Competition for invertebrate food between the endangered Seychelles Magpie Robin and endemic skinks

by
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ABSTRACT

The endemic landbirds of the Seychelles granitic islands have suffered considerable losses due to predation by introduced rats and cats and extensive habitat destruction. With less than 100 individuals, the Critically Endangered Magpie Robin *Copsychus sechellarum* Newton, faces the greatest risk of extinction. Translocations to three predator-free islands, Aride, Cousin and Cousine, have provided valuable opportunities for gaining insights into the ecology of the species. Of particular interest are links between the Magpie Robin, endemic skinks *Mabuya spp.*, ground-living invertebrates and seabird colonies.

Magpie Robin faecal pellet and skink gut content analysis demonstrated a high degree of dietary overlap between the species. A widespread exotic cockroach *Pycnoscelus indicus*, was the favourite prey item for each species. However, behavioural observations and a dietary choice experiment indicated that there is no significant competition for food during the main seabird breeding season. Invertebrate sampling on Cousine identified 52 species which were available in all habitat types currently in use or those considered suitable for the Magpie Robin. Seabird and skink density counts on Cousine demonstrated the considerable magnitude of vertebrate organic food also available. Invertebrate sampling results on Cousin and Cousine were used to determine territory quality and the carrying capacity of each island for the Magpie Robin.

While most seabirds are not breeding, skink survival depends on invertebrate abundance. *M. wrightii* weight declined throughout this period but that of *M. sechellensis* remained fairly stable. The data were insufficient to conclude that inter-specific competition for food exists between *M. sechellensis* and the Magpie Robin during this period. Further expansion of the Magpie Robin population depends on eradicating mammalian predators from other islands and maximising the potential carrying capacities of those already supporting the species.

Keywords: Critically Endangered, Seychelles Magpie Robin, *Copsychus sechellarum*, mammalian predators, endemic skinks, exotic cockroach, competition, carrying capacity.

PREFACE

This thesis extends existing knowledge of the feeding ecology of the Magpie Robin *Copsychus sechellarum* Newton, the most threatened endemic landbird species in the granitic Seychelles. The first chapter provides an introduction to the decline of endemic landbirds in Seychelles as a result of predation by introduced mammals and habitat destruction, with the focus on the Magpie Robin. The middle three chapters investigate aspects of its feeding ecology on Cousine and Cousin Islands. The final chapter is a general discussion on the results given in previous chapters.

In chapter one, after a short overview of endemic landbirds in the Seychelles, a historical review of the decline and recovery of the Magpie Robin following implementation of a Recovery Plan in 1990 is given. Since 1992, birds have been translocated to three predator-free islands. These support large colonies of breeding seabirds, indigenous vegetation and dense populations of endemic skinks. The following three chapters investigate the relationship between these skinks and the Magpie Robin by comparing diet and foraging behaviour (chapter two) and looking at the availability of invertebrate and vertebrate food resources (chapter three). Chapter four investigates the relationship between invertebrate abundance and skink weight fluctuation to determine whether or not inter-specific competition for food between skinks and the Magpie Robin may occur while the majority of seabirds are absent from Cousine.

Chapters two to four are written for future publication. There is therefore some repetition, particularly in the introductions, site descriptions and references.

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Chapter 1

General Introduction

Bird Extinctions

A recent study has shown that approximately 11% of the world's bird species are threatened with extinction (Collar *et al.*, 1994), while 116 species have become extinct since the year 1600 (Smith *et al.*, 1993).

Prior to this time, the Polynesians had eliminated around 15% of the world's bird species (Steadman, 1995). The Hawaiian islands have lost over 90% of their endemic bird species (Pimm, 1996; Olson & James, 1982) and 18 species have become extinct since the arrival of Europeans at the end of the eighteenth century (Warner, 1968). New Zealand has lost 44 species of land and freshwater birds since the arrival of Polynesians in A.D.900 (Caughley & Gunn, 1996). In turn, the Indian Ocean islands of Mauritius, Rodrigues and Reunion have lost 33 of their endemic bird species over the past 300 years (Pimm *et al.*, 1995) and similar patterns of decline and eventual extinction are being repeated all over the globe.

Of the bird extinctions which have been recorded, it has been estimated that over 90% have occurred on islands, whether on isolated patches on continents or in mid-ocean (Johnson & Stattersfield, 1990). Birds confined to islands are particularly vulnerable to change because they have small populations with restricted breeding ranges, low reproductive rates and have often evolved in isolation with few natural predators (McCulloch, 1996; Lovegrove, 1992; Moors *et al.*, 1992).

The primary causes of extinctions of island bird species have been, and continue to be, attributed mainly to changes wrought by humans on the environment. Introduction of alien taxa and widespread habitat destruction are cited most often as the principal culprits. Most famously, the Dodo *Raphus cucullatus* (Linnaeus), died out on Mauritius as a result of hunting plus competition from introduced pigs, crab-eating macaques *Macaca fascicularis* (Raffles), cats and rats (Cheke, 1987) Humans and pigs almost eliminated the Bermuda Petrel *Pterodroma cahow* Nichols &

Mowbray, within 20 years of its discovery (Wingate, 1985). Since the accidental introduction of the predatory Brown Tree Snake *Boiga irregularis* Merrem, nine of Guam's thirteen endemic birds have been extirpated (Savidge, 1987; Anon, 1998). Rat predation has been implicated in 54% of all avian extinctions (King, 1985) and has also caused extensive extinction amongst many other taxa.

Bird Protection

Some of the oldest conservation societies such as the Audubon Society, Birdlife International (formerly the International Council for Bird Preservation or ICBP) and the Royal Society for Protection of Birds (RSPB) were originally established to protect birds, particularly those species threatened by the fashion trade. Birds deserve protection because of their intrinsic value, our moral responsibility towards them and because their conservation contributes to the maintenance of global biodiversity. For example, some endangered birds have become flagship species as a result of efforts to protect them, including the Puerto Rican Parrot *Amazona vittata* (Boddaert), (Caughley & Gunn, 1996) and the Mauritian Kestrel *Falco punctatus* Temminck, (Cade & Jones, 1993).

In other cases, the importance of endangered bird conservation is achieved by demonstrating its potential economic benefits to local people who may otherwise, usually out of necessity, destroy their immediate environments for short-term gains (Birdlife International, 1995).

It will become increasingly difficult to ensure the survival of endangered species and global biodiversity as human populations continue to increase. A study of threatened birds has identified certain areas where there are concentrations of endemic birds, known as "endemic bird areas" or "hotspots" (Stattersfield *et al.*, 1998). A large proportion of these endemic birds occur on islands and, with their restricted range sizes, these species are often most in need of conservation action, particularly as many are found on only one island. As it has been suggested that bird hotspots overlap with those of mammals, amphibians, reptiles and plants, protecting areas rich in threatened birds may also ensure protection for other endangered taxa in some areas (Bibby *et al.*, 1992, Myers, 1990) although some studies dispute this (Lombard, 1995).

Cousin Island Special Reserve in the Seychelles, which is managed by Birdlife International, is a classic example of how action to save one Critically Endangered species has led to the protection of several other taxa. It also illustrates the value of successful co-operation between conservation and tourism, which is one of the most lucrative and rapidly developing global industries (Goodwin, 1996). The island was bought in 1968 to save the Seychelles brush warbler *Acrocephalus sechellensis* (Oustalet), from extinction. The world population of under 30 individuals was confined to Cousin (27ha) at the time. Since then, the species has recovered and has been successfully established on two other nearby islands (Komdeur, 1994; Komdeur *et al.*, 1995). With no predatory mammals, the island is also a safe haven for the Seychelles Fody *Foudia sechellarum* Newton, a recently introduced population of the Critically Endangered Seychelles Magpie Robin *Copsychus sechellarum* Newton, endemic reptiles and large colonies of breeding seabirds. It is also the main breeding site in the granitic Seychelles for the endangered Hawksbill Turtle *Eretomochelys imbricata* (Linnaeus). Under close supervision from the local Seychellois staff, tourists have been visiting the island since the early 1970's and it is one of the most popular tourism destinations in the Seychelles. In recognition of its important role in preserving Seychelles biodiversity, it was awarded Special Reserve status in 1975 by the Seychelles government.

Decline of endemic land birds in the Seychelles.

The Seychelles archipelago consists of 115 islands. The central group (Fig. 1) are the only oceanic granitic islands in the world and lie between 4-5°S and 55-56°E. They were first described in 1609, with observations of large numbers of giant tortoises, sea crocodiles and birds as well as lush, dense forest cover on Mahe (Stoddart, 1984a). The first permanent human settlement was not established until 1770 and early settlers swiftly destroyed much of the lowland forest for agricultural purposes with the result that plantations were established on most granitic islands by 1787 (Gerlach, 1996). Humans also introduced alien species such as pigs, dogs, goats, cows, Indian mynas *Acridotheres tristis* (Linnaeus), cats *Felis cattus* Linnaeus, and rats *Rattus norvegicus* Linnaeus, and *R. rattus* Linnaeus. As plantations were extended and more islands were colonized, endemic landbirds (see Table 1) soon declined due to the devastating combination of habitat clearance or modification, predation by rats and cats and direct persecution from hunting.

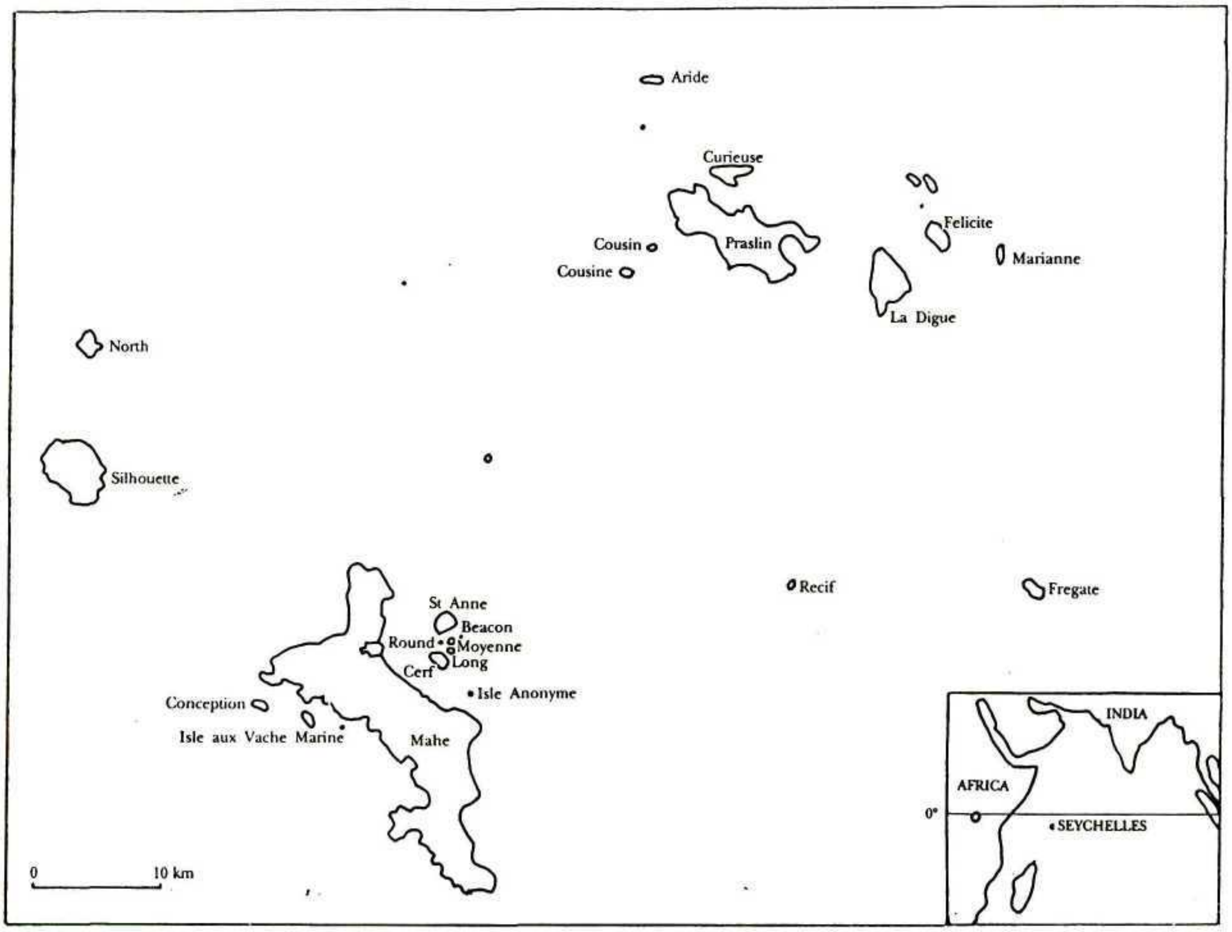

Fig. 1: The granitic Seychelles islands.

By the middle of the nineteenth century, several island extinctions had already occurred (Newton, 1867). The parakeet *Psittacula wardi* Newton had been almost completely eradicated as it was considered a pest by plantation owners. Extensive collecting activity during the latter half of the century (Oustalet, 1878; Knox & Walters, 1994; Newton, 1867) also ensured that bird populations, particularly on the smaller islands, dwindled further. Diamond and Feare (1980) suggested that at least 41% of island populations of birds in the Seychelles had become extinct since the first human settlements were established. On the smaller islands, this was blamed entirely on predation by rats and cats.

Species		**Global Status**
Seychelles Scops Owl	*Otus insularis*	CR
Seychelles Magpie Robin	*Copsychus sechellarum*	CR
Seychelles Paradise Flycatcher	*Terpsiphone corvina*	CR
Seychelles White Eye	*Zosterops modesta*	CR
Seychelles Kestrel	*Falco araea*	VU
Seychelles Swiftlet	*Aerodramus elaphrus*	VU
Seychelles Warbler	*Acrocephalus sechellensis*	VU
Seychelles Fody	*Foudia sechellarum*	VU
Seychelles Blue Pigeon	*Alectroenas pulcherrima*	lc
Seychelles Bulbul	*Hypsipetes crassirostris*	lc
Seychelles Sunbird	*Nectarinia dussumieri*	lc
Seychelles Parakeet	*Psittacula wardi*	EX
Chestnut-sided White Eye	*Zosterops mayottensis semiflava*	EX

Table 1: The endemic landbirds of the Seychelles granitic islands (Stattersfield *et al.*, 1998). CR = Critically Endangered, VU - Vulnerable, lc = least concern, EX = Extinct.

Current Status of endemic landbirds of the Seychelles

Of the eleven endemic landbird species confined to the granitic islands, four are listed as being Critically Endangered (Table 1). Threats continue to be habitat destruction and predation by rats, cats and the barn owl *Tyto alba* (Scopoli), the latter of which was introduced in the 1950's to control rats (Penny, 1974; Feare, 1984). Habitat destruction is of particular concern for the paradise flycatcher *Terpsiphone corvina* (Newton), due to continued housing development on La Digue (Rocomoro, *et al.*, 1997). The recent colonization on Fregate by Norway rats *R. norvegicus* (Jones & Merton, 1996; McCulloch, 1996) means that there are now only three small granitic islands remaining free of mammalian predators: Aride, Cousin and Cousine. These have a combined area of little over 100 ha. The rat eradication programme on Fregate has been postponed indefinitely until the completion of a 5-star hotel resort. Unfortunately, the rats have spread all over the island and pose a serious threat to endemic birds, reptiles, amphibians and invertebrates.

In spite of this catalogue of ongoing threats, there have been a number of positive developments. These include comprehensive monitoring and research programmes which are being carried out by Ministry of Environment staff, with collaboration from Birdlife Seychelles, the Royal Society for the Protection of Birds (RSPB), the Royal Society for Nature Conservation (RSNC), the Nature Protection Trust of the Seychelles (NPTS) and a number of private islands.

There have also been a number of recent discoveries. In January 1997, a substantial breeding population of white-eyes was found on a small (60.3ha) island off the west coast of Mahe (Rocomoro *et al.*, 1998). The kestrel is breeding on North Island (Lucking *et al.*, 1997; P Hitchins, C Hennig, pers.comm.) and flycatchers have been seen on Marianne, after an absence of around 60 years (Shah & Parr, 1998). In addition, it is thought that a few Seychelles turtle doves *Streptopelia picturata rostrata* Bonaparte, continue to exist on Cousin, Cousine, Aride and Bird Islands (Feare & Gill, 1995). This sub-species is generally considered to be extinct due to hybridization with the Madagascan form *S. p. picturata* (Temminck).

Probably as a result of habitat management, other species have re-colonized islands from which they had been extirpated. The sunbird and blue pigeon are breeding again on Aride (Lucking, 1994; Betts, 1996) and one fody became established there in 1988 (Bullock, 1989). However, intentional re-introductions of the latter species are threatened due to evidence of hybridization with the Madagascan fody *Foudia madagascariensis* Linnaeus, which occurs there in large numbers (Lucking, 1997).

The brush warbler and Magpie Robin have been re-introduced to islands within their former range, with mixed success. Translocations have only involved the three islands remaining free of rats and cats. With a warbler population of between 300-360 birds on Cousin by the mid-1980's, the species was re-introduced to Aride in 1988 and Cousine in 1990 (Komdeur, 1994; Komdeur *et al.*, 1995).

Both translocations have been successful, spectacularly so on Aride where the latest population census estimate was about 1600 individuals (J. Bowler, pers.comm.). The latest census on Cousine estimated 147 individuals (Blaakmeer, 1998).

However, of all the endemic birds, the Magpie Robin has perhaps received the greatest proportion of attention both within the Seychelles and on the international stage. For over thirty years, its plight has been the concern of Birdlife International. Other supporters and contributors to the project have been the Seychelles Government, The Royal Society for the Protection of Birds(UK), The Royal Society for Nature Conservation (UK), Bristol University (UK), the New Zealand Department of Conservation, the Jersey Wildlife Preservation Trust, the Mauritian Wildlife Foundation, the Zoological Society of London, the Nederlands Instituut voor Oecologisch Onderzoek, the owners of Fregate and Cousine, plus several volunteers.

A short historical review of the Seychelles Magpie Robin and its current status

The Seychelles Magpie Robin is a member of the sub-family Turdinae and is a large, predominantly ground-feeding, chat. It is the largest species of a genus which includes both Magpie Robins and Shamas, most of which are found in Asia where some are popular cage birds.

The first description of the Seychelles species was made from a caged bird which had been kept on Mauritius in 1864 (Newton, 1865). The original range of the species included Mahe, St Anne, Praslin, La Digue, Marianne, Aride and Fregate (Fig. 1). Although no records exist, the species probably occurred on other granitic islands where there was suitable habitat (McCulloch, 1994).

The Magpie Robin spends most foraging time looking for invertebrates and reptiles in leaf litter and upper soil layers. Preferred habitat consists of closed canopy woodland where ground covering shrubs, grasses or ferns are scarce (Watson *et al.*, 1992; McCulloch, 1996; Komdeur, 1996). Being a particularly inquisitive species, individuals will often approach humans to within a metre, especially if food is available. As there are no endemic predatory mammals in Seychelles, they are easily caught by cats and rats, particularly newly-fledged birds. These cannot fly very proficiently for up to two days after fledging and usually spend a minimum of another four weeks begging loudly.

These confiding characteristics coupled with one-egg clutches led to a rapid decline of the species following human colonization of the Seychelles. By the late 1870's, it had been extirpated from Mahe and Praslin (Blackburn, 1878). There are no records of the species on La Digue this century, where nest-robbing had once been reported as being a common pasttime (Newton, 1867).

Extinction on Aride by the late 1930's has been attributed to cats which were introduced between 1918-1925 (Watson, 1984) but the last confirmed record was in 1905 (Diamond & Feare, 1980). The Magpie Robin may therefore have become extinct on the island prior to the cat introduction. By the early 1950's, the species survived only on Alphonse, a coralline island in the Amirante group, and Fregate. It probably died out from the former within a decade (Gaymer *et al.* ,1969), again following the introduction of cats. Cats were also taken to Fregate and the Magpie Robin was on the brink of extinction when a census there in 1965 found only eight birds (Dawson, 1965). However, a reprieve came in the form of an outbreak of feline enteritis which greatly decreased the cat population. The Magpie Robin population then increased steadily to 41 individuals in 1978 (High, 1974; Wilson & Wilson, 1978; Watson *et al.*, 1992).

This recovery prompted two attempts at re-introducing the species to Aride and ten birds were translocated in 1978 and 1979. Neither attempt was successful, and by October 1980, only one individual, a male, was found. It survived there for a further eight years (Bullock, 1989). Meanwhile, cats were finally eradicated from Fregate in 1982 (Todd, 1982) but the Magpie Robin population did not increase as expected (Warman & Warman, 1983). This was thought to have been partially due to the closure of the island's coconut plantation. While this industry remained economic, the Magpie Robin benefited considerably by foraging alongside plantation workers clearing ground vegetation from beneath the plantation as well as in the extensive vegetable gardens on the fertile plateau. The population fluctuated between 18-25 individuals for the remainder of the decade until a recovery plan was launched by the International Council for Bird Preservation in 1990 (Rands & Komdeur, 1989).

A subsequent ban on insecticide/pesticide use plus the provision of supplementary food and nestboxes, resulted in increased productivity and a decrease in chick and adult mortality. By the end of 1993, the population had risen from 22 to 41 birds (McCulloch, 1994). Further attempts were made at establishing satellite populations of the species on the other predator-free islands from 1992 onwards. Those to Cousin and Cousine have been successful with populations of 19 and 13 on each at the end of September 1998 (Parr, 1998). Those to Aride have repeatedly ended in failure (Lucking & Ayrton, 1995). The reasons for this remain unclear although translocation stress, barn owl predation and disease have all been implicated (Cooke, 1998; Jones & Merton, 1996).

Cousin, Aride and Cousine represent safe havens for several other formerly widespread endemic and native flora and fauna. They are the only remaining granitic islands with large colonies of breeding seabirds, which have, traditionally, been heavily exploited (Stoddart, 1984b; Feare, 1984; Diamond, 1990). The most abundant tree-nesting species is the Lesser noddy *Anous tenuirostris* (Temminck), with estimates of 166,000 and 92,000 pairs given most recently for Aride and Cousine respectively (Bowler & Hunter 1998; Copsey, 1998). Ground beneath the colonies during the main breeding season, May to September, is permanently littered with dropped fish, broken egg, faeces and dead chicks. Species such as the White Tern *Gygis alba* (Sparrman), and Brown Noddy *Anous stolidus* (Linnaeus), which occur in lower numbers, also contribute. An attempt at quantifying the organic input was carried out on Cousin, where it was estimated that 60,000 pairs of Lesser noddies produced in the region of 4000kg of wet fish, 300kg of eggs and approximately 11,400kg of faeces every year (Brooke & Houston, 1983).

The most prolific ground scavengers beneath these seabird colonies are two species of endemic, diurnal skink: the Seychelles skink *Mabuya sechellensis* (Dumeril and Bibron), and the Wright's skink *Mabuya wrightii* (Boulenger). These lizards occur at extremely high densities, possibly the highest in the world. The smaller *M. sechellensis* is widely distributed throughout the granitic islands but is considerably scarcer on those with rats (Cheke, 1984). *M. wrightii* is almost entirely restricted to the three rat-free islands and may have evolved in association with seabirds (Vesey-Fitzgerald, 1947). It has been demonstrated that *M. wrightii* derives particular benefit from seabird organic input as there is a significant mean weight fluctuation throughout the year (Brooke &

Houston, 1983). With maximum weight reached in June, fat deposits laid down during the Lesser noddy breeding season enable survival without further food for over three months. However, both skink species also prey on a wide variety of invertebrates, fruit and even young skinks, the availability of which is relied upon for survival when most seabirds are absent from the islands. Accordingly, there is probably a high degree of dietary overlap and competition for food between the Magpie Robin and skinks.

Aims of the present study

Small islands such as Aride, Cousin, Cousine, Marianne and Fregate are all thought to have supported large seabird colonies prior to permanent settlement by humans in the Seychelles, and historical records show that the Magpie Robin existed on three of them. On the first three, management policies have been designed primarily to ensure the maintenance and improvement of biodiversity by restoring flora and fauna which probably existed on each one prior to human settlement on the islands. Current knowledge concerning Magpie Robin ecology is based largely upon studies carried out on Fregate where over 90% of the vegetation consists of exotic species. Close observation of the birds on the seabird islands may provide further valuable insights into the ecology of the rarest landbird in the Seychelles.

The present study was carried out between July 1996 and August 1998, and data were collected from Cousine and Cousin Islands. The focus was on Magpie Robin feeding ecology and the ecological relationship with skinks. The study is divided into three sections. The first decribes the natural diet and foraging behaviour of each species during the main seabird breeding season (May to September) to determine whether or not there is competition between them for food. The second describes and quantifies the invertebrate and vertebrate food resources available on Cousine. The invertebrate data are used to calculate Magpie Robin territory quality and to estimate the carrying capacities of Cousin and Cousine for the species. The third section investigates the relationship between skink weight fluctuation and invertebrate abundance. This was carried out to determine whether or not inter-specific competition for food exists between the Magpie Robin and skinks while the majority of breeding seabirds are absent from the island. The results of the first two sections are used to make recommendations for future conservation management of the Magpie Robin.

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Chapter 2

Diet of the Seychelles Magpie Robin *Copsychus sechellarum* and endemic skinks (*Mabuya spp.*) on Cousine Island

ABSTRACT

The Critically Endangered Seychelles Magpie Robin *Copsychus sechellarum* Newton, is currently confined to four small granitic islands in the central group of the Seychelles archipelago. Its original range declined rapidly following permanent settlement of the Seychelles by humans in 1770, mainly due to habitat destruction and predation by introduced mammals. The world population stood at 74 fledged individuals at the end of September 1998, having been as low as 8 in 1965. In 1990, Birdlife International initiated a recovery plan for the species. Since 1992, 25 birds have been translocated to three small rat- and cat-free islands. Key features of these islands are their large colonies of breeding seabirds and considerable dense populations of endemic skinks, *Mabuya sechellensis* and *Mabuya wrightii*. Observations of the feeding ecology of the Magpie Robin and skinks during the main seabird breeding season on Cousine Island indicated a high degree of dietary overlap. Common prey items included several species of invertebrate plus small skinks and organic material such as fish and egg which drops to the ground beneath tree-nesting seabirds. Examination of their different patterns of resource use in one Magpie Robin territory suggested that there was no significant competition for food between them.

INTRODUCTION

The Seychelles Magpie Robin *Copsychus sechellarum* Newton, is one of four Critically Endangered endemic landbirds surviving on the granitic islands of the Seychelles archipelago (Stattersfield *et al.*, 1998). The world population currently numbers 74 individuals (Parr, 1998), distributed on four small islands (Fig.1).

Being a particularly confiding species with no natural mammalian predators, the two main reasons for its decline have been destruction of habitat and predation by introduced mammals since the first permanent human settlement was established in 1770 (Watson *et al.*, 1992).

By the early 1960's, the species was entirely confined to Fregate (219ha) where it nearly became extinct as a result of cat predation. Only 8 individual birds were identified there during a brief census in 1965 (Dawson, 1965). The cat population was controlled by a combination of outbreaks of feline enteritis and eradication attempts carried out by the Seychelles Government. Somehow, the Magpie Robin survived.

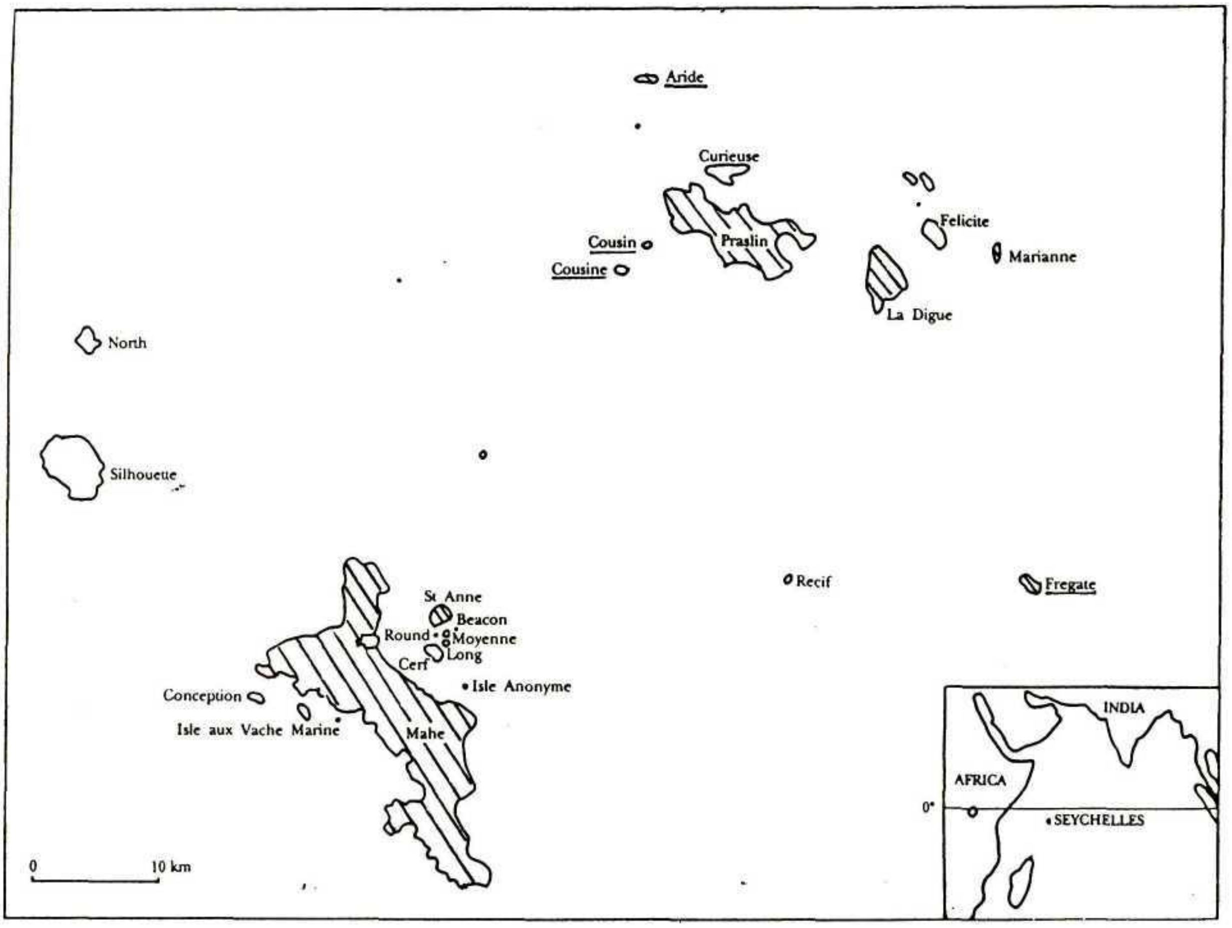


Fig 1: The granitic Seychelles islands showing past (hatched) and present (underlined) distribution of the Magpie Robin.

Cats were eventually eradicated from Fregate in 1982 (Todd, 1982). By the end of the 1980's, the species had not recovered as expected, having fluctuated at around 20 individuals throughout the decade. The Magpie Robin prefers to forage in leaf litter and bare earth beneath closed canopy woodland, taking small invertebrates and lizards. When Fregate's coconut plantation was effectively closed down in the early 1980's, a number of areas previously used for foraging became unusable because, without plantation workers, the ground became covered with thick vegetation. An intensive two year ecological study initiated in 1988 identified a number of factors limiting Magpie Robin population growth. The most important were high adult and chick mortality, low numbers of suitable nesting sites (usually cavities in tree trunks) and competition from the introduced Indian Myna *Acridotheres tristis* (Linnaeus), (Komdeur, 1996; McCulloch, 1996a). As a result, a recovery plan (Rands & Komdeur, 1989) was implemented in 1990 by Birdlife International.

To reduce the vulnerability of the species to extinction while confined to one island, a number of birds have been translocated to three other granitic islands since 1992. Breeding populations have been successfully established on two of these, Cousin and Cousine, but only one female remains on Aride. These islands were chosen primarily because of the absence of rats and cats. In addition, invertebrate sampling demonstrated that similar habitat on Aride supported comparable invertebrate densities to those on Fregate (Komdeur, 1996).

With no mammalian predators, Aride, Cousin and Cousine are of considerable biological importance. The most striking features of each are their large breeding seabird colonies and extremely high densities of endemic diurnal skinks, the Seychelles skink *Mabuya sechellensis* (Dumeril and Bibron), and the Wright's skink *Mabuya wrightii* (Boulenger). With no significant natural predators, the lizards are the top secondary consumers on these islands and it is thought that dense populations are supported on seabird islands because of considerable authochthonous input (Polis & Hurd, 1996; Brooke & Houston, 1983). The seasonality of this energy flow, May to September, means that skinks are forced to rely on other sources of food while the majority of the seabirds are absent e.g. ground-based invertebrates, generally found in leaf litter, and fruit. It is likely, therefore, that a certain degree of dietary overlap exists between skinks and the Magpie Robin on the three seabird islands.

This relationship is of ecological interest mainly because little is known of the Magpie Robin in its natural habitat, particularly with regard to feeding ecology. Previously, most research has been carried out on Fregate where over 90% of the vegetation consists of exotic species (McCulloch, 1996b).). Although there are no references to existence of the Magpie Robin on Cousin and Cousine, the original coastal woodlands, which are similar to those on Aride, probably supported small populations. This paper describes a study undertaken to test the hypothesis that if the Magpie Robin and skinks have a similar diet, they may compete for food. I investigate here, qualitatively and quantitatively, Mapgie Robin diet and that of each skink species on Cousine Island. This includes Magpie Robin faecal pellet and skink gut content analysis, chick food provisioning data, foraging behaviour of the Magpie Robin and both species of skink, and a prey item preference experiment.

MATERIALS AND METHODS

Site Description

The study took place on the small (26ha) granitic island of Cousine (55°39'E, 4°21'S)(Fig 2). A wooded rocky ridge, rising to almost 70m and 40 m at its highest points, runs the length of the island. Most of this is covered in closed canopy woodland dominated by native tree species such as *Pisonia grandis* 'R.Br.', and *Ficus reflexa* Thunb.. Screwpine *Pandanus balfourii* (Martelli), dominates approximately 2ha of the north-eastern side of the main hill and around 4ha on the eastern side is characterised by boulders, ferns *Nephrolepis 'biserrata'* and *Euphorbia pyrifolia* (Lammarck). The small coastal plain of approximately 8ha is largely devoid of woodland and vegetation consists of a mixture of native shrubs, a few stands of *Casuarina equisetifolia* J.R. and G. Forster, and grassland.

The island is of major biological interest and conservation importance. It is managed as a nature reserve, chiefly to protect a number of endangered endemic landbirds: the Magpie Robin, the Seychelles brush warbler *Acrocephalus sechellensis* (Oustalet), and the Seychelles fody *Foudia sechellarum* Newton. The more widely distributed Seychelles sunbird *Nectarinia dussumieri* Hartlaub, and the Seychelles blue pigeon *Alectroenas pulcherrima* (Scopoli), also occur there.

Seven species of seabird breed on the island at various times during the year: the Lesser noddy *Anous tenuirostris* (Temminck), the Brown noddy *Anous stolidus* (Linnaeus.), the White-tailed tropic bird *Phaethon lepturus* Daudin, the Bridled tern *Sterna anaethetus* Scopoli, the White tern *Gygis alba* (Sparrman), the Wedge-tailed shearwater *Puffinus pacificus* (Gmelin),and the Audubons shearwater *Puffinus lherminerii* Lesson. In addition to the skinks, other reptiles include a

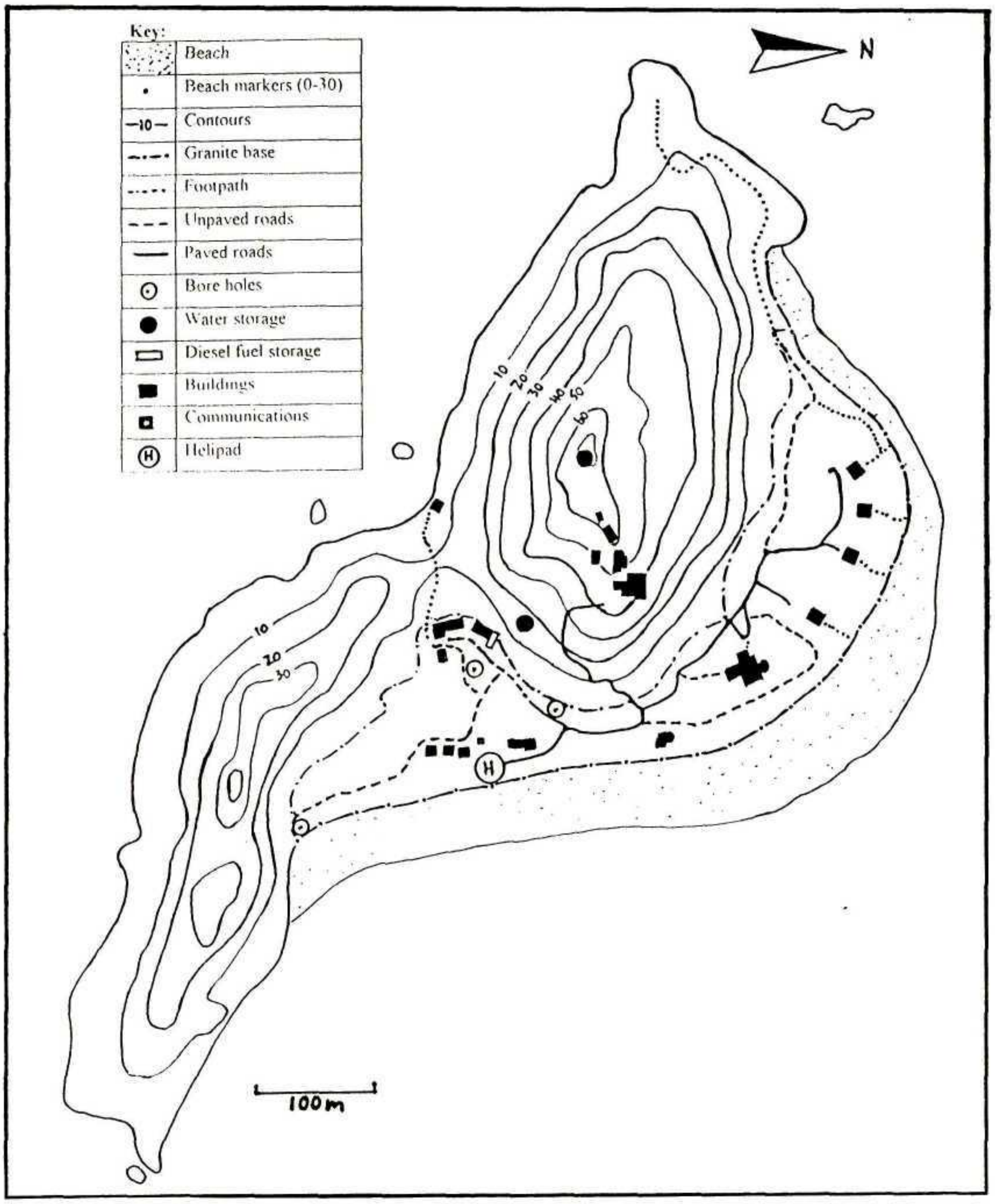


Fig 2: Cousine Island.

population of sixteen Seychelles Giant Tortoises *Dipsochelys dussumieri* (Gray), the Green Gecko *Phelsuma astriata* (Tornier), the Bronze House Gecko *Ailuronyx sechellensis* (Dumeril and Bibron) and a small population of the Seychelles Wolf Snake *Lycognathophis seychellensis* (Schlegel). Of a number of endemic invertebrates, the most conspicuous is a large population of the Seychelles Giant Millipede *Seychelleptus seychellarum* (Desjardins).

Faecal pellet analysis

Thirty-six Magpie Robin faecal pellets and two oral pellets were collected from both adult and juvenile birds in three territories between January 1997 and May 1998. These were stored in 80% ethyl alcohol. Invertebrate and vertebrate prey species were identified, but not quantified, from fragments of exoskeleton and bone respectively.

Gut content analysis

Between April and August 1997, thirty-one adult *M. wrightii* and twenty-one adult *M. sechellensis* were collected for gut content analysis. The animals were selected at random during a skink biometric study being carried out simultaneously (see chapter four). Samples were also stored in 80% ethyl alcohol and prey items identified as above.

Chick food provisioning

Between April 1997 and April 1998, fifteen continuous 12h observations were carried out on prey items supplied to six Magpie Robin chicks. The approximate size and identity of each prey item was recorded as far as possible. The mass of food supplied to chicks was estimated from the mean weights of twenty-one earthworms, eighteen cockroaches *Pycnoscelus indicus* (Fabricius), five Giant click beetle larvae *Megapenthes curtus* Candexe, three fish, twelve young skinks and geckos *Mabuya spp./Ailuronyx astriata* and data from invertebrate sampling (see next chapter).

Foraging behaviour

Observations of foraging behaviour of the Magpie Robin and both skink species were carried out in 1998 during the main seabird breeding season (between May and September), as follows.

The Magpie Robin

Fifty-four half-hour observations, spread evenly throughout the day, were carried out in the largest territory (Fig. 3). The method involved locating a bird and following its movements for 30 minutes. Its behaviour was recorded at 30s intervals, and movements were mapped using a map of the territory overlaid by a 50m x 50m grid. Foraging behaviour was scored according to whether a bird was foraging in leaf litter, in soil, on a tree, under a rock, on grass, in mid-air or simply scanning the ground (from ground level) and all prey items found were identified as far as possible.

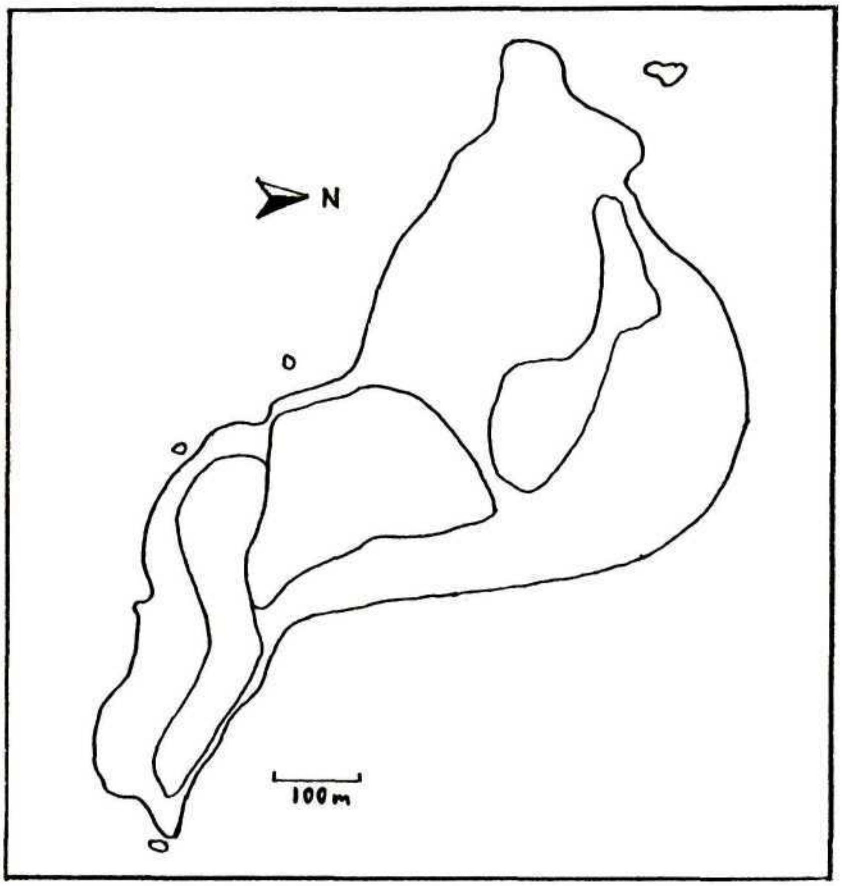


Fig 3: Cousine Island, showing the location of three Magpie Robin territories.

It is thought that immature birds (less than nine months) and those in moult or breeding spend significantly more time foraging (Komdeur, 1996). As there were several Magpie Robin breeding attempts during the 1998 seabird breeding season, a small percentage (approximately 5%) of observations were carried out on seven month old immatures. The rest were carried out on non-breeding and non-moulting adults.

Skinks

One hundred and four observations, also spread evenly throughout the day, were carried out, fifty-four of *M. wrightii* and fifty of *M. sechellensis*. The method was similar to that used above and all half-hour observations were carried out within the same Magpie Robin territory. Each observation was made according to the first animal sighted in a randomly chosen grid square within this territory. A skink was assumed to be foraging when it was actively searching in leaf litter or soil and/or on any occasions when it was observed tongue flicking .

Dietary choice experiment

As field observations of skink foraging behaviour showed that each species searched for food in a similar manner, this experiment was only carried out using *M. wrightii*. It involved offering Magpie Robin and *M.wrightii* individuals a range of prey items to discover whether either of the species had a particular preference. Prey items were chosen according to the results of faecal pellet and gut content analysis and observations of chick food provisioning. They consisted of the exotic cockcoach *P. indicus*, (Fabricius), the larva of the Rhinoceros beetle *Orystes monoceros* (Olivier), the juvenile (3-4cm) Giant millipede *Seychelleptus seychellarum* (Desjardins), and an earthworm (Oligochaeta). *O. monoceros* was chosen in preference to the Giant click beetle larva *M. curtus* because it was an easier species to find in abundance and preliminary trials indicated that it was readily taken by both skinks and the Magpie Robin. Two sizes of *O. monoceros* were used, alternatively, during trials, to test whether or not either Magpie Robin or *M. wrightii* prey choice would be influenced by one prey item being approximately double the size and mass of others on offer.

The method involved locating a Magpie Robin or *M. wrightii*, each of which was presented with a tray containing one individual of each invertebrate species and recording which one was eaten first. This was repeated on fifty occasions for both the Magpie Robin and *M. wrightii*, using ten different birds and fifty different *M. wrightii*. To avoid choice being biased, tests involving interference from conspecifics were not included in analysis. Only adult birds were tested as it is likely that foraging involves a certain degree of learning about the nutritional value of various types of prey (Shettleworth *et al.*, 1993) and tests for both birds and skinks were distributed amongst the three Magpie Robin territories.

The tests on the Magpie Robin were carried out as early in the day as possible, usually between 07h00-09h00. To test when the birds were most likely to be actively searching for food, this period was chosen to coincide with a peak in foraging activity. Skinks were tested between 09h00-12h00 since skinks become increasingly active as they absorb heat from the sun. The control for each test was offering some leaf litter in addition to the four invertebrates.

RESULTS

Faecal pellet analysis

The remains of eight food types were identified in the Magpie Robin faecal and oral pellets. The relative importance of each is given in Table 1.

PREY ITEMS	**May - September** **n = 19**	**October - April** **n = 19**
Cockroach *Pycnoscelus indicus*	94.7	89.5
Giant click beetle larvae *Megapenthes curtus*	68.4	73.7
Giant millipede *Seychelleptus seychellarum*	52.6	73.7
Skinks *Mabuya spp.*	47.4	31.6
Coleoptera (adults)	21.1	31.6
Fig fruit *Ficus reflexa*	10.5	10.5
Chilopoda	0.0	5.3
Geckos *Phelsuma astriata* and *Ailuronyx seychellensis*	5.3	0.0

Table 1: The frequency of occurrence (%) of eight prey items within Magpie Robin faecal and oral pellets collected between January 1997 and 1998.

Gut content analysis

The remains of eighteen food items were identified from the gut contents of *M. wrightii* and *M. sechellensis* (Table 2). Table 3 compares the percentage of Magpie Robin faecal pellets and skink gut samples containing seven of these food items.

PREY ITEMS	***M. wrightii*** **n = 31**	***M. sechellensis*** **n = 21**
Cockroach *Pycnoscelus indicus*	64.5	71.4
Seabird organic material	54.8	14.3
Isopods	35.5	47.6
Coleoptera (adults)	35.5	38.1
Fig fruit *Ficus reflexa*	12.9	23.8
Chilopoda	9.7	0.0
Skinks *Mabuya spp.*	9.7	4.8
Arachnida	6.5	14.3
Giant millipede *Seychelleptus seychellarum*	6.5	0.0
Lepidoptera	6.4	14.4
Diptera	3.2	4.8
Orthoptera	3.2	0.0
Dermaptera	3.2	0.0
Hymenoptera	3.2	0.0
Hemiptera	0.0	4.8
Pseudoscopidae	0.0	4.8
Giant click beetle larva *Megapenthes curts*	0.0	4.8
Neuroptera	0.0	4.8

Table 2: The frequency of occurrence (%) of a number of prey items within the guts of fifty-one skinks. Seabird organic material included dropped fish, dropped egg and *A. tenuirostris* embryonic tissue.

	C. sechellarum	*M. wrightii*	*M. sechellensis*
Prey Items	**n = 19**	**n = 31**	**n = 21**
Cockroach *Pycnoscelus indicus*	94.7	64.51	71.4
Giant click beetle larva *Megapenthes curtus*	68.4	0.0	4.8
Seabird organic material	0.0	54.8	14.3
Giant millipede *Seychelleptus seychellarum*	52.6	6.5	0.0
Coleptera (adults)	21.1	35.5	38.1
Skinks *Mabuya spp.*	47.4	9.7	4.7
Isopoda	0.0	35.5	47.6

Table 3: The frequency of occurrence (%) of seven prey items within Magpie Robin *Copsychus sechellarum* faecal pellets and skink guts *Mabuya spp.* collected during the main seabird breeding season , May to September, in 1997.

Although there were considerable differences in the frequency of occurrence of certain prey items found in Magpie Robin pellets and skink guts, none of these were significant (x^2 contingency analysis, using percentage data.).

Overlap in the diets of the Magpie Robin and skinks, both species combined, was calculated by applying presence/absence data to a general overlap index (Petraitis, 1979). Using the prey items shown in Table 3, the overlap was high, at 0.923 (6 d.f.). Between skinks, overlap was given as 0.961 (6 d.f.).

Chick food provisioning

An observer could often approach a recently fledged Magpie Robin chick to within 3-5m. Prey identification was therefore much easier than when a chick was nest-bound. The results given here involve data collected during 12-hour observations of six chicks in May, July, August (2), September 1997 and May 1998 during the week after fledging; e.g. each chick was between 25-28 days old. All three Magpie Robin territories are represented. From a total of 374 prey items supplied, 271 (72.5%) were identified. Fig. 4 gives a breakdown of these items.

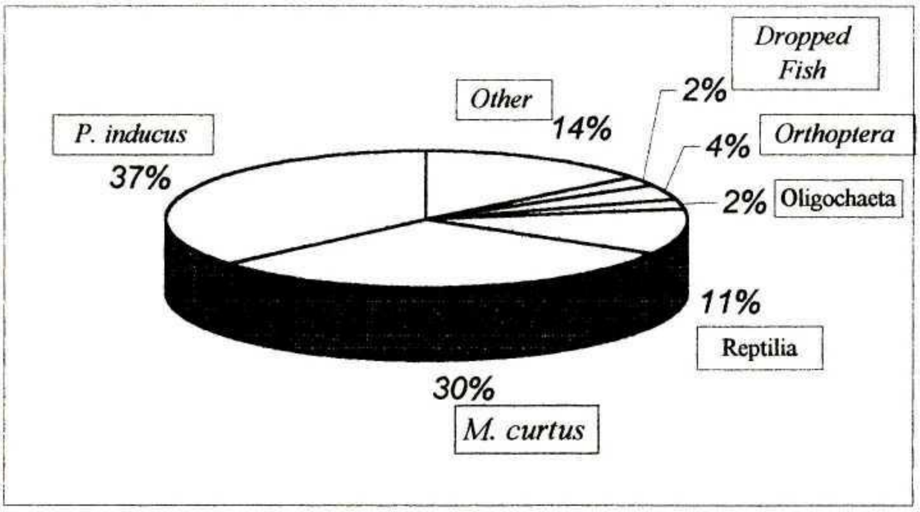


Fig. 4: The frequency of occurrence of a number of prey types supplied to six newly fledged Magpie Robin chicks on Cousine during 1997 and 1998. Reptilia includes both *Mabuya spp.*, *P. astriata* and *A. seychellensis*. Orthopterans were all crickets *Gryllodes supplicans* and the dropped fish were mostly pelagic larval forms of a common coral reef fish species. Other includes *Ficus reflexa* fruit, Isopoda, Chilopoda, *S. seychellarum* and Lepidopteran larva.

P. indicus and *M. curtus* were supplied to all six chicks and the overall percentage of invertebrate prey was 85.2% (n=231). The number of items supplied per 12-hour observation ranged from 24-111, with a mean (±s.d.) of 62.33±28.8. A high percentage of prey items were identified, down to species, during each observation with a mean (± s.d.) of 76.7±11.12. Table 4 gives estimates of the mass of food supplied to each chick and compares the frequency of occurrence of three prey items.

(a)

	PREY ITEMS		
CHICK	**Number supplied**	**Number identified**	**Estimated mass (g) of identified prey items**
GP (T1)	24	21	22.7
YV (T1)	47	37	29.4
ZB (T3)	60	42	20.9
MZ (T2)	111	79	31.4
SR (T2)	61	56	33.3
MM (T2)	71	44	23.0

(b)

	Frequency of occurrence (%)		
Chick	**Skink/gecko** ***Mabuya spp./ Ailuronyx***	**Giant click beetle larva** ***Megapenthes curtus***	**Cockroach** ***Pycnoscelus indicus***
GP	38.1	57.1	4.8
YV	18.9	43.2	24.3
ZB	0.0	28.6	57.1
MZ	1.3	19.0	25.0
SR	17.9	21.4	25.0
MM	0.0	34.1	43.2

Table 4: (a) The number of food items, and estimated mass of those identified, supplied to 6 Magpie Robin chicks during one 12-hour observation of each. The letters refer to the colours of plastic identification rings on the legs of each chick. Figures in parenthesis signify the relevant Magpie Robin territory. (b) The frequency of occurrence of three prey items supplied to each chick.

Foraging behaviour

Figures 5 and 6 show the mean percentage foraging times during half hour observations of the Magpie Robin and each species of skink. There was no significant temporal variation (t-test, log transformed data) in time spent foraging by either the Magpie Robin of *M. wrightii*. There was also no significant difference between the mean % time spent foraging by either species (t-test, log transformed data).

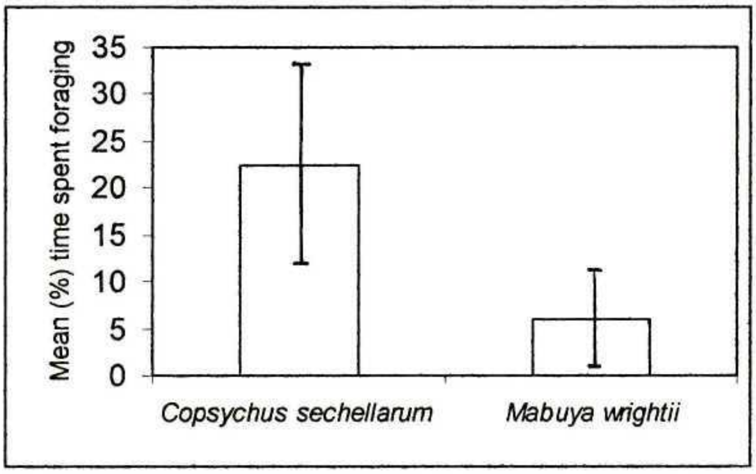


Fig 5: Mean (± 95% confidence limits) % time spent foraging by the Magpie Robin *Copsychus sechellarum* and *M. wrightii* during 54 half-hour observations of each species.

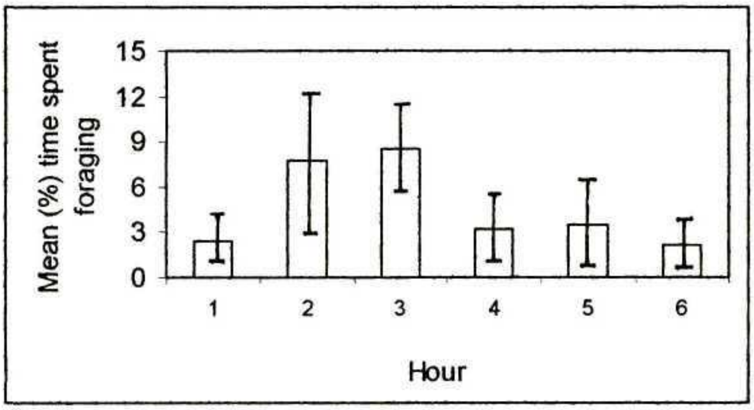


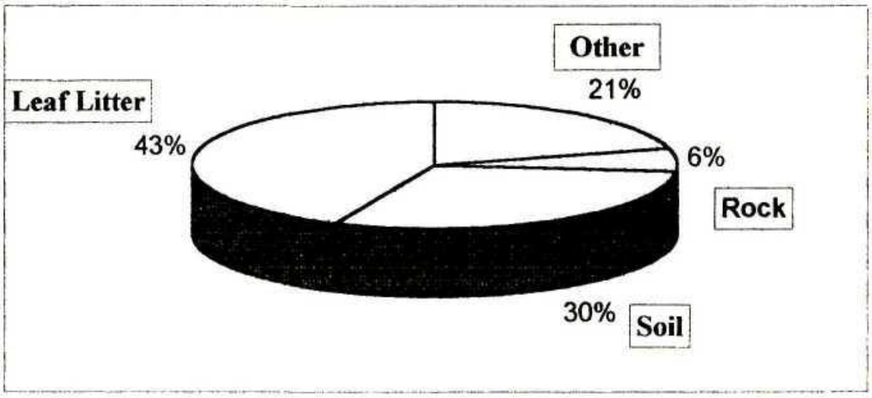
Fig 6: Mean (± 95% confidence limits) % time spent foraging by *M. sechellensis* during 50 half-hour observations. The hours shown refer to two-hour periods of daylight, i.e. 1=0600-0800hrs, 2=0800-1000hrs, etc. There was a significant increase between the first and second 2-hour periods (t=5.26, d.f.=3, p<0.01, log transformed data) and between the third and fourth periods (t=6.82, d.f.=16, p<0.01, log transformed data).

Species	No. of observations where foraging was observed	Mean Foraging Success (Prey items min $^{-1}$)	% of observations where successful foraging was observed	Mean no. of grids visited per observation
C. sechellarum	54	0.936± 0.036[1]	96.3*	3.15
M. wrightii	33	0.115± 0.110	14.8	1.00
M. sechellensis	29	0.135± 0.104	20.0	1.00

Table 5: Foraging activity (±95% confidence limits) by the Magpie Robin *C. sechellarum* (during 54 half-hour observations) and each skink species (54 and 50 observations of *M. wrightii* and *M. sechellensis* respectively). [1] equals significantly greater mean foraging success than *M wrightii* ($z=22.19$, $p<0.01$, log transformed data) and *M. sechellensis* ($z=22.25$, $p<0.01$, log transformed data) * equals a significant difference to *M. wrightii* ($x^2=89.3$, $p<0.001$, Yates correction) and *M. sechellensis* ($x^2=17.25$, $p<0.01$, Yates Correction).

Out of 288 prey items taken by Magpie Robin individuals, 163 (56.6%) were identified. During 104 skink observations, only 25 prey items were taken by skinks and 14 (56%) were identified. Figs. 7 and 8 compare prey item composition and the locations of successful foraging.

(a) Magpie Robin



(b) Skinks

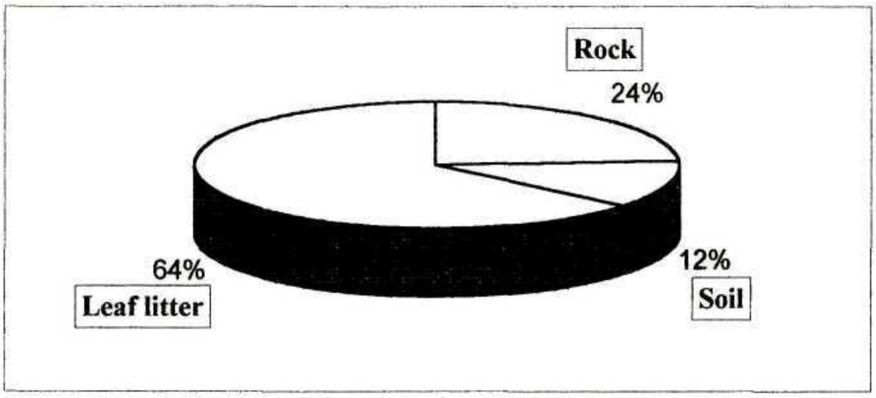
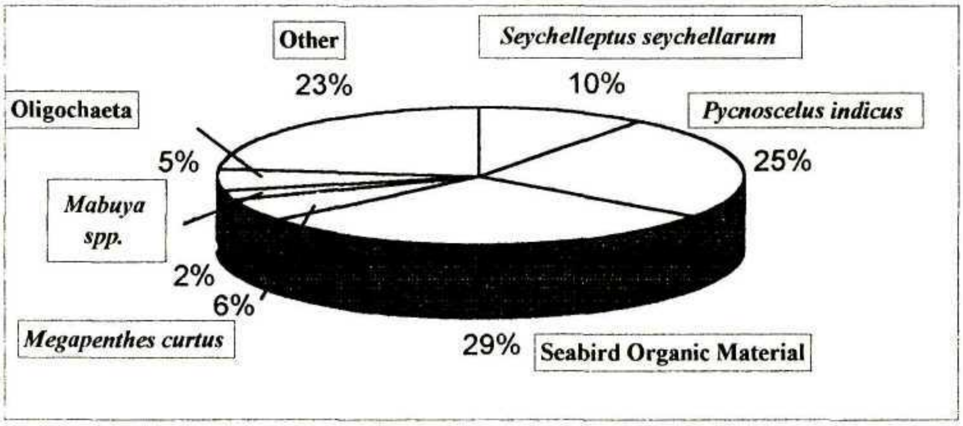
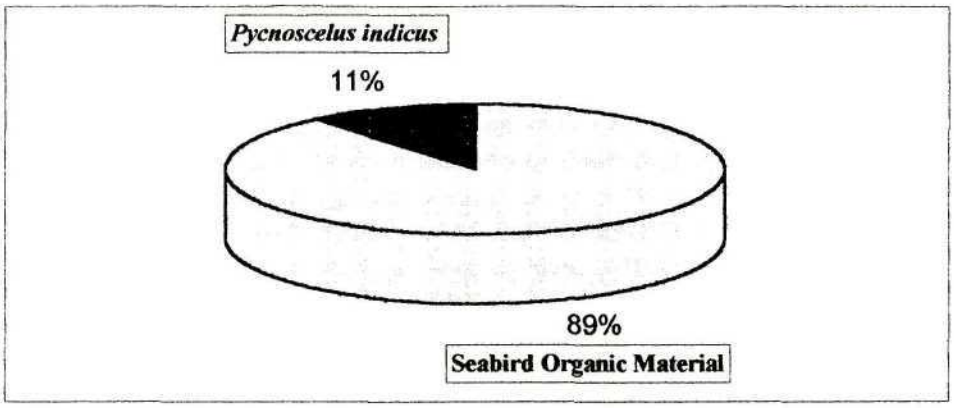


Fig. 7: The proportions (%) of prey items found, in or on a variety of substrates, during foraging observations of the Magpie Robin (a) and skinks (b). Data on skinks were combined as only 25 prey items were taken during all 104 observations. "Other" included flycatching, on a tree trunk, on grass or simply moving across the ground. "Rock" included instances where dropped fish was picked up off a rock or invertebrates such as Orthopterans were found in rock crevices

(a) Magpie Robin



(b) ***Mabuya wrightii***



(c) ***Mabuya sechellensis***

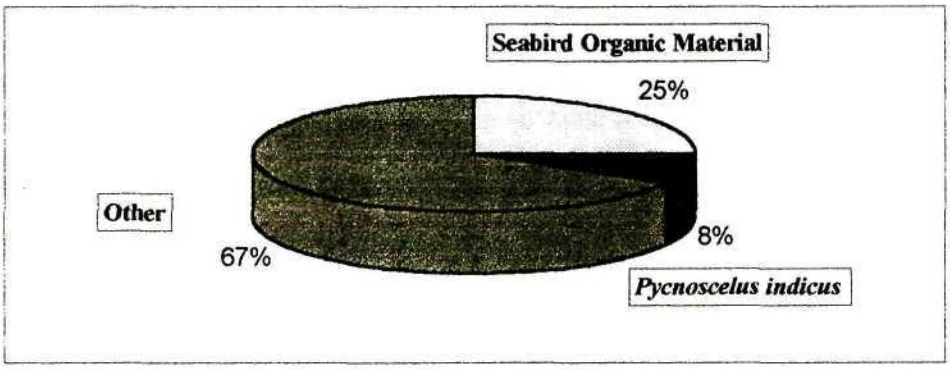


Fig 8: The frequency of occurrence of different prey items taken by the Magpie Robin (a), *M. wrightii* (b) and *M. sechellensis* (c) during foraging observations. 'Other' signifies unidentified invertebrates.

68.7% of prey items taken by Magpie Robins were invertebrates and most prey items were found in woodland on the edge of the coastal plain (Fig. 9).

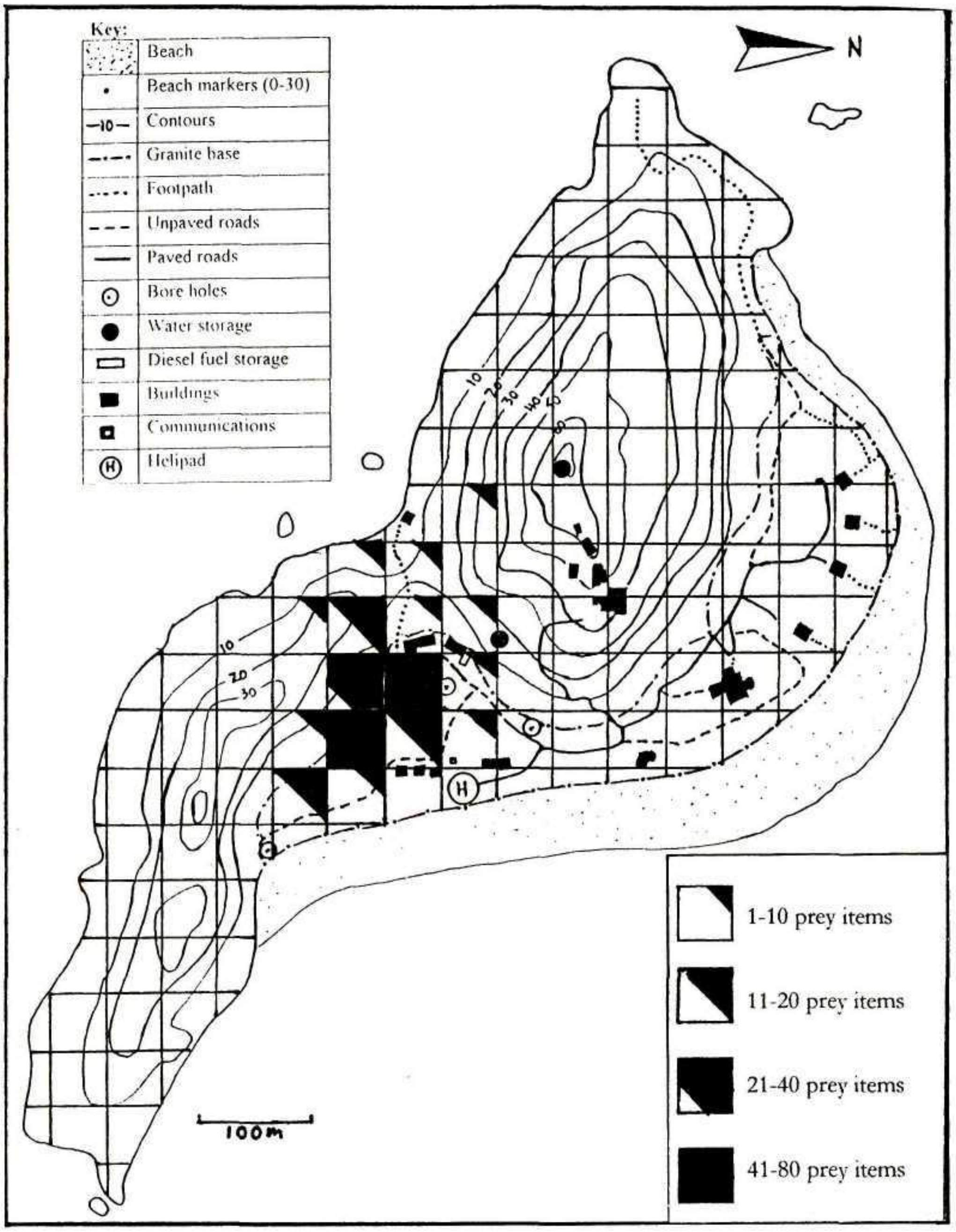


Fig 9: Cousine Island, showing where prey items were successfully caught by the Magpie Robin during foraging observations.

Dietary choice experiment

In 92% (46) of tests, Magpie Robins chose *P. indicus* first. In the remaining four tests, the larva *O. monoceros* was chosen first and this difference was highly significant (x^2=35.3, p<0.001, Yates correction). This choice persisted regardless of the size of *O. monoceros* with no significant difference in the number of times *P. indicus* was chosen first for either size of *O. monoceros* (x^2=0.06, n.s., Yates correction). *M. wrightii* had no significant preference for any of the prey items and *S. seychellarum* was avoided altogether.

DISCUSSION

Faecal pellet and gut content analysis

Differences in the frequency of occurrence of certain prey items in Magpie Robin faecal pellets suggested seasonal variation in availability. On Cousin, Brooke and Houston (1983), observed that the cockroach *P. indicus* appeared to be particularly abundant while 60,000 pairs of Lesser noddies were breeding between May and September. Studies carried out on islands in the Gulf of California showed that authochthonous input to terrestrial systems by seabirds supported much higher abundances of primary and secondary consumers (Polis & Hurd, 1996). In this study, the remains of *P. indicus* and skinks *Mabuya spp.* were found more frequently in faecal pellets collected during the main seabird breeding season. The remains of other invertebrates were found more frequently in pellets collected during the remainder of the year, which suggests that *P. indicus* and *Mabuya spp.* were more abundant than other prey items during the main seabird breeding season. As cockroaches and skinks are perhaps more nutritious than other prey items this may explain why the Magpie Robin appears to time its own breeding activity to coincide with the same period (Le Maitre, unpubl. data).

Regarding skink diets, each species takes a wide range of prey items, particularly invertebrates, with *P. indicus* being the most popular. Although a very high degree of dietary overlap was recorded, *M. sechellensis* appears to eat more smaller and less profitable prey items such as isopods, arachnids and *F. reflexa* fruit. This suggests that some degree of exploitation competition exists between the species. These interspecific differences in diet were also found on Cousin (Brooke & Houston, 1983). Classical optimal diet theory (MacArthur & Pianka, 1966) predicts that diet should expand and contract according to the quality and availability of food sources. One would therefore expect the diets of *M. wrightii* and *M. sechellensis* to become broader and to include prey items of lower nutritional value while the majority of seabirds are absent. In addition, that of *M. sechellensis* would probably include an even higher proportion of smaller prey species.

Chick food provisioning

Data on prey items supplied to newly fledged chicks demonstrated further the importance of young skinks and invertebrates such as *P. indicus* and *M. curtus* in Magpie Robin diet.

As the first two chicks were supplied with fewer prey items and higher proportions of cockroaches, beetle larvae and small reptiles, this suggests that these prey items were more abundant and accessible in this territory. The differences could not have been strongly biased by seasonal variation in prey availability as all observations were carried out during the main seabird breeding season. However, habitat differences between the Magpie Robin territories suggest that prey such as cockroaches and skinks are easier to catch and more abundant in territory one.

Closed canopy woodland, with abundant leaf litter, little ground-covering vegetation and a low percentage of rock cover. dominates this territory (approximately 4ha). The area includes a small section of the coastal plain, the lower reaches of each hill and the saddle between each hill on the western side of the island. There is also approximately 0.3ha of open grassy lawn and fruit trees. The grass is kept short thereby making it easier for predators such as the Magpie Robin to find prey, as they scan the ground from perches in the fruit trees. This area is used mostly during the first and last hours of daylight as the Magpie Robin generally avoids foraging in strong sunlight.

In contrast, the other two territories are smaller (approximately 2.4ha and 2.7ha) and characterised by steeply wooded slopes with a high degree of rock cover, sparse leaf litter and high percentage of ground covering vegetation.

Foraging behaviour

As with studies on other Seychelles islands (Komdeur, 1996; Lucking & Ayrton, 1995), on Cousine, the Magpie Robin found most prey items in leaf litter or soil, in cultivated areas and woodland (94.0 % v 94.1% for Fregate and Cousine respectively). The majority of prey items were invertebrates but a higher proportion of lizards (*Mabuya spp, A. seychellensis* and *P. astriata*) was taken on Cousine where lizard density is probably considerably greater than on Fregate. Prey items taken by skinks confirmed what had been found by gut content analysis. Firstly, only 8% were soil-dwelling (*P. indicus*). Secondly, the majority chosen by *M. wrightii* consisted of some form of seabird organic material. Those chosen by *M. sechellensis* were mostly invertebrates which were too small to identify.

Although many more foraging observations were carried out on Fregate, the composition of Magpie Robin prey items recorded on each island was fairly similar. However, in addition to lizards, seabird organic material features as a prey item more commonly on Cousine than on Fregate where there are low numbers of breeding seabirds. The apparent absence of fish, egg or earthworm remains in Magpie Robin faecal pellets is probably due to digestive processes.

Competition

Regarding possible competition between the Magpie Robin and skinks, the high dietary overlap index given here does not necessarily indicate the existence of competition (Sale, 1974). Animals partition environmental resources temporally, spatially and trophically (Pianka, 1973). In addition, they possess different perceptions of prey availability. To assess whether or not these species compete for food resources, it is necessary to examine foraging activity in terms of niche dimension and prey perception abilities.

Taking the temporal scale first, the Magpie Robin tends to show peaks of foraging activity in the early morning and late afternoon (McCulloch, 1996b) although foraging occurs throughout the daylight hours. In common with most diurnal reptiles, skinks require time to bask to absorb heat from the sun and therefore remain fairly inactive for at least the first few hours of the day. *M. sechellensis* peak activity occured around midday and this has also been recorded on Praslin (Crawford & Thorpe, 1979).

On the spatial scale, results from foraging studied showed that the Magpie Robin and skinks found prey items in the same microhabitats. However, the Magpie Robin was considerably more active, often covering a distance of up to 150m during observations. The Magpie Robin therefore exploited a much larger number of food patches during any single observation than skinks which rarely moved further than a total of 10m during the same period of time.

Regarding the trophic scale, it would have been misleading to make direct comparisons between Magpie Robin and skink diet using the data from faecal pellet and gut content analysis because they had been subjected to different digestive processes. For example, no seabird organic material was identified in faecal pellets but foraging observations showed that *A. tenuirostris* egg and dropped fish were favoured food items. However, there are two striking differences in prey species composition concerning the different proportions of the soil-dwelling click beetle larva *M. curtus* and *Mabuya spp.* Both of these species were poorly represented in skink gut contents. These differences indicate different perceptive capacities and foraging modes. In other words, they suggest that the Magpie Robin has a more highly developed sense of prey perception.

Perception of prey

The two skink species belong to the family Scincidae, whose members are considered to be what are known as active foragers as opposed to ambush or "sit-and-wait" foragers (Cooper, 1997). Actively foraging species have the ability to detect prey items by chemical means (tongue flicking), including those which cannot be detected visually (Cooper & Vitt, 1989). It does not appear that this capacity extends to skinks on Cousine being able to detect the presence of *M. curtus* underground. In contrast, the Magpie Robin appeared to find *M. curtus* with ease. This ability is common to other species in the same family (Turdinae) whereby birds are frequently observed cocking their heads while foraging on the ground, as if they are listening to sounds of buried prey. Indeed, an experimental study on American robins found that the birds could locate buried mealworms using auditory cues alone (Montgomerie & Weatherhead, 1997). With their greater agility and habit of scanning the ground from a perch in a tree, the Magpie Robin also has the added advantage of being able to use the element of surprise in prey capture. This is used with particular success when catching small skinks.

Differences in perception of potential prey items were also demonstrated by the results of the prey choice experiment. Optimal diet theory predicts that an increase in capture or consumption success of any prey item should also increase preference for that prey item (Sih, 1993). The strong preference by the Magpie Robin for *P. indicus* during tests suggests that, in terms of yield per unit handling time, it is by far the most profitable prey item available. In contrast, *M. wrightii* appeared to chose whichever prey item was moving the most, an expression of the opportunistic, scavenging nature of skinks. The important point to note here is that *M. wrightii* was rarely observed foraging in soil and yet soil-inhabiting prey items were chosen first in 62% of preference tests. However, although *M. wrightii* may not have shown any preference for *P. indicus* in the tests, gut content analysis showed that it is certainly an important component of skink diet.

The main reason for these apparent differences in prey perception is likely to be related to parental care. A female skink lays her eggs under stones or fallen tree trunks, occasionally in soil, and then abandons them. Young skinks have to fend for themselves as soon as they hatch. In contrast, Magpie Robin chicks experience intensive parental care usually for eight to nine weeks after hatching. They gradually learn how to forage by following their parents and other conspecifics. In this way, they learn how to find important prey items such as *P. indicus*, *Mabuya spp.* and *M. curtus*.

A study of *Anolis* lizards and insectivorous birds of the West Indies (Wright, 1981), identified the existence of exploitation competition for common arthropod prey. In this study, differences in foraging behaviour and prey perception indicate that there is no significant competition for food between the Magpie Robin and skinks on Cousine. However, there may be some seasonal and spatial variation, particularly while the majority of breeding seabirds are absent from the island.

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Chapter 3

Food resources available to the Seychelles Magpie Robin *Copsychus sechellarum* and endemic skinks (*Mabuya spp.*) on Cousine Island

ABSTRACT

The Critically Endangered Seychelles Magpie Robin *Copsychus sechellarum* Newton, is one of the rarest bird species in the world. A census in 1965 found only 8 individuals, all on one granitic island. Due to a number of conservation management initiatives, the species had recovered to a population of 74 individuals in September 1998, distributed on four islands. Earlier ecological research of the species has mostly been carried out on an island where vegetation is dominated (>90%) by exotic species. In contrast, the three remaining islands currently supporting the Magpie Robin are dominated by woodland consisting of native tree species. Lacking mammalian predators, these islands also support large seabird colonies and considerable populations of endemic, diurnal skinks, *Mabuya sechellensis* and *Mabuya wrightii*, the Seychelles and Wright's skinks. The *Mabuya spp.* benefit considerably from organic material inadvertently provided by tree-nesting seabirds such as the Lesser noddy *Anous tenuirostris*, in the form of dropped egg, fish and faeces. The Magpie Robin also takes seabird material, mainly dropped fish, but generally forages on ground-living invertebrates and small *Mabuya* individuals. The *Mabuya spp.* also prey on invertebrates, particularly while the majority of seabirds are absent. The ecological relationship between skinks and bird was studied on Cousine Island by a qualitative and quantitative assessment of food sources available to each species. 52 invertebrate species were identified using two sampling techniques. Invertebrate diversity and abundance (numbers and biomass) was greatest in areas dominated by closed-canopy woodland on or near the coastal plain. Seabird organic input for the whole island was estimated at 22,000kg. Skink biomass ranged from 12.2kg ha^{-1} to 30.0kg ha^{-1} for *M. sechellensis* and 19.2kg ha^{-1} to 36.7kg ha^{-1} for *M. wrightii*. Invertebrate abundance data were used to estimate the quality of existing Magpie Robin territories and that of a potential area which is currently poorly used. The carrying capacity of Cousin and Cousine for the Magpie Robin was also estimated. Cousin has the potential to support 32-40 (8-10 breeding pairs) in 8-10 territories. Cousine could support 20-24 (5-6 breeding pairs) in 5-6 territories. Field observations have indicated these estimates as being too high and it is suggested that supplementary feeding would be necessary to encourage Magpie Robin breeding activity in certain areas, particularly on Cousine.

INTRODUCTION

The Seychelles Magpie Robin, *Copsychus sechellarum* Newton, is one of eleven endemic landbird species remaining in the granitic group of the Seychelles archipelago. It is the rarest of four species which are listed as Critically Endangered (Stattersfield *et al.*, 1998).

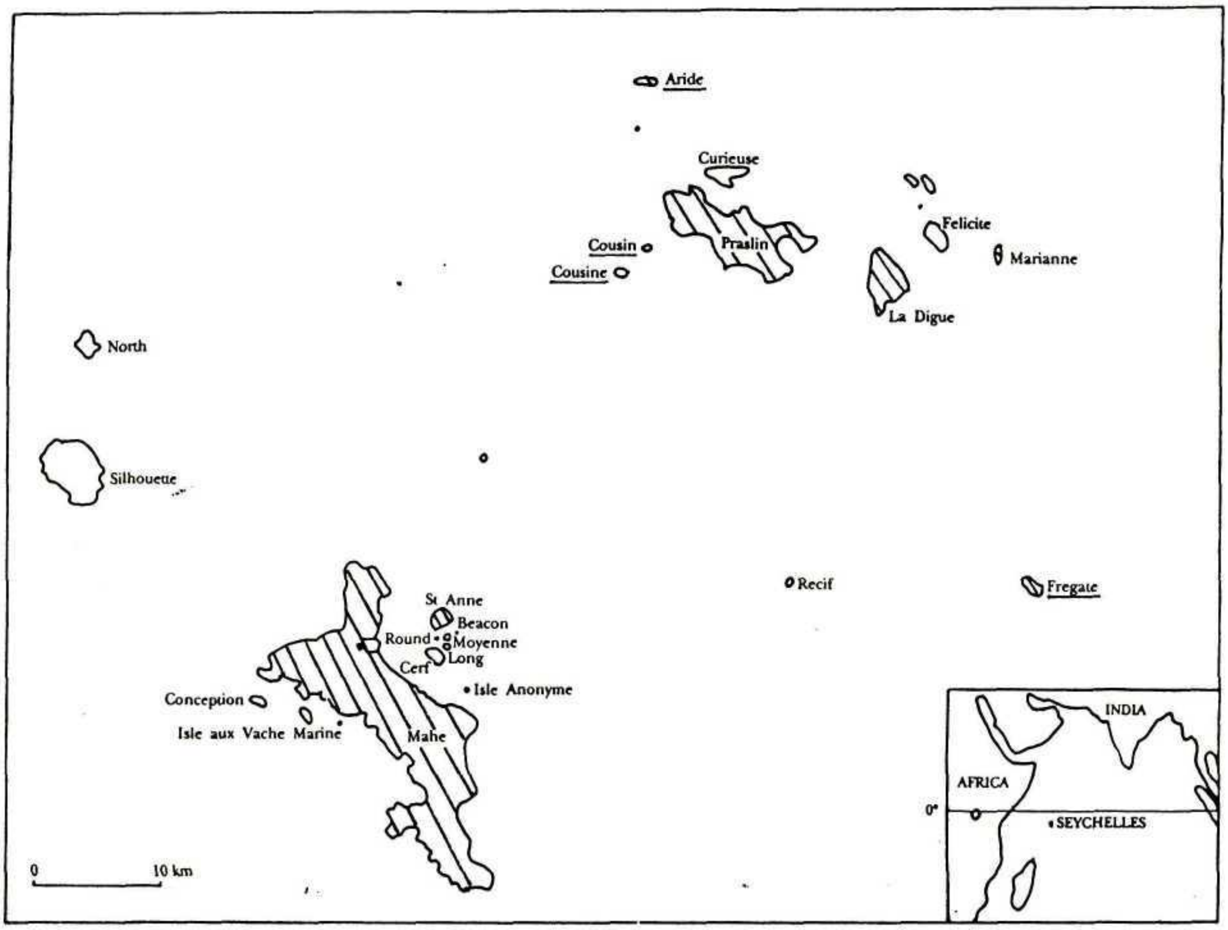

Fig 1: The current distribution (underlined) of the Seychelles Magpie Robin. Shaded islands indicate the former range of the species.

With only 74 individuals (Parr, 1998) distributed on four small granitic islands (Fig 1), it is also one of the rarest bird species in the world. Following permanent human settlement in the granitic islands in 1770, it was one of many endemic species which declined drastically in range mainly due to extensive habitat clearance and the introduction of predatory mammals (Watson *et al.*, 1992).

By the early 1960's, the species was only found on Fregate Island (219 ha) (McCulloch, 1996). It was almost eliminated there as a result of cat predation and only eight birds were recorded during a census in 1965 (Dawson, 1965). The cats were controlled and finally eradicated in 1982 (Todd, 1982).

The world population fluctuated around 20 individuals throughout the 1980's. From 1988, a two-year intensive ecological study of the species identified a number of factors limiting population growth. These included high chick and adult mortality, few suitable nesting sites (usually cavities in tree trunks), interference from Indian mynas *Acridotheres tristis* (Linnaeus), and insufficient food in certain areas. A recovery plan (Rands & Komdeur, 1989) was implemented in 1990. One of the conservation management recommendations was translocation of birds to other suitable islands as the species was particularly vulnerable to extinction while confined to one island. Only three small granitic islands, Aride (69ha), Cousin (27ha) and Cousine (26ha) were available, primarily because they had no rats or cats. Furthermore, the vegetation on each island was dominated by closed-canopy woodland which had been identified as high quality habitat for the Magpie Robin on Fregate (Komdeur, 1996).

Since 1992, twenty-four adult birds have been translocated from Fregate to these three islands, and one female was taken from Cousin to Cousine. Breeding populations have been successfully established on Cousin and Cousine but not on Aride, where one adult female remains. The world population is now at its highest level in the last half century. Ecological research on the species has mostly been carried out on Fregate, where over 90% of the vegetation consists of exotic species. In contrast, vegetation on Aride, Cousin and Cousine is thought to be fairly representative of what formerly occurred prior to human settlement (McCulloch, 1996) . Study of the species on these islands may therefore provide valuable insights into its ecology.

In addition to native vegetation and the absence of mammalian predators, these are the only remaining granitic islands which support large colonies of breeding seabirds and very dense populations of endemic, diurnal skinks; the Seychelles skink *Mabuya sechellensis* (Dumeril and Bibron) and Wrights skink *Mabuya wrightii* (Boulenger). *M. sechellensis* is widespread throughout the granitic islands but the larger *M. wrightii* is almost entirely restricted to those with seabird colonies. The existence of dense skink populations occurring on islands with no natural predators and large seabird colonies is well known elsewhere (Ruibal & Philibosian, 1974; Wright, 1981; Polis & Hurd, 1996).

Indeed, it appears that dense populations of secondary consumers such as skinks are supported and maintained by seabird organic input, in the form of dropped eggs, fish and faeces. A study on Cousin recorded a significant positive correlation between skink biomass and Lesser noddy *Anous tenuirostris* (Temminck) density. This species is the most prolific tree-nesting seabird on all three islands with the latest estimates for Aride and Cousine being 166,000 and 92,000 breeding pairs respectively (Bowler & Hunter, 1998; Copsey, 1998). The main seabird breeding season runs between May and September. While the majority of seabirds are absent, skinks rely on their fat stores and the availability of ground-based invertebrate prey.

The Magpie Robin also finds most of its prey on the ground and prefers foraging in leaf litter beneath closed canopy woodland. In addition, during the main seabird breeding season, dropped fish and egg are popular food items. An adult female on Cousin was once seen taking a seabird embryo to her nestling (P. Edelaar, pers.comm.) and on one or two occasions, the same individual was observed breaking into unguarded eggs. They are also adept at catching juvenile skinks.
Data presented in the previous chapter indicated considerable overlap in food choice between the Magpie Robin and skinks during the main seabird breeding season, with the cockroach *Pycnoscelus indicus* (Fabricius), and seabird organic material being common prey. Behavioural observations suggested that there was no significant competition for food but that there could be some spatial and seasonal variation.

This paper gives the results of a study carried out on Cousine Island which investigated the food available to skinks and the Magpie Robin throughout the year. Previous studies of food availability for the Magpie Robin have largely focused on invertebrate resources (Komdeur *et al.*, 1989, Lucking & Ayrton, 1995; Le Maitre, 1995). Qualitative and quantitative data on invertebrate and vertebrate food resources available to both bird and skinks, in a variety of habitat types, are presented. I will also present comparative data for invertebrate abundance on Cousin. The results will be correlated to current Magpie Robin distribution on each island and will be used to estimate the carrying capacity of each island.

MATERIALS AND METHODS

Site Description

Sampling took place on Cousine Island (55°39'E, 4°21'S) which is a small (26ha) granitic island in the central group of the Seychelles archipelago (Fig. 2). A wooded rocky ridge rising to almost 70m and 40m at its highest points, runs the length of the island and a coastal plain of approximately 8ha is largely devoid of woodland. Vegetation on the ridge is dominated by mature, closed-canopy woodland consisting of *Pisonia grandis* 'R. Br.', and *Ficus reflexa* Thunb.. However, screwpine *Pandanus balfourii* (Martelli), dominates the north-western slope and a section (approximately 2ha) of the north-eastern slope is characterised by *Euphorbia pyrifolia* (Lammarck), grasses and ferns *Nephrolepis 'biserrata'.* Coastal plain vegetation consists largely of a number of native shrubs, *Casuarina equisetifolia* J.R. and G. Forster, and grassland although there is a small (approximately 1ha) stand of mixed woodland in the northern section.

The island is managed chiefly to protect a number of endemic landbird species, including the Seychelles brush warbler *Acrocephalus sechellensis* (Oustalet), the Seychelles fody *Foudia sechellarum* Newton, and the Magpie Robin. Seven species of seabird breed on the island: *A. tenuirostris*, the Brown noddy *Anous stolidus* (Linnaeus), the Fairy tern *Gygis alba (*Sparrman), the Bridled tern *Sterna anaethetus* Scopoli, the White-tailed tropic bird *Phaethon lepturus* Daudin, the Wedgetailed shearwater *Puffinus pacificus* (Gmelin) and the Audubon's shearwater *Puffinus lherminerii* Lesson. Large numbers of skinks, *M. sechellensis* and *M. wrightii,* occur and a small population of the Seychelles wolf snake *Lycognathophis seychellensis* (Schlegel), has also recently been re-discovered.

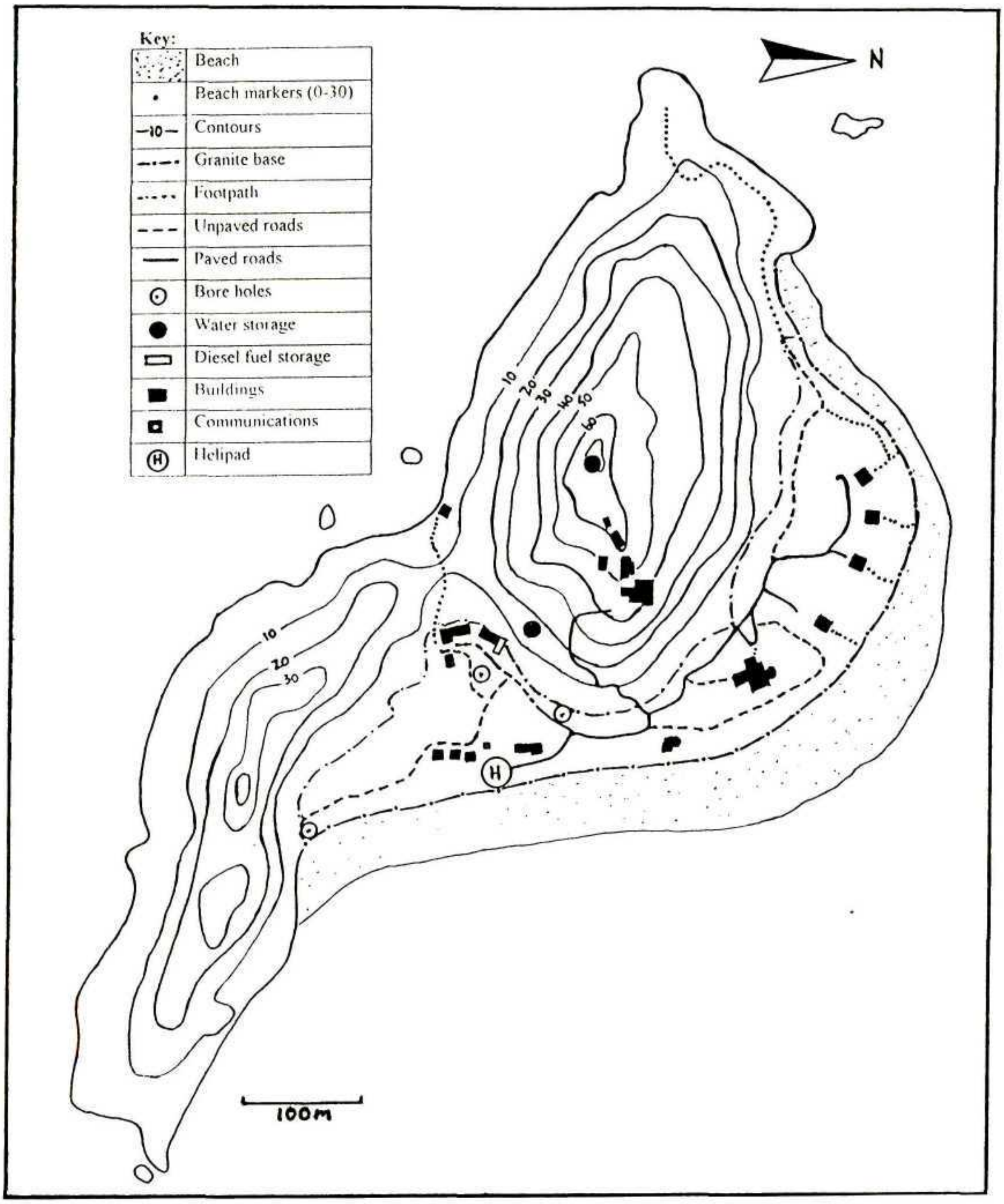

Fig. 2: Cousine Island.

Invertebrate sampling

Invertebrates were sampled by two methods: handsorting and pitfall trapping. Fig. 3 shows the locations of the sampling sites. These were chosen so that a minimum of three different vegetation types were sampled within each Magpie Robin territory. An additional four sites, which lay outside these territories, were chosen to act as controls.

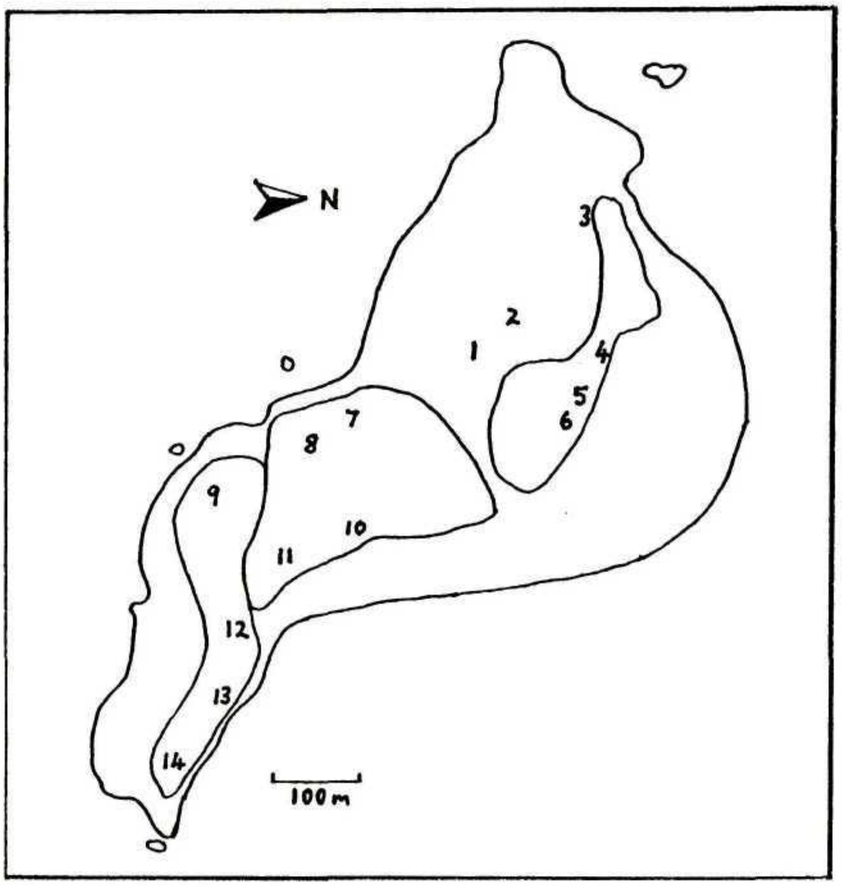

Fig. 3: Cousine Island, showing the locations of invertebrate sampling sites and three Magpie Robin territories.

Handsorting

A belt transect, approximately 20m x 2m was established at each sampling site. These were chosen so that sampling would be carried out in an area most representative of the dominant vegetation type occuring in each area. Between July 1997 and July 1998, six regularly spaced (but not fixed) quadrats (0.3m x 0.3m) were sampled within each transect on a monthly basis, giving a total of eighty-four quadrats each month. In the field, invertebrates were extracted by hand from leaf litter and a soil core of 0.1m diameter and 0.02m depth. They were sorted into general morphological groups: cockroaches, larvae, millipedes, centipedes, beetles, earthworms, earwigs, woodlice, spiders, snails and crickets. Ants were not recorded as field observations have shown that they are not eaten by either the Magpie Robin or skinks. An invertebrate reference collection was built up with specimens being preserved in 80% ethyl alcohol. Invertebrates were also sorted according to four different size classes:>0.5cm, >1cm, >2cm and >3cm. Leaf litter depth, to the nearest cm, was recorded for each quadrat.

Pitfall trapping

To sample the invertebrate fauna available to the Magpie Robin and skinks as thoroughly as possible, pitfall trapping was also carried out in six sites. Four of these were at handsorting sites, 1,6,9 and 11 and were chosen to encompass a variety of habitat types at different altitudes. The remaining two were situated on grassy lawns with no tree canopy cover because these are popular Magpie Robin foraging areas (pers. obs.), particularly during the first and last few hours of daylight.

Again, belt transects of approximately 20m x 2m were established at each sampling site . Between August 1997 and July 1998, traps were laid at regular intervals, not in fixed positions, within each transect. The traps consisted of plastic honey jars (0.05m diameter) filled with between 0.01-0.02m of salty water and were left in place for 72 hours. Ethyl alcohol and glycerol was not available in sufficient quantities, so salt water was, from preliminary sampling, thought to be the best alternative. Trapped animals were counted and recorded according to the same morphological groups used for the handsorting method. Animals smaller than 0.005m were not recorded as this would have taken too much time. Also, although both skinks and the Magpie Robin prey on small invertebrates, it was thought that identifying such small animals would prove impossible using the resources available.

Territory and island quality

As the Magpie Robin forages mainly for invertebrates found in leaf litter and bare earth. invertebrate abundance was used to assess territory quality within existing and potential territories on Cousin and Cousine. Sampling was carried out on Cousin between October 1996 and October 1997. The method used was identical to that on Cousine and thirty-five quadrats were sampled each month. The sampling areas were selected so that all the main vegetation types and three existing Magpie Robin territories were represented. The formula used to calculate territory quality accounted for mean invertebrate abundance (per unit area), vegetation type and the extent of vegetation type (the number of 25m x 25m grid squares) within each territory (Komdeur, 1996). The extent of various vegetation types on each island was estimated from vegetation maps of each island (Bourquin, 1996; Le Maitre & Brand, 1994). Invertebrate abundance data was also used to calculate island quality, using a similar formula to that for territory quality (Komdeur, 1996).

Skink density

In April 1998, sixteen belt transects measuring 30m x 3m were established in several wooded areas (Fig 4). Ten of these were randomly selected within two Magpie Robin territories. The remaining seven were selected to coincide with a third robin territory and in areas on the ridge not frequented

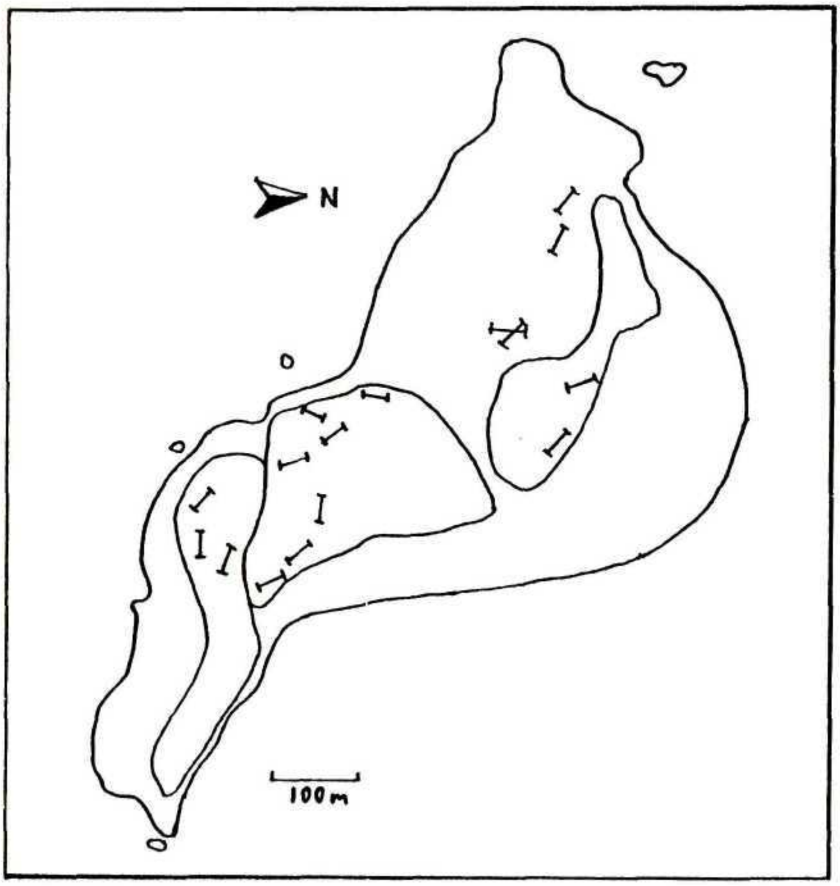

Fig. 4: Cousine Island, showing the locations of sixteen skink density belt transects and three Magpie Robin territories.

by the Magpie Robin. As the Magpie Robin and skinks have similar diets (prev. chapt), this was to investigate whether areas generally avoided by the birds were also less densely populated by skinks. Each transect was walked once on three consequetive days, in similar weather conditions and between 08h30 - 11h00. Counts took place during the last week of April, May and June 1998, and only adult animals were recorded. The classification of animals as adults during counts was possible from extensive experience of handling skinks (see next chapter).

During the first count in June, it became apparent that the ambient temperature (28-29^{0}C) was as much as 4°C lower than it had been in April. To test for the potential effects of lower temperature on skink activity, transects were also walked between 13h00-15h00 on the first two days of counts in June.Prior to analysis using T, ANOVA and Spearman's Rank tests, all data were log transformed. Mean skink densities and mass are shown with ± standard deviation.

RESULTS

Invertebrates - Species diversity

52 species from 15 taxa were collected (Table 1, Fig. 5). 31 of these were recorded during handsorting and 47 were recorded in the pitfall traps 25 species were common to both methods and 22 species were only found in pitfall traps.

Table 1: Invertebrate species identified by handsorting and pitfall trapping. Intr. = Introduced species, End.= Endemic species (Gerlach, Matyot and Saaristo, 1997). Letters in parenthesis signify collectors' numbers. Authority names are given where known.

ANNELIDA One unidentified species of earthworm (W1).

MYRIAPODA

Chilopoda

Family GEOPHILIDAE *Mecistocephalus insularis*(C1)

Family SCOLOPENDRIDAE *Otostigmus c.f. insularis* (C3)

Family LITHOBIOBIDAE *Lamycites spp*.(C5)

One unidentified species (C2).

Diplopoda

Family SPIROSTREPTIDAE *Seychelleptus seychellarum* (Desjardins)(M1).End.

Family PARADOXOSOMIDAE *Orthomorpha gracilis*(M2)

INSECTA

Thysanura

Two species, unidentified (SF1 and TH1).

Blattodea

Family BLABERIDAE *Pycnoscelus indicus* (Fabricius)(CR1).Intr..

One unidentified species.

Coleoptera

Family MELASIDAE - possible new species for Seychelles, awaiting identification (B1)

Family TENEBRIONIDAE *Camarothelops scotti* Gebien.End.(B2)

Camarothelops braueri (Kolbe).End.(B9)

Family ELATERIDAE *Meloxanthus insularis* (Fleutiaux).End.(B3)

Megapenthes curtus Candexe (L3 and B8), *Porthmidius solitarius* (Fleutiaux).End.(B7), and three species unidentified (two as larva, L2 and L4, and one as a pupa, ?C).

Family SCARABAEIDAE c.f. *Rhyssemus sp.* (B4),*Ataenius c.f.frater*(B6)

Family SCARABIDAE *Orystes monoceros* (Olivier)(L5)

Family CARABIDAE *Chlaenius bisignatus* (Dejean)(B5)

Dermaptera

Family CARCINOPHORIDAE *Euborellia annulipes* (Lucas)(E1).Intr., *E. stali* (Dohrn)(also=*E. annulata*, Fabricius)(E2)

Diptera

Two unidentified species (one larva, L7, and one adult, ?D).

Hemiptera

Family CYDNIDAE *Macrocytes spp.*(H1).

Hymenoptera

One unidentified species.(?A)

Lepidoptera

Eight unidentified species (six as larva, L1,L6,L8-L12, and one adult moth, ?E)

Orthoptera

Family GRYLLIDAE c.f.*Gryllodes supplicans*(CK1)

Pteronemobius taprobanensis (Walker)(species now in new genus - *Dianemobius* (1981))(CK2),

One unidentified species (instar, CK3)

CRUSTACEA

Isopoda

Three unidentified woodlouse species (WL1,WL2,WL3).

ARACHNIDA

ARANEAE

Suborder ARANEOMORPHA

Family CORINNIDAE *Oedignatha scrobiculata* (Thorell) (SP1 andSP7),

Corinnidae sp. (SP8)

Family GNAPHOSIDAE *Camellina cordifera* (Tullgren) (SP2,SP3,SP9)

Family CLUBIONIDAE (Wagner) *Clubionidae sp.*. End.

Family LYCOSIDAE *Bristowiella seychellensis* (Bristowe) (SP5,SP6).End.

Trochosa urbana (Picard-Cambridge) (SP11,SP12)

Family SALTICIDAE *Hasarius adansonii* (Savigny and Audonin) (SP10)

MOLLUSCA

Family SUBULINIDAE *Subulina octona* (Bruguiere)(SN1)

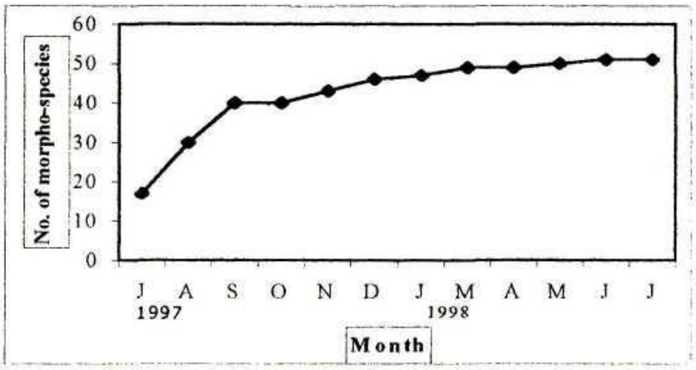

Fig 5: Cumulative curve for the number of morpho-species recorded.

Fig.6 shows the number of species recorded at each sampling site. Using the handsorting data alone, there was a significant difference between the mean number of species recorded per site ($F_{10,121}=5.68$, n=12, $p<0.05$), with the largest mean species diversity recorded at site 5. This analysis excluded species at sites 6 and 8 because of differences in variance. The results from sampling at site 10 have not been used as the effects of flooding in August 1997 and January 1998 seriously depleted the invertebrate fauna for at least 50% of the sampling period.

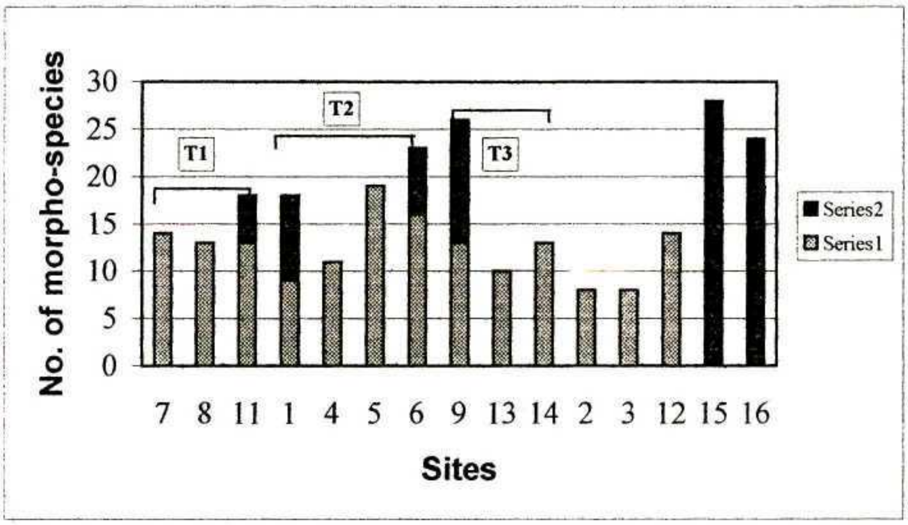

Fig 6: Number of morpho-species recorded at each sampling site. Series 1 show the number of species collected by handsorting and Series 2 shows those collected by pitfall trapping. T1, T2 and T3 refer to three Magpie Robin territories.

Species abundance

Fig.7 shows the total number of animals recorded at each site. There were significant differences between the mean number of animals found at each site ($F_{11,132}=6.78$, $p<0.05$) with the largest mean abundance recorded at site 5. Leaf litter depth and the number of animals recorded were positively correlated ($r_s=0.631$, $p<0.05$, Spearman rank). The mean (±s.d.) number of invertebrates in soil was 8.9 times higher than those in leaf litter (4.44 ± 0.02 v 0.50 ± 0.03, paired t-test, $t=5.30$, $p<0.01$, df=12, log transformed data).

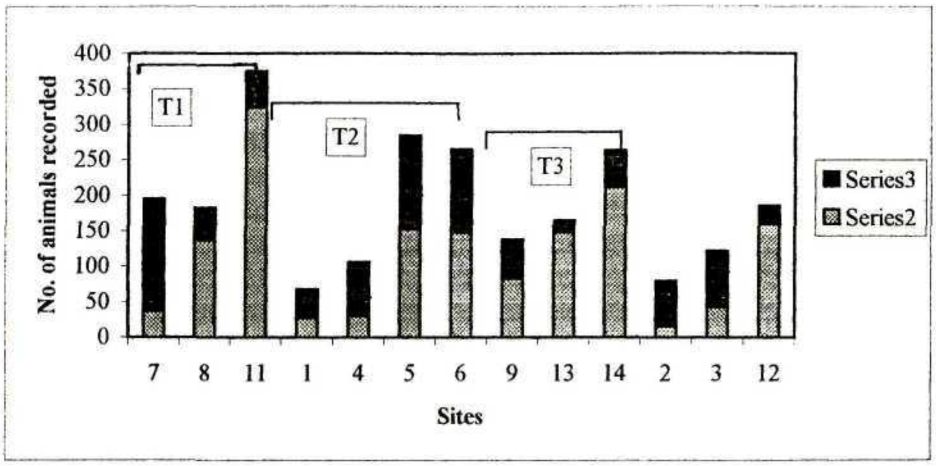

Fig 7: Total number of invertebrates recorded per handsorting site during the twelve month sampling period. Series 2 refers to animals found in leaf litter and Series 3 to those found in soil. T1,T2 and T3 refer to three Magpie Robin territories.

Fig.8 shows that that a large proportion (80.5%) of the total number of animals recorded at all handsorting sites consisted of individuals from a small number of species. These were: a Lepidoptera larva (O. Bourquin, pers.comm.), a cockroach *Pycnoscelus indicus*, the giant millipede *Seychelleptus seychellarum*, an oligochaete species and the larva of the giant click beetle *Orystes monoceros*.

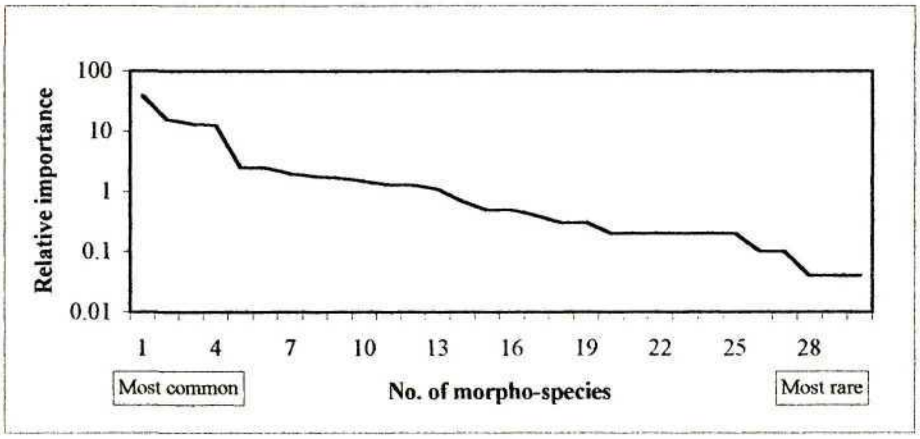

Fig 8: Lognormal distribution of number of morpho-species recorded at handsorting sites.

The abundances of these five species at the handsorting sites were compared according to an evenness index, the modified Hill's ratio (Alatalo, 1981) which decreases, from a maximum of 1.0, to zero as relative abundances become increasingly dominated by a single species (Table 2)

Sites

	1	2	3	4	5	6	7	8	9	11	12	13	14
No. spp.	9	8	8	11	19	16	14	13	13	13	15	10	13
Ratio	0.78	0.55	0.73	0.67	0.78	0.79	0.52	0.49	0.54	0.68	0.40	0.43	0.71

Table 2: Evenness index (Hill's ratio) figures for species abundance at each handsorting site.

64% of animals recorded at Site 2 were *O. monoceros*. Those sites with low index scores, Sites 7,8,9,12 and 13 were all dominated by the lepidopteran larva (L1), which accounted for a minimum of 60% (by number) of invertebrates recorded at each site. The dominance of L1 was also reflected by the proportions of invertebrates in different size classes. The mean length of L1 was approximately 1cm and 70% of all invertebrates were $\leq$ 1cm, compared with 14.2% between 1-3cm and 15.8% $>$ 3cm. In fact, L1 and *P. indicus* were the only species found at every handsorting site and *P. indicus* was the only species found at all sampling sites.

However, when the abundance of these species was converted to biomass, the mean biomass of L1 per site ranged from 0.5% - 19.6% of that of *P. indicus*. As the latter species is known to be a favourite Magpie Robin prey item (prev. chapt.), its distribution and abundance was of particular interest (Fig. 9). There was a significant positive correlation between mean leaf litter depth and *P.indicus* biomass per site ($r_s=0.77$, $p<0.01$, $n=13$, Spearman rank) and significantly more *P. indicus* in soil than in leaf litter (paired $t=2.33$, $p<0.05$, d.f.$=13$).

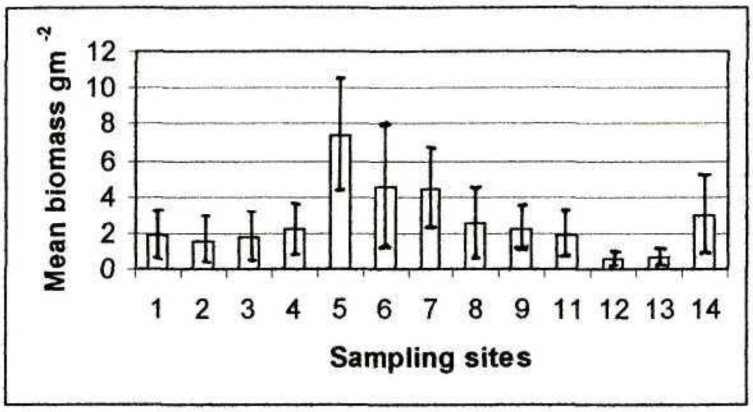

Fig 9: The mean biomass m^{-2} (± 95% confidence limits) of *Pycnoscelus indicus* at each hand-sorting site. Mean biomass was significantly greater at some sites ($F_{11,132}=3.28$, $p<0.05$, $n=12$, log transformed data).

Seasonal abundance

There was no correlation between monthly rainfall and the mean number of species per quadrat, but 69% of those recorded in pitfall traps were found on fewer than six occasions. There was a significant correlation between the mean number of individuals recorded (all sampling areas combined) and rainfall one month previously ($r_s=0.673$, $p<0.05$, $n=13$, Spearman Rank). Despite heavy rainfall in August 1997, the only significant increase in the abundance was shown by L1 (paired $t=5.234$, $p<0.01$, d.f.=10). Following heavy rain in May 1998, there was a significant increase in the number of *S. seychellarum* recorded in June at five sites (paired $t=12.93$, $p<0.01$, d.f.=13). Otherwise, there were no further significant changes in abundance of either of the five most abundant species during the sampling period and no significant correlations between mean abundance of each and rainfall. However, there was a significant positive correlation between overall abundance of *P. indicus* and the supply of seabird organic material ($r_s=0.64$, $p<0.05$, $n=11$, Spearman Rank).

Comparison with Cousin

Invertebrate densities (per unit area) were higher on Cousin (Table 3) in both leaf litter and soil and there was no significant seasonal variation in abundance on either island.

	LEAF LITTER		SOIL	
ISLAND	**Mean**	**n**	**Mean**	**n**
Cousin	6.04±0.38	70	41.75±1.25	70
Cousine	4.39±0.40	70	24.46±1.23	70

Table 3: Invertebrate densities per $30cm^2$ (±95% confidence limits) in leaf litter and soil on Cousin and Cousine between October 1996 and October 1997. Soil invertebrate density was significantly greater on Cousin (paired $t=3.14$, d.f.=9, $p<0.02$, log transformed data).

Territory and island quality

Territory quality ranged from 2.5-4.4 in territories of 1.6-3.1ha and 1.4-2.0 in territories of 2.4-4.0ha on Cousin and Cousine respectively. The quality of an area of woodland (approximately 2.5ha) on the northern ridge of Cousine where there is no Magpie Robin territory was 1.6. Using the minimum territory quality (1.29) required to allow a breeding pair to ensure future survival, i.e. by producing a minumum of 2 recruits during the estimated life-span of 4.3yrs for each bird (Komdeur, 1996), the carrying capacity of each island for the Magpie Robin was also calculated.

With a minimum territory size of 1.6-2.0ha (26-32 grid squares), estimated prey densities of 33.5-41.3 (1.29 x 26 and 1.29 x 32), and an island quality of 336.6, Cousin could support 8-10 territories. Field observations indicate that most Magpie Robin territories support an annual mean of one breeding pair and two non-breeding birds. Cousin could therefore support 8-10 breeding pairs and up to 40 birds. On Cousine, with a minimum territory size of 2.4ha (38 grid squares), an estimated prey density of 49.02 (1.29 x 38), and an island quality of 289.07, Cousine could support 5-6 territories, i.e. 5-6 breeding pairs and up to 24 birds.

Skink density and biomass

M. sechellensis

Skink density varied according to transect location, particularly between the ridge top and coastal plain areas. There was a significantly greater number of skinks counted in the coastal plain transects than in the four ridge-top transects (paired $t=6.126$, $p<0.01$, d.f.=11). There were also significant declines in the mean number of skinks counted in the same four coastal plain transects between April and June ($F_{2,33}=11.5$, $p<0.05$) but this was not observed at the same four hill-top transects. Counts made during the hottest part of the day in June did not result in significantly more skinks, of either species, being observed but skink density ranged from 440 ha^{-1} to 1580 ha^{-1}. An estimate for the island population size was made using the highest mean density figures, in April, and accounting for the differences in density between hill-top transects and all those remaining. In other words, the mean density of skinks in transects 13-16 was worked out separately from that in transects 1-12. It was assumed that the density of skinks in un-wooded areas on coastal plain (8ha) would be similar to that recorded in sparsely wooded areas on the hill-top (approximately 3ha). For the latter group (transects 1-12), there was a mean of 12.32±1.33 skinks per transect or 1219-1516ha^{-1}, indicating a population of 18,285-22,740 animals in 15 ha. For the second group, the mean density of 4.95±0.84 per transect or 457-643ha^{-1} indicated a population of 5027-7073 animals in the remaining 11ha. The island population was therefore estimated as between 23,312-29,813 animals.

Biomass was calculated by multiplying the mean number of skinks recorded per transect by the mean weight of animals during the same month (April 1998). From a random sample of 60 adults taken from four sampling sites situated around the island (see next chapter), the mean weight was 20.8±3.5g. The number of skinks recorded in the larger group of transects ranged from 6-16 animals/transect, equivalent to 0.12kg - 0.33kg/transect and a mean of 0.27kg/transect or 30.0kg ha^{-1}. In the second group, between 3-10 skinks were recorded per transect, equivalent to 0.06kg - 0.21 kg ha^{-1} and a mean biomass of 0.11kg/transect or 12.2kg ha^{-1}.

M. wrightii

There were no significant differences between the mean number of skinks observed per transect but there was a significant decrease in the numbers recorded between April and June ($F_{2,150}=6.481$, $p<0.05$, $n=51$), for counts made at the same, earlier, time of day. Skink density ranged from 4.84/transect in April to 3.19/transect in June or 538 ha^{-1} to 354 ha^{-1}. In un-wooded areas on the coastal plain density was estimated to be approximately fifty per cent of that measured in the transects and a density of 2.42/transect in April gave a population of 270 ha^{-1}. Therefore, the island population consisted of approximately 11,840 individuals, with 2160 on the coastal plain and 9680 distributed over the rest of the island.

The mean weight of a *M. wrightii* in April was again taken from a random sample of 60 adults caught in four different areas (71.3±10.7g). The number of skinks counted ranged from 1-12/transect with a mean of 4.63±1.96/transect. This gave a biomass ranging from 0.10 - 0.86kg/transect, with a mean of 0.33kg/transect or 36.67kg ha^{-1}. Biomass on the coastal plain was estimated as 19.17kg ha$^{-1.}$

DISCUSSION

Invertebrate sampling and Magpie Robin preferred prey items

When considering the range of invertebrate fauna available to the Magpie Robin and skinks, pitfall trapping turned out to be a useful technique with the addition of 22 species unrecorded by handsorting. It also provided the only records of crickets, not found by handsorting, which are known to be popular Magpie Robin prey items (prev. chapt.). In addition, trapping also revealed a number of invertebrate species present on grassy lawns. These are regularly used by the Magpie Robin for foraging during the first and last few hours of daylight (see prev. chapt).

However, the cumulative curve demonstrated that there were probably a few additional species which remained unrecorded. These may well have been trapped but then lost as a result of heavy rainfall, particularly in August 1997 and January 1998. Trap contents had to be discarded on a number of occasions because of flooding. Compared with handsorting, this may explain the higher proportion of trapped species recorded infrequently throughout the sampling period. This problem could perhaps have been overcome had the traps been left in the field for shorter periods. One important and rarely recorded species was the soil dwelling larva of the Giant click beetle *Megapenthes curtus*, which is an extremely popular Magpie Robin prey item (see prev. chapt). An alternative sampling technique is required in order to quantify abundance and distribution of this species.

With no more than basic research facilities available, the hand-sorting method employed was probably the most direct and practical way of estimating leaf-litter and soil invertebrate abundance.

Sampling methods involving light and heat would have been biased by skink and gecko predation. A greater number of quadrats at each sampling area would have given a more accurate assessment of the differences between various vegetation types.

However, the species diversity and abundance data obtained revealed considerable spatial differences between sampling sites. These explained the locations of Magpie Robin territories and why there is no territory on the northern end of the ridge. The highest levels of diversity and abundance were recorded at sites on or near the coastal plain where vegetation was dominated by closed canopy woodland. This is comparable to data collected on Aride (Lucking & Ayrton, 1995), Cousin (Le Maitre, unpubl. data) and Fregate (Komdeur, 1996). Another important feature of vegetation at these sites was leaf litter thickness and the relationship between leaf litter layer and invertebrate abundance, particularly of key prey items such as *Pyncoscelus indicus*.

The abundance of *P. indicus* also explains its importance and frequency of occurrence in Magpie Robin diet (see prev. chapt.). It is not known whether or not the Magpie Robin preys on the most abundant invertebrate, referred to as L1. This would be extremely difficult to prove as this species is small and of a dull grey colour, making it difficult to identify correctly in the time between being swiftly picked up and swallowed. Furthermore, it was not identified from Magpie Robin faecal pellets (prev. chapt.), most probably because of being small, of very low biomass and possessing little exoskeleton which would be identifiable following digestion. Although overall invertebrate abundance showed significant seasonal variation in association with rainfall, this was, surprisingly, not shown by important species such as *P. indicus*. This was perhaps due to the small number of quadrats per site.

Skink density

Skink density showed seasonal as well as spatial variation. The declines in density recorded for both species between April and June corresponded with the beginning of the *A. tenuirostris* breeding season. Since there were no obvious mass skink die-offs and the change in ambient temperature not being a significant factor, the declining densities may indicate that animals were perhaps changing their distribution according to that of the density of nesting seabirds. This contrasts with data collected on Cousin where there were no significant differences in skink density between 30 quadrats situated around the island or between monthly counts (Brooke & Houston, 1983). This behaviour is perhaps a reflection of habitat quality differences between the islands. Cousin is dominated by wooded coastal plain of approximately 18-19ha and Cousine by 16-17ha of rocky, wooded hillside.

Some long term studies have shown that lizard population size, e.g. *Anolis limifrons* at Barro Colorado Island, Panama, varied considerably according to changing environmental conditions (Andrews, 1991). With no natural predators, bar the small population of the Magpie Robin, skink populations on Cousine are likely to stay fairly constant in size (Schoener, 1985). However, the skink population size estimates given here are probably too large for two reasons. Firstly, the data gave an indication of seasonal dispersal behaviour in response to nesting seabirds. Secondly, the estimates for both species have not taken into account that about 1.5-2ha of the wooded hill consists of closed canopy woodland little used by nesting seabirds. This is due to the unsuitability of the dominant vegetation which consists, primarily of *Pandanus balfourii.* In addition, a similar area consists of bare rock and grasses and probably supports skink densities similar to those found on the coastal plain. However, although crude in design, the census method employed was considered to be the most practical, especially given difficult terrain and the unavailability of field assistants.

Seabird organic material

During a seabird census in 1998, the *A. tenuirostris* colony was estimated at 93,454 pairs with around 89,000 nesting in the forested hill region (Copsey, 1998). The amount of organic material which fell to the ground was quantified using estimates provided by Brooke and Houston (1983). In summary, the *A. tenuirostris* colony produced around 16,900kg of faeces, 4,700kg of fish and 460kg of egg, all of which dropped to the ground. The small number of breeding White terns *G. alba* , and *A. tenuirostris* present outside the main breeding season will make the annual organic input slightly higher. Although chick carcasses also represent considerable organic biomass, they were not included in calculations as most carcasses were removed from sight by an abundant, burrowing species of landcrab *Ocypode cordimana* (Desmarest), and were therefore mostly unavailable to other ground scavengers.

Two important points about this last food resource are its seasonality and the observation that seabird density is fairly uniform throughout areas of the forested hill used by the Magpie Robin. It is therefore likely that the existing Magpie Robin territories receive similar quanitities of fish, egg and faeces. Brooke and Houston (1983) suggested that faecal material represented an important food supply for *P. indicus*. Studies carried out on a number of midriff islands in the Gulf of California found that arthropods were up to 2.2 times more abundant on islands with seabird colonies than those without (Polis & Hurd, 1996), due to organic material provided by breeding seabirds. Further invertebrate sampling is required to clarify trends in seasonal abundance and whether or not invertebrates such as *P. indicus* are more abundant on seabird islands than on those with no seabirds in the Seychelles.

Carrying Capacity and conservation management

As the Magpie Robin carrying capacity estimates for Cousin and Cousine do not account for other food resources such as skinks and seabird organic input, one might predict that carrying capacities could increase further. However, data on breeding activity (Parr, 1998) indicate that the estimates are too large, particularly on Cousin. Since December 1996, the Magpie Robin population there has remained fairly stable at between 16-19 birds, which suggests that the island is currently at carrying capacity. There are also indications that Cousine's carrying capacity is between 12-14 birds as, after an increase of 6-12 birds during 1997, the population had only increased to 14 birds by November 1998.

In the short term, opportunities for further increases on each island are limited. Although an area on Cousine, on the northern ridge, had a territory quality greater than two existing territories, it is unlikely that the Magpie Robin will settle there. This is mainly because of patchy, closed canopy woodland which provides little shade or leaf litter. Despite an abundance of soil-dwelling beetle larvae, field observations (Le Maitre, unpubl. data and prev. chapt.) have indicated that the Magpie

Robin is least likely to forage in an area with exposed, bare earth except during the first and last few hours of daylight. Supplementary feeding would undoubtedly be a necessary requirement to encourage birds to settle down in such an area. Another option for population expansion would be a split in the largest existing territory (4ha).

In the long term, it is hoped that an extensive native tree planting programme on the coastal plain will create another 7-8ha of closed canopy woodland. This could potentially provide habitat for another 2-3 territories and the Magpie Robin population could expand to between 28-32 pairs, with 7-8 breeding pairs. Cousin currently supports 6 territories, five of which have seen successful breeding activity (the survival of a chick to independence) during 1998. The creation of more suitable habitat requires extensive clearance of ground-covering vegetation. However, this is unlikely to provide space for more than one additional territory where successful breeding would be expected to occur.

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Chapter 4

The relationship between endemic skinks (*Mabuya spp.*), invertebrate abundance and the Lesser noddy *Anous tenuirostris* on Cousine Island Seychelles

ABSTRACT

The Seychelles Magpie Robin *Copsychus sechellarum* Newton, is one of the world's rarest birds. It is currently restricted to four small granitic islands. Until translocations to three of these, Aride, Cousin and Cousine, little was known of the ecology of the species in its natural habitat. Due to the absence of rats and cats on the three islands, each one supports large colonies of breeding seabirds and considerable populations of two endemic skinks, *Mabuya sechellensis* and *Mabuya wrightii*. The ecology of these skinks is of interest given the high degree of dietary overlap between them and the Magpie Robin, particularly regarding organic material provided by nesting seabirds and certain invertebrate species. It is thought that there is no significant competition for food between skinks and the Magpie Robin but data were only collected during the main seabird breeding season. During the remaineder of the year, skinks have to rely on their fat stores and invertebrates for survival raising the possibility that inter-specific competition with the Magpie Robin for food could exist during this period. Significant skink weight increases coincided with the beginning of the main seabird breeding season but weights declined steadily while the majority of seabirds were absent. *M. wrightii* weight declined considerably more than that of *M. sechellensis*. There were no significant correlations between *M. wrightii* weight fluctuation and invertebrate abundance in a variety of habitats. It was concluded that the larger skink species was adapted to reliance on the seasonal supply of seabird organic material for survival throughout the year and that there was probably no significant competition for food with the Magpie Robin at any time. It was suggested that *M. sechellensis* can maintain body weight, by finding sufficient invertebrates, throughout the year. There were insufficient data to analyse whether or not inter-specific competition for food exists with the Magpie Robin while most breeding seabirds are absent from the island.

INTRODUCTION

The Critically Endangered Seychelles Magpie Robin *Copsychus sechellarum* Newton,is one of the world's most threatened bird species (Stattersfield *et al.*, 1998). It is currently found on four small granitic islands in the central group of the Seychelles archipelago (Fig. 1) and the world population stood at 74 individuals in September 1998 (Parr, 1998).

Formerly widespread within the granitic islands, the range of the species declined drastically following permanent settlement on the islands by humans in 1770 (Watson *et al.*, 1992; McCulloch, 1996). Being a particularly confiding species and with no natural predators, the Magpie Robin was easy prey for introduced mammals such as rats and cats. The other major cause of its disappearance was extensive habitat clearance (Gerlach, 1996), mainly for agricultural purposes, on most of the islands.

By the early 1960's, the species was entirely confined to Fregate Island where it was almost extirpated completely as a result of cat predation. The lowest recorded population level was eight individuals in 1965 (Dawson, 1965). The cats were controlled and eventually eradicated (Todd, 1982) but the expected Magpie Robin population increase did not materialize.

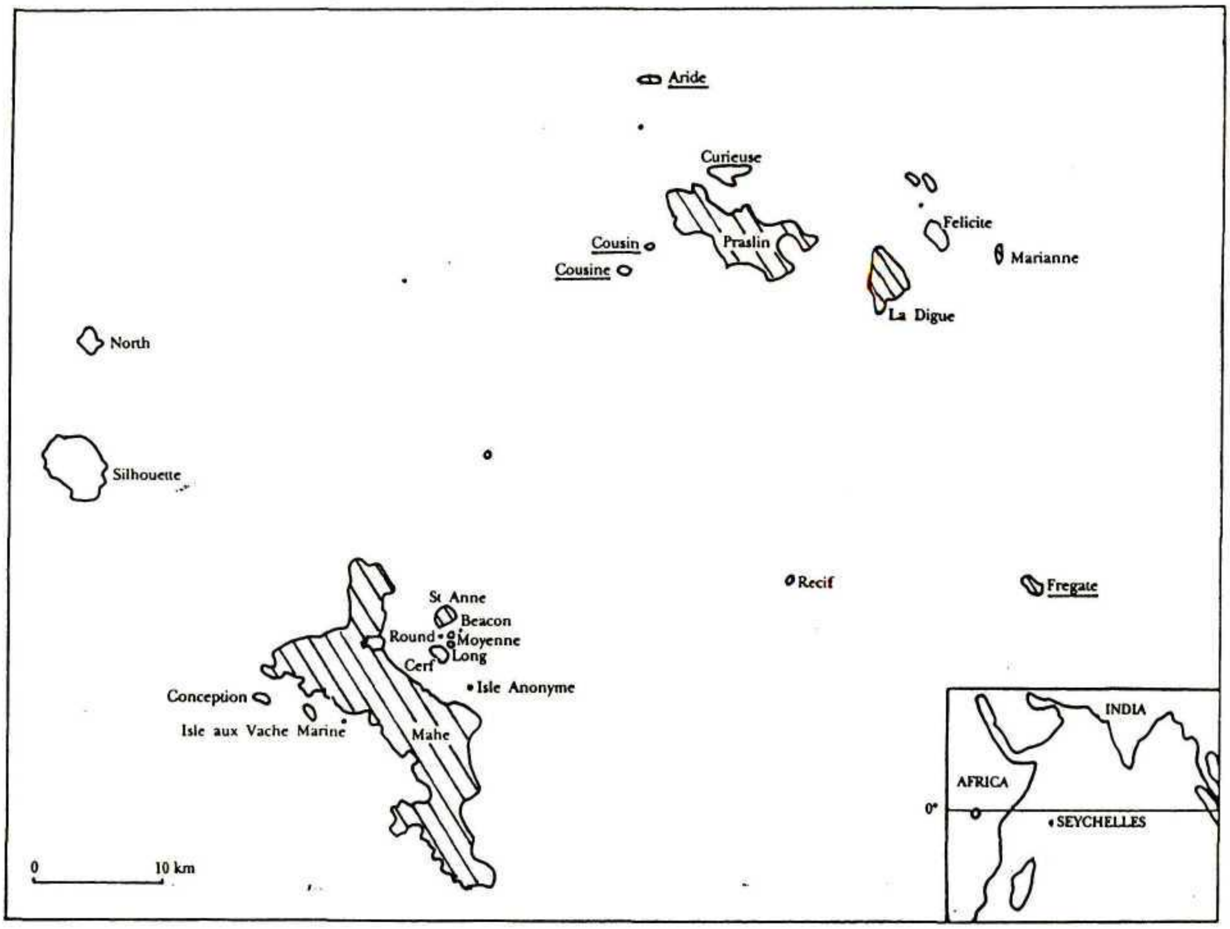


Fig. 1: Current (underlined) and former (hatched) range of the Seychelles Magpie Robin within the granitic Seychelles islands.

An intensive ecological study between 1988-1990 (Komdeur, 1996) identified a number of factors, such as high chick and adult mortality, a shortage of suitable nest sites and insufficient food, which were limiting population growth of the species. As a result, a recovery plan (Rands & Komdeur, 1989) was put into action by Birdlife International in 1990. As the species remained particularly vulnerable to extinction while confined to one island, a medium-term aim of the recovery plan was to establish breeding populations on other suitable islands. Between 1992-1996, twenty-five birds were translocated to three other granitic islands. Aride, Cousin and Cousine were chosen principally because they were the only islands remaining free of mammalian predators.

Without rats and cats, these three islands are of considerably biological and conservation importance (Moors *et al.*, 1992). In addition to the Magpie Robin and other threatened landbird species occurring on each, they are the only granitic islands which continue to support large colonies of breeding seabirds. They also harbour extremely large populations of endemic, diurnal skinks, the Seychelles skink *Mabuya sechellensis* (Dumeril and Bibron), and the Wright's skink *Mabuya wrightii* (Boulenger). It has been estimated that *M. sechellensis* occurs in densities of up to $1393.ha^{-1}$ on Cousin (Brooke & Houston, 1983) and $1516.ha^{-1}$ on Cousine (prev. chapt.). Corresponding figures for the larger *M. wrightii* were given as $320.ha^{-1}$ and up to $538.ha^{-1}$ on Cousin and Cousine respectively

Due to rat and cat predation, *M. wrightii* is probably almost entirely restricted to these three islands. It has been suggested that this species may have evolved in association with seabirds (Vesey-Fitzgerald, 1947). Indeed, studies on both Cousin and Cousine (Brooke & Houston, 1983; prev. chapt.), have indicated that seabird organic input provided by the tree-nesting Lesser noddy *Anous tenuirostris* (Temminck), in the form of dropped egg, fish and chicks, is a major component of *M. wrightii* diet. The diet of the smaller *M. sechellensis* is composed of a large proportion of small invertebrates.

While Lesser noddies are absent from these islands, skinks are forced to rely on their fat stores and the availability of ground-based invertebrates for survival. Brooke and Houston (1983) found that *M. wrightii*, in particular, appeared to lose a considerable amount of weight during this period (October to March). Although it has been found on Cousine that skink diet is very similar to that of the Magpie Robin, it was suggested that there was no significant competition between them (prev. chapt). However, data was only collected during the main seabird breeding season; May to September. It was therefore also suggested that there may be competition for invertebrate food while the majority of seabirds were absent from the island (October to March), particularly in areas where invertebrates are scarce.

In early May 1996, several *M. wrightii* with protruding hip and back bones were observed on Cousine, suggesting that there was a food shortage. The majority were observed in an area which was known, from preliminary invertebrate sampling (Le Maitre, 1995), to support a relatively poor invertebrate fauna. This study was undertaken to assess whether or not there was a relationship between skink weight loss and habitat quality, measured by invertebrate abundance. The hypothesis was that skinks would lose less weight in areas where invertebrates were more abundant and that this could indicate that competition for food may exist between the Magpie Robin and skinks at certain times of the year. Biometric data collected from each skink species on Cousine Island, in four habitat types, between May 1996 and May 1998 are presented here. These are related to invertebrate abundances and Lesser noddy densities in the same habitats.

MATERIALS AND METHODS

Site description

Cousine Island (26ha)(55°39'E and 4°21'S) (Fig. 2) is dominated by a rocky ridge which rises to two peaks of almost 70m and 40m. The vegetation is dominated by mature, closed-canopy *Pisonia grandis* 'R.Br.', and *Ficus reflexa* Thunb., woodland which is mostly restricted to the rocky ridge and its steep slopes. Approximately 2.5ha of the north-western side of the ridge is characterised by screwpine woodland *Pandanus balfourii* (Martelli). Around 4ha of the eastern side is characterised by isolated stands of *Euphorbia pyrifolia* (Lammarck), open glacis rock, boulders, grasses and ferns *Nephrolepis 'biserrata'*. The coastal plain (approximately 8ha) to the east of the ridge is largely devoid of mature woodland. Vegetation there consists mostly of herbs, sedges and grasses with scattered small woody plants, including the Indian Mulberry *Morinda citrifolia* Linneaus, the sourplum *Ximenia americana* Linnaeus, and *E. pyrifolia* (Bourquin, 1999).

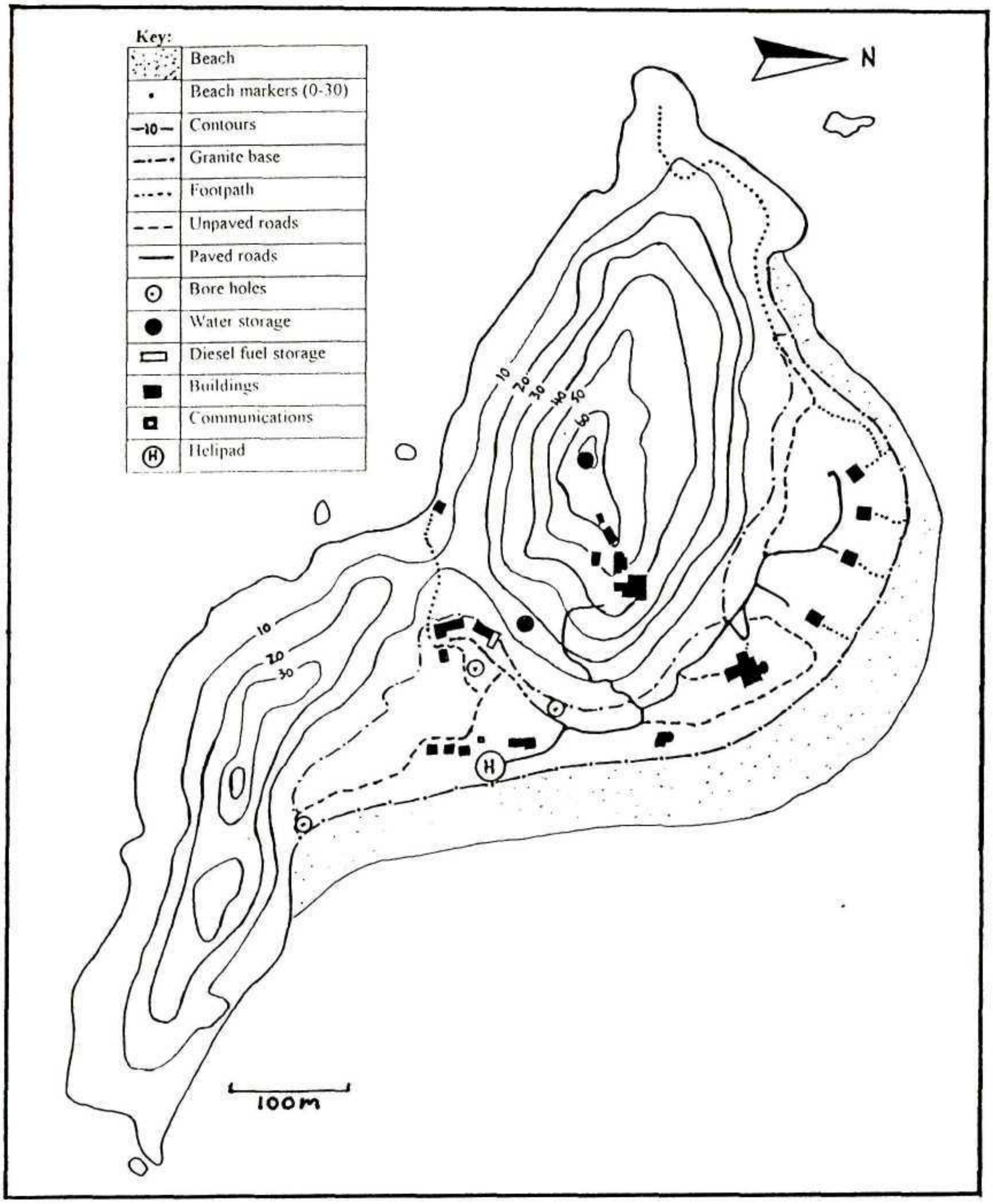


Fig. 2: Cousine Island.

The island is managed as a nature reserve chiefly to protect populations of endangered landbirds such as the Magpie Robin, the Seychelles brush warbler *Acrocephalus sechellensis* (Oustalet), and the Seychelles fody *Foudia sechellarum* Newton. Seven species of seabird breed on the island: the Lesser noddy *A. tenuirostris*, the Brown noddy *Anous stolidus* (Linnaeus), the White-tailed tropic bird *Phaethon lepturus* Daudin, the Bridled tern *Sterna anaethetus* Scopoli, the White tern *Gygis alba* (Sparrman), the Wedge-tailed shearwater *Puffinus pacificus* (Gmelin) and the Audubons shearwater *Puffinus lherminieri* Lesson. The most prolific of these is the Lesser noddy of which approximately 92,000 pairs nested on the island during 1998 (Copsey, 1998).

In addition to the *Mabuya spp.*, other species of reptiles which occur include the Giant tortoise *Dipsochelys dussumieri* (Gray), the Green gecko *Phelsuma astriata* (Tornier), the Bronze gecko *Ailuronyx sechellensis* (Dumeril and Bibron), and a small population of the Seychelles wolf snake *Lycognathophis seychellensis* (Schlegel). Of a number of invertebrates, by far the most prolific and conspicuous, is the Seychelles Giant millipede *Seychelleptus seychellarum* (Desjardins). It is estimated that around a million individuals occur on the island, some of which can reach 300mm in length (J.M. Lawrence, pers.comm.).

Skink biometrics

Between May 1996 and April 1997, 30 mature skinks of each species were caught by hand during the last week of each month at Sites 1 and 2 (Fig. 3). Sites were chosen according to differences in invertebrate abundance, vegetation and altitude. Each animal was weighed to the nearest 0.1g and measured to the nearest 0.1mm, with body length being taken from the tip of the snout to the vent. It was subsequently found that halving the sample size did not make a significant change to the standard deviation of either mean weight or mean snout-vent length of each species per site. Therefore, from November 1996 to April 1997, only 15 adults of each species were caught per site. Following the protocol of Brooke and Houston (1983), mature animals were considered to be those whose snout to vent lengths were over 120mm in *M. wrightii* and over 75mm in *M. sechellensis*.

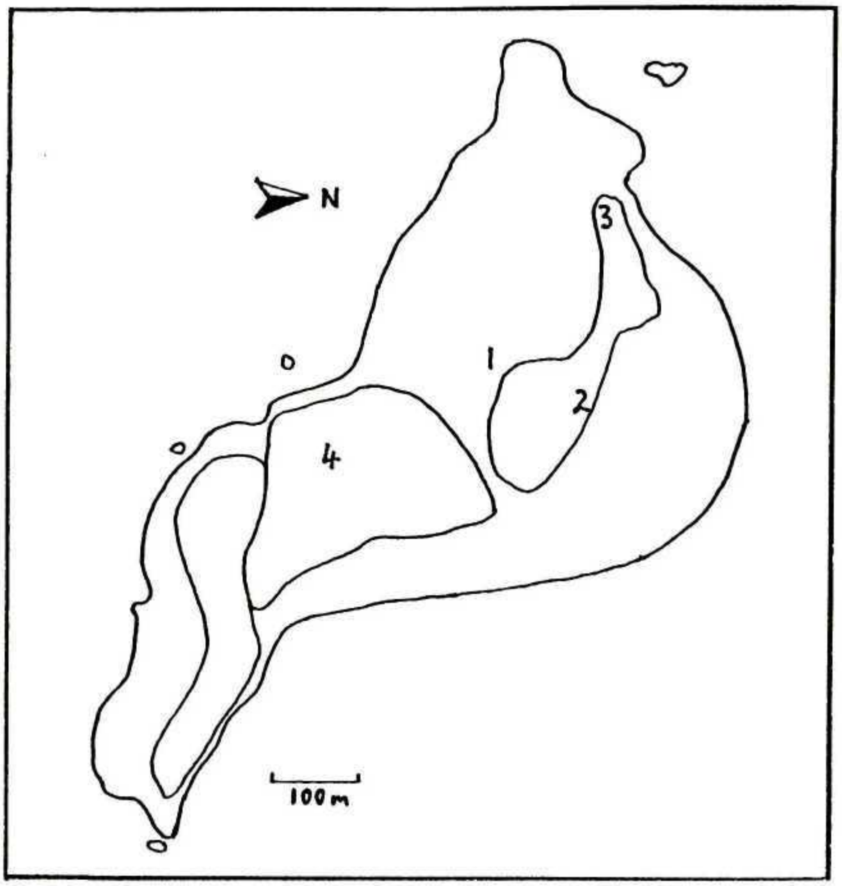


Fig 3: Cousine Island, showing the locations of skink sampling sites and three Magpie Robin territories.

To assess the quality of a wider range of habitats, between May 1997 and April 1998, sampling was also carried out in a similar manner at two further sites (3 and 4). As there were large variances in the *M. wrightii* data, they were all log transformed before analysis. This was unnecessary with the *M. sechellensis* data.

Lesser noddy density

At each skink sampling site, four mature trees of similar height and canopy cover were chosen at random. Between May 1997 and April 1998, the number of Lesser noddy nests was counted in each tree on the same day that skinks were being weighed and measured.

Invertebrate sampling

This was carried out at each site between July 1996 and April 1998. The method is given elsewhere in full (prev. chapt.). In summary, it involved handsorting invertebrates from leaf litter collected from six randomly chosen quadrats ($30cm^2$) per site at the end of each month. Invertebrates were sorted according to the following taxonomic groups: Isopoda; Oligochaeta; Diplopoda; Chilopoda; Blattodea; Dermaptera; Lepidoptera; Coleoptera; Arachnida.

RESULTS

Skink biometrics

The mean weights of both species rose to their highest levels between June and August in both 1996 and 1997, thereafter decreasing to lowest levels between February and May (Fig. 4 (a-d)). The maximum weight recorded for *M. wrightii* was 112.5g and maximum snout to vent length was 149.9mm. Corresponding values for *M. sechellensis* were 37.0g and 103.2mm respectively.

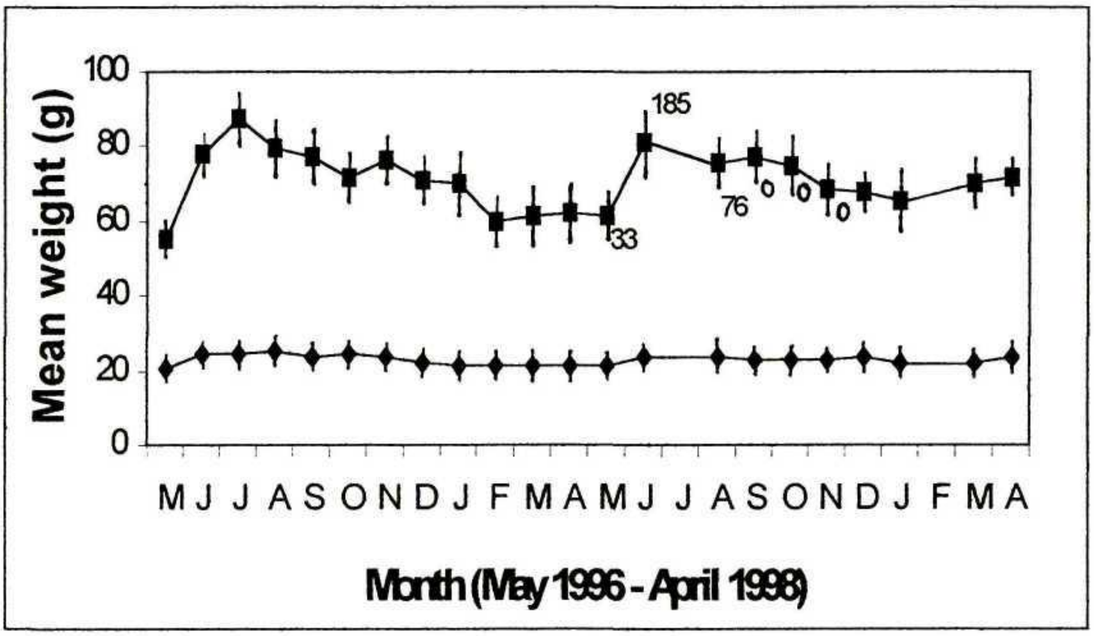
M. sechellensis

The increases in weight between May and June in both 1996 and 1997 were significant ($p<0.01$ and $p<0.02$, t and z tests), except at sites two and three in 1997. During the first year, skinks at Site 1 were significantly heavier than those at Site 2 during August, September and November (t and z tests, $p<0.01$). They were also significantly larger (t and z tests at $p<0.05$ and $p<0.01$) between May and November, although there were no significant changes in snout to vent length at each site throughout the study. In June 1997, there was a significant difference between mean weights at each site ($F_{3,56}=11.27$, $p<0.05$, $n=15$) with the heaviest skinks found at Site 4. There was also a significant difference between mean snout to vent lengths at each site in June ($F_{3,56}=7.30$, $p<0.05$, $n=15$), again with the longest skinks found at Site 4.

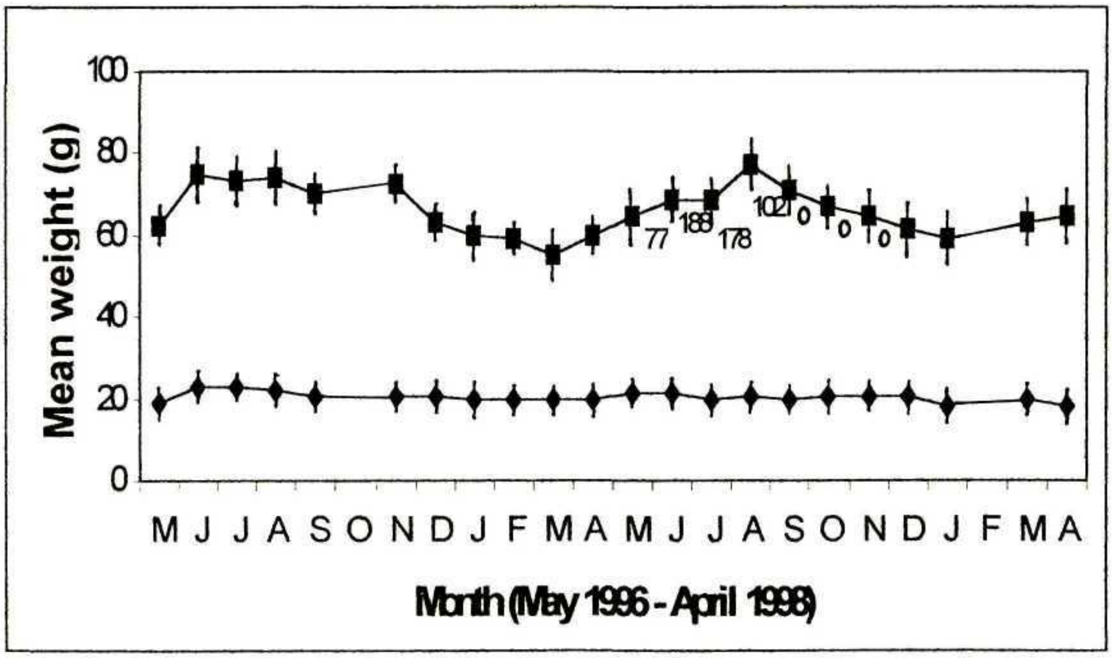
M. wrightii

As for *M. sechellensis*, the increases in weight between May and June in both 1996 and 1997 were all significant (z and t tests, $p<0.05$ and $p<0.01$) except at Site 2 in 1997 where a significant weight increase was only recorded between July and August ($t=3.18$, $p<0.01$). During 1996 to 1997, skinks at Site 1 were significantly heavier than those at Site 2 during July, September, December, January and March (z and t tests, $p<0.01$ and $p<0.05$). In addition, Site 1 skinks in January 1997 were significantly longer ($t=3.15$, $p<0.01$) although there were no significant changes in mean skink snout-vent length between months at any site throughout the study.

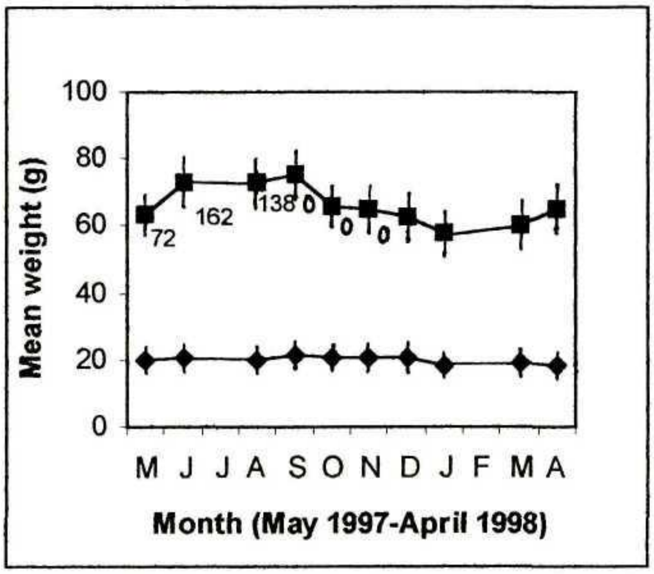
(a) Site one



(b) Site two



(c) Site three



(d) Site four

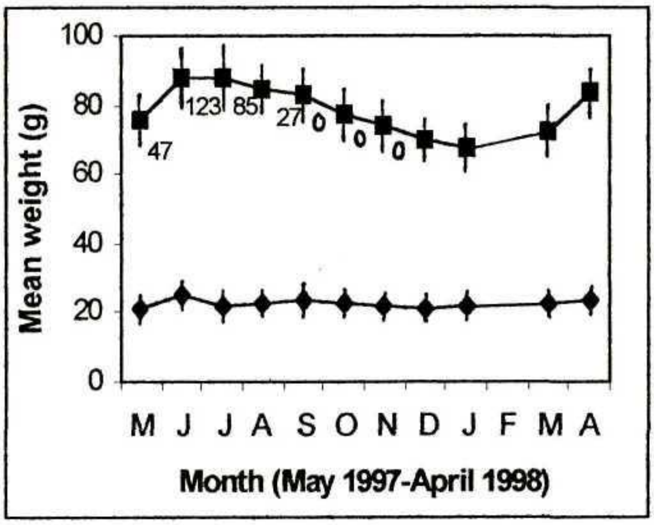


Fig. 4: Mean weight fluctuation (±95% confidence limits) of *M. sechellensis* (lower series) and *M. wrightii* (upper series) at four sampling sites on Cousine Island between May 1996 and May 1998. The figures on each graph denote the number of Lesser noddy nests counted from four marked trees at each site.

Using 2-way ANOVA, there were significant differences in mean weight between months and sites ($p<0.01$) between May-August 1997 and November 1997-January 1998. 2-way ANOVA also found significant differences in mean snout to vent length between sites in June, October (1997) and March 1998 ($F_{3,168}=47.67$, $p<0.01$). The heaviest and longest skinks were recorded at Site 4 throughout the second sampling period

Skink weight and Lesser noddy density

Although the same trends of weight change were recorded for each species, due to much smaller variation in mean *M. sechellensis* weight, only the *M. wrightii* data were used here. Furthermore, only data collected from Sites 2 and 4 were used because there were no breaks in sampling at either site. At Site 4, there was a significant correlation between variation in mean *M. wrightii* weight and Lesser noddy nest density between May and November 1997 ($r_s=0.786$, $p<0.05$, Spearman's rank). At Site 2, the correlation was not significant ($r_s=0.45$).

Invertebrate sampling

In the 1996 - 1997 season, there was no significant difference between the number of invertebrates recorded at each site although significantly greater species diversity was recorded at Site 2 ($t=4.09$, $p<0.01$), which was also invertebrate sampling site 5 (prev. chapt.). In the 1997 - 1998 season, significantly more invertebrates were recorded at Site 2 ($F_{11,132}=6.78$,.$p<0.05$, $n=10$, log transformed data) but there were no other significant differences between sites. In addition, the greatest species diversity was also held at Site 2 ($F_{10,121}=5.68$, $n=12$, $p<0.05$, log transformed data)(prev. chapt.).

There were no significant correlations between mean *M. wrightii* weight and the number of invertebrates recorded in leaf litter per month at each site. Indeed, at site one, there was a strong negative correlation during each sampling period ($r_s=-0.5$ for 1996 - 1997 and $r_s=-0.248$ for 1997 - 1998).

Skink sexual dimorphism

Using data concerning skink gut content analysis collected on Cousine during another study (prev. chapt.), there were no significant differences between the mean weights or mean snout to vent lengths of each sex. This ruled out the possibility that weight increases were being biased by females carrying eggs.

DISCUSSION

On Cousine, the amount of seabird organic material which dropped to the ground beneath the breeding Lesser noddy colony in 1998 was estimated as being approximately 22,000kg (prev. chapt.). The data presented here clearly confirm what has been found elsewhere (Brooke & Houston, 1983; Polis & Hurd, 1996; prev. chapt.), that *M wrightii* derive greater benefit from this food source than *M. sechellensis*. The results also provided further indication of links between invertebrates and the supply of organic material from seabirds. In other words, there appears to be a positive relationship between invertebrate abundance recorded at each of the skink sampling sites and the number of nesting seabirds recorded at each site.

Differences between sampling sites may be attributed to the distribution of nesting seabirds. Analysis of skink density data (prev. chapt.) suggested that at the beginning of the breeding season, skinks were attracted to areas where there were more tree-nesting seabirds (Sites 1 and 2), i.e. where there was more food being dropped to the ground. This may explain why skinks at Site 2 did not gain so much weight as skink density may have been higher and intra-specific competition for food therefore greater. This distribution change may also explain why *M. sechellensis* at Site 1 during the first sampling period were significantly heavier and longer than those at Site 2 while Lesser noddies were breeding.

However, during the period when Lesser noddies were not breeding, it was surprising that there was no relationship between invertebrate abundance and *M. wrightii* weight loss. As weight decline occurred at a similar rate at each sites, it appears that there was insufficient food available for individuals from this species, in a variety of habitats, to maintain the same body weight throughout the year. Thin *M. wrightii* observed just prior to the beginning of the main seabird breeding season had clearly almost exhausted their fat stores. The much lower weight fluctuations shown by *M. sechellensis* suggest that the opposite is true for this species. During the main seabird breeding season, its diet is dominated by invertebrates and the results presented here indicate that it can maintain body weight by finding sufficient invertebrate food throughout the year.

Some studies comparing diets of competing foragers in seasons of high versus low food availability found dietary divergence and narrower diets during lean times in relation to seasons of plentiful food (Schoener, 1982; Dunham, 1983). In this case, it appears that the diet of *M. wrightii* narrows considerably while the majority of seabirds are absent from the island. This confirms the suggestion by Brooke and Houston (1983), that this species is adapted to reliance on the seasonal food supply provided by breeding seabirds for survival throughout the year. Consequently, if any interspecific competition for food exists between skinks and the Magpie Robin whilst the majority of seabirds are not breeding, it is therefore more likely to involve *M. sechellensis*.

However, for a more detailed understanding of competition between the Magpie Robin and skinks , particularly *M. sechellensis*, during this period, further analysis of skink gut contents, combined with density counts and foraging observations are required.

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Chapter 5

General discussion

Conservation status of the Seychelles Magpie Robin

Out of eleven species of landbird which are endemic to the granitic Seychelles islands, the Magpie Robin *Copsychus sechellarum* Newton, is the rarest of four which are listed as Critically Endangered (Stattersfield, *et al.*, 1998). Its former range declined drastically following human settlement of the granitic islands in 1770, mainly as a result of predation by introduced mammals and habitat destruction (Watson *et al.*, 1992). By the late 1980's, the world population had been entirely confined to one island, Fregate, for just over 25 years and only about 20 individuals survived. A recovery plan for the species (Rands & Komdeur, 1989) was initiated by Birdlife International in 1990. To reduce the vulnerability of the species to extinction while confined to one island, one of the management recommendations was translocation of birds to other suitable, predator-free islands. Aride (69ha), Cousin (27ha) and Cousine (26ha) were the only ones available. Since 1992, a number of translocations have been carried out and breeding populations have become established on Cousin and Cousine.

The species originally occurred on Aride (Diamond & Feare, 1980) and, although there are no historical records, the original coastal forests on Cousin and Cousine probably also supported small populations. In spite of extensive habitat clearance in the past, existing vegetation on these islands is considered representative of that which existed prior to human settlement and there is an ongoing programme of native forest restoration on each one. Studying the Magpie Robin in such environments provides valuable insights into the ecology of the species in semi-natural habitat. Previously, most ecological work was carried out on Fregate, where over 90% of the vegetation consists of exotic species.

Due to the absence of mammalian predators, these islands continue to support large colonies of breeding seabirds. They also harbour two species of endemic diurnal skink, *Mabuya sechellensis* (Dumeril and Bibron), and *Mabuya wrightii* (Boulenger), the Seychelles and Wright's skinks. The high densities at which these occur are probably maintained by organic material in the form of dropped fish, egg, chicks and faeces, provided by tree-nesting Lesser noddies *Anous tenuirostris* (Temminck) (Brooke & Houston, 1983; Polis & Hurd, 1996).

Of key interest is the relationship between the Magpie Robin and skinks, each of which preys on invertebrates and young skinks, plus seabird organic material, found in leaf litter and soil. This thesis has addressed the question of whether or not there is any competition between these species for food on Cousine Island. The results have been used to make conservation management recommendations for the species.

Diet of the Magpie Robin and skinks

This section indicated that the Magpie Robin and skinks have very similar diets. However, behavioural observations strongly suggested that there is no significant competition for food. The most popular prey item for each species was the cockroach *Pycnoscelus indicus* (Fabricius), which is widespread amongst the granitic islands (Roth, 1996). Considered to be a cosmopolitan pest, it is an Indo-Malayan species which has also been recorded outside the region. In the Seychelles it is commonly associated with chicken farms (P Matyot and J Gerlach, pers.comm.) and has probably been present in the country throughout this century (Bolivar, 1924). Its effect on the local invertebrate fauna is unknown although it is interesting to note that out of 22 cockroach species endemic to Seychelles, none have yet been recorded on Cousine (Bourquin, 1999). In addition, it is also the only cockroach species identified in Magpie Robin faecal pellets and skink gut contents. Current theory on alien species is that they should be eradicated as quickly as possible. This is invariably because of the damage caused to natural ecosystems after alien species have assumed keystone roles within communities they have invaded (Samways, 1998).

Food resources available to the Magpie Robin and skinks

Using invertebrate abundance data collected from a variety of locations, this section showed that there are considerable differences in quality of habitat available to the Magpie Robin. These differences explained the current distribution of the species on the island. Estimates of the amount of organic material produced by nesting Lesser noddies *Anous tenuirostris* (Temminck), and of the size of skink populations demonstrated the importance of each species as keystone members of the island system. Of interest was the link between organic material dropped by *A. tenuirostris* and abundance of the cockroach *P. indicus*, a key Magpie Robin and skink prey item. Historically, it is thought that the Magpie Robin timed its breeding cycle to coincide with the rainy season, November to March, due to the positive relationship between invertebrate abundance and rainfall (Lucking & Ayrton, 1995; Komdeur, 1996). However, the positive relationship between invertebrate abundance and the supply of organic material from seabirds elsewhere (Brooke & Houston, 1983; Polis & Hurd, 1996) imply that the Magpie Robin would be able to breed throughout the year on seabird islands. In fact, since breeding began on Cousine in early 1997 and on Cousin since 1995, most successful attempts (i.e. those were a chick survived to independence) have occurred during the main seabird breeding season (Le Maitre, unpubl. data). This suggests that Magpie Robin breeding seasonality on seabird islands is quite distinct from that on Fregate.

Skink weight fluctuation

While most seabirds were absent from the island, it was expected that skink weights would decline according to levels of invertebrate abundance. In other words, skinks would lose more weight in areas with low numbers of invertebrates. It was found that *M. wrightii* weight fluctuated considerably more than that of *M. sechellensis* and at a similar rate in four different areas. Density counts indicated that there were no significant differences in *M. wrightii* density in a variety of habitats around the island and the results in this section support the suggestion that the larger species is considerably more reliant on seabird organic material. In contrast, the low levels of *M. sechellensis* weight fluctuation indicated that individuals from this species can find sufficient invertebrate prey to maintain body weight throughout the year.

The dietary study in Chapter two showed that invertebrate prey formed the bulk of *M. sechellensis* diet while *A. tenuirostris* were breeding. Density counts (Chapter three) showed that there *M sechellensis* occurred at higher densities in woodland on the edge of the coastal plain and the lower reaches of either hill which are the areas where the highest levels of invertebrate abundance were recorded. Assuming that predation rates for both skink species by *Rattus spp.* Linnaeus, and *Felis cattus* Linnaeus,are the same on islands without seabirds, these results and those from Chapter four support the theory that *M. wrightii* and *M. sechellensis* distribution is determined, respectively, by adaption to a seasonal supply of seabird organic material and a diet dominated by invertebrates (Vesey-Fitzgerald, 1947). Interspecific competition for food between the Magpie Robin and skinks is therefore more likely to involve *M. sechellensis*. However, although the Magpie Robin is outnumbered by several orders of magnitude and the distribution of each species is related to invertebrate abundance, competition for food is unlikely at any time during the year due to fundamental differences in foraging behaviour.

Nevertheless, this study has suggested that skink biology, invertebrate abundance and Magpie Robin breeding seasonality are closely linked to authochthonous material supplied by breeding seabirds. The Lesser noddy can therefore be considered to be the main keystone species on Cousine (Fig. 1).

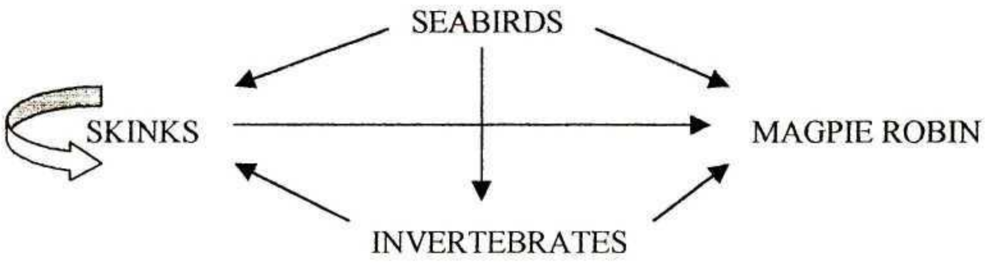

Fig. 1: A food web showing energy flow from seabirds to skinks, invertebrates and the Magpie Robin on Cousine Island.

Implications for future management

Current population sizes on Fregate, Cousin and Cousine (Table 1) suggest that the abundance of invertebrate and vertebrate food on seabird islands means that they can each support a greater density of the Magpie Robin than Fregate.

It is important that populations on the remaining two islands should not be permitted to decline from present levels. If necessary, intensive conservation management practices should be initiated to increase numbers. In the original recovery plan, recommendations for increasing numbers included provision of supplementary food, habitat management, predator control and the creation of nest sites. All of these are being implemented on Cousine. Supplementary feeding has been carried out on a daily basis since the translocation of four birds in November 1996.

Island	Total Area (ha)	Area in Use	Total No. of Fledged Birds	Territory Size (ha)
Fregate	219	70	41	2.6 - 11.1
Cousin	27	12	19	2.0 - 3.0
Cousine	26	10	12	2.0 - 5.0

Table 1: The total number of fledged individuals on Fregate, Cousin and Cousine as at the end of September 1998 (Parr, 1998) and the approximate total area of land occupied by Magpie Robin territories on each island. The territory size range for Fregate is taken from McCulloch (1996). The ranges for Cousin and Cousine are taken from Le Maitre (unpubl. data).

The supplementary food consisted of Exact Rainbow^{TM} (Kaytee), a scientifically tested, nutritious, low iron softbill birdfood in pellet form. See Appendix 1 for details of the ingredients and the distributor. There have been no known instances of birds becoming ill as a result of eating this food on either Fregate, where it is also provided, or Cousine. Breeding females were also offered around 10 adult cockroaches *P. indicus*, daily, although no supplementary food was supplied during the 12h continuous chick feeding observations. Calculations indicated that supplementary food taken by adult females during breeding attempts represented an increase of 4.5g-5.1g or 12.8 - 14.6% of the daily food requirement. When no breeding was underway, the equivalent range was 3.4 - 6.0%. These figures are maxima as they were calculated using observations of adult females during breeding attempts. During non-breeding periods, food was provided during the last hour of daylight so that birds spent most of the day foraging naturally. It is therefore unlikely that foraging observations carried out during these periods (Chapter two) could have been significantly biased by the extra food supply (D. Merton, pers. comm.).

However, there were significant differences between the amount of supplementary food taken by three breeding females during 1997 (February, March, September, October) and 1998 (January and February)(z tests, $p<0.01$ and $p<0.05$, log transformed data). This indicated that there was an inverse correlation between territory quality and the amount of supplementary food taken which suggests that the birds only take what they require rather than everything that is on offer. Furthermore, there was a highly significant difference ($p<0.01$, paired $t=9.25$, d.f.=19, log transformed data) between the amount of supplementary food taken by one female in January and July 1998. This is another indication of the importance of seabird organic material to Magpie Robin breeding and prey availability as it suggests that the female was foraging more successfully during the seabird breeding season.

Further invertebrate sampling on Cousin, with coverage of all six existing territories and any unused areas, may indicate that supplementary feeding is required to ensure successful breeding in certain areas. Sampling should also be carried out on Aride simultaneously, to establish habitat quality all over the island. It is also important that a thorough investigation of the reasons behind repeated failed attempts at re-introducing the Magpie Robin to Aride is carried out in the immediate future (Cooke, 1998). In addition, further mammalian predator-free islands are urgently required to establish additional satellite populations of this critically endangered species.

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APPENDIX 1

Exact RainbowTM is distributed by: Kaytee Products, Inc.
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U S A

Indredients:

Ground Corn, Wheat Flour, Ground Wheat, Wheat Middlings, Corn Gluten Meal, Dried Whole Egg, Dehulled Soybean Meal, Corn Oil, Meat Meal, Wheat Germ Meal, Calcium Carbonate, Dicalcium Phosphate, Vitamin A Supplement, L-Lysine, Salt, Brewers Dried Yeast, Riboflavin Supplement, Choline Chloride, DL-Methionine, Vitamin E Supplement, Orange Oil, Propionic Acid (a preservative), Manganous Oxide, Zinc Oxide, Niacin, Calcium Pantothenate, Copper Oxide, Menadione Sodium Bisulfite Complex (source of vitamin K), D-Activated Animal Sterol (source of Vitamin D3), Beta-Carotene, Thiamine Mononitrate, Pyridoxine Hydrochloride, Calcium Iodate, Cobalt Carbonate, Biotin, Folic Acid, Sodium Selenite, Artificial Colours, Natural Flavour.