1. Introduction: The Island Wide Survey (IWS):

The Christmas Island IWS has now been conducted on four occasions (2001, 2003, 2005, 2007) and is due to run again in May-July 2009. In December 1998, a pilot survey indicated that Yellow Crazy Ant (YCA; *Anoplolepis gracilipes*) supercolonies occurred over around 2-3% of the Islands' rainforest areas (O'Dowd et al. 1999). Subsequent estimates, based on additional searches by Peter Green in 2000, indicated that around 12% or more of rainforest on the island was infested with YCAs (O'Dowd and Green 2000). In response to the Action Plan for research and management of the YCA, an IWS was designed to determine the extent of supercolony formation and the impact of YCAs (O'Dowd and Green 2000). The IWS was initially designed to:

1) Determine the island-wide status of rainforest invasion by the YCA.
2) Establish distribution and magnitude of associated impacts (e.g., crab burrow densities, seedling densities, and litter cover).
3) Provide spatial information on which to base decisions about which areas to target and then base an ant control program and monitor its effects.
4) Allow identification of environmental correlates with ant invasion using the Christmas Island Geographical Information System (CIGIS).
5) Provide additional information useful for estimation of total control effort and resources needed for management of the invasion.
6) Produce a spatial database for identifying threats to native species of special conservation value, using overlays of known distributions of these species (e.g., crab migratory routes, Abbott's booby nesting sites).
7) Provide a basis for modelling spread, dynamics, and impact of YCAs at the island-wide spatial scale.

Although the initial design requirements of the IWS are still germane to current management of CI and YCAs, there is now an opportunity to update the survey to provide information for the management of other environmental issues. The IWS has been a successful initiative as outlined in the YCA program review paper (attached). After a brief description of the IWS sampling design, the current needs for the IWS will be outlined.

2. IWS Sampling Design

The IWS incorporates a near evenly spaced (≈ 365.7 m) grid of survey points (n= 877) across the entire island (Figure 2.1) that coincides with a pre-existing network of drill lines, but is offset by 25 metres into undisturbed forest. Where terrain was too rugged, sampling points were relocated to the nearest accessible point. Survey sites on land owned by Christmas Island Phosphates were dropped from the 2007 survey.

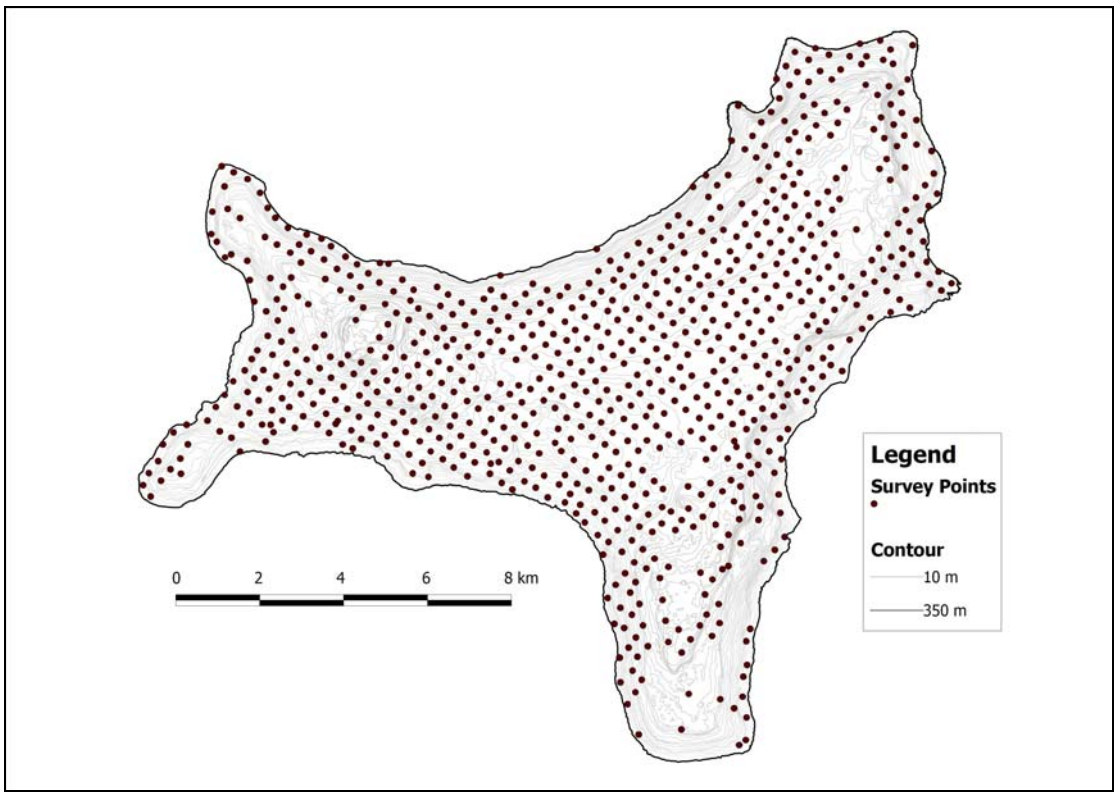

Figure 2.1: Location of the IWS points.

Each IWS sampling site comprises a 50 m transect along a random bearing. On each transect the following information has been collected:

2.1. Every Survey

- 20 cm x 20 cm laminated cards, which are divided into four even 10 cm x 10 cm quadrats, are positioned on the ground every 5 m along each 50 m transect to count YCA abundance. Before placement, litter is cleared and the card is placed on the ground. After 30 seconds, all crazy ants crossing the boundaries of one 10 cm x 10 cm quadrat are counted over a 30 second period. Counts are summed across the 11 card counts.

- Counts of intact and ant-occupied Red Crab (*Gecarcoidea natalis*) burrows are made within 1 m of either side of each transect for the whole 50 m.

2.2. Only in 2001 Survey

- Counts of seedlings were made in two randomly chosen 4 m x 2 m quadrats along each transect. Additionally, the numbers of seedlings over 30 cm tall in each quadrat was recorded.

- A litter cover index was measured using a 0.25 m^2 quadrat frame (randomly placed within the seedling density quadrats) within

which percent cover (0, 1-20, 21-40, 41-60, 61-80, 81-100%) was estimated.

2.3. 2003, 2005 and 2007 Survey

- In 2003, presence data along each transect was recorded for sightings of several weed species (e.g., *Antigonon leptopus*, *Cordia curassivica*, *Clausena excavate*, *Tithonia diversifolia*, and *Mikania micratha*), other land crabs (visual observation), and giant African land snails (GALs; *Achatina fulica*) and by sighting and/or hearing terrestrial birds and reptiles.

2.4. 2005 and 2007 Survey

- In 2005, presence data along each transect was collected by sighting land crabs and Cycads (*Cycas rumphii*), and sighting and/or hearing terrestrial birds, reptiles, and the Christmas Island Flying-fox (*Pteropus melanotus natalis*).

2.5. 2007 Survey

- In 2007, presence data along each transect was collected by sighting GALS and sighting and/or hearing the Christmas Island Emerald Dove (*Chalcophaps indica natils*) and the Christmas Island Thrush (*Turdus poliocephalus erythroplerus*).

3. Island Wide Survey 2009

3.1. General Description

The IWS will be conducted from May to July 2009. In addition to providing information for the management of YCAs, the survey will be redesigned to incorporate new survey protocols. The survey will allow us to:

1) Assess the distribution and abundance of several exotic species, including Asian Wolf Snakes (*Lycodon capucinus)*, Grass Skinks (*Lygosoma bowringii*), Asian House Geckos (*Gehyra mutilata*), Barking House Geckos (*Hemidactylus frenatus*), GALS, Black Rats (*Rattus rattus*), Domestic Cats (*Felis catus*), and Giant Centipedes (*Scolopendra morsitans*).
2) Assess the distribution of various weed species, including (e.g., *Antigonon leptopus*, *Cordia curassivica*, *Clausena excavate*, *Tithonia diversifolia*, and *Mikania micratha*).
3) Determine the spatial distribution of Red Crab size classes by measuring burrow width.
4) Assess the distribution and abundance of a significant component of the native fauna, including land birds, Christmas Island Pipistrelle Bats, terrestrial reptiles, Robber Crabs (*Birgus latro*) and other land crabs. Note, there are a number of other programs that provide a range of information to CINP on other significant fauna on the Island. The Islands' seabirds and raptors are the focus of a number of current research programs. For example, Dr Janos Hennicke runs a regular research program on Abbots Booby which provides distribution, demographic, and life-history information to CINP.
5) Search for species that are currently thought to be extinct, such as Lister's Gecko (*Lepidodactylus listeri*), the Christmas Island Shrew (*Crocidura attenuate trichura*), and the Christmas Island Blind Snake (*Typhlops exocoeti*).
6) Add another data point to the current IWS time series.

In line with the original intentions of the IWS, the redesigned approach will aim to provide information to allow us to:

1) Assess the island-wide status of rainforest invasion by a range of exotic pest species.
2) Establish patterns of distribution of native and exotic species.
3) Collect spatial information to base decisions about which areas, ecosystems, and species should be the target of management.
4) Identify environmental correlates with pest species invasion and native species decline using the CIGIS.
5) Collect additional information useful for estimation of total control effort and resources needed for management of the Park and its ecosystems.
6) Add to a spatial database that is used to identify threats to native species of special conservation value, using overlays of known distributions of these species (e.g., changes in red crab densities, crab migratory routes).
7) Develop a basis for modelling spread, dynamics, and impact of exotic species on an island-wide spatial scale.

3.2. 2009 Survey Methods

As a consequence of time and resource limitations and the large number of sites that have to be surveyed, protocols need to be developed such that they will allow us to detect species with some measurable probability, but are practical given the various limitations of the Island (e.g., terrain, climate, damage by Robber Crabs, etc). Three broad sampling approaches are under consideration for incorporation into the survey, the latter two of which are new:

1) Physical surveying along the transect at time of surveying (e.g., counting ants, land birds, etc) as used in previous surveys.
2) Provision of artificial refuges that will be examined during the survey.
3) Installation of automatic monitoring equipment (movement sensor cameras and Anabat detectors) at a small number of sites (≈ 20). Equipment will be rotated through sites over time (e.g., 24 months) until a significant subset of sites has been surveyed, and a smaller subset repeat surveyed.

To allow the estimation of detection probabilities for each target species/survey protocol combination, a random subsample of survey sites will be re-surveyed (cf. Royle and Dorazio 2008). The number of survey sites to be re-surveyed, and the number of re-visits to each site, will be determined once we have fully developed the survey protocol.

Survey approach (1) will allow us to survey ants, weeds, land birds, skinks, land crabs and their burrow densities and diameters. Approach (2) will allow us to survey for Giant Centipedes and both exotic and native terrestrial reptiles (skinks, snakes, and geckos). Approach (3) will allow us to survey for cats, rats, Robber Crabs, and the Christmas Island Pipistrelle Bat.

Surveying for birds, feral cats and rats is essential as it will provide a base-line data set for a cat eradication program that is currently under development. Before the program can begin, we need to develop an understanding of the densities of feral cats and to monitor any ecosystem changes that may follow their eradication.

3.3. Preparation for the IWS

In line with the proposed changes to the IWS, the development of new survey protocols is necessary. These changes are outlined below.

3.3.1. Reptiles

Given the apparent declines in all of the endemic reptiles and the spread of the introduced species (Schultz and Heywood Barker 2008), we need to use the IWS to better understand the distribution of all terrestrial reptile species. Our survey protocols need to reflect varied life histories of the reptile fauna on the Island, while still being practical within the constraints of the broader IWS protocol.

Skinks. - Previous experience suggests that our skink species are best monitored by passive observation, however, the timing and location of the observation sites can be better understood and the detectabilities associated with this technique have not been determined. Because the Coastal Skink (*Emoia atrocostata*) has not been recorded on Christmas Island since 2004 (Schulz and Heywood Barker 2008) and there are currently no known areas of occupation, it is difficult to include this species in any survey development program. Consequently, we will initially concentrate on the Blue-tailed Skink (*Cryptoblepharus egeriae*), Forest Skink (*Emoia nativitatis*), and the introduced Grass Skink. Blue tailed and Forest Skinks are now only known to occur in two areas on the island (Figure 3.1). Grass Skinks are known to occur from a number of areas across the Island (see Schultz and Heywood barker 2008).

To develop an appropriate survey protocol for the skinks in the IWS, we will conduct an initial and targeted study within the known areas of occupation. For the native

skinks, forty study points (15 m^2 quadrat; Figure 3.1) have been randomly selected from each of two 525 m x 60 m grids that were divided into 15 m^2 cells. Both of the grid areas encompassed the known areas of occupancy of the Blue-tailed and Forest Skinks.

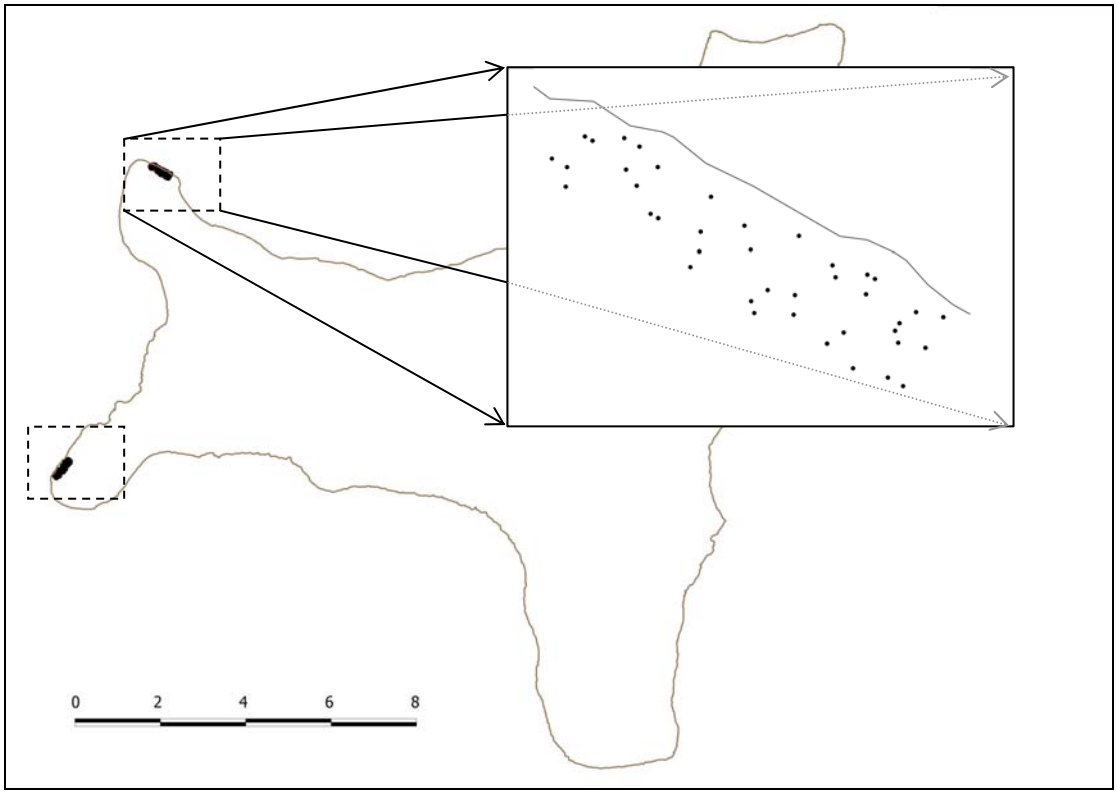

Figure 3.1: Last known areas of occupancy for the Blue-tailed and Forest Skinks (boxes with dashed lines) and example of random survey points (expanded box).

Traditionally, CINP staff have used a passive survey technique where they observe quietly for 10 minutes at a given survey point. Given the scale of the IWS, minimising the time needed to conduct the survey at each survey point will save considerable time and effort. Accordingly, one of the aims of this survey is to determine whether shorter survey times than 10 minutes are appropriate. At each survey point for each survey time, we will measure sighting times for all skink species up to 10 minutes. We will

also measure, and model as a covariate, viewing distance (up to 15 m) as the extent of the viewing area will vary with vegetation density.

By measuring a number of environmental variables (e.g., light intensity, substrate type, temperature, etc) we can develop a better understanding of the habitat requirements of both species and can use this information to improve the IWS methods. By counting numbers of lizards and by repeat surveying, we can begin to develop an understanding of population sizes (cf. Royle and Dorazio 2008). A similar protocol will be used to develop survey protocols for the Grass Skink in two areas of known occupation. The results of this study may also provide prior information for Bayesian models developed for the IWS results (cf. Gelman and Hill, 2006).

Geckos, snakes, and skinks. - In addition to passive observation, a number of other survey techniques have been used for the herpetofauna on Christmas Island (e.g., refer to Schultz and Heywood Barker 2008; James and Retallick 2008), but they are currently either inefficient and/or impractical within the context of the IWS (e.g., eye-shining, physically searching for reptiles). Accordingly we are in the process of trialling a range artificial refuges that includes attaching layers of Onduline to trees (Onduline is a lightweight composite corrugated roofing material), wood and plastic sheeting on the ground, and a range of different plastic tube designs to be attached to trees or pushed into the ground where possible. All of these techniques effectively create refuge habitat and are typical survey techniques for reptiles (e.g., Reading 1997). The different survey techniques will be trialled along 50 m transects that will run from a road edge into forest habitat. The artificial refuges will be placed at 5 m intervals along each transect. We will repeatedly visit each transect on a weekly basis

over a 1 month period and use the results of the trials to determine which protocols are effective and appropriate for the IWS.

Giant Centipede. – The use of artificial refuges for the reptiles is also very likely to provide a survey technique for the Giant Centipede. Accordingly, presence/absence of Giant Centipedes will also be monitored in the trial.

Depending on the outcomes of the trials, we envisage using some form of passive observation at each survey point in combination with some form of artificial refuge provision to sample the entire herpetofauna and Giant Centipedes.

3.3.2. Native and introduced mammals and Robber Crabs

The distribution and status of many of the mammal fauna of Christmas Island is still unclear (James and Retallick 2008). The Island has several introduced mammals (feral cats and rats) and several native species (e.g., Christmas Island Flying-fox, Christmas Island Pipistrelle Bat, and Christmas Island Shrew). With the exception of the Flying-fox, the native mammal fauna of Christmas Island is in a state of crisis. Two native rats (*Rattus macleari* and *R. nativitatis*) have gone extinct (Wyatt et al. 2008), the Christmas Island Shrew has not been seen since the 1980s (Schultz 2004) and the Pipistrelle Bat is on the verge of extinction (Lumsden and Shultz 2009). In view of the status of the native mammal fauna and the potential for a feral cat eradication program, it is now critical that we understand the distribution and abundance of Christmas Islands' mammal fauna.

Most survey techniques for mammals are either not appropriate for Christmas Island (e.g., traps can catch species which become lures for robber crabs and be damaged by land crabs) or in view of the large scale of the IWS, there are numerous logistical constraints associated with repeatedly checking traps. We propose to use Reconyx R45 Infrared motion sensing cameras (http://www.reconyx.com/page.php) and Anabat Bat Detection Systems (Waldren 2000) to survey for most of the mammal fauna and Robber Crabs of Christmas Island. The recording equipment will be deployed at a subset of IWS sites (number will be determined by the availability of equipment, but we are planning on having 20 cameras and 20 recorders) and systematically moved to as many IWS sites as possible over a pre-designated time period. Automatic detection cameras have been used to survey a range of mammals across the world (e.g., Lyra-Jorge et al. 2008, Varma et al. 2006) and have been used successfully, at a small scale, on Christmas Island. Anabat detectors are a common survey tool for bats which have been used successfully on Christmas Island for several years (Lumsden and Schultz 2009).

The installation period at each site, the number of sites, and the time period within which all sites will be monitored (and a subset repeat monitored) will depend upon the availability of equipment. However, we envisage equipment staying at each site for approximately one month. With 20 cameras and 20 Anabat recorders, for example, around 400 IWS sites could be monitored over a two year period with around 80 sites repeat visited on at least one occasion. We estimate that three teams consisting of two staff members each could move equipment from 15 completed sites to 15 new sites in one day. Accordingly, the equipment could be rotated over a two day period every month.

Motion sensor camera surveys often use some form of attractant to lure the target species to the cameras (Moen and Lindquist 2006). Feral cats, rats and Robber Crabs are all attracted to a Belacan shrimp paste (Retallick pers. comm.), which we will trial, along with other potential attractants, to determine the best way to lure the target species into the camera's detection zone. There is virtually no information on the Christmas Island Shrew (Schultz 2004) and accordingly, we view this more as an ad-hoc opportunity to detect the species.

We will be able to collect presence/absence information for each of the target species across Christmas Island. Adjustments for time effects and spatial relatedness can be made in the statistical modelling process (e.g., Thogmartin et al. 2006) as can the detection capacity of each approach for each species (cf. Royle and Dorazio 2008).

3.4. Other considerations

We have not included invertebrates in the survey (with the exception of GALS, crabs, and Giant Centipedes) as the costs (both time and money) of identifying the insect diversity is currently prohibitive. A range of insect collection techniques have been successfully used on Christmas Island (see James and Retallick 2008), so there may be opportunity to engage universities and students to participate in an assessment of the insect fauna of the Island as part of the IWS.

Currently, we have virtually no data on changes in microclimates. The collection of rainfall, humidity, soil moisture, and temperature data at a subset of IWS points using automated equipment may help in understanding the potential impacts of climate

change and in understanding the response of ecosystems and their diversity to changing climates. We are currently investigating this possibility.

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