
|---|---|
| Aspect * | A categorical variable determined by the map bearing in degrees along the down slope direction of the watercourse. This variable was included due to the potential for south-facing sites to have different ecological attributes from north-facing ones. |
| Baiting | The total number of poisoned fox baits laid per hectare around the swamp since feral animal control began in 1994. Higher levels of baiting in the northern jarrah forest have been shown to result in significant increases in the density of predation-sensitive native fauna and to have reduced densities of foxes (de Tores, 1999). The range of baiting levels arose due to variations in the annual frequency of bait delivery within the *Western Shield* and Operation Foxglove programmes which range from an unbaited control region through biannual, quarterly and two monthly baiting regimes and more frequent and intense baiting at specific sites (e.g. around quokka populations) where monthly baiting was implemented (de Tores, 1999; Hayward *et al.* 2003; Thomson and Algar, 2000). |
| Distance from forest edge | The distance from the interface between the state forest and cleared, residential or agricultural lands and the centre of each particular swamp. This variable was used following the finding that foxes reinvaded areas near the forest boundary rapidly after poison baits were laid (de Tores, 1999). |
| Distance to nearest disturbance | The distance from the centre of the swamp to the nearest source of anthropogenic disturbance (mining, agriculture, urban areas). This variable was used to investigate the effect of disturbance on quokkas. |
| Disturbed habitats * | The number of habitat types at each site which were classified as disturbed (cleared or revegetation) by Hayward *et al .(in review-a).* This variable was also intended to investigate the effect of disturbance on quokkas. |
| Ecotone * | The percentage of the site made of up ecotonal habitat types surrounding the *Agonis* swamp shrubland (bullich swamp forest, bullich-blackbutt open forest, blackbutt open forest) Hayward (2002). This variable was included to test whether the species was an ecotonal specialist. |
| Habitat number * | The number of different habitat types found at a site. This variable was intended to investigate the mosaic preference of quokkas (Christensen and Kimber, 1975). |
| Habitat type | The percentage of each habitat type (according to the methods in Hayward (2002) and Hayward *et al. (in review-a)*) which made up the one km section of swamp and an area 100 metres wide either side of the swamp. Visual examination of digital images was used to delineate habitat unit boundaries which were subsequently ground-truthed during the quokka surveys. Habitat units were described according to floristic, structural and other biological features (Hayward, 2002; Hayward *et al.* in review-a). The percentage which each habitat unit made up of the entire study site was subsequently combined using principal components factor analysis. Habitat factors were denoted as NJFF1-5. This variable was used following previous findings that quokkas prefer a mosaic of freshly burnt and long unburnt areas of swamp (Christensen and Kimber, 1975; Hayward *et al.* in review-a). |
| Rainfall | Mean annual rainfall was derived from distances from rainfall isohyet maps provided by CALM Information Management Branch. Rainfall was thought to be an important descriptive variable after it was found that all extant quokka populations are found in areas receiving more than 1,000 mm of precipitation per year (de Tores *et al.* in review; Hayward, 2002; Hayward *et al.* 2003). |
| Slope | The angle from horizontal to the ground that the one km length of swamp fell by, calculated using topographical maps. Although all *Agonis* swamps exist in the relatively flat, broad upper reaches of creek systems along the eastern edge of the northern jarrah forest (Hayward *et al.* in review-a), they appear to change into different habitat types where the terrain becomes too steep or too flat (Hayward, 2002). Consequently, the slope of each site was used as a descriptive variable. |
| Swamp age (in years since last fire) | The average number of years since fire burnt the swamp (Hayward *et al.* in review-a) calculated as the area of each swamp habitat unit at a site multiplied by the average number of years post fire of that unit and then divided by the total area of swamp to obtain an average number of years post fire. This meant sites with a mosaic of burn ages could be compared with sites with one age class. With age since fire previously identified as a factor affecting quokka presence (Christensen and Kimber, 1975; Hayward *et al.* in review-a), the average swamp age was used to determine whether there was a preference for any particular age class (Hayward *et al.* in review-a). |
| Swamp mosaic value | The number of swamp habitat units found at each site was considered as a variable in conjunction with swamp age following the habitat preferences of quokkas. |
| Swamp length | The number of kilometres that the creek line retained the characteristic *Agonis* vegetation. This was determined from raster images of aerial photographs that were imported into a GIS and geo-referenced. Tributaries were added to the total swamp length with the expectation that larger swamps would possess larger populations. |

In the absence of this management intervention, regional extinction of the northern jarrah forest quokka populations is highly likely (Hayward *et al.* 2003).

## *Western Shield*: management for critically endangered, endangered or vulnerable species?

Priority for allocation of *Western Shield* resources is largely directed to 'threatened' species (CALM, undated). Within the category 'threatened', there also appears to be a philosophy of prioritising allocation of *Western Shield* resources to species at higher levels of threat (PdeT, personal observations). We recommend adoption of the alternative, environmental triage approach (see Possingham, 2001).

Although the environmental triage process is fraught with the danger from inappropriate and/or veiled political agendas, it provides a strategy for allocating resources to those species which can respond/recover as a result of early management intervention. Adopting this approach may provide a more strategic use of *Western Shield* resources.

## The importance of quantitative analysis and accurate information dissemination

Compiling lists of species presence and occurrence is a useful component of fauna conservation and fauna management – it provides managers with base line information on the resources to be managed. However, compiling lists of occurrence should not be seen as an end in itself. Generating lists does not equate with long term persistence of species and does not infer effective conservation management has, or will be implemented. Similarly, we caution against providing lists of the number of species translocated and lists of species within areas where fox control has been implemented. We recommend these lists be supported by quantified analyses. In the case of translocation programs, we recommend data be collected and reported on translocation success and progress towards success or recognition of shortcomings. In the case of areas managed for fox control, we recommend data be collected and reported on the effectiveness of the fox control effort (i.e. by monitoring and reporting on fox populations at baited and unbaited sites) and the response of the fauna at baited and unbaited sites.

Two recent publications promoting the success of *Western Shield* have referred to the western ringtail possum translocations to Lane Poole Reserve and Yalgorup National Park. Curry and Kierath (1999) claimed:

> '… there have been numerous successful species reintroductions. These include … the western ring-tail possum (*Pseudocherus* [sic] *occidentalis*) to Lane Poole Conservation Park, Yalgorup National Park ….'

The eight page, March 2000 supplement 'WA forests today' inserted in all local Perth metropolitan newspapers claimed:

> *… Other endangered native animals such as the … ring-tailed possum are also beginning to thrive after being reintroduced into forest inside and outside reserves.*

In neither case did the authors check the validity of the claims with the researchers concerned. Neither the Lane Poole nor the Yalgorup National Park translocations can yet be considered successful. The Lane Poole translocation may have failed (see Table 1).

Similarly, claims have been made of increases in the abundance of the quokka in southern forest areas. Although these claims may be true, there are no quantifiable data to support them. Unsubstantiated claims of translocation success and fauna recovery can only serve to undermine the validity of genuine successful translocations and quantifiable achievements of *Western Shield*.

The success of *Western Shield* will ultimately be judged by the long term effectiveness of the conservation management actions implemented. Claims of effectiveness can best be demonstrated by quantified data analysis, not by anecdotal accounts and unsubstantiated claims of success. The *Western Shield* program has the potential to deliver significant conservation gains. To unequivocally demonstrate these gains, we recommend the data collection, collation, analyses and reporting processes be reviewed to ensure data are collected in a manner to allow objective analyses and scrutiny. Under this proposed scenario, any conservation gains can be quantified and documented. Conversely, in circumstances where desired outcomes have not been met, the failure to meet set goals can be identified and mechanisms can be implemented to improve conservation management.

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## APPENDIX 1

## Record of 1080 baiting at Leschenault Peninsula Conservation Park, September 1997–April 2002

| DATE | ENTRY IN 'DISTRICT 1080 REGISTER' [(1)] | NUMBER OF BAITS USED | COMMENT | IRV NO. |
|---|---|---|---|---|
| 19/09/1997 | Lesch. Pen. Hadfield | 319 | Can't determine how many baits laid at Leschenault and how many at Hadfield | 676 |
| 15/10/1997 | No record in 'District 1080 Baiting Register' of baits removed. Source of baits is therefore not clear | 100 | CALM 'Property Baiting Report' and informal baiting return show 100 baits laid at Leschenault [(3)] | |
| 12/11/1997 | No record in 'District 1080 Baiting Register' of baits removed. Source of baits is therefore not clear | 100 | CALM 'Property Baiting Report' and informal baiting return show 100 baits laid at Leschenault [(3)] | |
| 10/12/1997 | No record in 'District 1080 Baiting Register' of baits removed. Source of baits is therefore not clear | 100 | CALM 'Property Baiting Report' and informal baiting return show 100 baits laid at Leschenault [(3)] | |
| 5/01/1998 | Ground baiting | 228 | Additional informal baiting return and CALM 'Property Baiting Report' show 100 baits laid at Leschenault. Nothing to indicate where the remaining 128 baits were laid [(2) (3)] | 687 |
| 4/02/1998 | GB monthly ?…. | 200 | Additional informal baiting return and CALM 'Property Baiting Report' show 100 baits laid at Leschenault. No indication where remaining 100 baits were laid [(2) (3)] | 695 |
| 6/03/1998 | Hadfield. L. Peninsula | 356 (375 less 19 returned same day) | Can't determine how many baits laid at Leschenault and how many at Hadfield [(2)] | 3401 (?) |
| 30/03/1998 | Penn | 156 (200 less 44 returned same day) | Additional informal baiting return shows 100 baits laid at Leschenault. Can't determine where remaining 56 were laid [(2) (3)] | 3408 |
| 5/05/1998 | L/Penn. Gervasse | 226 | Can't determine how many baits laid at Leschenault and how many at Gervasse | illegible |
| 2/07/1998 | Monthly ground baiting | 214 (328 less 114 returned same day) | Additional informal baiting return shows 100 baits laid at Leschenault. No indication of where remaining 114 baits were laid [(2) (3)] | 3430 (?) |
| 30/07/1998 | Lesch Pen. Hadfield, Gervasse | 200 | Can't determine how many baits laid at Leschenault, Hadfield or Gervasse | 3434 |
| 26/08/1998 | L/Penn Had/Gervasse | 200 | Can't determine how many baits laid at Leschenault, Hadfield or Gervasse | 3435 |

## APPENDIX 1 (continued)

| DATE | ENTRY IN 'DISTRICT 1080 REGISTER' (1) | NUMBER OF BAITS USED | COMMENT | IRV NO. |
|---|---|---|---|---|
| 24/09/1998 | Hadfield | 400 | Additional informal baiting return shows 176 baits laid at Leschenault, 76 more than historically required (2). Presumably the remaining 224 baits were laid at Hadfield | 3443 |
| 30/10/1998 | No record in 'District 1080 Baiting Register' of baits removed. Source of baits is therefore not clear | 100 | Additional informal baiting return shows 100 baits laid at Leschenault (3) | Louisa |
| 4/12/1998 | Hadfield | 146 | Additional informal baiting return shows 111 baits laid at Leschenault (2). Unlikely the remaing 35 only were laid at Hadfield | 3456 |
| 31/12/1998 | Ground Bait | 175 (200 less 25 returned same day) | Additional informal baiting return shows 100 baits laid at Leschenault. No indication of where remaining 75 baits were laid (3) | 3459 |
| 24/03/1999 | Lesch | 141 | Additional informal baiting return shows 101 baits laid at Leschenault. No indication of where remaining 40 baits were laid (2) | 3473 |
| 23/04/1999 | Lesch Hadf | 248 | Can't determine how many baits laid at Leschenault and how many at Hadfield | 3475 |
| 26/05/1999 | Lesch | 130 | Unlikely all 130 laid at Leschenault (2) | 3476 |
| 6/07/1999 | L/Penn | 200 | Unlikely all 200 laid at Leschenault (2) | 3486 (?) |
| 11/08/1999 | Leschenault/Hadfield | 200 | Can't determine how many baits laid at Leschenault and how many at Hadfield | 3488 |
| 23/09/1999 | Lesch | 313 | Unlikely all 313 baits laid at Leschenault (2) | 348? (?) |
| 18/10/1999 | Lesch Pen | 299 | Unlikely all 299 baits laid at Leschenault (2) | 3496 |
| 18/12/1999 | Leschenault Hadfield Gervasse | 440 | Can't determine how many baits laid at Leschenault, Hadfield or Gervasse | 3498 |
| ?/1/2000 | Gervasse Lesch Hadfield | 200 (381 less 181 returned presumably on the same day) | Can't determine how many baits laid at Leschenault, Hadfield or Gervasse | 5805 |
| ?/2/2000 | Hadfield Gervasse Lesch | 315 (651 less 336 returned presumably on the same day) | Can't determine how many baits laid at Leschenault, Hadfield or Gervasse | 5807 |
| ?/3/2000 | Leschenault Peninsula | 98 (200 less 102 returned presumably on the same day) | | 5813 |
| 17/05/2000 | Ground baiting Gervasse Lesche Had | 321 | Can't determine how many baits laid at Leschenault, Hadfield or Gervasse | 5825 |
| 29/06/2000 | Ground bait Batalling Leschenault Hadfield | 527 (629 less 102 returned same day) | Can't determine how many baits laid at Batalling, Leschenault or Hadfield | 5837 |
| 19/07/2000 | Ground bait Gervasse Hadfield Leschenault | 354 (502 less 148 returned following day) | Can't determine how many baits laid at Gervasse Hadfield or Leschenault | 5839 |

## APPENDIX 1 (continued)

| DATE | ENTRY IN 'DISTRICT 1080 REGISTER' (1) | NUMBER OF BAITS USED | COMMENT | IRV NO. |
|---|---|---|---|---|
| 13/09/2000 | Leschenault Hadfield | 200 | Can't determine how many baits laid at Leschenault or Hadfield | 5851 |
| 17?/10/2000 | Lesch Hadfield Gervasse | 360 | Can't determine how many baits laid at Leschenault, Hadfield or Gervasse | 5854 |
| 23/11/2000 | Leschenault Peninsula | 200 | Unlikely all 200 baits laid at Leschenault (2) | 5857 |
| 20/12/2000 | Lesch Gervasse Hadfield Well | 574 | Can't determine how many baits laid at each location | 5864 |
| 23/1/2000 (presumably 2001) | Leschenault Peninsula | 340 (400 less 60 returned following day) | Unlikely all 340 baits laid at Leschenault, no other location listed (2) | 5866 |
| 7/03/2001 | Leschen Welly NP Hadfield | 400 | Can't determine how many baits laid at each location | 5904 |
| 9/04/2001 | Leschenault Hadfield | 245 | Can't determine how many baits laid at each location | 5867 |
| 16/05/2001 | Batalling Block / Lesch | 400 | Can't determine how many baits laid at each location | 5869 |
| 20/06/2001 | Ground bait Leschenault WR | 266 (318 less 52 returned same day) | Unlikely all 266 baits laid at Leschenault, no other location listed (2) | 5870 |
| 23/07/2001 | Leschenault / Gevasse | 105 | 100 baits required for Leschenault alone, so presumably either one or both sites baiting was not completed | 5883 |
| 7/09/2001 | Ground bait Leschenault WR | 66 (256 less 190 returned same day) | 100 baits required for Leschenault, unclear why only 66 laid | 5886 |
| 23/10/2001 | Leschenault | 87 (200 less 113 returned same day) | | 5921 |
| 4/01/2002 | Leschenault / WDC (not highlighted by Frank, but presumably went to Leschenault as indicated) | 117 (301 less 184 returned same day) | Can't determine if all 117 went to Leschenault or WDC (?) | 5941 |
| 31/01/2002 | Ground baiting Leschen / Hadfield | 200 | Can't determine how many baits laid at each location | 5946 |
| 11/04/2002 | Ground baiting Wellington Lesch Pen | 170 (539 less 369 returned same day) | Leschenault added as a location post photocopying of original. Can't determine how many baits laid at each location. | 5960 |

(1) Identified (highlighted on a copy of 'District 1080 Register') as baiting at Leschenault, unless otherwise specified.

(2) Historic/traditional required number of baits for Leschenault is 100. Therefore, it seems unlikely the number of baits indicated in the District 1080 Register were all laid at Leschenault.

(3) Without the informal baiting return there would be no record of where baits were laid.

# ADVICE TO AUTHORS

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*Book*— Brown A, Thomson-Dans C, Marchant N (1998) *Western Australia's Threatened Flora*. Department of Conservation and Land Management, Como.

*Chapter in a book*— Villiers TA (1972) Seed dormancy. In *Seed Biology : Volume 2* (ed. TT Kozlowski), pp. 219-281. Academic Press, New York.

*Report or Bulletin*—Strelein GJ (1988) Site classification in the southern jarrah forest of Western Australia. Department of Conservation and Land Management Western Australia, Research Bulletin No. 2, Como.

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