Project Plan SP 2014-003

Cat Eradication on Dirk Hartog Island

Animal Science

Project Core Team

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Approved and active

Document endorsements and approvals as of Dec. 12, 2017, 4:46 p.m.

Project Team	granted
Program Leader	granted
Directorate	granted
Biometrician	granted
Herbarium Curator	not required
Animal Ethics Committee	not required

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Science and Conservation Division Program

Animal Science

Parks and Wildlife Service

Service 2: Conserving Habitats, Species and Ecological Communities

Project Staff

Role	Person	Time allocation (FTE)
Supervising Scientist	Dave Algar	0.5
Technical Officer	Gary Desmond	1.0
Technical Officer	Jason Fletcher	1.0
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Related Science Projects

2003-005 Development of effective broad-scale aerial baiting strategies for the control of feral cats

Proposed period of the project

Jan. 2, 2014 – Dec. 31, 2018

Relevance and Outcomes

Background

There is extensive evidence that domestic cats (Felis catus) introduced to offshore and oceanic islands around the world have had deleterious impacts on endemic land vertebrates and breeding bird populations (eg. van Aarde 1980; Moors and Atkinson 1984; King 1985; Veitch 1985; Bloomer and Bester 1992; Bester et al. 2002; Keitt et al. 2002; Pontier et al. 2002; Blackburn et al. 2004; Martinez-Gomez and Jacobsen 2004; Nogales et al. 2004; Ratcliffe et al. 2009; Bonnaud et al. 2010). Feral cats have been known to drive numerous extinctions of endemic species on islands and have contributed to at least 14% of all 238 vertebrate extinctions recorded globally by the IUCN (Nogales et al., 2013). In addition, predation by feral cats currently threatens 8% of the 464 species listed as critically endangered (Medina et al. 2011; Nogales et al. 2013). Island faunas that have evolved for long periods in the absence of predators are particularly susceptible to cat predation (Dickman, 1992). Dirk Hartog Island–once a high biodiversity island–is no exception. On Dirk Hartog Island (620km2), which is the largest island off the Western Australian coast (Abbott and Burbidge 1995), 10 of the 13 species of native terrestrial mammals once present are now locally extinct (Baynes 1990; McKenzie et al. 2000) probably due to predation by cats (Burbidge 2001; Burbidge and Manly 2002). The extirpated species of mainly medium-sized mammals include: boodie (Bettongia lesueur),woylie (Bettongia penicillata), western barred bandicoot (Perameles bougainville), chuditch (Dasyurus geoffroii), mulgara (Dasycercus cristicauda), dibbler (Parantechinus apicalis), greater stick-nest rat (Leporillus conditor), desert mouse (Pseudomys desertor), Shark Bay mouse (Pseudomys fieldi), and heath mouse (Pseudomys shortridgei). Only smaller species still inhabit the island: ash-grey mouse (Pseudomys albocinereus), sandy inland mouse (Pseudomys hermannsburgensis), and the little long-tailed dunnart (Sminthopsis dolichura). It is possible that the banded hare-wallaby (Lagostrophus fasciatus) and rufous hare-wallaby (Lagorchestes hirsutus) were also on the island as they are both on nearby Bernier and Dorre Islands, and were once on the adjacent mainland. The island also contains threatened bird species including: Dirk Hartog Island white-winged fairy wren (Malurus leucopterus leucopterus), Dirk Hartog Island southern emu-wren (Stipiturus malachurus hartogi), and the Dirk Hartog Island rufous fieldwren (Calamanthus campestris hartogi). A population of the western spiny-tailed skink (Egernia stokesii badia) found on the island is also listed as threatened. Since the 1860s, Dirk Hartog Island has been managed as a pastoral lease grazed by sheep (Ovis aries) and goats (Capra hircus). More recently, tourism has been the main commercial activity on the island. Cats were probably introduced by early pastoralists and became feral during the late 19th century (Burbidge 2001). The island was established as a National Park in November 2009, which now provides the opportunity to reconstruct the native mammal fauna (Algar et al. 2011). Dirk Hartog Island could potentially support one of the most diverse mammal assemblages in Australia and contribute significantly to the long-term conservation of several threatened species. Successful eradication of feral cats would be a necessary precursor to any mammal reintroductions.

Aims

This project aims to eradicate feral cats on, and improve the biodiversity values of Dirk Hartog Island.

Expected outcome

This project aligns with the Corporate Plan and Science Division Strategic Plan for Biodiversity Conservation Research as outlined below.

Corporate Plan

1. Conserving biodiversity

1.5 Protect diversity from threatening processes, agents and activities including pest animals

Expand and enhance the Western Shield wildlife recovery program incorporating introduced predator control

Expand programs for the control of pest animals

Implement integrated management strategies to control pests and diseases

Give special attention to the protection of internationally recognised natural values of World Heritage sites

Science Division Strategic Plan for Biodiversity Conservation Research

G2 Understand the threats to biodiversity and develop evidence-based management options to ameliorate threats

Threatened species and communities

2.7 Participate in active adaptive management programs that will lead to improved conservation status of threatened arid zone medium-sized mammals (links with 2.2), a group that has declined significantly since European settlement. Adaptive management plans have been developed for Dirk Hartog Island.

Threatening processes

2.20 Complete research into sustained, effective control of feral cats across a range of biomes.

2.34 Develop safe and effective control technologies for feral cats, camels, goats and pigs on DPaW-managed lands.

G6 Promote and facilitate the uptake of research findings and communicate the contribution of science to biodiversity conservation and natural resource management.

This process has already commenced with a number of manuscripts published on preliminary work (see below).

Knowledge transfer

This will be among the largest islands in the world where feral cat eradication has been attempted and there will be global interest in the outcome of this project and the techniques used. Knowledge and technology transfer to other agencies contemplating cat eradications on islands will be through publication of manuscripts in scientific journals and presentations at various conferences.

Tasks and Milestones

- 2013-14 Construction of infrastructure southern site, cat barrier fence and monitoring grid access. Baiting southern section late autumn/early winter.
- 2014-15 Monitoring and trapping programs southern site. Construction of infrastructure northern site and monitoring grid. Baiting northern section late autumn/early winter. Use of detector dogs in southern section late winter.

- 2015-16 Monitoring and trapping programs northern site. Use of detector dogs in northern section late winter.
- 2016-17 Surveillance monitoring.
- 2017-18 Surveillance monitoring.

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Study design

Methodology

Site Description

Dirk Hartog Island is an area of 620km2 (25°50'S 113°0.5'E) and lies within the Shark Bay World Heritage Property of Western Australia. The island is approximately 79km long and a maximum of 11km wide with its long axis in a south-east to north-west direction. Vegetation on the island is generally sparse, low and open and comprises spinifex (Triodia) hummock grassland with an overstorey of Acacia coriacea, Pittosporum phylliraeoides over Acacia ligulata, Diplolaena dampieri, Exocarpus sparteus shrubs over Triodia sp., Acanthocarpus preissii and Atriplex bunburyana hummock grasses, chenopods or shrubs (Beard 1976). Adjacent to the western coastline is mixed open chenopod shrubland of Atriplex sp., Olearia oxillaris and Frankenia sp. and slightly inland in more protected sites, Triodia plurinervata, Triodia sp., Melaleuca huegelii, Thryptomene baeckeacea and Atriplex sp.. There are patches of bare sand and several birridas (salt pans). On the east coast there are patches of mixed open heath of Diplolaena dampieri, Myoporum sp. and Conostylis sp. shrubs (Beard 1976).

The climate of the region is 'semi-desert Mediterranean' (Beard 1976; Payne et al. 1987). The mean annual rainfall for Denham (recording station 006044, located 37km to the east of Dirk Hartog Island) is 224mm (Bureau of Meteorology 2013; long-term records 1893-2013). The wettest month is June with an average of 55mm. February is the hottest month with a mean daily maximum of 31.8°C while July is the coolest month with mean daily maximum of 21.7°C (Ibid.). Prevailing winds are southerly in the morning swinging to the south-west in the afternoon with the sea breeze (Bureau of Meteorology 2013).

Dirk Hartog Island is classified as a 'Coastal Dune' geomorphic district (Payne et al. 1987) and consists of coastal dunes and undulating plains of shallow calcareous sand over limestone or calcrete. Five land systems occur on the island, three of which (Coast, Edel and Inscription collectively form 99% of the island; Payne et al. 1987) and are described below: -

Coast–occurs along the entire western side of the island and consists of large long-walled parabolic dunes and narrow swales, unstable blow-out areas and bare mobile dunes, minor limestone hills and rises and steep sea cliffs (41.9%);

Edel–occurs in eastern and south-eastern parts of the island and consists of undulating sandy plains with minor low dunes, limestone rises and saline flats (32.5%);

Inscription–is found in the north-east and central-east of the island. It consists of gently undulating sandy plains over limestone (24.3%);

The two remaining land systems are Birrida (0.7%) and Littoral (0.6%).

Since the 1860s, Dirk Hartog Island has been managed as a pastoral lease grazed by sheep (Ovis aries) and goats (Capra hircus). More recently, tourism has been the main commercial activity on the island. Cats were probably introduced by early pastoralists and became feral during the late 19th century (Burbidge 2001). The island was established as a National Park in November 2009, which now provides the opportunity to reconstruct the native mammal fauna (Algar et al. 2011). Dirk Hartog Island could potentially support one of the most diverse mammal assemblages in Australia and contribute significantly to the long-term conservation of several threatened species. Successful eradication of feral cats would be a necessary precursor to any mammal reintroductions.

Cat Eradication

Control of feral cats is recognised as one of the most important fauna conservation issues in Australia today and as a result, a national 'Threat Abatement Plan (TAP) for Predation by Feral Cats' has been developed (EA 1999; DEWHA 2008). The TAP seeks to protect affected native species and ecological communities, and to prevent further species and ecological communities from becoming threatened. In particular, the first objective of the TAP is to: -

- Prevent feral cats from occupying new areas in Australia and eradicate feral cats from high-conservation-value 'islands'

There are a number of obligate rules that must be met for an island-based species eradication program to be successful (Parkes 1990; Bomford and O'Brien 1995; Myers et al. 2000).

1. community support for the program;

2. all target species are at risk;
3. the population can be killed faster than replacement;
4. reinvasion must be prevented. Eradication will only be temporary if the influx of individuals continues;
5. the target species can be detected at relatively low densities. Easy detection allows residual pockets of individuals to be identified and targeted for treatment;
6. the cost can be justified and resources must be sufficient to fund the program to its conclusion.

In addition to these rules, an additional requirement for successful eradication must be that the lines of authority must be clear and must allow the individual or lead agency to take all necessary actions (Myers et al. 2000).

The eradication of feral cats proposed for Dirk Hartog Island follows a similar course of action (phases) outlined by Ramsey et al. (2011). Their first phase involves a succession of removal events that reduce the pest population to such low levels that further efforts often do not find and remove any more animals. Their second phase attempts to validate or assess whether in fact this lack of detection means eradication may have been achieved. Assuming no more pests are found, their third phase is one of surveillance to confirm the assessment and it may continue until a decision is made to stop and declare the eradication a success. Detecting survivors and interpreting the lack of such detections to set stop rules are critical elements of this strategy (Ibid.). Their process collects spatially explicit data on the numbers of animals removed and on the effort to do this as it proceeds.

The size of Dirk Hartog Island, in particular its length, pose logistical constraints on conducting an eradication campaign across the entire island simultaneously. It is not practical or feasible to monitor for cat activity over such a large area and as such, the eradication campaign will be conducted in stages. Each of these stages is outlined briefly below and then each of the techniques to be used are detailed further later in this document.

- Stage 1 (January-April 2014) will be dedicated to establishment of infrastructure in the southern section (Herald Bay) including accommodation and equipment storage, installation of the southern monitoring track network and construction of the barrier fence (see below for details of barrier fence-line). Infrastructure construction will be transportable to provide flexibility in its use and options for utilization elsewhere at the completion of the project. Transport of people, equipment and supplies will follow the biosecurity protocols developed for Dirk Hartog Island to ensure that this project does not introduce or spread additional invasive species on Dirk Hartog Island. Time restrictions due to delays in delivery of the barge have meant that only infrastructure south of the barrier fence can be established within this time period. Infrastructure north of the fence (Sandy Bay accommodation site) and installation of the northern monitoring track network will need to be established when time permits later in 2014.

- Stage 2 (May/June 2014-May/June 2015) [Phase 1] a baiting campaign will be conducted May/June 2014 south of the cat barrier fence, an area of approximately 220km2. An intensive monitoring program will be adopted following the baiting campaign to locate any cat activity. Where warranted, ground-baiting and trapping will be implemented to remove any cats that remain. [Phase 2] At the completion of the monitoring/trapping program, a team of detector dogs and their handlers will be contracted to independently verify eradication.

- Stage 3 (May/June 2015-May/June 2016) [Phase 1] a baiting campaign will be conducted May/June 2015 north of the cat barrier fence, an area of approximately 420km2. As above, an intensive monitoring program will be adopted following the baiting campaign to locate any cat activity. Where warranted, ground-baiting and trapping will be implemented to remove any cats that remain. [Phase 2] At the completion of the monitoring/trapping program, a team of detector dogs and their handlers will be contracted to independently verify eradication.

- Stage 4 June 2016-June 2018) [Phase 3] a two year surveillance monitoring program will be instigated for a further two years prior to any native species reintroductions.

Note that delays in getting a barge built and delivered have resulted in a number of setbacks to the start date for this campaign. It is now anticipated that the program will commence at the beginning of 2014 and will be conducted over a five-year period (2014-2018). The barge is a critical component to the conduct of the project and will be used for to transport infrastructure materials, vehicles, equipment and personnel to the island.

Cat Barrier Fence

A temporary electrified cat barrier fence is being constructed east-west across the island at Herald Bay (13km in length) effectively dividing the island into two allowing a concentration of control efforts in the two discrete sections of the island (see location Fig. 4). Use of an interior fence has been demonstrated to reduce the cost and increase the overall likelihood of successful eradication on the island (Bode et al. 2013).

The fence design is based on those described in Moseby and Read (2006) and Robley et al. (2006) and will consist of an 1800mm high 'rabbit wire' fence with a 600mm 'floppy' overhang and a 300mm 'foot' buried into the ground (see example shown at Fig. 1). Due to the strong prevailing southerly winds (right angles to the fence) the support poles (star pickets) will be positioned every 6m with galvanised strainer posts every 100m. Four high tensile galvanised wires will be installed–one at ground level, one at 750mm high, another at 1500mm and the highest at 1800mm. The fence mesh will consist of 40mm diameter hexagonal mesh 'rabbit netting'. Figure 1 shows the lower parts of the fence as 30mm mesh; however this is not required for this fence as the design shown at Figure 1 was to prevent infant rabbits from passing through (rabbits are not present on Dirk Hartog Island). The mesh is to be fixed to the northern side of the fence, with overhang and foot facing to the north. The overhang is to be shaped using 1200mm lengths of heavy gauge galvanised wire that is woven through to the top 60mm of the mesh (i.e. 1200mm to 1800mm height) and then continued through the entirety of the overhang. The 300mm foot is to be bent in the lower part of the mesh and buried into the ground at a slight angle so that the end of the foot is approximately 100mm deep (see Fig. 2).

Figure 1. Example of 1800mm fence with 600mm floppy top and 300mm foot, taken from Robley et al. (2006), fence design 1

Whilst erosion is not envisaged to be a problem because the fence is at right angles to the prevailing winds (Oceanica 2013), the fence will be monitored on a very regular basis enabling inspection of any points where erosion of the foot is possible (eg dunes) and can be modified as necessary. Where the fence travels over any limestone outcropping, especially at the western and eastern ends, the foot of the fence will be secured to the limestone in such a fashion that there are no gaps between the foot and the immediate substrate. A galvanised gate is to be installed at the intersection of the main track that runs north along the eastern coast to permit vehicle movement. The same mesh material and design, including overhang, is to be used on the gate as is on the fence. The gate will be positioned so that it swings 30mm above the level of the track. A concrete mesh barrier will be placed under the gate.

The fence will be equipped with two active electric wires, one at 1500mm high and the other at approximately 1800mm high (different to that in Figure 1). Wires will be positioned 70mm from the fence (anything over 80mm has been found generally ineffective for cats). Where the fence crosses the main track the electrification wires will pass underground in conduit. The gate will not be electrified, as it is anticipated this could present problems arising from tourist activities. The powering (energizer) system will be of sufficient power to energise the active wiring to between 5-7kV along the length of the fence. The energiser will be powered by a deep cycle or marine battery in combination with a solar panel, the combination of which will be capable of supplying the required power 24 hours a day, 365 days a year.

Figure 2. Fence design showing the foot bent into the lower netting and wire overhang support

The fence is to end within 2m of the limestone cliff at the west end of the island and within 1m of the eastern end of the island. The design comprises a swinging gate at the end of the fence that has light chain hanging from its base and dangling over the cliff edge. For maintenance purposes, the locking pins of the gate can be lifted and it can be swung landward. The electrified wiring along the fence can be extended onto the gate. The gate will have a floppy top the same as that on the fence. Motion-activated sirens and strobe lights will be used to deter cats from approaching the fence-end. To monitor possible incursions a number of motion detector cameras will be installed at both ends of the fence and a network of traps installed to capture any invading cats. Baits will also be deployed 5km past the barrier fence-line to reduce incursion pressure by providing a buffer zone into which cats would initially disperse.

Figure 3. Fence-end design

Baits and Baiting Application

Baiting is recognised as the most effective method for controlling feral cats on mainland Australia (Short et al. 1997; EA 1999; Algar and Burrows 2004; Algar et al. 2007; Algar et al. 2013a), and has been used as the primary technique for eradicating cats on islands (Algar et al. 2002; Algar et al. 2010). World-wide, cat eradications have been attempted on a number of islands with 82 successful campaigns that range in size from 5-29,000ha (Campbell et al. 2011). There have also been eradication attempts on a further 15 islands that have failed (Ibid.). All successful campaigns on islands >2,500ha utilised primary poisoning with toxic baits, with the exception of Santa Catalina (3,020ha). Interestingly, seven failed campaigns on the five largest islands (all >400ha) did not use toxicants (Campbell et al. 2011).

The bait designed and developed by DPaW researchers for the control of feral cats is known as Eradicat®. These baits are manufactured at the DPaW Bait Factory at Harvey. The Eradicat® bait is described in detail in Algar and Burrows (2004) and Algar et al. (2007). Eradicat® baits contain 4.5mg of directly injected toxin '1080' (sodium monofluoroacetate). Frozen baits will be transported to Denham in the dedicated Western Shield bait truck. Prior to deployment, baits will be distributed on established bait racks on Peron Peninsula so they may thaw and 'sweat'. This process causes the oils and lipid-soluble digest material to exude from the surface of the bait making the bait more attractive to feral cats.

To optimise baiting efficacy, it is essential that baiting campaigns are conducted prior to the onset of late autumn/winter rainfall, which long-term weather records suggest for the Shark Bay area often begins in late May/early June (Bureau of Meteorology 2013). A dedicated baiting aircraft is used to deploy the baits at previously designated bait drop points. The baiting aircraft flies at a nominal speed of 160kt and 500ft (Above Ground Level) and a GPS point is recorded on the flight plan each time bait leaves the aircraft. A bag of 50 baits is loaded into the 'cat bait carousel', through a funnel, for each drop. The carousel is rotated by a DC motor speed controller which sets the carousel rotation speed (and therefore the bait distribution distance). The carousel has been designed with five segments separated by vanes so that, when loaded, the baits are distributed reasonably evenly around the segments of the carousel. The baits are loaded prior to the 'aerial baiting computer system' initiating the bait drop. When triggered by the 'aerial baiting computer system', the carousel rotates one complete revolution distributing the cat baits over the distance set by the carousel motor speed controller. The bombardier releases a bag of 50 baits into each 1km map grid, along flight transects 1 km apart, to achieve an application rate of 50 baits km-2. The ground spread of 50 baits is approximately 200 x 40m (Algar et al. 2013b).

A 25,000ha, pilot study was conducted on Dirk Hartog Island in March-May 2009 to assess the efficacy of the current aerial baiting strategy, the primary control technique to be used in the proposed eradication campaign (Algar et al. 2011). Prior to the baiting program, a number of cats were fitted with GPS data-logger radio-collars, to assess baiting efficacy and also to provide detailed information on cat activity patterns. Two independent methods were used to monitor baiting efficacy. Baiting efficacy was firstly determined from the percentage of radio-collared cats found dead following the baiting program. The second method involved surveys of cat activity at sand plots and along continuous track transects to derive indices of activity. The difference in indices pre- and post-baiting was then used as a measure of baiting efficacy.

The pilot study achieved very positive results with radio-collar returns (12 of 15 radio-collared cats ate at least one toxic bait) and indices of activity indicating that 80+% of the feral cat population died following bait consumption (Algar et al. 2011). These results demonstrated that a baiting program, with the Eradicat® bait as the primary control technique, would be highly effective in an eradication campaign on Dirk Hartog Island. High baiting efficacy was achieved despite what appeared to be a plentiful prey resource on the island with an abundant rodent population present following significant rainfall events over the previous two years. Several radio-collared feral cats were also implicated in predation of Loggerhead turtle (Caretta caretta) hatchlings (Hilmer et al. 2010). It is possible that an even greater baiting efficacy could have been achieved when the prey resource was less abundant as optimal rates of bait consumption by feral cats are achieved during periods of food stress (Short et al. 1997; Algar et al. 2007; Algar et al.2013a).

Consumption of baits is not only a function of bait attractiveness and palatability but also bait encounter (Algar et al. 2007). All cats in this study should have had some opportunity to encounter baits given the baiting intensity and pattern flown by the aircraft. Despite being opportunistic predators, cats will only consume a food item if they are hungry (Bradshaw 1992); if a bait is encountered when the animal is not hungry it may not be consumed regardless of the attractiveness of the bait. Therefore baiting intensity and distribution pattern as well as bait longevity are critical components of successful baiting campaigns. Analysis of daily cat movement patterns on the island and encounter rates for various transect spacings (see Monitoring) suggest that reducing flight path widths to 500m may result in increased bait encounter, particularly in the short-term and may further improve baiting efficacy (Algar et al. 2011). However, increasing baiting intensity beyond 50 baits km-2 along 1.0km flight paths will not necessarily improve baiting efficacy (Algar and Burrows 2004). The home ranges inhabited by several cats in this study were almost centrally located between aerial bait transects and as a result these animals had less opportunities to encounter a bait. These cats would have experienced a greater bait encounter rate if the flight lines were at 0.5km intervals rather than 1.0km.

All three radio-collared cats that survived the baiting campaign were in excellent body condition and were obviously not food stressed. Two of these animals occupied/patrolled beaches while the remaining cat was utilising other food sources as it was not thought to be accessing beaches where turtle hatchlings were available. All three animals frequented one or more 'Bait Exclusion Zones' but also spent time where bait encounter was likely. The Western Australian guidelines for use of 1080 baits provides for 'Bait Exclusion Zones' of 500m radius at and around sites subject to high human visitation. The eradication plan will seek exemption from the requirement to establish 'Bait Exclusion Zones', as these may provide a bait-free refuge for cats, particularly those with small home ranges such as sub-adults.

The information gained from this pilot study has been used in the planning of flight transects to maximise the likelihood of feral cats encountering a bait within the shortest possible time, rather than arbitrarily assigning transect spacing. This will optimise baiting efficacy and provide a more cost-effective baiting campaign. The modifications proposed to the current baiting regime will maximise the likelihood of the entire cat population encountering a bait(s) when hungry. Modifying the bait pattern to provide baits in more complex topography such as that fringing the coast is also proposed. Unlike baiting campaigns on mainland sites where baits are required to be laid annually to control cat numbers, a single-site baiting leading to eradication of cats on Dirk Hartog Island will provide extremely cost-effective control.

In summary, the results obtained in the pilot trial demonstrated that a baiting program, with the Eradicat® bait as the primary control technique, will be highly effective in an eradication campaign on Dirk Hartog Island. The effectiveness of this management tool on the island could be further optimised by integrating the following recommendations: -

- Baiting intensity should be increased from 50 to 100 baits/km2. This would maximise the likelihood of the entire cat population encountering a bait (s) when hungry;
- Modifying the bait pattern to provide baits in narrower transects as well as more baits in complex topography such as dunes and/or swales. Cats would experience a greater bait encounter rate if the flight lines were at 500m intervals rather than 1000m;
- Considering whether 'Bait Exclusion Zones' are necessary on the island as they would provide a bait free refuge for cats particularly those with small home ranges, such as sub-adults;
- Timing of bait application could be delayed to allow for cooler weather (but not rain) and completion of turtle hatching.

It is unlikely that an aerial baiting program alone will result in cat eradication. Following the monitoring survey for cat activity post-baiting (see Monitoring), a ground baiting program will be undertaken with baits either laid by hand or strung at 'Bait Suspension Devices' (see Algar and Brazell 2008; Algar et al. in press) in the vicinity of cats that are still alive. This will then be followed by the intensive monitoring and trapping campaign to remove cats that survive baiting outlined below.

Monitoring

Monitoring is to be conducted within an adaptive management framework to inform decision making, whereby actions will be taken if/when certain events occur. The monitoring program will provide information on where control effort is required and whether additional measures and/or resources are needed. Decisions must be made while there is opportunity to act; delaying decisions will remove these chances and risk the success of the eradication campaign. This framework will allow project management to change tactics as results dictate; flexibility in planning is therefore essential. A key component of this eradication program is to employ monitoring methods that will provide quantitative estimates of the effectiveness of control operations; the techniques must also be capable of detecting animals at low density populations. Of necessity, the monitoring of feral cat activity must be conducted across the entire island and requires the provision of suitable access (see below; Survey tracks). Monitoring of cat activity on the island will serve four purposes: -

1. Firstly, monitoring surveys conducted pre- and post-baiting will be used in conjunction with radio-collar returns to assess baiting efficacy;
2. Secondly, following the baiting campaigns an intensive monitoring program will be adopted to locate any cat activity and where warranted, ground-baiting and a trapping program will be implemented to remove any cats that remain;
3. Thirdly, following the completion of each of the two intensive monitoring programs (southern [winter 2015] and northern sections [winter 2016]) detector dogs and their handlers will be contracted to verify the absence of cats and to independently corroborate that eradication has been successfully achieved;
4. Finally, surveillance monitoring for cat activity will then be conducted on a seasonal basis for a following two years prior to the native species reintroductions, as an insurance policy that no cats have been overlooked or reintroduced.

Survey tracks

Much of the former pastoral road network has regenerated, with many roads and fence lines shown on the pastoral plan being impassable and in many instances difficult to identify. The monitoring program is to be conducted from ATVs which will need to traverse the entire island in a safe and efficient manner. Prior to implementing the monitoring program, it will be necessary to construct a grid network of survey tracks to allow monitoring of cat activity across the island. The spacing of these tracks must of necessity be of width that will permit detection of any cat during the survey period (i.e. two weeks each month) and therefore provide confidence in the survey technique. Information obtained from the GPS data-logger radio-collars during the pilot study (Algar et al. 2011) was used to determine the likelihood of detection and to optimise the proposed spacing of the survey tracks for the eradication program. Analysis was performed in R2.9.0. (R Development Core Team 2009). Data from all cats alive immediately prior to baiting were utilised but only locations with an HDOP6 are less precise and are more likely to have shown a cat crossing a track line which it did not actually cross. For each simulation, four sets of track lines were located at random starting points and spaced at intervals of 500, 1,000, 1,500 and 2,000m respectively. Track lines were parallel to the long axis of the island and the orientation of the dune system. This is the preferred course for survey tracks for logistic reasons and to minimise disturbance and erosion to dunes. For each set of track lines, the time from initial collaring of each cat to when it would have first crossed the track line was determined. This process was repeated 5,000 times with different random starting locations for the track lines each time. For each spacing (500, 1,000, 1,500 and 2,000m), the 95th percentile of the time to cross a track line for each cat was interpreted as the time it would take to be 95% sure of detecting that cat during survey. Analysis of daily movement patterns, pooled for all cats, indicated that the time (mean + s.e.) to encounter track lines spaced at 500, 1000, 1500 and 2000m was 1.0 + 0.2, 1.8 + 0.5, 4.6 + 1.1 and 12.2 + 3.2 days respectively. Cat movement data suggest that placement of monitoring tracks at a width of approximately 2.0km across the full length of the island will be sufficient to enable detection of these animals within each survey period. Choice of this spacing for the monitoring tracks and separation of camera traps (see later) is further strengthened by data collected on home ranges (100% MCP) of the radio-collared cats in the pilot study which were 12.7 km2 for males and 7.8km2 for females (Johnston et al. 2010). Thus, every cat has at least some probability of its sign being observed or the animal being photographed (i.e., one camera trap within each animal's home range).

Placement of monitoring tracks will strike a balance between limiting vegetation disturbance and erosion and optimizing cat encounters during survey periods. The location of the access route (tracks) has also taken into account factors such as logistics and efficiency of servicing. The track network linking the monitoring plots utilises existing tracks and fence lines where possible and has considered visual impacts and erosion potential. There is a total of 184km of secondary tracks on the island of which 103km will be used to access some of the monitoring plots and 62km will need to be maintained to provide ATV access. Approximately 147 km of new track will be created across the island. Any new tracks will be established using a rubber tracked skid steer loader (Positrack) fitted with a front mounted mulcher that will permit vegetation rehabilitation of the survey tracks at the completion of the program. The new tracks will be the width of the Positrack (less than 2m wide) and the vegetation mulched as the machine moves forward along the proposed alignment, leaving the mulched vegetation laid on the track as it progresses. Natural openings in the vegetation will be used in preference to clearing vegetation. The new tracks were initially located by DPaW staff (primarily P. Rampant; Remote Sensing Officer and J. Asher; Project Manager 'Dirk Hartog Island Restoration') using a number of software packages and datasets (listed by Oceanica 2013). Several minor changes were made to the location of these tracks following consultation with Oceanica who have endorsed track location and are considered appropriate to minimise the risk of erosion (Oceanica 2013).

The following guidelines were used to help to determine the track position (Oceanica 2013):

1. Utilise existing tracks and fence lines;
2. Relocate monitoring points to existing tracks if point is within a few hundred metres;
3. Avoid placing monitoring points on birridas or on active dunes;
4. Avoid areas of floristic, Aboriginal heritage or European heritage importance;
5. Avoid unstable and sensitive vegetation;
6. Avoid crossing dunes;
7. Minimise slope on proposed tracks;
8. Position tracks at low points in the terrain;
9. Minimise track visibility when approaching the island via boat;
10. Minimise visibility down the proposed tracks from main access roads;
11. Minimise wind tunnel effect from prevailing southerly wind by avoiding long straight north-south tracks.

The creation of the combined monitoring track network and in some cases the repositioning of the monitoring plots was an interactive 2D/3D process. The track placement decisions were primarily determined by the above guidelines and were applied in approximately the above order. Tracks and plots if necessary, were positioned in a 2D environment using ArcMap (ESRI) and were viewed and refined in the 3D environment of ArcScene (a component of ESRI's 3D Analyst extension).

The ATV tracks and fence line will be monitored for signs of potential erosion on a daily basis for two weeks of each month during the cat monitoring phase. Any early signs of erosion will be immediately ameliorated with brushing and/or matting. Tracks not required following completion of the cat eradication project will be allowed to rehabilitate.

1. Monitoring baiting efficacy

Two independent methods for monitoring baiting efficacy will be implemented: 1) trap, radio-collar and release of feral cats prior to the baiting program (see Trapping); and 2) detection of site occupancy using camera trap surveys of feral cat activity. The proportion of collared feral cats killed, i.e. direct mortality, and the difference in occupancy before and following baiting (determined by activity at camera trap monitoring plots; see Camera trapping) will be used as a measure of baiting efficacy.

2. Intensive monitoring program

An intensive monitoring program will be conducted post-baiting to locate cats that have survived so that they may be removed. Rapid detection of cats surviving the initial application of baits is critical to successfully eradicating cats as soon as possible. Detection of cats will be based on camera trap surveys which will be conducted for a two-week period each month when staff are not on the island so human disturbance will be at a minimum and the population will be closed (i.e. no removal of animals). Analysis of data from each camera trap survey will be conducted immediately upon return to the island to provide information on areas of cat activity and inform required control measures to be undertaken during that field period. In addition to the camera trap data, evidence of sign, principally cat track activity will also be used to locate areas where control effort is required. The network of survey tracks many of which will consist of a sandy surface substrate will enable cat footprints to be observed and thus daily cat activity to be recorded along their length. In addition to the conducting surveys along the monitoring tracks, sweeps along all beaches will be routinely undertaken. Track activity is unlikely to be used to provide indices of cat activity as animals will be removed during these observational periods however; evidence of sign, location and effort will be recorded. The detection of any cat sign during the course of the intensive monitoring programs will instigate an intensive ground baiting of the general location and the implementation of a trapping program at the site of the sign and surrounding area. It is anticipated that 12 intensive monitoring programs will be conducted in both the southern and northern sections of the island.

Cats are social animals and when at low numbers are likely to actively seek other cats in the area, particularly during the breeding season. The possibility of using several ‘sentinel cats’ will be investigated; these animals are brought in from outside the control area and sterilised (not de-sexed) so they maintain normal hormonal activity. Fitting radio-collars to these animals will allow their locations to be plotted and their subsequent removal. Information collected from the animals will be useful on two fronts: -

1. firstly, recording these animals on the monitoring transects will give further confidence in cat detectability especially at low population densities;
2. secondly, once the ‘sentinel cats’ have been removed intensive searching of the area for subsequent cat sign will indicate whether the ‘sentinel cats’ had located additional animals in the area.

3. Verification monitoring using detector dogs to corroborate absence of cats

Following the completion of each of the two monitoring programs, specialist detector dogs and their handlers will be contracted to: 1) detect the presence and location of cats so that they can be destroyed (shot) and/or 2) further independently verify the absence of cats and corroborate that eradication has been successfully achieved. The use of detector dogs can greatly increase the efficacy of monitoring especially when cats are wary of other methods and/or are at low densities. Dogs are able to detect cats from wind-borne or ground scents and track them to their resting places or dens, enabling their removal. Dogs are especially useful when cat densities are low because of their keen sense of smell and ability to follow scents over large distances in a relatively short amount of time.

The two sections of the island will be divided into blocks, allowing dogs and their handlers to systematically search the island. Blocks will be worked in an order that reflects wind direction; blocks yet to be worked remain upwind of teams who maintain a rolling front going into the wind. This will provide dogs with the best chance of detecting wind scents and minimises opportunities for cats to detect and avoid dogs. Blocks will be delineated by GIS and uploaded into GPS units carried by dog handlers. Handler’s GPS units will be programmed to create track logs, showing where they have been. Dogs will be fitted with GPS collars, which along with the handler’s units will be downloaded each evening to the GIS, allowing staff to visually track progress, determine any areas not sufficiently covered.

‘Sentinel cats’ may again be used to test the ability of the detector dogs in a blind trial. Dog handlers will not know whether or not ‘sentinel cats’ have been deployed, their number or location.

4. Surveillance monitoring

Surveillance monitoring for cat activity will be conducted on a seasonal basis for a following two years prior to the native species reintroductions, as an insurance policy that no cats have been overlooked or reintroduced. Surveillance monitoring will employ both camera trap monitoring and cat sign searches along the survey tracks. It is anticipated that surveillance monitoring will be conducted over a 10-day period in each of the southern and northern sections every three months but will be guided by 'stopping rules' used to determine the probability that eradication has occurred (see later).

Camera trapping

Monitoring the abundance of feral cats, like many mammalian carnivores, is difficult because they occur at low densities, have large home ranges and tend to be secretive and cryptic (Saunders et al. 1995; Witmer 2005; Long et al. 2007; Marks et al. 2009). Capture-recapture studies to estimate abundance are usually impractical (especially in eradication program where animals are removed when captured) because the animals are difficult to trap, leading to low capture rates and recapture probabilities (Saunders et al. 1995). Consequently most monitoring schemes rely on indices of abundance derived from data such as den counts (Coman et al. 1991), catch per unit effort indices (Algar and Kinnear 1992), spotlight surveys (Edwards et al. 2000; Sharp et al. 2001; Vine et al. 2009), scent station counts, (Phillips 1983; Harrison et al. 2002; Schauster et al. 2002), and track counts (Engeman et al. 1998; Mahon et al. 1998; Edwards et al. 2000; Algar and Burrows 2004; Engeman 2005; Algar et al. 2013a). Each of these techniques has advantages and disadvantages but they are unable to identify individuals and potentially confound animal activity with abundance (Anderson 2001).

Techniques that identify individual animals provide data that can be analysed using conventional capture-recapture statistical modelling, to provide robust estimates of abundance. In situations where individual animals can be identified from photographs (e.g. through variations in natural pelage patterns or markings), use of remotely deployed automatic cameras in camera trap studies have been employed to provide estimates of abundance. Camera trap studies have provided estimates of abundance for a number of species, particularly felids such as tigers (Panthera tigris, Karanth 1995; Karanth and Nichols 1998; Karanth et al. 2006) snow leopards (Uncia uncia, Jackson et al. 2006), bobcats (Lynx rufus, Heilbrun et al. 2006), jaguars (Panthera onca, Maffei et al. 2004; Silver et al. 2004; Soisalo and Cavalcanti 2006), ocelots (Leopardus pardalis, Trolle and Kery 2003). Camera trap studies are useful in providing information on feral cat presence/absence but usually individuals cannot be easily distinguished with any degree of certainty especially if black cats are present in the population. At a rudimentary level presence/absence data from camera trap sites can be used to provide indices of relative activity (e.g. Jenks et al. 2011). Raw detection rates (i.e. total number of events/number of sites) are naive estimates of occupancy that do not account for probability of detection (Long et al. 2010). If detection probabilities are determined, estimates of occupancy can be derived from presence/absence data (MacKenzie et al. 2006; Long and Zielinski 2008). Occupancy is often used as a metric for estimating various species occurrence and is a function of abundance as it concerns the probability of a particular animal being at a given site (MacKenzie et al. 2006; Long et al. 2010; O'Connell and Bailey 2011), in this case a camera trap plot. In addition, occupancy surveys require lower sample sizes than abundance surveys (MacKenzie et al. 2006).

Camera traps will provide an ideal technique for monitoring the impact of control measures through the progression of the eradication campaign as they will allow remote monitoring of cats following each control period/activity when staff are not present on-island. Automated cameras will be installed at a minimum of 50 (see Fig. 4) and 104 (see Fig. 5) locations in the southern and northern zones respectively to survey for the presence of feral cats. Additional cameras may be installed once the monitoring tracks have been positioned and assessed. The cameras to be used are Reconyx HC600 (Reconyx, Wisconsin; USA) and will be set horizontally. Cameras are to set on "Scrape" program which records five pictures per trigger, picture interval is on "RapidFire" which is two frames per second; there is no quiet period. At each plot the camera will be mounted 30 cm above the ground on a 45 cm heavy duty plastic tent peg. The camera is to face south, and a 3m x 1m strip of vegetation will be pruned to ground level between camera and lures to provide an uninterrupted view between lure and camera and minimise false detections from taller, moving vegetation. A combination of olfactory and visual lures will be used to attract cats to the camera traps. Plots that do not have lures often generate sample sizes that are too low to adequately monitor population changes (Fleming et al. 2001), they also provide more precise population estimates by increasing the number of recaptures (Gerber et al. 2012). Lures for the camera trap surveys will consist of a spice jar with perforated lid containing an oil-based scented lure (Catastrophic, Outfoxed Pest Control, Victoria) which is attached to a wooden stake approximately 30 cm from the ground. A 1.5 m long bamboo cane is joined to the wooden stake, with white synthetic turkey feathers connected to the cane approximately 30 cm above the scented lure. A 30 cm length of tinsel is fixed to the top of the stake in a position where it is not within the field of view of the camera. This set up and combination of lures has recently proven successful elsewhere in attracting cats to the camera traps (Tiller et al. 2013; Comer et al. in draft; Johnston et al. in press). Lures to be used in the leg-hold trapping program (see Trapping) will not be used for camera traps.

Camera trap plots will be established well in advance of their use to avoid any neophobic reaction by cats and remain in place during the course of the eradication campaign. Lures, memory cards and batteries will be removed at the end of each survey period (i.e. commencement of each field trip) and reinstated/refreshed at the commencement of each survey period (termination of each field trip). At the time of installation, all cameras will be test-fired to confirm functionality and correctness of aim. A series of set-up photos will be taken in which a white board with the location details and date recorded will be held in front of the camera.

The software program 'Camera Base' (Atrium Biodiversity 2013) will be used for data storage and management. This software program also allows exporting data into formats for further analysis. Daily collection of detection–non-detection data will encompass the period from 18:00h one day to 18:00h the following day rather than the conventional 24h period and will be considered a sampling occasion.

Biometrician's Endorsement

granted

Data management

No. specimens

Herbarium Curator's Endorsement

not required

Animal Ethics Committee's Endorsement

not required

Data management

Budget

Consolidated Funds

Source	Year 1	Year 2	Year 3
FTE Scientist			
FTE Technical			
Equipment			
Vehicle			
Travel			
Other			
Total			

External Funds

Source	Year 1	Year 2	Year 3
Salaries, Wages, OVertime			
Overheads			
Equipment			
Vehicle			
Travel			

Source	Year 1	Year 2	Year 3
Other Total			