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The Introduced and Native Terrestrial Vertebrates of Fiji[1]

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ABSTRACT: A complete list of native and introduced Fijian terrestrial vertebrates has been compiled that includes a number of previously unrecorded reptiles. An analysis has been made of the habitat distribution of most species. The past and present status of the various native vertebrates is examined, and the impact of post-European vertebrate introductions on the indigenous and endemic fauna is assessed in the light of current knowledge. It is concluded that the success of certain introduced bird species is due in part to their close association with human-modified habitats, while the native species are primarily adapted to a forest environment. Although the introduced mongoose may be implicated in the decline of some native vertebrate species, its effect may be less important than previously stated and is certainly less than the effect of native habitat destruction and environmental modification by humans.

NUMEROUS STATEMENTS MAY BE FOUND in the literature concerning the effect of introduced plant and animal species on the native communities found on Pacific islands (Berger 1972, Guppy 1906, Thaman 1974, Williams 1953). The bulk of such comments refer to deleterious effects in terms of causing reduction in numbers of native species; or the elimination of such species from certain habitats, areas, or islands through competitive exclusion (Mercer 1964, Parham 1956, Thaman 1974, Watson 1960, Wood and Wetmore 1925); or direct mortality due to introduced predators (Brewster 1935, Gorman 1972, 1975*a*, *b*, Mercer 1964). In contrast, Lack (1975) suggests that the introduced land birds of Jamaica have had no direct or indirect competitive effect on the native species and that the successful establishment of certain post-European bird introductions results from their close association with people.

The purpose of the present paper is to assess the extent of the interaction between introduced and native species of terrestrial vertebrates in Fiji. It is based upon an extensive review of the often anecdotal literature, together with 9 years of observational data on birds (D. W.) and the extensive collection and observation of reptiles, amphibia, and mammals by both authors on various islands of the Fiji group.

THE FIJI ISLAND GROUP

The Fiji group consists of approximately 320 islands located between 16° and 20° S, 177° W, and 175° E. The land area totals 18,270 km², the bulk of which forms two major islands, Viti Levu and Vanua Levu (Figure 1). Southwest tradewinds blow steadily from September to April, resulting in a hot, wet summer and a drier, cooler winter. Mean monthly temperatures range from 23°C in July and August, to 27°C in January; humidity ranges from 75% during winter to 88% in summer (Fiji Weather Bureau statistics).

The geological history of the islands indicates that Viti Levu consists of an Eocene

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volcanic base, Miocene clastic sediments, and volcanic intrusives (Houtz and Phillips 1963). Later periods of uplift have resulted in extensive areas of reef-formed limestone and coastal sedimentary deposits being located far from the present coast. Vanua Levu and Taveuni appear to be formed from coalesced centers of volcanic activity of Mid- to Upper-Miocene age linked in part by reef-formed limestone (Rickard 1966). The islands are, therefore, a mixture of high, large, volcanic landmasses with a number of smaller limestone islands and sandy cays. The high central plateaus and mountains of the main islands (1200+ meters) create a significant rain shadow, such that the western sides of these islands are drier and have more distinct seasonal weather differences than the eastern sides. The rugged and eroded landscape of the main islands is a consequence of their recent geological origin and high annual rainfall (mean: 300 cm on the east coast; 165 cm on the west coast).

HABITAT TYPES

The habitat types of Fiji have received a great deal of attention and have been classified in various ways by different authors (Berry and Howard 1973, Gibbs 1909, Parham 1972, Smith 1951, Sykes 1933, Twyford and Wright 1965). It would appear, however, that prior to the arrival of the Europeans and the development of large-scale cash crops such as sugar cane and copra, much of these islands was forested (Twyford and Wright 1965). The major plant communities that still exist in quite large areas are the lowland and montane rain forests, coastal communities and mangroves, inland swamps, mixed grassland and light forest of the intermediate zone, and grasslands of the western sides.

The lowland forest is dominated by hardwoods such as *Callophyllum vitiense* and *Endospermum macrophyllum* and occupies the wetter eastern regions from sea level to 600 meters. On the coast are found communities of various species of *Pandanus*, *Barringtonia*, and *Hibiscus*, together with *Cocos nucifera* and *Ipomea braziliensis*, which are replaced in estuarine and soft sediment areas by mangrove forests of *Rhizophora* spp. and *Bruguiera* spp. At elevations from 600 to 1200 meters lie the montane forests, which may once have occurred down to 300 meters on the drier western side of Viti Levu. Such forests are characterized by tree ferns, *Cyathea* spp., the tree *Podocarpus vitiensis*, and the valuable softwood, *Agathis vitiensis*. Smaller areas at higher elevations consist of a high montane or cloud forest, with stunted trees and abundant moss and epiphytic growth. Another minor but important habitat is the inland swamp, often fringed with *Pandanus* spp. and dominated by the reed *Phragmites*. A number of these swamps lack open water and are little more than peat bogs (Twyford and Wright 1965).

On the western sides of the main islands, much of the original forest has been replaced by cultivated fields and grassland. Twyford and Wright (1965) suggest that grassland habitats are maintained in an early seral stage as a result of periodic firing by humans. They are dominated by the introduced mission grass, *Pennisetum polystachyon*, and wire grass, *Sporobolus indicus*, which have replaced the native reed grass, *Miscanthus floridulus*, in most areas (Parham 1956). Between the grasslands and agricultural areas of the west and the forests of the east lies an intermediate rainfall zone with mixed cover. The leeward hill slopes carry grasses as well as reed or bamboo, *Bambusa* spp. or *Schizostachyon glaucifolium*, while the windward slopes are lightly forested. Several introduced, invasive, scrubby weeds, such as *Piper aduncum*, *Psidium guajava*, and *Leucaena leucocephala*, are abundant in this zone while the aboriginally introduced Makosoi, *Canaga odorata*, is a common tree of forest associations.

Figure 1 shows the present distribution of habitat types on the main islands of Fiji. It can be seen that the bulk of modern agricultural activity is concentrated in the coastal and dry zones. To suggest that over the last 150 years European colonizers have been entirely responsible for the destruction of original lowland forest cover and the present extent of the grasslands is probably incorrect.

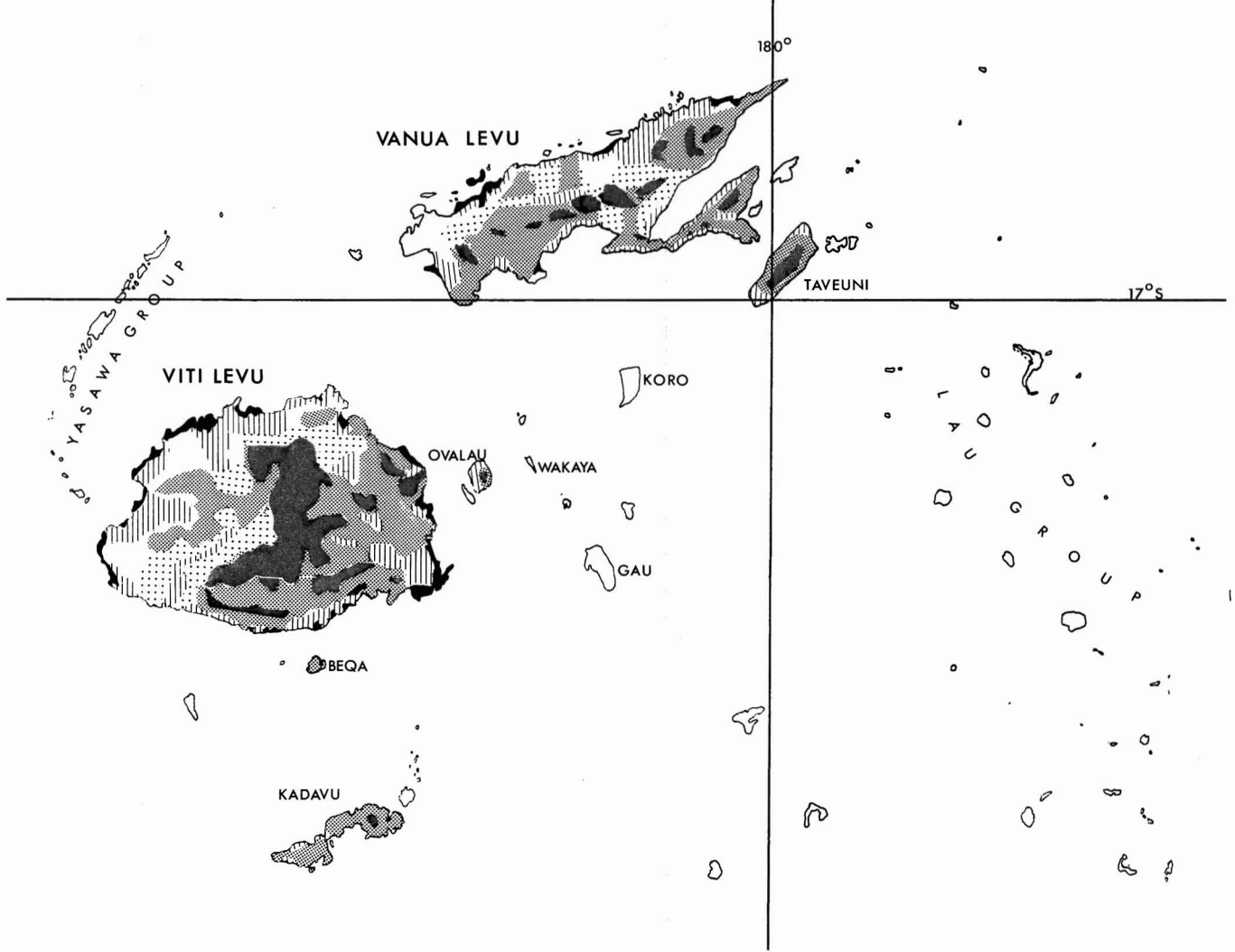

FIGURE 1. Map of the main islands of the Fiji group named in the text. Scale 1 cm = 45 km. The distribution of major habitats is indicated as follows: ▩ = Montane forest; ▒ = Lowland forest; ⁝⁝⁝ = Intermediate zone vegetation; |||| = Agricultural land; ■ = Mangrove swamps; □ = Grassland.

TABLE 1

HABITAT DISTRIBUTION OF FIJIAN TERRESTRIAL VERTEBRATES

	FOREST								
	MONTANE	LOWLAND	INTERMEDIATE ZONE	AGRICULTURAL	SUBURBAN	COASTAL/MANGROVE SWAMPS	FRESHWATER INLAND SWAMPS	NUMBER OF SPECIES OMITTED	TOTAL NUMBER OF SPECIES
Amphibia	2	2	—	—	—	—	2*	—	2
Reptilia	9	9	9	6†	6†	8	3	5	21‡
Aves	38	46	31	23	15	17	11	6	59
Mammalia	3	4	3	1	—	1	—	—	6
Total native species	52	61	43	30	21	26	16	11	88
Introduced species, all classes	5	5	10	16	13	5	1	10 unsuccessful introductions	18

NOTE: A number of species that may be extinct or for which data are not available have been omitted (see Appendix).
*In forest only.
†Three species in association with buildings only.
‡Data for the two nominal *Engyrus* spp. are combined, since the authors were unable to distinguish them (Burt and Burt 1932).

Although pre-European agriculture appears to have been of a shifting, clearance type (still extensively practiced in many areas), its effect on natural vegetation may have been great. Berry and Howard (1973) identified large areas of mature secondary forest within the lowland rainforest habitat of the interior of the larger islands. This, combined with the observation of old, abandoned village sites; village names on early maps and in written and verbal records where no villages are found today; and, in places, extensive hill terracing which is no longer practiced; suggests the occurrence of widespread forest clearance in pre-European times. This, in turn, indicates the presence of a far larger, more industrious population in the inland parts of the major islands than has previously been suspected. This suggests that secondary habitats may have been present for a long period in prehistory and thus have been an important part of the environment of the native animals. Secondary habitats may also have been significant on small islands subjected to not infrequent hurricane damage.

A possible sequence of events in habitat terms may be outlined as follows: initially, prior to human arrival, the islands were probably forested from shore to mountain top, with some relatively small areas of native grassland occurring in restricted areas of the dry zone. As the aboriginal population increased, patchy clearance of forests around the coast and inland along river valleys created a mozaic of secondary plant growth following agricultural clearance. Clearance of forest in the intermediate and dry zones by the use of fire created more extensive areas of grassland. European forestry and agricultural activities further increased the area of such secondary habitats; changed the floral composition through the introduction of exotic weeds and the selective elimination of some plant species such as sandalwood, *Santalum yasi*; and greatly increased the land area under permanent cultivation.

HABITAT UTILIZATION BY TERRESTRIAL VERTEBRATES

Table 1 and the Appendix present data on the habitat distribution of native vertebrates. It is at once apparent that the bulk of the native species of birds (87 percent, $n = 53$), amphibia (100 percent, $n = 2$), reptiles (59 percent, $n = 17$), and mammals (66 percent, $n = 6$) are found predominantly in forest habitats.

In the case of the reptiles, the skinks found

in agricultural and suburban habitats were ground-dwelling open habitat types such as *Emoia cyanura*, or species confined to coastal communities such as *Lipinia noctua* and *Emoia nigra*. Of the geckos, three of the five species collected during the present study were found only in association with humans, and their original, natural habitats are unknown. Of the 17 reptile species that are well known from the group, seven are confined to primary forest or forest associations of the intermediate zone. The two native amphibia are similarly confined to primary forest, and the native mammals (all bats) feed mainly in forest associations. Although at least four of the six bats may occasionally be seen in agricultural or suburban situations, these are not their primary habitats but are utilized merely as feeding areas on an intermittent basis.

The bulk of the native species of birds are found in forest situations. Only 23 species (43 percent) may be observed in agricultural areas and 15 (28 percent) in suburban habitats (Table 1). Eighteen of the 59 native land birds are confined to forest habitats or the intermediate zone, and all those species observed in agricultural and suburban situations also occur in forest habitats (see Appendix). Exceptions are the swamp and coastal rails (four species), the reef heron, *Demigretta sacra*, the little mangrove heron, *Butorides striatus*, and the Pacific swallow, *Hirundo tahitica*.

It is also apparent from Table 1 and the Appendix that in a majority of cases, native forest vertebrates may be found in both montane and lowland wooded habitats, a point noted by Gorman (1975*b*) in the case of birds. This suggests that there is a lack of the habitat and ecological specialization among Fijian vertebrates that is characteristic of mainland vertebrate faunas (Lack 1971).

INTRODUCED VERTEBRATES

Table 2 presents details of the successful introductions of vertebrates to Fiji. These animals fall into two categories—the aboriginal introductions and the post-European introductions, both deliberate and accidental.

It has long been accepted that the Melanesian and Polynesian peoples transported plant and animal species that were economically or culturally important from island to island. In the case of the terrestrial vertebrates, the jungle fowl, *Gallus gallus*, domestic pig, *Sus scrofa*, and Polynesian rat, *Rattus exulans*, probably all represent introductions of important protein sources (Bahr 1912, Gressitt 1956, Tate 1935). Since both the Pacific boas, *Engyrus* (= *Candoia*) spp., and the Fijian ground frog, *Platymantis vitianus*, were extensively consumed in Fiji prior to the arrival of the Europeans (and are still eaten in some areas), they may well represent additional, deliberate, prehistoric introductions of potential food sources.

Except for such intentional introductions, the role of aboriginal peoples in the accidental transport of reptiles and amphibians has received little attention to date. In view of the extensive voyages undertaken in the Pacific by such people, and the large food and planting stocks carried by them, it is not inconceivable that eggs or even adults of many small species may have been carried from Papua New Guinea and the Solomons to Fiji. A number of the geckos and skinks presently found in Fiji lay their eggs in cracks in tree bark and might equally well lay eggs between the planks or in the cargo of voyaging canoes drawn up the beach for loading. In addition, eggs might be accidentally included in planting stocks (Pernetta and Goldman 1977) or leaf mold used to pack plant roots for transport. While such accidental transport of amphibians (Darlington 1957) and especially small reptiles is probable, the accidental transport of birds is highly unlikely.

In contrast to aboriginal introductions, the species of vertebrates introduced following European colonization are more numerous and varied. They include deliberate introductions as early attempts at biological control. The cane or marine toad, *Bufo marinus*, was introduced from Hawaii in 1936 to control various coleopterous pests of sugar cane, banana, and other cash crops (Hinkley 1962). The small Indian mongoose, *Herpestes auropunctatus*, was introduced in

TABLE 2

INTRODUCED TERRESTRIAL VERTEBRATES CURRENTLY ESTABLISHED IN FIJI

SPECIES	DATE OF INTRODUCTION	DISTRIBUTION	STATUS	HABITAT	DIET
Bufo marinus marine or cane toad	1936	Main islands	Common	Agricultural, urban, suburban	Millipedes, Orthoptera, Hymenoptera
Gallus gallus jungle fowl	Aboriginal	Formerly all islands (?)	Rare	Forest, inland swamps	Insects, seeds, fruit
Synoicus australis brown quail	c. 1900	Viti Levu, Vanua Levu	Rare	Agricultural, grass	Seeds
Acridotheres tristis Indian mynah	c. 1890	Main islands	Common	Agricultural, suburban, urban	Insects, fruit, refuse
Acridotheres fuscus jungle mynah	c. 1890	Main islands, except Taveuni	Common	Agricultural, suburban, urban, scrub	Insects, fruit
Pycnonotus cafer red-vented bulbul	c. 1900	Viti Levu, Ovalau, Wakaya Beqa, Taveuni	Common Present, but rare	All habitats	Fruit, insects
Streptopelia chinensis Malay turtle dove	c. 1900	Main islands	Common	Agricultural, urban, suburban	Seeds, grain
Amandava amandava strawberry finch	c. 1900	Main islands	Common	Agricultural, urban, suburban, grass	Seeds
Padda oryzivora Java rice sparrow	c. 1930	Viti Levu, Vanua Levu, Taveuni	Locally abundant	Agricultural, urban, suburban, wet zone only	Seeds, grain
Gymnorhyna tibicen black-headed magpie	c. 1900	Taveuni	Locally abundant	Coconut plantations	Seeds, insects, fruit
Sturnus vulgaris European starling	c. 1930	Ono-i-Lau, Votua	Locally abundant	Agricultural, villages	Fruit, insects, seeds
Columba livia domestic pigeon	c. 1900	Towns only	Locally common	Urban, suburban, agricultural (rare)	Grain, food refuse
Sus scrofa domestic pig	Aboriginal	Main islands	Common	Forest, intermediate zone, grass	Fruit, roots
Rattus exulans Polynesian rat	Aboriginal	All islands	Abundant	All habitats	Vegetable seeds, roots, insects
Rattus norvegicus brown or Norway rat	Nineteenth century	Main islands	Common	Agricultural, urban, suburban, coastal	Vegetables, grain, refuse
Rattus rattus black rat	Nineteenth century	Main islands	Locally abundant	Agricultural, plantations, urban, suburban, coastal	Fruit, vegetables
Mus musculus house mouse	Nineteenth century	Viti Levu, Vanua Levu	Locally abundant	Urban, suburban, agricultural	Vegetable seeds, fruit, refuse
Herpestes auropunctatus small Indian mongoose	1883	Viti Levu, Vanua Levu	Common	All habitats	Invertebrates, amphibia, aves, reptiles, rodents

1883 to control rats in sugar cane (Gorman 1975*a*). The black-headed magpie, *Gymnorhyna tibicen*, was introduced from Australia around 1900 to control phasmid pests of coconut (A. Tart, personal communication). The Indian and jungle mynahs, *Acridotheres tristis* and *Acridotheres fuscus*, were introduced from India around 1890 to control orthopterous pests of sugar cane (Veitch 1923). In addition, deliberate introductions of other species were made, some of which were successful—for example, the brown quail, *Synoicus australis*, and Sambar deer, *Cervus unicolor* (introduced to Wakaya Island only)—and some of which were not—such as the turkey, *Meleagris gallopavo*, pheasant, *Phasianus* sp., an unidentified grouse species, laughing kookaburra, *Dacelo gigas*, tawny frogmouth, *Podargus strigoides*, and partridge, *Perdix* sp. (Wood and Wetmore 1925). The bulk of the remaining bird introductions appear to have been made as cage birds or for esthetic reasons. Unsuccessful introductions of this kind include the blackbird, *Turdus merula*, spotted-sided finch, *Stegonopleura guttata*, Australian crow-shrike, *Strepera melanoptera*, magpie lark, *Grallina* (*cyanoleuca* ?), and native companion, *Antigone rubicunda* (Wood and Wetmore 1926). Of the eleven successful bird introductions, the jungle fowl, both mynahs, Malay turtle dove, and strawberry finch are at present found on all main islands; the red-vented bulbul is common only on Viti Levu but is also found on Ovalau, Wakaya, Beqa, and Taveuni; the black-headed magpie is found only on Taveuni; the European starling is found only on Ono-i-Lau and Votua; the domestic pigeon is restricted to large towns; and the Java rice sparrow is found only on the wet sides of Viti Levu, Vanua Levu, and Taveuni. The brown quail is rare and restricted to the grasslands of western Viti Levu and Vanua Levu. Mercer (1964) suggests that the European starling may represent a ship-assisted natural colonization from Australia or New Zealand, via the Kermadec Islands, because no record exists of its deliberate introduction and it appears to be a relatively recent addition to the avifauna [it was not mentioned by Wood and Wetmore (1925, 1926)]. A similar explanation may be advanced for the occurrence of the domestic pigeon.

Accidental introductions by Europeans include the three rodent species as commensals of humans (*Rattus norvegicus*, *Rattus rattus*, and *Mus musculus*), all of which have succeeded in establishing feral populations that are closely associated with buildings and agricultural land. Domestic animals such as horses and cattle are also widespread throughout the islands and may roam in a relatively unrestricted manner over the unfenced grasslands of the dry and intermediate zones. In a number of localities in the intermediate zone of Viti Levu and Kadavu, feral goats are found in small numbers. These animals are also found on various islands, such as Goat Island in the Yasawas, and Namara Island in the Kadavu group. Although European introductions of dogs and cats have resulted in their widespread distribution throughout the islands, no feral populations of these animals are known at present. European breeds of domestic pigs and sheep are maintained under agricultural conditions, as are large numbers of fowl, ducks, geese, and turkeys.

STATUS OF THE NATIVE SPECIES

In assessing the present status of the native vertebrates, one is faced with the problem of a lack of good biological data on the ecology and numbers of such species. However, useful historical information on the birds may be found in Bahr (1912), Finsch and Hartlaub (1867), Layard (1875, 1876), and Wood and Wetmore (1925, 1926). Similar information may be obtained for the reptiles and amphibia from Burt and Burt (1932), Mertens (1934), Schmidt (1923), and, more recently, Brown (1956), Gorham (1965, 1968), and Watson (1960).

Although the literature on birds does not provide sufficient data to form definitive conclusions concerning changes in the status of all Fijian native species, it is possible to state conclusively that the banded rail, *Rallus phillipensis*, sooty rail, *Porzana tabuensis*,

white-browed rail, *Poliolimnas cinereus*, and purple swamphen, *Porphyrio porphyrio*, were all common on Viti Levu in the last century. These now survive in any numbers only on islands that are free of the mongoose. Similarly, the Australian gray duck, *Anas superciliosa*, was once recorded as abundant by Brewster (1935) and Seeman (1862), but it is now relatively uncommon on Viti Levu.

The nominate subspecies of the rare, native, long-legged warbler, *Trichocichla rufa rufa* is known from only four specimens, the last of which was collected in 1894. However, a different subspecies, *T. rufa clunei*, has recently been discovered on Vanua Levu (Kinsky 1975). The pink-billed parrot finch, *Erythrura kleinschmidti*, and the red-throated lorikeet, *Charmosyna amabilis*, have apparently always been rare (Mayr 1945, Mercer 1964), although *E. kleinschmidti* has recently been found attempting to nest in secondary forest on Viti Levu (Clunie 1973). The barred-wing rail, *Nesoclopeus poeciloptерus*, is now possibly extinct, and the whistling tree duck, *Dendrocygna arcuata*, is almost certainly extinct. These may always have been rare (Mayr 1945, Mercer 1964), although Layard (1875) terms the former species as "generally distributed." A. von Hugel notes on the label of a specimen he collected on Ovalau in 1877 (now in the Cambridge University Zoological Museum) that it was "difficult to procure," but whether he was alluding to the elusive habits of this rail or to its rarity is not clear. The grass owl, *Tyto longimembris*, is known from only two specimens collected on Viti Levu in the 1860s and has not been seen since and may be extinct (Clunie 1972*b*).

The smaller reptiles are, on the whole, common and widely distributed throughout the group regardless of the presence of the mongoose, although the patchy distribution of many species makes comparison between islands with and without the mongoose difficult. It is interesting to note that during the present work an undescribed species of *Emoia* (Brown and Pernetta in prep.) was encountered on Viti Levu, Taveuni, and Kadavu. Also, two species of gecko, *Hemidactylus garnotti* and *Hemiphyllodactylus typus*, previously unrecorded from the group, were collected in several localities. This would seem to indicate either that these species are recent introductions or that earlier work on the reptiles of these islands has been far from systematic. Both gecko species were encountered only in close association with buildings. These species are widely distributed throughout the Pacific (Brown 1956), and neither were recorded by Watson (1960); thus, the possibility of their recent introduction from other Pacific islands via interisland copra boats or other vessels is not remote. In the case of the *Emoia* sp. novum, this possibility is less likely because the species was encountered only in inland forest habitats on the three islands.

Apparently, a number of the larger reptile species have, like many of the birds, always been rare. The elapid snake, *Ogmodon vitianus*, has been only occasionally collected on Viti Levu. During the present investigation, a single headless specimen (possibly a mongoose kill) was collected in the intermediate zone. The agamid lizard, *Goniocephalus godfreyi*, is known from only two specimens collected in the late nineteenth century (Boulenger 1887). W. C. Brown (personal communication) seriously doubts the existence of a natural population of this species in Fiji and suggests that the two known specimens were not collected in Fiji. The two semiarboreal boas are both difficult to find, rather than really rare, and may still be regularly encountered in the intermediate zone of Viti Levu. However, they are possibly less common on this island than on Ovalau and Taveuni. Indirect confirmation of the continued existence of snakes on Viti Levu comes from Gorman's (1975*a*) analysis of mongoose feces. Four percent of those collected from lowland forest contained snake remains. The banded iguana, *Brachylophus fasciatus* (the only Fijian terrestrial vertebrate with neotropical affinities), has apparently declined in numbers over the last century on both Viti Levu and Taveuni (Cahill 1970, Cogger 1974, Gorman 1975*a*) but is still common on Kadavu and various smaller islands (Cogger 1974).

According to Gorham (1965, 1968), the

TABLE 3

INTERSPECIFIC AGGRESSION BETWEEN *Pycnonotus cafer* AND OTHER BIRDS IN THE SIGATOKA VALLEY, VITI LEVU, FIJI

BULBUL AGGRESSOR	SPECIES	BULBUL RECIPIENT
7	*Lalage maculosa*, Polynesian triller	—
7	*Acridotheres tristis*, jungle mynah	1
8	*Acridotheres fuscus*, Indian mynah	4
5	*Foulehaio carunculata*, Wattled honeyeater	12
3	*Zosterops lateralis*, gray-backed white-eye	—
—	*Artamus leucorhynchus*, white-breasted wood swallow	1
2	*Amandava amandava*, strawberry finch	—
—	*Halcyon chloris*, white-collared kingfisher	1
1	*Streptopelia chinensis*, Malay turtle dove	—
1	*Myiagra vanikorensis* Vanikoro broadbill	—
Totals 34		19

NOTE: Data from 411 hr of observation, February 1974–January 1976.

two Fijian frogs are now both less common in localities where early collectors recorded them as abundant. Gorman (1975*a*) states that their decline on Viti Levu is attributable to the mongoose. However, the field investigations of one of the present authors (J. C. P.) suggests that the tree frog is capable of maintaining high densities in areas where the mongoose is also abundant. Although it is probable that the arboreal behavior of this species reduces its susceptibility to ground predators in comparison with the more terrestrial ground frog, both species may be found on Viti Levu (Gorham 1968, Pernetta and Goldman 1977) and there is no evidence to suggest that they are significantly less common in the presence of the mongoose than in its absence. Gorham (1968) suggests that habitat destruction may be responsible for their decline in certain localities, particularly on the island of Ovalau.

Of the six bat species, four are abundant throughout the group, while *Tadarida jobensis* is known only from Taveuni, where it may be seen hawking insects among the crowns of coconut palms at the southern end of the island. The recently discovered *Pteralopex* sp. is known from a single specimen collected in montane forest on the same island (W. Beckon, personal communication).

In addition to the above, two further literature records should be mentioned: the marine crocodile, *Crocodylus porosus*, and the long-necked water tortoise (species unknown). In the latter case [listed by Loveridge (1945)], the record is unsubstantiated by either specimens or detailed observations, and thus may be taken as an error. In the former case, however, Derrick (1965) gives a reliable account of the killing of a single crocodile that may well represent a vagrant individual of *C. porosus* from the Solomons. Despite the presence of large areas of suitable habitat in the form of mangrove swamp and river deltas, a breeding population of this species does not appear to be present in the islands.

INTERACTION BETWEEN INTRODUCED AND NATIVE VERTEBRATES

During the course of extensive work on the ecology of the red-vented bulbul in Fiji (Watling 1977), records were kept of direct interaction between this and other species of birds. The numbers of encounters observed over 411 hr of transect counts are summarized in Table 3. In 34 (64 percent) of the encounters, the bulbul initiated attacks against eight species, four of which were native species. The wattled honeyeater, *Foulehaio carunculata*, and the Polynesian triller, *Lalage maculosa*, were the most frequently attacked native species, but both were challenged less frequently than the two introduced mynah

TABLE 4

DIET, SIZE, FEEDING STATION, AND HABITAT OF POTENTIAL AVIAN COMPETITORS ON VITI LEVU, FIJI

	SIZE (cm)	NATIVE (n) OR INTRODUCED (i)	FEEDING STATION	HABITAT
Granivores				
Erythrura pealii	10	n	Ground zone/understory (partly insectivorous)	Agricultural, grass, intermediate, forest
Amandava amandava	10	i	Ground zone	Urban, suburban, agricultural, grass, intermediate
Padda oryzivora	14	i	Ground zone	Suburban, agricultural, wet zone
Synoicus australis	16	i	Ground zone	Agricultural, grass, intermediate
Streptopelia chinensis	30	i	Ground zone	Urban, suburban, agricultural, grass
Gallicolumba stairii	37	n	Ground zone	Forest
Frugivores				
Aplonis tabuensis	17	n	Canopy/understory	Forest
Pycnonotus cafer	18	i	Scrub/ground zone	Urban, suburban, agricultural, grass, forest edges
Ptilinopus perousii	20	n	Canopy	Forest
Ptilinopus luteovirens	20	n	Canopy/understory	Forest, intermediate
Columba vitiensis	37	n	Canopy/scrub	Forest, intermediate, agricultural, grass
Ducula latrans	40	n	Canopy	Forest
Prosopeia personata	48	n	Canopy/understory	Forest, intermediate
Flower/nectar feeders				
Myzomela jugularis	10	n	Scrub/understory/canopy	Forest, intermediate, agricultural, suburban, urban
Foulehaio carunculata	16	n	Scrub/canopy	Forest, intermediate, agricultural, suburban, urban
Charmosyna amabilis	16	n	Canopy	Forest
Phigys solitarius	20	n	Canopy	Forest, intermediate, agricultural, suburban
Gymnomyza viridis	26	n	Canopy	Forest
Omnivores				
Acridotheres fuscus	21	i	Ground	Suburban, agricultural, intermediate
Acridotheres tristis	23	i	Ground	Urban, suburban, agricultural
Columba livia	35	i	Ground	Urban, suburban
Gallus gallus	55	i	Ground	Forest, intermediate
Insectivores				
Petroica multicolor	10	n	Aerial, understory	Forest
Zosterops explorator	11	n	Scrub/understory/canopy	Grass, intermediate, forest
Zosterops lateralis	11	n	Scrub/understory/canopy	Grass, intermediate, forest
Collocalia spodiopygia	12	n	Aerial	All habitats
Vitia ruficapilla	13	n	Scrub/understory	Forest, intermediate
Myiagra vanikorensis	13	n	Aerial, all	All habitats
Myiagra azureocapilla	13	n	Aerial, canopy/understory	Forest
Mayrornis lessoni	13	n	Aerial, canopy/understory	Forest, intermediate
Hirundo tahitica	13	n	Aerial	Urban
Rhipidura spilodera	13	n	Aerial, understory	Forest, intermediate
Artamus leucorhynchus	16	n	Aerial/ground	All habitats
Lalage maculosa	17	n	Ground/understory	All habitats
Clytorhynchus vitiensis	18	n	Understory	Forest, intermediate
Clytorhynchus nigrogularis	18	n	Canopy/understory	Forest
Turdus poliocephalus	20	n	Ground zone/scrub	Forest, intermediate
Cacomantis pyrrhophanus	24	n	Understory/scrub	Forest, intermediate

NOTE: Data from personal observation (D. W.) and Mercer (1964). See Table 2 and Appendix also.

species. The wattled honeyeater initiated aggressive encounters more frequently than it received them, and this species accounted for 12 of 19 attacks directed toward the bulbul. A monthly breakdown of bulbul aggressive activity showed that most interspecific aggression occurred during the breeding season. Of the total of 53 encounters, 8 involved aggression by the bulbuls around their nests, 7 involved food, and 38 were of unknown causes. This, combined with similar evidence for the two introduced mynah species (Watling 1975), suggests that direct aggressive activity between introduced and native species does not occur often enough to explain entirely the habitat separation of the two groups.

Food is perhaps the most important item of potential competition between introduced and native species. The bulk of the introduced birds are medium-sized omnivores or granivores. The native bird fauna in the same size range is composed of small specialized insectivores and a single granivore that also feeds a great deal on insects (Table 4). The rare finch *Erythrura kleinschmidti* appears to be primarily an insectivore (Clunie 1973). In the case of the native frugivores, however, the red-vented bulbul constitutes a potential competitor, except that the feeding strategies and stations of the species are different. The bulbul, which might be termed an "opportunist frugivore" (McKey 1973), feeds primarily on the fruits of introduced, invasive weeds found in secondary seral associations (*Solanum torvum* and *Piper aduncum*) and cultivated land (*Physalis angulata*) (Watling 1977). Almost all native frugivores feed mainly in forest associations on native and aboriginally introduced fruits such as the makosoi, *Canaga odorata*, kauvula, *Endospermum macrophyllum*, and koka, *Bischoffia javanica*. The exception, the white-throated pigeon, *Columba vitiensis*, feeds extensively on the fruits of *S. torvum* and is frequently seen in agricultural areas.

Bulbuls may be readily observed in open forest situations in the intermediate zone, feeding in association with native species and without direct aggressive interactions. Such sightings, however, are usually made in or around areas of secondary vegetation such as river banks, old land slips, or forest clearings.

In the case of the marine toad, no direct or indirect ecological interaction is apparent with the native amphibia, as they are essentially separated on a habitat basis. The toad is a ground feeder and takes large numbers of Diplopoda, Orthoptera, and Hymenoptera (Hinkley 1962) in open situations. The two native frogs are found either along stream banks or in foliage in dense forest, and apparently feed on night-flying insects (Gorham 1968, Pernetta and Goldman 1977). Although large adult *Bufo marinus* may occasionally be encountered in the lowland forests and secondary forest areas, large viable populations of this species are only maintained in the flatter coastal areas. This may be because the species has a free-swimming tadpole stage that would be swept away during the flash floods to which the montane streams are subjected. The native frogs overcome this difficulty by laying eggs in *Pandanus* leaf axils and rotting logs, and metamorphosis occurs within the egg, resulting in the emergence of a fully formed frog (Gorham 1968, Pernetta and Goldman 1977).

The more recently introduced rats and mice have no apparent effect on the distribution of the prehistorically introduced *Rattus exulans*, as all three species may be found in the same habitats. There is some indication that the Norway rat is more abundant in suburban situations than the other two species (Table 5); that the black rat may preferentially inhabit plantations and coconut palm crowns (Williams 1971, 1973); and that these species are restricted in their distribution to a close association with humans (Table 5).

DISCUSSION

In discussing the effect of vertebrate introductions on the native fauna of Fiji one should first make the point that all introduced species, with the exception of the small Indian mongoose and to a lesser extent the red-vented bulbul, are closely associated with

TABLE 5

PERCENTAGE COMPOSITION OF RODENT SAMPLES FROM DIFFERENT HABITATS, FIJI

	COASTAL COCONUT PLANTATIONS, TAVEUNI	INTERMEDIATE ZONE VEGETATION, NEAR NATIVE GARDENS AND HOUSES, VITI LEVU	BARN OWL PELLET REMAINS—INTERMEDIATE ZONE, VITI LEVU	SUBURBAN SUVA, VITI LEVU	NAMARA, UNINHABITED ROCKY ISLET, KADAVU GROUP
Mus musculus	—	14	10	36	—
Rattus exulans	80	77	82	8	100
R. rattus	—	1	—	18	—
R. norvegicus	20	8	8	38	—
Total number of animals	20	113	61	39	21

human-modified habitats. In contrast, the bulk of the native species are confined to, or more frequently encountered in, the forest habitats. Of the 32 species of nonpredatory land birds regularly seen on Viti Levu, only one—the Pacific swallow—was not observed in lowland or montane forest. However, only 16 of these 32 native species are regularly seen in agricultural land and only 13 in suburban and urban situations. While it may be reasonably assumed that the Pacific swallow should have increased in numbers since urbanization (following an increase in potential nest sites and hunting areas), no concrete evidence exists support this.

Several views may be advanced to explain the habitat isolation of native and introduced bird species. First, the native species are adapted to forest habitats and are incapable of modifying their behavior and ecology to invade the secondary human-modified habitats. Second, the native species are forced out of such habitats by competition for food and nesting sites with introduced species. Third, direct predation by the mongoose has reduced the numbers of native species in habitats where the mongoose is abundant. Fourth, direct destruction by people or effects of human activities (such as the destruction of nest sites or areas of former habitat, or the use of insecticides) have caused a decline in the native species in human-modified habitats.

The use of insecticides to control insect pests of various cash crops has been noted as the cause for the decline of the banded iguana on Taveuni (Cahill 1970). In view of the fact that this species is a specialized flower feeder (most commonly encountered in forest) and that the Fiji Agriculture Department strictly controls the types of insecticide imported and used in the country, such an explanation is unlikely. Similarly, since many native and introduced bird species appear to thrive in agricultural situations, selective elimination or reduction in numbers of individuals of some native species due to insecticide poisoning seems unlikely.

The mongoose has been blamed for the decline of the banded iguana, native frogs, and various bird species on Viti Levu. Although some circumstantial evidence does exist for the coincident decline of various ground-dwelling bird species on Viti Levu with the spread of this predator, the work of Gorman (1975*a*) has shown that much of the present diet of this species is composed of invertebrates and introduced vertebrates such as rats and the cane toad. Historical evidence, in combination with evidence from islands where these native species are presently common but where the mongoose is absent, suggests that the mongoose is indeed implicated in their decline. In contrast, a number of rare bird species that are now possibly extinct (see Appendix) were apparently rare prior to the introduction of the mongoose. In considering the impact of this predator on

the reptile fauna and native frogs, it seems that its effect may have been overemphasized. In the case of the smaller lizards and the tree frog, observations made during the present study indicate that these animals may occur normally in a rather patchy distribution and are able to maintain high population numbers in areas where the mongoose is also abundant. Gorman (1975*a*) records that in some areas of Viti Levu, the ground frog and snakes are still eaten by the mongoose, indicating that they are still sufficiently abundant to contribute part of the diet of this species. The mongoose has been present on Viti Levu for nearly 100 years and its spread and numerical increase were rapid, suggesting that its prey have been subjected to the present level of predation for a considerable time. It would appear that the snakes and frogs are able to maintain viable populations under such predation pressure.

In regard to the effect of competition between introduced and native species, the paucity of observations of direct interaction between these two groups, combined with the fact that some native vertebrates successfully maintain populations in human-modified environments, suggests that the section of the native fauna capable of utilizing such habitats has done so. Whether competition with introduced species has resulted in lower population densities of these native species in human-modified habitats than might be possible in their absence is unknown. One must conclude that interspecific competition is relatively unimportant in the majority of cases, because the present situation has existed for about 80 years and because none of the rare native species compete in any way with the introduced species.

When one considers the native species that are now confined to forest habitats, one sees that the possibility of competitive exclusion of such species from other habitats exists. Examination of the Appendix shows that species found only in forest environments are the giant forest honeyeater and pink-billed parrot finch, while the generally forest-inhabiting blue-crested broadbill and black-faced shrikebill were only occasionally encountered in the intermediate zone vegetation. An additional six species of birds that are regularly encountered in the intermediate zone vegetation fail to range into agricultural land, although potential competition with introduced birds provides an explanation of this restricted distribution for only one native species.

In Fiji, the Polynesian starling, *Aplonis tabuensis*, is restricted to forest areas. It is not frequently seen in the intermediate zone, and never in agricultural or urban situations; this observation is supported by Gorman (1972, 1975*b*). However, on Tongatapu, Tonga, the same species is a common bird all over the island, which is denuded of natural vegetation and intensively farmed. This starling was also regularly seen in urban Nuku'alofa (Watling, personal observation). Although the frugivorous bulbul is a likely potential competitor, the habitat range of *A. tabuensis* on Vanua Levu, where the bulbul is absent, is no different from that on Viti Levu. In addition, the bulbul is also present on Tongatapu, Tonga, and on Upolu and Savai'i in Samoa, where it frequently occurs in the same habitat as *A. tabuensis*. The jungle mynah, *Acridotheres fuscus*, is not present in Tonga and is only a recent arrival in Samoa [Dhondt (1976) incorrectly identifies it as being *Acridotheres tristis* (Watling in press)], so the present restricted range of *A. tabuensis* in Fiji may be due to the combined competitive pressure from both mynah species. Similarly, the present restricted range of the European starling in Fiji may be due to competitive exclusion from other areas by these two species. On Tongatapu, in the absence of the mynahs, the European starling does well.

If, as is suggested above, the two gecko species discovered during the present study do represent recent additions to the Fiji fauna, then evidence for competitive interactions between them and the species *Lepidodactylus lugubris* and *Gehyra oceanica* is notable by its absence, since all four species may be encountered on the walls of the same buildings. It is probable that the marked difference in size between species reduces potential competition for the live insect food upon which all four species prey.

The occurrence of six, or possibly eight, species of the skink genus *Emoia* is of interest. From the data available, it appears that habitat isolation is important in the maintenance of these species on the same islands. Both *Emoia concolor* and *E. samoensis* are arboreal; the former is confined to coastal areas and the open woodlands of the intermediate zone, while the latter is abundant in the lowlands and montane forests. W. C. Brown (personal communication) considers that these two nominal species are in fact conspecific, as they are inseparable on the basis of squamation. If this is the case and the two animals represent two color morphs of *E. samoensis*, then it is of interest to note the apparent habitat separation between them. *Emoia nigra*, a large ground-dwelling species, is again confined to coastal areas and is abundant beneath coconut palms, whereas the smaller *E. cyanura* is found in open situations from the coast to forest glades. The undescribed *Emoia* sp. novum is similar in size to *E. cyanura*, but is apparently confined to inland forests; occasionally, both species may be found together. *Emoia caeruleocauda* is smaller in size than the preceding two species and like them is found on the forest floor. Although both *E. adspersa* and *E. cyanogaster* are recorded from Fiji (Sternfield 1920, Werner 1899), they were not encountered during the present study and their ecological interactions with the other species are unknown.

In examining the native fauna of Fiji it is noticeable that, with the exception of the reptiles, the number of sympatric congeners is low. One congeneric pair of bats and six pairs of birds overlap in habitat and altitudinal range on Viti Levu: *Pteropus*, *Ptilinopus*, *Clytorhynchus*, *Myiagra*, *Zosterops*, *Erythrura*, and, doubtfully, *Tyto*. The two *Tyto* species occur sympatrically from Africa to Australasia, and thus competition is an unlikely explanation for the apparent demise of the grass owl in Fiji. Although the native congeners overlap in habitat on Viti Levu, only the *Clytorhynchus* pair do not have clearly separable optimum habitats. In the other cases, one species is restricted to forest habitats and the other is a more generalized species with wide habitat tolerance. In the case of the two fruit bats, *Pteropus tonganus* is strongly colonial and feeds in forest areas and coconut plantations, whereas *Pteropus samoensis* is solitary, feeding in more open habitats.

With the exception of the *Mayornis* pair that occur together on Ogea Levu only, all other congeneric species are allopatrically distributed within the Fiji Island group (Appendix). This overall low occurrence of sympatric congeneric pairs is in accordance with the findings of Lack (1969, 1975), who suggests that due to the absence of such pairs, birds on islands generally show relaxed ecological isolation with consequent expansion of individual species' habitat utilization. This is in contrast to mainland situations where habitat and ecological isolation are important features of bird faunas. It is possible that in the case of the birds, at least, these congeneric Fijian pairs represent speciation through double invasion, with the earlier arriving and speciating form being restricted to the primary forest habitats for which they had become better adapted.

The importance of people in the decline of some of the native species should not be underestimated. Both the barred-winged rail and jungle fowl were once hunted with dogs (Bahr 1912, Mercer 1964) and, in inland areas of Viti Levu, the banded iguana was eaten by the hill tribes (Cahill 1970). In addition, as previously mentioned, boas and native frogs are still eaten in some areas and were more extensively eaten in the past. Perhaps of greater impact on the native fauna is the extensive deforestation that has accompanied the expansion of modern agriculture. Such habitat destruction may have an important effect on the ecological communities to which many of the native species are adapted. It should be noted, however, that large tracts of land are still covered with mature forest, and due to the nature of the terrain the complete deforestation of these islands is improbable. This, combined with the protection now afforded native species by the Fiji government, may be sufficient to maintain the present surviving members of the native fauna.

CONCLUSIONS

With the probable exception of the Polynesian starling, no evidence exists to support the claim that direct or indirect competition between native and introduced species has restricted the distribution of the former. It would appear that the introduced species of birds, mammals, and amphibia have expanded in numbers and range as a result of the creation of suitable habitats through prehistoric and historic agricultural activities. Further, most native species are adapted to a forest environment and a number may be incapable of adapting—ecologically and behaviorally—to human-modified habitats. The introduced small Indian mongoose has probably caused the decline in abundance of various ground-living birds on the islands of Viti Levu and Vanua Levu. However, the possible extinction of the barred-winged rail, grass owl, and whistling tree duck, and the present rarity of the red-throated lorikeet, pink-billed parrot finch, long-legged warbler, and banded iguana cannot be directly attributed to this or any other introduced vertebrate.

APPENDIX

HABITAT, DISTRIBUTION, STATUS, AND ORIGINS OF FIJIAN VERTEBRATES

ORIGINS/ STATUS	SPECIES	PREFERRED HABITAT TYPES 1	2	3	4	5	6	7	DISTRIBUTION AND COMMENTS
	Amphibia								
1 (A) E	*Platymantis vitiensis* Fiji tree frog	†	†					†	Viti Levu, Vanua Levu, Taveuni, Ovalau
1 (A) E	*Platymantis vitianus* Fiji ground frog	†	†					†	Viti Levu, Vanua Levu, Taveuni, Ovalau
P.E.	*Bufo marinus* marine or cane toad	*	*		†	†	†		Main islands
	Reptiles								
	Goniocephalus godfreyi								Viti Levu; only two known specimens (Boulenger 1887)
E	*Brachylophus fasciatus* banded iguana	?	†						Widespread
3 (A)	*Engyrus bibronii* and *Engyrus australis* Pacific boa	†	†	†	*	*	†	†	Widespread; two nominal species not valid (Burt and Burt 1932)
(1) E*	*Ogmodon vitianus* bolo	†	†	†					Viti Levu; only 18 known specimens (Gorham 1970)
1 (A)	*Gehyra oceanica* oceanic gecko	†	†	†	†	†	†	†	All islands
1 (A)	*Lepidodactylus lugubris* mourning or Pacific gecko				†	†			Buildings only; widespread
E	*Lepidodactylus manni* Fiji; Mann's gecko	†	†	†					Previously known from few specimens. Abundant on rock faces. Viti Levu only
(1) E	*Lepidodactylus gardineri* Rotuma gecko				?	?			Rotuma

NOTE: Data based on observations of birds over 9 years (D. W.); Collection of 124 specimens and approximately 230 additional recorded observations of reptiles and amphibia; mist netting and observations of bats; and 254 trapped specimens of rodents.

KEY TO SPECIES ORIGINS: E, species endemic to Fiji islands only; E *, genus or subgenus endemic to Fiji; A, aboriginal introduction; (A), probable aboriginal introduction; P.E., post-European introduction; (P.E.), possible post-European introduction; N, indigenous species; M, migrant species; V, vagrant species; 1, species colonized from Papua, New Guinea, region; 2, species colonized from Australia; 3, species colonized from Papua, New Guinea, or Australia; 4, species endemic to central Polynesian subregion (Fiji, Samoa, Tonga, and outlying islands); 5, species of probable central Polynesian origin, now more widespread; 6, species widespread, entered the Pacific via the Philippines. Numbers in parentheses indicate possible origin on the basis of close relationships between endemic species and those found elsewhere. For example, (1) 4 N *Vini australis*, blue-crowned lory—native species to Fiji; endemic to the central Polynesian subregion; a closely related species indicating a Papua, New Guinean, origin.

KEY TO PREFERRED HABITAT TYPES: 1, montane forest; 2, lowland forest; 3, intermediate zone vegetation (including grassland); 4, agricultural land; 5, suburban and urban; 6, coastal and mangrove swamps; 7, freshwater and inland swamps; †, normal habitat; *, occasional habitat.

APPENDIX (*Cont.*)

HABITAT, DISTRIBUTION, STATUS, AND ORIGINS OF FIJIAN VERTEBRATES

ORIGINS/ STATUS	SPECIES	PREFERRED HABITAT TYPES 1	2	3	4	5	6	7	DISTRIBUTION AND COMMENTS
6 (P.E.)	*Hemidactylus garnotti* fox gecko				†	†			Buildings only; Viti Levu, Taveuni
6 (P.E.)	*Hemiphyllodactylus typus* tree gecko				†	†			Buildings only; Viti Levu
1 (A) N	*Cyrtodactylus pelagicus* pelagic gecko	†	†	†					Forest floor; main islands only
1 (A) N	*Lipinia noctua* moth skink					†	†		Coastal/dry zones
1 (A) N	*Cryptoblepharus boutoni* snake-eyed skink						†		Supralittoral zone
1 (A) N	*Emoia nigra* black skink				†		†		Coastal/plantation ground zones
(1) E	*Emoia concolor* green skink			†	*	*	†		Palm trees in agricultural and suburbs
(1) 5 N	*Emoia samoensis* Samoan skink	†	†	†					Widespread
(1) 5 N	*Emoia cyanura* striped skink	†	†	†	†	†	†		Widespread
(1) E	*Emoia* sp. novum	†	†	†					Viti Levu, Taveuni, Kadavu
1 N	*Emoia caeruleocauda* blue-tailed skink	†							Viti Levu, Taveuni
	Emoia adspersa and *Emoia cyanogaster*								Not seen by present authors (Sternfield 1920, Werner 1899)
	Long-necked water tortoise (species unknown)								Record unsubstantiated by specimens (Loveridge 1945)
1 V	*Crocodylus porosus* estuarine crocodile								Single record of this species (Derrick 1965)
	Birds								
3 N	*Demigretta sacra* reef heron						†	†	Widespread
3 N	*Butorides striatus* little mangrove heron						†		Large islands
3 N	*Anas superciliosa* Australian gray duck						†	†	Large islands, decreased
P.E.	*Anas platyrhynchos* domestic duck								Under domestication only
3 N	*Dendrocygna arcuata* whistling tree duck						?	?	Extinct? Viti Levu, Vanua Levu (Mayr 1945)
P.E.	*Anser anser* domestic goose								Under domestication only
E	*Accipiter rufitorques* Fiji goshawk	†	†	†	†	†			Widespread
2 N	*Circus approximans* swamp harrier	†	†	†	†				Widespread
3 N	*Falco peregrinus* peregrine falcon	†	†	†	*	(‡)			Viti Levu, Wakaya (‡Clunie 1972*a*)
A	*Gallus gallus* jungle fowl	?	†	†					Common on large islands free of the mongoose; otherwise rare/absent
P.E.	*Synoicus australis* brown quail			†					Viti Levu, Vanua Levu; grasslands only, uncommon
P.E.	*Meleagris gallopavo* domestic turkey								Under domestication only
3 N	*Porphyrio porphyrio* purple swamphen		†		†			†	Common on islands free of the mongoose; otherwise rare/absent

APPENDIX (*Cont.*)

HABITAT, DISTRIBUTION, STATUS, AND ORIGINS OF FIJIAN VERTEBRATES

ORIGINS/ STATUS		SPECIES	PREFERRED HABITAT TYPES 1	2	3	4	5	6	7	DISTRIBUTION AND COMMENTS
	E	*Nesoclopeus poecilopterus* barred-wing rail								Viti Levu, Ovalau; extinct?
3	N	*Rallus phillipensis* banded rail				†		†	†	Common on islands free of the mongoose; otherwise rare
3	N	*Poliolimnas cinereus* white-browed rail						†	†	Rare; recorded from Viti Levu, Ovalau, Gau (Mayr 1945)
3	N	*Porzana tabuensis* sooty rail						†	†	Rare; recorded from Viti Levu, Ovalau, Gau, Kadavu (Mayr 1945)
4	N	*Ptilinopus perousii* many-colored fruit dove	†	†	†		*			Widespread
4	N	*Ptilinopus porphyraceus* crimson-crowned fruit dove		†		†				Outlying islands
	E	*Ptilinopus victor* orange dove	†	†						Vanua Levu, Taveuni, and adjacent islands
	E	*Ptilinopus luteovirens* golden dove	†	†	†	*				Viti Levu, Ovalau, Gau, Yasawas
	E	*Ptilinopus layardi* velvet dove		†						Kadavu group
	P.E.	*Streptopelia chinensis* spotted; Malay turtle dove				†	†			Main islands
4	N	*Gallicolumba stairii* friendly ground dove	†	†	*					Widespread
5	N	*Ducula pacifica* Pacific pigeon		†						Outlying islands
	E	*Ducula latrans* Peale's pigeon	†	†	†					Widespread
	P.E.	*Columba livia* domestic pigeon				*	†			Large islands
1	N	*Columba vitiensis* white-throated pigeon	†	†	†	†	†			Widespread
	E	*Charmosyna amabilis* red-throated lorikeet	†	(‡)						Viti Levu, Ovalau, Taveuni (‡Gorman 1975*b*)
(1) 4	N	*Vini australis* blue-crowned lory		†		†				Outlying islands
	E*	*Phigys solitarius* collared lory	†	†	†	†	†	†		Southern Lau
	E*	*Prosopeia tabuensis* red-breasted musk parrot	†	†		†				Koro, Gau, Kadavu, Taveuni, Vanua Levu; Introduced Viti Levu (Wood and Wetmore 1926)
	E*	*Prosopeia personata* yellow-breasted musk parrot	†	†	†					Viti Levu, ?Ovalau
2	N	*Cacomantis pyrrhophanus* fan-tailed cuckoo	(‡)	†	†	†				Large islands (‡Gorman 1975*b*)
	M	*Eudynamis taitensis* long-tailed New Zealand cuckoo		†	†					Migratory species
3	N	*Tyto alba* barn owl	†	†	†	†	†			Widespread
3	N	*Tyto longimembris* grass owl			(‡)					Extinct? Viti Levu (‡Clunie 1972*b*)
1	N	*Collocalia spodiopygia* white-rumped swiftlet	†	†	†	†	†	†	†	Widespread

APPENDIX (*Cont.*)

HABITAT, DISTRIBUTION, STATUS, AND ORIGINS OF FIJIAN VERTEBRATES

ORIGINS/	STATUS	SPECIES	PREFERRED HABITAT TYPES 1	2	3	4	5	6	7	DISTRIBUTION AND COMMENTS
1	N	*Halcyon chloris* white-collared kingfisher	†	†	†	†	†	†	†	Widespread
1	N	*Hirundo tahitica* Pacific swallow					†			Widespread
2	N	*Artamus leucorhynchus* white-breasted wood swallow	†	†	†	†	†	†	†	Not southern Lau, Kadavu
5	N	*Lalage maculosa* Polynesian triller	†	†	†	†	†	†	†	Widespread
	P.E.	*Pycnonotus cafer* red-vented bulbul		†	†	†				Common; Viti Levu, Ovalau, Wakaya; rare—Beqa, Taveuni
1	N	*Turdus poliocephalus* island thrush	†	†	†					Large islands
	P.E.	*Sturnus vulgaris* European starling								Ono-i-Lau only
5	N	*Aplonis tabuensis* Polynesian starling	†	†	†					Widespread
	P.E.	*Acridotheres fuscus* Indian mynah			†	†	†			Main islands, except Taveuni
	P.E.	*Acridotheres tristis* jungle mynah			†	†	†			Main islands
	E*	*Lamprolia victoriae* Silktail	†	†						Vanua Levu, Taveuni
	E	*Vitia ruficapilla* Fiji warbler	†	†	†	†	*			Large islands
	E	*Trichocichla rufa* long-legged warbler	?	?						Nominate race; Viti Levu; Extinct? rediscovered Vanua Levu
	E	*Rhipidura personata* Kadavu fantail		†						Kadavu
	N	*Rhipidura spilodera* spotted fantail	†	†	†	*				Large islands
	E	*Mayrornis lessoni* slaty flycatcher	†	†	†	*				Widespread
	E	*Mayrornis versicolor* versicolor flycatcher								Ogea Levu only
4	N	*Clytorhynchus vitiensis* Fiji shrikebill	†	†	†	†				Widespread
5	N	*Clytorhynchus nigrogularis* black-faced shrikebill	†	†	*					Large islands
(2)	E*	*Myiagra vanikorensis* Vanikoro broadbill	†	†	†	†	†	†	†	Widespread
(2)	E*	*Myiagra azureocapilla* blue-crested broadbill	†	†	*					Viti Levu, Vanua Levu, Taveuni
2	N	*Petroica multicolor* scarlet robin	†	†	†	*				Large islands
2	N	*Pachycephala pectoralis* golden whistler	†	†	†	*				Widespread
	E	*Myzomela jugularis* orange-breasted honeyeater	†	†	†	†	†	†		Widespread
2	N	*Myzomela cardinalis* cardinal honeyeater		?		?	?	?		Rotuma only
5	N	*Foulehaio carunculata* wattled honeyeater	†	†	†	†	†	†	†	Widespread
	E*	*Xanthotis provocator* Kadavu honeyeater		†		†	†	†		Kadavu
	E	*Gymnomyza viridis* giant forest honeyeater	†	†						Viti Levu, Vanua Levu, Taveuni

APPENDIX (*Cont.*)

HABITAT, DISTRIBUTION, STATUS, AND ORIGINS OF FIJIAN VERTEBRATES

ORIGINS/ STATUS		SPECIES	PREFERRED HABITAT TYPES 1	2	3	4	5	6	7	DISTRIBUTION AND COMMENTS
	E	*Zosterops explorator* Layard's white-eye	†	†	†	*				Large islands
2	N	*Zosterops lateralis* gray-backed white-eye	†	†	†	†	†	†	†	Widespread
	E	*Erythrura pealii* Fijian parrot finch	†	†	†	†	†	†		Widespread (see Ziswiler et al. 1972 for nomenclature)
	E*	*Erythrura kleinschmidti* pink-billed parrot finch	†	(‡)						Viti Levu (‡Clunie 1973)
	P.E.	*Amandava amandava* strawberry finch			†	†	†			Main islands
	P.E.	*Padda oryzivora* Java rice sparrow				†	†			Viti Levu, Vanua Levu, Taveuni
	P.E.	*Gymnorhyna tibicen* black-headed magpie				†				Coconut plantations; Taveuni only
		Mammals								
5	N	*Pteropus tonganus* Tongan fruit bat	†	†	†	*	*	†		Widespread
5	N	*Pteropus samoensis* Samoan fruit bat			†					Viti Levu, Vanua Levu
1	N	*Notopteris macdonaldi* long-tailed fruit bat		†	†	*				Large islands
1	E	*Pteralopex* sp.	†							Taveuni only (W. Beckon, personal communication)
3	N	*Tadarida jobensis* long-tailed mastiff bat				†				Taveuni only
1	N	*Emballonura semicaudata* sheath-tailed bat		†	†	†	*			Large islands
	P.E.	*Herpestes auropunctatus* small Indian mongoose	†	†	†	†	†	†		Viti Levu, Vanua Levu only
	P.E.	*Canis familiaris* domestic dog								Domestic only; widespread
	P.E.	*Felis domesticus* domestic cat								Domestic only; uncommon
1	(A)	*Rattus exulans* Polynesian rat	†	†	†	†	†	†		Widespread
	P.E.	*Rattus rattus* black rat				†	†			Large islands in association with people
	P.E.	*Rattus norvegicus* brown or Norway rat			†	†	†			Large islands in association with people
	P.E.	*Mus musculus* house mouse			†	†	†			Large islands in association with people
	P.E.	*Equus caballus* domestic horse								Domestic only; free-ranging in some grassland areas
	A	*Sus scrofa*	*	†	†	*				Aboriginally introduced pigs
	P.E.	domestic pig								feral on main islands; post-European introduction of various domestic strains
	P.E.	*Bos taurus* domestic cattle								Domestic; free-ranging in some grassland areas; widespread
	P.E.	*Bos indicus* Zebu cattle								Domestic; uncommon
	P.E.	*Ovis aries* domestic sheep								Domestic only; uncommon
	P.E.	*Capra hircus* domestic goat			†					Domestic; feral in grassland and on some small islands
	P.E.	*Cervus unicolor* Sambar deer								Wakaya Island only

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