Monitoring Source Populations of Fauna for the Dirk Hartog Island National Park Ecological Restoration Project – 2018

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Biodiversity and Conservation Science

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GOVERNMENT OF WESTERN AUSTRALIA

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Summary

Monitoring of source populations of six mammal species was undertaken by the Department of Biodiversity Conservation and Attractions in 2018 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. Monitoring of three of these species (banded hare-wallabies, Shark Bay bandicoots and Shark Bay mice) was also undertaken to inform proposed translocations to the Mt Gibson wildlife sanctuary by the Australian Wildlife Conservancy.

Spotlight and trap monitoring of all species on Bernier and Dorre Islands occurred in April 2018 and harvesting of species for translocation occurred in September and October 2018.

Banded and rufous hare-wallabies

Spotlight monitoring of banded and rufous hare-wallabies on Bernier and Dorre Islands in April 2018 provided combined estimates of abundance on both islands of 5888 (4292-8077) banded and 2482 (1739-3544) rufous hare-wallabies. Subsequent harvesting in spring 2018 removed an estimated 3.0% (129 individuals) of the combined banded hare-wallaby population (60 or 3.3% from Bernier and 69 or 3.1% from Dorre) and 3.5% (50 individuals) of the combined rufous hare-wallaby population (27 or 4.3% from Bernier and 23 or 3.6% from Dorre).

Boodies and Shark Bay bandicoots

There was lower confidence in the spotlight generated population estimates of boodie and Shark Bay bandicoot on Bernier and Dorre Islands, than for the hare wallabies, due to the smaller number of individuals observed. Sufficient numbers of animals were captured during trapping to calculate population estimates from SECR analysis but these were two to five times those derived from spotlighting.

Estimates of Shark Bay bandicoot populations varied widely between monitoring techniques. Combined abundance was conservatively estimated at between 1901 (1177-3070) based on spotlight transect data, and 4603 (2333-9701) based on analysis of the trapping data. Harvesting of Shark Bay bandicoots by AWC removed just 1.1% (11 individuals) of the combined islands population (9 or 1.7% from Dorre and just 2 or 0.5% from Bernier).

The combined island abundance for boodies was conservatively estimated at between 2850 (1770-4589) based on spotlight transect data, and 5849 (3002-11409) based on analysis of the trapping data. No boodies were removed for translocation in 2018.

Shark Bay mice

Population abundance for Shark Bay mouse on Bernier Island, based on SECR analysis of trapping data from Red Cliff Bay was estimated at 1251 (369-4238).

Dibblers

Dibblers *Parantechinus apicalis* were collected from Whitlock and Escape Islands in 2018/19 to establish a breeding colony at Perth Zoo to provide founders for release on DHI. This activity had been delayed by a year as low numbers were caught during the first attempt in January 2018. Further monitoring in May and October 2018 showed that the Boullanger population was still too small to risk removing animals. Between November 2018 and February 2019 a total of nine individuals from Whitlock Island and nine from Escape Island were transferred to Perth Zoo. The introduced Escape Island population was established using dibblers bred in captivity from mixed Boullanger and Whitlock stock. Two females died under anaesthetic not long after arriving at the Zoo, leaving the final founder group of four males and four females from Whitlock and four males and four females from Escape Island.

Environmental conditions

Abundance estimates for most species on Bernier and Dorre Islands in April 2018 were less than those for August 2017, and this coincided with lower than average rainfall recorded 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 than Carnarvon (190mm c.f. 109mm), it was still below average, with the main deficit being in the second half of the year. The low rainfall recorded for Dorre Island through the spring and summer of 2017/18 (just 14.2mm for the six months from Oct 2017 – Mar 2018) was ameliorated by high falls in early spring 2017, and autumn and winter 2018, facilitating high reproduction and recruitment prior to the harvesting in spring 2018. Reproductive rates of the hare-wallaby species on Bernier and Dorre Islands in early spring 2018 were much higher than for the same period in 2017.

Annual rainfall for Jurien Bay for 2017 (464mm) and 2018 (469mm) were less than the average of 549mm.

The next monitoring of the Bernier and Dorre Island populations will occur in April 2019 and dibblers at Jurien Bay in May 2019.

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 and feral goats, and indications that feral cats have also been eradicated, Stage 2, the reconstruction of the island's vertebrate fauna has commenced (Morris *et al*. 2016). Twelve mammal species (mostly threatened species) and one bird species will be translocated to Dirk Hartog Island (DHI) over a 12-year period, from 2018 - 2030. The Department of Biodiversity, Conservation and Attractions (DBCA) Translocation Proposals follow 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 *Lagostrophus fasciatus* and the rufous hare-wallaby *Lagorchestes hirsutus* 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, monitoring of populations of banded hare-wallaby, rufous hare-wallaby, boodie *Bettongia lesueur*, Shark Bay bandicoot *Perameles bougainville* and Shark Bay mice *Pseudomys fieldi* was undertaken on Bernier and Dorre Islands in April-May.

Dibblers *Parantechinus apicalis* were originally planned for a release on DHI in October 2018 after harvesting of 20 animals (10 pairs) 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, Jurien Bay, 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. Further monitoring was planned to be carried out in May and October 2018 to determine if populations would be sufficiently robust to harvest in late October.

This report documents the monitoring activities undertaken in April and May 2018 on Bernier and Dorre Islands in Shark Bay, and May and October 2018 on the Jurien Bay islands. It presents both qualitative assessments and quantitative analysis of data collected during this monitoring, and where possible, a comparison with 2016 and 2017 monitoring results.

2 Methods

2.1 Logistics and transport

Access to the source populations on Bernier and Dorre Islands in Shark Bay 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

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. Dorre Is grid was trapped for three nights only, whilst Bernier Is grid was open for four. 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 192 cage trap nights and 192 Elliott trap nights for Dorre and 256 cage and 256 Elliott trap nights for Bernier Island 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).

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. This grid was also opened for four trap nights. 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. All captured animals were individually identified with either a Passive Implant Transponder (PIT, Allflex™ FDX-B Microchip, ca.11 x 3mm) for larger species or ear punch number for the smaller Shark Bay mice. 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.

Because of previous incidences of the wart like disease in Shark Bay bandicoots, these individuals 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 Papilloma Carcinoma Virus one (BPCV1).

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, sex, date and location. They will be used to contribute to a number of studies on genetic variation, taxonomy and species health.

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

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 rendering and adjustable focus), powered by 6 or 9 amp hr LiFePO4 batteries, and infra-red range finder. The second person acted as a recorder, navigator and secondary observer, using a Trimble PDA 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 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.

2.4 Capture and transport of dibblers for Perth Zoo breeding program.

All dibblers collected for the captive breeding colony at Perth Zoo, were trapped using medium Elliott traps at regular trap sites in two trapping sessions (one of two nights and a second, single-night session) on Whitlock Is, and in two, single-night trapping sessions on Escape 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 Capture, handling and transport of hare wallabies for translocations to DHI

All banded and rufous hare-wallabies 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. 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. The majority of hare-wallabies received treatment with Selenium and Vitamin E to protect against stress myopathy, and atropine sulphate to reduce fluid loss through hypersalivation, and placed in medium Pet Packs, two animals per pack. These 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, rufous hare-wallabies were injected with the sedative diazepam prior to transfer in the helicopter. Animals were captured and processed between dusk and 0230 hrs.

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 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 addition, where number of observations for each species did not reach the recommended minimum for calculating detection functions in a single year, data from 2017 and 2018 (plus 2016 in the case of SBBs), were combined to calculate detection functions which were then applied separately to each year of data.

Trapping data from Bernier and Dorre Islands 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 4 - 10 April 2018, with only three nights trapping completed from 4 - 7 April and four nights of spotlighting (all transects completed) from 6 - 9 April.

3.1.1 Trapping

Only three nights trapping were completed on Dorre Island and trap results, with comparisons to 2016 and 2017, 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 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 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 2018	1	1(1:0)	1(1:0)	N/A	0.4%	N/A
RHW 2018	5	3(1:2)	3(1:2)	1+1?/2	2.6%	N/A

SBB = Shark Bay bandicoot; **BHW** = banded hare-wallaby; **RHW** = rufous hare-wallaby; (male: female ratio).

*Only 3 nights trapping in 2018, but more traps, so total trap nights similar (192 c.f.196)

A similar number of Shark Bay bandicoots were captured on Dorre Island in 2018 as 2016 and 2017. The trapping was shifted to mid-autumn in 2018 (cf. late winter in 2016 and 2017), so reproductive activity was expected to be lower. In 2018, no females had pouch young, although three showed some sign of reproductive activity. The same number of boodies were trapped in 2018 as in 2017, with slightly more individuals captured. Less females had pouch young but 50% were showing some sign of reproductive activity. In autumn 2018, most boodies were in average or slightly below average body condition.

No ash-grey mice were captured on Dorre Island in 2018.

Density estimates from spatially explicit capture recapture (SECR) analysis for boodies and Shark Bay bandicoots on Dorre Island are displayed in Table 6 a and c. and Figure 2a.

3.1.2 Spotlighting

All 27 spotlight transects on Dorre Island were completed in 2018, with several nights overlapping with trapping in order to complete the work in the narrow weather window available. Numbers of animals observed of each species per km of transect are shown in Table 2.

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

Species	No. per km transect 2016	No. per km transect 2017	No. per km transect 2018	PY/YAH/SA 2018 (Y/N)
SBB	0.211	0.470	0.258	Y
Boodie	0.984	1.261	0.750	Y
BHW	1.265	2.008	1.804	Y
RHW	0.867	1.184	0.445	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 both hare-wallaby species were sighted during the spotlight surveys, indicating that some breeding had occurred during spring/summer 2017-18.

3.2 Bernier Island, Shark Bay

Bernier Island monitoring was undertaken between the 17 - 27 April 2018, with four nights trapping on the main grid from 17 - 21 April, four nights trapping on the SBM grid from 18 - 22 April, and three nights trapping the beach from 19 - 22 April. Five nights of spotlighting occurred from 21 - 26 April with all 27 transects completed.

3.2.1 Trapping

Four nights trapping of each grid was completed on Bernier Island, although this was staggered due to the time it took to set up the Shark Bay Mouse grid with boodie excluders. In addition, an extra 15 Elliott traps were opened for three nights in the *Spinifex longifolius* habitat on the fore-dunes of the Red Cliff Bay beach area. The results of the trapping on Bernier Island in 2016, 2017 and 2018 are shown in Table 3.

The numbers of animals trapped on Bernier Island were higher in 2018 than in 2017 or 2016, but this was over more trap nights, so for some species the trap success rate was actually less than in 2017, and there was little sign of reproductive activity in females. This is not unexpected for the time of year.

The trap success rate for Shark Bay bandicoots in 2018 increased significantly to be three times that recorded in 2017, and there were also three times as many individuals in total. No females had pouch young, but three animals did show early signs of reproductive activity, and at least one animal captured was of sub-adult size, indicating there had been some breeding earlier in the year.

There were slightly more boodie captures in 2018 than in 2017, and more individuals captured as well, although the trap success rate was slightly lower. None of the five females were reproductive.

The employment of boodie exclusion techniques on the small (SBM) trap grid was successful and 5 of the 16 captures of Shark Bay mice occurred on this grid, compared to the single individual that was captured in 2017. However, a further 10 captures of 6 different individuals on the main grid represent a significant increase in detectability of this species at the Redcliff Bay site as a whole given no Shark Bay mice where captured at all on the main grid in 2017.

SECR analysis of captures of Shark Bay bandicoots, Shark Bay mice and boodies on Bernier Island has provided density estimates for these species at Redcliffe Bay (Table 6b, d and e).

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 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 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 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 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.

3.2.2 Spotlighting

All 27 spotlight transects were surveyed on Bernier Island over five nights in 2018.

As with Dorre Island, the total number of observations for all species were lower than in 2017 or 2016, and to improve confidence in results, Distance analysis was applied to both Bernier and Dorre Island 2018 data (Global), using a combination of 2017 and 2018 observations to produce a more robust detection function. A comparison of population estimates for each year, and their Upper and Lower confidence limits is provided in Table 5a and 5b, and Figures 1a-e.

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

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

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

SBB= Shark Bay bandicoot; **BHW** = banded hare-wallaby; **RHW** = rufous hare-wallaby; **PY/YAH/SA**= pouch young/young at heal/sub-adult.

Sub-adult banded hare-wallabies were observed during spotlighting, indicating that there had been some breeding by this species over the spring/summer of 2017-18.

3.3 Bernier and Dorre Island population estimates

Monitoring (both spotlight and trapping) was carried out in autumn 2018 (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 2018. 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 and 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 in that year as it is not the normal peak period. This does however mean that there is a reduced welfare risk associated with the ejection of pouch young.

3.3.1 Abundance estimates of spotlight data using Distance analysis

Although abundance estimates were slightly lower in 2018 than in 2017 (~8 months prior), they were sufficiently high for harvesting approval to be given for all four species (BHW, RHW, SBB, SBM) (albeit less than the maximum requested for RHW). Harvesting guidelines (Page, 2017) are set conservatively and utilise the Lower Confidence Level (LCL) calculation of abundance resulting from Distance analysis, and set harvest levels at <10% (preferably no more than 5%) of this figure. Table 5a compares the 2011 to 2018 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 2018 abundance estimates (with lower and upper confidence limits) for the species on Bernier and Dorre Islands are also shown in Figure 1e, and plotted against previous estimates in Figures 1a-d.

Of the species targeted by spotlighting in 2018, only banded hare-wallabies were observed in sufficient numbers on both Bernier and Dorre Islands combined, to satisfy the recommended minimum number (60) for calculating a detection function with confidence. To overcome this limitation, observations from 2017 and 2018 were combined (and 2016 in the case of SBBs) in order to obtain a minimum of 60 observations to calculate a combined island, multi-year global detection function for each species (the inherent assumption is that the shape of the detection function curve will not vary significantly between these few years). These derived detection functions were then applied separately to each year of data to obtain global (combined island) abundance estimates for each species in each year. This resulted in smaller standard errors and tighter confidence intervals for the estimates. The abundance estimates derived for Shark Bay bandicoots from spotlight data should still be viewed as a very conservative estimate. Observability of this species tends to be very low due to their small size and cryptic nature in the landscape.

Table 5a. Abundance estimates for all species, Bernier and Dorre Island, 2011-2018 (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

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

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

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

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

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

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
2017	**1370**	**311.12**	**837**	**2244**
2018	**873**	325.23	407	1876

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	**2539**	**602.46**	**1570**	**4105**
2018	**1215**	507.23	528	2796

Notes:

Estimates for each species by island

2011 to 2016 figures calculated using Program
Distance 6.2

2017and 2018 analysis using Distance in 'R' v 3.4.1

Figures in red – detection function calculated using less than recommended minimum number of observations (<60)

Table 5b. Combined abundance estimates all species, Bernier and Dorre Island, 2011-2018 (figures in red did not reach the recommended minimum sample size in a single year. Figures in blue are produced using a detection function derived from > one 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

	Bernier and Dorre: Boodie				Combining 2017/18			
	N	SE	LCL	UCL	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**	**3950**	684.10	**2802**	**5569**
2018	**2991**	963.31	1596	5608	**2850**	678.48	**1770**	**4589**

	Bernier and Dorre: RHW				Combining 2017/18			
	N	SE	LCL	UCL	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**	**3416**	684.59	**2293**	**5091**
2018	**2081**	398.86	1420	3049	**2482**	442.28	**1739**	**3544**

	Bernier and Dorre: SBB				Combining 2016/17/18			
	N	SE	LCL	UCL	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	**2297**	**524.60**	**1468**	**3594**
2017	**3909**	**781.85**	**2619**	**5834**	**2487**	**603.88**	**1544**	**4006**
2018	**2089**	798.22	960	4545	**1901**	**462.78**	**1177**	**3070**

Notes:

Observations combined from both islands to give a global estimate.

2011 – 2016 analysis using Program Distance 6.2

2017 and 2018 analysis using Distance in 'R' v 3.4.1

Figures in red - calculated using less than recommended minimum number of observations (<60)
Adjusted figures in blue and purple, calculated using a multi-year global detection function (>60).

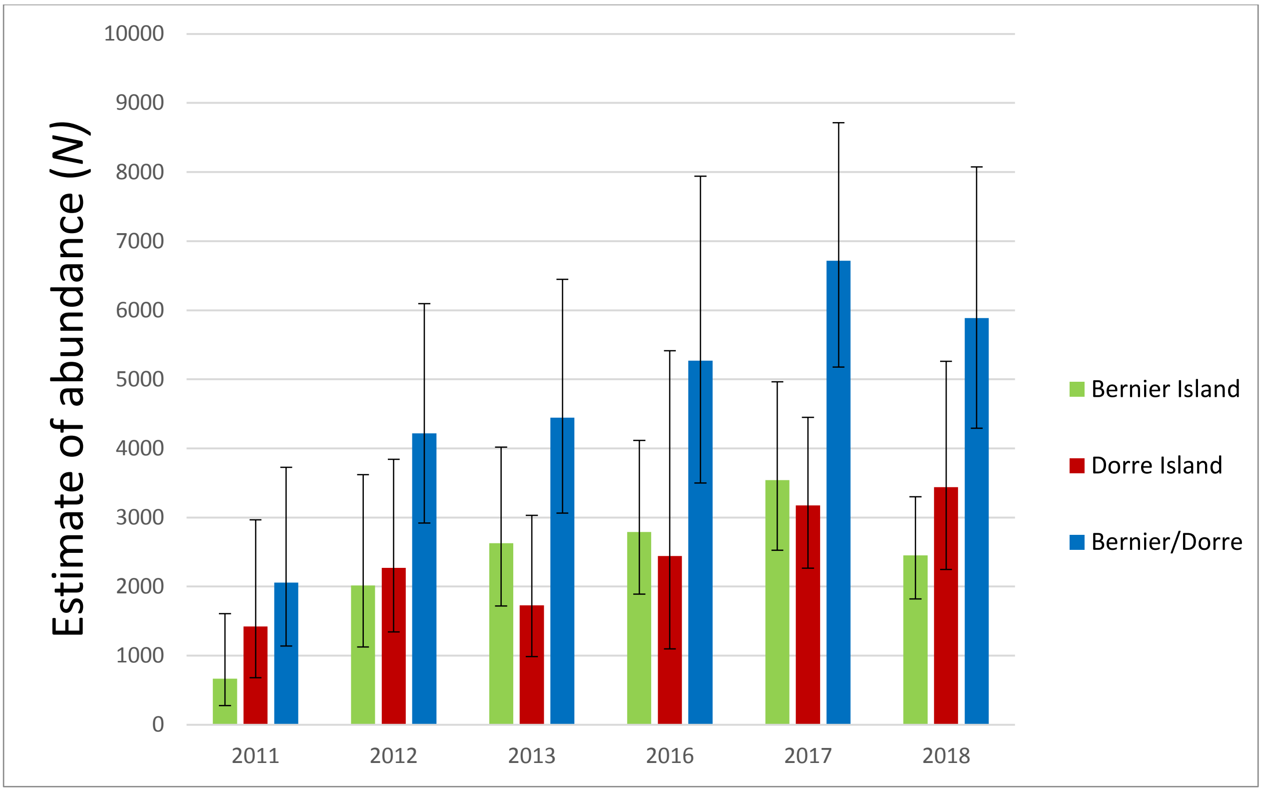

Figure 1a. Abundance estimates for banded hare-wallabies on Bernier and Dorre Islands 2011-2018 (including LCL and UCL bars).

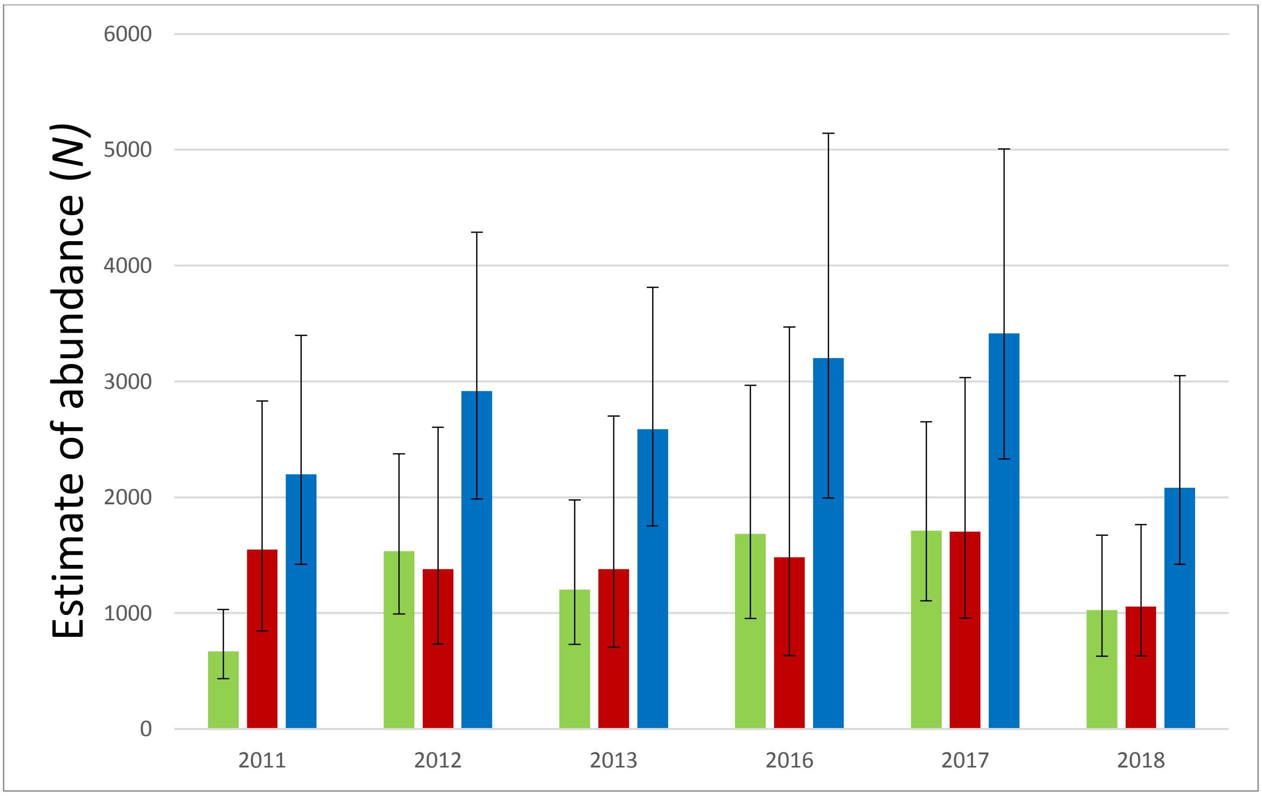

Figure 1b. Abundance estimates for rufous hare-wallabies on Bernier and Dorre Islands 2011-2018 (including LCL and UCL bars).

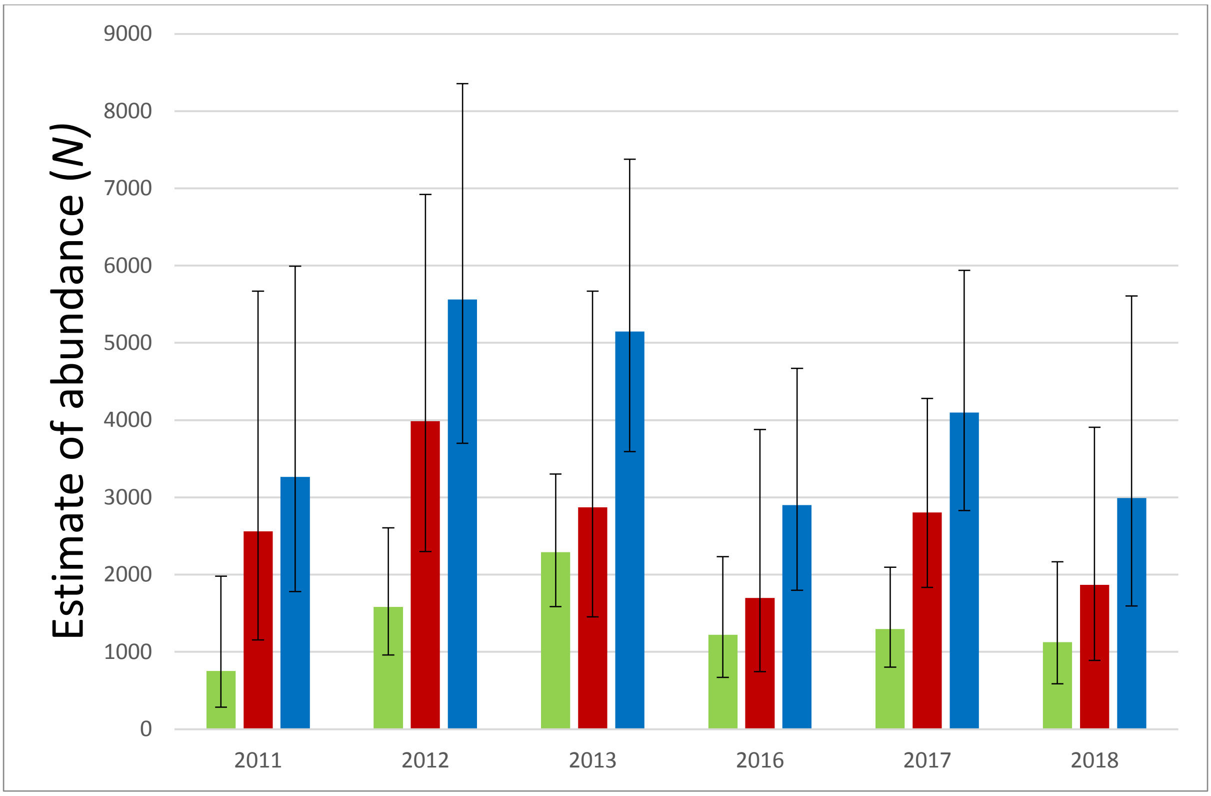

Figure 1c. Abundance estimates for boodies on Bernier and Dorre Islands 2011–2018 (including LCL and UCL bars)

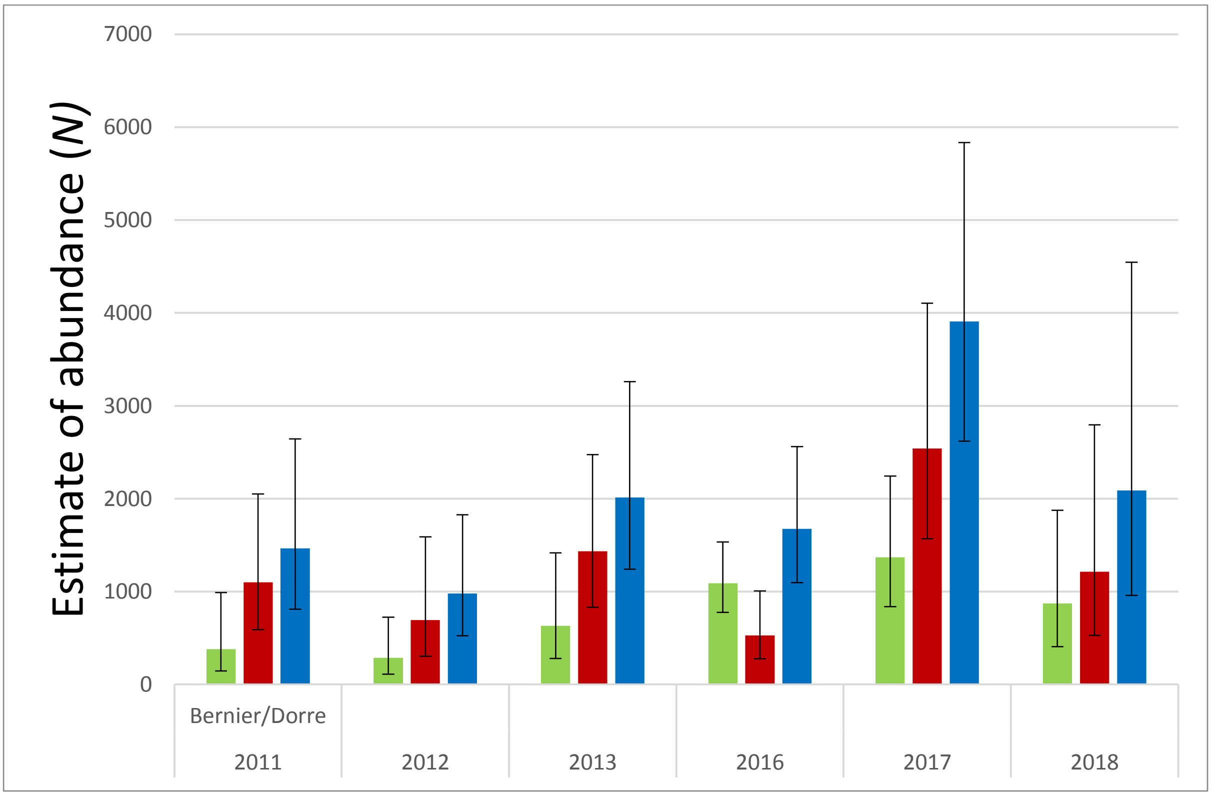

Figure 1d. Abundance estimates for SBB on Bernier and Dorre Islands 2011-2018 (including LCL and UCL bars).

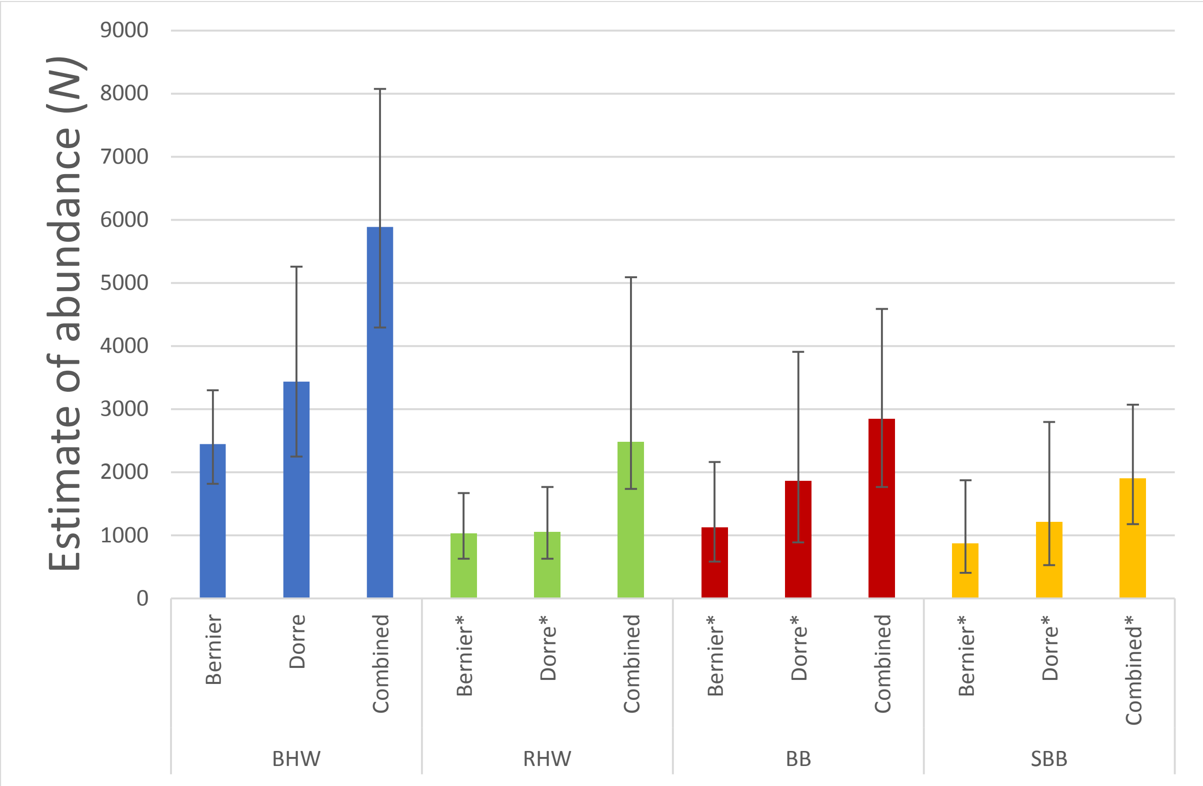

Figure 1e. Abundance estimates for banded hare-wallabies (BHW), rufous hare-wallabies (RHW), boodies (BB) and Shark Bay bandicoots (SBB) on Bernier and Dorre Islands in 2018 (including UCL and LCL bars).

3.3.2 Abundance estimates based on trapping data using SECR

Obtaining robust density estimates for trappable 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 in 2018 were sufficient to provide estimates of density for all three species on both islands. 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 the other habitat types. 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 are three to five times those calculated from spotlight data. However, trap monitoring is important to provide morphometric and demographic data for the trappable species, and providing information on the 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 likely projected trends. The results from trap data are also useful in providing a 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 three years, Bernier Island density and abundance estimates are consistently estimated as lower than those for Dorre Island (Table 6), and the general trend in relative abundance for most species tends to be mirrored from year to year regardless of technique. Bernier Island appears to display more variability (Figure 2).

Table 6. Density and abundance estimates from trapping data at Dorre and Bernier Island 2016-18

a. 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
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

b. 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
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
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

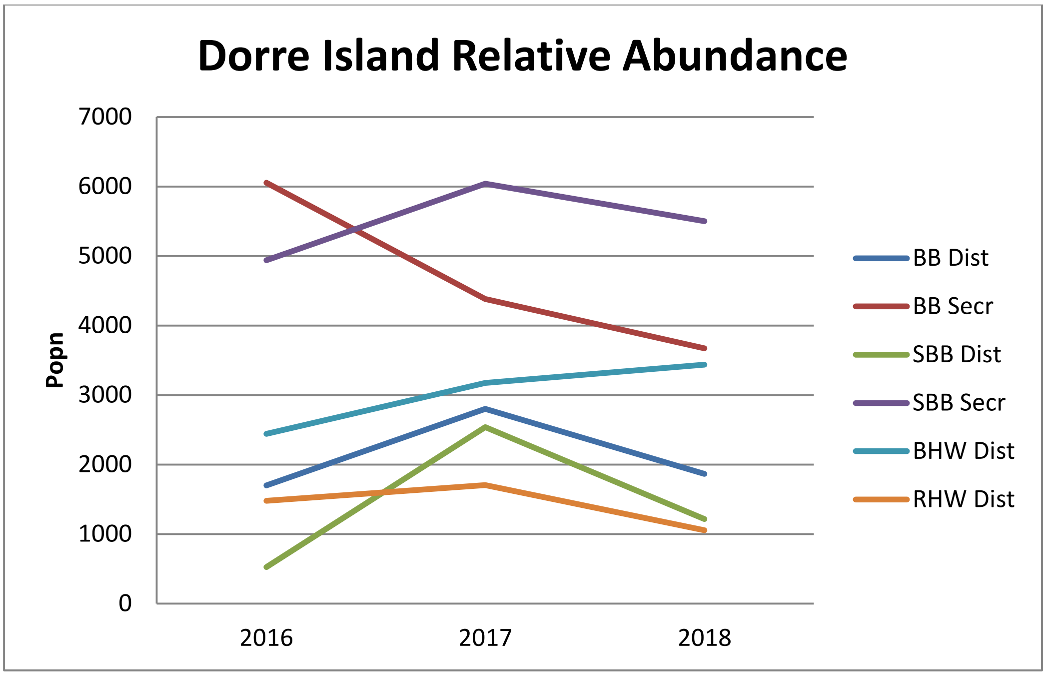

Figure 2a. Relative abundance on Dorre Island (2016-18). [banded hare-wallabies (BHW), rufous hare-wallabies (RHW), boodies (BB) and Shark Bay bandicoots (SBB)]

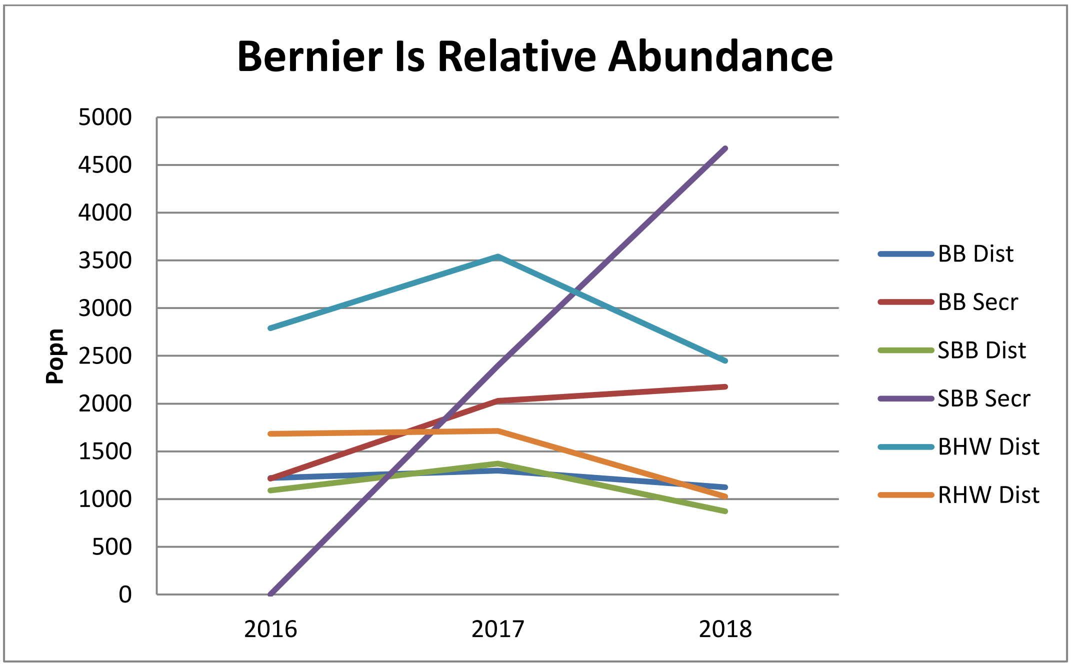

Figure 2b. Relative abundance on Bernier Island (2016-18). [banded hare-wallabies (BHW), rufous hare-wallabies (RHW), boodies (BB) and Shark Bay bandicoots (SBB)]

3.4 BPCV1 Disease screening

None of the Shark Bay bandicoots captured at White Beach on Dorre Island in 2018 had suspicious lesions warranting swabbing for further analysis. However, two male Shark Bay bandicoots (both new individuals) trapped on the monitoring grid at Redcliff Bay on Bernier Island, were recorded as having some suspicious lesions on the eyelids. These were swabbed along with the lips, feet and flanks as recommended in Woolford (2007) and sent for PCR analysis for identification of the bandicoot papillomatosis carcinomatosis virus type 1 (BPCV1) (Woolford 2007). Swab samples from both bandicoots were PCR positive for BPCV1 (Appendix 1).

In addition, one bandicoot captured as part of translocation activities by AWC at Hospital Bay, on Bernier Island in October 2018, also had lesions that were swabbed, and these also proved PCR positive for BPCV1. This latter is the first confirmation of the virus at a location other than Redcliff Bay.

3.5 Translocations from Bernier and Dorre Islands

Based on the population estimates (section 3.3) and using the harvesting guidelines developed by DBCA (Page, 2017), approval from the Executive Director of Science and Conservation Division, DBCA, was given for the DHINP and Mt Gibson translocations to proceed, with maximum harvest numbers prescribed.

Translocations by DBCA of 50 (26:24) rufous hare-wallabies comprising 23 (12:11) from Dorre Island and 27 (14:13) from Bernier Island and 90 (35:55) banded hare-wallabies, comprising 47 (22:25) from Dorre Island and 43 (13:30) from Bernier Island, occurred from 16 September – 4 October 2018 (Table 7). Sixteen of the 24 rufous hare-wallaby females translocated to DHI were carrying a small pouch young, and seven of the 55 banded hare-wallaby females had 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 high proportion of both rufous and banded hare-wallabies were highly reproductive and recruiting new individuals into the island populations through winter and early spring on 2018.

The DHINPERP translocation was followed later in October 2018 by removal of a further 39 banded hare-wallabies (19 males: 20 females) from Bernier (17 individuals) and Dorre Islands (22 individuals) by the Australian Wildlife Conservancy (AWC) as part of their translocation program to Mt Gibson sanctuary. None of the female banded hare-wallabies translocated to Mt Gibson were carrying pouch young. At the same time, AWC also translocated 11 (5:6) Shark Bay bandicoots, comprising nine from Dorre Island and two from Bernier Island to Mt Gibson. None of the six 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 Sept-Oct 2018 make up only 3.0% (129/4292) of the combined banded hare-wallaby population (60/1819 or 3.3% of Bernier and 69/2247 or 3.1% of Dorre); 3.5% (50/1420) of the combined rufous hare-wallaby population (27/628 or 4.3% of Bernier and 23/632 or 3.6% of Dorre) and 1.1% (11/960) of the combined Shark Bay bandicoot population (9/528 or 1.7% of Dorre and just 2/407 or 0.5% of Bernier), in autumn 2018.

Table 7. Numbers of different species translocated off Bernier and Dorre Islands in spring 2018.

2018 Translocation	Total	M	F	%F with PY	% F reprod	% 2018 LCL Popn
DBCA RHW DI to DHI	23	12	11	100%	100%	3.5%
DBCA RHW BI to DHI	27	14	13	38%	85%	4.3%
Total RHW Harvest	50	26	24	67%	92%	3.5%
DBCA BHW DI to DHI	47	22	25	16%	53%	
AWC BHW DI to MG/FI?	22	12	10	30%		
BHW DI Harvest	69	34	35	20%		3.1%
DBCA BHW BI-DHI	43	13	30	10%	80%	
AWC BHW BI to MG/FI?	17	7	10	20%		
BHW BI Harvest	60	20	40	12.5%		3.3%
Total BHW Harvest	129	54	75	16%		3.0%
AWC SBB DI to MG/FI?	9	4	5	0		1.7%
AWC SBB BI to MG/FI?	2	1	1	0		0.5%
Total SBB Harvest	11	5	6	0		1.1%

MG = Mt Gibson; **FI** = Faure Island.

3.6 Boullanger, Escape and Whitlock Islands, Jurien Bay.

The DHINPERP Stage 2 Plan proposed the translocation of dibblers to DHINP in 2018 - 2019, to be sourced from the northern population on the Jurien Bay Islands (Boullanger, Whitlock and Escape). The plan proposed capture of 20 (10:10) founder individuals and captive breeding at Perth Zoo during 2018 to provide larger release numbers for a spring 2018 release. Monitoring of these populations has been occurring regularly in May and October each year. Although 2017 data suggested the population size was sufficient for harvesting as planned, extremely low capture rates of dibblers on Boullanger and Whitlock Islands, during the initial founder collection attempt in January 2018, resulted in a decision to abandon the harvest at this time. Escape Island could not be safely reached in January 2018 due to adverse wind and sea conditions.

Further monitoring occurred on Boullanger and Whitlock Islands during the usual May and October periods in 2018. Escape Island was again unreachable in May, but was trapped in October. Resource limitations and access issues have meant that the reintroduced population on Escape Island had not been monitored in over five years.

The trapping in May occurred on Boullanger and Whitlock Islands over four nights from 28 May -1 June 2018. Only seven dibblers (all females, six with pouch young) were captured from Boullanger Island in 500 trap nights, representing a severe decline in capture rate from May 2017 (57 animals), and one of the lowest recorded since 2005 (Fig. 3a). A total of 23 (12:11) dibblers were captured on Whitlock Island in 160 trap nights and seven of these females were carrying pouch young (Friend and Button, 2018).

The spring trapping program occurred from 28 October - 2 November 2018 and resulted in capture of only five dibblers on Boullanger Island in 500 trap nights and only one of these was a juvenile which normally dominate the population at this time of year. A total of 32 (20:12) dibblers were captured on Whitlock Island in 160 trap nights and 17 of these were new recruits since May (Friend and Button, 2019).

Four pairs were collected from Whitlock Island on the last two nights of the spring 2018 monitoring program. On the following day, 75 traps (at a subset of the 100 standard monitoring trap sites, using two or three traps at each site) were set on Escape Island. Five (3:2) dibblers were captured, all of which were collected for the breeding program. No animals were collected from Boullanger Island due to the alarmingly 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: the female was collected for the Zoo program. On Escape Is 14 (8:6) dibblers were captured, and 5 (4:1) more collected for the Zoo breeding program. The final total comprised eight founder pairs (four pairs each from Whitlock and Escape Islands (Friend and Button 2019).

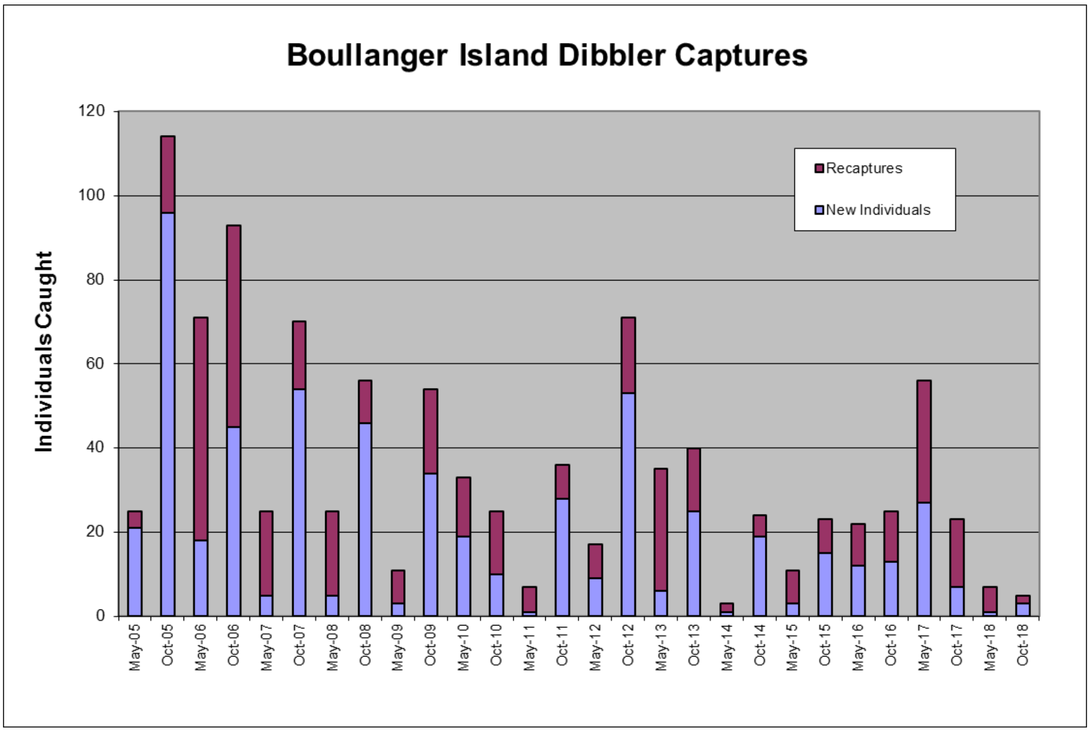

Figure 3a: Numbers of dibblers captured on Boullanger Island in monitoring sessions since 2005 (Friend and Button, 2019)

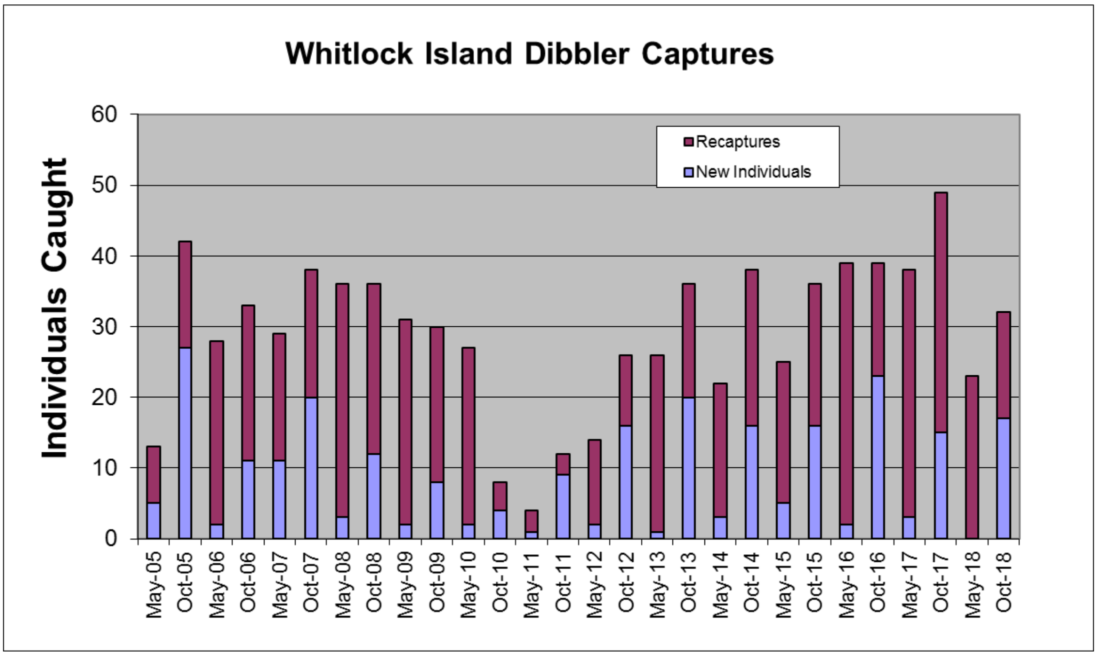

Figure 3b: Numbers of dibblers captured on Whitlock Island in monitoring sessions since 2005 (Friend and Button, 2019).

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. 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 is in need of repairs and an upgrade and has provided unreliable data collection in 2018. If this maintenance can occur as soon as possible, then we will have a good distribution of weather stations and rainfall data from around Shark Bay.

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 4). 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). The last two years has seen one of these periods of below average rainfall at the mainland BOM stations, however rainfall has not been as low according to the Dorre Island station.

Although the 2017/18 summer rainfall at Dorre Island was considerably lower than the previous summer (14.2mm for Oct17 - Mar18 cf. 82mm for Oct16 - Mar17), there were good falls (47.4mm) in September 2017, which may have provided improved condition of both vegetation and animals entering the dry summer period, improving their survival. In addition, significant rainfall recorded on Dorre Island in autumn and winter 2018 (212mm of rain fell in the 105 days between 27 April and 16 September), would have ensured ongoing survival of the populations that made it through the summer, and stimulated high reproductive activity in all three translocated species in spring 2018. This was in stark contrast to almost no reproductive activity recorded in these species in spring 2017. The annual rainfall figure for Dorre Island for 2018 was 226mm, equal to that recorded at Denham (Annual average = 224), and more than twice the 106mm recorded at Carnarvon (Annual average = 223).

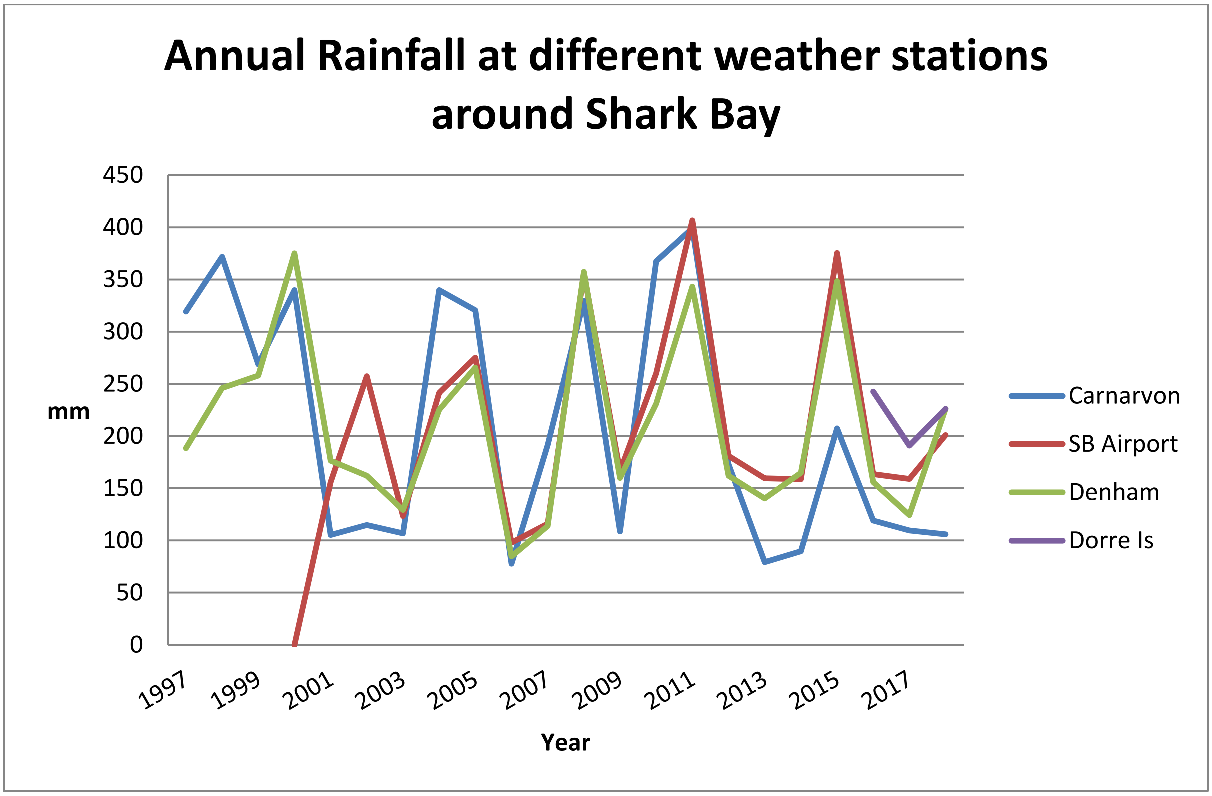

Figure 4. Annual rainfall at Carnarvon airport, Shark Bay airport, Denham and Dorre Island 1997-2018.

4.2 Jurien Bay

Annual rainfall for Jurien Bay for 2017 (464mm) and 2018 (469mm) were less than the average of 549mm.

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 2018 program was affected by adverse weather requiring a flexible response to complete the program.

Weather conditions were challenging during work on Dorre Island, and prevailing conditions required the vessel to relocate to safe anchorages, at Turtle Bay (Dirk Hartog Island), and Pin Bay (northwest side Dorre Island) for three nights. This required a transit time of between two to four hours to and from the field site. Despite this, only one night of trapping was lost, and all spotlight transects were completed on Dorre Island. However, this regime created fatigue issues with both island teams and boat crew, which can become a serious safety risk as weather deteriorates and is not a desirable situation to repeat too often.

Milder weather and sea conditions during the Bernier Island schedule, allowed all schedule tasks to be completed. The prevailing conditions also 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.

The translocation activities in Sept/Oct were also severely disrupted by bad weather, but the cooperation and flexibility of both capture teams and the skipper and crew of the Keshi Mer, allowed the successful capture and translocation of 140 animals in 8 working nights; albeit staggered over 25 days and three separate trips to the islands as the weather allowed.

5.1.2 Methodological considerations

The trapping grid design instigated 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. Despite the increase in grid size (from 49 to 64 trap sites) in 2018, the number of individuals captured was not much higher than previous years. However, a greater number of recaptures generated better quality data and improved confidence in the results. Future trap rates may once again be reduced in low population years when environmental conditions are harsher, which could complicate analyses further. Capacity to further increase trap effort is limited by financial, safety, and welfare considerations which are magnified under these challenging logistical conditions. The interference problems on the second Shark Bay mouse grid on Bernier Island in 2017 was successfully ameliorated in 2018 surveys by adopting the ‘pipe excluders’.

Similarly, the spotlight survey design for Distance analyses is robust, but low sample size will reduce confidence in the abundance estimates. One solution to this is to survey more transects to increase the sample size for each species. But as illustrated in the outcomes of the 2016, 2017 and 2018 field trips, and discussed above in relation to trap surveys, the financial, safety and welfare considerations of working on these remote and exposed locations limits the capacity to increase survey effort with the resources available. An alternative solution is to use pooled data for more than one year and then analysing each year separately, which was adopted to rerun analyses in 2018. This assumes that the detection function resulting from Distance analyses will be similar between sessions over a small span of 2-3 consecutive years. This assumption is based on continuity of observers (team leaders/primary observers were the same) and limited change in vegetation structure/density over this short time frame. Van Dongen, 2019 supports this latter assumption, concluding that observations are not influenced by vegetation cover. However, a disadvantage of pooling data for improved detection function is that it is not possible to also separate the individual island populations in this analysis.

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. 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 further decreases as trap rates 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. The demographic and individual health and condition data derived from trapping contributes valuable information to the assessment of population health 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 2018 were set, based on non-pooled data from the spotlight surveys.

5.1.3 Estimates of abundance and translocation

The population estimates for both hare-wallabies and the Shark Bay bandicoots in 2017 were the highest since 2011. Although somewhat lower in 2018, the banded hare-wallaby and Shark Bay bandicoot estimates were still the second highest. The rufous hare-wallaby estimates were only the second lowest since 2011, but the LCL still placed the population in the ‘moderate’ category (Page, 2017) that allowed a slightly reduced translocation target of 70 max individuals which ensured harvesting levels would remain below 5%. Despite low summer rainfall, good falls before summer were likely to have supported improved subsequent survival through the summer, and very good rains in late autumn provided a boost to breeding activity in 2018. These factors combined to ensure there was a sufficient number in the populations for translocations of rufous and banded hare wallabies, and Shark Bay bandicoots by 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. Although approval was given to translocate the full complement of 100 banded hare-wallabies (90 were translocated), only 50 of the 70 approved rufous hare wallabies were translocated. If population numbers of rufous hare wallabies are healthy enough for further harvesting in spring 2019, then we recommend additional animals (up to the remaining 50 sought in the Translocation Proposal) be harvested from Bernier and Dorre Islands.

Approvals will be sought in 2019 for the translocation of Shark Bay bandicoots from Bernier and Dorre Islands to Dirk Hartog Island pending suitable population estimates from the autumn 2019 monitoring. This may include harvesting from Bernier and Dorre, or Dorre alone, depending on current disease activity and population health on Bernier Island.

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 2018, 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.

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 requires access to suitable vessels and seafaring skills to successfully complete scheduled programs. In January 2018, adverse weather conditions prevented access and monitoring of the dibbler population on Escape Island.

Despite above average population estimates in 2017, the Boullanger and Whitlock Island the population sizes had substantially declined by January 2018. Further monitoring in May 2018 also indicated considerably lower numbers on Boullanger Island than for the same time in 2017, although the Whitlock Island population appeared quite strong. October monitoring on Whitlock Island revealed the expected pattern of increase in capture rates with a relatively high proportion of new recruits, indicating that this population is still reproductively healthy. However, the continuing low capture rate on Boullanger in October raises questions regarding the continuing viability of this island population.

5.3 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 plans to upgrade the DHI station to the same quality as soon as possible, will 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.

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Appendices

Appendix 1 Field schedules for monitoring trips

1.1 Dorre Island monitoring 2018.

DATE	Program	Comments
03/04/18	Drive ex Perth o/n Carnarvon	
04/04/18	Steam to Dorre, set trap grid	
05/04/18	Processing day 1	
06/04/18	Processing day 2 + Spotlight night 1	Doubling up to try and use limited weather window.
07/04/18	Processing day 3 (close traps), + Spotlight night 2	
08/04/18	Spotlight night 3	All team and boat crew require rest as fatigue is major issue
09/04/18	Pick up traps + Spotlight night 4	
10/04/18	Return to Carnarvon + clean traps	Aborted due to weather
11/04/18	Reload traps on boat etc, Fly to Perth	Aborted due to weather

1.2 Bernier Island monitoring.

DATE	Program	Comments
17/04/18	Fly ex Perth to Carnarvon, steam to Bernier and set traps	
18/04/18	Processing day 1	
19/04/18	Processing day 2	
20/04/18	Processing day 3	Emptied traps
21/04/18	Processing day 4 + Spotlight night 1	
22/04/18	Processing day 5 + Spotlight night 2	
23/04/18	Spotlight night 3	
24/04/18	Spotlight night 4	
25/04/18	Spotlight night 5	
26/04/18	Spotlight night 5	
27/04/18	Steam back to Carnarvon and drive to Perth	

1.3 Translocation

DATE	Program	Comments
9-13/09/18		Aborted due to weather
14/09/18	Drive Perth to Carnarvon	
15/09/18	Steam to Dorre Is, 1st night Net	
16/09/18	Helicopter Hare Wallabies to DHI, Return to Carnarvon, fly to Perth	
17-19 /09/18		Aborted due to weather

20/09/18	Fly Perth to Carnarvon, steam Dorre, 2nd night Net	
21/09/18	Helicopter Hare Wallabies to DHI. Dorre 3rd Night Net	
22/09/18	Helicopter Hare Wallabies to DHI. Dorre 4th Night Net	
23/09/18	Helicopter Hare Wallabies to DHI. Bernier 1st Night Net	
24/09/18	Helicopter Hare Wallabies to DHI	
25/09/18	Return to Carnarvon then Perth	Aborted due to weather
26-28/09/18		Aborted due to weather
29/09/18	Fly Perth to Carnarvon,	Aborted due to weather
30/09/18	Stay in Carnarvon	Aborted due to weather
1/10/18	Steam to Bernier. 2nd Night Net	
2/10/18	Helicopter Hare Wallabies to DHI. Bernier 3rd Night Net	
3/10/18	Helicopter Hare Wallabies to DHI. Bernier 4th Night Net	
4/10/18	Helicopter Hare Wallabies to DHI. Steam Bernier to Carnarvon	
5/10/18	Drive Carnarvon - Perth	