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Monitoring Source Populations of Fauna for the Dirk Hartog Island National Park Ecological Restoration Project – 2019

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Monitoring Source Populations of Fauna for the Dirk Hartog Island National Park Ecological Restoration Project – 2019

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Biodiversity and Conservation Science

February 2020

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Acknowledgments

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Summary

Monitoring of source populations of six mammal species was undertaken by the Department of Biodiversity Conservation and Attractions' (DBCA), Biodiversity and Conservation Science in 2019 to obtain information on their distribution and abundance prior to their translocation to Dirk Hartog Island National Park as part of the Dirk Hartog Island National Park Ecological Restoration Project (DHINPERP). Monitoring of these source populations in 2019, also fulfilled the requirements of Corporate Guideline 36 (Sections 1.2 and 5.2.9), to monitor their status post-harvesting in 2018. Monitoring of two of these species (Shark Bay bandicoots and Shark Bay mice) was also undertaken to inform proposed translocations to the Mt Gibson wildlife sanctuary and to other mainland sites by the Australian Wildlife Conservancy (AWC).

Spotlight and trap monitoring of all species on Bernier and Dorre Islands occurred in Mar/April 2019 and harvesting of species for translocation occurred in August/September and October 2019.

Banded and rufous hare-wallabies

Spotlight monitoring of banded and rufous hare-wallabies on Bernier and Dorre Islands in Mar/April 2019 provided combined estimates of abundance on both islands of 6029 (4743-7664) banded and 2913 (2011-4220) rufous hare-wallabies. Subsequent harvesting in spring 2019 removed an estimated 3.5% (50 individuals) of the combined rufous hare-wallaby population (20 or 3.2% from Bernier and 30 or 2.4% from Dorre). Banded hare-wallabies were not harvested in 2019, as the 102 individuals translocated in the previous two years (12 in 2017 and 90 in 2018) was a projected by population viability analysis (PVA) to be a suitable founder size for DHINPERP translocation (D. White, Pers. Comms.). Australian Wildlife Conservancy did not require further banded hare-wallabies for Mt Gibson in 2019 either. The 2019 population estimates for banded and rufous hare-wallaby were equivalent to ~102% and 140% of the 2018 pre-harvest estimates for these species and indicate there was no measurable negative impact on the populations by the 2018 harvest events.

Boodies and Shark Bay bandicoots

Population estimates for boodies and Shark Bay bandicoots on Bernier and Dorre Islands in 2019 were generated from both spotlight (Distance Analysis) and trap (Spatially Explicit Capture, Recapture [SECR]) monitoring. Neither technique provides consistently robust data every year, but together, they provide a better understanding of population demographics and health parameters.

Combined Shark Bay bandicoot population for 2019 was conservatively estimated at between 4511 (2576-7899) based on spotlight transect data, and 7656 (4422-13485) based on analysis of the trapping data. As with previous years, trapping data provided larger estimates (approximately two times) that obtained using spotlighting data. But also in keeping with most other years, population estimates for Dorre Island were nearly two to three times those for Bernier with both techniques, and

approved harvesting numbers reflected this. Harvesting of Shark Bay bandicoots by DBCA and AWC together removed 3.6% (93 individuals) of the combined islands population (50 or 3.1% from Dorre and 43 or 5.0% from Bernier).

The combined island abundance for boodies was conservatively estimated at between 3388 (2050-5600) based on spotlight transect data, and 7449 (4127-13533) based on analysis of the trapping data. No boodies were removed for translocation in 2019.

Shark Bay mice

Population abundance for Shark Bay mice on Bernier Island in 2019, based on SECR analysis of trapping data from Red Cliff Bay was estimated at 5335 (1823-15614), (~ four times the 2018 estimate) and on North West Island in the Montebello Archipelago, (also using SECR analysis of trapping data) the population was estimated at 2131 (1302-3486). But comparative density was only 1.42 ha^{-1} on Bernier Island compared to 18.06 ha^{-1}on North West Island.

Dibblers

Dibblers were collected from Whitlock and Escape Islands in 2018/19 to establish a breeding colony at Perth Zoo with sixteen (eight pairs) comprising four pairs each from Whitlock and Escape Islands entering the 2019 captive breeding program. A total of 26(13:13) individuals (including 2(1:1) original founders from Escape Island) were translocated to Dirk Hartog Island on 7th October 2019 from the zoo. Regular annual monitoring of the Jurien Bay Island populations continued in May and October 2019, with capture rates marginally better than 2018 and 3(2:1) additional dibblers were harvested from the larger Boullanger Is population in October 2019 to contribute to the ongoing breeding program at Perth Zoo for 2020.

Environmental conditions

Combined island abundance estimates for most species on Bernier and Dorre Islands in April 2019 were greater than those for April 2018. However, the two islands faired differently, with this increase being driven by a much higher increase in populations on Dorre Island and an actual decrease in population estimates on Bernier Island. This coincided with another below average rainfall record at nearby Carnarvon for the previous 12 months (less than half the long term annual average). Although the Dorre Island weather station recorded much better annual rainfall in 2018 than Carnarvon, the summer rainfall in 2018/19 was even lower than the previous year, and all stations around Shark Bay recorded less than half the long term annual average in 2019. Remote sensing of vegetation cover on Bernier and Dorre Islands found that values are among their lowest since Landsat imagery became available in 1988 and there is a strong positive relationship between vegetation cover and rainfall (van Dongen *et al.* 2019).

Rainfall at Barrow Island was 84mm for 2019 (also less than half the long term average), and has for the last two years in a row (87mm for 2018).

Although mammal populations on the Montebello and Shark Bay Islands are currently relatively abundant, if these lower than average rainfall conditions persist, they may result in population crashes in the near future.

Annual rainfall for Jurien Bay of 366mm for 2019 was again below the long term average of 549mm, and follows on from below average rainfall from the previous 2 years (2017 (464mm) and 2018 (469mm). However, the annual rainfall deficit over the last few years has not been as severe here, as in the more northerly island groups.

Future monitoring

The next monitoring of the Bernier and Dorre Island populations will occur in April 2020 and dibblers at Jurien Bay in May 2020.

DHINPERP staff will be involved in some greater stick nest rat and heath mice source population monitoring in 2020.

1 Introduction

The Dirk Hartog Island National Park Ecological Restoration Project (DHINPERP) aims to return Western Australia's largest island (63,300 ha) to the ecological state it was in when the Dutch navigator Dirk Hartog first visited the island in 1616. With the eradication of sheep, feral goats, and feral cats, the Stage 2 reconstruction of the island's vertebrate fauna officially commenced in 2018 (Morris *et al*. 2016). Twelve mammals (mostly threatened species) and one bird will be translocated to Dirk Hartog Island (DHI) over a 12-year period, from 2018 - 2030. The species are; banded hare-wallaby *Lagostrophus fasciatus fasciatus,* rufous hare-wallaby *Lagorchestes hirsutus bernieri,* boodie *Bettongia lesueur,* Shark Bay bandicoot *Perameles bougainville,* Shark Bay mouse *Pseudomys fieldi,* dibbler *Parantechinus apicalis* greater stick-nest rat *Leporillus conditor,* woylie *Bettongia penicillata,* heath mouse *Pseudomys shortridgei,* desert mouse *Pseudomys desertor,* brush-tailed mulgara *Dasycercus blythi,* chuditch *Dasyurus geoffroii,* and western grass-wren *Amytornis textilis textilis.* The Department of Biodiversity, Conservation and Attractions (DBCA) Corporate Guidelines on the Recovery of Threatened Species (Guideline #36) follows the IUCN guidelines for reintroductions and other conservation translocations (IUCN 2013). These require that monitoring of source populations is undertaken before and after harvesting of founders, to ensure that the viability and health of these populations is not compromised by harvesting.

The DHINPERP Stage 2 plan originally proposed starting translocations of species to DHI in 2018, two years after eradication of feral cats from the island. However after successfully eradicating cats from the southern half of the island (fenced-off from the north) in 2015, a trial translocation of a small number of the banded hare-wallaby and the rufous hare-wallaby was undertaken in August / September 2017 to trial logistics, capture, transport and monitoring techniques. In preparation for this, monitoring of the potential source populations on Bernier and Dorre Islands in Shark Bay, and North West and Trimouille Islands in the Montebello group for the species to be translocated over the first few years occurred in 2016 and 2017. In 2018 and 2019, monitoring of populations of banded hare-wallaby, rufous hare-wallaby, boodie, Shark Bay bandicoot and Shark Bay mice was undertaken on Bernier and Dorre Islands in April-May both years, and Shark Bay mice on North West Island in October 2019.

The Jurien Bay Island population of dibbler were identified as the preferred source for the DHI translocations due to their closer geographic proximity to Shark Bay. The population consists of animals on three small islands: two extant populations that have persisted on Boullanger and Whitlock Islands, and the introduced Escape Island population which was established using dibblers bred in captivity from mixed Boullanger and Whitlock stock. Dibblers were originally planned for a release on DHI in October 2018 after harvesting of 20 animals (10 pairs) for a program of captive breeding at Perth Zoo to provide sufficient founders for release. Regular monitoring of the proposed source populations on Boullanger and Whitlock Islands occurred in 2017. However a trip in January 2018 designed to collect breeding stock for the

Perth Zoo failed to catch sufficient animals and the translocation was delayed for 12 months. Further monitoring was carried out in May and October 2018 and determined that populations were sufficiently robust to harvest 5(3:2) animals from Escape and 8(4:4) from Whitlock Islands in October 2018. However numbers were still too low to remove animals from Boullanger Island at that time. Two of the founder females at Perth Zoo died before breeding began and five more animals were collected [1(0:1) from Whitlock and 4(1:3) from Escape Island] in early 2019. The final total founder population for the 2019 breeding season comprised eight founder pairs (four pairs each from Whitlock and Escape Islands) (Friend and Button, 2019).

Because of the difficulty in capturing significant numbers of Shark Bay mice on Bernier Island, in the presence of the other mammal species which interfere with traps (esp. boodies) it is possible that at least some of the founders for this species will be sourced from the introduced population on North West Island. This population was established from 47 Shark Bay mice bred in a captive colony at the Perth Zoo and released in 1999-2000. Despite early setbacks, it has persisted for 20 years and now appears to be a robust population spread across most of the island. No regular monitoring had been in place, although observations of plenty of signs across the island and trapping in 2011 and 2012 for translocations to Matuwa (Lorna Glen), indicated that the population was widespread and at a good density across the island.

A monitoring grid was put in place in 2016 to provide data on the density and abundance prior to potential harvesting of Shark Bay mice for translocation to DHINP and elsewhere. Trap capture rates in 2017 were less than half that of 2016, reducing confidence in the density and population estimates from analysis. As a result, a second trap grid was established in 2019 to try to alleviate this problem if capture rates were found to be low again. Monitoring of the North West Island Shark Bay mouse population in 2019 was carried out in conjunction with the triennial monitoring of reintroduced mammals on other islands in the Montebello Archipelago associated with the Gorgon Gas Development Offset program.

This report documents the monitoring activities undertaken in March and April 2019 on Bernier and Dorre Islands in Shark Bay (Shark Bay bandicoot/little marl, Shark Bay mouse/djoongari, banded hare-wallaby/mernine, rufous hare-wallaby, boodie) and in May and October 2019 on the Jurien Bay islands (dibbler) The report also covers the monitoring done in October 2019 on North West Island in the Montebello Islands (Shark Bay mouse/djoongari). It presents both qualitative assessments and quantitative analysis of data collected during this monitoring, and a comparison with 2016, 2017 and 2018 monitoring results where these are available.

Finally we discuss, in brief, the monitoring undertaken by other DBCA regional and district staff of the greater stick-nest rat (Salutation Island, Shark Bay) and heath mouse (South Coast Region) populations. These surveys were not carried out by DHINPERP staff and were not funded by the project, but are included as they relate to populations of animals that may potentially be future sources for translocation to DHI.

2 Methods

2.1 Logistics and transport

Access to the source populations on Bernier and Dorre Islands in Shark Bay and North West Island in the Montebello group is a difficult and expensive operation, due to the remoteness, ruggedness and frequent exposure to strong winds and variable tides. None of the islands have infrastructure from which to work and all were accessed for extended field trips of 7-11 days using the ‘live-aboard’ charter vessel *Keshi Mer II*. Access onto the islands for survey and trapping work was via a semi-rigid inflatable tender and was dependent on favourable weather, wind and sea (including tide) conditions. Judgements and modifications to the program were required at times based on current and forecast conditions for the next 24 hours, to ensure the welfare and safety of the animals being monitored, personnel and vessel.

The Jurien Bay Islands are a relatively short distance off the coast adjacent to the mid-west town of Jurien. Consequently, personnel stayed in accommodation in Jurien and accessed the islands daily using a small semi-rigid inflatable boat made available by the Jurien Bay District DBCA office. As with the other islands, access to check and clear traps was dependent on favourable weather conditions.

2.2 Trapping

2.2.1 Bernier and Dorre Islands

One trapping grid of 64 trap points in an 8x8 pattern with each trap point spaced at 40m intervals has been established on Bernier and Dorre Islands. Both grids were open for four nights. Traps were left open during the day, but checked morning and evening. Each trap point had one collapsible small cage trap (~31 x 31 x 70cm – Sheffield Wire) plus one medium Elliott trap (90 x 100 x 330mm aluminium box trap). The total trapping effort was 256 cage and 256 Elliott trap nights for both the main Bernier and Dorre Island grids. All cage traps were covered with an individual new hessian bag which is replaced for each trip, and for each island in accordance with quarantine and disease control protocols (Woolford 2007; Chapman *et al*. 2011). Elliott traps were also covered with hessian, to provide shade and protection from rain. Traps were checked and cleared within three hours of sunrise. Except where weather conditions prevented it, traps were rechecked in the late afternoon and diurnal non-target captures such as birds and reptiles were released, and traps re-set before sunset. All trap points have a permanent short peg in the ground and are re-flagged with fresh flagging tape as required each session. Each is also recorded on a hand-held GPS.

Trapping grids were located at the most accessible and weather-flexible landing points on each island (White Beach on Dorre Island and Red Cliff Bay on Bernier Island). (Figure 1)

A second, smaller permanent grid of 21 trap points, in a 7x3 pattern, spaced at 40m intervals located in sand dune habitat near Red Cliff Bay on Bernier Island, was also operated together with the larger grid, to specifically target Shark Bay mice. This grid consists of only medium Elliott traps, which are protected from boodie interference by placing them inside 125mm diameter PVC pipe pegged to the ground with an ‘excluder’ cap restricting the access hole to just 35mm diameter, and mesh rear end (Figure 2). This grid was also opened for four trap nights concurrently with the larger grid.

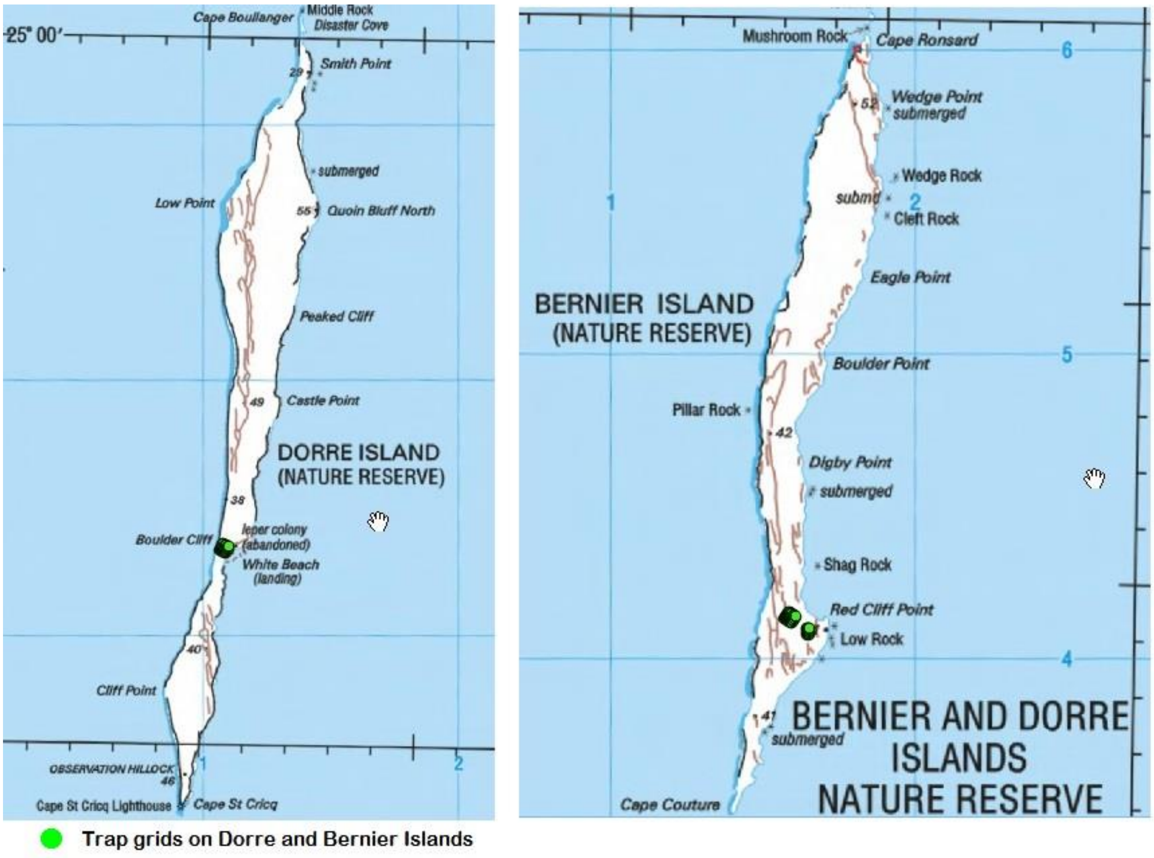


Figure 1. Location of permanent trap grids on Bernier and Dorre Islands

Figure 2. Boodie ‘pipe excluder’. Medium Elliott traps placed inside to target Shark Bay mice without boodie interference.

All traps were baited with ‘Universal bait’ comprising peanut butter and rolled oats. Permethrin (Coopex ™) @ 25g/5L dilution was sprayed on the ground underneath and around traps to deter ants. Ant activity on Bernier Is was significantly worse than on Dorre and required doubling concentration of Coopex ™ to 25g/2.5L to get control. Some traps had to be moved daily within a radius of ~ 15m to avoid being overrun by ants.

All captured animals were individually identified with either a Passive Integrated Transponder (PIT), (Allflex™ FDX-B Microchip, ca.11 x 3mm) for larger species or ear notch numbering system for the smaller Shark Bay mice (Figure 3.) (Orell, 1997). Ash-grey mice (*Pseudomys albocinereus squalorum*) were temporarily marked in the ear with a non-toxic marking pen. The weight, pes length, head length, (and tail width in boodies) was measured, and their reproductive condition, body condition (on a scale of 1-5) and measurements recorded.

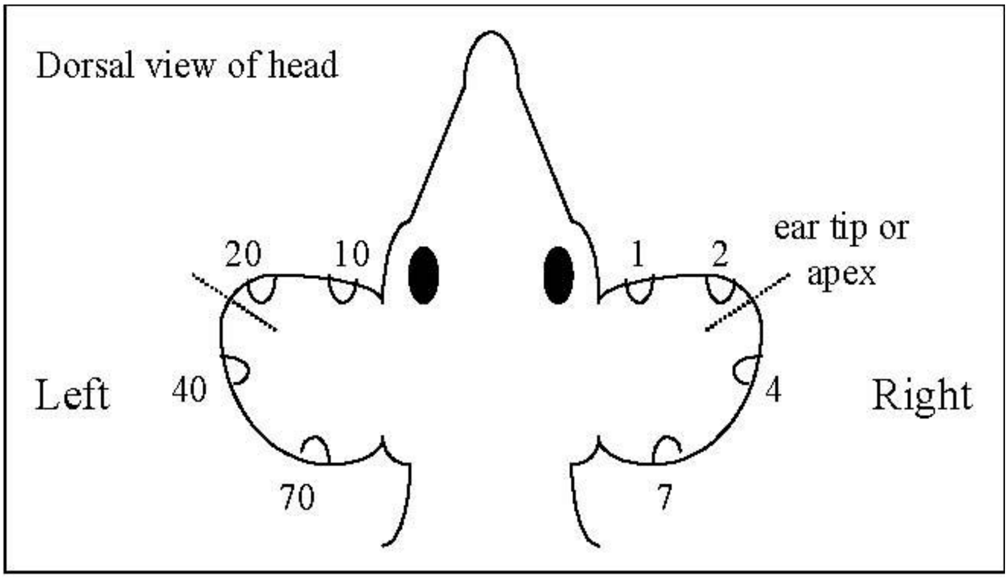


Figure 3. Ear notch numbering system for small mammals (After Orell, 1997).

Because of previous incidences of the wart like disease in Shark Bay bandicoots, individuals of this species had their health and skin/coat condition carefully examined for signs of warty/eczema-like lesions that could be indicative of active infection with Bandicoot Papillomatosis Carcinomatosis Virus One (BPCV1). This disease is only known from bandicoots from Bernier Island and has not been detected to date in the Dorre Island population. However, all bandicoots captured on both islands were examined for possible symptoms of the virus.

All tissue samples collected from ear punches for each new individual (usually two samples, one from each ear, placed in a single vial) were stored in 80% ethanol and labelled with species, animal ID, sex, date and location and held in the laboratory at Woodvale Wildlife Research Centre until transferred to the DBCA fauna geneticist at Kensington, WA, when required. They will be used to contribute to a number of studies on genetic variation, taxonomy and species health.

2.2.2 Jurien Bay Islands

Trapping for dibblers on Boullanger, Escape and Whitlock Islands involved medium Elliott traps placed on permanent monitoring transects. Weight, animal ID, sex, reproductive condition, pes length and head length were also measured and recorded for this species, and individuals were marked with a Passive Integrated Transponder (Trovan™ ID-100C, FDX-A Midichip, 11.5mm x 2.12mm).

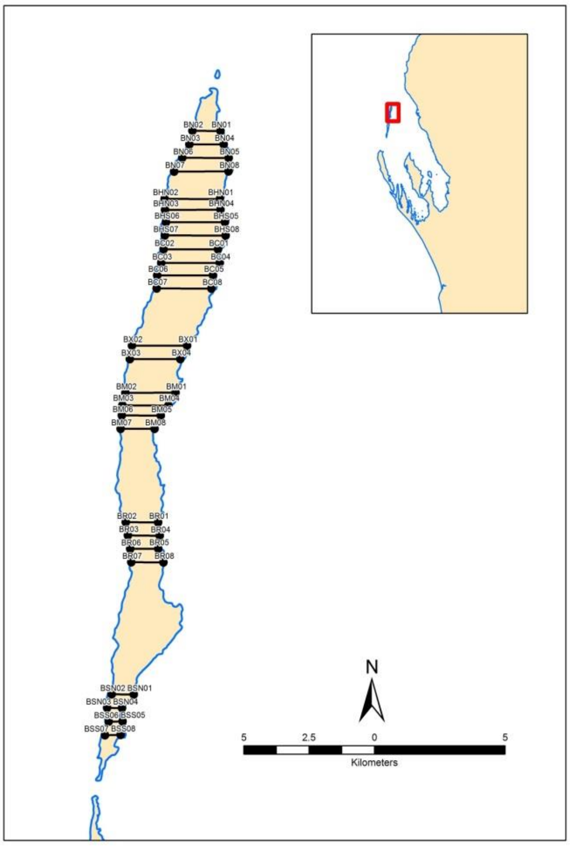
2.2.3 North West Island

Trapping for Shark Bay mice on North West Island, Montebello Islands group used medium Elliott traps (described above) placed on the permanent monitoring grids. Two grids each of 21 traps (3 x 7) at 40m intervals were opened for 4 nights. The grids were 400m apart with trap locations identified using handheld GPSs, and marked with flagging tape at the beginning of the session. Traps were covered with hessian and placed under vegetation, to provide shade and protection from rain. Traps were checked and cleared within three hours of sunrise, closed and folded, and reset again before sunset. As described above for the Shark Bay Islands, traps were baited with universal bait and Permethrin (Coopex ™) @ 25g/5L dilution, used if required to control ants. Weight, animal ID, sex, reproductive condition, pes length and head length were measured and recorded, and animals were permanently identified by the ear notch numbering system. Ear notch tissue was collected and stored for future DNA analysis as described above.

2.3 Spotlighting

Spotlight surveys for banded and rufous hare-wallabies, boodies and Shark Bay bandicoots were undertaken using three teams each comprising two observers. The primary observer used a Lightforce ™ ‘Striker’ hand-held spotlight (170mm reflector, 12V 35W HID globe with 4200K colour temperature rendering and adjustable focus), powered by 6 or 9 amp hr LiFePO4 battery pack (Lightforce CBLP6/CBLP9), and infra-red laser range finder (Laser Technology Inc. TruPulse 360^{o}B). The second person acted as a recorder, navigator and secondary observer, using a Trimble PDA (Trimble ™ Juno T41/5 Rugged Handheld Computer) loaded with the TerraSync ™ software program and Bluetooth connection to the range finder, to follow pre-programmed transect lines and record GPS location of, and distance to the target animals observed.

All transect lines were laid out in an east-west orientation across the width of Bernier and Dorre Islands (Figure 4a and 4b) and were walked on a single latitudinal line using the UTM ‘Northing’ which uses a scale in metres that allows estimation of position in relation to transect line. Each team surveyed between two and five transects per night with surveys beginning soon after dark and last transects completed before midnight. Walking pace was maintained at approximately 3kph.



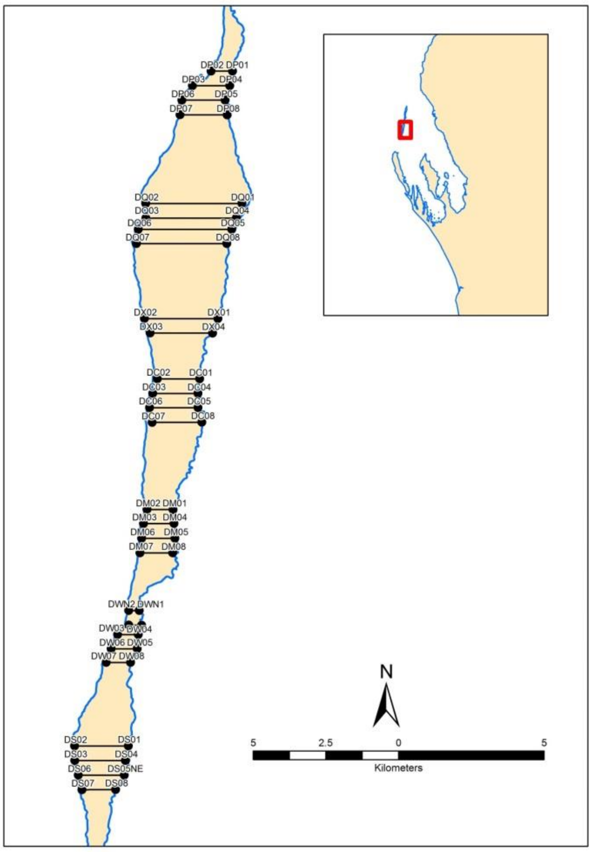


Figure 4a. Bernier Island spotlight transects.

Figure 4b. Dorre Island spotlight transects

2.4 Camera Traps

A trial of passive camera traps were run on Bernier and Dorre Islands in 2019 to determine the feasibility and effectiveness of using this method to supplement and potentially replace trap and spotlight monitoring on the islands in the future. This consisted of 50 x Passive Infra-Red (PIR) cameras (Reconyx™ PC900) placed in pre-defined randomly stratified positions across each island, constrained with a minimum separation distance of 800m and 50m from 'boundary of island' (Figure 5). Cameras used high capacity, low self-discharge NiMH batteries (Fujitsu HR-3UTK) and were secured to tripods (Slik F630) with legs cable-tied to steel tent pegs for additional stability. Each camera was positioned facing south at a height of 75cm above ground level and pre-set with RapidFire™ picture interval (up to 2 frames per second), 3 pictures per trigger event with no delays (quiet period) between triggers and a scheduled trigger inactivity (i.e. camera off) period between 10:00am-3:00pm to reduce false triggers. Cameras were also pre-programmed to automatically take a single time-lapse picture at 12:00am each day to confirm continued functionality throughout the trial and a WalkTest performed at setup. These cameras were deployed between 1 and 4 May and collected between 14 and 17 November 2019. Trimble PDA's pre-programmed with a surveying software package (GPS Pathfinder Office) were used by teams to collect camera and site location data including waypoint, camera ID, set and collect dates, battery % at set and collect, condition of

PIR motion detector lens, soil type and colour, vegetation type and cover, major plant height and landform type. Trimble PDAs were also used to take a single landscape-oriented site photo looking north, centred on the face of the camera trap and tripod setup from ~12-15m away (Figure 6a).

In addition, 5 x camera trap stations (totalling 10 cameras) were placed in the vicinity of the Shark Bay mouse trapping grid at Red Cliff Bay, Bernier Island to test if either PIR (Reconyx™ PC900) or white flash (Reconyx™ PC850) cameras could be utilised to distinguish between the two mouse species present (*P. fieldi* and *P. albocinereus*). Each station consisted of one camera of each type placed side-by-side and set as above, but with an array of 8 wood blocks (25 x 25 x100mm) pinned horizontally to the ground at 25cm intervals, from 125cm to 300cm distance from the centre of the tripods (Figure 6b). These cameras were deployed from 10 April to 17 November 2019.

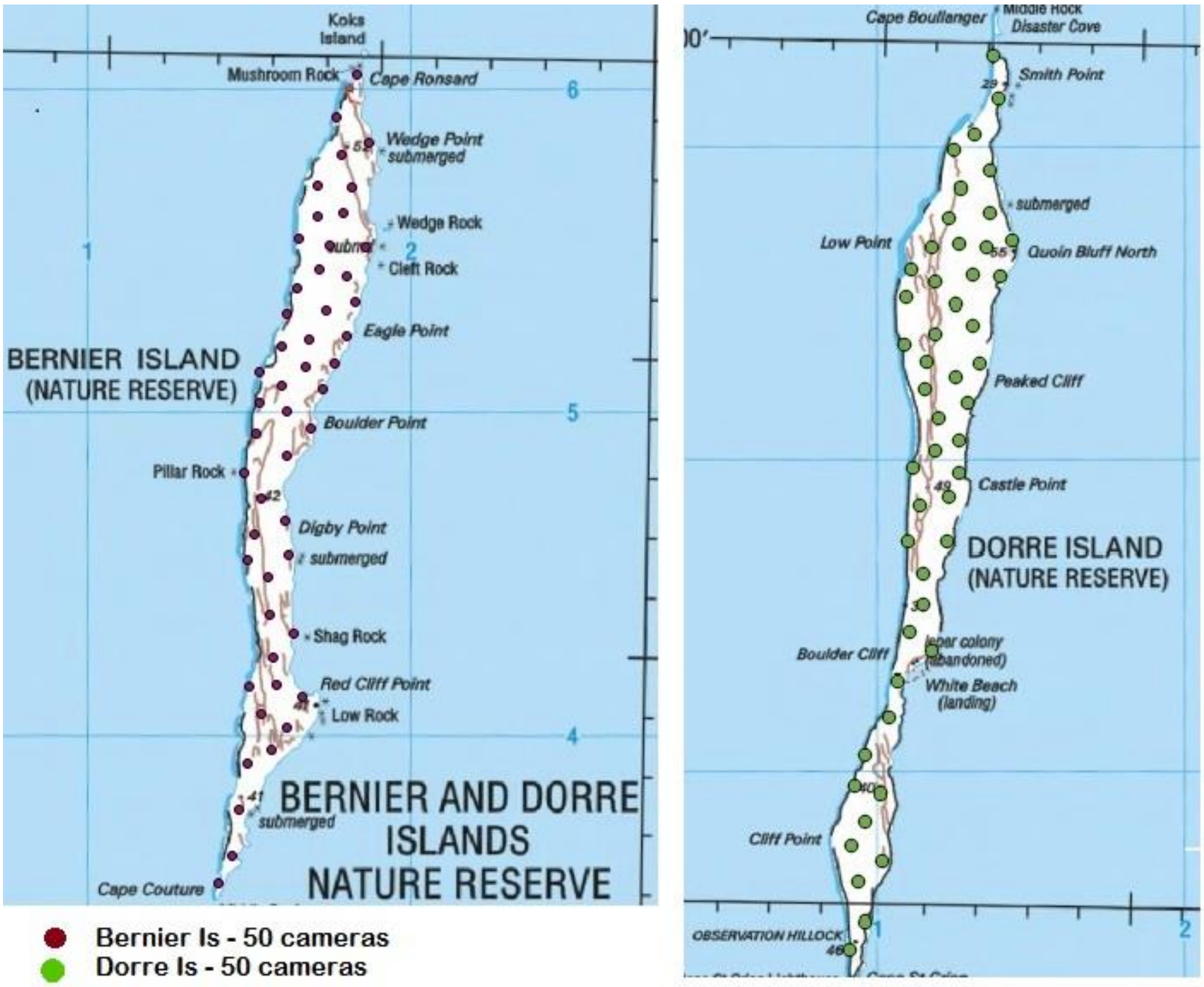


Figure 5. Distribution of camera arrays on Bernier and Dorre Islands May – Nov 2019.

Figure 6a. Typical camera trap set-up of main 50 camera array on Bernier and Dorre Island, 2019.

Figure 6b. Infra-red versus White flash camera trap trial set up.

To set and collect cameras, three teams of two people typically walked 10-20km each per day. Teams went ashore around sunrise until late morning, followed by lunch on board the vessel as it relocated during midday. Teams then went ashore again at a new location from around 2:00pm-5:00pm. Each island sojourn generally consisted of setting or collecting three to nine cameras per team per morning or afternoon session.

Images are being managed and analysed using CPW Photo Warehouse (Colorado Parks and Wildlife).

2.5 Harvesting and Transport

2.5.1 Dibblers from Jurien Bay Islands.

All dibblers harvested for the captive breeding colony at Perth Zoo in 2019, were trapped with medium Elliott traps and universal bait, at regular trap sites in three trapping sessions (two special trap events of one night each on Whitlock and Escape Islands, and the third harvest event on the last night of the regular four night trap monitoring session on Boullanger Island). They were placed in clean Elliott traps with shredded paper and transported to the Jurien Bay marina by boat. They were then transferred immediately to Perth Zoo in an air-conditioned vehicle.

2.5.2 Rufous hare-wallabies and Shark Bay bandicoots from Bernier and Dorre Islands.

All rufous hare-wallabies harvested for translocation to DHINP were captured at night using the Lightforce ™ spotlights described above, head torches and long handled scoop nets with an open soft mesh net and a hoop diameter of 400-500mm. Teams of six to seven personnel went ashore at last light (~18:30hr) in the evenings. The search-and-capture operation consisted of a single person with a handheld Lightforce spotlight flanked on both sides by evenly-spaced hand netters (five to six) with head torches walking in a line approximately 10-20m apart. Once captured, each animal was checked for condition, weight and sex and either selected for translocation or released at capture site. Those selected for translocation were placed into a black cotton handling bag which was labelled with individual identification, weight, species and sex and carried to a central point for processing, where animals were implanted with a PIT as described above. Animals were captured and processed between dusk and 0230 hrs.

All hare-wallabies received treatment with Selenium and Vitamin E to protect against stress myopathy, (some hare-wallabies also received atropine sulphate to reduce fluid loss through hypersalivation), and were placed in medium Pet Packs (PP30 62 x 43 x 45 cm), up to two animals per pack. Pet Packs were lined with unscented absorbent training pads (Animaze brand) to soak up urine and saliva, and help keep animals dry during holding and transfer. These packs were then carried to the beach and placed in shelter until dawn. They were then transferred to DHI by helicopter (R44 Raven 2, Robinson). Flight time was a maximum of 1 hr 15 mins. If deemed necessary, some rufous hare-wallabies were injected with the sedative diazepam prior to transfer in the helicopter.

The majority of Shark Bay bandicoots were also captured at night using spotlights and long handled nets as described above for rufous hare-wallabies. The small size and fast movements of this species required careful use and selection of design and structure of net to minimise risk of injuring animals during capture attempts. Only nets with finer/softer mesh material attached to a light weight metal hoop with minimal or no protruding knots were used for this species. Once captured, bandicoots were checked for condition, weight and sex as for hare-wallabies. They were also carefully examined for signs of possible early stage infection with BPCV1. Any animals deemed unsuitable for translocation were released at site of capture, and all equipment, including nets and hands, were sprayed with F10 disinfectant between every animal. Once selected for translocation, animals were placed into a small white cotton handling bag which was labelled with individual identification, weight, species and sex and carried to a central point for processing, where animals were implanted with a PIT as described above. Bandicoots were then placed in medium Pet Packs (PP30 62 x 43 x 45 cm), up to four animals per pack and transferred as described above for hare-wallabies.

A small number of bandicoots were captured using medium Elliot traps (as used for monitoring) baited with peanut butter and rolled oats, which were set at 10-20m intervals behind fore-dune of suitable beaches, whilst teams were netting further inland. Traps were cleared before sunrise and all bandicoots treated and transported as described above.

Two additional adult male Shark Bay bandicoots were captured from Dorre Island, White Beach on 4 May 2019 using the spotlight and hand netting technique described above and transported to Native Animal Rescue (NAR), Malaga to undergo radio-collar trials in preparation for a large-scale bandicoot translocation in September. These two individuals were processed on-site immediately upon capture, which included measuring head and pes length, weight, receiving a PIT tag and undergoing a thorough health examination of their skin and fur looking for superficial signs of an active BPCV1 infection as previously described. They were placed in black handling bags, situated within a splash-proof barrel and brought onboard the vessel at 21:30 where they were held separately in bags within Pet Packs lined with unscented absorbent training pads (Animaze brand). The bandicoots were provided with food in their bags (small pieces of carrot, apple and hard-boiled egg) then transported 3 hours by boat to Carnarvon that night. They were held overnight in Carnarvon, fed again at 06:30hr before being transported via air-conditioned vehicle to Perth. They were placed in fresh handling bags at 12:30hr and arrived safely at NAR at 18.30 on 5 May.

2.6 Sampling for bandicoot papillomatosis carcinomatosis virus type 1 (BPCV1).

All Shark Bay bandicoots were carefully examined for abnormalities of the hair and skin, and any suspicious lesions were photographed and then sampled, along with other potential viral shedding sites on the bandicoots (eyelids, lips, feet and flanks) using sterile saline swabs (Woolford, 2017). Swabs were then frozen and sent for PCR assay for detection of BPCV1 (Woolford, *et al.* 2007).

2.7 Data analysis

Abundance and density estimates were obtained from spotlight survey data using the Distance package (Thomas *et al*. 2010) in 'R' version 3.4.1 (R Core Team 2018). Individual island population estimates were calculated, as well as global population estimates by combining data from both Bernier and Dorre Islands in 2019. Although total numbers of observations for most species in 2019 did not reach the nominal minimum of 60, data were not pooled over more than one year, as was trialled in 2018 analysis.

Trapping data from Bernier and Dorre Islands and North West Island were analysed using the Spatially Explicit Capture Recapture package (secr 3.1.6) in 'R' version 3.5.1 (R Core Team 2018) to provide density and abundance estimates.

3 Results

3.1 Dorre Island, Shark Bay

Dorre Island monitoring was undertaken between the 26 March - 3 April 2019, with four nights trapping completed from 26 - 30 March and four nights spotlighting (all 27 transects completed) from 30 Mar - 2 April.

3.1.1 Trapping

Four nights trapping were completed and trap results, with comparisons to 2016, 2017 and 2018, are provided in Table 1.

Table 1. Dorre Island trapping results.

Species / Year	No. captures	No. Individuals	No. New individuals	# Females reproductive	Trap rates	Density (/ha)
SBB 2019	50	19(10:9)	11(6:5)	0+6?/9	9.8%	1.20
SBB 2018	40	16(6:10)	4(2:2)	0+3?/10	10.4%	1.14
SBB 2017	41	16(6:10)	5(2:3)	0/10	10.5%	1.25
SBB 2016	46	17(9:8)	N/A	5/9	11.7%	1.03
Boodie 2019	46	16(8:8)	6(2:4)	4+1?/8	18.0%	0.94
Boodie 2018	33	14(6:8)	4(2:2)	1+3?/8	17.2%	0.76
Boodie 2017	33	13(5:8)	7(3:4)	2+2?/8	16.8%	0.91
Boodie 2016	20	12(8:4)	N/A	4/4	10.2%	1.26*
BHW 2019	0	N/A				
BHW 2018	1	1(1:0)	1(1:0)	N/A	0.4%	N/A
RHW 2019	0	N/A				
RHW 2018	5	3(1:2)	3(1:2)	1+1?/2	2.6%	N/A

BHW = Banded hare-wallaby; **RHW** = Rufous hare-wallaby; **SBB** = Shark Bay bandicoot; (male: female ratio)

NB: Only 3 nights trapping completed in 2018, but more traps, so total trap nights similar to 2016 and 2017 (192 c.f.196). 4 nights of trapping on the enlarged 8x8 grid provided 256 trap nights in 2019.

? – denotes # females assessed as being reproductively active despite not carrying PY at time of capture (ie. Pouch preparing for new PY and/or teats still regressing from a recently weaned PY).

* Denotes poorer model fit (** worse)

The number of Shark Bay bandicoots captured on Dorre Island in 2019 was higher than in 2016, 2017 or 2018, with the density of 1.20 ha^{-1} the second highest recorded. As with 2018, trapping occurred in mid-autumn in 2019 (cf. late winter/spring in 2016 and 2017). As a result, reproductive activity might be expected to be lower at this time of year. Although no females had pouch young in autumn 2019, six showed some sign of recent reproductive activity.

The number of boodies trapped in 2019 was also higher than any of the previous three years, and although the density of 0.94ha^{-1} is lower than the 1.25 ha^{-1} for 2016, this is likely to be an artefact of the smaller sample size in 2016. 50% of female boodies had pouch young which was only exceeded in spring 2016.

Density and abundance estimates from spatially explicit capture recapture (SECR) analysis for boodies and Shark Bay bandicoots on Dorre Island are displayed in Table 6a and Figure 8a.

3.1.2 Spotlighting

All 27 spotlight transects on Dorre Island were completed over four nights from 30 March to 2 April 2019. Numbers of animals observed of each species per km of transect are shown in Table 2.

Table 2. Dorre Island 2016, 2017, 2018 and 2019 spotlighting results.

Species	No. per km transect 2016	No. per km transect 2017	No. per km transect 2018	No. per km transect 2019	PY/YAH/SA 2019 (Y/N)
SBB	0.211	0.470	0.258	0.820	N
Boodie	0.984	1.261	0.750	1.031	Y
BHW	1.265	2.008	1.804	2.413	N
RHW	0.867	1.184	0.445	0.843	Y

SBB = Shark Bay bandicoot; **BHW** = banded hare-wallaby; **RHW** = rufous hare-wallaby;

PY/YAH/SA= pouch young/young at heal/sub-adult.

Pouch young, young at-heel and sub-adult individuals of rufous hare-wallaby and boodies were sighted during the spotlight surveys, indicating that some breeding had occurred for these species during spring/summer 2018-19.

Although numbers of each species observed per km of transect on Dorre Island was generally within the range observed over the previous three years, numbers of Shark Bay bandicoots observed per km was unusually high.

3.2 Bernier Island, Shark Bay

Bernier Island monitoring was undertaken between the 8 - 16 April 2019, with four nights trapping completed on both grids from 8 - 12 April and four nights spotlighting (with all 27 transects completed) from 12 – 15 April.

3.2.1 Trapping

Four nights trapping of each grid was completed on Bernier Island. The results of the trapping on Bernier Island from 2016 to 2019 are shown in Table 3.

Table 3. Bernier Island trapping results (only 3 nights trapping in 2016 and 2017).

Species/ Year	No. captures	No. Individuals	No. New individuals	# Female reproductive	Trap rate	Density (/ha)
SBB 2019	19	7(2:5)	4(2:2)	1+3?/5	3.7%	0.50*
SBB 2018	31	15(7:8)	12(7:5)	0+3?/10	6.1%	1.25
SBB 2017	8	5(2:3)	5(2:3)	0/3	2.0%	0.64**
SBB 2016	2	2(1:1)	N/A	1/1	0.5%	N/A
Boodie 2019	21	10(4:5:1)	6(2:3:1)	3+1?/5	8.2%	0.78
Boodie 2018	25	8(3:5)	2(0:2)	0/5	9.8%	0.58
Boodie 2017	21	7(3:4)	5(2:3)	0/4	10.7%	0.54*
Boodie 2016	7	5(4:1)	N/A	1/1	3.6%	0.32**
BHW 2019	3	2(2:0)	1(1:0)	N/A	1.2%	N/A
BHW 2018	2	2(1:1)	2(1:1)	1/1	0.8%	N/A
BHW 2017	2 (both juv.)	2(2:0)	2(2:0)	N/A	1.0%	N/A
BHW 2016	0		N/A			
SBM 2019 (+SBM grid)	14	11(6:5)	11(6:5)	0/5?	2.3%	1.42*
SBM 2018 (+SBM grid)	15	8(4:4)	8(4:4)	0/4?	2.5%	0.33*

Above + beach traps	16	9(5:4)	9(5:4)	0/4?	1.4%	N/A
SBM 2017 (+SBM grid)	1 (escaped)	1	?	?	---	N/A
SBM 2016 (+SBM grid)	8	7(3:4)	N/A	3/4	2.9%	1.55**

SBB = Shark Bay bandicoot; **SBM** = Shark Bay mouse; **BHW** = banded hare-wallaby.

4 nights of trapping on the 8x8 grid provided 256 cage trap nights in 2018 and 2019 cf. only 147 for 2016/17.

(NB: calculated trap rate for SBM and SBB includes both cage and Elliott traps)

? – denotes # females assessed as being reproductively active despite not carrying PY at time of capture (ie. Pouch preparing for new PY and/or teats still regressing from a recently weaned PY).

* Denotes poorer model fit (** worse)

As with Dorre Island, the numbers of animals trapped on Bernier Island were generally lower in 2019 than in 2018, but still higher than 2017 or 2016 figures. However, there was more sign of reproductive activity in females, even at this time of year.

Capture rates and number of individuals of Shark Bay bandicoots were considerably less than in 2018, but still higher than in 2016 and 2017. Calculated density was also low at 0.5ha^{-1}, but one female had pouch young, and another three showed signs of reproductive activity, indicating there had been some breeding earlier in the year.

There were slightly fewer boodie captures in 2019 than in 2018, but more individuals captured (the highest number of the last four years). Three of the five females had pouch young at this time in autumn.

Although captures of Shark Bay mice in 2019 were similar to 2018, the total number of individuals and calculated density was higher.

SECR analysis of captures of Shark Bay bandicoots, Shark Bay mice and boodies on Bernier Island has provided density and abundance estimates for these species at Red Cliff Bay (Table 6b and Figure 8b).

3.2.2 Spotlighting

All 27 spotlight transects were surveyed on Bernier Island over four nights in 2019.

Numbers of animals observed for each species per km of transect are shown in Table 4.

Table 4. Bernier Island 2016, 2017, 2018 and 2019 spotlighting results.

Species	No. per km transect 2016	No. per km transect 2017	No. per km transect 2018	No. per km transect 2019	PY, YAH, SA 2019 (Y/N)
SBB	0.521	0.211	0.118	0.142	N
Boodie	0.853	0.599	0.237	0.260	Y
BHW	1.681	2.396	1.113	0.853	N
RHW	1.137	1.339	0.592	0.237	Y

SBB= Shark Bay bandicoot; **BHW** = banded hare-wallaby; **RHW** = rufous hare-wallaby;

PY/YAH/SA= pouch young/young at heal/sub-adult.

Pouch young or sub-adult rufous hare-wallabies and boodies were observed during spotlighting, indicating that there had been some breeding by these species over the spring/summer of 2018-19.

Total number of observations per km of transect for all species on Bernier Island were lower than Dorre Island in 2019. The 2019 figures for Bernier Island were also lower relative to the previous three years than on Dorre Island, suggesting Bernier Island as a whole had fared worse than Dorre Island over the previous 12 months, and has been steadily declining since 2016.

3.3 Bernier and Dorre Island population estimates

As in 2018, monitoring (both spotlight and trapping) was carried out in autumn 2019 (instead of spring monitoring as in 2016 and 2017), in order to allow time to assess abundance estimates and inform the decision making framework on harvesting approvals, prior to the planned translocations in spring 2019. The general pattern of dry summers usually means that if a population crash is going to occur, it is likely to happen prior to monitoring in mid-autumn (Short *et al.* 1997). Therefore population sizes are unlikely to significantly reduce between then and the planned translocations in spring, meaning estimates will be a conservative base from which to develop harvesting limits. The downside of monitoring at this time of the annual cycle is that there is likely to be less information obtained on the reproductive activity of the species as it is not the normal peak breeding season. This does however mean that there is a reduced welfare risk associated with the ejection of pouch young during trapping. In 2019 however, there was plenty of evidence of breeding even at this time of year.

3.3.1 Abundance estimates of spotlight data using Distance analysis

Although combined abundance estimates for all four species in 2019 were slightly higher than in 2018, there was a discrepancy between the two islands. For all species except SBB, there was an inverse trend on the two islands, with the population of all species on Dorre Island increasing from 2018 to 2019, but decreasing on Bernier Island in the same period. The exception was SBB, where there was an increase in population on both islands. Table 5a compares the 2011 to 2019 abundance estimates for banded and rufous hare-wallabies, boodies and Shark Bay bandicoots for Bernier and Dorre Islands individually. Estimates for the two islands combined, along with the upper and lower confidence limits are shown in Table 5b. The 2019 abundance estimates (with lower and upper confidence limits) for the species on Bernier and Dorre Islands are also shown in Figure 7e, and plotted against previous years for each individual species in Figures 7a-d.

Of the species targeted by spotlighting in 2019, only banded hare-wallabies were observed in sufficient numbers on Dorre Island alone, and for both islands combined, to satisfy the recommended minimum sample size (60) for calculating a detection function with confidence (Buckland *et al.* 1993). In 2018, to overcome this limitation, observations from two or three years were combined in order to obtain a minimum of 60 observations to calculate a combined island, multi-year global detection function for each species, and then apply these separately to each year of data to obtain global (combined island) abundance estimates for each species in each year. Although this resulted in lower standard errors and smaller confidence intervals for the estimates for most species, the abundance estimates derived did not vary significantly from those obtained using the single year detection functions and so analysis of 2019 data used single year data only.

Table 5a. Abundance estimates for all species, Bernier and Dorre Island, 2011-2019 (figures in red did not reach the recommended minimum sample size) (LCL = lower 95% confidence limits, UCL= upper confidence limits)

Bernier: BHW

	N	SE	LCL	UCL
2011	668	262.02	277	1609
2012	2017	526.41	1124	3620
2013	2627	508.65	1717	4020
2016	2790	504.22	1892	4115
2017	3540	586.98	2523	4966
2018	2449	367.02	1819	3298
2019	1814	334	1243	2647

Dorre: BHW

	N	SE	LCL	UCL
2011	1420	465.48	679	2967
2012	2271	535.85	1342	3844
2013	1729	434.25	986	3033
2016	2440	865.41	1099	5415
2017	3175	531.59	2266	4449
2018	3438	730.5	2247	5260
2019	4215	556	3241	5482

Bernier: Boodie

	N	SE	LCL	UCL
2011	751	324.62	284	1980
2012	1581	349	960	2606
2013	2289	377.55	1586	3303
2016	1221	331.12	668	2232
2017	1297	301.12	803	2094
2018	1125	370.56	585	2165
2019	776	187	472	1275

Dorre: Boodie

	N	SE	LCL	UCL
2011	2561	898.38	1156	5671
2012	3988	968.81	2298	6921
2013	2871	859.58	1454	5669
2016	1698	619.4	744	3877
2017	2803	594.22	1835	4282
2018	1866	706.88	891	3907
2019	2613	846	2050	5600

Bernier: RHW

	N	SE	LCL	UCL
2011	669	132.29	434	1032
2012	1535	305.48	992	2374
2013	1203	270.39	731	1978
2016	1683	435.66	955	2966
2017	1712	360.5	1105	2652
2018	1025	243.24	628	1671
2019	958	202	**622**	1476

Dorre: RHW

	N	SE	LCL	UCL
2011	1548	417.59	847	2830
2012	1381	391.04	732	2603
2013	1381	412.97	706	2701
2016	1481	563	632	3470
2017	1703	485.53	956	3031
2018	1056	260.95	632	1765
2019	1955	423	**1271**	3006

Bernier: SBB

	N	SE	LCL	UCL
2011	381	167.47	147	989
2012	287	122.92	113	726
2013	632	236.74	281	1419
2016	1090	187.64	776	1533

Dorre: SBB

	N	SE	LCL	UCL
2011	1100	322.41	590	2051
2012	695	266.7	304	1591
2013	1434	373.18	831	2475
2016	527	159.89	276	1006

2017	1370	311.12	837	2244	2539	602.46	1570	4105
2018	873	325.23	407	1876	1215	507.23	528	2796
2019	1556	468	**855**	2832	2955	925	**1602**	5451

Notes:

Estimates for each species by island

Distance analysis using Program Distance 6.2

2017, 2018, 2019 analysis using Distance in 'R' vs 3.4.1

Figures in red - calculated using less than recommended minimum No. of observations (<60)

Table 5b. Combined abundance estimates all species, Bernier and Dorre Island, 2011-2019 (figures in red did not reach the recommended minimum sample size in a single year.

Bernier and Dorre: BHW

	N	SE	LCL	UCL
2011	2059	592.48	1138	3727
2012	4219	758.14	2920	6097
2013	4445	806.43	3065	6447
2016	5271	1054.6	3499	7942
2017	**6715**	**882.37**	**5176**	**8712**
2018	**5888**	942.28	4292	8077
2019	**6029**	733	4743	7664

Bernier and Dorre: Boodie

	N	SE	LCL	UCL
2011	3265	957.28	1779	5992
2012	5561	1092	3700	8358
2013	5149	894.55	3593	7377
2016	2899	669.13	1799	4672
2017	**4100**	**767.73**	**2831**	**5938**
2018	**2991**	963.31	1596	5608
2019	**3388**	846	2050	5600

Combining 2017/18

N	SE	LCL	UCL
3950	684.10	**2802**	**5569**
2850	678.48	**1770**	**4589**

Bernier and Dorre: RHW

	N	SE	LCL	UCL
2011	2197	466.23	1420	3397
2012	2917	548.92	1985	4288
2013	2589	492.41	1754	3812
2016	3202	740.03	1994	5143
2017	3415	857.66	2329	5006
2018	2081	398.86	1420	3049
2019	2913	546	**2011**	4220

Combining 2017/18

N	SE	LCL	UCL
3416	684.59	2293	5091
2482	442.28	1739	3544

Bernier and Dorre: SBB

	N	SE	LCL	UCL
2011	1464	430.15	811	2644
2012	981	303.3	526	1827
2013	2012	486.5	1241	3262
2016	1676	358.49	1096	2562
2017	3909	781.85	2619	5834

Combining 2016/17/18

N	SE	LCL	UCL
2297	524.60	1468	3594
2487	603.88	1544	4006

2018	2089	798.22	960	4545	1901	462.78	1177	3070
2019	4511	1287	**2576**	7899				

Notes:

Observations combined from both island to give a Global estimate

Distance analysis using Program Distance 6.2

2017, 2018, 2019 analysis using Distance in 'R' vs 3.4.1

Figures in red - calculated using less than recommended minimum No. of observations (<60)
Adjusted figures in blue and purple, calculated using a multi-year global detection function (>60).

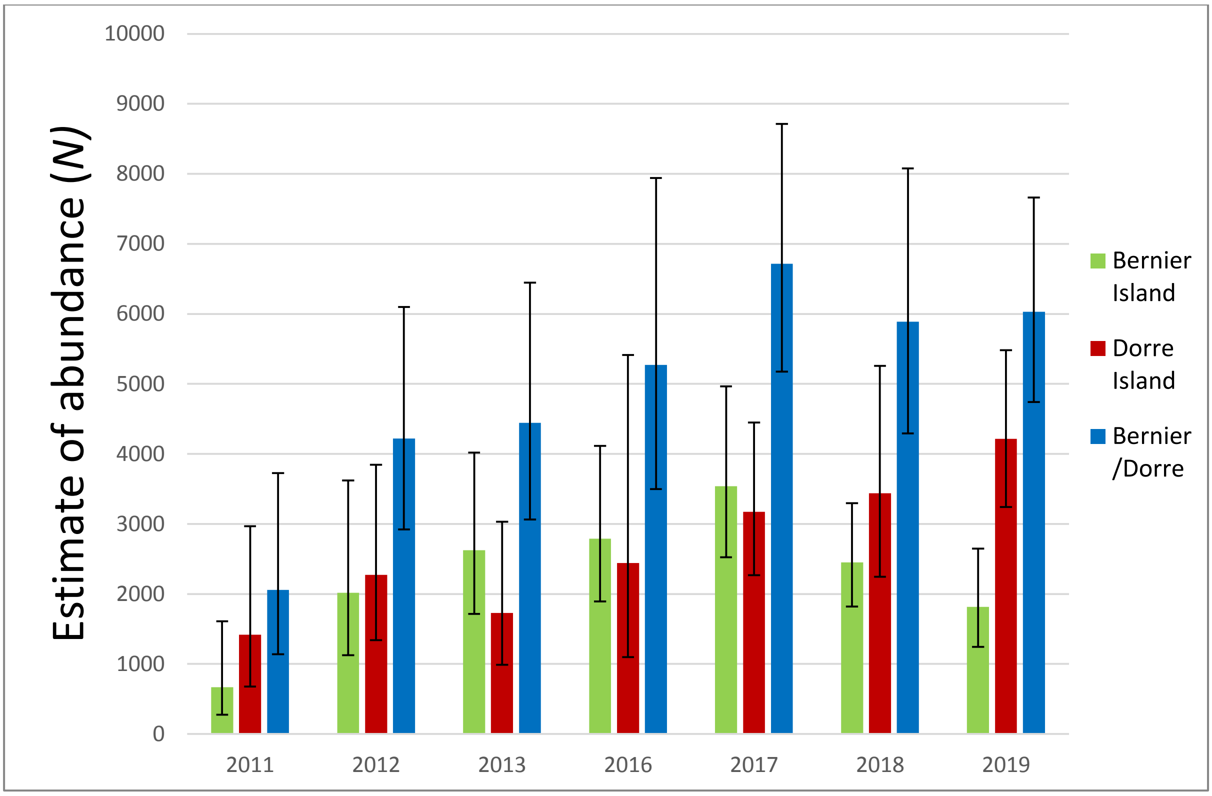


Figure 7a. Abundance estimates for banded hare-wallabies on Bernier and Dorre Islands 2011-2019 (including LCL and UCL bars) (Distance analysis of spotlight transects).

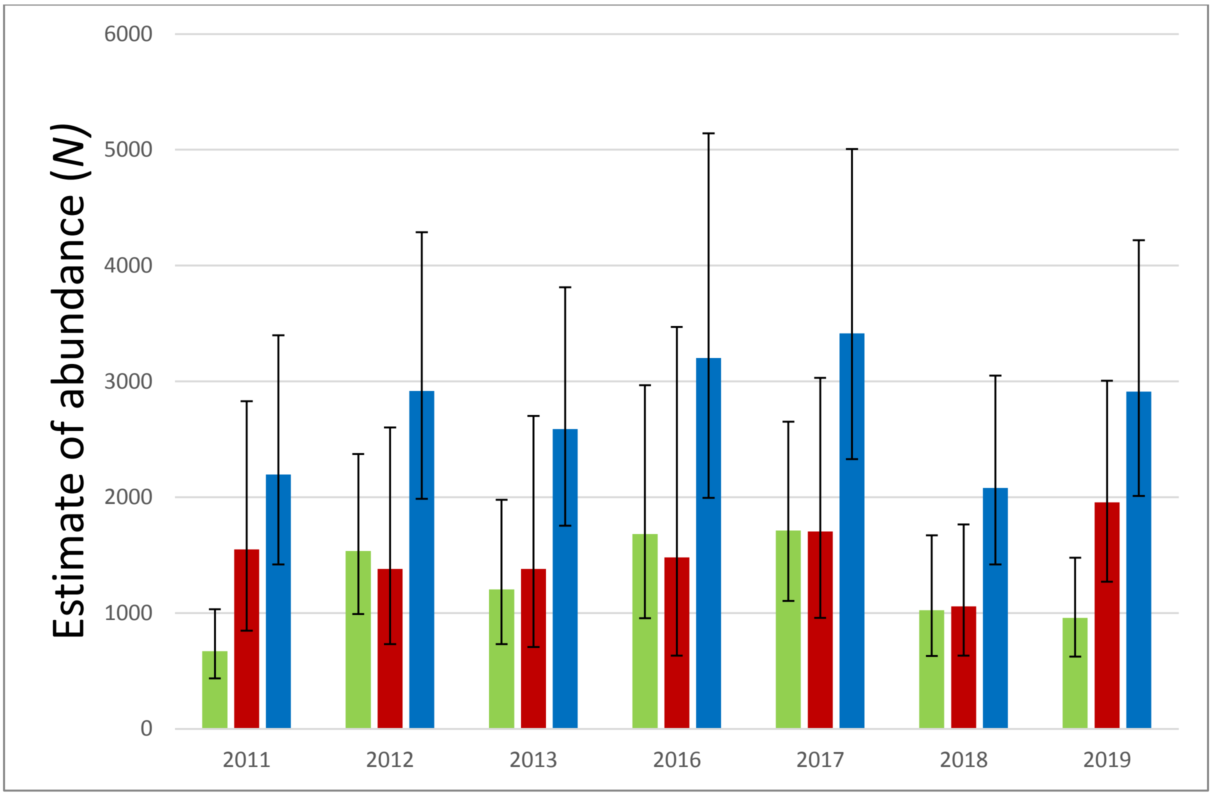


Figure 7b. Abundance estimates for rufous hare-wallabies on Bernier and Dorre Islands 2011-2019 (including LCL and UCL bars) (Distance analysis of spotlight transects).

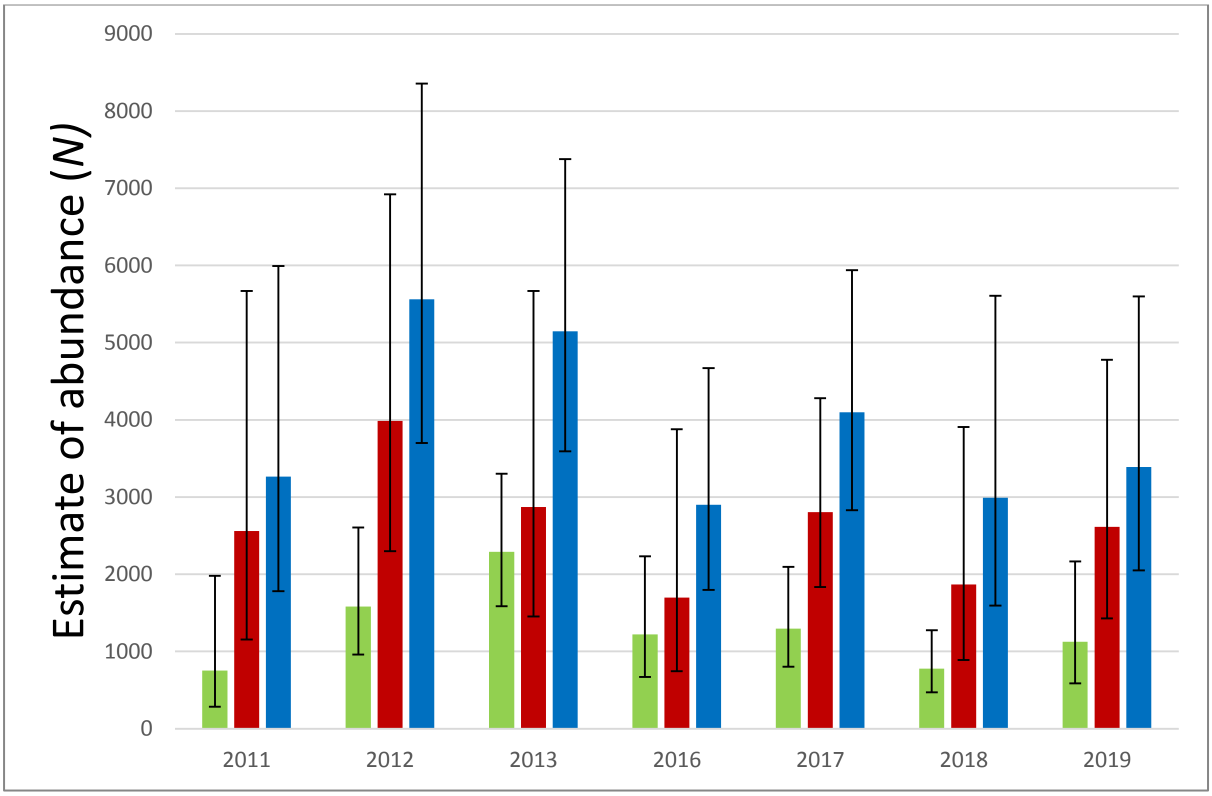


Figure 7c. Abundance estimates for boodies on Bernier and Dorre Islands 2011–2019 (including LCL and UCL bars) (Distance analysis of spotlight transects).

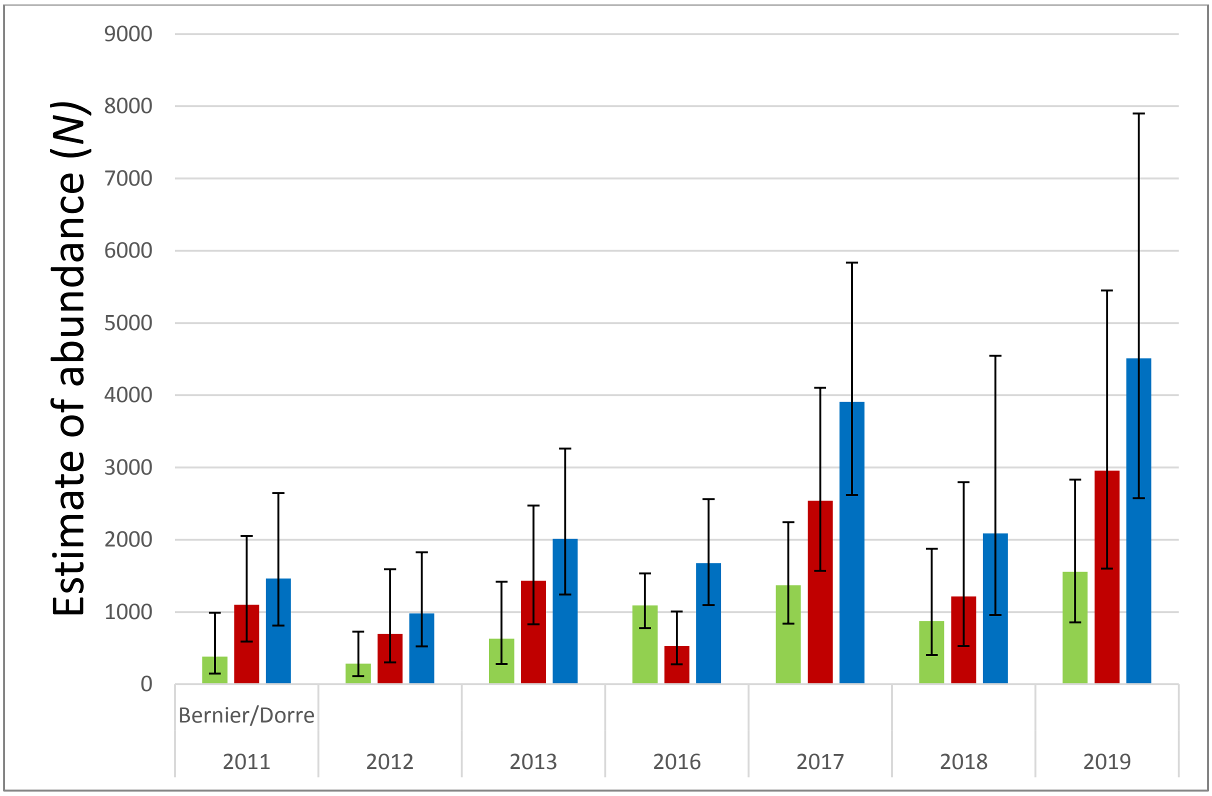


Figure 7d. Abundance estimates for SBB on Bernier and Dorre Islands 2011-2019 (including LCL and UCL bars) (Distance analysis of spotlight transects).

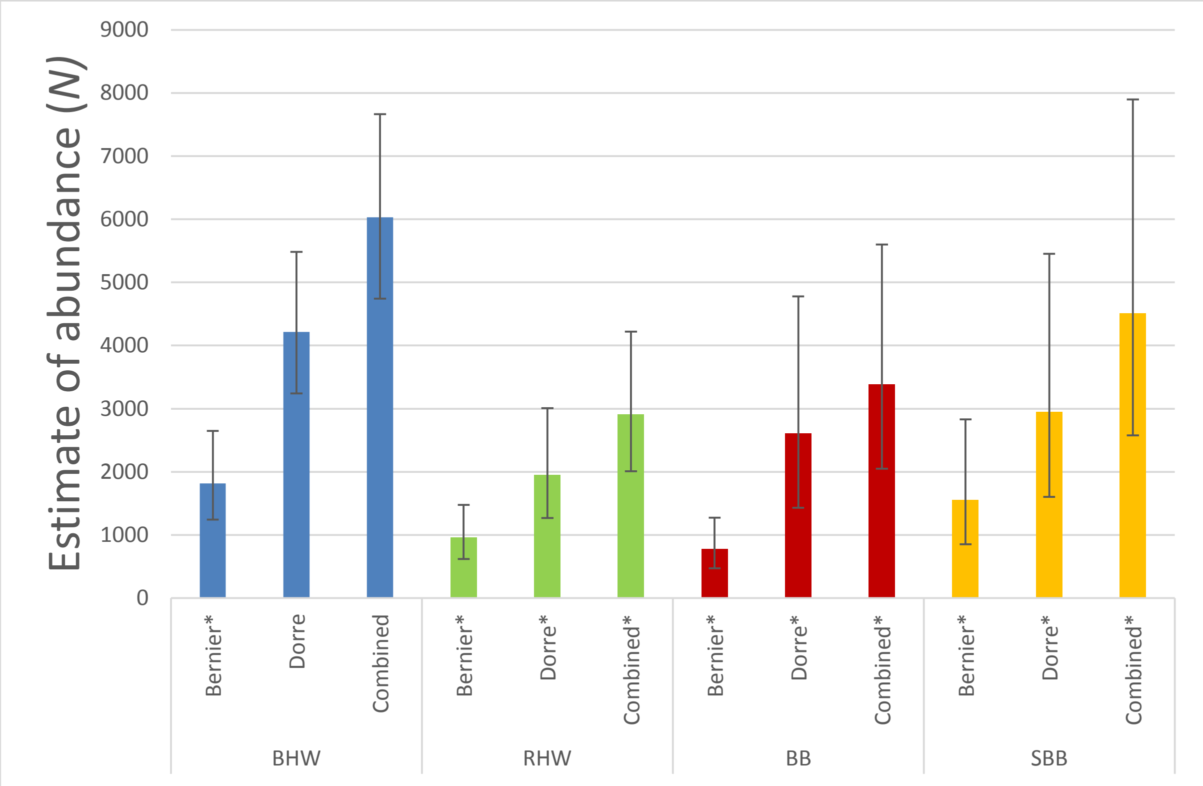


Figure 7e. Abundance estimates for banded hare-wallabies (BHW), rufous hare-wallabies (RHW), boodies (BB) and Shark Bay bandicoots (SBB) on Bernier and Dorre Islands in 2019 (including UCL and LCL bars) (Distance analysis of spotlight transects).

3.3.2 Abundance estimates based on trapping data using SECR

Obtaining robust density estimates for readily trappable (i.e. not ‘trap-shy’) species (Shark Bay mice, boodie and Shark Bay bandicoot) from the trap data is dependent on the number of individuals and trap events recorded in each session. When populations appear relatively low, these sample sizes can be too small to do meaningful analysis. Bernier Island in particular, seems to have generally lower trap numbers for most species compared to Dorre Island. However, capture rates on Dorre Island in 2019 were the highest since 2016 and able to provide good estimates of density for both boodies and bandicoots. Similarly Shark Bay mouse and boodie captures on Bernier Island were higher than the previous three years and provided reasonable estimates of density. Capture rates for Shark Bay bandicoots on Bernier Island in 2019, were less than half that for 2018 and consequently density estimates derived from SECR analysis for this population in 2019 have less certainty. Using these density estimates to calculate population abundance creates additional challenges in interpreting how representative the species density at these locations are of the entire island area, and the various habitats represented across them.

We currently have little information on the distribution and relative area of different habitats across the two islands, so for now, a very coarse calculation of abundance has been produced by simply multiplying the density at the trapping grid by the area of each island (excluding major areas of unvegetated and unusable geology such as coastal cliff on both islands and large areas of open, mobile dune on Bernier Island in particular).

The abundance estimates obtained by this method are likely to be over-estimates, as the same densities obtained from the grids are unlikely to be replicated across all of the other habitat types, and baited traps can draw animals in (particularly boodies) from distances outside normal home ranges. This can be evidenced in the estimates obtained for boodies from trap data which are consistently twice those from spotlighting data. The abundance estimates from trap data for Shark Bay bandicoots have been as much as three to five times those calculated from spotlight data. In 2019, although the abundance estimates from trapping are still larger than those from spotlight surveys, the difference is less extreme.

Despite the above limitations, trap monitoring provides important morphometric and demographic data for the trappable species, including current body condition and reproductive status of individuals (as well as presence of disease) which contributes important information to the assessment of population health and demographics. The results from trap data are also useful in providing potential upper limits of population size and illustrating changes and trends in relative abundance between years.

Notable here is that for all species and all four years, Dorre Island density and abundance estimates are consistently estimated as higher than those for Bernier Island (Table 6), and the general trend in relative abundance for most species tends to be mirrored from year to year regardless of technique on Dorre Island. Bernier Island appears to display more variability (Figure 8).

Table 6. Density and abundance estimates from trapping data at Dorre and Bernier Island 2016-19 (* Denotes poorer model fit (** worse))

6a. 5134ha Dorre Island (habitat area used for calculating abundance ~ 4815ha)

Species	Year	N	Density/ha	SE	LCL density	UCL density	Mean popn	LCL popn	UCL popn
SBB	2016	16	1.02587	0.32270	0.56186	1.87307	4939	**2705**	9018
SBB	2017	16	1.25477	0.35415	0.72930	2.15883	6041	**3511**	10394
SBB	2018	16	1.14307	0.31073	0.67732	1.92910	5503	**3261**	9288
SBB	2019	19	1.20214	0.30040	0.74211	1.94735	5788	**3573**	9376
BB	*2016	12	1.25713	0.55046	0.55320	2.85677	6053	**2664**	13755
BB	2017	12	0.91008	0.29351	0.49127	1.68591	4382	**2365**	8118
BB	2018	14	0.76253	0.25594	0.40193	1.44666	3672	**1935**	6966
BB	2019	16	0.94265	0.25920	0.55532	1.60014	4539	**2674**	7705

6b. 4267ha Bernier Island (habitat area used for calculating abundance ~ 3750ha)

Species	Year	N	Density/ha	SE	LCL density	UCL density	Mean popn	LCL popn	UCL popn
SBB	**2017	8	0.63933	0.39193	0.21132	1.93428	2397	**792**	7253
SBB	2018	15	1.24682	0.38266	0.69250	2.24485	4675	**2596**	8418
SBB	*2019	7	0.49802	0.20874	0.22636	1.09569	1868	**849**	4109
BB	**2016	5	0.32340	0.44437	0.04297	2.43413	1213	**161**	9128
BB	*2017	7	0.54112	0.23030	0.24322	1.20392	2029	**912**	4515
BB	2018	8	0.58066	0.21847	0.28458	1.18478	2177	**1067**	4443
BB	2019	10	0.77600	0.28382	0.38749	1.55406	2910	**1453**	5828
SBM	**2016	7	1.54557	2.28113	0.18783	12.71802	5458	704	47692
SBM	*2018	8	0.33360	0.22953	0.09847	1.13016	1251	**369**	4238
SBM	*2019	11	1.42257	0.84185	0.48602	4.16385	5335	**1823**	15614

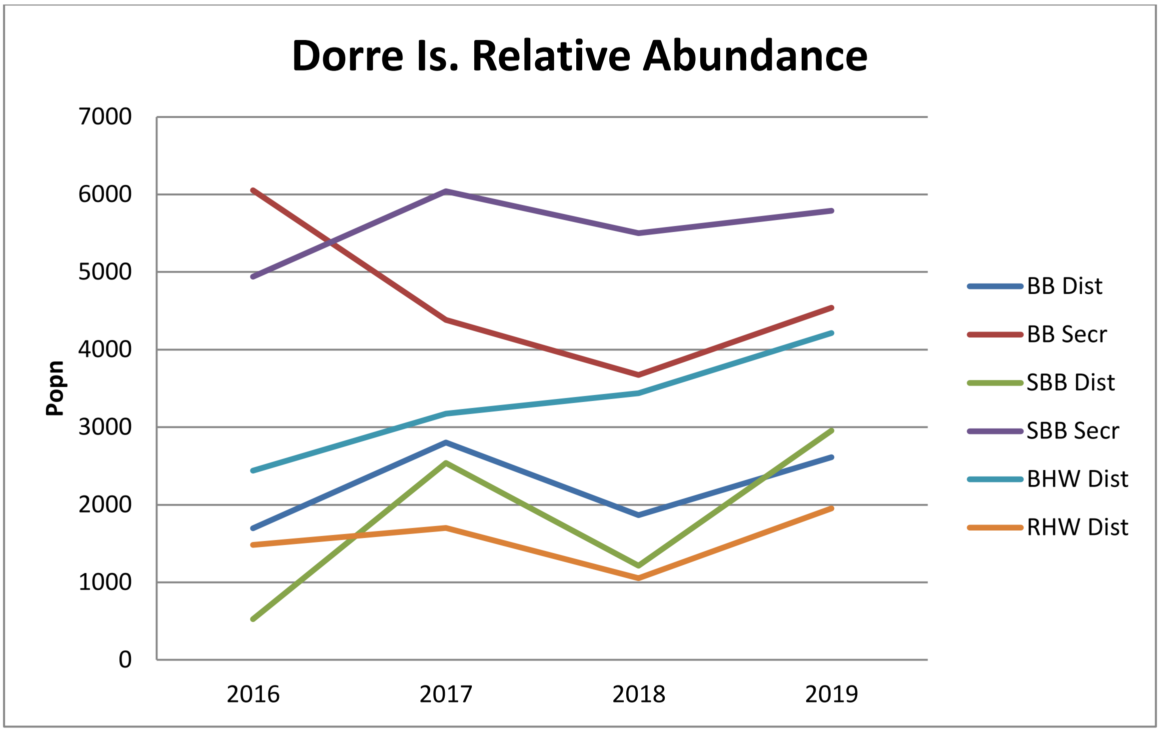


Figure 8a. Relative abundance on Dorre Island (2016-19). [banded hare-wallabies (BHW), rufous hare-wallabies (RHW), boodies (BB) and Shark Bay bandicoots (SBB)]

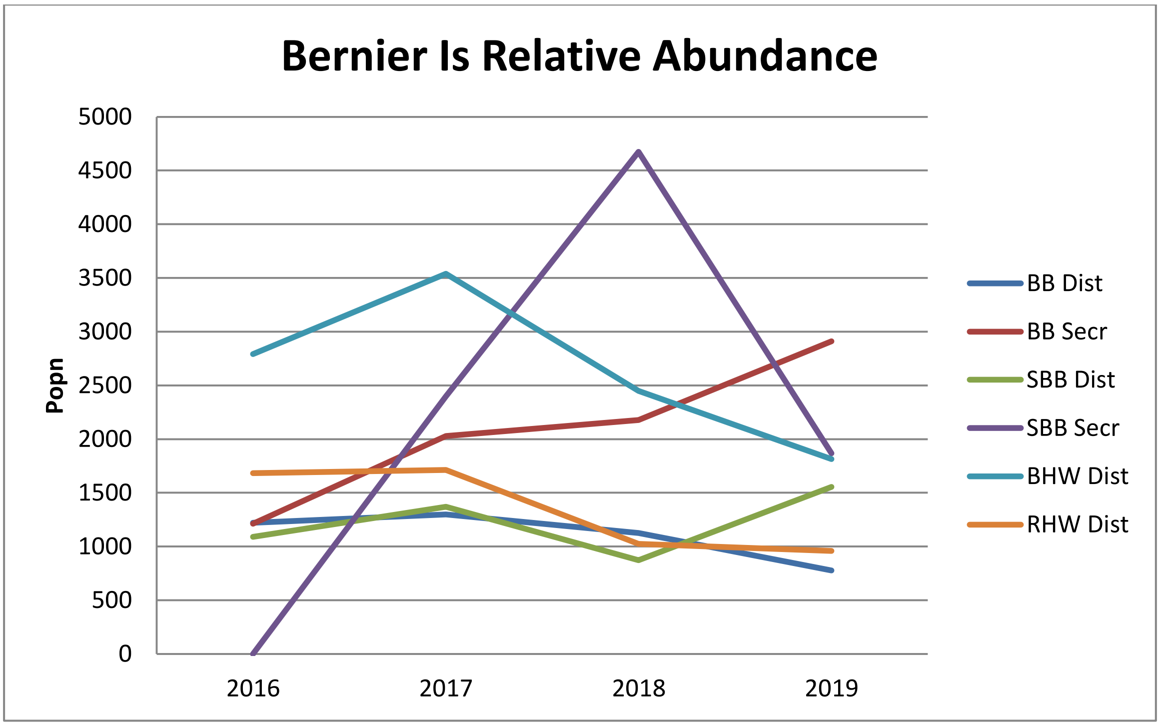


Figure 8b. Relative abundance on Bernier Island (2016-19). [banded hare-wallabies (BHW), rufous hare-wallabies (RHW), boodies (BB) and Shark Bay bandicoots (SBB)]

3.4 BPCV1 Disease screening

In 2018, no Shark Bay bandicoots on Dorre Island had suspicious lesions warranting screening for BPCV1. However, two Bernier Island bandicoots from the monitoring grid at Red Cliff Bay in autumn and another one from Hospital Bay in October (from AWC translocation harvesting work) were swabbed and proved positive on PCR analysis for the bandicoot papillomatosis carcinomatosis virus type 1 (BPCV1) (Woolford 2007). This latter was the first confirmation of the virus at a location other than Red Cliff Bay.

The smaller number (5) and younger average age of individual Shark Bay bandicoots captured on Bernier Island in autumn 2019 probably contributed to the lack of observation of any suspicious lesions, so no swab sampling was required. However, two individuals were sampled on Dorre Is (clinical signs of hair loss and reddened skin on forefeet did not appear likely to be due to BPCV1, but screening was considered prudent to ensure the potential presence of the virus is not missed due to erroneous assumptions). PCR analysis for BPCV1 virus was negative for both individuals sampled.

During harvesting for translocations to DHI (DBCA) and Mt Gibson (AWC) in spring 2019, a number of animals were rejected for translocation due to various signs suggesting possible BPCV1 infection. Very obvious lesions and abnormalities were usually released immediately without swabbing, but seven animals rejected on review by the veterinarian, were swabbed and samples sent for PCR analysis by DBCA. One individual tested positive for the virus, but the animal with the most suspicious clinical signs was negative for BPCV1 on PCR analysis. It is possible this result was a false negative. A further six animals were also swabbed by AWC during their harvesting, but these have not yet been tested for BPCV1.

In 2019, approximately 20% of all adult animals captured and examined on Bernier Island were rejected for translocation due to skin abnormalities that were considered suspicious for BPCV1. Only one out of seven (14%) of animals swabbed and tested proved positive for the virus.

Table 7. Proportion of captured Shark Bay bandicoots rejected or accepted for translocation in 2019.

Harvesting	# adults checked	#rejected for BPCV1	#rejected for eyes	# rejected for all reasons	% animals translocated
DBCA	38	8 (21%)	6/38(16%)	21/41(51%)	20/41
AWC	35	6(17%)	2/35(6%)	12/35(34%)	23/35
Total BI	73	14(19%)	8/73(11%)	33/76(43%)	43/76
Total DI	92	0	4/92(4%)	43/93(46%)	50/92

The wider distribution of positive BPCV1 bandicoots over the last two years confirms that the virus is present throughout the bandicoot population across the whole of Bernier Island. Sampling of possible cases from Dorre Island has so far confirmed the BPCV1 disease free status of this population.

3.5 Harvesting from Bernier and Dorre Islands

Based on the population estimates from the monitoring carried out in autumn 2019 (Section 3.3) and using the harvesting guidelines developed by DBCA (Page, 2017), maximum harvest numbers for rufous hare-wallabies and Shark Bay bandicoots were set by the Principal Zoologist and approved by the Executive Director of Biodiversity and Conservation Science, DBCA, for both the DHINP and Mt Gibson translocations proposed for spring 2019.

Harvesting guidelines (Page, 2017) were designed conservatively and utilise the Lower Confidence Level (LCL) calculation of abundance resulting from Distance analysis, and limit harvest levels at <10% (preferably no more than 5%) of this figure, depending on a number of complex factors including recent and future predicted rainfall, population trajectory (i.e. early or late phase increasing or decreasing population) and where it is in relation to projected carrying capacity. Population estimates in 2019 were sufficiently high for harvesting approval to be given for both projects and species. Lower harvest limits were prescribed for populations on Bernier Island, reflecting the lower estimated abundances.

Harvesting by DBCA of 50 (25:25) rufous hare-wallabies comprising 30 (15:15) from Dorre Island and 20 (10:10) from Bernier Island and 70 (32:38) Shark Bay bandicoots, comprising 50 (25:25) from Dorre Island and 20 (7:13) from Bernier Island, occurred from 27 August – 14 September 2019 (Table 8). Fourteen of the 25 rufous hare-wallaby females translocated to DHI were carrying a small pouch young, and nine of the 38 Shark Bay bandicoot females carried pouch young. A large number of animals captured were rejected for translocation due to their reproductive condition (females with large pouch young or still lactating [i.e. with dependent young outside the pouch]) or as small juvenile animals which did not meet the size criteria. This indicates that a reasonable proportion of both rufous hare-wallabies and Shark Bay bandicoots were reproductive and recruiting new individuals into the island populations through winter and early spring of 2019. There was however, a distinct difference between islands with Dorre Island animals of both species having higher reproductive activity than Bernier Island animals, which corresponds with the lower population estimates for the latter from earlier in the year and supports the decision for reduced harvesting from Bernier Island.

The DHINPERP harvest was followed later in October 2019 by removal of a further 23 (12:11) Shark Bay bandicoots (all from Bernier Island) to Mt Gibson by the Australian Wildlife Conservancy. Two of the eleven females carried pouch young at capture.

Using the Lower Confidence Levels (LCL) of the estimate of abundance obtained from spotlighting, the total number of each species harvested from Bernier and Dorre Island in Aug-Oct 2019 make up only 2.5% (50/2011) of the combined rufous hare-wallaby population (20/622 or 3.2% of Bernier Island and 30/1271 or 2.4% of Dorre Island) and 3.6% (93/2576) of the combined Shark Bay bandicoot population (43/855 or 5.0% of Bernier Island and 50/1602 or 3.1% of Dorre Island), as estimated from monitoring in autumn 2019.

Table 8. Numbers of different species harvested from Bernier and Dorre Islands in spring 2019.

2019 Translocations	Total	M	F	%F with PY	% 2019 LCL Population Est.
DBCA RHW DI to DHI	30	15	15	60%	2.4%
DBCA RHW BI to DHI	20	10	10	50%	3.2%
Total RHW Harvest	50	25	25	56%	2.5%
DBCA SBB DI to DHI	50	25	25	28%	3.1%
SBB DI Harvest	50	25	25	28%	3.1%
DBCA SBB BI to DHI	20	7	13	15%	2.3%
AWC SBB BI to MG	23	12	11	18%	2.7%
SBB BI Harvest	43	19	24	17%	5.0%
Total SBB Harvest	93	44	49	22%	3.6%

MG = Mt Gibson; **FI** = Faure Island; **DHI** = Dirk Hartog Island, **DI** = Dorre Island, **BI** = Bernier Island

3.6 Bernier and Dorre Islands camera trap monitoring trials

The array of 50 camera traps on each of Bernier and Dorre Islands was deployed for approximately 200 days from 1 May to 17 November 2019 for a total of 19,664 trap nights (9,910 on Bernier; 9,754 on Dorre). In excess of 95,000 images (60,374 for Bernier, 35,353 for Dorre) were taken by the cameras across both islands.

Six tripods were toppled over sometime during deployment, but 92 of the remaining 94 (~98%) cameras found standing retained sufficient battery life throughout to still be collecting images at the end of the nearly 6½ month period. Aside from the six cameras that fell over, all but one PIR motion detector lens were still in fair to good condition upon collection.

Images from this large scale camera trap survey have not yet been fully processed and interrogated using CPW Photo Warehouse and false triggers have yet to be removed.

In addition to the main array, another five trap stations (each with two cameras) were deployed on Bernier Island for 221 days from 10 April to 17 November 2019, for a total of 2,210 trap nights and collected 16,355 images (6,877 PIR; 9,478 white-flash). All cameras retained functionality across the entire 7 month period.

Images taken during the smaller Bernier Island camera station trial comparing white flash against PIR cameras to distinguish between ash-grey mice and Shark Bay mice have also not yet been analysed.

The results of these trials and their feasibility as a future monitoring technique will be reported on separately when analysis is complete.

3.7 Boullanger, Escape and Whitlock Islands, Jurien Bay.

In spring 2018, four pairs of dibbler were collected from Whitlock Island and five individuals (3:2) from Escape Island for the Perth Zoo breeding program. No animals were collected at that time from Boullanger Island due to the low numbers trapped during the previous two monitoring sessions.

In response to the loss of two of the founder females at Perth Zoo, two further visits were made to the Jurien Bay islands in early 2019: to Whitlock Island on 8 - 9 January (50 traps) and to Escape Island on 21 - 22 February (75 traps). On Whitlock Island a male and a female were captured and the female was collected. On Escape Island 14 (8:6) dibblers were captured, and 4 (1:3) more collected for the Zoo breeding program. This made a total of 18 individuals harvested for the program prior to the first captive breeding , and resulted in eight founder pairs (four pairs each from Whitlock and Escape Islands) for the 2019 breeding program (Friend and Button 2019).

Further monitoring occurred on Boullanger and Whitlock Islands during the usual May and October periods in 2019. Escape Island was not monitored in 2019.

The trapping in May occurred over four nights from 28 - 31 May 2019. Only eight (3:5) dibblers were captured from Boullanger Island in 500 trap nights, continuing the low capture rate (seven) from May 2018. This was still well below the 57 animals captured in May 2017, and one of the lowest recorded since 2005 (Figure. 9a). A total of 18 (10:8) dibblers were captured on Whitlock Island in 160 trap nights. (Friend and Button 2019b).

The spring trapping program occurred from 21 - 25 October 2019 and resulted in capture of eleven dibblers on Boullanger Island in 500 trap nights, and a total of 20 dibblers captured on Whitlock Island in 160 trap nights (Friend pers. comms.).

After release of 26(13:13) individuals (including two (1:1) original founders from Escape Island) from Perth Zoo to Dirk Hartog Island on 7 October 2019, a further three (2:1) individuals were harvested from Boullanger Island at the end of the October 2019 monitoring, to replenish the breeding population for 2020.

Table 9 Dibblers harvested from Jurien Bay Islands for captive breeding program.

	Whitlock Is	Escape Is	Boullanger Is	Totals
October 2018	8(4:4)	5(3:2)		13(7:6)
January 2019	1(0:1)			1(0:1)
February 2019		4(1:3)		4(1:3)
October 2019			3(2:1)	3(2:1)
Total harvest	9(4:5)	9(4:5)	3(2:1)	21(10:11)

. (NB. One female from each of Whitlock and Escape Island died before breeding).

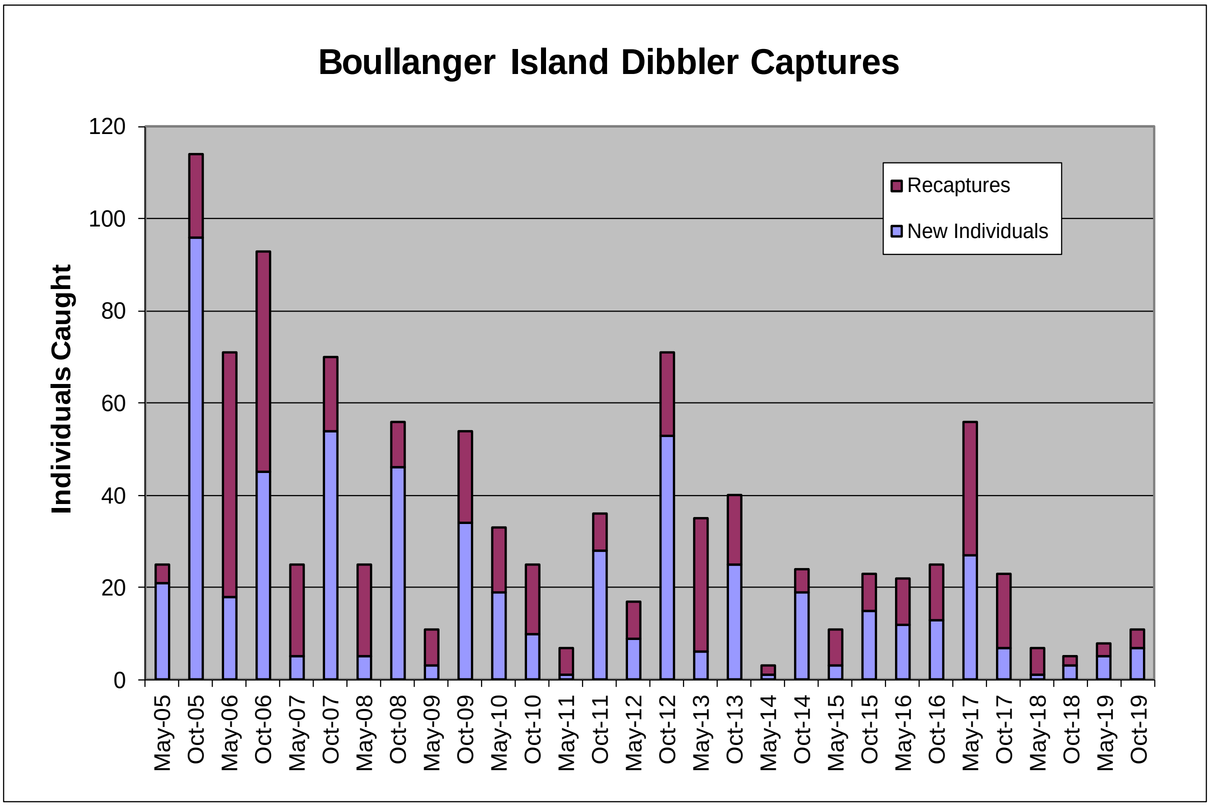


Figure 9a: Numbers of dibblers captured on Boullanger Island in monitoring sessions since 2005 (Friend and Button, 2019b)

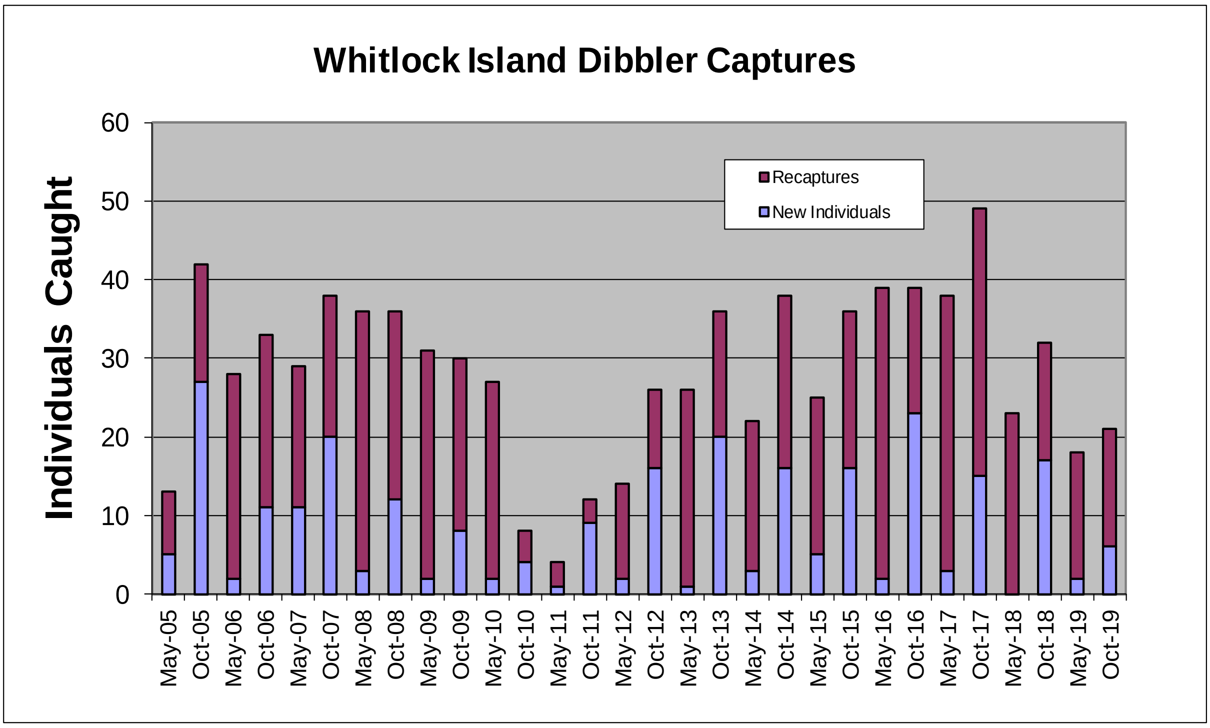


Figure 9b: Numbers of dibblers captured on Whitlock Island in monitoring sessions since 2005 (Friend and Button, 2019b).

3.8 North West Island, Montebello Island group.

3.8.1 Trap grid monitoring

In 2019 trapping occurred at the regular monitoring grid used in 2016 and 2017, concurrent with a second identical grid (to increase capture numbers for analysis if needed). Traps were open for four nights from 20-24 October 2019. Table 10 provides capture results for 2016, 2017 and 2019.

Table 10. Trapping results for North West Island monitoring grid.

Year	No. captures	No. Individuals	No. New individuals	% Female reproductive	Trap rates	Density (/ha)
2016	63	49(25:24)	N/A	8% (2/24)	75%	12.65
2017	27	21(11:10)	12(6:6)	0	32%	8.00*
2019	67	52(29:23)	51(29:22)	N/A	79.8%	19.50
2019 (x2)	124	102(56:46)	101(56:45)	22%(5/23)	73.8%	18.06

* Denotes poorer model fit (** worse)

Total trap nights = 84 for first 3 rows and 168 for last row (includes two grids of 21 traps instead of one).

Trap rates and numbers of individuals captured in 2019 were similar to those in 2016 and about 2.5 times those of 2017. SECR analysis revealed a density estimate that was 50% higher than in 2016.

3.8.2 Shark Bay mouse population estimates.

Density and abundance estimates for Shark Bay mice on North West and Bernier Island are compared in Tables 11 and 12 respectively. The density of mice on North West Island in 2019 is more than twelve times greater than the density of the population at Red Cliff Bay on Bernier Island. However, the mean population estimate is 5335 for Bernier Island compared to the 2131 estimated for North West Island.

Table 11. Density and population abundance estimates (SECR) for Shark Bay mice on North West Island in 2016, 2017 and 2019.

Northwest Is (118ha)	N	Density/ha	SE	LCL density	UCL density	Area (ha)	Mean popn	LCL popn	UCL popn
2016	51	17.83741	7.56462	8.03834	39.58194	**118**	2104	**948**	4670
*2017	21	8.00369	3.51801	3.51190	18.24059	**118**	944	**414**	2152
2019 (NW1)	51	19.50122	5.29066	11.56697	32.87790	**118**	2301	**1364**	3879
2019 (NW1+2)	100	18.05990	4.60986	11.03728	29.55076	**118**	2131	**1302**	3486

Table 12. Density and population abundance estimates (SECR) for Shark Bay mice on Bernier Island in 2016, 2018 and 2019.

Bernier Is (4267ha)	N	Density/ha	SE	LCL density	UCL density	Area (ha)	Mean popn	LCL popn	UCL popn
**2016	7	1.54557	2.28113	0.18783	12.71802	**~3750**	5795	704	4769
*2018	8	0.33360	0.22953	0.09847	1.13016	**~3750**	1251	**369**	4238
*2019	11	1.42257	0.84185	0.48602	4.16385	**~3750**	5335	**1823**	15614

(* Denotes poorer model fit (** worse))

4 Rainfall and environmental conditions

Fluctuating rainfall in Shark Bay has been shown to be correlated with population abundance of the mammal species on Bernier and Dorre Islands (Short *et al.* 1997; Chapman *et al*. 2015; Speldewinde and Morris, unpublished.), although the exact relationship and time lag is uncertain and likely to vary depending on the species. Rainfall can be locally highly variable (within a kilometre or two), and although rainfall records for Carnarvon Airport and Shark Bay Airport/Denham have the longest continuous data sets and likely represent the general cycles of low and high rainfall years across the whole Shark Bay area, they may not be accurate representations of the actual falls on Bernier and Dorre Islands in any given year. Consequently, a rain gauge was put in place on the north end of Dorre Island in 2007. However, this gauge had numerous problems with disruptions to data collection and downloads, resulting in interrupted and unreliable rainfall data, until it was replaced with a satellite linked automatic weather station in 2015. A further automatic weather station was placed on the northern end of Bernier Island in January 2019. A weather station has been in place on DHI since 2014 but was in need of repairs and provided unreliable data collection in 2018 and 2019. An upgrade of this station occurred in November 2019.

Although work by van Dongen *et al.* (2019) showed that there is a strong to moderate correlation in rainfall between Carnarvon and Dorre Island weather station and these data are probably sufficient for evaluating long-term trends, there is evidence of latitudinal variation in rainfall in individual years between the Carnarvon and Shark Bay/Denham BOM stations. The addition of a weather station at Bernier Island to the current network should now provide a good distribution of rainfall data from around the whole of Shark Bay.

Rainfall at the Montebello Islands is assessed using Barrow Island Airport and Varanus Island weather data as proxies.

4.1 Shark Bay

Rainfall over the last 22 years in Shark Bay has been recorded at several Bureau of Meteorology (BOM) weather stations. It is clear that the recorded annual falls are not the same across the Shark Bay area, but the annual pattern of rainfall across the stations is clearly correlated (Figure 10). The pattern observed indicates a trend of significantly below average rainfall every three to five years, which may have a flow-on effect on the population size of island mammals (Chapman *et al*. 2015, Short *et al.* 1997). Although the last three years has seen one of these periods of below average rainfall based on the mainland BOM stations, rainfall recorded at the Dorre Island station was significantly higher in 2017 and 2018. However, in 2019 all five stations collecting rainfall data in Shark Bay recorded falls significantly below the long term average of approximately 220-230mm.

The 2019 annual rainfall figure for Dorre Island was just 93mm, similar to the 73mm recorded at Shark Bay Airport (Annual average = 209), and 99mm at Denham (Annual average = 224), and whilst Bernier Island and Carnarvon in the northern section of Shark Bay recorded slightly higher falls for the year of 128mm and 131mm respectively, these are still little more than half the annual average for Carnarvon of 223mm.

The 2018/19 summer (Oct – Mar) rainfall at Dorre Island was even lower than in 2017/18 at just 7.4mm (c.f. 14.2mm for 2017/18 and 82mm for 2016/17), there were again, moderately good falls (~30mm) in late Aug/September 2018 following good autumn/winter rains, which together, may have provided improved condition of both vegetation and animals entering the dry summer period, improving their survival. However, although the dry 2018/19 summer was followed by moderate rainfall on Dorre Island in autumn and winter 2019 (86.8mm), it fell well below the 212mm recorded for the same period in 2018, and although seemingly enough to support survival and breeding of most species through winter and spring 2019, it has been followed by just a further 2.2mm from then to the end of the year.

Vegetation cover on both islands in 2018 was ranked as among the lowest level since 1988 (van Dongen *et al.* 2019), and unless significant summer (cyclonic) rainfall occurs in Shark Bay over 2019/20 it may be expected that ongoing dry conditions will begin to negatively impact the fauna populations on the islands.

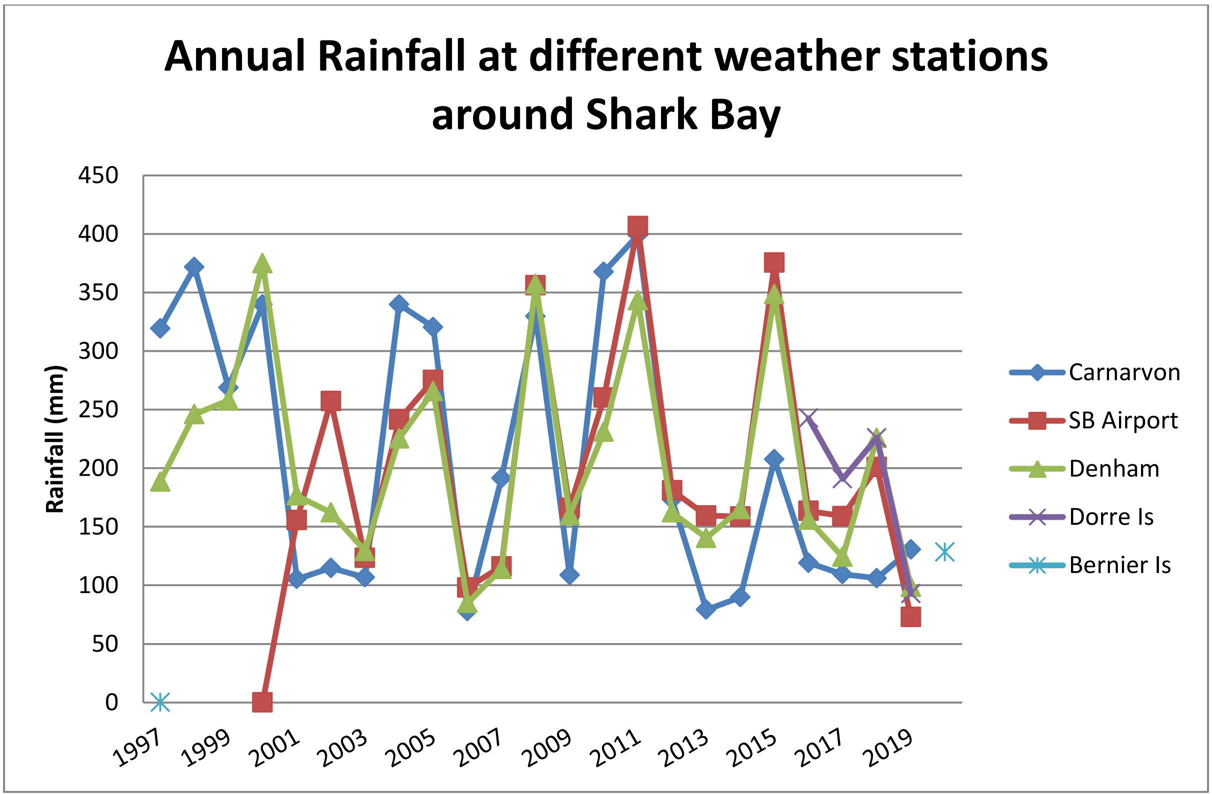


Figure 10. Annual rainfall at Carnarvon airport, Shark Bay airport, Denham, Dorre and Bernier Islands 1997-2019.

4.2 Jurien Bay

Annual rainfall for Jurien Bay for 2017 (464mm), 2018 (469mm) and 2019 (365.7mm) were all less than the recorded average of 549mm, (2019 figures were only two thirds of that average).

4.3 Montebello Islands (Barrow and Varanus)

The annual rainfall as recorded at the BOM Barrow Island Airport weather station, since its establishment in 1999, can be used as a surrogate for rainfall on the Montebello Islands group and also demonstrates a similar cycle of well below average rainfall every three years or so. Varanus Island is closer to the Montebello Group and mirrors the general rainfall pattern of Barrow Island. However, its data has poorer quality control. (Figure 11).

This data has shown that when annual rainfall has fallen to 100mm or less it has generally been followed the next year by significantly above average rainfall. The driest period on record to date has been the first four years (2001-2004) of the century with consecutive below average falls, with the first three years being little more than 100mm and less than half the average of 271mm. However the annual rainfall figures for 2018 and 2019 of 87mm and 84mm respectively is the first time in the 21 years since records where two years in a row have experienced below 100mm.

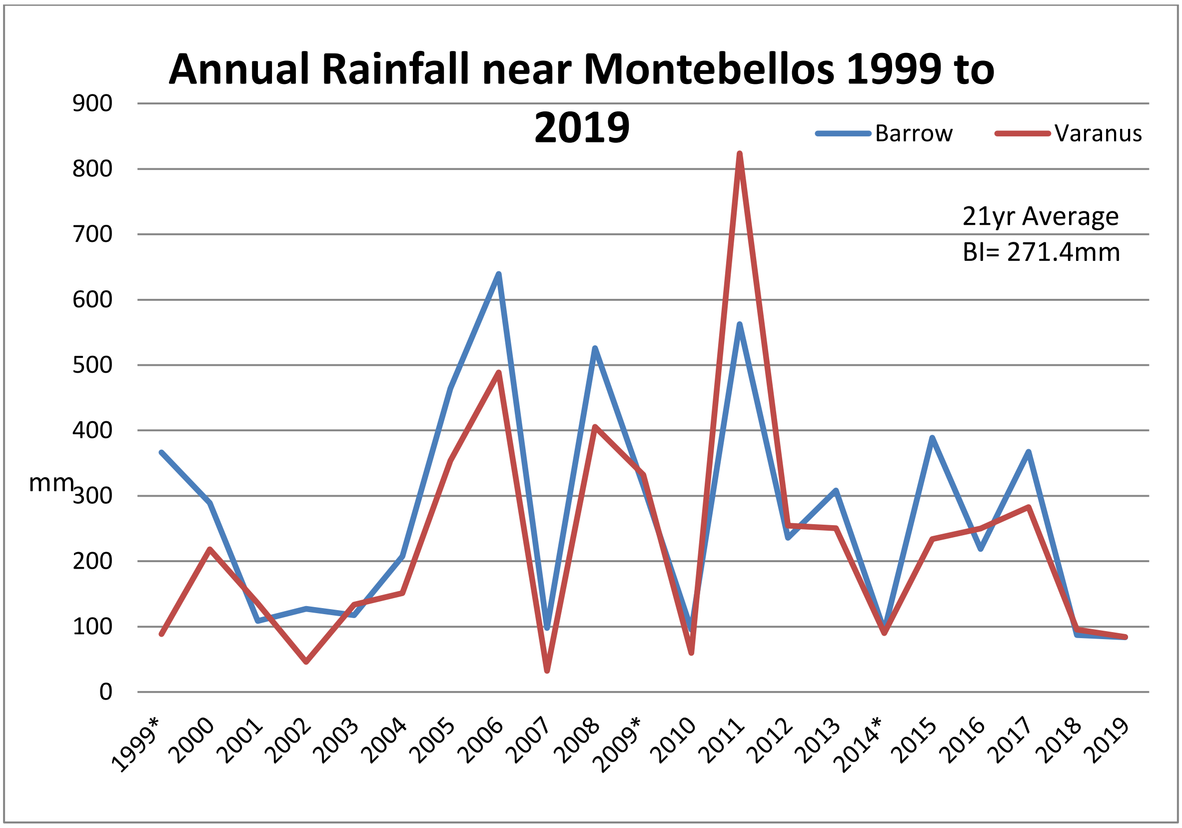


Figure 11. Annual rainfall at Barrow Island airport and Varanus Island (~25-30km south of Montebello Islands), 1999-2019.

5 Discussion

Despite the logistical challenges associated with accessing these remote islands and monitoring their threatened mammal populations, significant gains in knowledge of the status of these source populations have been achieved. This information is providing valuable inputs to decision-making frameworks for managing the timing, size and frequency of fauna harvesting activities for these last surviving populations, both for the DHINPERP translocation program and those being proposed by other groups across Australia.

5.1 Bernier and Dorre Islands

5.1.1 Logistical considerations

As with previous monitoring programs on Bernier and Dorre Islands, the 2019 program was affected by adverse weather requiring a flexible response to complete the program.

Milder weather and sea conditions during the Bernier Island schedule allowed all schedule tasks to be completed. The prevailing conditions made it difficult landing on and getting off beaches, particularly with the night landings and pickups. Safety of the personnel and vessel, and welfare of the animals, is of paramount importance in these situations and guides all decisions.

Weather conditions were challenging during work deploying and collecting cameras and during the spring translocation. However, allocation of extra days and more flexibility in the schedule (with the cooperation of the vessel and helicopter charter operators and the multiple staff and volunteers of the ground teams) allowed the program to make the most of small weather windows, and work around the worst of the weather. Eleven days of harvesting was spread over 19 days in two separate trips. This level of flexibility and cooperation is crucial in the successful completion of these works.

Although bad weather limited the number of days available for deployment and collection of camera stations in these field trips, the favourable sea and weather conditions on the days that were available, allowed access to virtually all island landings making completion of the work possible in the relatively short timeframes; this likely represents the best-case scenario for future trip planning.

Shark Bay mouse trapping on North West Island occurred in conjunction with the triennial monitoring of other translocated populations from Barrow Island as part of the Gorgon Gas Development Offset program. Due to early mechanical delays, three of the four nights trapping had to overlap with boodie trapping on Alpha Island. This did put more strain on boat crews and trapping teams, and could only be completed in this manner due to skilled volunteers (other DBCA staff) who were able to take on greater roles and allow splitting into more teams. However, this was also facilitated by reducing some parts of processing and data collection for Shark Bay mice to allow traps to be cleared in an acceptable time frame.

5.1.2 Methodological considerations

The trapping grid design deployed on Bernier and Dorre Island in 2016 was aimed at being both directly comparable to monitoring methodology used at Barrow Island for bandicoots, and to provide data suitable for producing density estimates, using SECR (Spatially Explicit Capture Recapture) analysis. The success of this strategy depends on both capture and recapture rates of individuals in each session. The 2018 increase in the main grid size on Bernier and Dorre Islands (from 49 to 64 trap sites) has improved confidence in the results from SECR analysis, even as some trap rates (e.g. SBB, SBM and boodies on Bernier Island) reduced in 2019. Analysis would have been even more difficult if fewer traps were available. Although the interference problems on the second, Shark Bay mouse grid on Bernier Island in 2017 was successfully ameliorated by adopting the ‘pipe excluders’ in 2018, the capture rates for Shark Bay mice on this grid was much lower in 2019 than 2018, and most mice were trapped on the main grid. It is unclear if the use of ‘boodie excluders’ also dissuades some mice from entering the traps.

Similarly, the spotlight survey design for Distance analyses is robust, but low sample size will reduce confidence in the abundance estimates. As discussed above in relation to trap surveys, increasing the number of transects on these islands is not logistically or financially feasible. The pooling of data from more than one year and then analysing each year separately, which was adopted to rerun analyses in 2018 was not repeated in 2019. Although the assumption that the detection function resulting from Distance analyses will be similar between sessions over a small span of 2-3 consecutive years based on continuity of observers (team leaders/primary observers were the same) and limited change in vegetation structure/density over this short time frame is supported by Van Dongen *et al.* (2019), it has the disadvantage that it is not possible to also separate the individual island populations in this analysis. Given this technique did not greatly change the population estimates that were generated in 2018, it was decided to analyse 2019 data in isolation.

As illustrated in the results section, the abundance estimates for the two monitoring techniques (boodies and Shark Bay bandicoots are the only species that are regularly sampled by both approaches) do not match, with the trap generated numbers being two to five times that generated from the spotlighting. However, they do generally display correlation in their trends from year to year (particularly on Dorre Island). It is likely that spotlight transect monitoring may underestimate population size for the Shark Bay bandicoot in particular, due to its small size and cryptic habits, which reduce its detectability with this method. A disadvantage of trap monitoring is that it can potentially draw animals in from a wider area than normal home range, and thus over estimate density. However, this aside, SECR analysis of trap data can provide a good estimate of local density when capture rates are sufficiently high, although confidence decreases as capture numbers reduce. Simply multiplying density by island area is unlikely to account for lower densities in poorer habitat areas, and improved information on habitat variability across the islands will improve the island-wide abundance estimates from this technique. These caveats aside, the demographic and individual health and reproductive condition data derived from trapping contribute valuable information to the assessment of population health and condition of these species (and by inference, the two hare-wallaby species).

The primary aim of monitoring these populations, for this project is to ensure planned harvesting does not threaten ongoing viability of the source populations. Using the Lowest Confidence Limit (LCL) abundance estimates from the technique providing the lower estimates, whilst taking into account the demographic and health information from the trapping, is a responsibly conservative, precautionary approach which is unlikely to risk overharvesting these populations. Harvesting limits for 2019 were set, based on non-pooled data from the spotlight surveys.

The 2019 trial of the camera trap array on Bernier and Dorre Islands was successful in demonstrating the logistical feasibility of deployment. It also showed that deployment and collection can be carried out in less days (and therefore less cost) than the current spotlight and trap monitoring program. However, we won’t know until analysis is complete whether sufficient observations were obtained to provide useful occupancy or relative abundance data for any or all of the species of interest. However, it needs to be remembered that even if good occupancy data are obtained from this survey method, it cannot provide population estimates or demographic, health or condition information on its own. Running this trial soon after the standard monitoring will hopefully have provided some correlative information to help interpret the camera trap data. Ideally these would be run concurrently for at least two years to better identify any correlations, but limited resources do not make this feasible at present. As harvesting and source monitoring of most of the Shark Bay Island species reduces over the next couple of years, the DHINPERP monitoring will wind down and it is hoped that the camera trap monitoring may provide a technique for the Regional nature conservation team to be able to continue some level of long term monitoring of these populations, albeit at reduced intensity.

During the camera trap monitoring period, six tripods were toppled over sometime during deployment, presumably due to strong winds or birds of prey. Nearly 98% (92 of 94) of the cameras found standing retained sufficient battery life throughout the nearly 6½ month period. While it is not yet known when the tripods fell over, it is hoped they collected some useful data before this occurred. Attaching longer tent pegs to the tripods in blowouts or soft-sand locations and using more rocks to brace the tripod legs on coastal platforms may prevent them from tipping over in the future.

While 21 cameras each captured over 1,000 pictures (ranging from 1,000-5,000), careful setting by the teams resulted in only 2 of these cameras collecting in excess of 9,000 pictures each; the vast majority of these pictures likely resulted from false trigger events.

5.1.3 Estimates of abundance and translocation

The population estimates in 2019 were the highest since 2011 for all four species on Dorre Island, but on Bernier Island they were some of the lowest records since 2011, except for Shark Bay bandicoots, where greater than usual spotlight observations resulted in a population estimate higher than any other survey period. For both rufous hare-wallabies and Shark Bay bandicoots, the harvest limits were set lower on Bernier than Dorre Island to reflect this, and the total numbers harvested ensured it remained at no greater than 5% of LCL population estimates (SBB from Bernier Island), but generally between 2.4 and 3.5% for the other populations.

Despite low summer rainfall, good rainfall in late winter and early spring of 2018 before summer were likely to have supported improved subsequent survival through the summer, and moderate rains in late autumn 2019 provided a boost to breeding activity in 2019 (although probably not to the same extent as observed in 2018). These factors combined to ensure there was a sufficient number in the populations for translocations of rufous hare wallabies for DHINPERP, and Shark Bay bandicoots for both DHINPERP (DBCA) and Mt Gibson NR (AWC), to go ahead in spring. A beneficial boost to the translocated populations was gained from the number of pouch young being carried by the female hare wallaby founders.

Decision making on harvesting approvals was based on outputs from the single year detection function analyses for each species on each island in autumn 2019. Approval was not sought to translocate any banded hare-wallabies in 2019, although the populations would have supported further harvesting, as a founder size of 102 (90 in 2018 and 12 in 2017) was considered sufficient for this species and resources should be concentrated on rufous hare-wallabies and Shark Bay bandicoots. Approval was given to harvest all of the 50 rufous hare wallabies sought to reach the maximum founders (112) proposed in the Translocation Proposal. The split of 30 from Dorre Island and 20 from Bernier Island reflected both the differing population estimates for the two islands and the preferred numbers to get a similar founder proportion from each island. Numbers were such that suitable animals with an even distribution of sexes were easily selected and translocated to DHI.

The population estimates from 2019 also provide a post-harvest assessment of the impact on populations that were harvested in 2018 (3.0% of 2018 banded hare-wallaby population and 3.5% of the 2018 rufous hare-wallaby population). The 2019 estimates are equivalent to ~ 102% and 140% of the 2018 pre-harvest estimates for banded and rufous hare-wallabies respectively, and indicate no measurable impact on the populations by the 2018 harvest events.

Approvals for harvesting of Shark Bay bandicoots also reflected both the different population estimates for Bernier and Dorre Islands and the competing demands for bandicoots from Bernier Island to complete the AWC translocation to Mt Gibson which began in 2017. The approved harvest numbers of 50 from Dorre Island and 20 from Bernier Island for DHI, in addition to 23 from Bernier for Mt Gibson, were also reached, although catching suitable individuals was a little more difficulty than for the hare-wallabies due to smaller population sizes and disease issues associated with this species. In 2019, factors such as potential disease, age (too young), reproductive condition (large PY or lactating) or wrong sex resulted in 46% of bandicoots that were captured being rejected as unsuitable for translocation meaning nearly twice as many animals needed to be captured to select the required number of founders.

Approvals will be sought in 2020 for the translocation of a further 30 Shark Bay bandicoots from Bernier Island to Dirk Hartog Island pending suitable population estimates from the autumn 2020 monitoring. Although the Mt Gibson translocation is complete, there will be additional demands from AWC for Shark Bay bandicoots for other reconstruction projects in NSW and SA in 2020 and beyond.

5.1.4 Disease

The BPCV1 virus was shown to be still active in the Bernier Island population (at both Red Cliff Bay and Hospital Bay) in autumn and spring 2019, and there is therefore still a disease risk associated with taking animals from anywhere on Bernier Island. Selection and quarantine protocols must be vigilant and adhered to, to minimise this risk as much as possible. Harvesting activity in spring by both AWC and DHINPERP resulted in about 20% of adult animals captured and examined on Bernier Island, being rejected for translocation due to concerns about possible papillomatosis, although only one out of seven swabbed animals proved positive for the virus.

Eye disease/injury has been noted during past monitoring activities in the past as being fairly common in these populations and may be attributable to physical injury or possible infection (e.g. chlamydia). Approximately 7% of all captured animals (on both Bernier and Dorre Islands) in spring 2019 had either cataracts or old injuries (including loss of an eye). This would seem to be an apparently natural prevalence in the wild populations of the Shark Bay islands, and may be related to the behaviour of these animals bolting into the low shrub and spinifex habitat.

5.2 Jurien Bay Islands

The closer proximity of the Jurien Bay islands to the mainland coast and regional centres, makes fauna monitoring less expensive and difficult than at other island sites. However, access to these islands is always dependent on favourable weather and sea conditions and still requires access to suitable vessels and seafaring skills to successfully complete scheduled programs.

The trap rates for dibbler on Boullanger and Whitlock Island continued to be relatively low in both the autumn and spring monitoring sessions of 2019. Monitoring on Boullanger Island in May 2019 picked up five young of 2018 that had been missed in October 2018 indicating a slightly better situation than was apparent at that time. The October 2019 capture rates had improved slightly on the same period in 2018, but were still the second lowest on record (behind 2018) since 2005. However, this increase was enough to allow three animals (27% of the October 19 KTBA population) to be harvested for the captive breeding program. October 2019 monitoring on Whitlock Island revealed capture rates lower than for 2018 and the third lowest recorded since 2005. However, as nine animals (28% of the October 2018 KTBA population) had been harvested for the captive breeding program in the previous 12 months, this is not unexpected and is not currently cause for concern.

5.3 North West Island

For the three years that data are available, the density of Shark Bay mice on North West Island has been consistently higher than on Bernier Island. This result may be partly due to difficulty of catching mice on Bernier Island due to interference from the other mammals on the island, or maybe a true lower density due to poorer habitat quality and/or competition for resources from the other mammal species present. Morphometric data from the two populations indicate that the mice on North West Island are larger in size on average, than those on Bernier Island, tending to support the idea that these animals have more resources available to them which is likely to be due in part to a lack of mammal competitors.

The density of mice on North West Island in 2019 has been calculated at more than twelve times greater than the density of the population at Red Cliff Bay on Bernier Island. Although the fact that Bernier Island is 36 times larger North West Island meaning it holds a population that is estimated at somewhere between 1.5 and 4.5 times larger than the smaller island, it does not follow that it will be easier to capture the number required for translocation to DHI from this island.

Even in 2017 when mouse density was less than half that of 2019, sufficient mice were easily trapped on North West Island to translocate over forty founders to Mt Gibson in 200 trap nights. Whereas trapping on Bernier Island has never captured more than 11 animals in 340 Elliott trap nights. Based on this, it is likely to be logistically easier and quicker to use North West Island as the primary source for most founder animals for DHI. However, the ease of capture needs to be balanced against the genetic quality of this reintroduced population. Genetic analysis of the two populations is currently underway and results should be available in early 2020 that will determine what numbers of source animals from each population will provide the best genetic diversity for the new DHI population.

Although numbers of Shark Bay mice (and other species) captured on the Montebello Islands in October 2019 were high, the poor rainfall of the last two years, and dry conditions on the island suggest a drought induced population crash may be expected in the near future unless significant monsoonal falls occur in the 2019/20 summer.

5.4 Rainfall, vegetation condition and climate trends on Bernier and Dorre Islands.

Satellite imagery used to examine changes in vegetation condition (Van Dongen *et al.* 2019) on Bernier and Dorre Islands indicates a gradual degeneration of vegetation cover over the last 20 years that correlates with declining rainfall. This is likely to be an ongoing trend with current projections of climate change on the southern rangelands NRM region encompassing the Shark Bay World Heritage Area that include;

- Average temperatures will continue to increase in all seasons (*very high confidence*).
- Winter rainfall is projected to decline over the century under both intermediate (RCP4.5) and high (RCP8.5) emission scenarios (*high confidence*);
- More hot days and warm spells are projected with *very high confidence*.
- Time spent in drought is projected, with *medium confidence*, to increase over the course of the century.
- Potential evapotranspiration is projected to increase in all seasons as warming progresses (*high confidence*).

(CSIRO, 2015).

The installation of a new weather station on Bernier Is and upgrading the DHI station to the same quality, should greatly improve the recording and understanding of rainfall patterns throughout Shark Bay in the future. This will facilitate our ability to predict future population trends for management planning.

In attempting to predict possible fauna population numbers and condition that may be observed in the immediate future (April 2020 monitoring), it is useful to compare the rainfall deficits for the immediately preceding 12 months for Denham weather station (6044) (as currently available with just over 1 month to go), to those recorded prior to three other recorded ‘drought’ events that coincided with observations of negative faunal population impacts. Two of these events were identified by Short *et al*. (1997), who correlated them with a ’12 month cumulative rainfall deficit’ at Denham, of 115mm in the 12 months to Oct 1988 (first survey), and of 153mm prior to June 1906 (when Shortridge observed deaths of both species of hare wallaby “during a very dry season” and animals that “were thin and apparently in a very unhealthy condition while numbers were lying about dead” (reported in Short *et al*. 1997). Short *et al*. also indicated that the poor 1986-89 conditions were the 3rd worst drought period since records began (1885) and estimated the reduction in populations of the four medium sized mammals at up to 75% below what was recorded 2 years later in ‘average’ environmental conditions.

In addition, a third environmental stress event was recorded between the first two years of fauna surveys begun by the then Dept. of Environment and Conservation (predecessor to DBCA) in 2006. Population reductions of up to 95% between the August 2006 and April 2007 surveys were preceded by a 12 month rainfall deficit at Denham of 171mm (the worst on record). Similar observations of animals in very poor condition and many dead animals lying on the ground were recorded by researchers in April 2007.

By comparison, the current rainfall deficit for Denham is ~ 119mm (similar to the 115mm deficit preceding the 1988/89 survey results), and although not as severe as the 2006/07 conditions, may be expected to potentially precipitate up to 40-75% reduction in some populations if further rainfall is not been received over the 2019/20 summer.

5.5 Monitoring of source populations for future translocations.

Among the species being considered next for translocation to Dirk Hartog Island, are the greater stick nest rat (GSNR) and Shark Bay mouse in 2020/21. The DHINPERP team have been monitoring the latter as part of the 2017-19 works programs, but to date, the GSNR population on Salutation Island in Shark Bay, has been trapped biennially by the Shark Bay district as part of a long term monitoring program. In 2020, the DHINPERP team will have greater involvement in this program and assist in increasing the frequency and intensity of monitoring to ensure sufficient data are available for population estimates and harvest planning.

Planning is already underway to identify potential source populations and develop monitoring for heath mice populations in the South West of WA prior to potential captive breeding of this species and proposed translocations in ~ 2023/24/25. This species has never been bred in captivity before and it will be necessary to begin captive breeding trials to determine housing, nutrition and behavioural requirements in the near future to prepare for this planned translocation date. Some early survey work was carried out in 2019 by South Coast Regional Nature Conservation staff which rediscovered single individuals at two sites (unfortunately one of these locations was burnt in subsequent fires) and further surveys are planned for 2020. This work is not part of the current DHINPERP funded program, but will provide an opportunity for some DHI staff to be involved and gain valuable experience with this species in 2020.

References.

Buckland, S.T.; Anderson, D.R.; Burnham, K.P.; Laake, J.L. (1993) Distance sampling: Estimating abundance of biological populations. Chapman and Hall, London, UK

Chapman T, Sims C, Mawson P (2011) 'Minimising Disease Risk in Wildlife Management' Unpublished, Department of Environment and Conservation, Western Australia.

Chapman TF, Sims C, Thomas ND, Reinhold L (2015) 'Assessment of Mammal Populations on Bernier and Dorre Islands, 2006-2013' Unpublished report, Department of Parks and Wildlife, Western Australia.

CSIRO (2015) 'Climate Change in Australia: Projections for Australia's NRM Regions' Whetton, P (Ed.), Technical Report, CSIRO 2015.

Friend T and Button T (2018) 'Dibbler Recovery Team meeting 43 Animal Science Report', Dept. of Biodiversity, Conservation and Attractions unpublished report.

Friend T and Button T (2019) 'Dibbler Recovery Team meeting 44 Animal Science Report', Dept. of Biodiversity, Conservation and Attractions unpublished report.

Friend T and Button T (2019b) 'Dibbler Recovery Team meeting 45 Animal Science Report', Dept. of Biodiversity, Conservation and Attractions unpublished report.

Orell P (1997) 'Western Shield Operational Fauna Monitoring Protocols', unpublished, Dept. of Conservation and Land Management, Western Australia.

Page M (2017) 'Interim Decision Framework for Harvesting Threatened Fauna from Bernier and Dorre Islands' Unpublished report, Department of Biodiversity Conservation and Attractions, Western Australia.

R Core Team (2013) 'R: A language and environment for statistical computing'. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/

Short J and Turner B (1992) 'The distribution and abundance of the banded and rufous hare-wallabies, *Lagostrophus fasciatus* and *Lagorchestes hirsutus'*. *Biological Conservation* **60**, 157-66.

Short J, Turner B, Majors C and Leone J (1997) 'The fluctuating abundance of endangered mammals on Bernier and Dorre Islands, Western Australia – Conservation implications' *Australian Mammalogy*, **20**, 5-61.

Speldewinde PC and Morris KD, 'Some observations on the ecology of the Shark Bay mouse, *Pseudomys fieldi*, on Bernier Island, Shark Bay.' Unpublished manuscript.

Thomas L, Buckland ST, Rexstad EA, Laake JL, Strindberg SL, Hedley J, Bishop R B, Marques TA and Burnham KP (2010) 'Distance software: design and analysis of distance sampling surveys for estimating population size'. *Journal of Applied Ecology* **47**: 5-14. DOI: 10.1111/j.1365-2664.2009.01737.x van Dongen R, Cowen S and Sims C (2019) 'Bernier and Dorre Islands vegetation cover report:2019', Dept. of Biodiversity, Conservation and Attractions unpublished report.

Woolford L (2007) 'Protocol for working with *Perameles bougainville* on Bernier and Dorre Islands.' Unpublished guidelines, Murdoch University, WA.

Woolford L. (2017) 'Protocol for detection of BPCV1 by surface skin or lesion swab' Unpublished.

Woolford L, Rector A, Van Ranst M, Ducki A, Bennett M. D, Nicholls P. K, Warren K. S, Swan R. A, Wilcox G. E and O'Hara A. J (2007) "A novel virus detected in papillomas and carcinomas of the endangered western barred bandicoot (Perameles bougainville) exhibits genomic features of both the Papillomaviridae and Polyomaviridae." J Virol **81**(24): 13280-13290.

Appendices

Appendix 1 Field schedules for monitoring and translocation trips

1.1 Dorre Island monitoring 2019.

(Personnel: Colleen Sims, Sean Garretson, John Angus, Emma Marsh, Leah Botten, Georgina Anderson)

DATE	Program	Comments
24/03/19	Drive ex Perth o/n Carnarvon	
25/03/19	Steam to Dorre, set trap grid	
26/03/19	Processing day 1	
27/03/19	Processing day 2	
28/03/19	Processing day 3	
29/03/19	Processing day 4 (close traps + clean Traps)	
30/03/19	Spotlight night 1	
31/03/19	Spotlight night 2	
01/04/19	Spotlight night 3	
02/04/19	Spotlight night 4	
03/04/19	Return to Carnarvon. Fly back to Perth	

1.2 Bernier Island monitoring 2019.

(Personnel: Colleen Sims, Sean Garretson, John Angus, Jodie Millar, Claudia Buters, Michaela Johnson, David Pongracz)

DATE	Program	Comments
8/04/19	Fly ex Perth to Carnarvon, steam to Bernier and set traps	
9/04/19	Processing day 1	
10/04/19	Processing day 2	
11/04/19	Processing day 3	
12/04/19	Processing day 4 + Spotlight night 1	Close traps
13/04/19	Spotlight night 2	
14/04/19	Spotlight night 3	
15/04/19	Spotlight night 4	
16/04/19	Steam back to Carnarvon and drive to Perth	

1.3 Bernier and Dorre Island Camera Deployment 2019.

(Personnel: Sean Garretson, John Angus, Kelly Rayner, Adele Thomasz, John Coetsee, Hannah Kilian)

DATE	Program	Comments
01/05/19	Fly ex Perth to Carnarvon, steam to Dorre and set cameras	
02/05/19	Dorre set cameras	
03/05/19	Bernier set cameras	
04/05/19	Bernier set cameras. Return to Dorre to catch SBB	Return to Carnarvon over night
05/05/19	Drive Carnarvon to Perth	Deliver SBBs to NAR

1.4 Translocation 2019.

(Personnel: Colleen Sims, Sean Garretson, John Angus, Hannah Killian, Bruce Ward, Cassy Gray, Rob Hemsworth, Jo Williams, Owen Raynor, Emma Marsh, Michael Raykos, Mark Blythman)

DATE	Program	Comments
26/08/19	Drive Perth to Carnarvon	
27/08/19	Fly Perth to Carnarvon. Steam to Dorre Is, 1st night Net	
28/08/19	Helicopter SBB to DHI, 2nd night Net	
29/08/19	Helicopter Hare Wallabies and SBB to DHI. Dorre 3rd Night Net	
30/08/19	Helicopter Hare Wallabies and SBB to DHI. Dorre 4th Night Net	
31/08/19	Helicopter Hare Wallabies and SBB to DHI. Dorre 5th Night Net	
1/09/19	Helicopter Hare Wallabies and SBB to DHI. Dorre 6th Night Net	
2/09/19	Helicopter Hare Wallabies and SBB to DHI. Bernier 1st Night Net	
3/09/19	Helicopter Hare Wallabies and SBB to DHI. Return to Carnarvon	Fly to Perth
4 - 9/09/19	Team rest and bad weather break	
9/09/19	Drive Karratha to Carnarvon	
10/09/19	Fly Perth to Carnarvon 2nd Bernier Night Net	
11/09/19	Helicopter Hare Wallabies and SBB to DHI. Bernier 3rd Night Net	

12/09/19	Helicopter Hare Wallabies and SBB to DHI. Bernier 4th Night Net	
13/09/19	Helicopter Hare Wallabies and SBB to DHI. Bernier 5th Night Net	
14/09/19	Helicopter SBBs to DHI. Steam Bernier to Carnarvon	Aborted due to weather
15/09/19	Drive Carnarvon - Perth	Aborted due to weather

1.5 North West Island monitoring 2019.

(Personnel: Colleen Sims, Sean Garretson, Mark Blythman Jessica McNamara, Nicole Godfrey, Clement Lynch)

DATE	Program	Comments
13-23/10/19	Monitoring on Hermite, Alpha, Trimouille Islands	
20/10/19	Set traps North West Island	
21/10/19	Processing day 1	
22/10/19	Processing day 2	
23/10/19	Processing day 3	
24/10/19	Processing day 4 + close traps	Return to Dampier
25/10/19	Fly Dampier to Perth	

1.6 Bernier and Dorre Island Camera Collection 2019.

(Personnel: Sean Garretson, Colleen Sims, John Angus, Dylan Isles, Sam Edwards, Kristen Nilsson)

DATE	Program	Comments
14/11/19	Fly ex Perth to Carnarvon, steam to Dorre and collect	

	cameras	
15/11/19	Dorre collect cameras	
16/11/19	Bernier collect cameras	
17/11/19	Bernier collect cameras	Return to Carnarvon
18/11/19	Fly Carnarvon to Perth	