

# Industry environmental offset funding facilitates a large multi-species fauna translocation program

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**Abstract.** Worldwide deterioration in natural communities has led to an increased use of fauna translocations to improve conservation status and restore ecological function. However, few translocation programs have sufficient resources to involve multiple species and destination locations with appropriate threat management and monitoring before and after release. As part of conservation actions to mitigate impacts of the Chevron Australia Gorgon liquefied natural gas project on Barrow Island Nature Reserve, biodiversity offset funding was provided to benefit species impacted by the development. Animals were translocated from three islands to two mainland locations in Western Australia. We aimed to: (1) improve conservation status and security of several threatened species; and (2) contribute to reconstruction of pre-European fauna assemblages. Nine hundred and seventy five individuals of six mammal and two bird species were translocated. These included 421 golden bandicoots (*Isoodon auratus barrowensis*), 111 spectacled hare-wallabies (*Lagorchestes conspicillatus conspicillatus*), 105 Barrow Island boodies (*Bettongia lesueur* ssp. Barrow Island), 104 brushtail possums (*Trichosurus vulpecula hypoleucus*), 62 mala (*Lagorchestes hirsutus* ssp. Tanami), 88 djoongari (*Pseudomys fieldi*), 37 black and white fairy-wrens (*Malurus leucopterus edouardi*) and 47 spinifexbirds (*Eremiornis carteri*). Of 11 new populations, only two failed to establish; attributed to native and feral predators. Additional populations of four species of threatened mammal (one of which has now been reduced in conservation listing) and one species of threatened bird were established. To our knowledge, this is the largest translocation effort ever undertaken in Australia and is a rare example of an offset that has provided tangible threatened species benefit.

**Keywords:** Australia, conservation biology, fauna reconstruction, marsupials, reintroduction.

Received 20 April 2020, accepted 21 June 2021, published online 16 July 2021

## Introduction

Ecosystems worldwide are experiencing unprecedented levels of biodiversity decline and extinction due to human impacts (Dirzo *et al.* 2014; Otto 2018). Islands have suffered disproportionate levels of loss, often because of introduction of invasive species including rodents (*Rattus* spp.), red foxes (*Vulpes vulpes*) and feral cats (*Felis catus*) (Jones *et al.* 2008; Medina *et al.* 2011; Pimm *et al.* 2014; Doherty *et al.* 2016). Of these global extinctions, Australia has the world's worst record with at least 53 vertebrate species becoming extinct since European settlement in 1788, including three in the past 10 years (Waller *et al.* 2017; Woinarski *et al.* 2017). Australia has the dubious honour as the site of approximately 30% of the world's modern mammal extinctions (Burbidge and Manly 2002; Woinarski *et al.* 2015b), and seven Australia mammal species are forecast

to be extinct by 2038 unless conservation management improves (Geyle *et al.* 2018). In addition to extinctions, many other species have suffered significant range contractions and local extinctions due to population decline (Woinarski *et al.* 2015a, 2015b; Moore *et al.* 2019) in Western Australia alone, 15 mammal species have become locally extinct from 10 islands (Burbidge and Abbott 2017). Such losses have negative flow-on impacts to ecosystem health and function (Fleming *et al.* 2014).

Despite these losses, the opportunity exists to reconstruct the fauna assemblages of suitably managed areas, thereby restoring ecological processes and the conservation status of their extirpated occupants (Burbidge 1999; Ostendorf *et al.* 2016). Translocation of animals from stable populations to previous parts of their range to boost, reinstate or insure the species is an increasingly common strategy being employed by conservationists

(Armstrong and Seddon 2007). Indeed, reintroduction is a management option recommended for many threatened Australian vertebrates to combat severe range contractions, population declines and local extinctions (Pedler et al. 2018; Ringma et al. 2018). However, many reintroduction programs fail due to the difficulty of removing the threatening processes that initially caused the local extinction (Moseby et al. 2011; Clayton et al. 2014; Andrew et al. 2018), poor habitat quality or suitability at release sites (Bennett et al. 2013; Short et al. 2019), or other environmental factors such as stress of translocation and establishing in a new location (Cabezas et al. 2007; White and Pyke 2008). Islands with predator free enclosures or areas where threatening process have been managed are therefore appealing choices for successful translocation.

Critical to successfully undertaking such reconstruction programs is access to adequate resources, funding and personnel to manage the threats and habitat quality, undertake the translocation and determine its success afterwards (Sheean et al. 2011; Pérez et al. 2012). In this case, financial resources for the translocation program were provided by biodiversity offsets for the clearing of 332 ha for the development of a liquid natural gas (LNG) processing facility on Barrow Island A-Class Reserve (Government of Western Australia 2003; Lagdon and Moro 2013). Biodiversity offsetting is a conservation tool that aims to generate biodiversity benefits in one area to compensate for losses in another (Maron et al. 2016). Generally, offsetting is used to permit some habitat loss due to industry or development whilst restoring or revegetating another location in an attempt to achieve no overall net loss in habitat extent or condition (Gibbons and Lindenmayer 2007). However, concerns have been raised about the actual conservation benefits from enacting compensatory offsets (Lindenmayer et al. 2017; May et al. 2017). In particular, projects demonstrating a net positive impact are rare because of the uncertainty in defining the counterfactual scenario if the offset was not created and the development did not go ahead (Maron et al. 2018). Other issues with effective offsetting include lack of 'like for like' habitat, a flawed ecological basis to secure a net benefit, or allocating an already 'safe' parcel as an offset resulting in no additionality (May et al. 2017).

The significant conservation values of Barrow Island prompted an extensive environmental, social and economic review and impact assessment prior to the construction of the LNG facility. A terrestrial fauna translocation program was developed and implemented by Western Australia's Department of Biodiversity, Conservation and Attractions (DBCA) to offset this habitat loss by establishing new populations of threatened and priority species of fauna from Barrow Island to other suitable habitats. We also used the opportunity to undertake two additional species reintroductions from other Pilbara islands while the facility to translocate relevant animals was available. The goal of all these translocations was primarily to improve the conservation status of these species and facilitate fauna reconstruction at recipient sites and included follow-up monitoring and management of populations and habitats. The total value of this project was AUD11 million, indexed to 2007 dollars, over 14 years (Government of Western Australia 2003, 2009). It is an example of an unusually large fauna translocation involving multiple species and destination sites as well as the resources for monitoring of effectiveness and management actions.

This paper describes the criteria used for the selection of species to be translocated, and the translocation sites, details of the translocations and their outcomes using short-, medium- and longer-term success criteria. We discuss this translocation as an offset strategy and whether there was a net benefit to biodiversity.

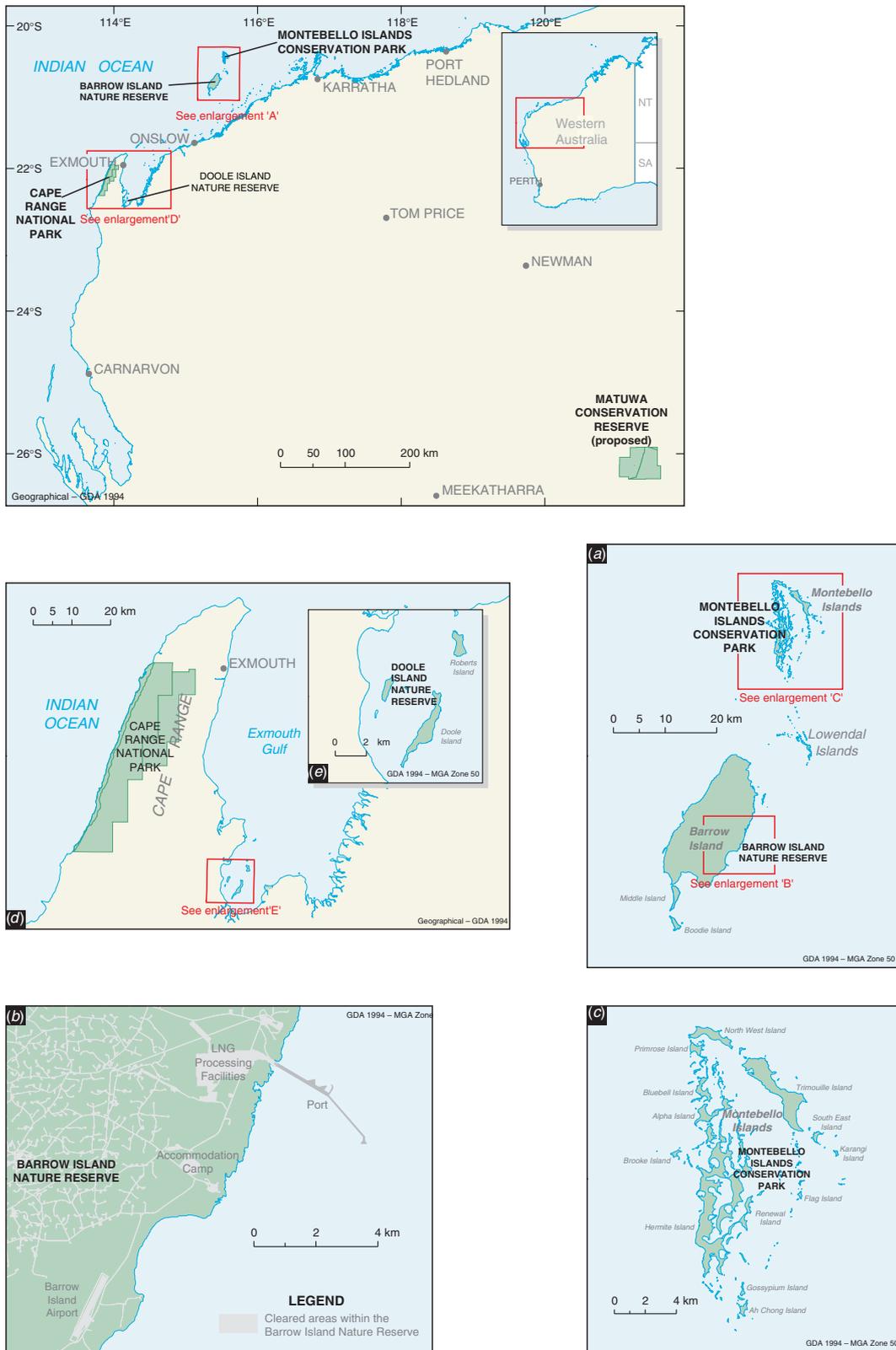
## Methods

### Source of animals

Animals were sourced from Barrow Island Nature Reserve and the Montebello Islands Conservation Park. Barrow Island (23 567 ha;  $-20^{\circ}795'S$ ,  $115^{\circ}390'E$ ) is Western Australia's second largest island, approximately 25 km long and 10 km wide, lying about 55 km north-west of the Pilbara coast (Fig. 1). The Montebello Islands ( $-20^{\circ}437'S$ ,  $115^{\circ}535'S$ ) are a group of 218 islands, islets and rocks 20 km north of Barrow Island and 80 km from the Pilbara coast (Fig. 1) (Lohr et al. 2014). All these islands were separated from the mainland during sea level rise approximately 8000 years ago (Dortch and Morse 1984). The islands experience a maritime, semi-arid climate with highly variable cyclone-driven rainfall (average rainfall on Barrow Island of about 320 mm per year). The primary habitat types on the islands are mostly spinifex (*Triodia* spp.) hummock grasslands, *Spinifex longifolius* tussock-grassland, *Acacia* dominated shrublands and mangrove thickets. Barrow Island has been a Nature Reserve since 1910, and since 1964 has been used for oil extraction and shipping activities. In 2009 construction of the Gorgon gas processing plant commenced on the island and gas exports commenced in 2016.

Barrow Island is one of Australia's most important A-Class Nature Reserves and supports a significant vertebrate assemblage of 15 mammal, 119 bird, 44 reptile, one frog and one subterranean fish species (Moro and Lagdon 2013), including 22 threatened taxa (Government of Western Australia 2018). Because of its geographic isolation, large size ( $\sim 23\,000$  ha), and no introduced predators, the assemblage of flora and fauna species has remained essentially intact since European colonisation of Australia. Black rats (*Rattus rattus*) and house mice (*Mus musculus*) have been inadvertently introduced to the island several times since the 1960s but were successfully eradicated by baiting and trapping (Morris 2002). Several taxa present on the island are virtually extinct on the nearby mainland, such as the golden bandicoot (*Isodon auratus*), and spectacled hare-wallaby (*Lagorchestes conspicillatus*), and others are recognised as unique from the mainland form, such as Barrow Island euro (*Osphranter robustus isabellinus*), Barrow Island boodie (*Bettongia lesueur* ssp. Barrow and Boodie Island), and Barrow Island black and white fairy-wren (*Malurus leucopterus edouardi*) (Government of Western Australia 2018). Barrow Island therefore represents a critically important natural ark for a number of Australia's endemic species.

The nearby source populations of mala (*Lagorchestes hirus* spp. Tanami) on Trimouille Island and djoongari (*Pseudomys fieldi*) on North-West Island in the Montebello group were both conservation introductions. Thirty mala were released on Trimouille Island from the Tanami Desert in 1998 when the last remaining wild population was being predated by feral cats (Langford and Burbidge 2001). Djoongari were introduced to North West Island from Bernier Island (via breeding facilities at



**Fig. 1.** (a) Source and destination sites for the fauna translocation in the north-west of Western Australia. (b) Barrow Island Nature Reserve, and nearby Montebello Islands Conservation Park. (c) Enlargement of the Montebello Islands Conservation Park, including Hermite Island, North West Island, Trimouille Island and Alpha Island. (d) Cape Range National Park. (e) Doole Island within the Exmouth Gulf. (f) Areas cleared on Barrow Island for the LNG processing plant relevant to the offset.

Perth Zoo) in 1999. Both conservation introductions were successful with abundant populations of both species within three years of release.

#### *Selection of species to be translocated*

The following criteria were used to select species of highest importance for translocation (Morris and Yates 2016):

- Species that were of conservation significance, endemic or threatened, and conservation status would be improved by establishing other populations.
- Species that had been lost from areas of former habitat, and where repatriation would be of benefit to the ecosystem.
- Sufficient knowledge was available on the distribution and abundance of the source population, and that it was sufficiently large to tolerate harvest of animals for translocation.
- Species that were likely to be impacted by the clearing activities at the LNG site on Barrow Island.
- Species for which there was good knowledge about translocation and monitoring techniques, and that had a good chance of translocation success.
- There were suitable translocation sites with adequate areas of quality habitat for the selected species with threatening processes mitigated.

The fauna species selected for translocation were Barrow Island golden bandicoot (*I. a. barrowensis*), Barrow Island spectacled hare-wallaby (*Lagorchestes conspicillatus conspicillatus*), Barrow Island boodie (*Bettongia lesueur* ssp. Barrow and Boodie Islands), brushtail possum (*Trichosurus vulpecula hypoleucus*), rakali (*Hydromys chrysogaster*), Barrow Island black and white fairy-wren (*Malurus leucopterus edouardi*), and spinifexbird (*Eremiornis carteri*) (Table 1). These species largely met all the above criteria for selection. Other threatened taxa were considered but not selected were the endemic Barrow Island euro (*Osphranter robustus isabellinus*) and Barrow Island leopard skink (*Ctenotus pantherinus acripes*), both of which had never been translocated before, or were known from many other locations. Two additional species were also translocated; although not at risk from the Barrow Island development; populations of mala (*Lagorchestes hirsutus* ssp. Tanami Desert) and djoongari (*Pseudomys fieldi*) were present on islands nearby to Barrow and were value-added to the translocation as part of a fauna reconstruction project being undertaken at Matuwa Indigenous Protected Area (Matuwa) (Algar *et al.* 2013), while the facilities to translocate were present.

The majority of these translocations were reintroductions; that is, there was good evidence of recent occurrence of those species previously occurring at the destination sites (Table 1). On surveys of the Montebello Islands in 1914, anthropologist and naturalist P. D. Montague noted the presence of spectacled hare-wallabies and ‘there was formerly a Bandicoot, *Isodon barrowensis*, Thom., which until very recently inhabited Hermite Island, but has now been exterminated. Of introduced species, cats and black rats (*M. rattus rattus*) are numerous, and... doing great damage to the endemic fauna.’ (Montague 1914). Evidence for other species included prior distribution, skeletal remains from caves or currently unoccupied boodie warrens (Abbott and Burbidge 1995; Abbott 2006; Burbidge and

Abbott 2017). The species were all locally extinct at the destination sites at the time of release (Appendix 1). As per IUCN translocation guidelines, every effort was made to ensure the likelihood of establishment of new populations and ensuring adequate genetic diversity by releasing as many individuals as possible, whilst not endangering the source population by over-harvesting (IUCN SSC 2013). Table 1 details the estimated source populations and the number translocated; in most cases fewer than 5% of the source population were harvested as founders. For this reason, translocations of rakali were not undertaken in 2010–2011 due to a lack of information on the distribution and abundance of the Barrow Island rakali that would be the translocation ‘source’ population.

#### *Selection of destination sites*

Release sites for translocated fauna were selected using the following criteria (Morris and Yates 2016):

- There was evidence of the former occurrence of the species to be translocated at the site, or it was within its former range.
- The threatening process(es) responsible for the decline or extinction of the target species was/were adequately managed or eliminated.
- The site contained adequate area(s) of habitat to support a viable translocated population.
- There was secure tenure and adequate management presence at the translocation site.
- It was logistically feasible to access the translocation site for monitoring and ongoing management.

Using the site selection criteria above, three island and two mainland sites were selected for translocation releases: Hermite and Alpha Islands in the Montebello Island Conservation Park, Doole Island Nature Reserve in Exmouth Gulf, Cape Range National Park, and a predator proof enclosure at Matuwa in the rangelands (Fig. 1). All these sites, except Matuwa, are conservation reserves managed by the WA State Government. Matuwa is managed by the Wiluna Martu traditional owners, Tarlka Matuwa Piarku Aboriginal Corporation and the WA State Government. Further details for each site can be found in Appendix 1.

#### *Description of offset*

This project was funded largely by an environmental offset provided by Chevron Australia as part of a ministerial agreement with the WA Government and approval to clear 332 ha of natural vegetation for the construction of the Gorgon LNG gas processing plant on the Barrow Island Nature Reserve. Additional funding as in-kind support for the translocation program was provided by Chevron Australia and the then Department of Environment and Conservation (DEC), who undertook the translocations. The Gorgon offset funding commenced in November 2009 and will continue to 2023. This offset did not follow traditional format as it has Parliamentary Acts associated with it, and required funds to be delivered to DEC, with DEC required to undertake the work and manage the funds in a way seen fit for the species. There were no specific completion criteria outlined in the Acts, so under May *et al.* (2017), it would fall into the category of ‘research, rehabilitation and restoration’. DEC set goals of securing threatened and priority species populations and

Table 1. Detail of species selected for translocation, their conservation status at the time of translocation, origin and destination sites, translocation classification and long-term success

Taxa	Scientific name	Conservation status at time of translocation WA Wildlife Conservation Notice	EPBC Act IUCN	Source location	Estimated population at source location	Release location	Classification (according to Armstrong and Seddon 2007)	Numbers moved	Long term success?	Reason for failure
Barrow Island golden bandicoot	<i>Isoodon auratus barrowensis</i>	Vulnerable	Vulnerable (species level)	Barrow Island	25 000–50 000 <sup>1</sup>	Matuwa Hermite Island	Reintroduction <sup>7</sup>	164	Yes	
Barrow Island spectacled hare wallaby	<i>Lagorchestes conspicillatus</i>	Vulnerable	Near Threatened (species level)	Barrow Island	7500–14 000 <sup>1</sup>	Doole Island	Introduction <sup>9</sup>	92	Yes	
Barrow Island boodie	<i>Bettongia lesueur</i> ssp. Barrow and Boodie Islands	Vulnerable	Vulnerable (species level)	Barrow Island	2300–32 00 <sup>1</sup>	Matuwa Alpha Island	Reintroduction <sup>7</sup>	65	Yes	
Common brushtail possum	<i>Trichosurus vulpecula hypoleucus</i>	Not listed	Least concern (species level)	Barrow Island	20 000 <sup>2</sup>	Cape Range National Park	Reintroduction <sup>9,11</sup>	104	No	Predation by red foxes
Mala	<i>Lagorchestes hirsutus</i> ssp. Tanami Desert	Endangered	Vulnerable (species level)	Trimouille Island	660–10 60 <sup>3</sup>	Matuwa	Reintroduction <sup>7</sup>	62	Yes	
Djoongari	<i>Pseudomys fieldi</i>	Vulnerable	Vulnerable	North West Island	750–10 00 <sup>4</sup>	Matuwa	Reintroduction <sup>7</sup>	88	No	Predation by native predators
Rakali	<i>Hydromys chrysogaster</i>	Priority 4	Not listed	Barrow Island	150–250 <sup>5</sup>	Hermite Island	Reintroduction <sup>10</sup>	Planned for 2022–23		
Barrow Island black and white fairy-wren	<i>Malurus leucopterus edouardi</i>	Vulnerable	Least concern (species level)	Barrow Island	4000–12 000 <sup>6</sup>	Hermite Island	Reintroduction <sup>10</sup>	37	Yes	
Spinfifxbird	<i>Eremiornis carteri</i>	Not listed	Least concern	Barrow Island	17 800–24 623 <sup>6</sup>	Hermite Island	Reintroduction <sup>10</sup>	47	Yes	

References: <sup>1</sup>Short and Turner (1994), Chevron Australia (2015), <sup>2</sup>Short and Turner (1991), <sup>3</sup>Dunlop *et al.* (2011), <sup>4</sup>Morris *et al.* (2000), <sup>5</sup>Bettink (2016), <sup>6</sup>Sedgwick (1978), Pruett-Jones and O'Donnell (2004), <sup>7</sup>Baynes (2006), <sup>8</sup>Montague (1914), <sup>9</sup>Baynes and Jones, (1993), <sup>10</sup>Burbridge *et al.* (2000), <sup>11</sup>Abbott (2012)

enhancing fauna restoration programs. Under the Gorgon Gas Processing and Infrastructure Project Agreement (Government of Western Australia 2003) and Variation Agreement (Government of Western Australia 2009), the initial funding agreement was for a total of AUD \$10 million to be provided over 12 years; \$1.3 million per year for 5 years, then \$0.5 million per year for 7 years. An additional \$0.5 million per year for 2 years was provided to the fauna translocation program in 2012 as an offset for the clearing of an additional 32 ha of land to support construction activities. The offset funding was indexed to 2007-dollar values and increased by Consumer Price Index for successive years.

#### *Methods of capture and release*

Mammals were captured using a variety of traps, including Elliott (Type A, Elliott Scientific Company, Upwey, Vic., Australia), medium cage traps (Sheffield Wire Products, Welshpool, WA, Australia), soft-walled Thomas traps (Sheffield Wire Products) or hand-netting. Traps were baited with peanut butter, oats and sardines, and were cleared twice per night to maximise captures of targeted species. On Barrow Island, we primarily targeted the LNG development envelope but to achieve adequate founder numbers, some mammals were trapped from a 2 km radius around the development site. Trap effort to collect founders totalled over 4200 trap nights through 2010–2011, the majority (85%) in January and February 2010. All captured mammals were assessed at the site for retention or release.

Mist-netting to collect black and white fairy-wrens and spinifexbirds for translocation was undertaken for a total of 26 days in May 2010 and June 2011 at 39 sites located adjacent to the LNG site, and near the west and south coasts of Barrow Island. Nets of a mesh size appropriate for small passerines (maximum stretched diagonal mesh size of 25 mm) were deployed, with netting attempts restricted to early morning and late afternoon. Call broadcasting was often used to attract individuals from the immediate location. Mist-netting operations were cancelled during hot or windy weather. One to three operators accredited by the Australian Bird and Bat Banding Scheme (ABBBS) and experienced in catching and extracting small passerines from mist-nets were present on the team during the entire field program. Fairy-wrens and spinifexbirds to be translocated were placed in calico bags (one bird per bag), given Spark Liquid electrolyte supplement (Vetafarm, Wagga Wagga, NSW, Australia) and then placed in specially designed shower-proof cardboard transport boxes for transport.

Non-target species and animals not suitable for translocation were released immediately. Reasons for being deemed unsuitable included females that were lactating or had large pouch young, animals that appeared in poor condition or were non-independent juveniles. Biological samples (tissue, swabs, blood or scats) were taken from a sub-set of each species per destination to provide a pre-translocation health and genetic reference. All mammals were implanted with a Passive Integrated Transponder (PIT) Allflex 12 mm FD-X transponder (Allflex, Australia) providing each with an individual identity number, and a full set of biometric data including measurements of weight, head and pes length, age, gender, reproductive status, presence of ectoparasites and intended final destination were recorded for each. Birds were leg-banded with uniquely

numbered metal bands provided by the ABBBS, followed by weighing and taking morphometric measurements. Macropods are susceptible to capture myopathy if unduly stressed (Jackson 2007; Vogelnest and Portas 2008), so veterinary administration of sedatives (Azaperone) and Vitamin E/selenium was used to reduce anxiety of spectacled hare-wallabies and mala during the translocation process.

All founder mammals were released at their destination site within 24 h of their initial capture. Some birds were held up to 48 h before release and provided with food (limited to termites) and water while held captive. All animals were held in a darkened and quiet air-conditioned room (21–26°C) for holding prior to early morning transport. Mammals were transported individually in black cotton drill bags, inside airline-approved pet carriers (K9 Pet Carrier 53 × 37 × 37 cm PP20). A quarantine-compliant helicopter was used to transport animals between islands (44 km) or to Karratha airport (143 km). Animals destined for Matuwa (781 km) or Exmouth (325 km) were transported from Karratha via a Beechcraft Bonanza fixed-wing aircraft. At the destination sites, birds were released on the morning of arrival, and mammals were held in a quiet, cool and darkened location and released at dusk (Parker *et al.* 2012).

#### *Translocation monitoring*

The translocated mammal populations were initially monitored via very high frequency radiotracking to provide preliminary survivorship and movement information. A combination of monitoring methods was used to monitor the populations in the following 8 years, and included radiotracking, trapping, resighting during transect searches, and camera trapping. Newly recruited individual mammals captured during trapping surveys were implanted with unique PITs. These were subsequently used in population estimates, calculated using RMARK openCR population models (Dunlop 2015), or Known To Be Alive (Department of Parks and Wildlife 2013). Area of occupancy was calculated from camera trap or sighting occupancy and analysed using program Presence (MacKenzie *et al.* 2017). Translocated birds on Hermite Island were monitored by aural and visual detection, during walked area or transect searches, using call-broadcast procedures to lure birds at sites where none were detected by passive survey. Population estimates were based on distance analysis calculations from leg band sightings. Frequency of monitoring decreased with time after release. Populations were approximated to our best knowledge at time of writing, and publications for each species or site will follow with more specific detail.

#### *Definitions of success*

Assessment of success or failure of each translocation was based on guidelines within IUCN SSC (2013) (Table 2), and further divided to short term (release to 12 months), medium term (1–5 years) and longer term (5+ years) in order to better identify success or failure. These time frames related to generation time; short-term criteria relate to the survival and establishment of founders, medium-term criteria relate to ongoing persistence, evidence of successful recruitment (evidence of breeding, and recapture/resight of newly marked animals surviving to adulthood), and expansion beyond the release sites to occupation of suitable habitat (based on camera trap arrays, or evidence of occupation of a new area) (IUCN

**Table 2. Success criteria for each of the eleven translocated populations, based on risk assessment guidelines of the IUCN SSC (2013). Short term criteria relate to the first 12 months, medium term is 1–5 years, and long term is 5 years and beyond**

	Matuwa golden bandicoot	Hermite Island golden bandicoot	Doole Island golden bandicoot	Hermite Island hare-wallaby	Matuwa boodie	Alpha Island boodie	Cape Range brushtail possum	Matuwa mala	Matuwa djoongari	Hermite Island black and white fairy-wren	Hermite Island spinifexbird
Short (12 months)	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y
Survival of more than 50% of founder individuals after 3 months											
Independent young produced within 12 months	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y
Founders established (home range, or weight gain)	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y
Evidence of recruitment	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y
Increased distribution within 5 years	Y	Y	N	Y	Y	Y	N	Y	N	Y	Y
Population extant after 5 years	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y
Genetic diversity maintained	Y	Y	Y	Y	Y	Y	N	Y	NA	Y	Y
Minimal intervention required for self-sustaining population	Y	Y	Y	Y	Y	Y	NA	Y	NA	Y	Y
Long (5+ years)											
Survival of more than 50% of founder individuals after 5 years											
Independent young produced within 5 years											
Founders established (home range, or weight gain)											
Evidence of recruitment											
Increased distribution within 5 years											
Population extant after 5 years											
Genetic diversity maintained											
Minimal intervention required for self-sustaining population											

SSC 2013). Longer-term criteria relate to the self-sustaining survival of the population without intervention (population increase from founder number), including gene pool health (IUCN SSC 2013). Assessing at which point an establishing population failed, and causes of failure, are critical to learning from the experience and improving translocation outcomes (Moseby *et al.* 2011; Lloyd *et al.* 2019). We also assessed the success of the offset, according to the framework set out in May *et al.* (2017). We assessed four aspects of the translocations that we felt were relevant here for each species; net individual loss/gain, new population locations created, whether the reintroductions were culturally significant to Traditional Owners, and whether the species was part of a faunal reconstruction providing ecosystem services to the landscape.

## Results

### Summary of translocations

In total, 975 individuals of nine species were translocated to five different destination sites as part of this program (Table 1). This included 11 separate repatriated populations as there were several populations of some species. Two of these were considered conservation introductions under IUCN SSC (2013) guidelines, as there was not good evidence to suggest that boobies previously inhabited Alpha Island in the Montebellos group, or golden bandicoots occurred on Doole Island (Baynes and Jones 1993; Burbidge *et al.* 2000). The release of fairy-wrens is considered a reintroduction, as they existed on Hermite Island in 1912, and were detected on Trimouille Island (also within Montebellos group) in 1950 (Burbidge *et al.* 2000). The remaining eight translocations, as well as the rakali translocation planned for 2022, are reintroductions of species to areas they previously inhabited but have become extirpated. A total of 825 individuals of six species were sourced from Barrow Island, in particular targeting those that would be directly impacted from the clearing of the LNG site. The remaining 150 individual mammals came from the Montebello Islands (Trimouille and North West Islands). As a result of these translocations, five threatened species have established new populations.

### Successes and failures

Of the 11 translocated populations, nine have persisted and are currently self-sustaining (populations have remained the same or increased following release) with minimal intervention in the long-term (Tables 1, 3). The population of djoongari released within the fenced enclosure at Matuwa did not establish, nor did the population of brushtail possums released at Cape Range National Park. Trapping revealed that the djoongari at Matuwa survived for up to 1 year, but long-term survival was unlikely, with evidence of predation by mulgara (*Dasyercus blythi*) and other native predators (barn owls, varanids, and snakes) resident within the enclosure (Lohr 2018). Seventy-four percent (20/27) of the radio-collared possums died within 6 months of release at Cape Range National Park and all radio-collared animals had died by 14 months post release. Despite 1080 fox baiting as part of the regional Western Shield program, fox predation was confirmed via DNA swabs for at least 85% of the collared animal deaths. While possums persisted within the gorge systems for up to 4 years post-release, and there was evidence of

breeding, there was no evidence of recruitment and possums have not been recorded at Cape Range National Park since 2014.

#### *Black and white fairy-wren and spinifexbird*

By September 2012, 15 months after the last birds were translocated, a minimum of 60 fairy-wrens and an estimated 100 spinifexbirds were recorded on Hermite Island, an approximate doubling of the founder populations of 37 and 47, respectively. Both species had persisted at their release sites and dispersed well beyond. At least 80% of the fairy-wrens and 96% of the spinifexbirds were unbanded individuals; since all translocated birds had been fitted with metal leg bands, this indicates that successful breeding and recruitment had occurred. By 2015, both species were widespread on Hermite Island and the spinifexbird had dispersed to another six islands adjacent to Hermite Island (Table 3). At that time, the population estimate for fairy-wrens on Hermite Island was ~70 birds, and there were more than 300 spinifexbirds. Both translocations are considered to be successful in the short and medium-term, and self-sustaining in the long term, but genetic analysis is required to assess diversity (Table 2). Further detail on the bird translocations will be presented in Burbidge A, Blythman M, Danks A, Hamilton N (unpubl. data).

#### *Golden bandicoot*

All three golden bandicoot translocations were successful in the short, medium and likely long-term (Table 2). Genetic assessment of the translocated populations compared with the source population indicated that the founder population was suitable to retain genetic diversity, but that occasional supplementation is required in a 10-year timeframe (Ottewell *et al.* 2014). Current population estimates are in the range of 580–2800 additional animals established at three locations, with a combined occupation area of more than 2367 ha (Table 3).

All three founder populations of golden bandicoots showed a dramatic increase in mass and skeletal body size following release (Dunlop and Morris 2018). Female bandicoots on Hermite Island and at Matuwa exhibited higher reproductive

output in the number, frequency and average mass of pouch young when compared with the founder population on Barrow Island (Dunlop and Morris 2018). More than 70% of female bandicoots at Matuwa were in a reproductive state during trapping efforts for the first 5 years, but this rate has declined as the population stabilised (Dunlop and Morris 2018; Lohr 2018). By May 2012, it was estimated there were 132–200 golden bandicoots inside the Matuwa enclosure, and current estimates are 130–680 (Dunlop 2015; Lohr 2018). In 2015, 92 bandicoots were released outside the enclosure at Matuwa, and small juvenile animals move through the fence netting and establish outside the enclosure. Currently, the population outside the enclosure is persisting, albeit at low densities. By September 2012, 31 months after release, it was estimated that there were at least 254 bandicoots on Hermite Island (Dunlop 2015). Bandicoots from Hermite Island also spread to nearby Buttercup Island (5.5 ha), which connects to Hermite Island at low tides (Department of Parks and Wildlife 2013).

At Doole Island, new animals were detected in the population within 10 months of release, and there was a 25% increase in average bodyweight of animals trapped. The estimated population size has remained between 80 and 100 individuals since the translocation in 2011; however, up to 80% of these animals are new to the population suggesting a relatively high turnover of individuals on the island. Up to 10% of the females are breeding during the monitoring periods.

#### *Spectacled hare-wallaby*

The spectacled hare-wallaby translocation to Hermite Island was successful in the short and medium term and is considered self-sustaining in the long term (Table 2). Eighty seven percent of the of the initial radio-collared founders survived the first 4 months, and by September 2012, hare-wallabies had occupied most of Hermite Island and in 2015 they were estimated to occupy 94% of available habitat. In 2016, the population density was estimated at 0.6–0.7 hare-wallabies per hectare of occupied area, equating to approximately 500–600 hare-wallabies on Hermite Island. Hare-wallabies increased bodyweight by

**Table 3.** Current status of the 11 translocated populations, with estimates of their population and area of occupancy

	Estimated current population size at translocated site	Current distribution	Area of occupation
Golden bandicoot, Matuwa	130–680	Entire enclosure plus constant leakage to outside	>1100 ha
Golden bandicoot, Hermite Island	400–2000	Entire island plus nearby Buttercup Is. (5.5 ha)	1022 + 5.5 ha
Golden bandicoot, Doole Island	50–125	Entire Island	240 ha
Spectacled hare-wallaby, Hermite Island	400–600	Approximately 80–85% of the island	960 ha
Boodie, Matuwa	250–700 in enclosure	Entire enclosure plus occasional leakage to outside	1100 ha
Boodie, Alpha Island	200–500	Entire island, limited by burrowing habitat	103 ha
Brush-tail possum, Cape Range National Park	0	NA. Last detected 2014	0
Mala, Matuwa	Unsure, persistent	Spinifex areas of enclosure	500 ha
Djoongari, Matuwa	0	NA	0
Black and white fairy-wren, Hermite Island	60–100	Widespread but patchily distributed on Hermite Island	190 ha
Spinifexbird, Hermite Island	150–200	Widespread on Hermite Island; natural dispersal to nine nearby islands by 2019 (Alpha, Bluebell, Campbell, Crocus, Delta, Kurrajong, North West, Renewal, Trimouille)	620 + 210 ha

15–25% within 12 months of release on Hermite Island. Trapping up to 2016 indicated between 75% and 100% of females trapped were either carrying a pouch young or were lactating. Current population estimates are between 400 and 600 individuals. Genetic variability of this population in the long term is currently unknown, but tissue samples are retained by DBCA.

### *Boodie*

Both boodie translocations were considered successful in the short and medium term, with population estimates of approximately 250–700 individuals at Matuwa and 200–500 individuals on Alpha Island from an initial founder population of 65 and 40, respectively. The total area occupied by these two translocated populations is 1203 ha. The Matuwa boodie population was genetically supplemented with Dorre Island sourced animals that had been in the Dryandra captive breeding facility, increasing their genetic variation with no apparent negative impacts (Rick *et al.* 2019; Thavornkanlapachai *et al.* 2019). Short-term survival of released boodies was determined by mark–recapture methods and radiotracking of 15 individuals to be 82.5% (Dunlop 2015). By May 2012, 90% of trapped females carried pouch young or were lactating (Dunlop 2015). The boodie population at Matuwa is highly seasonal, with estimates varying between 250 and 700 individuals depending on rainfall (Lohr 2018). Boodies were active across all Alpha Island by April 2012, and 70% of the females were carrying pouch young. In April 2013, at least 67.5% of the founders were still alive, and new recruits to the population were recorded. Boodies are now occupying all available warren habitat on Alpha Island.

### *Mala*

Radiotelemetry provided some information on early survival and movements. Targeted trapping and spotlight monitoring of radio-tagged animals have indicated long-term survival of individuals in the enclosure, with good body condition and breeding activity (Sims *et al.* 2017). Mala are occasionally still trapped and captured on camera trap, and there is evidence of many tracks and scats throughout the spinifex areas of the enclosure. Attempts at population estimates within the enclosure via trapping and spotlight transects were unsuccessful due to low number of sightings (Sims *et al.* 2017; Lohr 2018).

## Discussion

### *Translocation success*

To our knowledge, this is Australia's largest multi-species fauna translocation project, involving 975 individuals of eight species released at five different locations. Of the 11 translocated populations, nine were a success against our longer term (5+ year) criteria. These translocations have also progressed the fauna reconstruction of the Montebello Islands, and the Matuwa Rangelands Restoration project. This program was built on the experience of over 230 fauna translocations for conservation in WA over the past 40 years (Morris *et al.* 2015).

Critical reviews of other translocations (Sheean *et al.* 2011; Pérez *et al.* 2012) have highlighted the failure of translocations and introductions due to lack of adequate resourcing and long-term commitment of the proponents to undertake suitable and adequate monitoring. The requirement by Chevron Australia to

offset the impact of the Gorgon LNG development site on the Barrow Island biodiversity values has allowed a translocation program to be undertaken that has resulted in the establishment of five populations of three threatened species and contributed to the down-listing of a fourth threatened species (boodie). The funding over a 12-year period has ensured that adequate monitoring and continued management of all the translocated populations occurred, enabling a quantitative assessment of the success/failure of each population.

### *Offset success*

For an offset to be a success, there should be measurable and enduring benefits that counterbalance the impacts of the development. A frequent issue with determining the effectiveness of offsets is the uncertainty around the counterfactual scenario (i.e. what would have happened to the species if there was no development and no offset). In this case, although the translocations were listed as high priority within species recovery plans or habitat reconstruction projects, it is unlikely that they would have ever occurred without significant coordinated funding. Therefore, the counterfactual scenario for these species is that those populations remained locally extinct and the 332 ha on Barrow Island would have remained intact. We used the three-criteria framework produced by May *et al.* (2017) to evaluate the success of this offset.

#### *1. The offset was successful in producing a desired or intended results*

The goal of the offset was to improve the conservation status of species impacted by the gas works and to contribute to faunal reconstructions elsewhere in the state. For an improved conservation status, the combined source and translocated populations must have a lower risk of extinction than the counterfactual scenario – a scenario where no gas development took place. For the purposes of gauging offset success, extinction risk can be measured as combination of the number of target species populations and total population size. Six different species gained one or more secure new populations, and at least five of the eight species translocated have the same or greater total population size than was predicted to occur prior to the development, within the first 10 years.

#### *2. The offset brought measurable, successful, long-term benefits*

The creation of new populations of threatened species that are severely limited in range provides a significant insurance against extinction by catastrophic impacts (Waller *et al.* 2017). At the time of this program, the golden bandicoot, spectacled hare-wallaby, boodie and black and white fairy-wren were regarded as Barrow Island endemic subspecies listed as threatened (Vulnerable) species (Table 1). Islands can function as both a refuge for threatened species as well as a death trap in catastrophic circumstances such as wildfire, disease, predator invasion or climate change, and establishment of additional populations of unique island taxa reduces their risk of extinction via catastrophe (Woinarski *et al.* 2011; Waller *et al.* 2017). For example, threatening processes on Christmas Island have proved overwhelming for several species recently, resulting in the extinction of the Christmas Island pipistrelle (*Pipistrellus murrayi*) and Christmas Island forest skink (*Emoia nativitatis*) and the extinction in the wild of the blue-tailed skink

(*Cryptoblepharus egeriae*) and Lister’s gecko (*Lepidodactylus listeri*) (Woinarski et al. 2017; Andrew et al. 2018). Establishing additional populations of unique Barrow Island taxa, and extremely limited taxa such as Tanami Desert mala reduces this risk, as well as enhances their overall conservation status.

There is also a significant ecosystem benefit to returning species to areas they previously inhabited, especially when considering species that provide ecosystem services (James and Eldridge 2007). The Montebello Islands presumably suffered considerable loss in ecosystem function in the local extinction of five species of medium sized mammals and small passerine birds exterminated by feral cats, black rats, and nuclear weapons testing (Burbidge et al. 2000; Burbidge 2004). Analysis of vegetation cover on the islands before, during, and after feral cat and black rat eradications revealed the negative effect black rats had on vegetation density despite occurrence of good growing conditions, whereas vegetation density continued to increase in response to rainfall after the release of native mammals (Lohr et al. 2014).

Returning iconic mammal species to Country has significant cultural importance to Indigenous custodians beyond pure population numbers. Species such as golden bandicoots, boodies and mala reintroduced to Matuwa are culturally significant for lore, food resources, and for the benefits they provide to Country. Traditional Owners were involved in the Matuwa translocations from the first release, and as owners of exclusive native title rights dictate the land management activities occurring at this site.

New populations of threatened species have the potential to enhance species genetic diversity. For example, the combination of boodies from two different genotypes has produced a hybrid variety considered to be more diverse and fitter than the substantially bottlenecked founder populations (Rick et al. 2019; Thavornkanlapachai et al. 2019).

3. The benefit of the offset counterbalanced significant residual impacts or risk of a project

In this case, we can demonstrate that several species made a net gain in habitat area and population that compensates for the 332 ha habitat loss on Barrow Island. While we do not have a population estimate due to their cryptic nature and difficulty of trapping in the presence of boodie and bandicoots, mala gained a new persistent population location without being impacted by the development, as they were not present on Barrow Island.

Benefits of these translocations extend beyond pure numbers of animals lost/gained, and that returning iconic species to Country is culturally important (Table 4). Species successfully translocated from Barrow Island gained additional population numbers (four of eight species; Table 4), distribution locations (six of eight species) and contributed to a reconstruction of the pre-European fauna. For example, golden bandicoots were successfully reintroduced to mainland and island habitats where they persisted, successfully bred and occupied the available habitat (Dunlop and Morris 2018). Estimates of new populations exceed predicted loss from Barrow Island (Table 4).

Biodiversity offsets are a popular tool due to their potential ability to meet the objectives of biodiversity conservation and

Table 4. Quantification criteria relating to the translocations of each species in order to assess the success of the offset

Taxa	Scientific name	Barrow Island population estimate	Estimated Barrow Island density (individuals per ha)	Estimated individuals lost due to development	Maximum % of Barrow Island population lost	New population(s) estimate	Net individual loss/gain	New population locations	Culturally significant reintroduction	Part of faunal reconstruction/ecosystem services
Barrow Island golden bandicoot	<i>Isoodon auratus barrowensis</i>	25 000–50 000	1.24–2.48	411–821	3	580–2805	gain	3	yes	yes
Barrow Island spectacled hare wallaby	<i>Lagorchestes conspicillatus</i>	7500–14 000	0.37–0.69	123–230	3	400–600	gain	1	no	yes
Barrow Island boodie	<i>Bettongia lesueur</i> ssp. Barrow and Boodie Islands	2300–3200	0.11–0.16	38–53	2	450–1200	gain	2	yes	yes
Common brushtail possum	<i>Trichosurus vulpecula hypoleucus</i>	20 000	0.99	329.00	2	0	loss	0	NA	NA
Barrow Island black and white fairy-wren	<i>Malurus leucopterus edouardi</i>	4000–12 000	0.20–0.59	66–197	5	60–100	same or loss	1	no	yes
Spinifexbird	<i>Eremiornis carteri</i>	17 800–24 623	0.88–1.22	293–405	2	150–200	loss	10	no	yes
Mala	<i>Lagorchestes hirsutus</i> ssp. Tanami Desert	(not from Barrow Island)		0	0	unsure	gain	1	yes	yes
Djoongari	<i>Pseudomys fieldi</i>	(not from Barrow Island)		0	0	0	same	0	NA	NA

economic development in tandem (Bull *et al.* 2013). Offsets may be used to counterbalance impacts on biodiversity values, ecosystem function or ecosystem services (May *et al.* 2017), and schemes are underway in nearly 40 countries (Maron *et al.* 2015). However, biodiversity offsets are rarely effective for their predetermined purpose, and lack rigorous standards for compliance, definitions of success or accurate tallies on the environmental losses that triggered them (Gibbons and Lindenmayer 2007; Maron *et al.* 2012). For example, an offset in NSW included the replacement of hollow bearing trees by nest boxes that were subsequently found to be poorly used by the intended species and therefore failed to be effective in counteracting the loss of hollow-bearing trees, a long term environmental impact (Lindenmayer *et al.* 2017). In Western Australia, a wealthy first-nation state with strict environmental regulation, at most 39% of offsets delivered an outcome and could be considered effective (May *et al.* 2017).

Since the translocations, the conservation status for boobies as a species has been revised downwards to be Conservation Dependent under the Western Australian *Biodiversity Conservation Act* 2016 but remains 'Vulnerable' under the *EPBC Act* 1999. This is in part due to the establishment of two additional populations within this project. While we can consider this offset to be an example of a net positive outcome for several threatened species and ecosystems, issues around defining nature as a tradable commodity, or eroding the value of reserves by allowing industry values to be prioritised still remain and must be treated with caution (McCauley 2006; Ives and Bekessy 2015).

The overall increased likelihood of population persistence for four of the eight Barrow Island species would suggest residual impacts have been counterbalanced. However, the predicted lifespan of the project is 40 years, and ongoing impacts are possible. Predicting long-term consequences for Barrow Island species viability is difficult based on short-term data, so ongoing monitoring at the source and translocation sites will be critical for detecting long-term population trends.

The key reasons for the successes of this offset in the first 10 years included:

- recognition of the conservation values of Barrow Island, it was guided by legislated agreements and government statements that outlined the nature and extent of the translocation program.
- it was a well-resourced program and had an ecologically sensible timeframe that allowed for adequate site management and monitoring.
- it was planned and implemented by an independent body (WA State Government), with oversight on funding, and in the context of a legislated agreement and government statements (Government of Western Australia 2018).
- the translocation sites had been subject to appropriate management such as eradication/control of introduced species well before this program commenced (Algar *et al.* 2002; Burbidge 2004; Jones *et al.* 2016).
- the value and timeframe of the offset included follow-up management and monitoring.
- it was a large resource, allowing for high quality translocations to be undertaken.

- the source locations supported large numbers of the targeted species allowing large numbers of founders to be translocated.
- the value of the offset was unusually high for the area of disturbance.

While the mammal transfers proceeded without incident, there were several unexpected deaths of birds between capture at source site and release at their destinations. In 2010, of the 31 fairy-wrens captured, 3 died and 1 was euthanised, and of the 38 spinifexbirds captured, three died prior to release. In 2011, of the 15 fairy-wrens captured, 5 died and of the 16 spinifexbirds, 4 died in the process of being translocated. Although appropriate husbandry protocols for malurids (Holland 2007) were followed, these guidelines seemed inadequate for the situation encountered on Barrow Island. Keeping very small wild-caught insectivores in a captive situation can be challenging, often with species-specific requirements (Shephard 1994; Holland 2007). The increased holding time on Barrow Island over two nights increased the risk of death for both species (Burbidge 2011), probably because of stress response through capture, transport and holding (Dickens *et al.* 2009). Age of the birds and stage of the breeding cycle may also have been relevant (birds might be more stressed at the beginning of a breeding season (Goutte *et al.* 2010)) but we did not have the opportunity to determine the stage of breeding season on Barrow Island where breeding is less predictable than on the mainland (Ambrose and Murphy 1994). For any future translocations of these species, we recommend birds be transported to the translocation site within 24 h of capture to minimise stress or disruption of social networks.

The failure of the brushtail possum translocation can be attributed to predation by the red fox. Prior to the translocation, the baiting regime was via aerially deployed dried meat baits. Although baiting was intended to be undertaken four times annually, several logistical issues meant that the baiting regime leading up to this translocation was interrupted. Genetic testing of swabbed brushtail possum collars indicated that at least six individual foxes were responsible for the possum deaths, indicating that the baiting had not been sufficiently effective. There may also have been issues of predator naivety for an island population not exposed to mammalian predators for ~8000 years (Whitwell *et al.* 2012; Jolly *et al.* 2018), and perhaps future attempts at reintroduction to this site should not involve animals sourced from predator naive populations. In 2015, an integrated fox and feral cat control program was commenced at Cape Range National Park. Using *Eradicat* baits has been successful at reducing fox activity to almost zero, and feral cat activity to 40–70% of pre-baiting activity.

## Conclusion

This series of translocations have improved our knowledge of reintroduction biology through the planning and implementation of large-scale translocations to improve the conservation outlook for threatened species. Several publications have resulted including from studies in reintroduction genetics (Ottewell *et al.* 2014; Rick *et al.* 2019; Thavornkanlapachai *et al.* 2019), predator–prey interactions (Wysong *et al.* 2019), parasite transmission ecology (Dunlop and Watson, in press),

cost–benefit analyses of enclosure fence building (Bode *et al.* 2012) the demography of translocated populations (Dunlop and Morris 2018) and their impact on the environment (Lohr *et al.* 2014; Chapman 2015a, 2015b). Other large-scale fauna translocations in WA, such as the reconstruction of the Dirk Hartog Island fauna (Morris *et al.* 2017), are building on the information resulting from this translocation program.

The program was successful in making major contributions to fauna reconstruction programs at the Montebello Islands, Doole Island and at the Matuwa Indigenous Protected Area. The conservation status of one species, the boodie, was improved with a change in IUCN listing from ‘Vulnerable’ to ‘Near Threatened’, largely because of these translocations. Three other species of threatened mammal and one bird have additional secure populations as a result of these efforts, and one species of mammal, rakali is scheduled to be reintroduced to the Montebello Islands in 2021–2023. To our knowledge, this is the largest translocation effort ever undertaken in Australia and is an example of a biodiversity offset that has provided a tangible benefit to threatened species and semiarid ecosystems.

### Conflict of interest

The authors declare no conflicts of interest.

### Acknowledgements

This project received funding as part of the additional environmental undertakings of the *Barrow Island Act 2003* to ameliorate any potential impacts of the Gorgon Gas Development on the Barrow Island fauna. We thank Chevron Australia for additional in-kind support (airfares, accommodation) and their Barrow Island based staff, particularly Lee Mould and Todd Baldock who assisted with the program; their efforts in assisting in the trapping program, coordinating laboratory facilities, vehicles and field equipment was greatly appreciated. Bristow Helicopters (Barrow Island) assisted with logistics of animal movements at Barrow Island airport, Jayrow Helicopters (Karratha) transported animals from Barrow Island to the Montebello Islands and Karratha airport. We thank Peter McGinty for his efforts in flying animals from Karratha to Exmouth, and to Lorna Glen. Andy Edwards and the crew of Keshi Mer were invaluable for their assistance accessing islands. We are grateful to the assistance provided by Barrow Island based DEC staff Peter Kendrick, Paul Connelly, Misty Shipway, Brad Daw, Kim Onton and Wes Manson. Numerous other DEC staff assisted with initial planning, logistics and field work, including John Angus, Sophie Arnall, Ann Biasol, Mark Blythman, Wes Caton, Sarah Comer, Alan Danks, Ryan Ellis, Sean Garretson, Sandy Grose, Brent Johnson, Marion Massam, Marika Maxwell, Bill Muir, Jon Pridham, Kelly Rayner, Karen Rusten, Chris Schroder, Colleen Sims, Adrian Wayne and many volunteers who assisted with the translocation and monitoring. The City of Karratha provided a suitable animal holding facility at Karratha airport. Cheryl Lohr provided helpful advice for the manuscript. This project was approved by the DEC Animal Ethics Committee (approvals 2010/01, 2010/02, 2010/13, 2010/14 and 2013/32).

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Handling editor: Mike Calver

## Appendix 1.

### *Translocation site and species selection*

Three island and two mainland sites were selected for the translocations (Table 1; Fig. 1).

Hermite Island (836 ha; 20°28.04'S, 115°31.40'E) is the largest island in the Montebello Island Conservation Park and is located approximately 30 km north of Barrow Island Nature Reserve (Fig. 1). Until the early 20th century, Hermite Island supported golden bandicoots, spectacled hare-wallabies, spinifexbirds, and possibly black-and-white fairy-wrens (Montague 1914; Burbidge *et al.* 2000, 2019). Water rats persisted until the 1980s, but have not been detected on any subsequent survey (Burbidge 2004; Richardson *et al.* 2006) despite intensive management presence on the islands (Algar *et al.* 2002; Lohr *et al.* 2014). The proposal for the re-establishment of these species on Hermite Island was part of the Montebello Renewal program following the successful eradication of feral cats and black rats from the archipelago (Algar *et al.* 2002; Burbidge 2004).

Another island in the Montebello group, Alpha Island (86 ha; 20° 24.67'S, 115° 31.65'E) was selected as a conservation introduction site for the boodie (Barrow Island subsp.) as this taxon was only known from two other sites, Barrow and Boodie Islands. This island has been disturbed considerably as it was the site of an atomic weapons test by the British in 1956. No other mammal species were recorded on Alpha Island.

Doole Island Nature Reserve (210 ha; 22°27.92' S, 114°9.89'E) lies at the southern end of Exmouth Gulf, approximately 230 km south-west of Barrow Island. No native mammal species or introduced animal species have been recorded on the island; however, djoongari were introduced for conservation purposes in 1993 but did not persist (Morris *et al.* 2000). Doole Island is within the former range of the golden bandicoot (McKenzie *et al.* 2008, 2013), and has vegetation assemblages (*Acacia* shrubs, tussock grasses on sandy soils) considered suitable for golden bandicoots.

Matuwa Indigenous Protected Area (256 000 ha; 26°13.75'S, 121°19.41'E) is an ex-pastoral lease (formerly Lorna Glen) purchased by the State Government for conservation purposes in 2000. It is located 160 km north-east of Wiluna in the northern

Goldfields region, and ~820 km south-east of Barrow Island. A successful Native Title claim resulted in an Indigenous Protected Area being declared in 2015. The property extends across the boundary of the Gascoyne and Murchison Interim Biogeographic Regionalisation for Australia regions (Thackway and Cresswell 1995), and consequently supports a diversity of landscape systems. The area once also supported a range of small and medium-sized mammals, many of which are now extinct in the rangelands (Chapman and Burrows 2015). Pre-European skeletal remains of golden bandicoots were found at two locations on Lorna Glen and neighbouring Earahedy stations (Baynes 2006), and the multitude of abandoned boodie warrens throughout the area indicates their former presence at the site, potentially until the 1950s (Abbott 2008). Matuwa is the site of an integrated rangelands restoration project, including feral cat control, implementation of a small mosaic fire regime and control of feral herbivores, followed by the reintroduction of 11 species of medium-sized mammals (Algar *et al.* 2013; Lohr 2018). Boodies, golden bandicoots and mala were among those species selected for reintroduction. The reintroduction strategy involved the construction of an 1100 ha introduced predator proof enclosure into which some of the more predator naïve reintroduced mammals would be initially located (Bode *et al.* 2012). Following acclimatisation to the environment and native predators, and increasing abundances, the intention was to translocate the mammals outside the fenced enclosure, but within the area subject to ongoing feral cat control.

Cape Range National Park (CRNP, 50 600 ha; 22°10.80'S, 113°54.16'E) is located adjacent to the town of Exmouth on the Cape Range Peninsula, ~200 km south-west of Barrow Island. Thirty-eight species of ground-dwelling native mammals have been recorded from the Cape Range peninsula, but 27 of these have become locally extinct and only 11 species persist now. Species that once occurred in this area include the golden bandicoot, boodie and brushtail possum (Baynes and Jones 1993). Fox control to protect nesting marine turtles and rock-wallaby (*Petrogale lateralis*) populations has been underway at CRNP since the 1980s. In 2015, an integrated fox and feral cat control program was commenced, with the goal of protecting critical weight range species.