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Impact of rat species in Ouvea and Lifou (Loyalty Islands) and their consequences for conserving the endangered Ouvea Parakeet

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Abstract

This study assesses the impact of Pacific Rat *Rattus exulans* predation on the endangered Ouvea Parakeet *Eunymphicus cornutus uvaeensis* and investigates the feasibility of translocating this bird to the island of Lifou (despite the presence of Ship Rat *R. rattus*). A rat trapping campaign, conducted from July 1995 to October 1996 in the forest of Ouvea and Lifou (Loyalty Islands, New Caledonia, South-west Pacific), confirmed the presence of Pacific Rats in Ouvea and both Pacific and Ship Rats in Lifou. Population dynamics, sex ratio, age structure and diet of both rats were investigated. An experiment, using quail eggs in natural tree holes during the main bird breeding season, in Ouvea in 1994 and in Ouvea and Lifou in 1996, compares the nest predation rate between these islands. Mayfield's estimator for a 21 day theoretical incubation period gives a survival rate of 0.80 and 0.99 in the two experiments in Ouvea but only 0.22 in Lifou. Most of the difference in egg survival observed between the islands appears to be related to the presence of Ship Rat in Lifou, while the difference in the two experiments in Ouvea may estimate the effects of trapping. The study shows that Lifou is not a suitable place for translocating Ouvea Parakeets, unless active habitat management is carried out to protect this bird against Ship Rats. The value of low intensity rat control in Ouvea immediately prior to the parakeet breeding period is also suggested.

Keywords: Rats; Population dynamics; Nest predation; Ouvea Parakeet; Loyalty Islands

1. Introduction

Introduced species have long been recognised as an important factor responsible for the extinction of species in island ecosystems and were the subject of a considerable literature (see reviews by Atkinson, 1985, 1989; Burger and Gochfeld, 1994). 93% of the 176 land and fresh water birds species and subspecies which have become extinct since 1600 were island forms and 42% of these are attributed to predation by introduced species. Rats (*Rattus rattus*, *R. norvegicus*, *R. exulans*), alone are believed responsible for 54% of these extinctions (King, 1985). Several factors were recognised in the susceptibility of bird species to rat predation, including its nesting habits and anti-predatory behaviour, the species of predator involved and its ecology, and the dynamics of both populations (Atkinson, 1985; Burger and Gochfeld, 1994). A good understanding of the ecology of the species and the interaction between prey and predator is thus essential, prior to undertaking management actions for conserving birds threatened by rats. These actions may include the eradication of the predator, its control at key periods or alternatively, the translocation of the threatened bird to a predator-free habitat.

In Ouvea, (Loyalty Islands, South-west Pacific) a previous study (Robinet and Salas, 1996) has shown that both Ship *R. rattus*, and Norway rats *R. norvegicus* are absent from this island whilst they occur in the neighbouring islands including Lifou. This information has crucial implications as Ouvea is one of the only remaining islands of any importance in the tropical Pacific still free of these rodents (Atkinson, 1985, 1989), despite a wharf, an airstrip and a human population of more than 3000. This island is also important as being home of the Ouvea Parakeet *Eunymphicus cornutus uvaeensis*, an endemic subspecies already threatened with extinction by habitat loss and capture by local peoples for the pet market (Robinet et al., 1995, 1996). The absence of Ship and Norway Rats from this island may have been the only factor that has spared this bird

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until now, although its population and its range have declined since the beginning of the century (Macmillan, 1939; King, 1981; Hannecart, 1988; Lambert et al., 1993). Besides the measures that have subsequently been undertaken to avoid the introduction of these rodents to Ouvea, discovery of their absence has raised the viability of translocating this bird to the nearby island of Lifou. This island, which is much larger than Ouvea and still covered with large blocks of undisturbed native forest, seemed at first the best candidate for a translocation of the Ouvea parakeet. This option has thus been recommended by conservation organisations as a priority for the management of this bird (Lambert et al., 1993), despite the failure of two previous attempts (Delacour, 1966; Robinet et al., 1995).

We aim in this paper, firstly to assess the impact of predation by Kiore *R. exulans* on eggs and nestlings of Ouvea Parakeets. Secondly, to compare the population dynamics and ecology of rat species in both Lifou and Ouvea and their respective impact on avifauna. Thirdly, to evaluate if the presence of Ship and Norway rats in Lifou is an absolute barrier to the success of a translocation of Ouvea Parakeets in this island and if not, to investigate the possibilities of lowering the impact of these rodent on translocated parakeets to an acceptable level.

2. Study area

The experiment was conducted on Ouvea and Lifou, two islands of the Loyalty archipelago, 100 km northeast of New Caledonia. These islands are coral atolls secondarily raised by the influence of the Australasian plate slipping under the Central Pacific plate. Although the lagoon of Ouvea (166°30′E, 20°30 S) is still occupied by water, the lagoon of Lifou (167°30′E, 20°45′S) is now raised 30 to 40 m above sea level, forming a central plain in the island surrounded by the former barrier reef (CTRDP, 1987; Mathieu-Daudé, 1989) (Fig. 1).

The climate is tropical, tempered by trade winds. The mean temperature is 23.6°C in Ouvea and 23.0°C in Lifou with a minimum in July and a maximum in February. The average annual rainfall is 1250 mm in Ouvea and 1550 mm in Lifou, with a minimum in September and a maximum in March. Temperature and rainfall define four seasons, one hot and humid season from December to March when cyclones can occur, and a cold and dry season from July to October, separated by intermediate seasons (CTRDP, 1987).

Even if these islands have the same origin and geology, they are quite different in size, vegetation and human density. Ouvea (130 km^2), has an elongated shape and is covered by coconut plantations and a few remnants of native forest, with a human population density of about 30 inhabitants per km^2. By contrast, Lifou (1150 km^2), is almost tenfold the size of Ouvea is still covered by a dense and mainly undisturbed rain forest, and has a human population density of only 10 inhabitants per km^2 (Mathieu-Daudé, 1989).

Rat trapping sessions were undertaken both in 'high forests', in the north of Ouvea where the Ouvea Parakeets occur (Robinet et al., 1996) and in similar habitat, in the centre of Lifou. The choice of the study sites was dictated in Ouvea by the presence of a high density of parakeets, and in Lifou by an habitat of undisturbed forest with ready access (for description of the vegetation of Ouvea see Robinet et al., 1996; Robinet and Salas, 1996). The forest in Lifou is composed basically of the same species as in Ouvea, but the canopy is higher (10–15 m) with greater numbers of tall tree species: *Schefflera golip* (Araliacees), *Mimusops elengii*, *Planchonella lifuana*, *Manilkara dissecta* (Sapotacees), *Canarium balansae* (Burseracees), *Hernandia cordigera* (Hernandiacees), *Syzygium lifuanum* (Myrtacees), *Eaeocarpus angustifolius* (Elaeocarpacees) and *Aglaia elaeagnoidea* (Meliacees), especially in the centre of the island where the soil can reach a depth of up to 3 m (Jaffré and Veillon, 1987).

3. Methods

3.1. The rat trapping experiment

Line-transects were established at both sites in Lifou and Ouvea, following existing small tracks. We used EZESET 'Supreme' snap traps baited with peanut butter mixed with crackers following the technique described by Cunningham and Moors (1993). 50 traps were set in pairs, one meter apart, covered by the vegetation and tied to a support to avoid the loss of traps. Each pair of traps was at 30 m intervals. The traps were set prior to dusk and checked every morning for three nights in each session. The sessions were repeated every six weeks on average depending on the weather. Trapping was avoided when it was raining. General information collected in each session included the study site, time, weather and trap number and for each trap, if it was sprung or not, the presence of the bait, and captures of rats and non target species.

An index of abundance (IA) taking into account the number of corrected trap nights was calculated following the Nelson and Clark (1973) formula: $IA = 100*captures/(TU-S/2)$, and $TU = P*N$ with TU, the number of corrected trap nights; P, the number of trapping intervals; N the number of traps and S, the total of traps sprung by any causes. Capture rates were compared with a Chi square test of independence and ANOVA.

3.2. Necropsy data

The rats captured were collected and examined noting the general appearance and colour. The length of head and body, tail, right foot and right ear were measured with Vernier callipers to the nearest 1/10 mm and the weight taken with a Pesola scale to the nearest gram.

The rats were then autopsied, recording the sex, sexual maturity (measured by the presence of scrotal testes for males and perforated vagina for females), number of nipples and presence of lactation, and number of foetuses or uterine scars. The males were considered mature if they had scrotal testes or the scrotum had a dark bald patch. The females were considered mature when they had a perforated vagina and either foetus, uterine scars or were lactating. The stomach contents were washed into a glass petri dish and the proportions by volume of foliage, seeds, invertebrates and other animal matter were visually estimated to the nearest 10%. Some insects and parasites were identified to a species level.

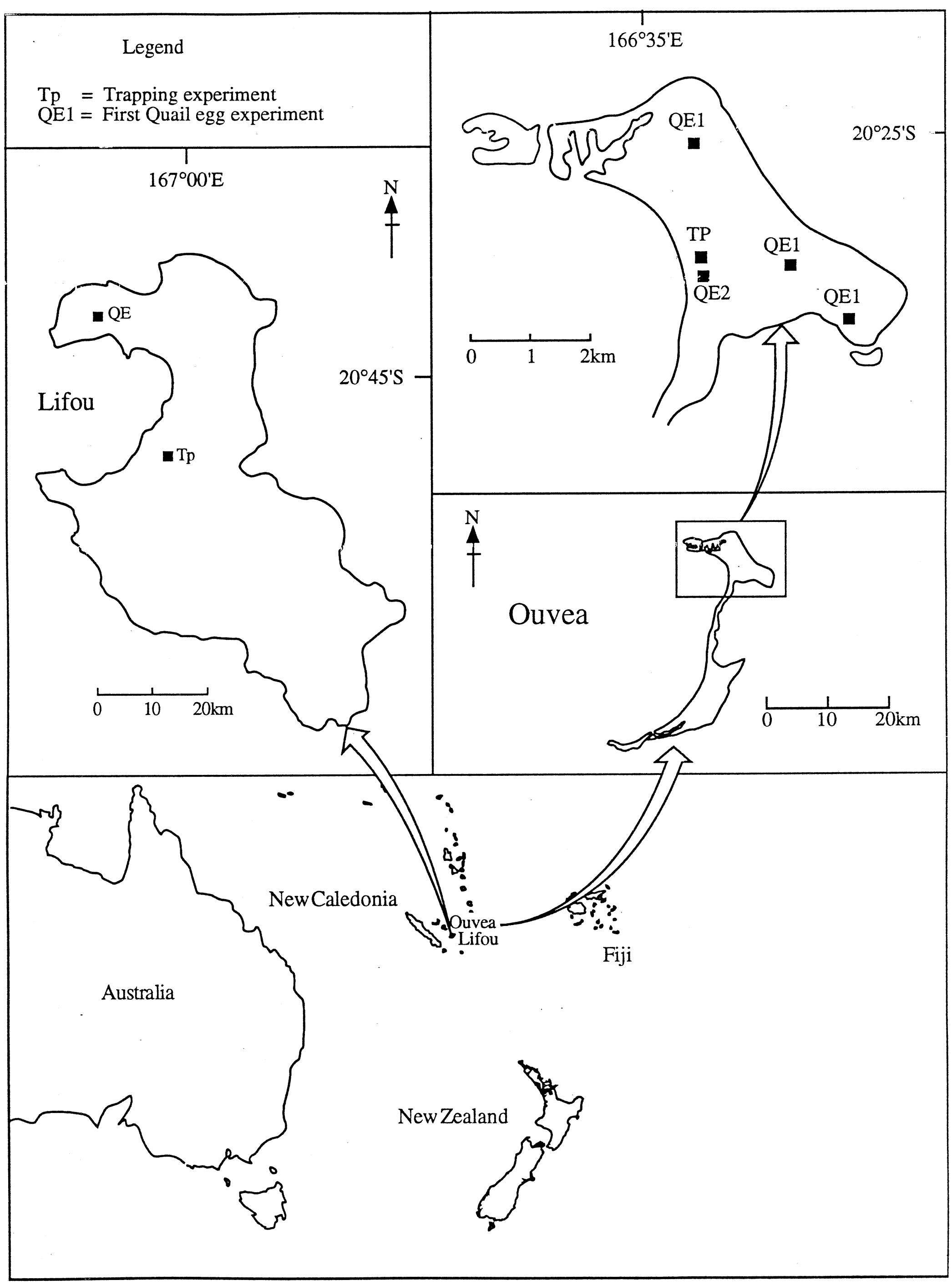

Fig. 1. Study sites for trapping and quail egg experiments in the islands of Ouvea and Lifou.

3.3. The quail egg experiment

Two different experiments were undertaken involving the use of Japanese Quail *Coturnix japonica* eggs to assess predation risk. Quail eggs (width range 19–23 mm) were chosen because of their similarity to the size of Ouvea parakeet eggs (width range 21–23 mm) (Robinet and Salas, in press). The first was done in the north of Ouvea in the habitat of the Ouvea Parakeet in order to assess the potential level of predation by *R. exulans* on nestlings. Three or four eggs were placed in 39 natural holes in trees assumed to be parakeet nest sites, from August to November 1995, and checked after four weeks. The holes were chosen because they most closely resembled those selected by parakeets as nest holes. Characteristics used included the tree species and the shape and size of the hole (see Robinet and Salas, in press for details of holes used as nest sites).

The second experiment was undertaken to compare the potential impact of *R. rattus* plus *R. exulans* predation on eggs and nestlings in Lifou and Ouvea. This experiment was conducted in the same area of Ouvea as the first, but in Lifou, the same experiment was done in the northwest of the island because of the higher occurrence of natural holes. 30 and 40 different natural holes in the trees, chosen as in the earlier experiment, were used respectively in Lifou and Ouvea, divided into four classes depending on the height of the hole entrance (0–2, 2–4, 4–6 and >6 m). The tree diameter at breast height (DBH), the diameter of the entrance and the depth of the hole, were also recorded to the nearest centimetre. Three quail eggs were placed in each hole and checked every 7 days for 21 days. The number of eggs remaining was counted and evidence of predation reported at each visit. This experiment was done at the same time in both islands in August and September 1996, at the beginning of the Ouvea Parakeet breeding season (Robinet and Salas, in press). The daily survival rate of nests in each site was estimated using Mayfield's estimator (Mayfield, 1975; Johnson, 1979).

4. Results

In Lifou, 60 rodents were captured including 22 Kiore, 34 Ship Rats, 2 House Mice *Mus musculus*, and 2 rat remains of unidentified species. Because the snap traps were designed for rats, the mice were caught by the tail and thus represent only a tiny portion of the animals that may have eaten the bait. Mice were not further considered in this study. A total of 39 Kiore were caught in Ouvea but no mice although they are known to be present (Robinet and Salas, 1996). The index of abundance for the whole study was 2.11 in Ouvea and 3.54 in Lifou. Non-target species caught included Hermit Crab *Coenobita* sp., Coconut Crab *Birgus latro* and Brachyuran Crabs, as well as African Giant Snail *Achatina fulica* mostly during the wet season. When the weather was dry, ants were infesting the baits during the first four sessions in Lifou and Ouvea with a likely deterrent effect on rats. An ant poison with cyanide compound added to the bait for the remaining sessions deterred ants.

4.1. Population fluctuation

There were notable differences in the capture rates between species and between the two islands (Fig. 2). In Ouvea, captures of Kiore were maximum during the first session (July) and decreased then to zero during January and February to increase again in the following seven months without ever approaching the initial level. The same pattern was observed in Lifou for Kiore although captures did not fluctuate very much during the year (except higher captures in summer). Ship Rats on Lifou were initially low through to March but reached their maximum from May to July.

4.2. Sex ratio

The sex ratio for the overall study was not significantly different from 1 for Kiore (22 males/16 females, $p_{(x=16)}=0.08$, $n=38$, n.s.), and Ship Rats in Lifou (17/17, $p_{(x=17)}=0.5$, $n=34$, n.s.). In contrast, the proportion of females was significantly higher for Kiore in Lifou (6 males/15 females, $p_{(x=6)}=0.03$, $n=21$). The sex ratio was, however, not equally distributed during time. Females represented almost all the captures of Kiore from November to March (10 out of 11) in Lifou and from November and December in Ouvea (5 out of 6), and of Ship Rats in August (7 out of 10).

4.3. Age and weight distribution

The proportion of adults to juveniles for the three different rodent-island groupings shows a presence of juveniles in March and April and again in July and August for Kiore in Ouvea and from January to May in Lifou. Juvenile Ship Rats were found from March to July. In contrast, all the rats captured from September to December were adults (Fig. 3). This is reinforced by the average weight of the rats captured per sessions (Fig. 4).

Even if the sample sizes are generally small, some trends, however, are apparent. The average weight of Ship Rats increased continuously during the year, while for Kiore in Ouvea, this weight follows a bimodal distribution with minima in March–April and July–August. The overall average weight of Kiore in Ouvea (mean 49.7 g, SE 2.1, $n=38$) was significantly lower than in Lifou (mean 61.8, SE 3.4, $n=21$), (one way ANOVA: $F_{1,55}=10.1>8.55$, $p<0.005$). The Ship Rats

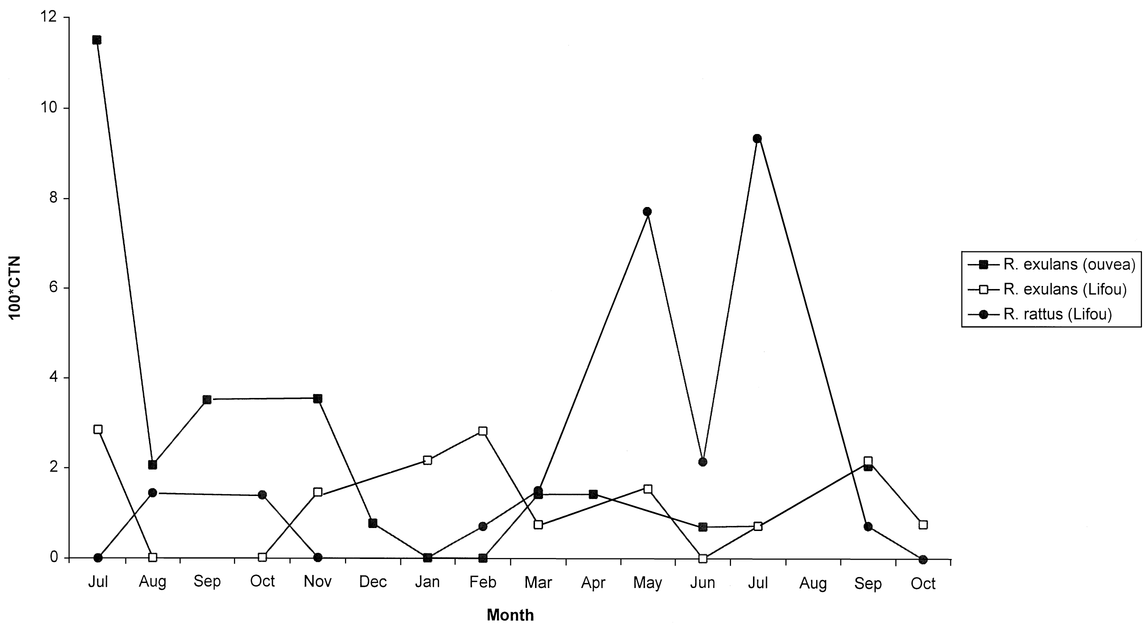

Fig. 2. Number of rats caught in Lifou and Ouvea over a 16 month period (per 100 corrected trap-nights).

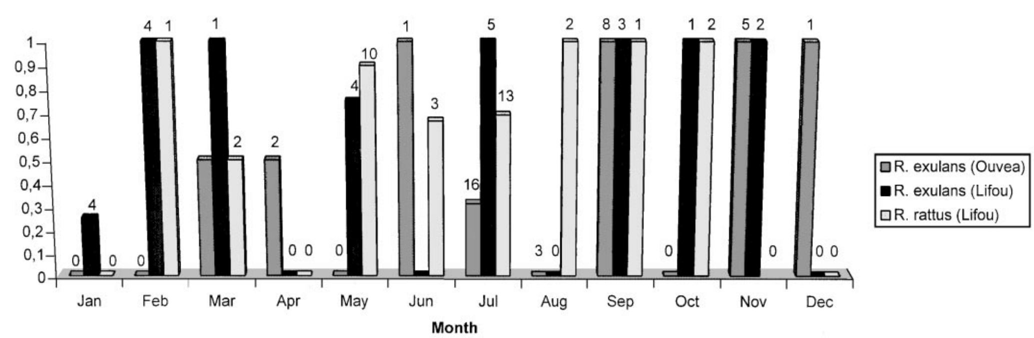

Fig. 3. Proportion of adults among the total rats caught in Lifou and Ouvea (sample size above each bar).

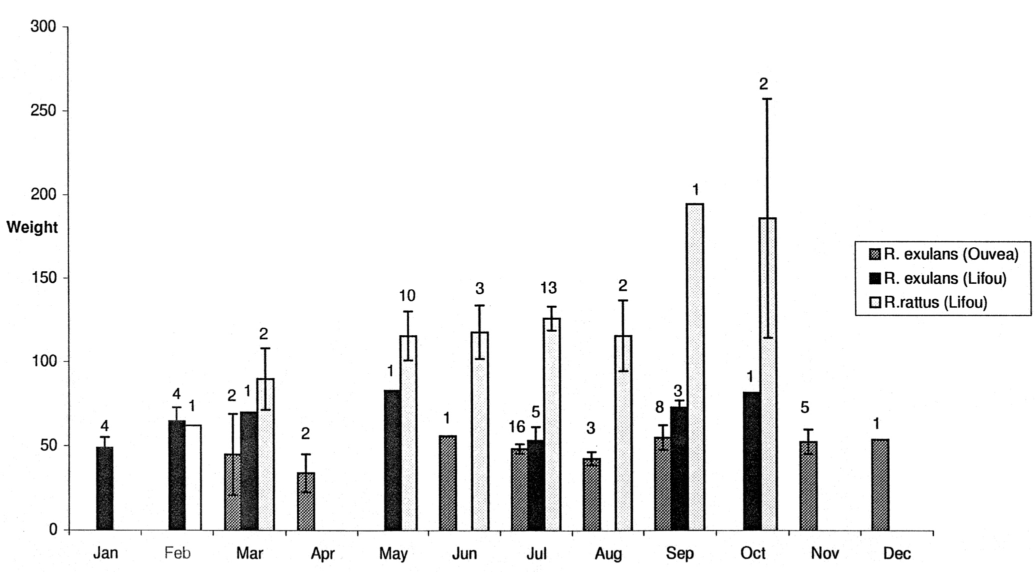

Fig. 4. Mean weight of rats captured in Lifou and Ouvea (SE and sample size above each bar).

weighed on average 123.4 g (SE 7.3, $n=34$), higher than the Kiore (ANOVA: $F_{1,88}=74.9>7.5$, $p<0.001$).

4.4. Fecundity and reproduction

Given the small sample size, it was not possible to determine precisely the beginning and end of the breeding season by recording the presence of embryos or lactation (Table 1). A general reproductive pattern for the three groups of rats studied can however be drawn, by using the reproductive data available (gestation and lactation) as well as the occurrence of juveniles caught (Table 1). Ship Rats in Lifou appear to reproduce most of the year (two pregnancies recorded, in October and May), except from July to September. There is a maximum of pregnancy from December to February, and subsequent emancipation of young from March to July. Kiore in Ouvea also have a breeding season from December to March, but with another peak in May and June, confirmed by the high number of juveniles captured the following month. Kiore in Lifou were breeding earlier, from September to March and did not apparently show a second peak of breeding in May–June as in Ouvea. Juveniles were thus only captured from January to May. The mean litter size was 3.7 (SE 0.27, $n=8$), for Kiore and the number of uterine scars was three in two cases and seven in one. One female Ship Rat had five embryos; three had five uterine scars, one 18 and one 27, suggesting a mean litter size close to five and the occurrence of at least quadriparous females in this species.

4.5. Analysis of stomach contents

Seeds and fruits represented the large majority of the stomach contents (mean 91.6% of total content), followed by arthropods (mean 5.3%) and green vegetation (3.1%) (Table 2). There were no significant differences between the proportion of seeds/fruits (ANOVA, $F_{2.46}=0.84<3.20$, n.s.), of green vegetation ($F_{2.46}=0.62$ <3.20, n.s.) and arthropods ($F_{2.46}=1.08<3.20$, n.s.) of the stomach contents, between Ship Rats and Kiore in Lifou and Ouvea. The seed/fruits included coconut kernel, and arthropod remains were mostly tarsi of ants (Hymenoptera) and grasshoppers (Orthopera), and lice eggs (Mallophaga). Hairs (of a black colour assumed to be of rats) were found in most stomachs, but feathers only in the stomach of one Kiore in Ouvea. Nematode parasites of the genera *Capilaria*, *Trichuris*, and *Strongyloides* and *Mastophorus* were often found in the stomach of both Ship Rats and Kiore. The high contamination rate observed is related to the frequency of Arthropods ingested, which are the natural hosts of most of these parasites.

4.6. Quail egg experiment

The egg predation estimated by the survival rate of quail eggs differed greatly between Lifou and Ouvea (Table 3). In fact, the Mayfield's survival estimator after 21 days, i.e. the length of incubation of Ouvea Parakeets (see Robinet and Salas, in press), was 0.80 and 0.99 in the first and second experiments in Ouvea, while the

Table 1
Reproductive status of rat species captured in Lifou and Ouvea

		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
R. exulans (Ouvea)	G												
	L							1					
	I			1	1			11	3				
R. exulans (Lifou)	G	2	4	1						1			
	L										1		1
	I	1		1		1							
R. rattus (Lifou)	G					1					1		
	L					2		2			1		
	I			1		1	1	4					

G: gestation; L: lactation; I: immatures.

Table 2
Composition of stomach contents of rats caught in Lifou and Ouvea (SE in parentheses)

	n	Seeds and fruits (% of total content)	Greens (% of total content)	Arthropods (% of total content)	Vertebrates (% of presence)	Parasites (Nematods) (% of presence)
R. exulans (Ouvea)	25	93.2 (1.4)	2.5 (0.7)	4.3 (0.9)	Hairs (96.0), feathers (4.0)	28.0
R. exulans (Lifou)	15	90.0 (1.7)	3.4 (1.3)	6.7 (1.8)	Hairs (47.7)	53.3
R. rattus (Lifou)	9	91.1 (2.7)	4.4 (1.9)	5.7 (1.8)	Hairs (88.9)	Absent

Table 3
Results of the quail egg experiment in Lifou and Ouvea

Site	Height class	Number of holes	Number of eggs	Number left after				Mayfield's daily survival rate	Mayfield's survival rate after 21 days[a]
				7 days	14 days	21 days	28 days		
Ouvea (8–10/1994)	total	39	149	—	—	—	72	0.989	0.80
	0–2 m	16	60	—	—	—	30	0.989	0.80
	2–4 m	11	42	—	—	—	20	0.989	0.80
	4–6 m	10	39	—	—	—	19	0.989	0.80
	> 6 m	2	8	—	—	—	3	0.986	0.76
Ouvea (9/1996)	Total	40	120	117	117	117	—	0.999	0.99
	0–2 m	10	30	27	27	27	—	0.997	0.95
	2–4 m	10	30	30	30	30	—	1.000	1.00
	4–6 m	10	30	30	30	30	—	1.000	1.00
	> 6 m	10	30	30	30	30	—	1.000	1.00
Lifou (9/1996)	Total	30	90	27	6	3	—	0.931	0.22
	0–2 m	11	33	9	0	0	—	0.921	0.17
	2–4 m	8	24	15	3	3	—	0.966	0.49
	4–6 m	9	27	3	3	0	—	0.941	0.28
	> 6 m	2	6	0	0	0	—	0.906	0.13

[a] Extrapolated from the daily survival rate for Ouvea 1994, and by the product of weeky survival rates for Ouvea 1996 and Lifou 1996.

survival rate was only 0.22 in Lifou. Comparison of the survival rates (using Mayfield's estimators) between height classes, shows no significant differences in the first and second experiment in Ouvea, but a significantly higher survival rate in the class 2–4 m in Lifou ($\chi^2_1 = 8.99 > 7.88$, $p < 0.005$). Even if the cause of the disappearance of the eggs was not always obvious, evidence of predation by rats (marks on the shell, droppings) were found in four cases in Ouvea, and seven in Lifou. In contrast, we found no clear evidence of other predation during this study. Among the other possible predators, the Pacific Boa *Candoia bibroni*, which occurs both in Lifou and Ouvea is a known predator of nestlings (Robinet et al., 1995). It swallows the eggs leaving no trace, a fate observed for only 40% of the eggs missing or damaged in Ouvea and 38% in Lifou. Both islands have the same suite of potential predators with the exception that *R. rattus* is present in the forest of Lifou.

5. Discussion

5.1. Population dynamics and ecological niches of rat species in Lifou and Ouvea

This study has confirmed previous results (Robinet and Salas, 1996), concerning the distribution of rat species, with the presence of only Kiore in Ouvea while in Lifou, Kiore and Ship Rats coexist in the forest. Norway Rats are present in Lifou but apparently do not occur in the forest. House mice are present in both islands with likely differences in their relative abundance in the forest but are not considered in this study.

Ship Rats in Lifou and Kiore in Ouvea, were most numerous in the middle of the year (winter), while captures of Kiore in Lifou were evenly distributed throughout the year. The reproductive pattern of rats in both islands is marked by a long breeding season, from November to June for Ship Rats in Lifou and Kiore in Ouvea. In Lifou, Kiore bred two months earlier (September to March) probably as a consequence of competition with Ship Rat. This breeding pattern is similar to that observed by Nicholson and Warner (1953) in New Caledonia, and in the tropics in general (Wirtz, 1972; Dwyer, 1975, 1978). The length of breeding season (8 months) and mean litter size (3.7) of Kiore in this study confirm the general trend shown by Moller and Craig (1987) of a shortening of breeding season and an increase of mean litter size with latitude.

No differences were found, during this trapping experiment, in the diet of the two rats' species, which was composed mainly of seeds, fruits and insects, both in Lifou and Ouvea, with no apparent seasonal variations. The same predominance of plant foods was noticed in other studies of Kiore in the tropics (Williams, 1973; Dwyer, 1975, 1978), and differs markedly from observations in New Zealand where animals are a principal component of the diet (Campbell et al., 1984). The homogeneity of the diet observed in this study can be related to the overall abundance of food as a result of a fruiting season that extends to almost all of the year (Robinet et al., in prep,). It differs greatly to that observed, in the temperate countries where seasonal and inter-annual abundance of food availability, especially related to seed falls have a major influence on demography of rodent populations (King, 1983; Murphy and Pickard, 1990; Miller and Miller, 1995).

The lower index of abundance (2.11) and a low average weight (49.7 g) of Kiore in Ouvea compared to Lifou (3.54 g for the two species and 61.8 g for Kiore), suggest that food abundance and thus the total carrying capacity for rats is lower in the forest of Ouvea than in Lifou. This is confirmed by the dramatic decrease of captures of Kiore in Ouvea after the first session, which never recovered subsequently, showing that the trapping campaign had a significant effect on the localised population level of Kiore in this island.

5.2. Assessment of nest predation using quail eggs experiment

Artificial nests were widely used in the studies on egg predation and their biases extensively discussed (Roper, 1992; Major and Kendal, 1996). These biases linked to the differences between experimental and natural conditions in egg type, nest type, location, season and length of exposure, habitat, etc., were largely avoided in this study because we used natural nest sites, with stratified heights, during the Ouvea Parakeets breeding season. The size of quail eggs is similar to those of Ouvea Parakeet (Robinet and Salas, in press), and they are widely used for assessing rat predation (Major and Kendal, 1996). Moreover, this experiment was not used to give an absolute value of the predation rate but to compare predation between different sites, with the presence of Ship Rats being the main explanatory variable.

These two islands lack recognised bird predators of nestling such as the New Caledonian Crow *Corvus moneduloides*, or aggressive introduced species such as Common Myna *Acridotheres tristis* that occur in New Caledonia (Hannecart and Létocart, 1983). If competition among native cavity nesters such as the Loyalty Island Starling *Aplonis striatus atronitens*, Barn Owl *Tyto alba* and the Ouvea Parakeet results in egg destruction, the effect is likely to be insignificant knowing the low density of these species. Hermit and Coconut Crabs can also eat eggs and nestlings of tree-cavity nesters (Yaldwyn and Wodzicki, 1979; Atkinson, 1985), including those of Ouvea Parakeet (pers. obs.).

However, one factor in the results of the quail egg predation in Ouvea tends to demonstrate the predominance of rats. In the second experiment, which was undertaken in the same study site as the rat trapping and at the end of it, the almost zero-predation observed may be related to the low density of Kiore following the trapping campaign. The difference in survival rates in Ouvea between the first (without rat control) and the second experiments (with control), (0.19 for 21 days) may thus be considered as a rough estimation of the quail egg predation by Kiore in Ouvea. Observations of natural predation on nests of Ouvea Parakeets tend to confirm this assumption (Robinet and Salas, in press). In contrast, in Lifou, Ship Rat, which is the only additional predator of nests to those of Ouvea, can thus be considered mainly responsible of the enormous differences observed between the two islands in survival rates of the quail eggs (0.58 for 21 days). Even if it is impossible to attribute definitively the respective importance of various predators, the quail egg experiment appears to emphasise the role of Kiore predation in Ouvea and especially of Ship Rats in Lifou.

5.3. Impact of rat species on the avifauna of Lifou and Ouvea

The impact of rat species on island avifauna is the subject of a considerable literature (see a review in Atkinson, 1985; Burger and Gochfeld, 1994). The factors affecting the population level of bird species exposed to rat predation include the rat species in relation to the type and position of the nest, the presence of anti-predator behaviour from the bird and the time of bird breeding in relation to the population dynamics of the rat predator. A dramatic impact was documented of Ship Rat predation on cavity-nesting birds because of its arboreal, and predatory behaviour, and the impossibility of the bird escaping. In temperate countries this effect is often worsened because the shorter breeding season and higher litter size of rodents leads to a massive release of young at the end of the summer, when food abundance declines. This brutal demographic increase, and subsequent food shortage, led to a shift in the diet of the rodents toward animal items including eggs and nestlings of late breeding birds (Atkinson, 1985; Moller and Craig, 1987).

The long breeding season, small litter size of Kiore (this study) and a fruiting season extended throughout the year (Robinet et al., in prep.) suggest that this phenomenon does not occur in Loyalty Islands. However, indirect evidence from the quail egg experiments shows that rats are significant predators of eggs and nestling, in Lifou and to a lesser extent in Ouvea. The lack of bird remains among stomach contents may be inconclusive in this case because of the small sample size and the difficulty of recognising egg remains.

The impact of Ship Rats on the avifauna of Lifou is likely to be important even if the peak of abundance in this species, in May and July, is before the beginning of the main bird breeding season (August to January, mainly September to November) (Robinet and Salas, in press). However, the continuous decline since the beginning of the century of the Blue-faced Parrotfinch *Erythrura trichroa cyaneifrons* and of the Island Thrush *Turdus poliocephalus pritzbueri*, in Lifou may be related to the presence of Ship Rat (Macmillan, 1939; Warner, 1947; Hannecart and Létocart, 1983).

5.4. Consequences for the conservation of the Ouvea Parakeet

The Ouvea Parakeet, which is endemic to this island, has declined continuously since its first description (Layard and Layard, 1882), as a result of the destruction of its habitat and capture by islanders for the pet market. Now only 3–600 birds (100–120 pairs) are assumed to be left in the wild mostly in a small (2–3000 ha) patch of forest in the north of the island (Robinet et al., 1996). The small size and the decreasing trend of both its population and habitat, meeting the Mace and Lande (1991) criterion of endangerment, have led both local and international conservation agencies to fear extinction (Hannecart, 1988; Lambert et al., 1993). A translocation of these birds to the island of Lifou, seemed at first one of the most promising techniques for its conservation.

The results of this study, however, show that in Ouvea, the high hatching success observed on Ouvea Parakeets nests (Robinet, et al., in prep.) is related to relatively low-impact predation exerted by Kiore (and other predators). In contrast, the almost four fold higher predation rate observed in Lifou, because of Ship Rats, is unlikely to allow a sustainable population of Ouvea parakeets to establish in this island. Alone it may thus explain the failure of two previous translocation attempts of this bird in Lifou (Delacour, 1966; Hannecart, 1988; Robinet et al., 1995).

The very high predation in Lifou was observed in height classes of nest position and thus shows that higher nest sites do not offer better protection against Ship Rats. If any translocation of Ouvea Parakeet is to be undertaken again in Lifou, it will need to be accompanied by aggressive rat control, as well as the provision of artificial nests and/or rat proofing of natural nest sites. Research on the design of suitable rat-proof nest boxes and a careful cost/benefit evaluation is thus needed to be sure of the long-term sustainability of this program.

The eradication of rat species was undertaken with success throughout the world in islands up to 130 ha (Veitch and Bell, 1990), and is currently being undertaken for islands up to 2000 ha with the rapid improvement of techniques (I. McFadden. pers. comm.). The size of Ouvea (13 000 ha) and Lifou (115 000 ha), are, however, far too big to consider the possibility of eradicating rats in the next decade. In contrast, the ability of researchers to significantly reduce the predation rate of Kiore on Ouvea suggest that even a low intensity rat trapping or poisoning programme on Ouvea may markedly assist the parakeets. A rat control, by trapping and poisoning during the breeding season was used successfully for the recovery of the Kakerori *Pomarea dimidiata* in Cook Islands (Robertson et al., 1995). It is also currently undertaken on a large scale to increase the breeding success of the Kokako *Callaeas cinerea wilsoni* in the forests of New Zealand (Innes et al., 1995). The Ouvea Parakeet would certainly benefit from a similar operation. The ongoing absence of rat other than Kiore from Ouvea is important for the long-term survival of the Ouvea Parakeet, and hence protection measures as outlined by Robinet and Salas (1996) must be implemented.

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