THE ECOLOGY, GENETICS AND CONSERVATION OF A TRANSLOCATED POPULATION OF *CNEMIDOPHORUS VANZOI* (TEIIDAE) ON PRASLIN ISLAND, ST. LUCIA.

by

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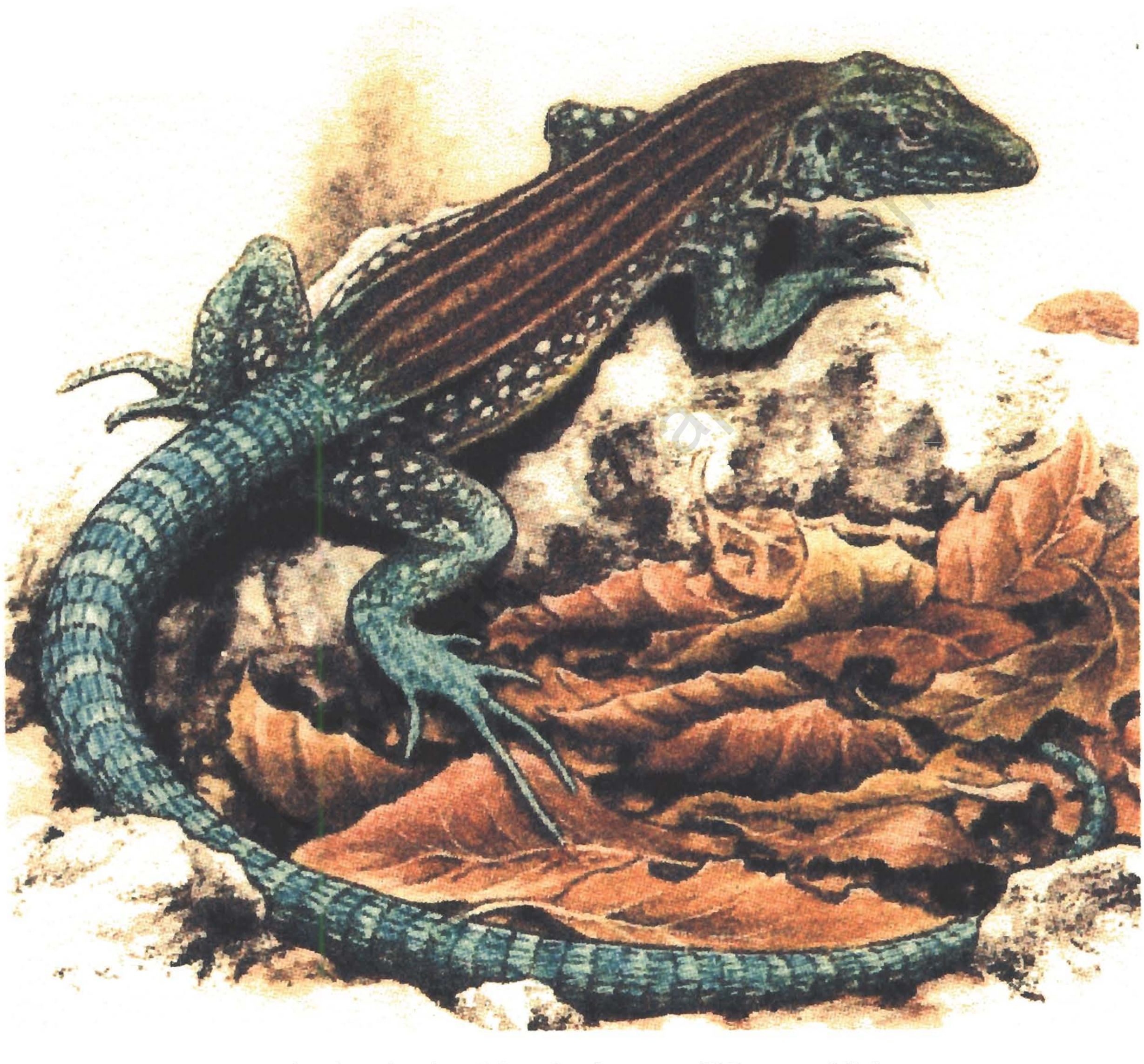

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Declaration

This thesis reports the results of original field research which I carried out on Praslin Island, St. Lucia, West Indies between October 1997 and March 1998 and genetic analysis was conducted during July - September, 1998 at the Department of Biochemistry, University of Sussex, East Sussex, UK. This work has not been submitted for a degree at any other university and any assistance that I received is fully acknowledged.

Signed by candidate

Hannah Christiana Dickinson Date

ABSTRACT

Dickinson, H.C. 2000. The ecology, genetics and conservation of a translocated population of *Cnemidophorus vanzoi* (Teiidae) on Praslin Island, St. Lucia. M.Sc. thesis, Department of Zoology, University of Cape Town.

Lizards of the genus *Cnemidophorus* (Teiidae) range from southern North America to central Argentina. They are a diurnal, ground dwelling and primarily insectivorous species. *Cnemidophorus vanzoi* is endemic to St. Lucia, and is the only representative of the genus in the Lesser Antilles. Prior to 1995, *C. vanzoi* was restricted to two small offshore islets (Maria Major and Maria Minor), with an estimated global population of 906. The species is listed as 'vulnerable' in the IUCN Red List. As a conservation measure, the St. Lucia Forestry Department and the Durrell Wildlife Conservation Trust translocated 42 lizards from Maria Major to Praslin Island in May 1995. This study investigates the colonisation of Praslin Island by *C. vanzoi*, three years after the translocation event. An examination of habitat use, lizard abundance, distribution and population genetics was conducted and population comparisons investigated changes in morphometrics or lizard condition since translocation. These investigations were conducted during the wet season and the dry season. This information will help determine the value of translocation as a tool for the conservation of this species.

Habitats on Praslin Island differed significantly in all measured biophysical variables, except slope, soil depth and litter depth, and showed significant seasonal change. Distribution of lizards also showed seasonal variation. Lizards shifted from the Mixed Wood to the Manchineel habitat during the dry season, as it offered a greater canopy cover and invertebrate diversity but Shrub habitat was preferred overall. Lizard density was correlated to the amount of coarse woody debris, litter and shrub cover, soil depth and modal shrub height, but lizards appear to respond only to differences among habitat types.

Line transect and mark-resight surveys estimated population size on Praslin Island at 147 ± 30. Genetic investigations using microsatellites showed that 16 – 23 of the founders survived, indicating that the population has more than doubled each year since translocation ($\lambda = 2.09$), and that Praslin Island now supports 14% of the global population. A significant decline in lizard abundance during the dry season coincides with the loss of canopy cover and lower floral diversity. The decreased activity level suggests lizards may aestivate.

A quantitative analysis of morphometrics showed snout-vent length differed significantly by age and by sex but body mass measurements did not. The species has a large sexual size dimorphism ratio (mean male to female snout-vent length = 1.2). Age ratio (1 adult : 2 juveniles) and sex ratio (1 male : 1 female) were stable throughout the study period. A seasonal decline in body mass and condition index (body mass / snout-vent length) indicates resource limitation during the dry season. Population dynamics may be influenced by intraspecific aggression as 35% of the population had evidence of tail autotomy and 16% of males above the minimum snout-vent length associated with adult coloration still displayed juvenile colours. Morphometric and condition index comparisons with the founding Maria Major population showed no significant changes.

Mean genetic diversity in the Praslin Island population has declined very little (2.3%) compared to the founding population indicating no founder effect associated with the translocation. However, 17% of alleles were lost during the founding event although one new allele has evolved in the population. The Maria Minor population showed great genetic differentiation from Maria Major indicating a long isolation.

These investigations focussed on the landscape ecology, species ecology, population dynamics and genetic diversity of a translocated population of *C. vanzoi*. Recommendations for monitoring his population and conducting future translocations of the species are made. This study offers objective data to claim establishment of a seemingly viable population on Praslin Island. The methodology used provides an autecological approach for the assessment of animal translocations.

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I gratefully acknowledge the work of Graham Rowe who finished developing the microsatellite primers for *C. vanzoi* under deadline of my arrival at the University of Sussex and for his help in running and reading gels. Grateful thanks are extended to Dr. Trevor Beebee and his graduate students, particularly Vicky Campbell, for providing me with lab space, sharing equipment with me, and giving me valuable advice. I also thank the Department of Geography at the University of Sussex for use of their soils lab and analytical equipment. Many thanks to Stuart Lenton, of Heath Group for creating the intensity maps using MapInfo and Dr. Paul Johnson, Wildlife Conservation Research Unit, Oxford University for his assistance in PCA analyses.

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Finally, I must thank my family, John, Liz and Lucy Dickinson for their pride and confidence in me; Darren Gough for his trust and support and his willingness to spend his holidays chasing insects in incredible heat; without all of you I could never have done so much. Thanks also to Liz & Martin Knight, Donna & Harry Dobson, Chris & Pauline Dickinson, Chris Dutton, and Nikla Tullie, for all their support and for never doubting that I could do this.

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Chapter 1. INTRODUCTION

Extinction risks are higher for island populations than mainland populations (Case & Bolger, 1992; Smith *et al.*, 1993; but see also Manne *et al.*, 1999). Island species account for 75% of extinctions since 1600 (Reid & Miller, 1989), and the extinction rates are higher for endemic island species of birds and reptiles (Frankham, 1989). The susceptibility of island populations is generally related to their isolation and the smaller population size compared with continental species, which leaves them at risk from demographic, catastrophic, environmental and genetic stochasticity (Shaffer, 1987; Frankam 1989). Reproductive isolation and small population size may further reduce genetic diversity by inbreeding and genetic drift, in a population that has already undergone the founder effect during colonization. If the rate of evolutionary change surpasses the effects of genetic exchange via immigration then characteristics such as fearlessness and a loss of anti-predator tactics may develop (Carlquist, 1974). Diminished genetic diversity also impairs a species' ability to adapt to environmental variation (Stockwell & Weeks, 1999), leaving the population susceptible to deterministic extinction risks.

It has been argued that extinction of small insular populations will result from demographic and/or environmental factors before genetic factors can have a significant negative impact (Eldridge *et al.*, 1999). Human-mediated, deterministic processes (over-exploitation, habitat destruction, introduced disease and exotic species) are the major causes of extinctions on islands in the last 50,000 years. (O'Brien & Evermann, 1988; Olson, 1989; Reid & Millar, 1989). The IUCN Redbook is incomplete for reptiles but the proportion of island extinctions is high compared with that on continents (Case & Bolger, 1992). Of the 30 reptile and amphibian extinctions documented since 1600, 73% were caused by introduced species, 10% from other causes, and 17% were unknown (Case & Bolger, 1992).

The goal of conservation biology is to preserve genetic diversity and evolutionary processes (Avise, 1994). The critical situation of endangered species has resulted in extensive research in conservation biology to understand the extinction process (Hendrick, 1996). Translocation can be a viable method in conservation biology for the preservation of wild species (Burke, 1991). It is defined by Griffith *et al.* (1989) as 'the intentional release of animals to the wild in an attempt to establish, re-establish, or augment a population' (p. 477). Translocations may be undertaken to reduce the risk of local extinction due to habitat loss or fragmentation, to protect small or endangered populations from becoming genetically stagnant, or to limit the risk of local disasters. The use of small offshore islands for translocation is appropriate as they can offer predator-free refugia and a discrete, often easily monitored setting with a similar biogeoclimatic environment to that of the mainland. However, these refugia do not remove any of the extinction risks associated with small population size, and may magnify risks in the short term by decreasing genetic diversity and altering population demographics.

Judging the success of a translocation can be controversial (Dodd & Seigel, 1991), as the definition is ambiguous with regard to a translocation. Griffith *et al.* (1989) define success as the establishment of a self-sustaining population, but when this can be declared depends on both the longevity and biology of the species in question (Dodd & Seigel, 1991). Few reptile translocations have occurred (Dodd & Seigel, 1991), and little research emphasis has been placed on understanding the factors important for initial success (Tasse, 1989). Dodd & Seigel, (1991) question the effectiveness of recent reptile translocation projects. Of 14 translocations of 12 reptile species two failed and six are considered to have 'unknown' success. Of the five lizard translocations [families Cordylidae (N=1), Iguanidae (N=2), Lacertidae (N=1), Teiidae (N=2)], only one was considered successful. Burke (1991) suggested the lack of success might result from the translocation of rare species that are already caught in an extinction vortex.

Establishment of a viable population following translocation tends to be unpredictable, and failed introductions may succeed at a second attempt (Burke, 1991; Duncan, 1997). On islands, the colonization and extinction processes vary between species but must be viewed relative to the ecological conditions (Carlquist, 1974). However, certain aspects of colonization appear to make an event more likely to succeed (Case, 1975; Rosenzweig, 1995). The best scenario involves a large founder population supplemented by regular immigration colonizing a large island that supports a diverse array of habitats. This island would lack competitors or predators (in reptiles, Case, 1975; Schoener & Schoener, 1983; in birds & mammals, Wolf *et al.*, 1998) and the entire process would occur in the absence of deterministic factors (e.g., predation or habitat loss from deforestation). A species is more likely to persist in this new environment if the founding population is genetically diverse (i.e. high heterozygosity) and has a high intrinsic rate of increase (e.g. large number of offspring and short generation times). Proximity to a source of new immigrants helps to offset demographic stochasticity and genetic drift, and slows adaptation to local conditions (Lande & Barrowclough, 1987; Nielsen, 1988).

The whiptail lizard *Cnemidophorus vanzoi* (Teiidae), endemic to St. Lucia, West Indies is listed as 'vulnerable' (sub-category D2) on the IUCN Red List. Because of its unique taxonomic status, the St. Lucian Government protects the two offshore islands where the lizard is found. The San Diego Zoo in 1984 and the Durrell Wildlife Conservation Trust (DWCT, formerly the Jersey Wildlife Preservation Trust) in 1986 initiated a captive-breeding programme for the *C. vanzoi.* Both programmes were unsuccessful due to health problems in the *ex-situ* population. Prior to translocation, the population of *C. vanzoi* was estimated at 906 (Anthony, 1993). The perceived external threats (wildfires, introduced predators etc.) to the lizard population and the inability to establish a viable ex-situ population, prompted consideration of a translocation effort.

The project was jointly planned and carried out by the government of St. Lucia and the DWCT. Prior to translocation, the St. Lucian government secured a lease from the owner of Praslin Island for the translocation site. Goats and rats were eradicated from Praslin Island (Johnston *et al.*, 1994) and vegetation was allowed to recover naturally. A biophysical survey of the island was conducted (Brice & Bloxam, 1995) and in May 1995, a translocation of the *C. vanzoi* took place. A total of 42 individuals were translocated from Maria Major Island to Praslin Island, previously uninhabited by the species (see Chapter 2).

Cnemidophorus vanzoi is a vulnerable species due to its small population size and restricted range. It may have been extirpated from the St. Lucia mainland to the Maria Islands as a result of introduced predators (See Chapter 2). The offshore islands it currently inhabits are maintained as predator free. However, these small islands are still threatened by the inherent extinction risks associated with small population size (demographic, environmental, catastrophic and genetic stochasticity). This species now exists as three insular populations in St. Lucia; Maria Major (source population), Praslin Island (translocated population) and Maria Minor.

Metapopulation theory (Levins, 1970) has been used to understand the population dynamics and structure of species of conservation concern (Sweanor *et al.*, 2000). Simply stated, metapopulations refer to a population of populations (Caughley, 1994), which are demographically independent (Sweanor *et al.*, 2000). The classical metapopulation model involves high subpopulation turnover and recolonisation rates (Hanski, 1991). Populations re-established by translocation, and managed to provide artificial dispersal and/or immigration are referred to as functional metapopulations (McCullough, 1996). Metapopulations can take many forms (e.g. source-sink subpopulations) with different genetic and evolutionary consequences (Rowe *et al.*, 2000). The evolutionary consequences of translocation are not well understood and are an area of concern in conservation biology.

The genetic diversity of a species is assessed by the level of heterozygosity, which is correlated to population survival and loss of evolutionary adaptability to environmental change (Lande, 1988; but see also Caughley, 1994). However, the absolute value of heterozygosity is less important than the relative levels between isolated populations and the changes within a single population over time. Heterozygosity within metapopulations may be much lower due to recolonization events and founder effects (Gilpin, 1991). Simulation models suggest that heterozygosity loss is not exponential and the rate of loss is slower in fragmented populations than individual populations of the same size (Harrison, 1991). In simulations involving small patches the time to extinction was much faster, genetic drift within each patch was common, and the variance among populations increased compared with large patches (Gilpin, 1991).

In this thesis I present data gathered from October 1997 to March 1998 on the translocated population of *Cnemidophorus vanzoi* on Praslin Island, three years after the translocation. These data are compared with unpublished data made available by the DWCT on the Maria Major and Maria Minor island populations. An ecological study of this population, its abundance, density, habitat use and genetics combined with data from the founding population provides a discrete microcosm in which to investigate the process of colonization following translocation. It also provides an arena to integrate the paradigms of small population biology, conservation biology, and metapopulation theory for the synthesis of a new method to assess translocations.

I present each chapter as an independent paper. Consequently, some information is repeated occasionally, but where possible references to other chapters are made. Chapter 2 describes the biophysical history of St. Lucia, the history of *Cnemidophorus vanzoi,* and the study site, Praslin Island. Lizard abundance and distribution in relation to habitat features on Praslin Island is presented in Chapter 3. Here, correlates between habitat variables and distribution are made to infer lizard habitat preference and estimates of population abundance and density are presented using two different sampling methods. Morphometrics and demographics of the population are presented in Chapter 4 and comparisons are made with the founding population. This chapter reviews all previously collected data on *C. vanzoi* because there have been no recent publications on this species and previous publications describe small sample sizes. Chapter 5 examines the genetic consequence of population subdivision, the genetic distance between subpopulations and estimates the rate of loss in genetic diversity in the absence of further translocations. Finally, Chapter 6 summarizes the findings and provides a synthesis of the analyses. The success of the translocation event in the short term is considered and recommendations for future management and investigations are made.

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Chapter 2. STUDY SITE AND HISTORY OF *CNEMIDOPHORUS VANZOI*

ST. LUCIA, WEST INDIES

The Lesser Antilles is a group of islands in the Caribbean Sea, north of Venezuela (Figure 2.1). They lie on a late Cretaceous paleogene deformed belt between the Aves Ridge and the Lesser Antilles subduction zone (Perfit & Williams, 1989). The island of St. Lucia (13°55'N, 60°59'W) is towards the southern end of this chain, 30 km south of Martinique and 30 km north of St. Vincent. The island has an area of 616 km^2 and is primarily volcanic in origin with some limestone outcrops. It reaches a maximum elevation of 950 m (Mt. Gimie).

Climate

St. Lucia has an average temperature of 27°C and a relative humidity of 75% with little seasonal or diurnal variation (Johnson, 1988). Rainfall is generally a function of elevation in St. Lucia and the mean range of annual rainfall varies by 20%. Mountainous areas in the south-central part of the country receive in excess of 3500 mm/year. The drier coastal plains and valleys generally receive less than 1500 mm/year (Applied Technology & Management Inc., 1996). The dry season (January - May) coincides with easterly 'trade-winds' which have a low moisture content. During the wet season (June - December) rain falls with varied intensity depending on elevation and windward exposure. Figure 2.2 shows temperature and precipitation data during the study period. Hurricane events and tropical storms are a threat to the island during August – September, when intense rain and wind combined with significant wave action and storm surges can cause extensive damage. On average, St. Lucia experiences 25 tropical storms per year (Applied Technology & Management Inc., 1996).

Flora and Fauna

St. Lucia supports most of the vegetation types found within the Lesser Antilles: cloud-forest, rainforest, dry woodland, cactus scrub, and littoral vegetation (Johnson, 1988). Most of the rainforest and woodland were felled for timber and replaced by sugar-cane plantations in the 1700s (Philpot, 1995). Patches of cloud-forest and rainforest still exist in small patches at high elevations in central St. Lucia.

St. Lucia supports four single-island endemic bird species and four threatened bird species endemic to the Lesser Antilles (Johnson, 1988). It has a relatively rich reptile fauna, which includes five single island endemics and four regionally endemic species (Table 2.1).

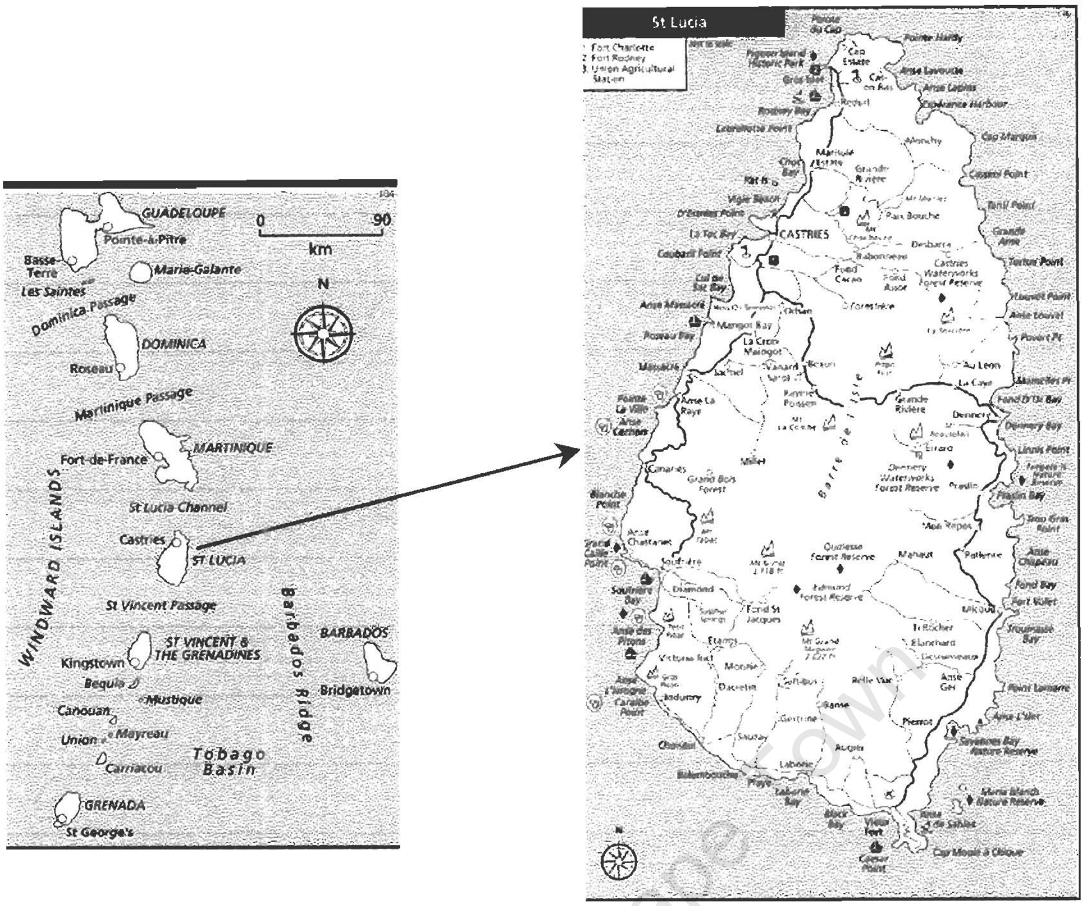

Figure 2.1. The Lesser Antilles showing St. Lucia.

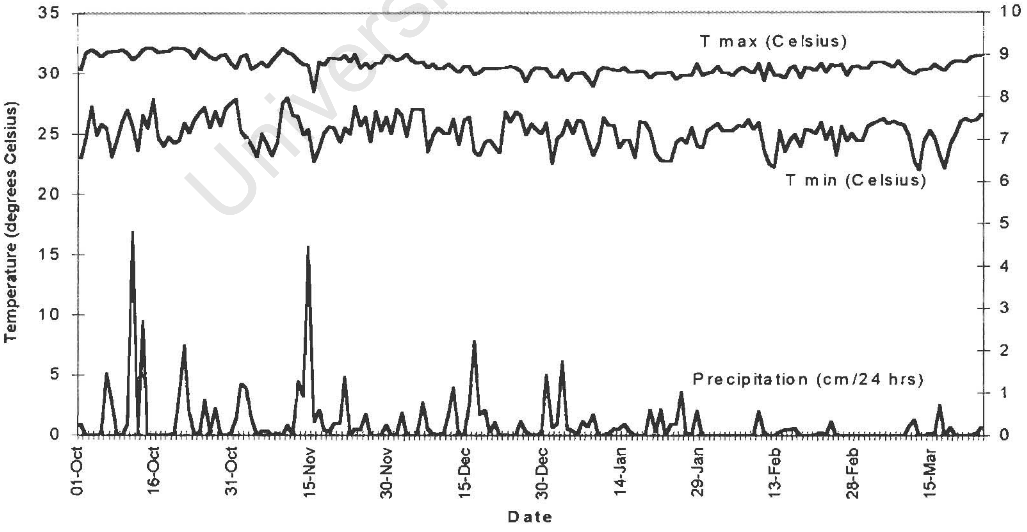

Figure 2.2. Climatic data recorded at Hewanorra International Airport by Meteorological Office, Vieux Fort, St. Lucia, October 1997 - March 1998.

The snake *Liophis ornatus* and the lizard *Cnemidophorus vanzoi* have been extirpated from the main island and exist only on small offshore islands. The beaches of St. Lucia are also used as nesting sites by four species of turtle. In the past century there have been four known reptile extinctions presumably due to predation by the mongoose, *Herpestes auropunctatus* and rats, *Rattus rattus* (Swartz & Henderson, 1991). There are no native mammals.

Table 2.1. Reptile species on St. Lucia. Endemic species are found only on St. Lucia, regionally endemic species are those found only in the Lesser Antilles (adapted from Corke, 1987; Johnson, 1988; Swartz & Henderson, 1991).

Species	Family	Status
Anolis luciae	Iguanidae	Endemic
Sphaerodactylus microlepis	Gekkonidae	Endemic
Cnemidophorus vanzoi	Teiidae	Endemic*
Liophis ornatus	Colubridae	Endemic*
Bothrops caribbaeus	Viperidae	Endemic
Sphaerodactylus vincenti	Gekkonidae	Regionally Endemic
Anolis wattsi	Iguanidae	Regionally Endemic
Gymnophthalmus pleei	Teiidae	Regionally Endemic
Leptotyphlops bilineata	Leptotyphlopidae	Regionally Endemic
Mabuya mabouia	Scincidae	Extinct
Clelia clelia	Colubridae	Extinct
Clelia errabunda	Colubridae	Extinct
Leptodactylus fallax	Leptodactylidae	Extinct

*Extirpated from the main island

Human History

The indigenous people of St. Lucia are an Amerindian race known as the Arawaks. They are believed to have reached St. Lucia in 300 BC from Asia via South America. The Caribs, another Amerindian race succeeded the Arawaks in 800 AD (Philpott, 1995). Columbus reached St. Lucia in 1502. It was colonised by the French and the English before becoming an independent state within the Commonwealth in 1979. The population of 150,000 is concentrated in the capital Castries on the northwest of the island. The economy is dominated by agricultural activities with 37% of the total area under cultivation (Johnson, 1988). Bananas, cocoa, copra and coconut oil are the primary crops but fishing and tourism also contribute to the economy (Johnson, 1988).

Following European colonization, black rats (*Rattus rattus*) and mongooses (*Herpestes auropunctatus*) were introduced to St. Lucia. Rats were brought from Europe during the mid-1700's (Johnston *et al.*, 1994). Mongoose introduction to the West Indies has been traced to one event in February 1872 (Hoagland *et al.*, 1989). Nine animals (four males and five females - one of which was pregnant) were brought from Calcutta to Jamaica to control rats. The subsequent population was exported other Caribbean islands. St. Lucia received mongooses from Barbados. At present, 29 islands, (all the Greater Antilles and 17 islands in the Lesser Antilles) have mongoose populations

(Hoagland *et al*., 1989). The opossum (*Didelphis virginiana*) was introduced to St. Lucia in 1902 from Dominica (Philpot, 1995).

HISTORY OF *CNEMIDOPHORUS VANZOI*

The family Teiidae is only found in the western hemisphere and *Cnemidophorus* is the only teiid genus found in North America. Whiptail lizards of the genus *Cnemidophorus* are a complex genus of bisexual and parthnogenic species. Their geographic range spans from southern North America to central Argentina (Figure 2.3). Species within this genus were described as part of *Lacerta* and *Amevia* until 1952 when Lowe and Zweifel defined the genus (Lowe, 1993). The 45+ species are divided into four bisexual species groups and fourteen parthnogenetic lineages (Wright, 1993). The St Lucia whiptail, *C. vanzoi* belongs to the *Lemniscatus* species group, which is one of the least studied (Wright, 1993). This species group is also the most primitive (i.e. *Ameiva*-like) and it has been suggested that all other North American groups may have derived from this root (Wright, 1993). *Cnemidophorus vanzoi* was discovered on the Maria Islands in 1958 and formally described as *Ameiva vanzoi* by Baskin & Williams (1966). The species was amended to genus *Cnemidophorus* after examination of the tongue structure (Presch, 1971).

The endemic *C. vanzoi* is the sole representative of its genus in the Lesser Antilles (Swartz & Henderson, 1991). The species is a ground-dwelling, diurnal, and primarily insectivorous macroteiid which inhabits two islands (Maria Major, 10.2 ha and Maria Minor, 1.8 ha) off the south-east coast of St. Lucia. The total estimated population is 906 (Anthony, 1993). The Maria Islands (13°14.4'N, 60°56.3'W) are land-bridge islands located approximately 1.0 km from the coast of St. Lucia. Maria Major reaches 90 m above sea level and Maria Minor reaches 20 m. The Maria Islands are a Nature Reserve (established 1983) managed by the St. Lucia National Trust. The St. Lucia National Trust Act (No. 16, 1975) established a statutory trust 'to promote, conserve and manage land and marine areas of special natural or historic interest, and protect the wildlife they contain'. It is assumed that *C. vanzoi* was extirpated from the main island to the Maria Islands.

Conservation of *Cnemidophorus vanzoi*

St. Lucia is a signatory of CITES and has conservation legislation in effect to identify wildlife as absolutely or partially protected, or unprotected (Wildlife Protection Act, No. 9, 1980). The Wildlife Department, Forestry Division of the Ministry of Agriculture is the CITES management authority and planning body with regard to the endemic fauna. *Cnemidophorus vanzoi* is absolutely protected under local conservation legislation and is listed as 'vulnerable' (sub-category D2) on the IUCN Red List. Because of its unique taxonomic status and restricted range, the St. Lucian Government protects the two islets where the lizard is found. To mitigate the risk of extinction (i.e.

accidental introduction of a predator or habitat loss from fire) on these islands, a translocation was planned between the Forestry Department and the Durrell Wildlife Conservation Trust.

Praslin Island was selected as a potential translocation site. Praslin Island (13°52.2'N, 60°53.1'W) is 220 m off the east coast of St. Lucia, 21 km north of the Maria Islands (Figure 2.4). It covers 1.1 ha and is privately owned but currently leased to the St. Lucia Forestry Department. It is nested in Praslin Bay approximately 900 m from the head of Praslin Bay (Figure 2.3). Praslin Bay has a broken reef system that extends southward to the shoreline. The shallow south-east side of the bay supports eelgrass (*Zoestra spp.*) vegetation and a large sand bar is exposed at low tides. The maximum depth of the bay is 5 m and it has a tidal range of 1.5 m. Coastal vegetation is comprised mainly of red and white mangrove (*Rhizophora mangle, Laguncularia racemosa*) and buttonwood (*Conocarpus erectus*).

Praslin Island slopes along the east-west axis from a maximum peak of approximately 15 m. The island geology is a conglomeratic mudflow (Applied Technology & Management Inc., 1996). The east coast of the island is severely undercut by wave action and there is evidence of a land slide on the north-east side. Approximately 55% of Praslin Island is covered by a mixed woodland and smaller patches of manchineel woodland. The rest of the island supports patches of shrub-dominated vegetation and grassland. The island has a small beach at its south-west point. A rough footpath circles the eastern section of the island. This path and the general welfare of Praslin Island are the responsibility of an Island Warden employed by the St. Lucia Forestry Department. Two other species of reptile (*Anolis luciae, Gynmopthalmus pleei*) and one species of amphibian (*Eleutherodactylus johnstonei*) are currently resident on Praslin Island.

The Praslin-Mamiku community has approximately 350 residents, who are predominately employed in agriculture. The head of the bay has a small dock used by local fisherman (not shown in Figure 2.3 as its construction was post-1985). The St. Lucia National Trust runs infrequent guided tours to Praslin Island in which locals provide transportation to the island and a packed lunch. The local community use Praslin Island for family picnics and as a base for spear fishing and sea-moss farming in the bay.

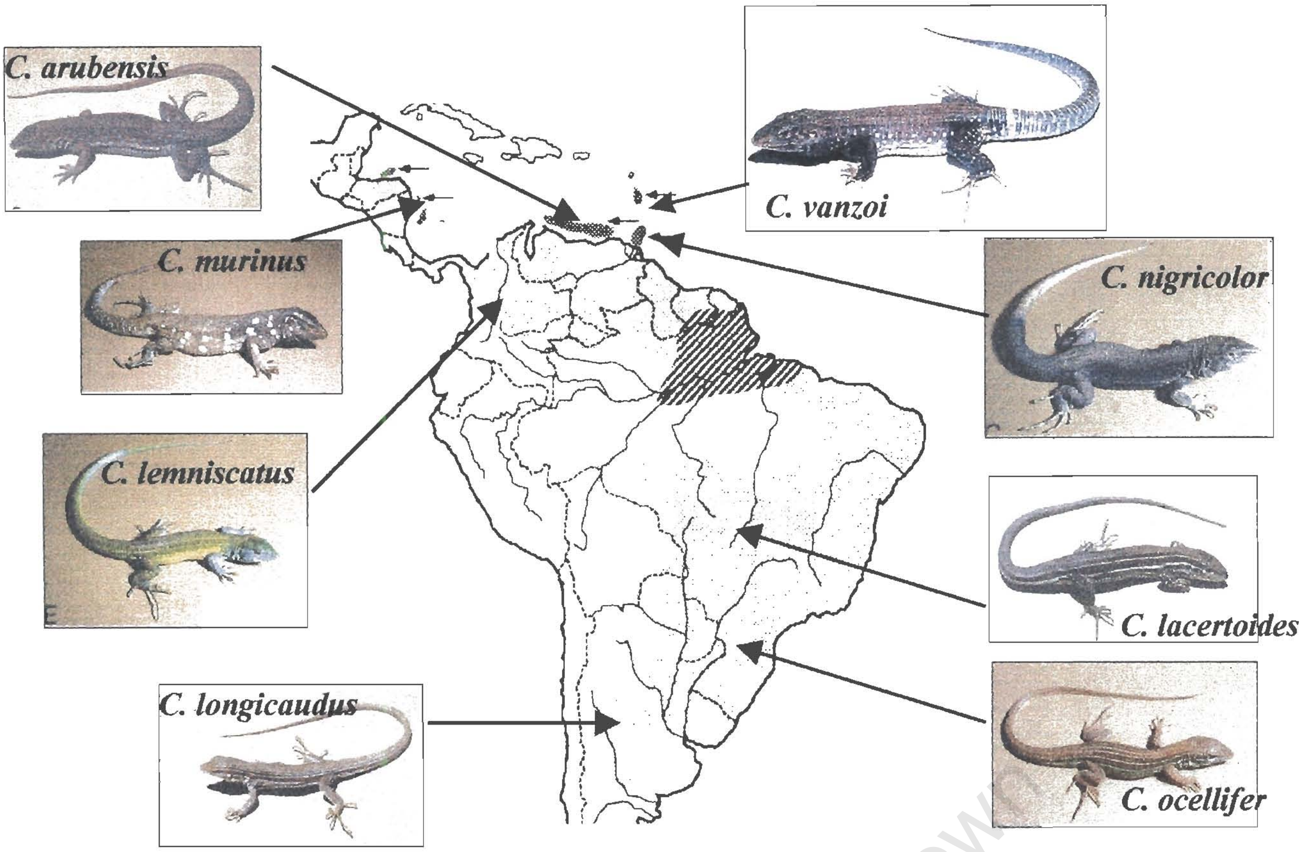

Figure 2.3. Representative *Cnemidophorus* species of the Lemniscatus species group (Adapted from Wright, 1993).

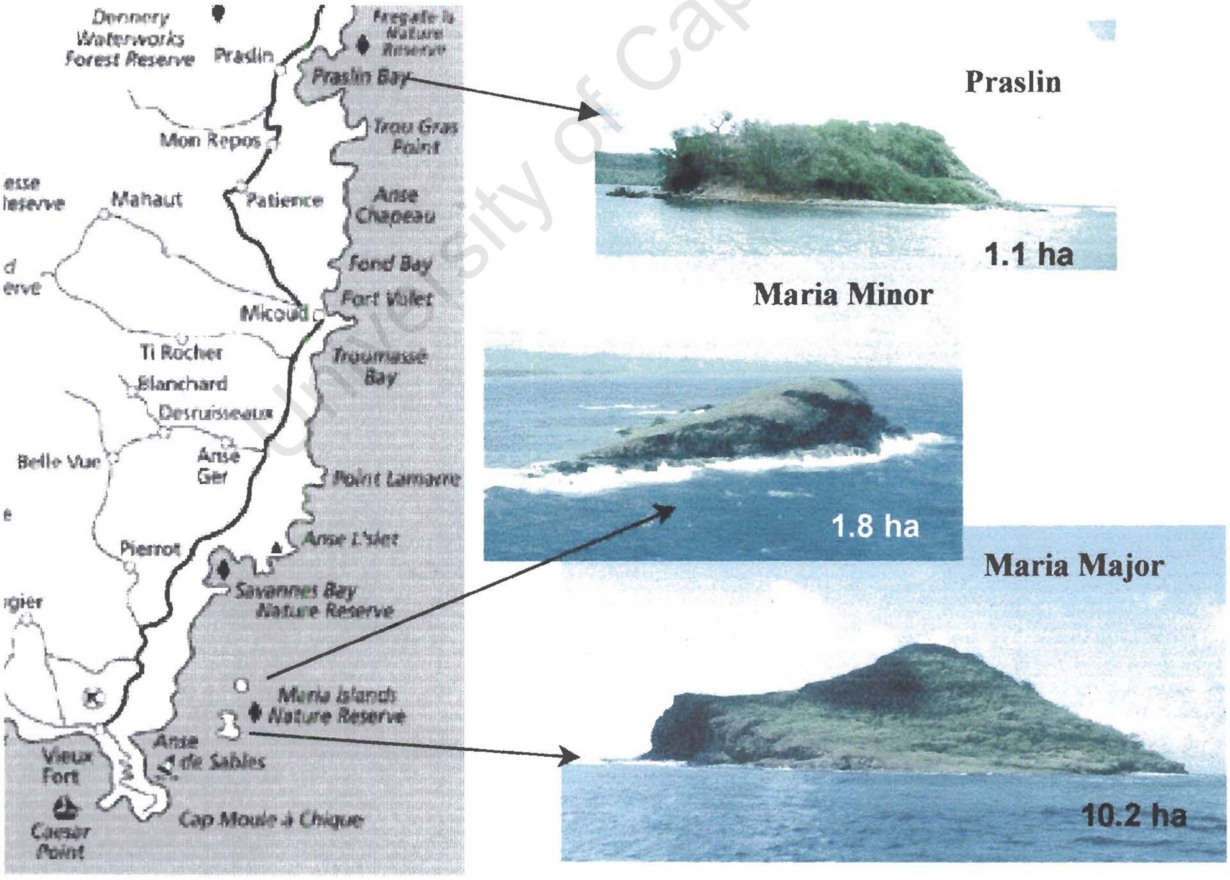

Figure 2.4. The islands in St. Lucia where *Cnemidophorus vanzoi* is found currently. Lizards were translocated from Maria Major to Praslin in 1995.

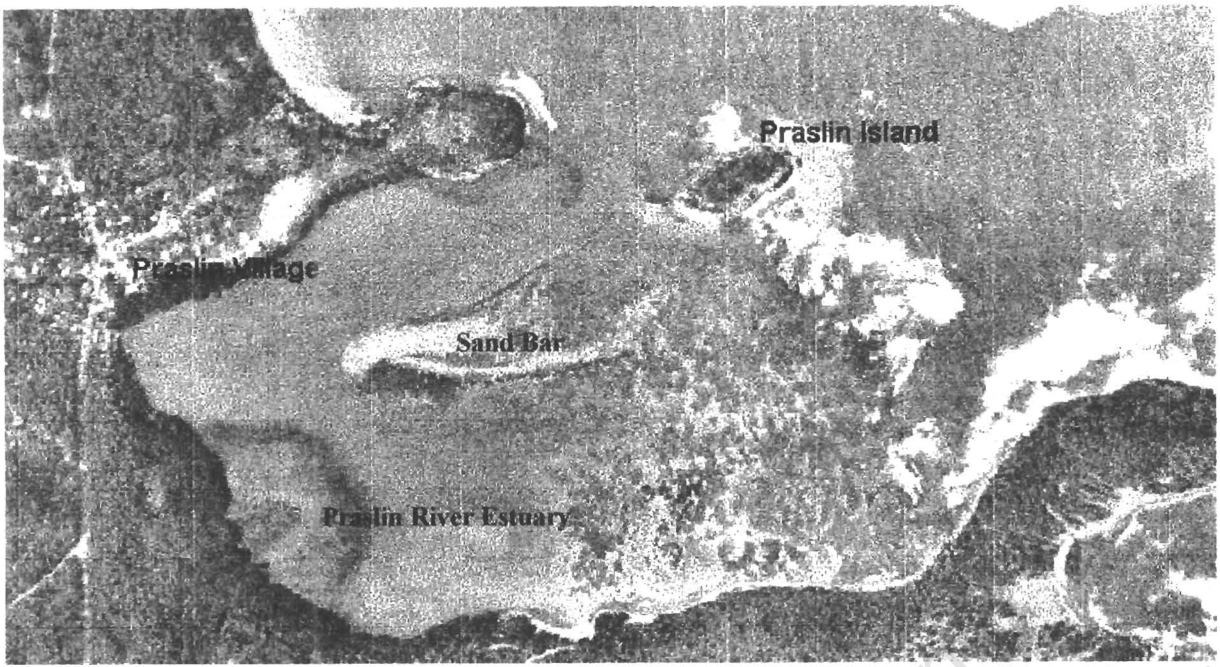

Figure 2.5. Praslin Island, Praslin Bay and community of Praslin. Praslin Island was the study site of the translocated population of *Cnemidophorus vanzoi* (October 1997 – March 1998). Island area is 1.1 ha. Aerial photo taken in 1985 (1:10,000) courtesy of the St. Lucia Forestry Department.

In May 1995, 14 pairs of *C. vanzoi* were translocated from Maria Major to Praslin Island. Shortly after a mongoose was seen on Praslin Island and was trapped and removed. Only one lizard was seen on Praslin Island following removal of the mongoose hence, a further seven pairs were translocated one week later. Both groups of lizards were released in the eastern area of the mixed wood habitat in the centre of Praslin Island (see Chapter 3, Figure 3.1) as this was deemed the most suitable habitat (Q. Bloxam, pers. comm.). It was estimated that a minimum of 15 founders survived the translocation (Q. Bloxam, pers. comm.).

The Maria Islands and Praslin Island now support populations of *Cnemidophorus vanzoi*. These islands have a no permanent population of mammalian predator although infrequent occurrence of rats (*Rattus rattus*) has been noted on Praslin Island since 1995. When rat tracks are seen in the sand, live traps are set on the island and the individuals caught and removed. Since translocation, two proposals for hotel developments in the Praslin Bay area have been submitted to the St. Lucian Government; one on the north side and one on the south side of the Bay. These developments are envisaged to have a major socio-economic impact on the community (Applied Technology & Management Inc., 1996).

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Chapter 3. ABUNDANCE AND MICROHABITAT USE BY *CNEMIDOPHORUS VANZOI* ON PRASLIN ISLAND

ABSTRACT

Microhabitat use studies of translocated species are crucial to assess their adaptation to the new environment. A total of 42 *Cnemidophorus vanzoi*, formerly restricted to two islets (Maria Major 10.2 ha and Maria Minor 1.8 ha) off St Lucia in the Lesser Antilles, were translocated from Maria Major to Praslin Island (1.1 ha) in 1995. Three years after the release, I studied the abundance, density and distribution of the established lizard population in the five habitat types on Praslin Island. Habitats varied from exposed, open grasslands to tall, continuously canopied woodlands. Although lizards were distributed throughout the island, some habitats were used more than predicted with respect to availability. There were significant seasonal differences in lizard abundance. Using line transect sampling and mark-resight surveys the population of lizards, estimated at 147 ± 30 individuals, was shown to be concentrated in the mixed woodland habitat although there is evidence of seasonal shifts in distribution. The population has more than doubled each year since translocation (λ=2.09). I studied the relationship between lizard abundance and density, and measured environmental variables within the five main habitats. Lizard density was significantly correlated with litter cover, coarse woody debris cover, shrub cover, modal shrub height and soil depth. I discuss factors affecting distribution (thermoregulation, food resources, and competitive exclusion). These results will help managers choose future translocation sites.

INTRODUCTION

Animal translocation is an increasingly important management tool used to promote the chances of a species' survival (Tasse, 1989). So far, few translocations have been successful; certain threatening processes, such as predation, have had particularly severe impacts on the emerging small populations. Furthermore, critics claim that most translocations suffer from poor documentation, lack of external evaluation and peer-review, and particularly from monitoring inadequacies and absence of comprehensive quantitative analysis (Dodd & Seigel 1991; Miller *et al*., 1999). The dearth of properly documented releases, especially the lack of knowledge of survival and identity of animals that eventually form the new population, is worrying (Platenberg & Griffiths, 1999).

Post-release monitoring of translocated animals is not simply determining number of survivors, but also interpreting the ensuing species-habitat relationships. Underpinning such studies is the understanding of how the target species behaves in the new habitat and how characteristics of the recipient habitats correlate with the distribution of individual animals in the translocated populations. Hence, how the translocated species' distribution and abundance can be predicted from habitat variables should be central to monitoring (Heatwole, 1977; Marsden & Fielding, 1999; but see Wolff, 1995). Variables such as food supply, physical features of the environment and presence/absence or abundance of competitors are important factors affecting persistence of a species. However, it is often the interaction of a number of these factors that may determine population status of a species. Additionally, temporal changes in these variables may influence the carrying capacity of the habitat and ultimately affect the size of the translocated population. For example, food may exhibit seasonal variations that may influence the life history and habitat use of the species (Patterson, 1991; Lister & Garcia-Aguayo, 1992; Martin & Lopez, 1998). Programmes that have taken into account the relationship between recipient habitats and the ecology of released species have been successful in translocation and in assessing potential areas for future releases (Miller & Mullete 1985; Dodd & Seigel 1991).

In 1995, the Durrell Wildlife Conservation Trust and the St Lucia Forestry Department translocated a total of 42 *Cnemidophorus vanzoi* from Maria Major Island (10.2 ha) to Praslin Island (1.1 ha) to increase the probability of survival of the species. The translocation took place in May, at the end of the dry season. All lizards were released in a mixed woodland area as this was assumed to be the most suitable habitat for the species (Q. Bloxam, pers. comm, Brice & Bloxam, 1995).

In this chapter I characterise ecological traits of a translocated population of *Cnemidophorus vanzoi*. I estimate the size of the lizard population and assess how the lizards are distributed on the island according to habitat types. I analyse correlations between habitat variables and lizard density and discuss how the attributes of the island are linked to the success of the translocated population. These results provide an interim measure of the colonisation of Praslin Island and provide information to enable the selection of appropriate translocation sites or the creation of suitable sites for future translocations.

METHODS & ANALYSIS

Vegetation Analysis

Vegetation types were delineated from aerial photos taken on 4 October 1997. Vegetation diversity, structure and biophysical attributes on the Praslin Island was assessed using 41 vegetation quadrats placed across the island at 10 m intervals on transects used for lizard population estimates (see section below). A subgroup of these (N=26) and additional quadrats (N=5) were monitored monthly to assess vegetation change. These quadrats were placed to avoid microhabitat variations and human disturbances (e.g., pathways and planted exotics). Within each habitat type, optimal quadrat size and the number of quadrats required to sample floristic diversity were determined from minimal-area and species-area curves (Krebs, 1989). Quadrats were 5.0 m^2 in the wood and shrub habitats and 1.5 m^2 in the grassland habitats. Shrubs were defined as a woody plant less than 2.0 m tall, sapling trees below this height were also classified as shrubs. The area of each habitat type was calculated using a CalComp^R 9000 Series Electromagnetic Digitizer.

Percentage cover for rocks, bare soil, leaf litter and coarse woody debris (fallen wood or branches > 6 cm) was determined by laying a cross on a cardinal axis through the plot centre. Vegetation cover (% of the quadrat) for the tree, shrub and vine strata was also estimated. Plants rooted outside the quadrat but trailing into the quadrat were included in estimations. Unknown species were described in the field and a sample was collected for identification at the Department of Forestry's herbarium. Modal heights for shrubs and herbs were calculated with a hand held 2 m stick. Tree heights were measured using a clinometer and a level distance to the tree. Exposure was defined as the estimated amount of sunlight reaching the ground through the canopy directly above the quadrat. Plant associations were determined using two-way indicator species analysis (Programme TWINSPAN PC-ORD Vers. 2.05) and these associations were correlated to biophysical variables using principal component analysis (PCA; SPLUS 2000, 1999, Mathsoft Inc.) Variation in habitat characteristics was determined by an independent analysis of variance (ANOVA) and described using Newman-Keuls multiple comparison (WINKS 4.5 Prof. Ed.). The null hypothesis was rejected if $P<0.05$. Shannon-Wiener diversity index was calculated each month in each habitat type and evenness was used to describe unequal representation of species in quadrats where diversity was similar (Krebs, 1989).

Maps of lizard distribution and biophysical habitat characteristics were generated using MapInfo (V.5.5). The accumulated number of lizards observed around each vegetation quadrat on the transect lines were used to create a point dataset. Each point was expressed as the percentage number of all lizards observed during the wet, dry and both seasons. These data points were then placed on a virtual grid through Vertical Mapper (V.2.2.1) within MapInfo, using a method of 'natural neighbourhood' interpolation. A continuous surface depicting intensity for each variable was created. To aid visual interpretation of the results, contours were threaded through the grids and the interlying bands coloured accordingly.

Biophysical & Invertebrate Sampling

Within each quadrat slope was determined with a clinometer and aspect was determined with a compass. Percolation tests were conducted at all sites on the same day. Litter and vegetation were removed from a level surface and a metal cylinder (diameter = 72.4 mm) was pushed into the soil to a depth of approximately 10 mm. Percolation of 175 ml of seawater was timed using a stopwatch.

A soil sample was taken from a representative site within each of the five habitat types. The organic layer was removed and approximately 100 g of soil was collected. Soil analysis involved grain size analysis to gravel (>2 mm), and fine fraction (sand, silt, clay, <2 mm). Organic matter was removed by wet oxidation using 40 volume hydrogen peroxide, followed by sieve analysis and laser particle sizing (Malvern Instruments SB-OD). The percentage of gravel, sand, silts and clay was calculated and soil type was defined by soil texture pyramid (United States Soil Survey).

Each month, the five habitat types were searched by hand for invertebrates. The litter layer, topsoil layer, stones and dead wood were turned and probed. A representative of each species found was collected and stored in 70% methyl alcohol with two drops of glycerol. Time spent sampling in each habitat type was constant, though varied between habitat types (i.e. 1.5 hr searching in Mixed Wood versus 1.0 hr searching in Manchineel each month).

Abundance Estimates

Two methods of population size estimation were used; line transect survey and a mark-resight survey. The latter was conducted in conjunction with the collection of morphometric and genetic data (see Chapters 4 and 5 respectively).

Line transect survey theory, concepts, statistical background and applications are described fully by Buckland *et al.* (1996). In this study, nine transect lines spaced approximately 15 m apart were oriented approximately north-south across the island (Figure 3.1). The first line was located a random distance (23 m) from the west tip of the island. White painted stones were numbered and placed every 3 m along each line. The total length of transect lines was 405.5 m. All transects were walked once per day (between 0900 and 1130 on sunny days without morning rain) on three to five consecutive days each month (October 1997 - March 1998). When a lizard was sighted, its exact location was flagged by pegging a marker recording age and sex on the spot. Sex was estimated from colour (males have blue coloration), length of tail and thickness of the base of the tail (generally greater in males), and behaviour (males often hold more prominent sites and react more aggressively toward other lizards). Individuals were observed carefully for distinguishing marks and direction of movement to ensure they were counted only once from the line. All sightings were made from the line. If another lizard not previously viewed from the line was disturbed whilst placing the marker, its location was not marked. When all transects had been surveyed, the lines were re-walked and the exact location of the lizard was measured to the line. Perpendicular distances were measured on an east-west bearing to the line, and the north-south distance was measured to the closest marker stone.

Lizard abundance was estimated from transect data using the Programme DISTANCE (vers. 2.1, Laake *et al.*, 1994). DISTANCE fits a probability density function (pdf) to model the decrease in detection of objects at greater distances from the line. Hazard rate models (with key and cosine adjustment functions, and a maximum of two fitted parameters) and half-normal models (with key, hermite polynomial and cosine adjustment functions, and a maximum of two fitted parameters) were run on each data set. A truncation distance of 10 m (S. Buckland, pers. comm.) was used in all analyses. Models were selected through comparison of Akaike's information criterion, χ-p value, and percent coefficient of variation (Buckland *et al.*, 1996).

Data were analysed by month and season (wet season = October - December 1997; dry season = January - March 1998). Raw data from wet season months and dry season months were combined to provide a larger data set for pdf modelling. Variance in estimates is primarily attributed to the variation in encounter rate, calculated from a sample size equal to the number of transect lines. Independence is violated by searching the same transect line more than once. Hence, multiplication of line length by the number of times the transect line is surveyed provides better precision of the overall encounter rate (i.e. five transect lines surveyed three times provides a sample size of five, not 15, for encounter rate estimation). Decreases in vegetation cover in the dry season may have affected detection distances as foliage and vine cover decreased. Hence in Mixed Wood, Shrub and Manchineel habitats the farthest distance seen from a specific location was measured in October, January, and March. In addition, transect data was stratified by habitat type for use in DISTANCE.

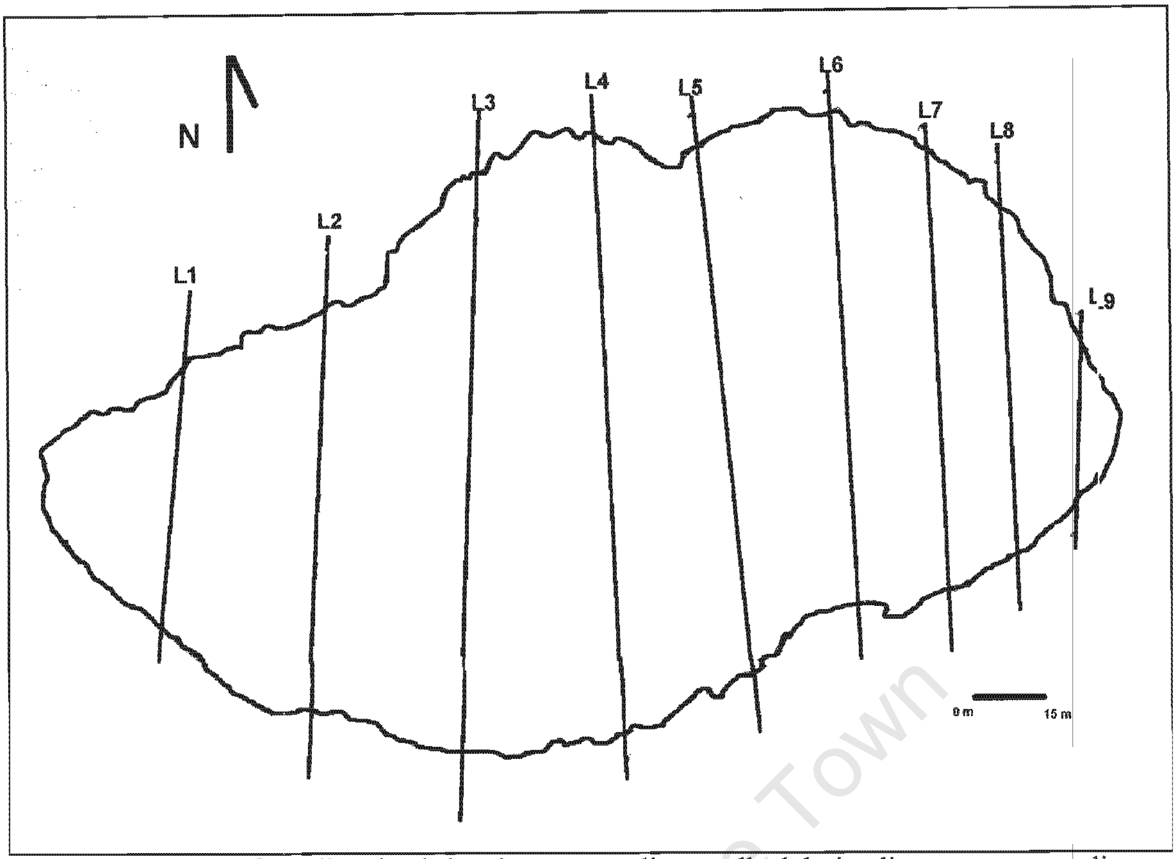


Figure 3.1. Map of Praslin Island showing transect lines walked during line transect sampling.

A Petersen mark-resight survey (consisting of one mark and one resight event each month) was also conducted due to its compatibility with the collection of morphometric data (see Chapter 4). Lizards caught for morphometric measurements were individually marked using colour paint (yellow, orange and red, "Cryla" heavy body acrylic co-polymer emulsion; Bracknell, Berkshire, UK) combinations on the dorsal surface between the forelegs, hindlegs, midsection, and head. Re-surveying for marked lizards was conducted the following day. Locations of lizards seen with marks were recorded to the nearest transect line. The programme PETERSEN (Krebs, 1989) was employed. The estimate equation assumes an individual is counted only once during resighting.

Lizard-Habitat Correlates

Basic univariate statistics were used to examine variation within the data set, and to compare biophysical characteristics between habitats. The relationship between lizard abundance and habitat variables was examined by principal component analyses. I used the components produced in the PCA as dependent variables in a general linear model to determine variation between habitat variables and lizard occurrence around the study quadrats. Possible habitat type preference by the lizards was estimated using the Ivlev electivity index (Krebs, 1989). Lizard occurrence by habitat was compared to the available area of that habitat type. DISTANCE-estimated abundance data stratified by habitat type was used. A negative electivity index indicates under-use with respect to availability whereas a positive index indicates over-use.

RESULTS

Habitat Patterns

Five habitat types were defined by TWINSPAN (minimum division level set at two) and could be delineated on air photos (Figure 3.2). There was a significant decrease in vegetation diversity on Praslin Island during the dry season (ANOVA, $F_{2,29} = 10.66$, $P<.001$). Invertebrate diversity was significantly different between habitat types ($F_{5,25} = 9.86$, $P < 0.001$).

A total of 45 plant species was identified from 31 permanent quadrats (Appendix 3.1). Of these 13% were trees, 36% were shrubs, 24% were herbs 11% were grasses and 15% were vines. Vegetation associations of the five habitat types are described below; the first division separates the woodlands from the grasslands (Figure 3.3). Mean habitat characteristics and the differences between habitat types (Newman-Keuls, $P<0.05$) are described in Table 3.1. Two non-vegetation types include rock 0.09 ha. (7.7%) of the island and bare/sand 0.08 ha. (6.9%; Figure 3.2).

The five habitat types can be described as follows:

- Mixed Wood has a canopy dominated by *Tabernaemontana citrfolia, Cornutia pyramidata*, with a moderate shrub layer of *Croton bixoides* and almost no herb layer
- Manchineel has a canopy of *Hippomane mancinella* with a *Rauvolfia verdis* shrub layer and a sparse herb layer of *Ruellia tuberosa*.
- The Shrub habitat is characterised by *Lantana camera, Cordia curassavica, Erithalis fruticosa* and *Croton flavens*.
- The Mixed Grass habitat is dominated by *Stachytarpeta jamaicensis*, the vine *Alysicarpus vaginalis* with an occasional shrub, *Sida glomerata*.
- Bunchgrass is primarily *Schizacyrium micostachym* with occasional *Enicostema verticullatum* and vine *Fabaceae sp*.

Biophysical characteristics of each habitat are shown in Table 3.1. Habitat types differed significantly in all measured variables, except slope, soil depth and litter depth. The distribution of rock cover, exposure, coarse woody debris, modal shrub height, slope, and litter cover on Praslin Island are shown in Figure 3.4. Exposure is greatest in the Bunchgrass habitats on the north-east of the island, on the southern beach area and through scattered openings in Shrub habitat. The highest

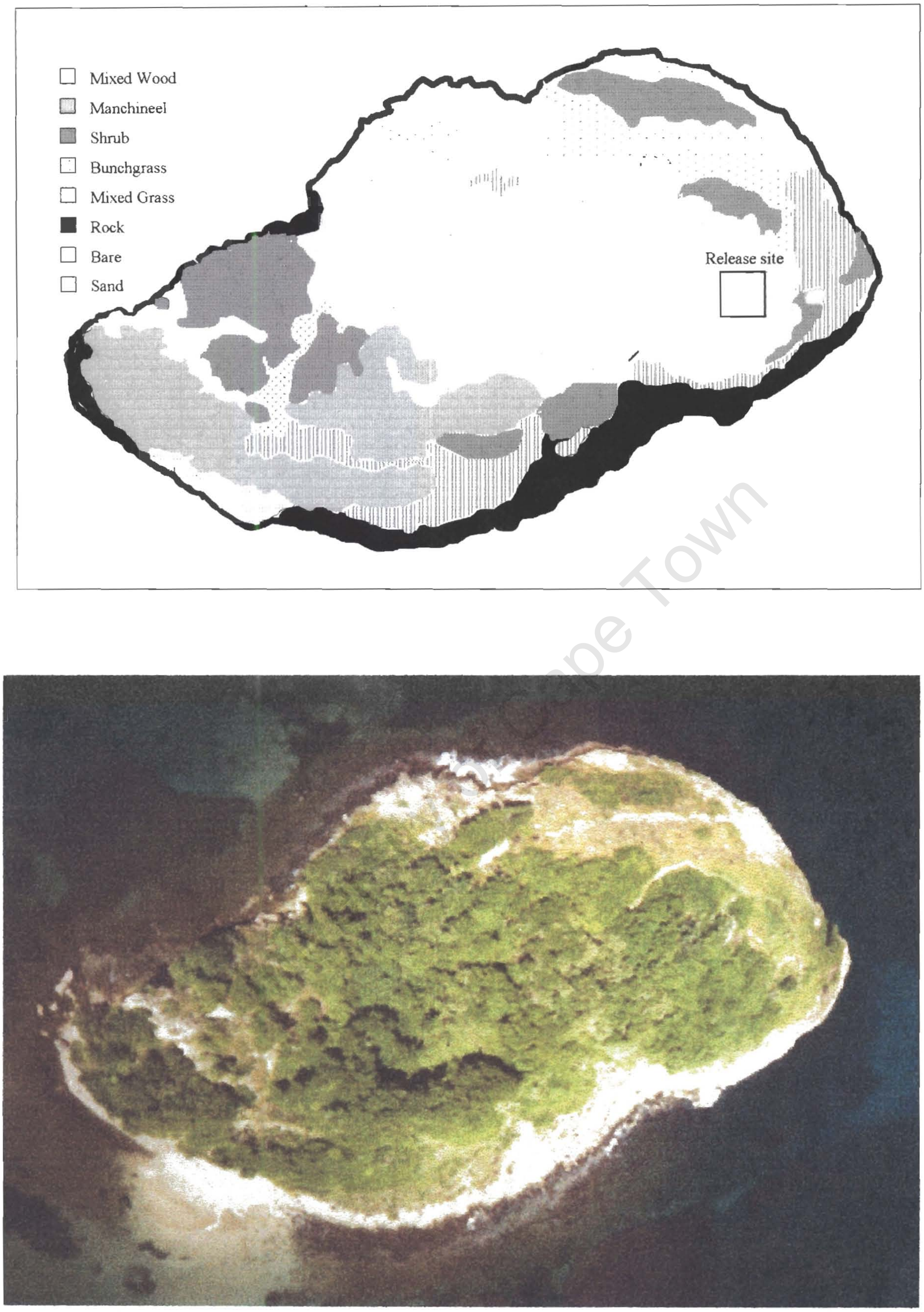


Figure 3.2. Habitat types on Praslin Island delineated from aerial photograph. East – West axis of Praslin Island is approximately 175 m. Photo taken October 1997.

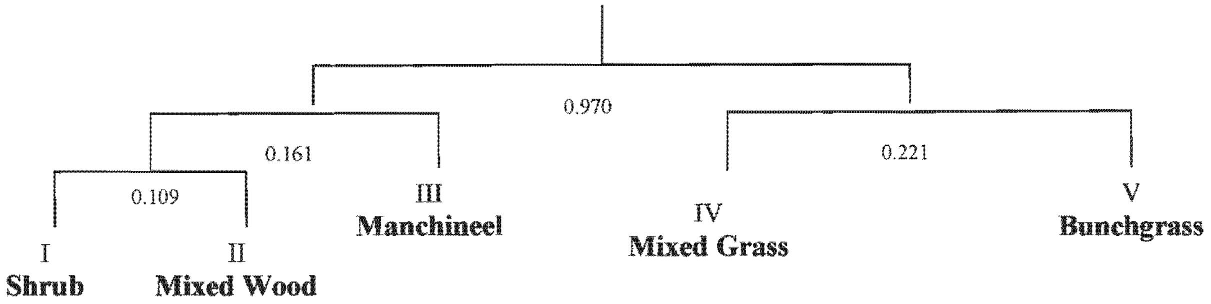


Figure 3.3. Vegetation associations determined by TWINSPAN, grouped into five habitat types. Numbers are eigenvalues calculated by TWINSPAN.

concentration of litter cover occurs under the forested areas of Manchineel and Mixed Wood and in some Shrub patches. Modal shrub heights are highest in the Shrub and Manchineel habitats. Steep slopes occur on the east and north coast of the island and descend from the very peak of Praslin Island itself. Rock cover is greatest at the island centre in the Mixed Wood habitat and at small outcrops on the east and west tips of the island. Coarse woody debris is generally found only in the centre of the Mixed Wood habitat and on the north-east coast of the island which is an area of land slip.

Lesser amounts of coarse wood debris were correlated with steeper slopes (R= -0.88, P = 0.04) and litter cover was positively correlated to exposure (R= 0.94, P = 0.018). Tree cover and rock cover were positively correlated (R= 0.955, P = 0.012) as well as modal shrub height with shrub cover and soil depth (R= 0.96, P = 0.008 & R= 0.909, P = 0.032 respectively). Tree cover and model tree height (R= 0.946, P = 0.015) were also positively correlated as were herb cover and soil depth and exposure (R= -0.886, P = 0.046 & R= 0.946, P = 0.015 respectively).

There was significant seasonal variation in some habitat variables. Litter cover increased during the dry season in the Manchineel, Mixed Wood and Shrub habitats ($F_{5,26}$ = 5.14, $P \leq 0.001$). Mixed Wood and Shrub showed a significant decline in floral diversity (t = 5.57, df = 26, P < 0.001 & t = 3.01, df = 11, P = 0.01 respectively) during the dry season but evenness declined significantly only in the Mixed Wood (t = 2.81, df = 26, P = 0.009). Exposure increased significantly in the Mixed Wood habitat during the dry season (t = -3.76, df = 14, P = 0.002) but no significant change was observed in Manchineel (t = -2.03, df = 8, P = 0.076) or Shrub habitats (t = -1.91, df = 6, P = 0.104). The amount of tree, shrub and herb cover significantly decreased within Mixed Wood and Manchineel, but the amount of shrub cover provided was similar in each season.

Praslin Island is covered by loamy sand type soils that show significant variation in the proportion of gravel and organic matter (Table 3.1). Manchineel habitat had significantly higher gravel content than all other habitats (Newman-Keuls multiple comparison MSE=10.25, Q=5.5, d.f.=4, $P<0.05$) and Mixed Wood showed a significantly higher proportion of organic matter (Newman-Keuls multiple comparison (MSE=14.7, Q=6.8, d.f.=4, $P<0.05$).

Invertebrate fauna was most speciose in Mixed Grass (Newman-Keuls MSE=4.66 df = 20, Q > 2.95) followed by Mixed Wood (Q > 2.95, Appendix 3.2). Lower levels of species richness were observed in Shrub, Manchineel and Bunchgrass but they did not significantly differ from each other. Invertebrate diversity increased significantly in Mixed Grass during the dry season ($F_{2,2} = 93.0$, P = 0.02; all other habitats P>0.09).

Abundance Estimates

Pooled line transect counts estimated the total Praslin Island population at 147±30 (range 72.7–196.5, Table 3.2). However, significant differences in monthly abundance estimates were observed ($\chi^2 = 36.9$, df = 5, $P<0.001$). Combined data for the wet and dry season stratified by habitat type (Table 3.3) were not significantly different from estimates generated from transect counts (χ^2= 0.98, df=1, P > 0.6 for all). A significant decrease in lizard abundance was observed in the dry season ($\chi^2 = 11.45$, df = 1, $P<0.001$) although visibility of lizards through vegetation cover increased significantly (repeated measures ANOVA, F=15.6, df=3, $P<0.001$) during the dry season (Figure 3.5).

An estimation of the discrete population growth rate (lamba, λ) can be made using the estimated population size three years after translocation. Starting from a minimum of 16 founders (see Chapter 5), a minimum of one reproductive period per year and a current population size of 147, the maximum value of $\lambda = 2.09$.

Abundance estimates generated by the different models for data in the same month did not vary significantly (described by sample standard deviation, Table 3.2), nor did monthly abundance estimates pooled by season (Mann Whitney U, Z=0.87, d.f.=1, P=0.4). Newman-Keuls multiple comparison (MSE=15.2, d.f.=4, $P<0.05$) showed that abundance estimates for November-January (Q=2.3) and December-February (Q<1.0) were similar. October differed significantly from March (Q=31.8) and both were significantly different from November-January and December-February (October, Q<11.5 & Q=23.3; March, Q=8.6 & Q<17.9 respectively). Data stratified by habitat type resulted in smaller data sets in some habitat types and increased the observed variation.

Table 3.1. Habitat characteristics of each type found on Praslin Island. Mean values ± standard deviations are calculated from plots surveyed in October, 1997. Mean diversity and evenness measures were calculated monthly October 1997 – March 1998. Habitat types with similar (Newman-Keuls) characteristics are shown in brackets.

Habitat Type	Mixed Wood	Shrub	Manchineel	Mixed Grasses	Bunchgrass	$F_{5,26}$ (P)*	Differences
Number of Quadrats	9	4	5	8	5		
Area (ha)	0.46	0.17	0.19	0.13	0.08		
Proportion of Island (%)	38.2	13.8	16	10.4	6.9		
Aspect (degrees)	162.1 ± 94.7	168.5 ± 43.1	163.6 ± 93.3	151.3 ± 52.1	204.2 ± 81.5		
Slope (degrees)	9.4 ± 7.7	8.0 ± 6.8	22.0 ± 17.5	18.5 ± 7.7	21.0 ± 7.4	2.6 (0.059)	
Soil Depth (cm)	8.8 ± 2.1	>10.0	8.8 ± 1.7	8.0 ± 1.6	5.8 ± 4.1	2.3 (0.086)	
Litter Depth (cm)	2.4 ± 0.45	2.3 ± 0.31	4.4 ± 5.2	1.3 ± 0.6	0.9 ± 0.6	2.3 (0.084)	
Mean Exposure (%)	40.7 ± 17.4	61.2 ± 25.9	54.5 ± 21.8	100.0 ± 0.0	100.0 ± 0.0	21.4 (<0.001)	(1,2) (3,4,5)
Mean Percolation Time (min)	0.67± 0.28	1.41± 1.83	1.02 ± 0.77	1.0 ± 0.8	2.9 ± 1.6	3.8 (0.014)	(1,2,3,4) (5)
Rock Cover (%)	34.4 ± 17.6	7.0 ± 5.4	44.0 ± 22.5	3.4 ± 3.2	10.4 ± 11.9	10.0 (<0.001)	(1,3) (2,4,5)
Soil Cover (%)	9.3 ± 3.4	12.6 ± 2.8	21.3 ± 16.6	2.2 ± 2.1	1.9 ± 1.4	7.4 (<0.001)	(2,3) (1,2,4,5)
Litter Cover(%)	60.2 ± 11.9	59.7 ± 15.5	40.5 ± 16.3	5.0 ± 2.3	4.1 ± 2.4	44.3 (<0.001)	(3) (1,2) (4,5)
Coarse Woody Debris (%)	2.9 ± 3.3	6.6 ± 4.8	0.5 ± 1.1	0	0.04 ± 0.09	6.2 (0.001)	(2) (1,3,4,5)
Tree Cover (%)	61.1 ± 16.3	7.2 ± 14.4	55.5 ± 21.7	0	0	35.7 (<0.001)	(1,3) (2,4,5)
Shrub Cover (%)	50.3 ± 28.2	70.5 ± 13.0	49.6 ± 16.1	20.4 ± 14.5	0.2 ± 0.4	10.9 (<0.001)	(1,2,3) (4,5)
Herb Cover (%)	4.4 ± 4.9	18.0 ± 15.0	17.1 ± 14.1	61.8 ± 19.2	93.1 ± 7.2	49.1 (<0.001)	(1,2,3) (4) (5)
Vine Cover (%)	15.5 ± 10.9	14.3 ± 15.0	9.1 ± 10.2	13.3 ± 14.6	2.6 ± 2.6	1.10 (0.36)	
Modal Tree Height (m)	12.9 ± 10.7	0	19.3 ± 9.2	0	0	1.19 (0.37)	
Modal Shrub Height (m)	0.9 ± 0.7	1.8 ± 0.4	1.2 ± 0.3	0.3 ± 0.2	0	17.1 (<0.001)	(1,3) (2,4,5)
Modal Herb Height (m)	0.02 ± 0.05	0.3 ± 0.2	0.2 ± 0.3	0.06 ± 0.1	0.3 ± 0.05	2.1 (0.16)	
Mean Diversity (wet season)	2.7 ± 0.3	2.8 ± 0.5	2.2 ± 0.7	1.9 ± 0.3	0.4 ± 0.2	31.68 (<0.001)	(1,2,3) (4) (5)
Mean Diversity (dry season)	2.2 ± 0.5	2.5 ± 0.4	2.1 ± 0.5	1.7 ± 0.4	0.4 ± 0.3	17.82 (<0.001)	as above
Mean Evenness (wet season)	0.8 ± 0.06	0.8 ± 0.2	0.7 ± 0.2	0.8 ± 0.1	0.2 ± 0.2	13.98 (<0.001)	(2,3) (1,4) (5)
Mean Evenness (dry season)	0.8 ± 0.2	0.8 ± 0.2	0.7 ± 0.1	0.8 ± 0.1	0.3 ± 0.2	9.49 (<0.001)	as above
Soil: Gravel (%)	28.7	28.1	51.87	34.1	27.8	7.44 (0.002)	
Soil: Organic (%)	49.3	23.8	15.9	33.1	13	.11 (0.015)	
Soil: Sand** (%)	84.6	81.9	84.2	78.1	72.3	NS	
Soil: Silt** (%)	13.2	15.6	12.9	14.8	12.6	NS	
Soil: Clay** (%)	1.4	2.5	2.5	2.5	3.7	NS	
Soil Type	Loamy Sand	Loamy Sand	Sand/Loamy Sand	Loamy Sand	Loamy Sand		

*Independent ANOVA, P<0.05. **Percent of the fine fraction (<2mm diameter).

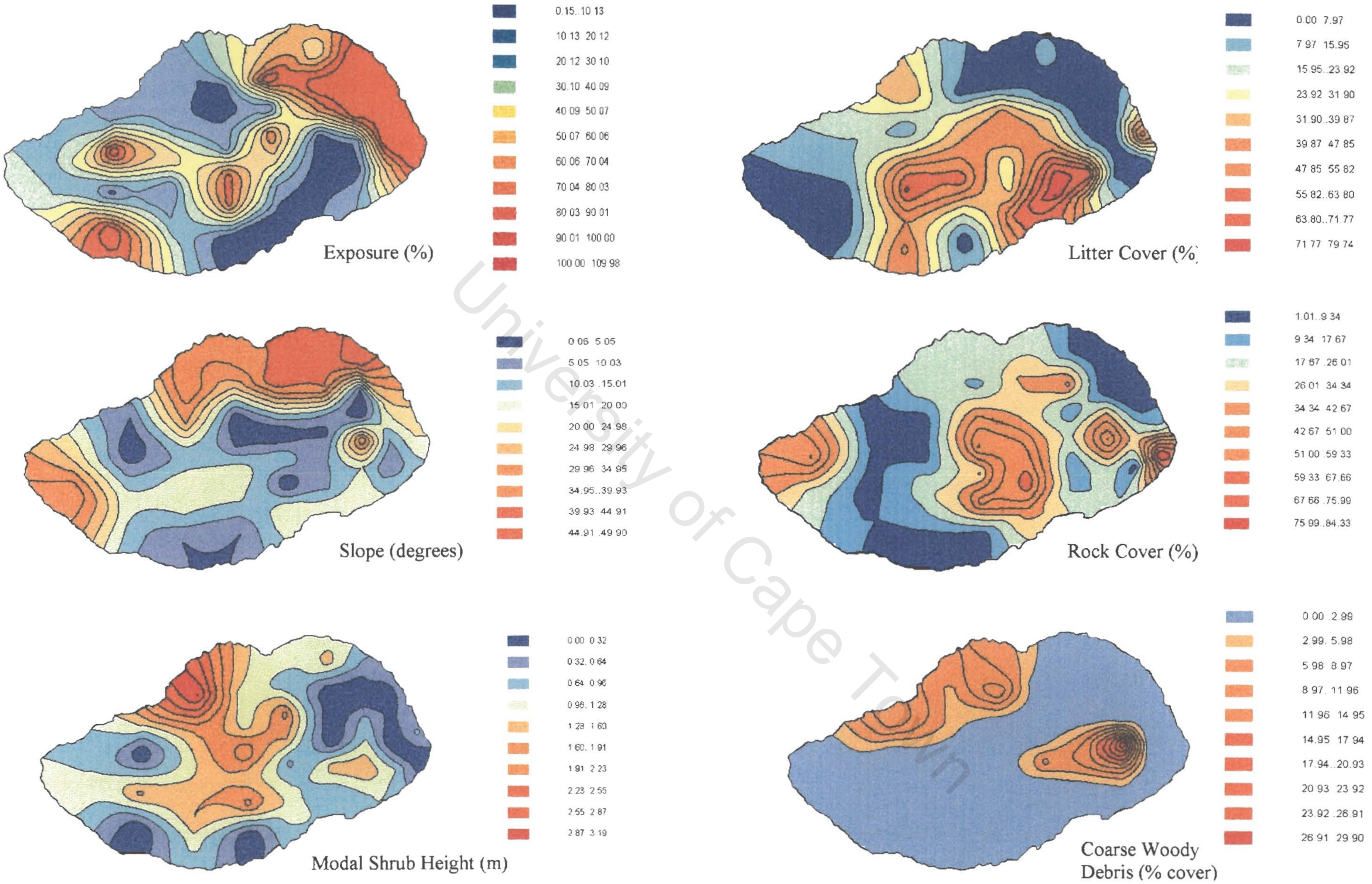


Figure 3.4. Intensity graphs of mean habitat characteristics during the field season. Red indicates the highest values and dark blue represents the lowest values.

Table 3.2. Monthly abundance estimates of *C. vanzoi* in Praslin Island using DISTANCE.

Month	Numbers counted	Abundance	Density (lizards ha^{-1})	Coefficient of Variation	Sample Standard Deviation	Encounter Rate (lizards/metre)	Model
October	212	196.5	178.7	19.8	15.9	0.13	Hazard, cosine adjustment
November	189	142.5	129.6	16.4	9.6	0.11	Half normal
December	98	105.7	96.1	15.8	0.8	0.08	Half normal
January	145	151.8	138.0	11.7	9.2	0.03	Half normal
February	154	105.1	95.6	9.6	4.5	0.07	Half normal
March	125	72.7	66.1	18.4	4.6	0.06	Hazard rate
WET[1]	499	149.2	135.6	15.3	4.8	0.11	Hazard rate
DRY[2]	424	96.4	87.6	8.5	5.8	0.07	Hazard rate
ALL[3]	923	118.3	107.5	9.3	1.7	0.09	Hazard rate

[1] data pooled over the wet season, October-December, 1997; [2] data pooled over the dry season, January - March, 1998; [3] data pooled October, 1997-March, 1998.

Table 3.3. Summary of abundance (#) and density estimates (#/ha.) for Praslin Island generated by DISTANCE after stratification of line transect data into vegetation types to accommodate possible heterogeneity in the original data. Data were pooled across the wet season and dry season to provide large enough sample sizes for analysis. Raw data from both seasons were combined to give an overall estimate of population size.

	Abundance (#)			Density (# / ha.)			% Coefficient of Variation			
HABITAT	wet	dry	all	wet	dry	all	wet	dry	all	N =
Mixed Wood	82.6	49.9	62.7	178.2	108.6	136.2	6.8	8.7	5.3	553
Shrub	40.1	33.0	38.9	238.4	194.3	228.7	13.1	15.8	13.1	157
Manchineel	17.9	30.1	25.9	92.2	158.3	135.5	22.5	20.1	20.8	78
Mixed Grass	9.2	6.6	8.5	72.6	51.1	65.2	25.6	23.2	17.8	54
Bunchgrass	12.3	3.8	5.2	46.0	47.8	65.0	37.1	37.2	21.9	28
Bare/Rock	4.3	3.7	3.9	51.5	41.2	44.1	50.0	48.8	31.8	14
ISLAND TOTAL	**166.4**	**127.2**	**147.1**							

Table 3.4. Monthly abundance estimates of *C. vanzoi* on Praslin Island using PETERSEN.

Month	Lizards Marked	Resighted with Marks	Total Resighted	Abundance Estimate	95% CI	Distribution
October	11	3	61	185	81-408	Poisson
November	20	10	90	173	118-284	Binomial
December	14	6	65	140	70-273	Poisson
January	20	7	60	159	98-328	Binomial
February	20	3	64	340	149-749	Poisson
March	19	9	34	69	48-116	Binomial

Table 3.5. Factor pattern of principal components describing variation in habitat variables. Bold indicates maximum and minimum values.

	Factor 1	Factor 2
Aspect (degrees)	-0.017	0.161
Slope (degrees)	-0.229	**0.763**
Soil Depth (cm)	0.364	-0.296
Litter Depth (cm)	0.551	0.592
Mean Exposure (%)	-0.877	0.042
Rock Cover (%)	0.624	0.183
Soil Cover (%)	0.677	0.546
Litter Cover (%)	0.826	-0.353
Coarse Woody Debris (%)	0.387	**-0.448**
Tree Cover (%)	**0.834**	0.168
Shrub Cover (%)	0.714	-0.367
Herb Cover (%)	**-0.913**	0.154
Vine Cover (%)	0.168	-0.230
Modal Tree Height (m)	0.642	0.279
Modal Shrub Height (m)	0.673	-0.280
Modal Herb Height (m)	-0.271	-0.193

Table 3.6. Results of the Tukey's Studentized Range (HSD) Test for Factor 1 and 2 of the General Linear Model for habitat types.

Tukey Grouping	Mean	N	Habitat Type
Factor 1			
A	0.89	9	Mixed Wood
A	0.88	5	Manchineel
A	0.44	4	Shrub
B	-0.92	8	Mixed Grass
B	-1.38	5	Bunchgrass
Factor 2			
A	1.06	5	Manchineel
A	0.46	5	Bunchgrass
B	0.02	8	Mixed Grass
B	-0.32	9	Mixed Wood
B	-1.23	4	Shrub

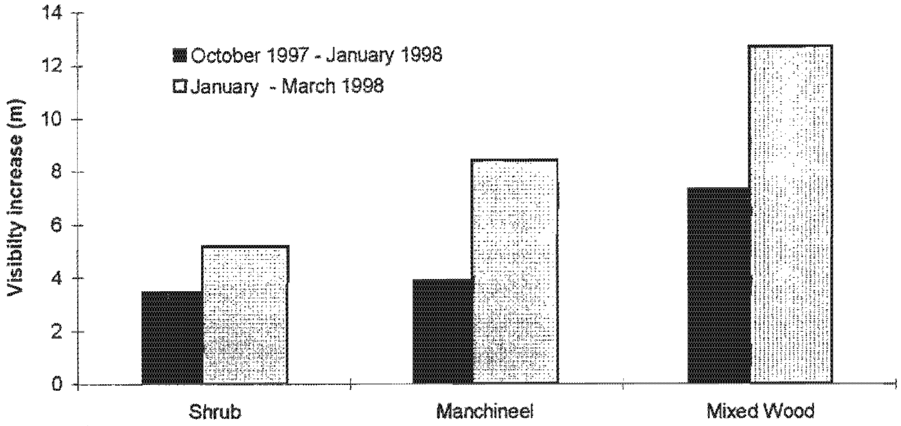


Figure 3.5. Visibility measurements taken from permanent points in three habitat types on Praslin Island.

Petersen mark-resight sampling estimated the mean population size at 177.7±81.6. Monthly population estimates showed large confidence intervals reflecting the small sample sizes (Krebs, 1989; Table 3.5). Comparisons between DISTANCE and Petersen abundance estimates (Figure 3.6) were similar for all months except in February, when the number of resightings was low relative to the number of animals marked (Table 3.5). The correlation between population size estimates was significant (Pearson correlation R^2=0.82, d.f.=3, P=0.035) when February estimates were removed from analysis, indicating a real change in monthly population sizes.

Patterns and Correlates of Lizard Distributions

Graphs of lizard density (Figure 3.7) during the wet season show the concentrations of lizard sightings around one area of the central eastern area of the island, comprised of two peaks. Both peaks occur within the Mixed Wood habitat. The western area accounts for 12.2% of the sightings whereas the eastern area accounts for 41.1%. During the dry season distribution is eroded into four peak areas (Figure 3.7). The northern most area is Mixed Wood–Bunchgrass edge habitat. The east peak is concentrated in the south-facing slopes of the Mixed Wood whereas the southern peak is the south-facing slope in Manchineel. The smaller peak in the north-west falls within the Shrub habitat. These peaks describe 7.7%, 21.1%, 14.9% and 3.7% respectively of the total number of sightings.

Principal component analyses of habitat variables summarised 34.6% of the overall variation in habitat variables in first PCA axis. The second PCA axis explained 13.3%. The first axis represents a gradient from open to sheltered habitat (low scoring on herb cover and mean exposure and tending to score highly on litter cover, and tree and shrub cover) whereas Factor 2 (21.75% of the variation) represents a gradient of structural diversity and ground cover (low scoring on coarse

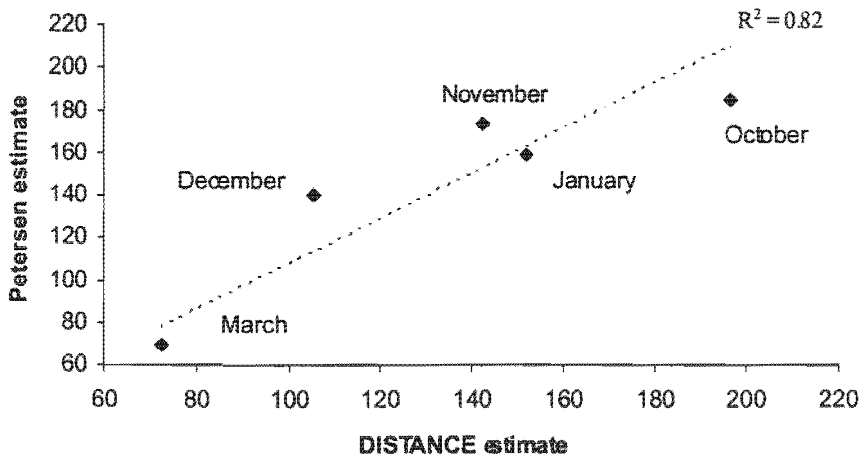
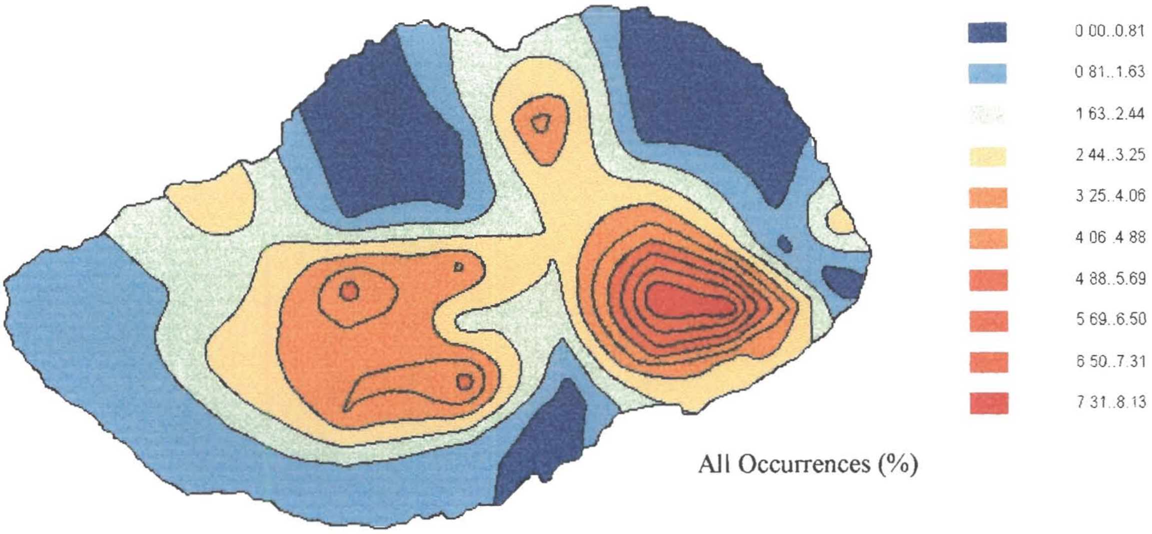


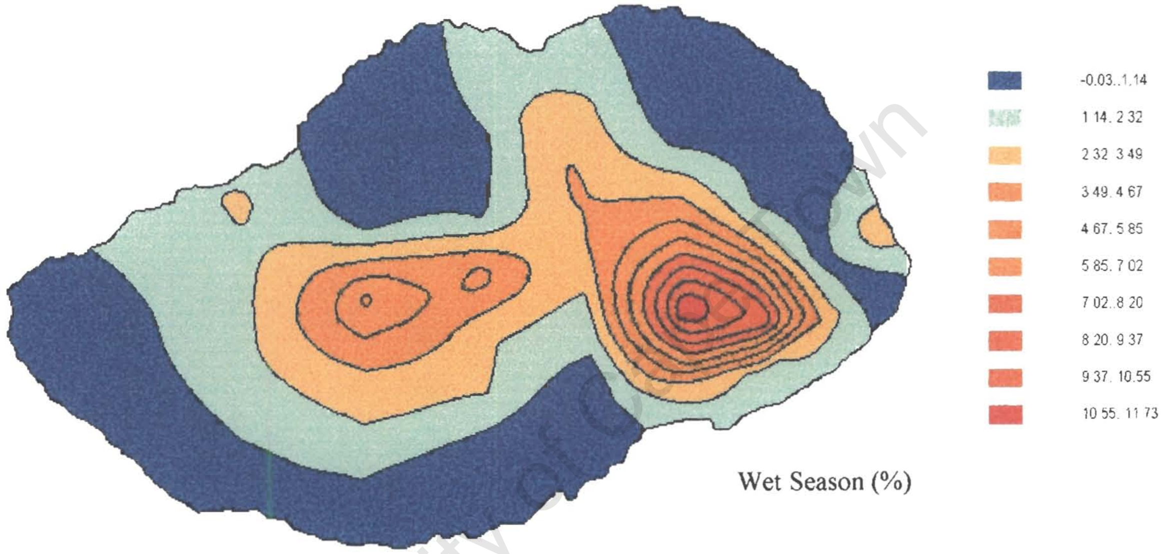
Figure 3.6. Monthly abundance estimates (October 1997 - March 1998) generated by mark-resight surveys (Petersen) and transect surveys (DISTANCE). Removing February as an outlier (See Table 3.6), Y=0.921x-0.124.

woody debris and litter cover and tending to score highly on tree and herb cover, litter depth and soil cover (Table 3.5). By habitat categories, each habitat type had characteristic scores (Tukey's Studentized Range Test, Factor 1 = Alpha = 0.05, d.f. = 26, MSE = 0.072; Factor 2 = Alpha = 0.05, d.f. = 26, MSE = 0.632; Table 3.6). The GLMs showed a significant difference between categories for both Factor 1 and Factor 2. The Factor plot shows close clustering for the majority of the points with hardly any overlap (Figure 3.8A).

All three lizard abundance indices were positively correlated with Factor 1 scores (wet season: R = 0.56, $P = 0.001$; dry season: R = 0.54, P 0.002; both seasons: R = 0.63, 0.0001), but there was no evidence of an Factor 2 effect (wet season: R = -0.26, $P = 0.15$; dry season: R= -0.20, P 0.27; both seasons: R = -0.27, $P = 0.14$). The weak positive relationship between lizard abundance and Factor 2 may be related to slope (factor loading +0.76 but positively correlated with the lizard indices); in the dry season the lizard/slope correlation is -0.34 (P=0.058).

Lizard abundance using the all occurrences was also plotted onto the PCA graph of Factors 1 and 2 (Figure 3.8B). Lizard abundance for each quadrat was indicated on the graph by a circle; the area of each circle being proportional to the value of the index. The index was categorised into four main groups: 0, 0 - 3, 3-6 & >6.), where zero values were given a notional 0.1 (or would not appear at all). Highest values appear on the right of the graph within the woodland and shrub habitats but a higher proportion of zero values appear on the left, corresponding to the grassland habitats.





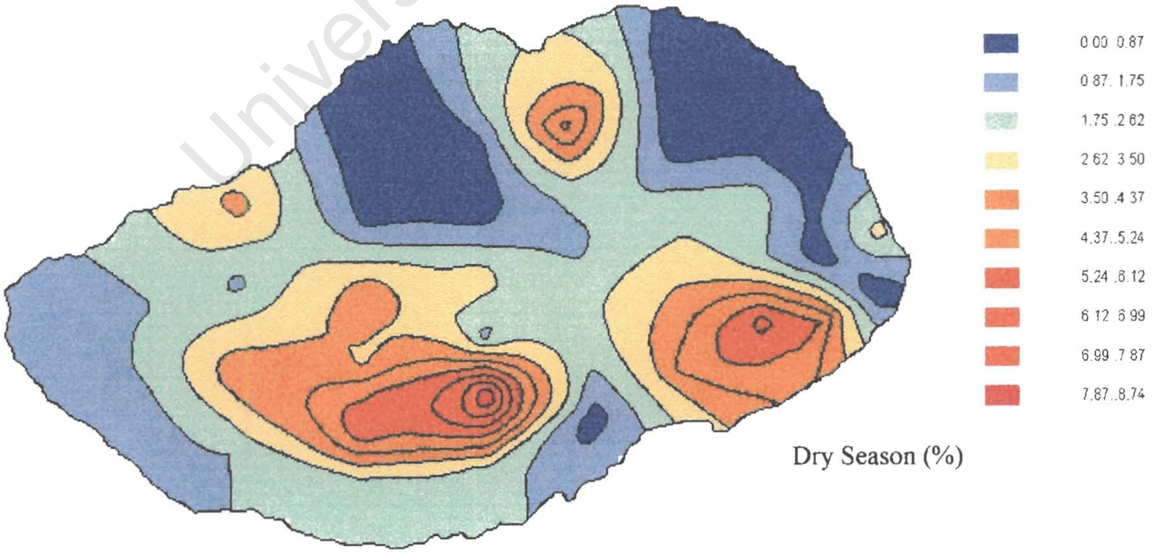


Figure 3.7. Intensity graph showing areas of high lizard density (red) to areas of low lizard density (dark blue) on Praslin Island during the field season and in the wet and dry seasons based on the proportion of occurrences.

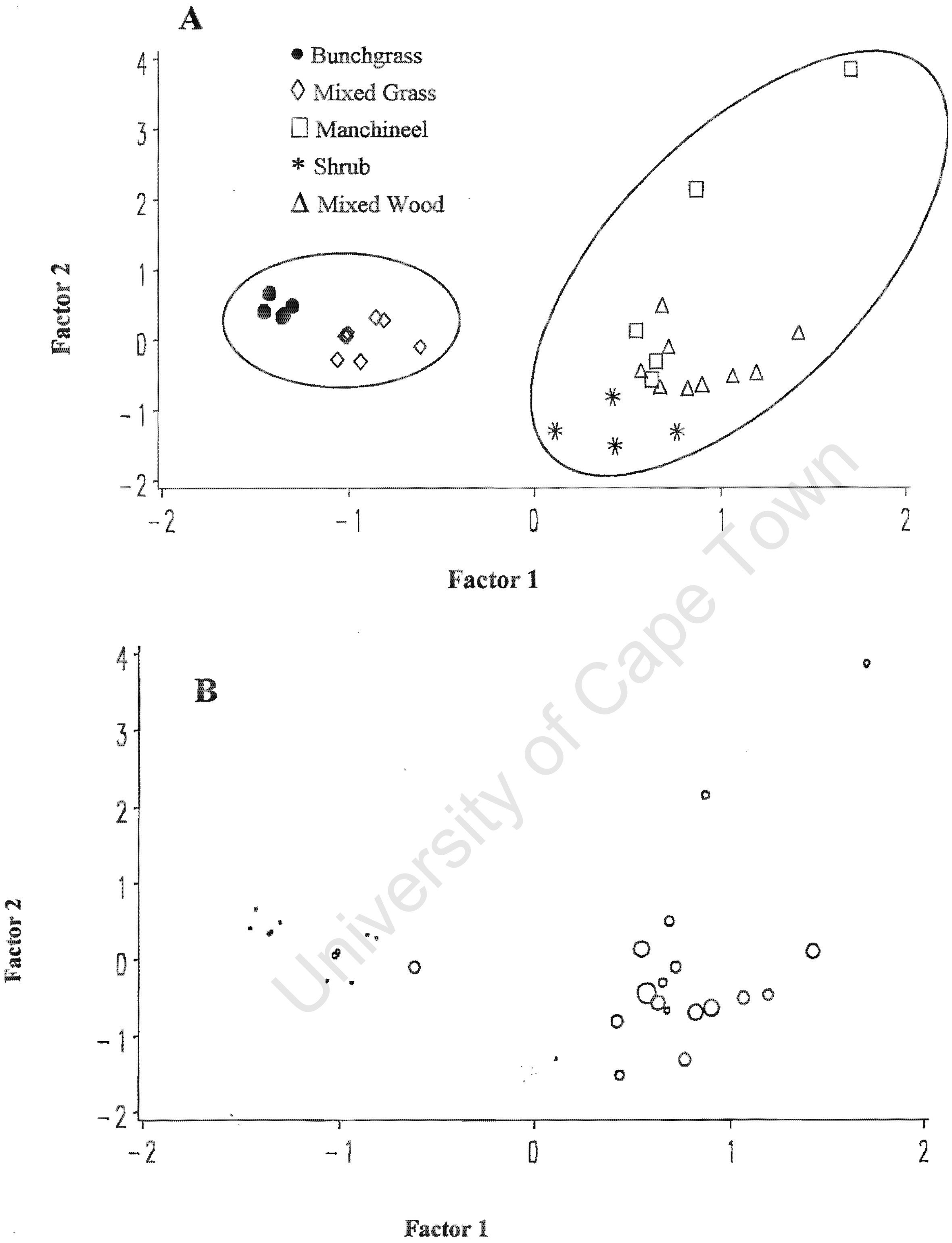


Figure 3.8. Principal Component Analysis; factor plot of habitat characteristics in permanent vegetation quadrats (A), and factor plot of lizard occurrences, where circle size indicates index value (B; see text for details).

The above analysis suggests that the lizards respond only to differences among habitat types as summarised by Factor 1 not Factor 2. Furthermore, habitat variation within habitat categories was not influential. Factor 1 score does not explain any lizard abundance when adjusting for habitat type ($F_{1,25} = 0.27$, $P = 0.60$).

Habitat use and distribution of lizards changed seasonally (Table 3.7, electivity index). Shrub habitat had the highest electivity index during both seasons but Manchineel was under-used in the wet season and used during the dry season. A significantly smaller proportion of lizards used Mixed Wood ($Z = 2.32$, df=2, $P = 0.002$) in the dry season. No significant difference in body size was observed in lizards found in the preferred Mixed Wood, Shrub and Mancineel habitats (Kruskal Wallis, $H=18.5$, df = 2, $P > 0.4$). Mixed Grass and Bare/Rock habitats were under-used in both seasons and Bunchgrass was more used during the wet season.

Lizard density was significant correlated (Pearson R, df = 3) with soil depth ($R = 0.84$, $P = 0.071$), litter cover ($R = 0.87$, $P = 0.055$), coarse woody debris cover ($R = 0.93$, 0.022), shrub cover ($R = 0.93$, $P = 0.022$) and modal shrub height ($R = 0.97$, $P = 0.005$). In addition to the above variables, rock cover is positively correlated with density ($R = 0.12$, $P = 0.045$) during the wet season and in the dry season coarse woody debris is not significantly correlated ($R = 0.41$, $P = 0.51$).

Table 3.7. Detection probability of lizards from the transect line and habitat use described by Ivlev's electivity indicies (Krebs, 1989). A negative electivity index indicates under-use with respect to availability.

Habitat	Detection Probability (%)	Total sightings (#)	Proportion of lizard sightings (%) wet	dry	Electivity Index wet	dry	both
Mixed Wood	43	553	0.50	0.40	0.14	0.02	0.09
Shrub	27	157	0.24	0.26	0.27	0.31	0.29
Manchineel	40	78	0.11	0.23	-0.18	0.18	0.02
Mixed Grass	30	54	0.05	0.05	-0.35	-0.35	-0.35
Bunchgrass	27	28	0.07	0.03	0.01	-0.39	-0.14
Bare/Rock	50	14	0.02	0.03	-0.58	-0.44	-0.52

DISCUSSION

The size of the translocated lizard population on Praslin Island was greater than that predicted for an island 1.1 ha in size (N=64) by Williamson's (1981) equation developed from species-area relationships or extrapolated from body size vs. density graphs (N=13) for vertebrate poikilotherms (Peters, 1983). This may be a function of a disharmonic island system with fewer species than is typical. If so, occupancy of these vacant niches by *C. vanzoi* would surpass this theoretical density.

However, the estimated density of *C. vanzoi* is much lower than other island densities for species within the genus (*C. arubensis*, Schall, 1974 and *C. murinus*, Dearing & Schall 1994), perhaps due to lower productivity of habitat or more likely a result of the short time since translocation. Although both census methods provided similar abundance estimates, the variance of mark-resight estimates was greater. As mark-resight estimates only the catchable population, it tends to underestimate population size relative to estimates provided by DISTANCE (Krebs, 1989).

However, the population has more than doubled each year since translocation and Praslin Island now supports 14% of the total population. The high growth rate observed in the population may be a result of habitat quality whereby surplus energy can be allocated to reproduction. Higher reproductive success and survival in high-quality territories has been observed on islands in the Seychelles warbler (*Acrocephalus sechellensis*; Komdeur *et al.*, 1995).

The seasonal decline in abundance likely indicates a change in lizards' activity levels. Aestivation has not been reported in this species although it does occur within the genus (Casas-Andreu & Gurrola-Hidalgo, 1993) during periods of resource dearth (Crowley, 1987). Lizards with sufficient fat reserves may aestivate while others remain active. The possibility of this behavioural response needs further investigation through telemetry and permanent mark-recapture studies. If aestivation is a behavioural response to seasonal changes in habitat and resource availability then the importance of soil characteristics and thermal stability of burrows will effect habitat use (Pye *et al.*, 1999).

Lizards were distributed on Praslin Island in a non-random manner according to habitat use. Distribution and lizard activity was affected by seasonal habitat changes. Generally, lizards use forested and shrub habitat more than predicted by availability and avoid grasslands (observed in *C. arubensis*, Schall 1974; *Gambelia sila*, Warrick *et al.*, 1998; *Lacerta lepida*, Castilla & Bauwens, 1992). Electivity indices showed rank use-preference of preferred habitats as Shrub, Mixed Wood, Manchineel, over the less used habitats Bunchgrass, and Mixed Grass. Lizard density was strongly positively correlated with shrub cover, coarse woody debris and litter cover, which are important characteristics of Shrub habitat. The lizards used shrub habitat the most during both seasons and this habitat also had the smallest area of the preferred habitats.

Distribution and habitat use in lizards is generally a reflection of trade-offs between aspects of thermoregulation (Aspland, 1974; Sartorius *et al.*, 1999), food availability (Henderson, 1974; Griffiths & Christian, 1996; Adler *et al.*, 1999), predator avoidance (Stamps, 1983) and population density (i.e. social interactions; Schall, 1974; Stamps & Tanaka, 1981). Thermal constraint in *C. vanzoi* may be the primary reason for the seasonal shift in habitats (Paulissen, 1988; Martin & Lopez, 1998; Sartorius *et al.*, 1999). The population is more dispersed during the dry season. A total of 47.5% of lizard sightings was concentrated in four discrete areas, whereas during the wet season 53.3% of the sightings were concentrated in two adjacent areas. A shift from Mixed Wood to Manchineel use and development of a strong avoidance of Bunchgrass occurred in the dry season. The significant increase in exposure in Mixed Wood during the dry season may make shuttling thermoregulation more difficult. The lack of cover in Bunchgrass during the hot dry season would also make thermoregulation difficult. Exposure is a cue for microhabitat selection in *C. sexlineatus* (Paulissen, 1988) and seasonal changes in thermal environments affect microhabitat choice in *Ameiva ameiva* (Sartorius *et al.*, 1999).

There may also be non-thermoregulatory explanations for the seasonal shift in distribution (Mysterud & Ims, 1998). I found no direct correlation between lizard distribution and invertebrate species richness within the habitats. However, *C. vanzoi* is a generalist and although primarily insectivorous, individuals were observed to eat leaves of *Rauvolfia virdis* by climbing vines, feed on picnic remains left on the beach, and one adult female was observed carrying a dead *Anolis luciae*. Therefore, diet is likely to reflect prey availability (Vrcibradic & Rocha, 1998), hence lizard distribution may be linked to food supply in various habitats. Indirectly, food supply on Praslin Island can be assumed as high leaf litter cover is associated with high invertebrate density (Martin & Lopez, 1998) and arthropod abundance is greater in wooded habitat than open habitats (Smith, 1996). Habitat use can be related to precipitation, plant productivity and invertebrate abundance in *C. tigris* (Anderson, 1994). During the wet season the peaks of lizard density strongly reflect areas where litter cover is greater than 48%. These areas may support greater invertebrate density during the wet season, but conversely high litter cover in the dry season may also imply extensive leaf drop and therefore, increased exposure. Although litter cover increased in all wooded habitats during the dry season, only Mixed Wood showed a significant increase in exposure. Peak densities for both seasons also reflected areas with gentle slopes (<20°) and a modal shrub height of 1.3 m to 1.9 m.

Another factor effecting habitat use could be predation risk, since lizards would be more exposed to predation following loss of vegetation cover (Martin & Lopez, 1998; Smith, 1998). However, little diurnal predation risk exists on Praslin Island. American kestrels (*Falco sparverius*) were occasionally observed in the Bunchgrass habitat but they are primarily canopy hunters. Furthermore, *C. vanzoi* represents the highest trophic level as no predatory snakes or mammals exist on Praslin Island, with the exception of infrequent occurrence of nocturnal black rats (*Rattus rattus*) that are removed immediately when discovered.

Density-dependent habitat use could also influence distribution if the population on Praslin Island is reaching carrying capacity. Juvenile lizards were seen more frequently in the grassland habitats than adults (pers. obs.). This may be a reflection of their greater heat tolerance (Paulissen, 1988) enabling the exploitation of the richer invertebrate diversity, but could also reflect a "sink" habitat. Antagonistic social interactions were seen between all sex-groups except female-juvenile and juvenile-juvenile and tail autotomy is common in this population (see Chapter 4). Competitive interference could develop into differential age-sex habitat use as lizard density increases (Jenssen *et al.*, 1998; Martin & Forsman, 1999) and does occur in *C. arubensis* (Schall, 1974).

Habitat use is dynamic and the distribution of lizards and individual occupancy patterns will overlap, as *C. vanzoi* is a highly mobile lizard. For example, occasionally marked lizards were seen during line transect sampling, at distances ranging up to 75 m from the original capture site. Behaviour, food habits and activity patterns were not specifically studied and will influence the use of habitat types for distinct activities. The lizards used Mixed Wood habitat more during the wet season and Mnchineel habitat more during the dry season and these habitat use patterns were correlated to habitat characteristics. This seasonality is a response to well defined climate patterns on Praslin Island which will broadly influence the processes associated with population dynamics (Paulissen, 1988). Hence, the colonisation process was not a systematic radiation or random dispersal from the release site.

Knowledge of patterns of habitat use and seasonal changes in distribution is crucial to planning releases of the *Cnemidophorus vanzoi* and for effective conservation measures to be undertaken by managers. These results allow managers to assess the suitability of, and improve potential translocation sites through habitat restoration, introduction of individuals to the colonising population in agreement with the species ecology, and to target specific research areas in the event of a decline in abundance. Future releases should be carried out on islands that are predator-free, with high floral diversity, an established cover layer of modal 1.3 m height, gentle south facing slopes (< 20 degrees), non-compact soils with a high organic content (50%), thick litter layer and rocky outcrops. The Praslin Island population could potentially be augmented through supplemental feeding of 'wet' fruits during the dry season and by increasing the area of shrub habitat by planting indigenous shrubs such as *Rauvolfia virdis* at the edge of the mixed woodland habitat.

Cnemidophorus vanzoi has flourished in the microhabitats found within Praslin Island. Conservation initiatives depend on understanding the relationship of a species with its environment. By studying the habitat use patterns of the colonising population and relating these patterns to specific habitat characteristics we understand some of the factors important to further translocation success and survival of the species. The translocated population has survived and reproduced successfully in the short term. Consequently, demographic and environmental stochasticity may play a smaller role in extinction risk to this population compared to the risk associated with catastrophic events (e.g. hurricanes or predator introductions).

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Appendix 3.1. Vegetation Matrix of Praslin Island. Season: ● = wet & dry O = wet only, , X = dry only. Rarity * = one quadrat wet season only, ** = one quadrat wet & dry season, x = one quadrat dry season only.

Species	Mixed Wood	Shrub	Manchineel	Mixed Grass	Bunch Grass
Trees/Shrubs					
Hippomane mancinella	●	●	●		
Tabernaemontana citrifolia	●		●		
Cornutia pyramidata	●	*	●		
Pisonia fragrans	●				
Croton bixoides	**	x			
Tabebuia heterophylla		●			
Pithecellobium unguis-cati	o	**			
Ficus citrifolia	x				
Ficus sp.	x		**		
Erythsoxyum ovatum	●		**		
Rauvolfia virdis	●	●	●		
Erithalis fructicosa	**		**		
Chameacrista glandulosa	●	●	●X	●	**
Solanum racemosum	●	*	X		
Rivina humilis	●	o			
Sida glomerata		o		o	
Eupatorium odoratum	●	*X	●		
Croton flavens		*X			
Lantana camera		**			
Cordia curassavica		*X			
Croton guildingiana		x			
Cephalocereuw royerii	●	*			
Herbs					
Ruellia tuberosa		**	**		
Enicostema verticullatum					**
Portulaca halimoides				ox	
Stachytarpheta jamaicensis				●	**
Emilia sonchifolia			*		
Spermacoce ernestii	o		**	*	
Spermacoce verticillata		X			
Evolvulus convolvuloides	*		O		
Microtea debilis	*				
Peperomia pellucia	*		*		
Bidens cynapifolia		*	*		
Grasses					
Schizacyrium microstachym	*	X			●
Cyperus sphacelatus	**	X	●	●	
Fibristylis ovata		X	*	x	
Green sp.				●	
Digitaria sp.			X		
Vines/Creepers					
Centrosema virginianum	o	*	o	●	●
Exogonium selanifulium	**	X	x		
Cissus verticillata	●		o		
Desmodium incanum	●	X	X		o
Fabaceae sp.				o	o
Alysicarpus vaginalis				**	
Tricchostigma octandrum	X				

Appendix 3.2. Invertebrate Diversity on Praslin Island

# Species / Classification	**Mixed Wood**	**Shrub**	**Manchineel**	**Mixed Grass**	**Bunch Grass**
Arachhnida – Araneae	2	1	0	2	1
Dictyoptera	1	1	1	0	0
Coleoptera	4	7	4	11	5
Coleoptera – Curculionidae	1	0	1	0	0
Coleoptera – Orthoptera	1	0	1	4	0
Chilopoda	2	2	1	1	0
Dermaptera	2	3	2	3	2
Crustacea – Isopoda	1	2	2	2	1
Grubs (larva/pupa)	2	1	2	1	2
Diptera	1	0	0	0	1
Hymenoptera	0	0	0	0	1
Siphonaptera	0	0	1	1	1
Mean Species / Month ± sd	8.0 ± 2.10	4.83 ± 1.72	4.83 ± 2.04	10.67 ± 3.61	4.16 ± 1.60
Total Number of Species Found	17	17	15	25	14

Chapter 4. DEMOGRAPHICS AND BODY CONDITION OF *CNEMIDOPHORUS VANZOI* ON PRASLIN ISLAND

ABSTRACT

As a conservation strategy, 42 *Cnemidophorus vanzoi* (Teiidae) were translocated from Maria Major Island to Praslin Island, St. Lucia, West Indies in May 1995. Three years post-release, I studied demography and morphometrics of the translocated lizard population, during a six-month period covering wet and dry seasons. Age, sex, snout-vent length (SVL), body mass (BM), tail length, tail regeneration, and overall condition (moulting, cuts, external parasites, reproductive condition) of 105 lizards caught during the study period are analysed. Sex ratios (adult males: adult females), and age ratios (adults: juveniles), did not vary significantly by month or season. The species has a large sexual size dimorphism ratio (SVL adult male: SVL adult female). Seasonal changes in BM and body condition index, (CI=BM/SVL), suggest severe resource limitation during the dry season. A high frequency of tail autotomy may indicate intense intraspecific competition since the island is relatively free from predators. Some adult males appear to maintain juvenile colours. Morphometric and CI comparisons between Maria Major lizards (N=22) and Praslin lizards (N=105) showed no significant difference nor has the Praslin population changed significantly compared to the founders (N=30). The introduced population has successfully colonised its new environment and no significant change in condition or body size has occurred in the population during the three years since translocation.

INTRODUCTION

Translocation is an important conservation technique that can be used to establish, re-establish, or augment a population (IUCN, 1987). Viable, free-ranging populations of a species that were locally extinct or extirpated in the wild can result requiring only minimal long-term management. Translocation success is judged by population persistence, which is affected by founder numbers, the species' ecological attributes (e.g. intrinsic rate of increase), and the condition of the recipient habitat (Griffith *et al.*, 1989). The last factor needs to be assessed according to the species' ecological requirements at the time of release, and by the temporal variation of crucial resources post-release. Founding populations must withstand fluctuations in both environment and demography but seasonally fluctuating resources can curtail the survival and reproductive potential of a small colonising population (Soulé *et al.*, 1986). Understanding the impact of periods of resource shortage and of severe environmental conditions is crucial for planning an effective translocation. These types of studies exist (Miura & Maruyama, 1986; Ianson, 1989; Sweitzer & Berger, 1993; Kennish, 1997), but there are few studies demonstrating how these variables influence the ecology and population dynamics of translocated populations.

Single species island colonisations are associated with ecological release that can manifest as an evolutionary release into larger body size (Andrews, 1979; Schoener & Gorman, 1968). Larger body size may be beneficial in fluctuating environments by providing fasting endurance and survival advantage during periods of food limitation (Lindstedt, 1985; see also Chapter 3). However, ecological release is effected by resource fluctuations, dietary shifts and changes in competition (Irschick *et al.*, 1997; Wikelski & Trillmich, 1997). Resource dearth will precipitate changes in energy allocation that in turn effect survival, reproduction and competition (Soulé *et al.*, 1986). Declines in growth rate, activity and body conditions have been documented in lizards during periods of resource limitation (Griffiths & Christian, 1996).

The endemic lizard, *C. vanzoi,* (family Teiidae) is the sole representative of its genus in the Lesser Antilles (Swartz & Henderson, 1991). Prior to 1995, this lizard inhabited two small offshore islands in St. Lucia. Due to the perceived risk from fires and introduced predators from the main island, a translocation was conducted by the St. Lucia Forestry Department and the Durrell Wildlife Conservation Trust, UK. Lizards were collected from Maria Major and translocated to Praslin Island (13°52.2N, 60°53.1W), a 1.1 ha. island located 220 m off the east coast of St. Lucia in May 1995. The composition of the translocated population was 13 adult males, 12 adult females, 2 juvenile males, and 1 juvenile female. Shortly after translocation, a single mongoose was discovered on Praslin Island and following removal, only one adult male was seen on the island (Q. Bloxam, pers. comm.). A further 14 lizards (7 adult males, 6 adult females, and 1 juvenile female) were translocated. There have been no subsequent translocations. Praslin Island has distinct wet and dry seasons (see Chapter 2) and shows significant seasonal variation in vegetation cover (see Chapter 3).

Comparing demographic traits between translocated and wild populations will help managers determine when a population has become an established viable entity (Miller *et al.*, 1999). Changes in body condition may act indirectly to decrease survival probability, hence observed changes can imply effects of the translocation event on the lizards and highlight any seasonal limitation of resources. The translocated population is subject to seasonally fluctuating resources in the new environment (see Chapter 3). All my data are presented in this Chapter as there has been no scientific publication on this species in the last decade, save the mention of *C. vanzoi* as a member of "one of the least understood of all of the species groups [(in the Genus *Cnemidophorus*), Wright, 1993, p.32].

The aim of this paper is to describe the morphometrics and demographic status of *Cnemidophorus vanzoi* translocated from a natural population to another island previously uninhabited by the species. I describe the temporal changes in body condition and demography of Praslin lizards. Wherever possible, comparisons with the founding population are made and seasonal changes are related to the ecology of the species. If the new environment were not suitable as a translocation site, a decline in body condition compared with the founding population would be expected. Condition indices would also be expected to reflect seasonal resource fluctuations on Praslin Island.

METHODS AND ANALYSIS

I studied the translocated population of *C. vanzoi* on Praslin Island from October 1997 to March 1998. Praslin Island was visited once each month to catch lizards for measurement. Lizards were temporarily marked (see Chapter 3) and checked carefully for any traces of previous capture (paint flecks, cut tail tips - see Chapter 5) so that the same lizard was not caught twice during the same session. However, repeated captures can not be ruled out hence sample size may be inflated.

Lizards were caught using a hand-held noose made from 4.5 kg breaking strain, monofilament line. Snout-vent length (SVL) and tail length were measured with 150 mm callipers to the nearest 0.5 mm or with a ruler (for tails > 150 mm). Body mass (BM) was determined to the nearest 0.5 g with a 100 g hand-held spring balance. Sex was determined by the number of scales above the vent (male; N=3, female; N>3). Adult status of males was determined by coloration. Adult males have a sulphur yellow ventral surface and turquoise tail and flanks. Juvenile males and females are predominantly brown with cream ventral surfaces. Females display no secondary sexual characteristics, and were categorised as adults if their SVL > 76.0 mm. This SVL measurement is used by Vitt & Breitenbach (1993) to define an 'average' female *Cnemidophorus* species based on a review of published papers describing the genus. The general condition of each individual was noted (i.e. moulting, gravid, cuts, external parasites). Information on tail regeneration was collected; four individuals who dropped tails during capture were not included in analysis.

Morphometric and demographic data were analysed by age-sex group (i.e., adult males, adult females, juvenile males, juvenile females) and pooled across months (N=6) and seasons (wet season = October - December 1997; dry season = January - March 1998). No significant differences were found between the unpublished data on the founder population (1995, N=29) and individuals on Maria Major (Buley *et al.*, 1997; N=22). These data were pooled and used for founder (Maria Major) and translocated (Praslin Island) population comparisons. Group means are influenced by age structure bias as there was no field method to determine age and individuals were not permanently marked.

Mean SVL and BM, age ratios (adults:juveniles), adult sex ratios (adult males:adult females), size dimorphism ratio (SVL adult male: SVL adult females; Stamps 1983), and condition indices (CI = BM/SVL; Wilson, 1991) were calculated. Age and sex ratios were calculated from data obtained during line transect sampling (see Chapter 3). Size dimorphism ratio used length instead of mass to avoid bias created by differences in reproductive status (i.e. gravid females; Stamps, 1983). Condition index calculations were restricted to adult males and adult, non-gravid females with no evidence of tail regeneration (Wilson 1991) to minimise the effects of high juvenile growth rates (Christian *et al.*, 1996). Comparisons of the above were made with the founding population where data were available. Statistical analyses were performed using Winks Professional 4.5 statistical package (Elliott, 1996).

RESULTS

An average of 17 lizards was caught each month (range 11-20). A total of 105 lizards (51% male : 49% female) was caught over the six month period. Three lizards escaped before all measurements were made. All data are presented in Appendices 4.1 - 4.3 to better describe the species.

Morphometrics

A two-way analysis of variance (ANOVA) showed a significant difference in SVL between ages ($F_{2,102}$ =210, P=0.04) and sexes ($F_{2,102}$ =87, P=0.05) but no interaction between effects ($F_{4,100}$ =0.7, P=0.44, df=100). The same analysis failed to detect significant differences in BM between age and sex (age, $F_{2,102}$ =18, P=0.15; sex, $F_{2,102}$ =10, P=0.19) but found a significant interaction between effects ($F_{4,100}$ =5.2, P=0.03) Morphometrics of each age-sex group are shown in Table 4.1. The smallest male to display adult coloration had a SVL of 81.1 mm. All males SVL > 98.5 mm showed adult colours (Figure 4.1). The smallest gravid female measured 78.0 mm. Five individuals were suspected recaptures (based on small regeneration seen on the tail tip). Two of these were confirmed as recaptures by residual paint marks. A juvenile female, initially caught in October and recaptured in November gained 15.0 mm SVL and 5.5 g BM. A juvenile male initially caught in November and recaptured in December gained 17.0 mm SVL and 17.0 g BM.

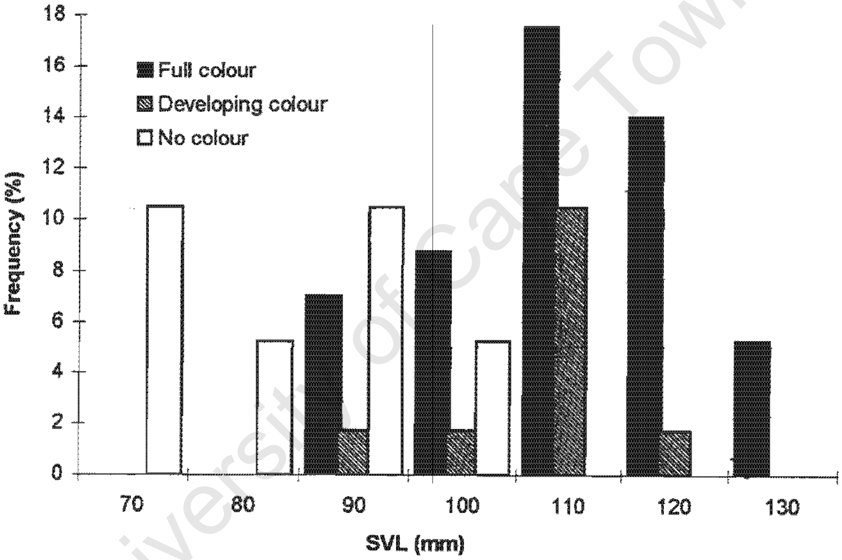

Figure 4.1. Presence of adult coloration and SVL (mm) in male *C. vanzoi* on Praslin Island.

Pooling all measurements showed SVL and BM were significantly correlated (r_s = 0.97, df=96, P<0.001). When sexes were analysed separately, a significant correlation was found in adult females (r_s = 0.71, df=31, P<0.001) but not adult males (r_s = 0.24, df=29, P=0.18). Both juvenile males and juvenile females showed a significant correlation between SVL and BM (juv. males; r_s = 0.96, df=17, P<0.001; juv. females; r_s = 0.81, df=13, P<0.001). Adults and juvenile females demonstrated a linear relationship whereas juvenile males showed a more exponential trend (Table 4.2; Figure 4.2).

Table 4.1. Morphometrics of *C. vanzoi* for each age-sex grouping on Praslin Island. Means calculated from all data collected October 1997 - March 1998.

SVL (mm)	**Mean ± sd**	**Range**	**N**
Adult Male	105.3 ± 10.2	81.0 – 125.0	38
Adult Female	87.8 ±5.9	77.0 - 98.0	32
Juv Male	79.1 ±11.9	62.0 - 98.5	19
Juv Female	65.7 ± 9.4	41.0 - 75.0	15
BM (g)			
Adult Male	37.8 ± 10.6	10.0 - 56.5	37
Adult Female	19.5 ± 5.4	11.0 - 33.0	32
Juv Male	15.5 ± 7.1	7.0 - 28.0	19
Juv Female	7.7 ± 2.1	3.5 - 10.5	15

Demographics and Dimorphism

The mean sex ratio and age ratio of individuals caught on Praslin Island was 1.1 males to 1 female and 2.0 adults to 1 juvenile. Juvenile sightings were most frequent at the end of the wet season (December, 1997; Table 4.3). Sex ratios and age ratios calculated from line transect sampling methods averaged 0.71 and 1.41, respectively. Size dimorphism (mean male to female SVL) was calculated as 1.20. No significance difference was observed in the monthly or seasonal ratios (monthly, Kruskal-Wallis non-parametric test, df=5, P>0.6, for both ratios; seasonal, Mann-Whitney U test, df=1 P>0.6 for both ratios). Bias in sampling methods may affect mean ratio determination. Juvenile males sighted from a distance may have been misidentified as females, resulting in a negatively biased sex ratio and positively biased age ratio. Averaging the two estimates gives a sex ratio of approximately 1.0 and age ratio of approximately 1.7.

Body Condition

The condition index (CI) of adult males was significantly greater than that of adult females on Praslin Island (t=6.05, df=37, P<0.001, Figure 4.3). All age-sex groups had lower CIs during the dry season but this was only significant for females and juvenile males (Mann-Whitney U; females, Z=2.16, df=15, P=0.03; juvenile males, Z=3.03, df=12, P=0.002; Figure 4.4). The decrease in mean body mass between seasons was 18% in adult males, 21% in adult females and 53% in juvenile males. Juvenile females showed a mean seasonal increase of 6%, but this is an artefact of the small sample size during the wet season (N=2). CI was significantly correlated with precipitation only in juvenile males (r_s=0.74, df=12, P<0.01; all other age-sex groups P>0.5).

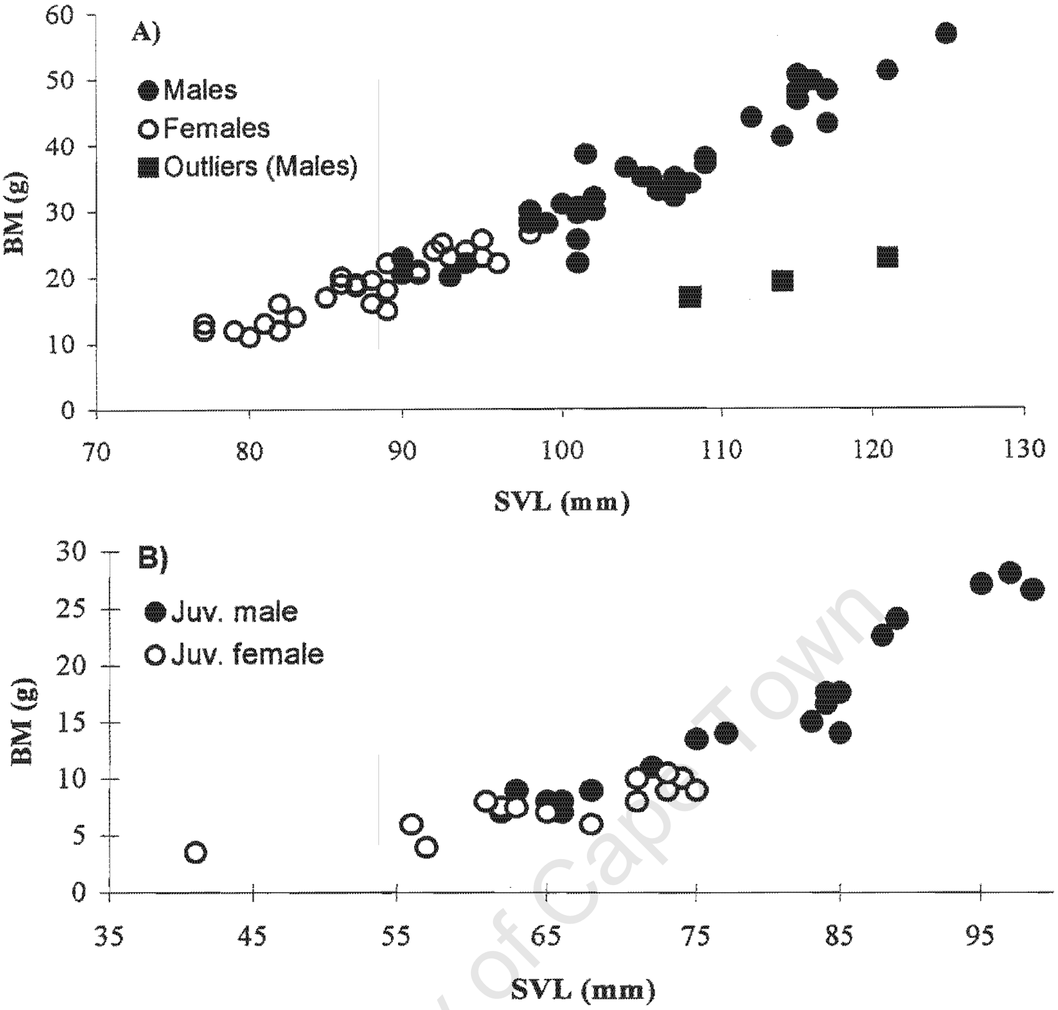

Figure 4.2. Scatterplot of BM and SVL for adult and juvenile *C. vanzoi* caught between October 1997 - March 1998 on Praslin Island. A) Adults. B) Juveniles. For equations and sample sizes see Table 4.2. Outliers were <10th percentile for BM.

Table 4.2. Mass-length relationships for each age-sex group and pooled on Praslin Island. Y = Body mass (g), X = SVL (cm); Outliers from adult males (below 10th percentile for BM, N=3) were removed from data prior to analysis (Fig. 4.3).

	Regression Equation	**R^2**	**N**
Adult Males	$Y = 1.05\,X - 75.58$	0.89	29
Adult Females	$Y = 0.75\,X - 48.97$	0.86	31
Adults Pooled	$Y = 0.94\,X - 63.68$	0.94	60
Juvenile Males	$Y = 0.663e^{0.0386X}$	0.95	19
Juvenile Females	$Y = 0.191\,X - 4.889$	0.74	15

Table 4.3. Sex and age ratios calculated from line transect data. Ratios were calculated by month, season (wet season = October - December 1997; dry season = January - March 1998) and pooled across all months.

Month	Sex ratio (male:female)	Age ratio (adults:juvenile)
October	0.56	2.40
November	0.88	1.16
December	0.72	0.98
January	0.73	1.67
February	0.90	1.10
March	0.62	1.21
Wet Season	0.68	1.51
Dry Season	0.75	1.30
Pooled all months	0.71	1.41

Evidence of tail regeneration was observed in 35% of individuals caught on Praslin Island (N=105). The highest frequency occurred in adult females (40%), then adult males (38%) followed by juvenile males (14%) and juvenile females (8%). Adults had significantly more tail breaks than juveniles (χ^2=11.9, df=1, P=0.001), but there was no difference in tail break frequency between sexes (χ^2=0.03, df=1, P=0.87) or seasons (χ^2=2.19, df=1, P=0.14). As evidence of tail regeneration is visible throughout life, the greater significance is likely a function of age. Mean SVL of adult males with evidence of tail regeneration was 107.2 mm (range=81.0-125.0 mm); adult females, mean=88.3 mm (range=77.0-95.0 mm); juveniles, mean=46.5 mm (range=11.0-71.0 mm). Overall, the highest proportion of autotomy was observed in individuals with SVL 80-100 mm (62%).

Population Comparisons

Adults on Praslin Island (N=69) were not significantly larger than the Founders (N=30; Mann-Whitney U test, SVL; P>0.24 for all comparisons). Masses of adult males also were similar (Mann-Whitney U test, Z=0.18, df=44, P=0.86) but adult females of the Founders were initially found to be heavier (Mann-Whitney U test, Z=4.41, df=28, P<0.001). After controlling for reproductive state in the Maria Major population (40% were gravid), there was no significant difference between female BM. Sample sizes were too small to test for differences between the Praslin Island and Maria Minor populations (N=7). However, SVL and BM measurements recorded at Maria Minor are much less than average measurements for the species (Appendix 4.3). Individuals on Maria Minor appear smaller and are less brightly coloured (K. Buley, Q. Bloxam, pers. comm.).

Tail break frequency was not significantly different between the founders and translocated population (χ^2=0.5, df=1, P=0.48). The founders (N=51) demonstrated 41% frequency of tail autotomy (males=60%, females=35%; and juvenile males=5%) similar to Praslin

Island (35%). Adults showed a significantly higher frequency of autotomy than juveniles on Maria Major (χ^2=16.2, df=1, P<0.001), but no difference between sexes (χ^2=1.8, df=1, P=0.18). Condition indices (excluding gravid females) did not differ significantly between the translocated population and the founder population (Mann-Whitney U; males, Z=0.53, df=43, P=0.60; females, Z=0.22, df=19, P=0.82).

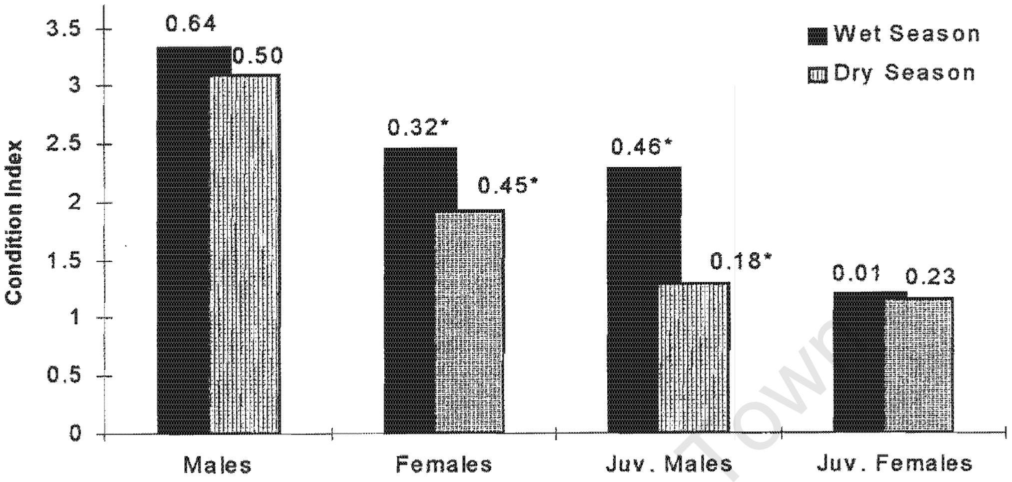

Figure 4.3. Mean condition index (BM/SVL) for each age-sex group on Praslin Island. Condition indices were calculated for individuals without evidence of tail autotomy (males, N=22; females, N=17; juv. males, N=14; juv. female N=12). Wet season = October - December 1997, dry season = January - March 1998. Numbers indicate one standard deviation and significant (P<0.05) seasonal differences are denoted by an asterisk*.

DISCUSSION

In tropical lizards, life history strategies have evolved to accommodate resource fluctuations associated with pronounced wet-dry seasons (James & Shine, 1988; Vitt & Blackburn, 1991; Wilson, 1991; Christian & Bedford, 1995). Variation in the resources, especially food supply during the dry season, can result in reduced growth and activity, a drop in general body condition (Huey *et al.*, 1977; Dunham *et al.*, 1978; Andrews, 1982; Taylor, 1986; Paulissen, 1988; Howland *et al.*, 1990; Griffiths & Christian, 1996; Smith, 1996), and associated seasonal physiological stress can increase mortality and lower reproductive success (Tinkle, 1970; Bradshaw, 1986; Marken-Lichenbelt, 1993). On Praslin Island, the wet season is characterised by higher precipitation, invertebrate diversity and vegetation cover, and lower temperatures (see Chapters 2 & 3). The decline in lizards' BM on Praslin Island indicates resource decline during the dry season. West Indian anoles are food limited on a seasonal basis (Lister, 1981; Stamps & Tanaka, 1981; Floyd & Jenssen, 1983) due to significant reduction in invertebrate availability during the dry season (Griffiths & Christian, 1996).

Strong seasonal changes in fat reserves and seasonal cycling of lipids are common in lizards with the highest fat reserves recorded after the wet season (Vitt, 1983; Taylor, 1986; Dearing & Schall, 1994). Caudal fat reserves supplement poor quality diets and can affect survival during periods of low food availability (Sweitzer & Berger, 1993; Perez-Mellado *et al.*, 1997). Low CI are also associated with reduced growth rates and activity in lizards during dry seasons in arid environments (Griffiths & Christian, 1996; Smith 1996). Although no measure of seasonal growth rate could be determined from my data, the linear relationship of BM and SVL in adults compared with the exponential relationship observed in juvenile males suggests that the two are part of a typically asymptotic growth curve. This also occurs in another insular species *C. murinus* (Dearing & Schall, 1994). The significant seasonal difference in abundance (see Chapter 3) combined with decreased seasonal body mass supports the suggestion of Casas-Andreu & Gurrola-Hidalgo (1993) that individuals of *C. lineatissimus* and *C. communis* with sufficient fat reserves aestivate whilst others must remain active to search for scarce food resources. Hence, the lower CI observed could be an artefact of selective aestivation. Aestivation and reduced activity levels are also behavioural responses to dehydration to reduce evaporative water loss in *Sceloporus undulatus* (Crowley, 1987).

Seasonal CI (length-corrected mass) were significantly different in adult females and juvenile males. In *Chlamydosaurus kingii*, male CI were constant whereas female CI were variable across seasons (Griffiths & Christian, 1996) and female *C. ocellifer* show a constant decline in body fat during the dry season (Vitt, 1983). Changes in male CI are related to energetically expensive activities associated with the breeding season (Fleming & Hooker, 1975; Howland *et al.*, 1990; Shine, 1990). Tropical *Cnemidophorus* species have reproductive seasons of various duration and frequency but generally occur during the wet season (Vitt & Breitenbach, 1993; Dearing & Schall, 1994; in *Ameiva plei*, Censky, 1995a). From the calculated age ratios and abiotic conditions necessary for incubation (Vitt & Breitenbach, 1993) and the fact that no copulations were observed during my study, I might have sampled only post-breeding season males at an already low CI. Hence, the low CI observed in males may have been maintained by the resource dearth rather than reflecting a seasonal change in resources.

If females are receptive only at the beginning of the wet season (Vitt & Breitenbach, 1993), intense male-male competition would be expected. Sexual size dimorphism has been used to infer high levels of male aggression (Molina-Borja *et al.*, 1997) and territoriality (Stamps, 1983), with larger males having a competitive advantage defending sites or procuring mates (Turner *et al.*, 1969; Case, 1978; Thorpe & Baez, 1987). Generally, teiid lizards are non-territorial (Stamps, 1983; Molina-Borja *et al.*, 1997) as would be expected due to patchy invertebrate distributions. The large size dimorphism ratio observed in *C. vanzoi* (1.20) is similar to that of other non-territorial, sexually dimorphic species within *Cnemidophorus* (e.g., *C. arubensis* 1.5, *C. lemniscatus*, 1.22 and *C. murinus*, 1.1; Stamps, 1983).

Sexual size dimorphism in *C. vanzoi* as a result of intrasexual competition is supported by two results. Firstly, the frequency of tail autotomy is an indirect measure of intraspecific aggression and predation (Schall, 1974; Wilson, 1991). Tailless *Uta stansburiana* show significantly reduced survivorship, especially in subadults (Fox & McCoy, 2000). Adults had a significantly higher frequency of tail breaks than juveniles, although there was no significant difference between sexes. Adult males may incur injury when competing for or guarding mates. *Cnemidophorus vanzoi* has been observed to guard gravid females (S. Lesmond, pers. comm.). Mate guarding occurs in other scincid lizards (e.g. *Eumeces laticeps*, Vitt & Cooper, 1984; in *Ameiva plei*, Censky 1995b) resulting in sexual size dimorphism in the absence of territoriality. Tail autotomy in females may result from oviposition site defence (R. Gibson, pers. comm). Juveniles (which are assumed to be non-breeders) would escape this reproduction related, intrasexual aggression.

Secondly, 16% of males above the minimum SVL associated with adult coloration maintained juvenile colours. Dearing & Shall (1994) have reported this phenomenon in *C. arubensis* and *C. murinus* (Netherland Antilles) and suggest that retaining juvenile coloration avoids aggressive interactions (Martin & Forsman, 1999). Both these species demonstrate a low reproductive rate (limited access to receptive females) and extreme sexual dimorphism. Aggressive interactions between males and females were observed on Praslin Island, usually resulting in one individual being chased away from the area. I did not determine whether large, uncoloured males were sexually mature. The maintenance of juvenile coloration could be a 'sneaky' strategy to avoid injury and improve fitness. However, Censky (1995b) found that only large *Ameiva plei* won intrasexual agnostic encounters, guarded mates and mated successfully. Paternity in *Ameiva exsul* is strongly associated with body size although small males are not completed excluded from reproduction (Lewis *et al.*, 2000).

Alternatively, tail break frequency may relate to predation pressure. Six black rats (*Rattus rattus*) were caught on Praslin Island during the field season (see also Johnston *et al.*, 1994). The nocturnal behaviour of rats could lead to predation on lizards whilst in burrows or crevices (Atkinson, 1985). However, no lizard remains were found in the stomach contents of two trapped rats and autotomy occurs in the source population which is rat-free. Regardless of the cause of autotomy, tail loss is energetically expensive. In addition to the loss of fat reserves and predation avoidance behaviour, regrowth incurs diversion of resources from growth and reproduction and can affect social status, home range size and thermoregulatory capacity (Arnold, 1988; Salvador *et al.* 1996; Perez-

Mellado *et al.*, 1997). Wilson (1991) found that predation decreased during the dry season as reduced activity levels decreased predator-prey interactions in *Uta stansburiana*.

No change in sex ratio, body size or condition between the founders and the current Praslin Island population has occurred during the three years since translocation, indicating no rapid effects of the translocation event. The small size of Praslin Island combined with habitat fluctuations that result in seasonal physiological stress could affect the activity, growth and reproduction in *C. vanzoi.* Although seasonal changes in the condition index implies seasonal resource fluctuations it does not appear to have affected population growth, perhaps as a result of good habitat quality (Komdeur *et al.*, 1995). However, independent sampling of the current Maria Major Island population is a priority to quantify any real change in the translocated population on Praslin Island.

This translocation provided an opportunity to collect data on a little studied species, to investigate the condition and demography following a colonising event, and to provide a baseline for future monitoring. The ultimate goal of the conservation initiative was to increase the survival potential of the species by reducing extinction risk (Q. Bloxam, pers. comm.) and *C. vanzoi* now exists on three small islands off St. Lucia. Small populations and endemic insular species are associated with greater extinction risk from the magnified effects of demographic, environmental, genetic and catastrophic stochasticity (Shaffer, 1987). Environmental variation and demographic stochasticity particularly impact small populations in the short term (Leigh, 1981; Pimm *et al.*, 1988). Understanding the demographics and health of this small island population enables managers to monitor the success of the translocation over the longer term to ensure species survival.

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Appendix 4.1. Data collected on *Cnemidophorus vanzoi* on Praslin Island, St. Lucia, West Indies.

Date	Age	Sex	SVL(mm)	Mass (g)	Total tail (cm)	Regen. end (cm)	Comments
15-10-97	adult	male	100.0	31.0	12.6		stumpy tail
15-10-97	adult	male	98.0	30.0	16.9	9.2	
15-10-97	adult	female	98.0	28.5	15.4		
15-10-97	juv	male	84.0	16.5	13.1		
15-10-97	adult	male	116.0		12	5.4	escape when weighing
15-10-97	adult	male	105.0	35.0	19.1		
15-10-97	adult	male	115.0	48.0	23.5		
15-10-97	adult	male	90.0	23.0	17.5		
15-10-97	adult	male	99.0	28.0	22.5		moulting
15-10-97	adult	male	90.0	20.5	8.2		
15-10-97	juv	female	62.0	7.5	8.2		
15-10-97	juv	female					escape - tissue taken
19-11-97	adult	male	105.5	35.0	24.1		no adult colour yet
19-11-97	adult	male	109.0	38.0	25.8		moulting
19-11-97	adult	female	91.0	20.5	12.8	3.1	regen tail
19-11-97	adult	female	92.5	25.0	16.6	4	moulting
19-11-97	juv	male	97.0	28.0	24.15		moulting
19-11-97	adult	male	115.0	46.5	21.9	5.9	moulting
19-11-97	adult	male	101.0	29.5	23.2		pinkish colour underneath
19-11-97	adult	female	88.0	19.5	18.7		moulting
19-11-97	adult	female	95.0	25.5	21.8		
19-11-97	adult	male	116.0	49.5	23.7		
19-11-97	juv	male	85.0	17.5	18.1		
19-11-97	adult	male	121.0	35.5	18.4	8.3	moulting, 2 cut toes
19-11-97	juv	male	95.0	27.0	20.9		cut on foot
19-11-97	juv	male	98.5	26.5	18.3	7.1	
19-11-97	adult	female	77.0	13.0	13.8	7.7	
19-11-97	adult	male	104.0	36.5	18.5	5.8	moulting
19-11-97	adult	male	101.5	38.5	23.7		moulting
19-11-97	juv	male	75.0	13.5	18.1		moulting
19-11-97	adult	female	93.0	23.0	16.4	3.4	moulting
19-11-97	adult	female	82.0	16.0	19.6		
18-12-97	juv	female	63.0	7.5	13.4		
18-12-97	adult	female	87.0	19.0	19	0.9	
18-12-97	adult	female	87.0	18.5	18.5		moulting, swollen dirty vent
18-12-97	adult	female	94.0	24.0	20.6		
18-12-97	adult	male	117.0	48.0	20.7		
18-12-97	adult	male	115.0	50.5	24.5		
18-12-97	juv	male	77.0	14.0	17.9		
18-12-97	adult	male	112.0	44.0	21	0.4	
18-12-97	juv	male	89.0	24.0	20.4		
18-12-97	juv	male	84.0	17.5	15.2		
18-12-97	adult	male	125.0	56.5	23.1	7.8	
18-12-97	adult	female	89.0	22.0	19.7		
18-12-97	adult	female	98.0	26.5	20.9		
18-12-97	juv	male	88.0	22.5	17	3.2	
21-01-98	adult	male	107.0	32.0	24.1		
21-01-98	juv	male	72.0	11.0	16.9		
21-01-98	adult	female	77.0	12.0	17.6		
21-01-98	adult	female	88.0	16.0	7.4	7	
21-01-98	juv	female	73.0	9.0	15.1		
21-01-98	adult	male	98.0	28.0	16.1	6.8	

Appendix 4.1 cont.

Date	Age	Sex	SVL(mm)	Mass (g)	Total tail (cm)	Regen. end (cm)	Comments
21-01-98	adult	male	114.0	41.0	19.2	6	
21-01-98	adult	female	89.0	18.0	16.1	2.2	
21-01-98	adult	female	95.0	23.0	14.4	5.1	
21-01-98	adult	male	86.0	35.0	19.8		
21-01-98	adult	male	121.0	51.0	22.7	7.2	cut under left forearm
21-01-98	adult	male	107.0	35.0	23.1		
21-01-98	adult	male	102.0	30.0	21.8		
21-01-98	adult	female	92.0	24.0	20.1		
21-01-98	adult	female	86.0	19.0	20.8		
21-01-98	adult	male	101.0	30.5	23.7		
21-01-98	adult	female	85.0	17.0	10.6	6.6	
21-01-98	adult	male	108.0	34.0	16.7		cut at left ear
21-01-98	adult	female	81.0	13.0	18.3		
21-01-98	juv	female	68.0	6.0	10.5	6.2	
18-02-98	adult	male	94.0	22.0	16	2.8/2.9	moulting
18-02-98	adult	male	81.0	12.0	8.1	5.4	
18-02-98	juv	female	71.0	10.0	15.9		
18-02-98	juv	male	63.0	9.0	15		
18-02-98	adult	female	86	20.0	20.1		
18-02-98	juv	female	60.0	8.0	10.4	4.2	
18-02-98	adult	female	87.0		16.9	3.7	escape before weighing
18-02-98	adult	female	96.0	22.0	13.5	7	
18-02-98	juv	male	68.0	9.0	15.4		
18-02-98	juv	male	66.0	8.0	12.2	5.1	
18-02-98	adult	male	102.0	32.0	23.5		moulting
18-02-98	juv	female	41.0	3.5	10.7		
18-02-98	adult	female	91.0	21.0	20		
18-02-98	adult	female	91.0	21.0	15.8	4.7	
18-02-98	juv	female	74.0	10.0	17		
18-02-98	adult	male	101.0	22.0	22.8		
18-02-98	juv	male	83.0	15.0	16.5	1.1	
18-02-98	juv	female	56.0	6.0	13.6		
18-02-98	juv	female	75.0	9.0	14.6		
18-02-98	juv	female	73.0	10.5	16.4		
18-03-98	adult	female	79.0	12.0	17.6		
18-03-98	adult	male	106.0	33.0	22.7		
18-03-98	adult	female	82.0	12.0	12.8	8.7	
18-03-98	juv	male	65.0	8.0	15.5		
18-03-98	juv	female	65.0	7.0	10.3		
18-03-98	juv	male	66.0	7.0	14.9		
18-03-98	adult	female	80.0	11.0	17.7		
18-03-98	juv	female	57.0	4.0	12.9		
18-03-98	adult	female	82.0	33.0	14	4.1	
18-03-98	juv	male	85.0	14.0	15.3	6.7	
18-03-98	adult	male	117.0	43.0	23.6		
18-03-98	adult	male	93.0	20.0	14.4	7.4	
18-03-98	adult	male	101.0	25.5	21.8		
18-03-98	juv	female	71.0	8.0	12.6	3.6	
18-03-98	adult	female	83.0	14.0	18.8		
18-03-98	adult	male	109.0	37.0	25.4	3.4	
18-03-98	adult	female	89.0	15.0	11.8	8.1	
18-03-98	juv	male	62.0	7.0	14.4		
18-03-98	juv	female	75.0	9.0	16.6		

Appendix 4.2. Data on *Cnemidophorus vanzoi* founders from Maria Major Island in 1995 before translocation to Praslin Island (Q. Bloxam, DWCT). Data from 1997 collected by K. Buley (DWCT) on Maria Major *C. vanzoi*.

Date	Age	Sex	SVL (cm)	Mass (g)	Regen.Tail (cm)	Comments
15-5-95	adult	female	8.7	40.0		gravid, toes truncated
16-5-95	adult	female	9.2	35.0		gravid
15-5-95	adult	female	8.4	35.0	x	
15-5-95	adult	female	8.1	35.0	x	
15-5-95	adult	female	8.8	30.0	x	
15-5-95	adult	female	7.8	30.0	x	gravid
15-5-95	adult	female	8.6	30.0	x	
15-5-95	adult	female	9.5	50.0		gravid
15-5-95	adult	female	7.6	30.0	x	
15-5-95	adult	male	8.2	30.0		
15-5-95	adult	female	8.5	40.0		gravid
15-5-95	adult	female	8.4	40.0		gravid
15-5-95	adult	female	9.2	45.0	x	
15-5-95	juv	male	7.7	35.0	x	
15-5-95	juv	male	9.3	50.0		
15-5-95	adult	male	10.2	50.0	x	
15-5-95	adult	male	10.3	50.0		
15-5-95	adult	male	11.3	20.0	x	
15-5-95	adult	male	11.0	15.0		
15-5-95	adult	male	11.3	30.0		tail lost in hand
15-5-95	adult	male	11.9	30.0	x	
15-5-95	adult	male	11.5	25.0		dropped tail, no genetic material
15-5-95	adult	male	11.4	30.0	x	
15-5-95	adult	male	10.7	40.0	x	
15-5-95	adult	male	10.2	30.0		
15-5-95	adult	male	11.1	30.0		bifulcated tail
15-5-95	adult	male	11.2	40.0		
15-5-95	adult	male	10.2	40.0	x	
15-5-95	adult	male	11.6	40.0		
11-9-97	adult	female	8.9	18.5		
11-9-97	adult	male	10.9	40.5		
11-9-97	adult	male	10.8	21.5		
11-9-97	adult	male	11.2	37.0		
11-9-97	adult	male	10.5	32.0		
11-9-97	adult	male	10.2	27.0	x	
11-9-97	adult	female	9.2	28.5		
11-9-97	adult	male	11.5	39.5	x	
12-9-97	adult	female	7.9	17.4		
12-9-97	adult	male	10.5	31.5	x	
12-9-97	adult	male	9.9	37.0		
12-9-97	adult	male	11.0	42.0		
16-9-97	adult	male	10.7	38.5	x	
16-9-97	adult	male	10.1	28.5	x	
16-9-97	adult	male	9.9	26.5		
18-9-97	adult	male	11.1	43.5		
18-9-97	adult	male	11.1	43.5		
18-9-97	adult	male	10.8	39.5	x	
23-9-97	adult	male	9.7	30.0		
23-9-97	adult	male	9.9	31.0		
23-9-97	adult	male	8.5	15.0		
26-9-97	adult	female	7.3	11.0		

Appendix 4.3. Data on *Cnemidophorus vanzoi* from Maria Minor Island collected by K. Buley (DWCT), in 1997.

Age	Sex	SVL (cm)	Tail Length (cm)	Mass (g)
adult	male	8.5	15.5	15.0
adult	male	7.3	11.8	11.5
adult	female	7.3	15.9	11.0
adult	female	7.4	12.2	11.0
adult	female	7.6	12.4	10.0

Chapter 5. GENETIC INVESTIGATION OF *CNEMIDOPHORUS VANZOI*

ABSTRACT

Microsatellite loci of *Cnemidophorus vanzoi* were identified from an existing genomic library and polymerase chain reaction (PCR) primers were developed. Genotypes for eight polymorphic loci that were easily amplified and scored were obtained for the three insular populations. One population is a recently translocated population on Praslin Island (Praslin) from a founder stock on Maria Major Island (Founders) subsequently incorporated into the Praslin population. The third population is from Maria Minor Island (Minor). For all loci, the number of alleles ranged from 3–6 and observed heterozygosity within populations ranged from 0.175–0.486. After three years the Praslin population did not differ genetically (R_{st} = 0.008) from the Founders population from Maria Major, but both were divergent from Minor (R_{st} = 0.21 and 0.19 respectively). Only 3 of 23 alleles found in the founder population have been lost and one new allele may have evolved in Praslin. A long isolation between populations on Maria Major and Maria Minor is suggested by $\Delta\mu^2$ calculations. Fixation indices imply some internal structuring in Praslin and Founders. Minor is panmictic although sample size from this population was small. Very little genetic change is observed as a result of the translocation. The degree of genetic divergence between Maria Major and Maria Minor may imply separate conservation management objectives are needed for these populations.

INTRODUCTION

This chapter uses microsatellites to assess genetic variation in three isolated populations of a vulnerable, endemic, island lizard, *Cnemidophorus vanzoi*, in St. Lucia, West Indies. The species inhabits two small offshore islands in St. Lucia. In 1995, a total of 42 lizards were translocated as a conservation measure from Maria Major Island to Praslin Island, previously uninhabited by the species. This chapter addresses two main questions: has the genetic diversity been significantly reduced by the translocation and subsequent colonisation of lizards from Maria Major to Praslin Island? And how distinct is the Maria Minor population from that on Maria Major?

The goal of conserving biodiversity includes conserving variation within and between populations. The assessment of variation within species is becoming increasingly viable with the development of genetic tools to investigate fine scale population level processes (for reviews see Avise, 1994; Parker *et al.*, 1998). Fragmentation, bottlenecks and inbreeding within small populations can lead to loss of genetic variation (Lande, 1988; Gullberg *et al.*, 1998) yet the effect of genetic factors on population survival is still debated (see Caughley, 1994; Frankham, 1995). Genetic studies can determine gene flow (particularly loss of genetic variation due to inbreeding and bottlenecks), and effective population size to aid planning for the management of threatened species and small populations (Taylor *et al.*, 1994; Frankham, 1995; Haig, 1998; O'Ryan *et al.*, 1998; Rowe *et al.*, 1998). Links between heterozygosity and fitness (i.e., growth rates, survivorship etc.) have been found in harbour seals, *Phoca vitulina* (Coltman *et al.*, 1998), red deer, *Cervus elephus* (Coulson *et al.*, 1998) prairie chickens, *Tympanuchus cupido pinnatus* (Bouzat *et al.*, 1998) and natterjack toads, *Bufo calamita* (Rowe *et al.*, 1999).

Microsatellite analysis, a technique of variable number tandem repeat investigation, is appropriate for the study of relatedness between small populations (Parker *et al.*, 1998). Jarne & Lagoda (1996) define microsatellites as tandem repeated sequences whose unit of repetition is between one and five base pairs. Properties which make microsatellites useful in fine scale genetic investigations include: wide dispersal in the genome and relatively high mutation rate (Kashi, 1997), high polymorphism (Schlotterer, 1998), co-dominant nature (Powell *et. al.*, 1996), and selective neutrality (Allen *et al.*, 1995). Because the mutation rate, putatively due to slippage (Jarne & Lagoda, 1996), is higher in microsatellites than non-repetitive sequences, variation in the repeat number is easily identified when used in combination with PCR and electrophoresis (Schlotterer, 1998).

The potential for genetic change and speciation is greater in small insular populations, which generally show less morphological and genetic variation compared to mainland populations (Wayne *et al.*, 1991). Island populations offer excellent natural models to examine genetic effects as they are isolated and usually of small size. Rapid evolutionary response may occur within a translocated population as a result of adaptive selection or genetic drift. An evolutionary shift in quantitative traits may impact fitness (Stockwell & Weeks, 1999) and this is of particular concern when translocation is being conducted as a hedge against extinction.

In 1995, 21 pairs of *Cnemidophorus vanzoi* from Maria Major Island (henceforth termed Founders) were introduced to the smaller, uninhabited Praslin Island (termed Praslin) on the same coastline (see Chapter 2). Due to high mortality following the initial translocation of 14 pairs (termed 1st Founders), a further seven pairs (termed 2nd Founders) were translocated one week later. Consequently, the size and demographics of founder population is unknown but is assumed to be a minimum of seven pairs. Tissue samples were collected from all translocated individuals. In this study, tissue samples were collected from a large cross-section of the present Praslin population. Another island population of *C. vanzoi* exists on Maria Minor (termed Minor). The Durrell Wildlife Conservation Trust (DWCT) had collected tissues from this population in 1997. Maria Minor is separated from Maria Major by 150 m of rough sea and individuals from this island appear smaller and darker than those from other populations (see Chapter 4).

Theoretical and simulation models predict a decrease in genetic diversity, resulting from the genetic bottleneck (Lande & Barrowclough, 1987; Leberg, 1990) associated with the establishment of an island population. *Cnemidophorus vanzoi* was discovered on Maria Major Island in 1958 (Baskin & Williams, 1966). The Maria Island populations are assumed to be a remnant of a now extirpated population from the main island of St. Lucia (Corke, 1987), although there are no records or specimens of *C. vanzoi* on St. Lucia itself. *Cnemidophorus vanzoi* evolved from a South American *Amevia* ancestor (Wright, 1993). Its history implies two possible founder events; immigration from S. America and immigration to the Maria Islands from St. Lucia, hence the genetic diversity would be expected to be low. There is no information on how or when the *C. vanzoi* population on Maria Minor became established. It is possible that Maria Major and Maria Minor were colonised independently from a presumed mainland (St. Lucia) population either when the islands were connected to St. Lucia or as rafting events.

METHODS

Tissue Collection

Tissue samples (N=91) from the population of *C. vanzoi* on Praslin Island (Praslin) were collected between October 1997 and March 1998. Sampling was non-destructive. Lizards were caught with a hand held noose (refer to Chapter 4) and their tail tips removed with canine nail clippers. Tail tips were stored in a 1.5 ml vial containing 1.0 ml of 20% DMSO, 6 M NaCl, and 0.1 M

EDTA. The size of the sample varied depending on tail morphology but generally a minimum of 10 mm was taken. The lizard's tail was then treated with Cicatrin Antibiotic Powder (Wellcome Foundation Ltd, London, UK) and OpSite Moisture Vapour Permeable Spray Dressing (Smith & Nephew Medical Ltd, Hull, UK). The tail clippers and tweezers were swabbed with 70% methyl alcohol between samples to prevent cross contamination.

Tissue samples (N=42) from the founding population were collected from the founding population during the translocation in May, 1995 (Q. Bloxam, DWCT). Five tissue samples were collected from the isolated Minor population in October, 1997 (K. Buley, DWCT). Tail tips from Major and Minor were collected in the method described for Praslin but stored in 5 ml 70% methyl alcohol.

DNA Extraction

DNA extraction from all *C. vanzoi* samples was done using a Chelex 100 medium kit. This procedure uses a chelating resin to bind metal ions that act to catalyse reactions that degrade DNA at high temperatures in low ionic strength solutions. This enables DNA extraction from small amounts of tissue or degraded samples and reduces the potential for contamination involved in proteinase-K extraction. A 5% solution of Chelex 100 was used following the protocols described by Walsh *et al.* (1991). Tissues were soaked in 70% EtOH overnight prior to Chelex treatment. This diluted the DMSO as 10% DMSO is know to inhibit *Taq* polymerase activity by 50% (Innis & Gelfand, 1990).

Microsatellite Primers

One tissue sample from the 1st Founders was used in the development of primers. Flanking regions of the microsatellites are sequenced and specific synthetic oligonucleotides are designed. These primers are used to locate and amplify the microsatellites by polymerase chain reaction (PCR).

An enriched satellite library was available for the development of primers. The library had been constructed with DNA from a single individual using bluescript pBGDS19 plasmids with Kanamycin resistance and part of an *E. coli* lacZ gene-cloning site. Recombinant colonies were screened with ^{32}P labelled $(AC)_n$ and $(AG)_n$ probes yielding 110 positives (G. Rowe, pers. comm). The M13-21 forward primer was used to sequence 45 positives and 20 of these clones were reverse sequenced by dideoxynucleotide sequencing (Avise, 1994). Primers were prepared in the method described by Rowe *et al.* (1997). Forward and reverse primers were designed using programme PRIMER v. 0.5 (Lincoln *et al.*, 1991). Oligonucleotides for 14 primer pairs were synthesised, purified and dried by Cruachem (UK).

Polymerase Chain Reaction (PCR) Amplification

Conditions for each primer set were optimised and reactions contained 0.4μM of each oligonucleotide, 0.2 μM d(GCT)TP, 0.06 μM unlabelled dATP, 0.02 μM $[\alpha^{33}$-P]-dATP, 25 – 100 μL *C. vanzoi* DNA, and 0.5 - 1.0 μL *Taq* polymerase and incubation buffer (1.5 mM MgCl2; Appligene) in a final volume of 20 μL and amplified using Techne PHC- 3 and Genius thermal cycler with heated lids. All PCR cycles involved 28 amplification cycles and one of two touch-down programmes were used as described below:

Touch-down I

95°C one minute initial denaturation
95°C one minute denaturation
68°C one minute annealing (2 cycles)
66 °C one minute annealing (2 cycles)
64 °C one minute annealing (2 cycles)
62 °C one minute annealing (2 cycles)
60 °C one minute annealing (2 cycles)
58°C one minute annealing (18 cycles)
72°C one minute elongation
Final 10 minute elongation

Touch-down II

95°C one minute initial denaturation
95°C one minute denaturation
62°C one minute annealing (2 cycles)
60°C one minute annealing (2 cycles)
58°C one minute annealing (2 cycles)
56°C one minute annealing (2 cycles)
50°C one minute annealing (18 cycles)
72°C one minute elongation
Final 10 minute elongation

Initial checking-gels to assay DNA concentration, purity and fragment lengths, were analysed using ultraviolet absorption and electrophoresis through 2% agarose gels in TAE buffer stained with ethidium bromide. PCR products were analysed by acrylamide gel electrophoresis (6%, Accugel). Fragments were sized against ^{35}S-labelled M13 sequence markets and following autoradiography were scored by hand. Fourteen microsatellites with high $(GC)_n$ content, long uninterrupted repeat lengths (11-33 copies), good relative position on the gel for easy sequencing, and sufficient flanking region were amplified. Ten polymorphic primer pairs were synthesised.

Analysis

Programme GENEPOP Version 3.1 (Raymond & Rousset, 1997) was used to test for Hardy-Weinberg and genotypic disequilibrium in pairs of loci from populations. Significant differences in allele frequencies were determined by exact tests, and bootstrap and jack-knife procedures were used to normalise variation in sample size. All tests were analysed with the Markov chain method (Guo & Thompson, 1992) of 50 batches with 1000 iterations and 1000 steps of dememorization to estimate the exact probability. Significance was accepted at the 5% level ($P<0.05$). The fixation index, F_{is}, was used to highlight homozygote excess and internal structuring in populations.

Three measures of gene flow were calculated. R_{st} values were used in preference to F_{st} as the latter uses an infinite model of mutation (Goodman, 1997) which tends to under-estimate the true level of differentiation when used with microsatellite data (Slatkin, 1995). R_{st} uses the squared difference in repeat number to determine the differentiation among populations based on a stepwise mutation process (Slatkin, 1995). $R_{st}V$ is based on Slatkin's R_{st} but incorporates variance in allele size (E. Harley, pers. comm.) and UR_{st} is an unbiased estimate of gene flow developed for microsatellite data (Valsecchi *et al.*, 1997).

R_{ST}-CALC Version 2.1 (Goodman, 1997) was used to calculate R_{st} values for individual loci, over all loci and produce pairwise population comparisons. The programme also provided derived estimates of the number of migrants per generation (Nm) based on private alleles and a genetic distance measure for microsatellites ($\Delta\mu^2$; Goldstein *et al.*, 1995).

RESULTS

All eight polymorphic microsatellite loci (with tandem repeats of 17-33) showed a low level of diversity (range 3-6 alleles per locus). A total of 33 alleles was found and they varied by 2-18 base pairs. Of the 23 alleles found in the founders, only 20 were observed in Praslin now three years post-translocation, although Praslin has evolved one new allele population. Minor had eleven alleles, of which only two were shared with the other populations. A total of 19.4% of the Praslin population, 12.8% of Major and 12.5% of Minor did not amplify following PCR.

Comparisons of alleles shared between the 1st Founders, 2nd Founders and Praslin current alleles suggests that 2-9 of the 1st Founders survived the initial translocation (a combination of 2 adult males, 6 adult females and one juvenile male) and six individuals did not survive to reproduce (1 adult male, 4 adult females, and 1 juvenile female). The 1st Founder survivors passed on cvan7 allele 134 (N=5), cvan19 allele 151 (N=2), and cvan23 allele 146 (N=3) to descendants on Praslin. One individual carried both cvan7 allele 134 and cvan23 allele 146 hence the minimum number of 1st Founder survivors is two. No unique alleles were shared between the 2nd Founders and Praslin. Allele frequencies for 1st Founders, 2nd Founders and Praslin are shown in Appendix 5.1.

Very little genetic differentiation was observed between the newly established Praslin and the founding population. Heterozygosity and allelic diversity were slightly greater in the founder population than in Praslin. Minor showed little genetic diversity. These trends held for both bootstrapped and jack-knifed procedures (Table 5.1) which normalise variation created by differing sample sizes. Heterozygosity and allelic diversity also showed strong positive correlation with estimated population size (R_s=1, R^2=0.62 and R_s=1, R^2=0.71 respectively; refer to Chapter 4 for population size estimations) but were not significant (P>0.4) due to small sample sizes. Allele size and frequency for each population is shown in Figure 5.1.

Table 5.1. Summary of allelic diversity for all populations based on Hardy-Weinberg expectations.

Population	Sample size (Est. Pop. Size)	Total Alleles	Mean Heterozygosity	Mean Alleles / Locus		
				Direct Count	Bootstrapped	Jacknifed
Praslin	91 (151[a])	21	0.475	2.63	2.20	2.21
Founders	42 (900[b])	23	0.486	2.87	2.38	2.42
Minor	5 (50[c])	11	0.175	1.38	1.37	1.38

[a]This study. [b]Corke, 1987. [c]Q. Bloxam, pers. comm.

R_{st} values for pair-wise population comparisons showed very little differentiation between Founders and Praslin, but great genetic differentiation (Wright, 1978) between these populations and Minor (Table 5.2). This trend was also observed for ρ calculations and reflected in gene flow estimates (Nm) based on private alleles (Table 5.3). Similar trends were observed in R_{st} and UR_{st} values for all loci. $R_{st}V$ calculations for population comparisons showed the same pattern as R_{st} values but were generally lower (Table 5.2).

Lizards sampled at Maria Minor showed unique alleles for all loci except cvan23 and were monomorphic in five of eight loci. Allelic distributions were significantly different between Praslin and Founders at three loci (cvan4, cvan24 and cvan27; $P<0.05$). Founders had low frequencies (<20%) of unique alleles at three loci and Praslin had one new allele (cvan23, 134 bp). Founders and Praslin showed similar frequency distributions for cvan7, cvan18, cvan19, cvan23, and cvan26 (Figure 5.1). Genetic distance calculations for Minor were large (Table 5.3). $\Delta\mu^2$ calculations and R-statistics reflected intuitive separation times, as Praslin are descended from Founders, relatedness between them is expected to be closer than between Praslin and Minor.

Within-population calculations for Founders and Praslin showed genetic disequilibrium at the same two loci, and at a different third locus in each population. Homozygote excess was more common in Founders than in Praslin (mean F_{is} across eight loci was –0.074 and 0.092 respectively; Table 5.4). Fisher exact test results for Hardy-Weinberg equilibrium within populations were significant for Praslin ($\chi^2=38.6$, df=16, P=0.0012) and Founders ($\chi^2=57.2$, df=16, P<0.001) but not on Minor ($\chi^2=4.0$, df=6, P=0.68).

Table 5.2. Polymorphic microsatellite loci in *Cnemidophorus vanzoi*. Microsatellite variation and R_{st} values by locus and for population comparisons. PCR was conducted using Touch-down I unless indicated by * when Touch-down II PCR protocol was used (see text for details).

Locus	**Alleles detected**	R_{st}	R_{st} **V**	UR_{st}	**Microsatellite**
cvan4*	3	0.44	0.45	-2.63	$[(ac)_3(agac)_4(ac)_7(at)_2(gcac)_2(ac)_3g(ca)_{20}]$
cvan7	4	0.64	0.50	2.44	$[(gt)_{20}]$
cvan18	3	0.63	0.60	2.77	$[(gt)_{19}\{ct(gt)_3\}_3ctgtct(gt)_3]$
cvan19*	4	0.30	0.36	-0.31	$[g(ga)_3g(gt)_{33}(ga)_{11}$
cvan23	6	0.05	0.06	0.00	$[(gt)_{24}]$
cvan24	6	0.66	0.63	2.21	$[(ca)_{17}]$
cvan26*	3	0.63	0.60	1.94	$[(gt)_{23}]$
cvan27	4	0.73	0.66	1.40	$[(ca)_4c(ca)_3(cacg)_5(ca)_{23}]$
Locus mean	4.125	0.51	0.48	0.98	
Variance	2.084	-	0.39	3.37	
Praslin vs. Founders	-	0.008	-0.02	-	
Praslin vs. Minor	-	0.19	0.62	-	
Founders vs. Minor	-	-0.21	0.66	-	

Table 5.3. Pairwise population comparisons from Rst values. Nm is a derived number estimating the number of migrants per generation. $\Delta\mu^2$ is a derived genetic distance measure (Goldstein *et al.*, 1995).

Population Comparison	ρ **(av. var. comp)**	**Nm**	**P**	$\Delta\mu^2$
Praslin vs. Founders	0.02	11.91	0.03	0.43
Praslin vs. Minor	0.91	0.02	0	8.70
Founders vs. Minor	0.81	0.03	0	8.66

Table 5.4. Genetic disequilibrium and fixation indices for each loci in the Praslin and Maria populations ($F_{is} > 0.1$ indicates significant homozygote excess).

	Praslin			**Founders**		
	[1]HW P=	**[2]**F_{is}	**N**	**HW P=**	F_{is}	**N**
cvan4	0.25	0.14	79	0.33	0.16	40
cvan7	0.02	-0.28	74	1.00	-0.21	21
cvan18	1.00	0.02	59	0.67	-0.13	28
cvan19	1.00	0.02	85	0.03	0.25	40
cvan23	0.0005	-0.74	73	0.01	0.27	27
cvan24	0.23	-0.24	41	0.54	0.08	36
cvan26	0.21	0.15	84	0.43	0.14	41
cvan27	0.05	-0.22	85	0.00	0.18	41

[1]Guo & Thopson, 1992. [2]Weir & Cockerham, 1984.

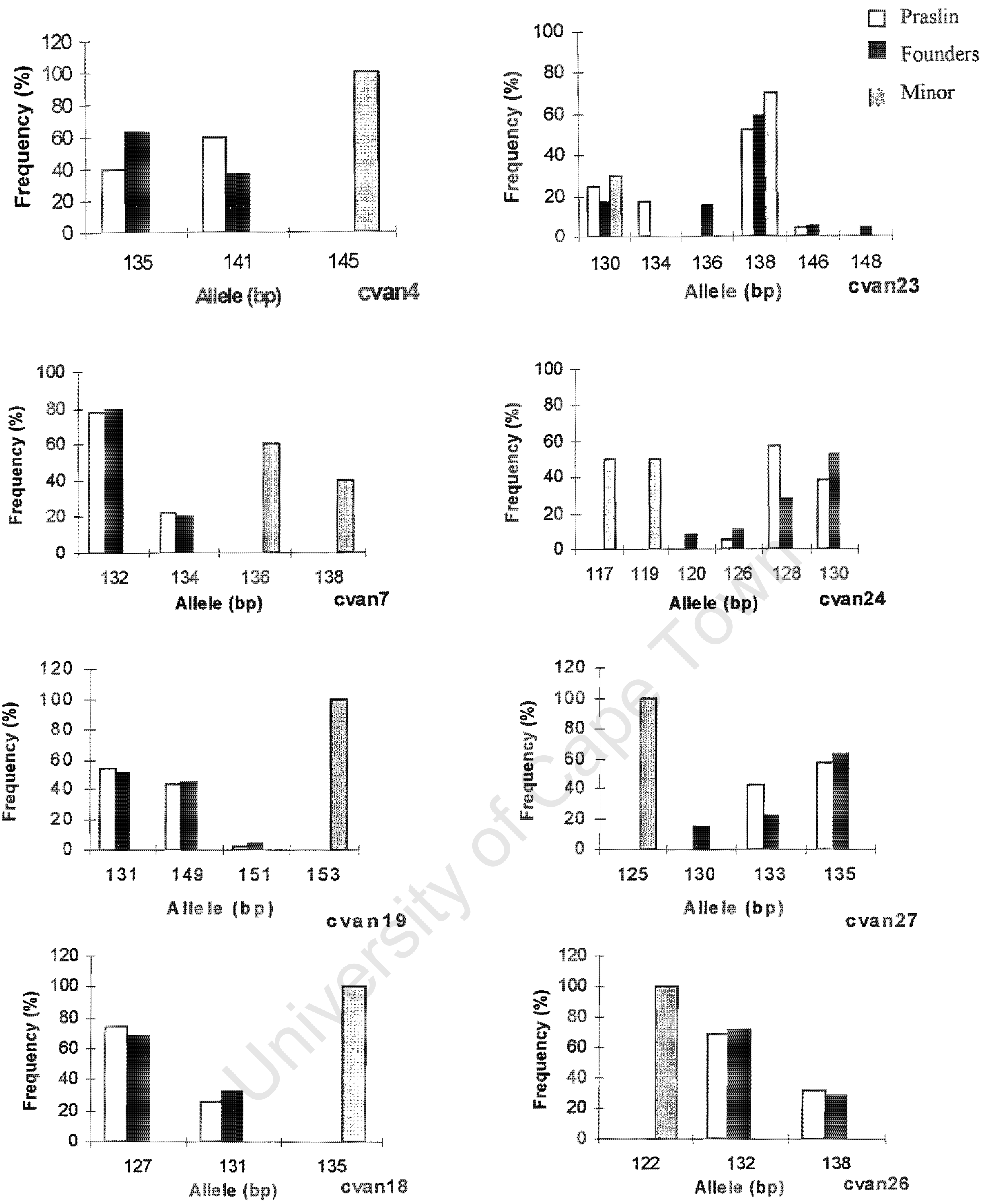

Figure 5.1. Graphical representation of allele frequencies of the eight microsatellite loci for each population of *Cnemidophorus vanzoi*.

DISCUSSION

The goal of this analysis was to determine the extent to which genetic diversity of the Praslin Island population was reduced by translocation of 42 founders in 1995 and whether the Maria Minor population is genetically distinct from that of Maria Major.

Maria Major and Praslin Populations

The observed decline in heterozygosity in the translocated population over three years was not exponential (Gilpin, 1991). Population bottlenecks of short duration may have a limited effect on levels of heterozygosity (Allendorf, 1986), but significantly reduce allelic diversity (Lacy, 1987). Rapid population size recovery may restore levels of heritable variation by mutation in 10^{2-3} generations (Lande, 1988). However, rare alleles may be lost without being manifested in heterozygosity levels (Lacy, 1987). These scenarios are supported by this investigation.

A population and genetic bottleneck was conducted as a translocation event in 1995 and the population expanded rapidly (see Chapter 4) in its new environment. Heterozygosity declined only slightly and the mean number of alleles in the Founders and Praslin are similar. However, three low frequency alleles observed in the Founders were not observed in Praslin; this is likely an effect of the high level of mortality of the 1st Founders from Maria Major. However, it is possible that the individuals of 2nd Founders which did not amplify may have possessed some of the unique alleles shared between 1st Founders and Praslin. This is unlikely as alleles of cvan 19 bp 151 and cvan 23 bp146 occur in very low proportions in the present Praslin population.

Allelic diversity (N=20; i.e., one allele contributed by one individual to the descendent population) suggests at least ten breeding pairs survived the translocation to contribute to the present Praslin gene pool. The potential founding population can now be better described by the unique alleles. A maximum founder population of 36 individuals (with a sex ratio of 20 males:16 females) and a minimum founder population of 16 individuals (7:9) could have given rise to the present population. However, six founding females were gravid and other founding females could have been carrying genetic material as sperm. This may reduce the minimum size of the founding population to ten or less. Those on Praslin who share unique alleles with 1st Founders are not the same individuals as their allelic structure or sex differ (i.e. 1st Founders with cvan 23 bp146 were females whereas the allele was found in males on Praslin).

Since translocation, one new allele may have evolved in the Praslin and two other loci occur in opposite frequencies compared with Founders. However, the 'new' allele may have existed in the founding population and been unsampled. A rare Maria Major allele, undetected in the genetic survey may have been translocated as genetic material from a non-translocated male via a gravid female. The most common Maria Major alleles have been retained and there is a decrease in homozygote excess in Praslin. This decrease may be due to chance but also supports the 'founder flush' hypothesis (Moreley & Katznelson, 1965) or the purging of poor genetic combinations and/or deleterious alleles (Lande, 1988) in the newly established population.

Maria Major and Maria Minor populations

The Maria Minor population shows little genetic diversity and is strongly differentiated from Founders and Praslin. The R_{st} value comparing the Maria Minor and Founder populations, which are separated by only 150 m, showed a large differentiation ($R_{st} = 0.21$) compared to other studies where populations are separated by great distances. For example, populations of Louisiana and Florida American alligators had an average R_{st} value of 0.387 (Glen *et al.*, 1998), whereas fragmented populations of Swedish sand lizards separated by 32-620 km had an R_{st} value of 0.30 (Gullberg *et al.*, 1998).

Very low Nm values and large genetic distances indicate that gene flow between Maria Major and Maria Minor has been insignificant and is insufficient to counter genetic drift. The low overall genetic variation observed in these populations suggests a common historic genetic bottleneck. The fixed unique alleles found in the Minor population indicate either a severe second bottleneck or a long isolation in which drift has been acute (Lande, 1988). The sub-division of a population often results in only the most common alleles of the source population being retained (Wayne *et al.*, 1991) and Minor shares alleles with the other two populations only at the two most common alleles of the most diverse locus.

Small insular populations, such as that on Maria Minor, are often considered at greater risk from demographic, catastrophic, and/or environmental stochasticity than from genetic factors (Eldridge *et al.*, 1999). Contrary to common belief that insular populations are panmictic, genetic disequilbrium was found in Major and Praslin. Although Praslin is the smallest island (0.7 ha smaller than Minor), it is not panmictic. Minor has the least diverse habitat and is panmictic. The lack of panmixia on Praslin combined with the potential for rapid genetic change highlights the potential for evolution in this insular population. Minor has survived both long isolation and small population size without being driven to extinction by demographic or environmental factors. The population has, however, lost most of its genetic variation. A similar small insular population of Rock-wallaby (*Petrogale lateralis*) with a low mean heterozygosity (0.053) shows significantly reduced fitness (Eldridge *et al.*, 1999). Although the impact of genetic factors on the fitness of this population was not investigated, the importance of genetic factors for long term survival must be recognised.

Conservation Implications

If translocation is to become a viable conservation option for small populations, the rate at which heterozygosity is lost during colonisation and establishment is important. It is generally accepted that populations with little genetic diversity may face further heterozygosity decline by the subdivision to smaller population sizes. This study suggests that the risk of inbreeding depression is limited as deleterious alleles probably have been eliminated (i.e., during the colonisation of St. Lucia). Hence, smaller numbers of individuals could be translocated to establish a new population. This is particularly important for species that have only a small pool of potential founders.

Heterozygosity and genetic diversity declined very little in three years following translocation. Most of the observed decline probably occurred as a result of the initial loss due to predation rather than genetic drift. However, it must be noted that the founder effect is incorporated into the Praslin population and independent sampling of the lizards on Maria Major needs to be conducted to determine any real founder effect. Further divergence in Praslin may be prevented by ensuring gene flow between the Maria Major and Praslin, and ensuring the habitat is protected to maintain current or greater population size. O'Ryan *et al.* (1998) suggest that the addition of one individual per generation from the most heterozygous population will retain 90% of that variability in the other population. Hence, regular exchanges of healthy individuals between Maria Major and Praslin should be considered especially as Hardy-Weinberg disequibrium suggests that a demic structure exists on Praslin Island. Caution must be used when planning supplementation as it could potentially introduce disease or prevent adaptation to local conditions. Island biogeography theory, on which most hypotheses of genetic modelling are based, assumes that islands, especially those of small size, support panmictic populations (MacArthur & Wilson, 1967). The lack of Hardy-Weinberg equilibrium in some loci and the significant fixation indices suggest that only Minor is panmictic and that the Founders and Praslin are not.

The qualitative changes observed on Maria Minor are unlikely to be attributed to plasticity given the large genetic difference between Minor and Founder populations. Cumulative changes in allele frequency through drift and lack of gene flow have resulted in evolution of Maria Minor population. Hence, small populations may survive the threat of demographic, catastrophic and environmental stochasticity long enough for genetic factors to impact the population (e.g. reduced fitness and genetic resilience; Eldridge *et al.*, 1999). Investigation of the mitochondrial DNA control region is underway to help determine the specific status of the Maria Minor population. If the Maria Minor population is sufficiently differentiated to warrant recognition as a distinct species, there will be large conservation implications, as this small island population will require separate management objectives to help preserve its evolutionary path.

Future monitoring of the Praslin population will provide great insight into the genetics of translocation. These microsatellite loci are ideal for monitoring fine scale changes in this population. The low levels of diversity (suggesting low mutation rates), the distribution of alleles and the relatively high R_{st} values compared to the average make these loci appropriate for monitoring the affects of the bottleneck (Gullberg *et al.*, 1998). Understanding the genetic changes and implementing measures to maintain the evolutionary potential of *C. vanzoi* can augment management for the survival of this species and be used as a model for future reptile translocations.

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Appendix 5.1. Allele frequencies for individuals caught on Praslin Island (October 1997 – March 1998) and the two founding groups. 1st Translocates were released on Praslin Island 15 May 1995. 2nd Translocates were released on 23 May 1995.

Allele	Locus	Praslin Island	1st Translocates	2nd Translocates
cvan4	135	0.40	0.34	0.65
cvan4	141	0.60	0.66	0.35
cvan7	132	0.78	0.80	1.00
cvan7	134	0.22	0.20	0.00
cvan18	127	0.74	0.59	0.80
cvan18	131	0.26	0.41	0.20
cvan19	131	0.54	0.80	0.55
cvan19	149	0.44	0.43	0.45
cvan19	151	0.02	0.07	0.00
cvan23	130	0.25	0.19	0.25
cvan23	136	0.00	0.06	0.00
cvan23	138	0.52	0.63	0.75
cvan23	146	0.04	0.09	0.00
cvan23	148	0.00	0.03	0.00
cvan24	120	0.00	0.03	0.00
cvan24	126	0.05	0.13	0.05
cvan24	128	0.57	0.58	0.45
cvan24	130	0.38	0.26	0.50
cvan26	132	0.68	0.73	0.75
cvan26	138	0.32	0.27	0.25
cvan27	130	0.00	0.14	0.09
cvan27	133	0.43	0.25	0.23
cvan27	135	0.57	0.61	0.68

Chapter 6. SYNTHESIS AND CONSERVATION IMPLICATIONS

INTRODUCTION

The translocation of *Cnemidophorus vanzoi* to Praslin Island, St. Lucia, West Indies has resulted in the formation of a seemingly viable population, three years after the event. Research into factors affecting landscape ecology and population dynamics was used to justify the conclusion that the translocation was a success (Figure 6.1). A caveat should be placed on this conclusion, because short-term success in a long-lived species may not predict long term population persistence (Dodd & Seigel, 1991). However, the risk of extinction is greater immediately following translocation and tapers with time (Burkey, 1995) which is promising for the future of this population. Successful translocation implies creation of a self-maintaining population without significant demographic or genetic manipulation for a long period of time, often centuries. This initial success could be thwarted by catastrophic stochasticity if conservation management recommendations are not employed. However, my findings enable such recommendations (see below) and the synthesis of a new method for assessing animal translocations.

LANDSCAPE ECOLOGY

The composition of habitats and their spatial arrangement describe a landscape which in turn affects the ecological processes (e.g., animal movements and habitat selection) that influence population dynamics and community structure (Dunning *et al.*, 1992; Lima & Zollner, 1996). Assessment of these processes within the context of a translocation provides information about the relative importance of various components of landscape structure affecting population distribution. Habitat changes can influence a species' vulnerability to extinction, yet monitoring provides an opportunity to identify and control changes for critical life history traits.

Praslin Island has a rich diversity of habitat types and flora for an island of only 1.1 ha. Five general habitat types support 45 floral species. Habitats include two types of woodland, two types of grassland and a shrub habitat. Small areas of rocks, sand and bare ground are also found on Praslin Island. Lizards concentrated in the south-centre of the island. The overall distribution showed the greatest frequency of sightings in the mixed woodland however shrub habitat had a high electivity index indicating that lizards over-used this habitat with respect to availability. The genus *Cnemidophorus* is a highly mobile lizard and marked lizards were seen to cover great distances on Praslin Island. This and the lack of any physiological or anthropogenic barrier suggest no impediment to lizard dispersal. However, distribution is not random, nor does it reflect a random

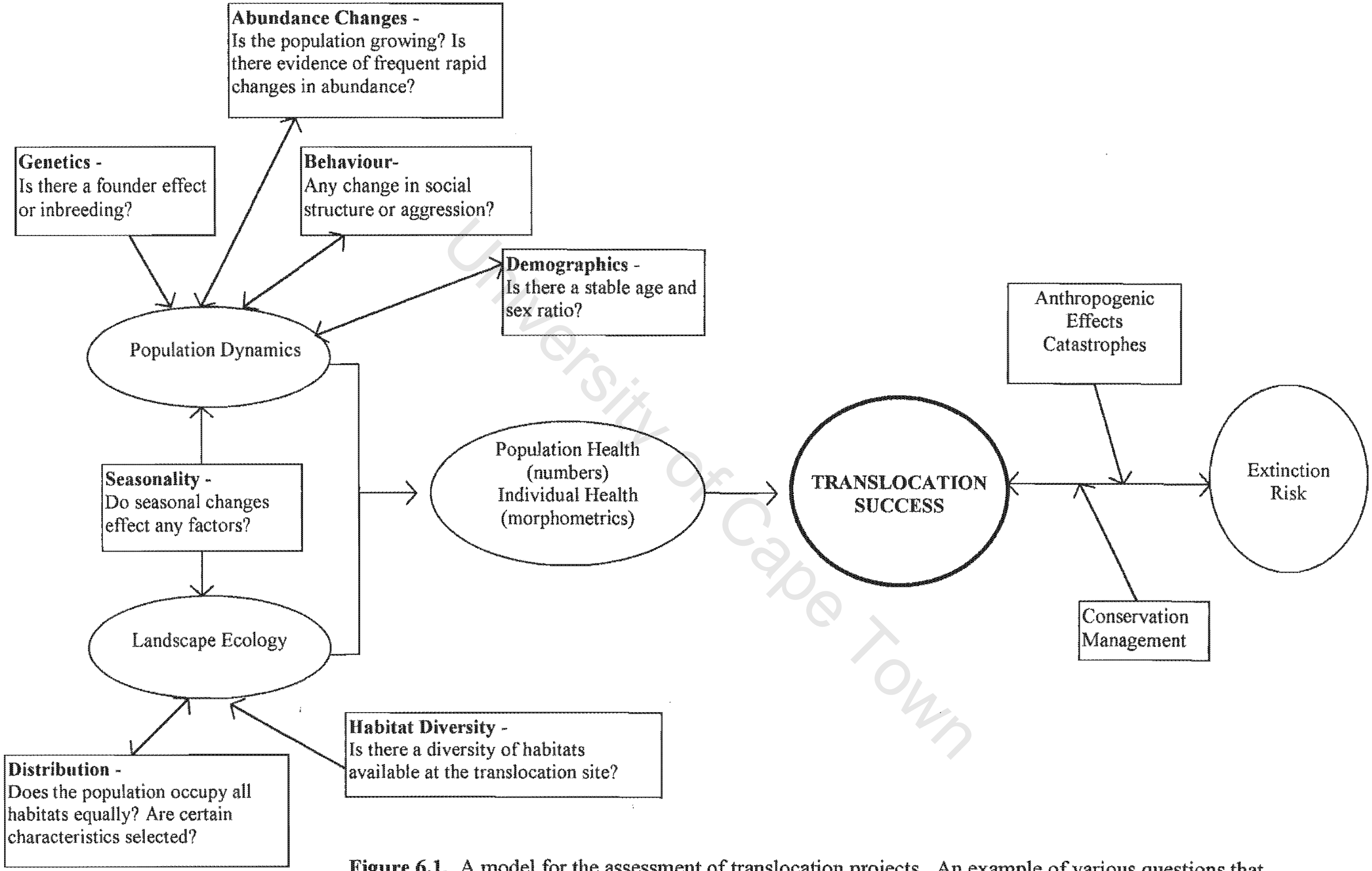

Figure 6.1. A model for the assessment of translocation projects. An example of various questions that can be investigated to help determine translocation success.

walk or uniform dispersal from the release site. The selection of particular habitat characteristics reveals information about factors important to *C. vanzoi* life history.

Since translocation, the population has increased in numbers. Areas of high lizard density can be strongly correlated with those habitat and biophysical characteristics that imply thermal constraint, and likely prey distribution. During the wet season, the mixed woods provide patchy canopy cover that affords basking sites, shelter and a high diversity of invertebrates. During the dry season the mixed wood habitat loses nearly all canopy and shrub cover, giving no protection from the hot sun or suitable conditions for invertebrates. However, the manchineel woods retain more canopy cover during the dry season, and offers both shade and the next highest species richness of invertebrates. The high population growth rate could be due to high habitat quality on Praslin Island resulting in the allocation of more energy reproduction (Komdeur *et al.*, 1995). Conducting abundance and habitat use investigations on Maria Island would test this hypothesis.

Seasonal vegetation changes are significant and the dry season constitutes a period of resource dearth (except in the exposed mixed grass habitat). The successful establishment of the lizard population and the calculated growth rate indicate that *C. vanzoi* are adapted to seasonal changes and by inference, to shifting habitat use. Using the manchineel wood in the dry season indicates that shade and invertebrate diversity are potentially important in their life history strategy. This behavioural plasticity may also help survival during periods of resource dearth.

The small size of the island and the lack of any barrier to dispersal within the island increase the risk of extinction from the accidental introduction of predators. During the wet season, storms result in strong floods of the Praslin River. Potential predators could reach Praslin Island by rafting on driftwood, as exemplified by the arrival of a pregnant opossum (*Didelphis virginiana*), during the field season. Rats (*Rattus rattus*) have also been found on the island. Although both species are nocturnal, they are omnivorous and if allowed to establish they could affect the lizard population directly through opportunistic predation on individuals or eggs, or indirectly through competition for invertebrates or alteration of habitat structure. The greatest threat comes from the introduction of mongooses (*Herpestes auropunctatus*). The mongoose is a major predator in the Caribbean and is probably responsible for species' declines (Hoagland *et al.*, 1989). A mongoose found on Praslin Island was responsible for the near loss of the first group of translocated lizards.

Fire is another risk to the population on Praslin Island. There is no fresh water source on the island and the lack of moisture on Praslin Island during the dry season presents an extreme fire hazard. The Department of Forestry and the community of Praslin appreciate this risk and warning signs are posted on the island. However, destruction of the canopy on Praslin Island would greatly increase the chance of extinction of the local population of *C. vanzoi*, should any lizards survive the fire itself.

SPECIES ECOLOGY AND POPULATION DYNAMICS

Monitoring population dynamics and species ecology of a translocated population assesses the performance and viability of the population and ensures that the social structure is maintained. This structure influences the spatial and temporal distribution of the population (mating system, animal spacing and movements) in its new environment. Regular assessment of population size and associated dynamics can highlight disturbances that may increase extinction risk.

The population of lizards on Praslin Island was estimated at approximately 150 individuals between October 1997 and March 1998. The highest densities (170 lizards/ha) were estimated in October 1997, at the beginning of the wet season, and declined during the dry season to 66 lizards/ha in March 1998. Line transect methods used to estimate the population size were found to be effective, versatile, and economical. I also used the raw data to estimate population size stratified by habitat type and season. This method was non-invasive, non-destructive and seemingly unstressful. This is important when dealing with vulnerable or endangered species. Mark-resight surveys, which were also employed, provided some indication of population size but had large variances and required animals to be captured and temporarily marked. Such a method of population assessment was considered less suitable for the scope and scale of this research.

As the lizard population has nearly doubled annually since translocation, it is unlikely that the observed seasonal fluctuation in numbers is the result of mortality. Other congeners are known to aestivate and this behavioural response to the dry season may explain my observations. This behavioural aspect requires further investigation, because it is critical to understanding social structure and could affect management strategies (e.g., artificial immigration). The dry season is a period of resource limitation as demonstrated by the lower body masses recorded. This may suggest that individuals without sufficient reserves must remain active during the dry season. Food resources can be a critical influence on population dynamics (Boutin, 1990) and research involving supplemental feeding during the dry season would be beneficial.

Juveniles were observed most frequently in December and least frequently in October suggesting a single breeding season when there is sufficient ground moisture for egg incubation (Vitt & Breitenbach, 1993). It also suggests that juveniles may become sexually mature within one year. The frequency of tail autotomy suggests aggressive interactions are common and tail loss is energetically and behaviourally costly. Juveniles were rarely seen to be involved in these interactions, which may explain the maintenance of juvenile coloration in adult males. Further study of the social hierarchy is needed to examine this phenomenon and to consider the possibility of suppression of adult coloration by dominant males.

GENETIC DIVERSITY

Genetic diversity is the hereditary component of biodiversity. For a population to survive over a long time period it must have sufficient genetic diversity to adapt to changing environments. Individual phenotype, genotype and the environment are interrelated and evolving. Therefore, understanding the genetic structure of a population and monitoring changes following translocation is important for the development of viable management. A significant decline in genetic diversity will increase the threat of disease, decreased fitness and climate or other environmental changes.

My data showed a gradual decline in heterozygosity rather than a precipitous drop expected from the founder effect. The founder effect describes a genetically impoverished population built up from a restricted subset of genetic material. On Praslin Island, mean heterozygosity declined 2.3% in three years from a small founding population of 16-23 individuals. However, the genetics of the Maria Major Island population is represented within the translocated individuals, hence 38%–55% of the founder effect is incorporated into the Praslin Island population. An estimated 17% of the alleles have been lost since the founding event and one new allele has evolved which depicts the rate at which this isolated population may evolve.

The lack of immigration makes conservation managers responsible for the maintenance of genetic diversity by incorporating regular introductions to the population. Small populations are known to evolve quickly (Stockwell & Weeks, 1999), be more susceptible to genetic drift (random loss of generic variation) and show reduced genetic viability and fitness as a result of inbreeding (Soulé, 1987). For example, the isolated population of *C. vanzoi* on Maria Minor shows significant evolution during its separation from the population on Maria Major (R_{st}=0.21). Genetic diversity of this population is extremely low (mean heterozygosity = 0.175), and most alleles are fixed (mean alleles/locus =1.38). Further research on genetics of this population is being conducted to determine its status as a separate taxonomic entity.

Fixation indices derived for the Praslin Island lizards show that the population is not panmictic even though there are no barriers to dispersal. Further research is also being conducted to determine parentage and genetic structuring within the island. If lizards on Praslin remain in 'family' groups, the level of inbreeding could increase and the introduction of new individuals will be important to maintain genetic diversity. Congeners have shown the ability to recognise kin and are more aggressive toward less related individuals (Leuck, 1985 & 1993). Behavioural studies should be conducted to determine the social structure of the lizards on Praslin Island. This will help managers successfully introduce individuals into the population and ensure their incorporation into the gene pool. However, repeated introductions can be problematic by preventing adaptation to local conditions or potentially transmitting disease. Introduced individuals may also suffer higher mortality than residents (Massot *et al.*, 1994). Small island populations may be at less risk from inbreeding as deleterious alleles can be purged. These considerations must also be taken into account if additions to the Praslin Island population are planned.

MODELLING

Small populations are challenged by intrinsic and extrinsic factors that increase the risk of extinction (Manne *et al.*, 1999). Development of the island theory of biogeography suggests that these factors result in magnification of extinction risk on islands, as the populations are generally isolated. Modelling provides a method for evaluating the relative importance of the factors that create extinction risk. Consequently, it is a useful tool in the development of sound conservation management strategies for translocated populations. My data on the Praslin Island lizards can be used in an extinction simulation model to examine effects of management strategies. There are unknown variables that must be estimated but by incorporating empirical data, relative risks can be compared.

The extinction simulation model VORTEX (Vers. 7.0; Lacy *et al.*, 1995), was used to determine the probability of extinction of the Praslin Island population. A density dependant model performed 100 iterations using various constants (Table 6.1). Catastrophes and immigration were added into the simulation. A high frequency, low impact catastrophes (e.g. tropical storms), a low frequency high, impact catastrophes (e.g. fire, predator introduction), and supplementing one pair of lizards every two or five years were used in the model to determine effects on extinction risk (Table 6.2).

Variation in catastrophic events and immigration rates showed that introductions to Praslin Island are capable of maintaining high levels of heterozygosity and a 99.9% chance of population survival for 100 years. Frequent population augmentation maintains a high level of genetic diversity and creates a negligible extinction risk even in the event of major catastrophes. The proportion of simulated populations going extinct stabilises after 50 years except in Run 4 where two catastrophes occur without any population supplementation (Figure 6.2). Introduction of one male and one female to the population every two years is more effective in maintaining genetic diversity than the same introduction at a five-year interval.

Table 6.1: Constants used in VORTEX for the estimation of extinction risk.

Constant	Value
Age at first breeding	1.0
Age at senescence*	10
Males in breeding pool	30%
Females producing no litter	50%
Maximum litter size	2
Percent producing litter of 1	10%
Percent producing litter of 2	40%
Mortality in the first year	50%
Starting population size	16
Stable age distribution	Yes
Carrying capacity	500
Recessive lethal alleles	Yes

* Q. Bloxam, pers. comm.

Table 6.2. Stochastic simulation of the extinction process on Praslin Island in 100 years.

Run	Immigration	Catastrophe 1		Catastrophe 2		Probability	Mean Years to 1st	Heterozygosity
	Frequency	Frequency	Impact	Frequency	Impact	of Extinction	Extinction (±sd)	
1	none	none	none	none	none	0.08	21.8±6.5	0.68±0.18
2	none	high	low	none	none	0.26	19.8±13.5	0.62±0.22
3	none	low	high	none	none	0.10	24.0±10.5	0.72±0.16
4	none	high	low	low	high	0.26	37.3±27.3	0.59±0.23
5	2 years	high	low	low	high	0.00	--	0.91±0.04
6	5 years	high	low	low	high	0.00	28.4±27.2	0.82±0.08

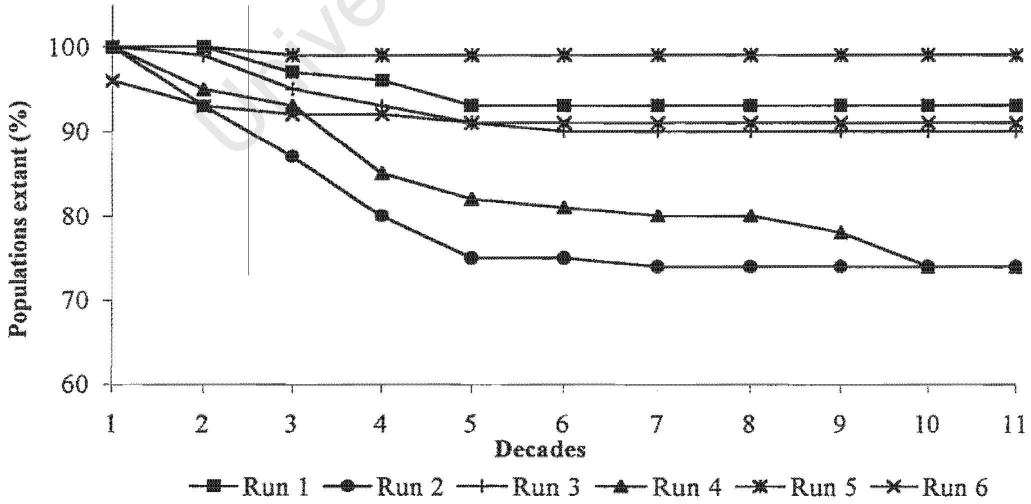

Figure 6.2. The percentage of populations remaining on Praslin Island after 100 iterations by VORTEX using various catastrophic and immigration variables (see Table 6.2).

MANAGEMENT RECOMMENDATIONS AND FURTHER STUDY

The release of lizards on Praslin Island has created a new isolated population of *C. vanzoi* in St. Lucia. The viability of this population will require management commitment. Co-operation between the involved agencies should result in a management plan that incorporates regular monitoring. I make the following management recommendations:

- There needs to be secure ownership or long-term jurisdiction over Praslin Island to provide continuity of management for the translocated population.
- Improve and protect the habitat on Praslin Island. Increase the cover of indigenous shrubs by planting at the edge of the mixed wood - mixed grass habitats. Use either a shade tolerant nursery-shrub for *Rauvolfia virdis* or provide temporary artificial shade for the *Rauvolfia virdis* saplings. Plant indigenous shrubs that attract and enhance invertebrate fauna. Involve the local community to help prevent the removal of fallen trees and branches for firewood.
- Conduct a supplemental feeding study during the dry season by providing 'wet' fruits, such as bananas, to provide moisture and food for lizards. Determine if there is an effect on survival (resource dearth), a functional response in population size, or an increase in lizard activity during the dry season (food limitation). Set baited live traps weekly on the Praslin Island (more frequently during the wet season or after storm events) to capture any predators introduced. Set the traps after 1700 – 1800 hrs. and collect traps by 0800 hrs to prevent accidental capture of lizards.
- Sample the genetic diversity and morphometrics of lizards on Maria Major Island to determine any true founder effect or change in general health between this and the Praslin Island population.
- Continue annual monitoring of the Praslin Island population, if possible. If introductions are deemed necessary (i.e. decline in abundance or genetic diversity) introduce one pair from Maria Major. Ensure that the individuals are disease/parasite free and monitor their integration into the Praslin population.
- Develop an action plan co-ordinated by the Island Warden in Praslin, in the event of fire. This should include preventative education and a plan to extinguish fires. This may require specialist training or co-ordination with other agencies. Damage assessment and mitigation plans should also be prepared. These plans should include population estimation, provision of temporary cover (such as agricultural canopies), planting of indigenous flora from the main island, and supplemental feeding and water provision.
- Consider planned tourism development and contact all interested parties to determine aims and objectives with regard to public visitation on Praslin Island.

In choosing sites for further *C. vanzoi* translocations the following island characteristics should be considered:

- Predator-free island.
- Habitats with an established canopy and shrub layer.
- Shrubs or cover layer of modal 1.3 m height.
- High floral diversity.
- Gentle (< 20 degrees) south facing slopes.
- Non-compact soils with a high organic content (50%) and thick litter layer.
- Rocky outcrops.

SUMMARY: A NEW METHOD IN TRANSLOCATION BIOLOGY

The conservation of species is all too often a 'crisis science' (Soulé, 1985). Although *Cnemidophorus vanzoi* is described as vulnerable rather than threatened or endangered, it has a global population of approximately 900 individuals and is a single island endemic. These factors were sufficient for proactive translocation of animals to another island in St. Lucia.

Translocation integrates the paradigms of small population biology and declining population biology (for an extensive review see Caughley, 1994). Each evaluates extinction risk from a different angle. Small population biology assesses a population with regard to the risks inherent in small numbers, stochastic effects and negative feedback. Declining population biology assesses the risk of extinction from a causative perspective (generally external, deterministic forces) and looks to find a solution. Metapopulation theory assesses extinction risk with regard to the effect of populations existing in habitat fragments and the frequency of immigration between them.

Cnemidophorus vanzoi existed on the Maria Islands after extirpation from mainland St. Lucia. From a declining population perspective, predation could have caused the extinction of this species. The extirpation reduced the extinction risk from deterministic factors. From a small population biology perspective the extirpation also resulted in a restriction of population size, due to the small island area, and the inherent stochastic extinction risks. The translocation of lizards from Maria Major Island to Praslin Island in 1995 reduced the risk of complete extinction by creating a new population with a novel set of extinction pressures. This small offshore island offers protection from predation and human disturbance (including fire) but needs to be managed to reduce overall extinction risk. From a metapopulation approach, two populations (Maria Major & Maria Minor) existed prior to translocation. Although both populations survive, the effect of fragmentation reduced immigration sufficiently to potentially cause speciation of the Maria Minor population to a new island form, and perhaps a different evolutionary significant unit (Waples, 1998). Praslin Island will need to be considered as a functional metapopulation if artificial immigration and island use management is needed to reduce extinction risks.

Pre-translocation assessment of the source and target habitats, the selection of the animals relocated (Brice & Bloxam, 1995, Rosenweig, 1995) and the collection of genetic information from each founding individual was an important part of this project's success. My research provided a carefully planned follow-up to the translocation. The study of habitat use, abundance, genetic diversity, morphometrics and demographics were necessary to determine the success of the translocation of this species. Investigations of these aspects individually would not reflect the multivariate interactions of the translocation (Griffith *et al*., 1989). My results add valuable information to the field of 'Cnemidophorology' (Lowe, 1993) particularly within the *Lemniscatus* species group, as little ecological information exists.

Praslin Island now supports 14% of the total *C. vanzoi* population. For this to have been a viable conservation measure then factors important to its initial success need to be understood and they must provide information about the colonisation process of this particular species. Assessment of the effectiveness of a translocation must include aspects of the species ecology that indicate success. Firstly, establishing the current population size is paramount in determining success, but on its own is insufficient. The absolute value of abundance offers no insight into the dynamics or ecology of the colonisation but only that some individuals persist. Secondly, determining population demographics gives insight into the potential growth of the population and breeding seasons. Thirdly, comparison of morphometrics between the translocated population and the source population give an indirect measure of health. Condition index offers a useful indication of successful integration and use of the new habitat. Fourthly, determining lizard distribution patterns provides understanding of habitat characteristics and structure that are correlated with lizard use. Finally, the genetics of the species needs consideration as small founding populations may evolve rapidly (Stockwell & Weeks, 1999) from the specific status that is being protected or fall into an extinction vortex impacting all of the above. For example, abundance may decline due to reduced or unsuccessful breeding between closely related individuals, fitness may be effected by genetic impoverishment altering age ratio, sex ratio, and other life history characteristics, or a demic structure could further effect genetic diversity. All these aspects need to be assessed across seasonal changes or during times of resource limitation to determine impact on the species ecology and population dynamics.

Figure 6.3 summarises this approach for the assessment of the Praslin Island translocation. Monitoring a recently established population in this way provides a continuous assessment of a project's success and provides valuable information on the colonisation process. It also offers objective data for the claim of a successfully established population and the estimation of extinction risk. The assessment of the Praslin Island population shows successful establishment and that the project to date has been successful.

An independent investigation of the Maria Major Island population is a priority in order to make true comparisons of genetics, habitat use, and body condition with the Praslin Island population. My data on the Praslin Island population incorporates the founding population and may reduce any real changes seen in the translocated population. The only aspect not quantitatively investigated in the Praslin Island population that would augment management practices was the behaviour of *C. vanzoi*. Determining social hierarchies, mating processes, (which can be partly resolved in understanding the population's genetics), diet, activity patterns, territoriality and aggressive interactions will improve the understanding of distribution and improve methods of introducing new individuals to the population. However, the autecological focus presented here gives the best picture for understanding the processes of colonisation and for assessing and monitoring translocation projects. It will provide conservation managers with the information needed to employ adaptive management in the continued success of their conservation efforts.

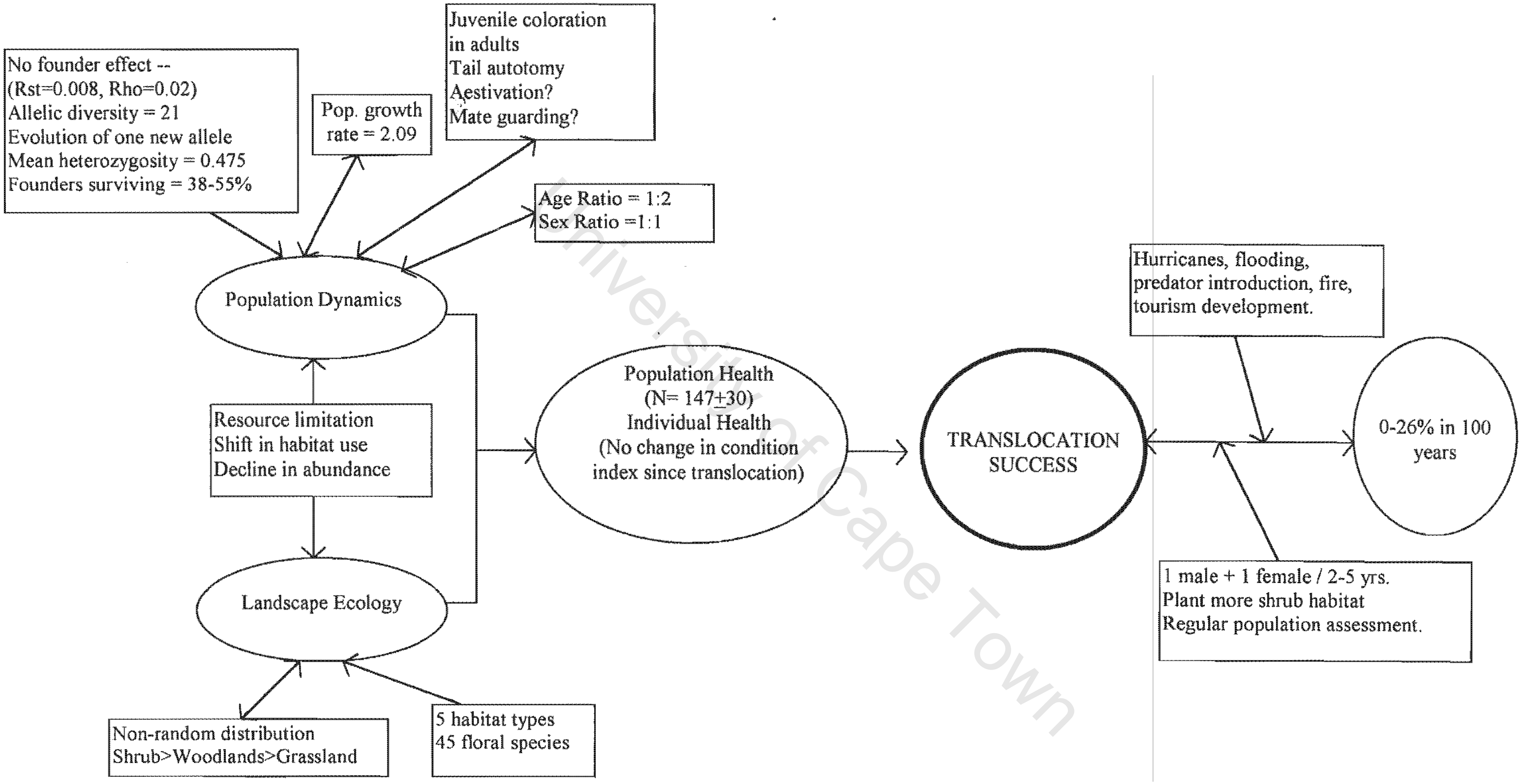

Figure 6.3. Assessment of the translocation of *Cnemidophorus vanzoi* from Maria Major to Praslin Island, St. Lucia, West Indies. Based on the model presented in Figure 6.1. The translocation has been a success, three years after the event.

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