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*Phil. Trans. R. Soc. Lond. B* 1990 **328**, 29-54  
doi: 10.1098/rstb.1990.0108

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## THE BIRDS OF THE KRAKATAU ISLANDS (INDONESIA) 1984–86

BY R. A. ZANN<sup>1</sup>, M. V. WALKER<sup>4</sup>, A. S. ADHIKERANA<sup>2</sup>, G. W. DAVISON<sup>3</sup>,  
E. B. MALE<sup>1</sup> AND DARJONO<sup>2</sup>

<sup>1</sup> *Department of Zoology, La Trobe University, Bundoora, Victoria 3083, Australia*

<sup>2</sup> *Museum Zoologicum Bogoriense, Bogor, Indonesia*

<sup>3</sup> *Department of Zoology, Universiti Kebangsaan Malaysia, Bangi, Selangor, Malaysia*

<sup>4</sup> *37 Johnson Street, Richmond, Melbourne, Victoria 3121, Australia*

(Communicated by Sir David Smith, F.R.S. – Received 19 September 1986 –  
Revised 14 December 1987)

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Fifty-five species of birds were recorded from the four islands of the Krakatau archipelago during three expeditions that took place in 1984, 1985 and 1986, just over a century after the destructive eruption of 1883. Thirty-six of these species were non-migrant land birds, the remainder seabirds, shorebirds or migrants. Fourteen species were recorded for the first time in this decade, eight of which are resident land birds. There were many new records for individual islands, especially for Panjang, an island ignored by previous expeditions; Anak Krakatau supported 24 species of resident land birds on some 12–14 ha (1 hectare = 10<sup>4</sup> m<sup>2</sup>) of vegetation. The avifauna of the Krakataus is compared and contrasted with that of two other islands in the Sunda Strait, Sebesi and Panaitan.

#### 1. INTRODUCTION

The birds of the Krakatau Islands (figure 1) are an important and conspicuous component of the fauna of the islands and, as such, their recolonization is of great intrinsic interest.

Furthermore, the birds of the archipelago have additional significance because of their implications for island biogeography theory; they were singled out for particular reference by MacArthur & Wilson (1967) in their seminal work on island biogeography theory.

In this paper, one of a series covering the recolonization of the Krakataus by various vertebrate groups, we list the species of birds now present on the different islands and habitats of the archipelago. We aim to provide a baseline of both raw data and methods for 1984–86 for comparison with past and future work on birds of the Krakataus. In a subsequent companion paper (Thornton *et al.* 1990) the process of bird recolonization is examined by using the new bird data, first, with respect to the whole archipelago and secondly, with special reference to the biogeographical predictions of MacArthur & Wilson (1967) on equilibrium and species turnover. In another paper on birds (Zann *et al.* 1990) we describe in detail the avifauna on the young emergent island, Anak Krakatau.

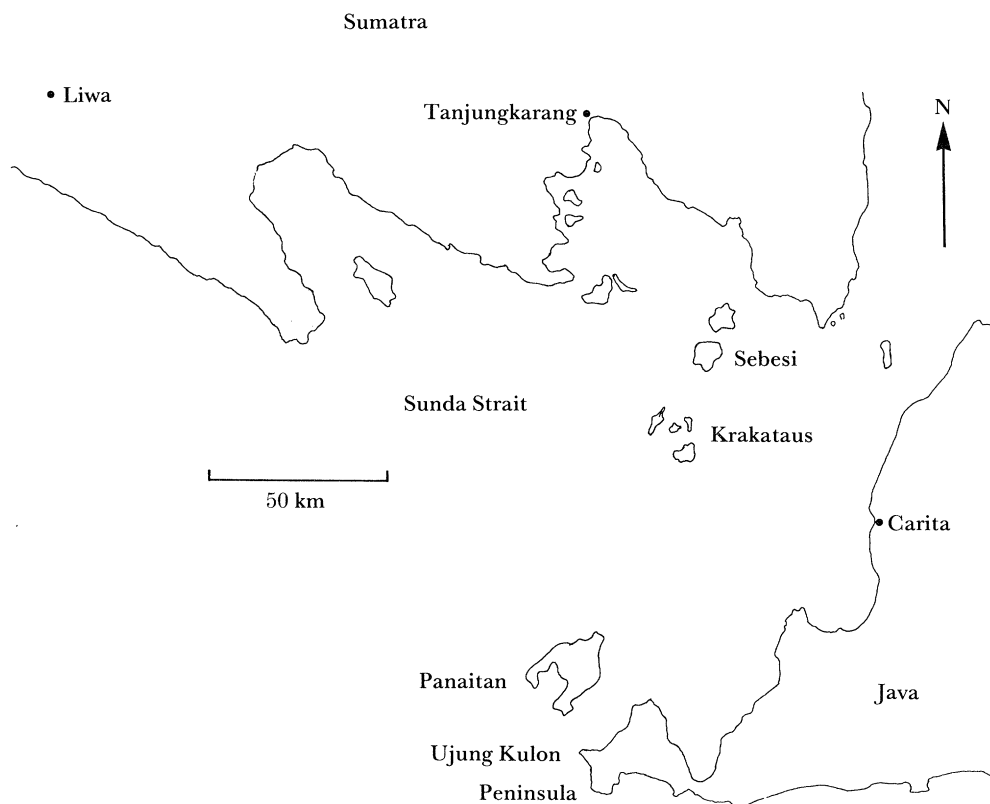


FIGURE 1. Sunda Strait and the Krakatau Islands, showing places mentioned in the text.

No records exist of the bird species inhabiting Krakatau before the 1883 eruption, and there have been surprisingly few surveys subsequently, despite the great scientific interest. Before our visit only four basic lists were made in the 100 years after the eruption. The first was produced in 1908 by Jacobson (1909) who found 16 species. From 1919 to 1934 Dammerman (1948) visited the islands on many occasions but the only systematic list exists for 1919–21 when he was accompanied by two ornithologists, M. Bartels and H. Siebers (Dammerman 1923), who found a total of 45 species. Although Dammerman himself was not an ornithologist it is possible to construct another list, of 48 species, from Dammerman's incidental sightings and collections

from 1930 to 1934, mostly in 1933. Thus there are three lists for the first fifty years. In the next fifty years the birds were surveyed only once, by Hoogerwerf (1953*a*) in 1951–52. He found 46 species.

## 2. METHODS

Our survey was part of a general survey of animals conducted by the 1984, 1985 and 1986 Zoological Expeditions to the Krakataus led by Professor I. W. B. Thornton. A general introduction to the archipelago and the work of the expeditions is provided by Thornton & Rosengren (1988).

The 1984 survey ran from 9 to 23 September (R. A. Z., A. S. A., M. V. W., G. W. D.), the 1985 expedition from 13 to 27 August (R. A. Z.) and the 1986 survey (Anak Krakatau only) from 16 to 30 September (E. B. M., D.). August and September are the driest months of the year in the region and the period when most species have completed breeding (Hoogerwerf 1953*b*).

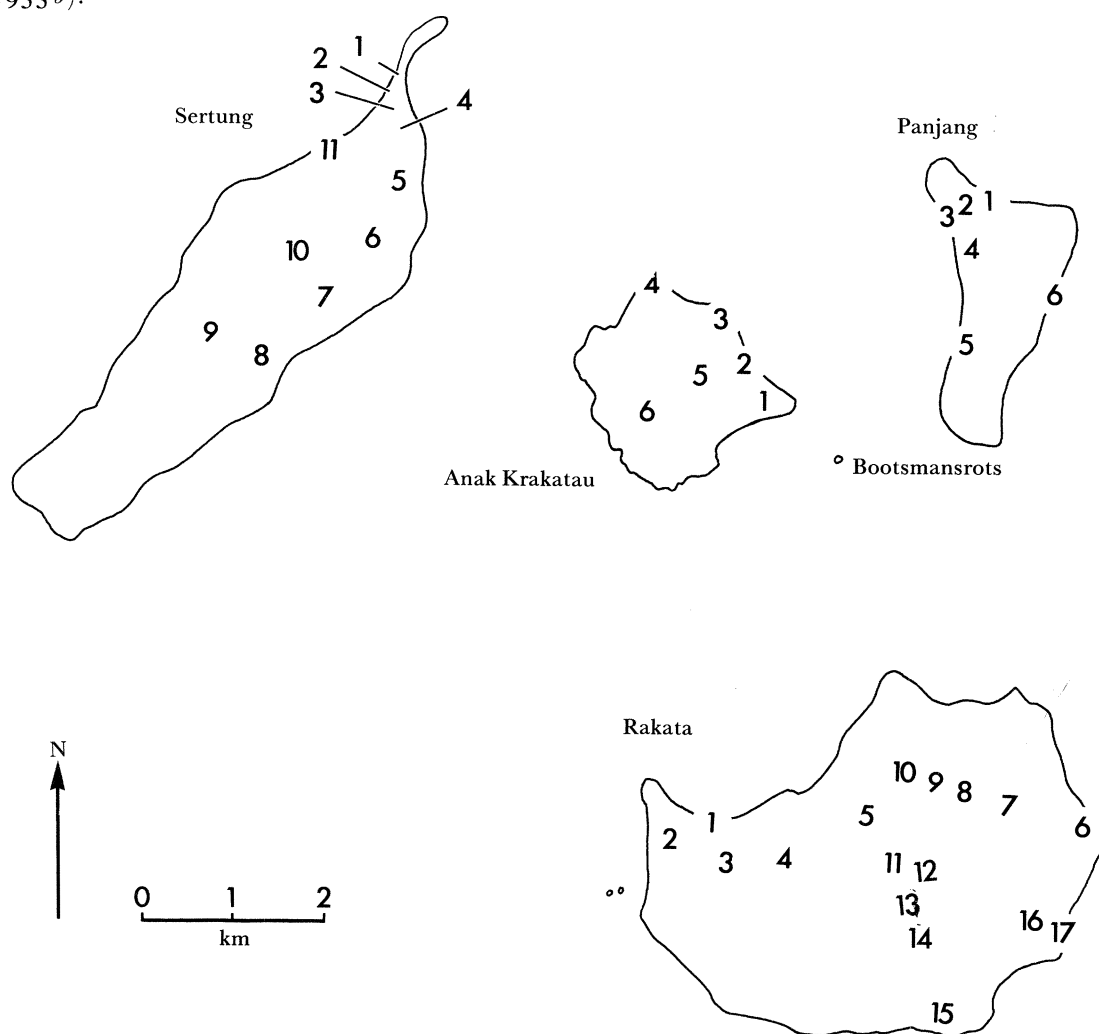


FIGURE 2. Bird study sites on the Krakatau islands. Each number represents at least one hour of observations; details are given in table 1. Overnight camps were made at the following sites: Rakata 1, 3, 5, 6 and 17; Sertung 1 and 9; Panjang 1 and 5; Anak Krakatau 1. Observations were frequently made offshore from a small boat, the routes of which are not shown; each island was circumnavigated at least once.

All islands and habitats of the 25000 ha† archipelago were surveyed for birds although it was not possible to make the intensity of coverage even over all study sites. The study sites are shown in figure 2, and table 1 summarizes the habitats at each site, the survey methods used and their extent. Each numbered site represents at least 1 h of the survey.

TABLE 1. BIRD STUDY SITES BY HABITAT, ISLANDS AND METHOD OF SURVEY

(Vegetation descriptions are based on Tagawa *et al.* (1984) and Whittaker *et al.* (1984); study sites are shown in figure 2; visual survey in man-hours with additional man-hours spotlighting given in brackets; mist-netting in square metres of net multiplied by number of rain-free hours for which nets were set; sound recording in hours.)

habitat	island	study site	visual survey	mist-netting	sound recording
I oceanic rock outcrop	Bootsmansrots	B	1	—	—
II volcanic ash-lava (desert)	Anak	5, 6, 7,	31 (6)	—	—
	Krakatau	8			
III <i>Casuarina-Ischaemum-Saccharum</i> (savannah woodland)	Anak	1, 2, 3	99 (10)	13351	6
	Krakatau				
IV <i>Imperata</i> (grassland)	Anak	4	8	—	—
	Krakatau				
V <i>Casuarina</i> (forest)	Sertung	1-3	22 (2)	699	—
VI <i>Barringtonia-Terminalia</i> (coastal forest)	Rakata	1, 6, 17	73 (28)	3446	2
	Sertung	11	4	—	—
	Panjang	1, 5, 6	18 (4)	—	—
VII <i>Neonauclea</i> (forest)	Rakata	2-3	51 (4)	1011	—
		7, 12-16	28 (8)	1573	0.3
VIII <i>Dysoxylum</i> (forest)	Sertung	4, 5, 10	13	935	1.0
	Panjang	2, 3	14	662	0.5
IX <i>Timonius</i> (forest)	Sertung	6-9	12 (1)	—	—
	Panjang	4	4	—	—
X <i>Neonauclea-Ficus</i> (moss forest)	Rakata	4	16	—	—
		8-11	7	—	—
XI <i>Schefflera-Leucosyke</i> (summit scrub and cliffs)	Rakata	5	10	—	—
total			411 (63)	21677	10

Sightings, vocalizations, mist-netting, sound recordings and playbacks were the survey methods used. We chose non-destructive methods because of difficulties associated with the use of firearms on the islands, which constitute part of the Ujung Kulon National Park, and because we were cognizant of the problems of destructive sampling on small and potentially fragile populations. Consequently, collecting was limited to specimens that could not be identified with confidence in the field. Of birds belonging to seventeen species, 215 were captured in mist nests over the three expeditions; all but nine individuals were released within 2 h of capture, four died in the net and five were killed to confirm identifications. All specimens are now lodged in the Museum Zoologicum Bogoriense, Bogor, Indonesia.

Although four of us were familiar with the birds of southeast Asia (A.S.A., three years experience in west Java; G.W.D., 10 years experience in Peninsula Malaysia, Borneo and Sumatra; D., five years experience in Java, Sumatra, Sulawesi and Irian Jaya; M.V.W., one year's experience in western Indonesia, mainly Java, Sumatra and Kalimantan); none had visited the Sunda Strait region before 1984. Hence, to familiarize ourselves with the field characteristics of birds expected on the Krakataus, in 1984 we visited two sites in western Java and one site in southern Sumatra before embarking for the islands (figure 1). These sites are

† 1 hectare =  $10^4$  m<sup>2</sup>.

now among the closest sources of potential colonists. Forty-five kilometres southeast of the Krakataus lies Ujung Kulon (52 475 ha), the famous national park of Java and sanctuary for the Javan rhinoceros. It is a wilderness area covered with primary and secondary lowland rainforest. The Carita area on the coast of west Java, about the same distance east of the Krakataus, consists of paddy fields and degraded secondary rainforest. We identified 91 species of birds from these two areas of west Java. In Sumatra, one of the most accessible sites close to the Krakataus with relatively undisturbed lowland rainforest is near Liwa, in the Barisan Selatan National Park (356 800 ha), some 180 km west of the islands, where 59 species were identified. At the above sites, and on the Krakatau islands, the field guide by King *et al.* (1975) was used extensively for identifications; Smythies (1981) was used occasionally. Hoogerwerf (1949) was used as an aid to identification of the endemic Javan species. As a result of these preparations we were familiar with many of the species we saw on our first visit to the Krakataus in 1984 (A. S. A., familiar with 58 % of species, G. W. D., 93 %; M. V. W., 70 % and R. A. Z., 47 %). Because of the previous experience of R. A. Z. and the increased incidence of singing, vocalizations were used more extensively for identification in 1985 than in 1984.

Mist-netting was done on all islands, but because of difficult terrain and limited access, not all habitats were sampled. *Timonius* forest on Panjang and Sertung, and the moss forest and summit scrub on the higher slopes of Rakata were the principal omissions. Most nets were 12 m × 3 m with 32 mm diagonal mesh; 9 m nets were used in dense vegetation and 18 m nets were used in open areas on Anak Krakatau. Most captives were weighed and measured and the moult in the right wing was scored. In 1986, on Anak Krakatau, birds were banded with coloured rings, weighed and measured; both crop and faecal samples were taken.

Mist-netting was used to confirm identifications and to detect furtive species not normally seen or heard. For example, the chestnut-capped thrush *Zoothera interpres* was captured in a net in 1984 on Rakata but not seen until the 1986 expedition to Anak Krakatau. Mist-netting was also used to obtain estimates of bird density, which is expressed as the number of birds captured per 1000 m<sup>2</sup> of mist-net per rain-free hour during which the nets were set.

Sound recordings were made on a Marantz Superscope cassette recorder with a Marantz dynamic microphone mounted on a Sony 330 mm parabolic reflector. The songs of birds expected on the Krakataus, but not seen in 1984, were played back on endless tape-loops at various sites in 1985 and 1986. The recordings of these songs were taken from White (1985). The calls of *Otus bakkamoena*, *Strix seloputo*, *Tyto alba* and *Eudynamis scolopacea* were played back on several islands, but all, except for the *Tyto*, were played back without result. On Anak Krakatau in 1984 the calls of *Aplonis panayensis* and *Centropus bengalensis* were recorded on tape but not recognized until after the 1985 expedition.

### 3. ANNOTATED LIST OF BIRDS

In the list below we follow the order and names adopted by King *et al.* (1975). The annotations after the scientific name are as follows: year of observation; island: R, Rakata; S, Sertung; P, Panjang; A, Anak Krakatau; (B+N), observations of Bush & Newsome (1986); (Ibkar), observations of Ibkar-Kramadibrata *et al.* (1986); site of observation, the number without brackets after each island's initial letter refers to the location in figure 2, the number in the brackets refers to the number of individuals seen during each observation, numbers with asterisks mean that only songs or calls were heard, identical observations on more than one

occasion are signified by multiples ( $\times$ ); general comments, these include any island and habitat restrictions, abundance and evidence of breeding and the collection of any museum specimens; number of individuals captured by mist-net and number undergoing wing moult; the existence of quality sound recordings made by the first author and held at La Trobe University; status, summarized as: (i) abundance (rare, occasional, moderately common, common, very common); (ii) distribution over islands and habitats (very restricted, restricted, widespread, very widespread); (iii) breeding state: breeding $\dagger$ , evidence from 1984–86; breeding\*, evidence from previous surveys; breeding presumed, no evidence but abundance and residential status indicates breeding; breeding status unknown, no evidence; (iv) residential status – resident, wanderer or migrant according to Chasen (1937) and Hoogerwerf (1953 *a, b*, 1970); (v) lifestyle – landbird, shorebird or seabird. Thirty-six of the 55 species listed are resident landbirds, and of these there are breeding records for 21. We have breeding evidence for 15, and presume breeding for another 13.

1. Lesser frigatebird *Fregata ariel*. 1979, (B+N). 1982, A (Ibkar). 1984, R (3), S (3), P (3), A (2). 1985, R (1)  $\times$  2, P (3).

The species was seen soaring and diving close to all four islands; diagnostic features of both sexes were observed. Status: occasional non-breeding seabird.

2. Greater frigatebird *Fregata minor*. 1983, (B+N). Status unknown.
3. Pacific reef-egret *Egretta sacra*. 1979, R, (B+N). 1982, A (Ibkar). 1983, R, S, P (B+N). 1984, R1 (1)  $\times$  2, A7 (1). 1985, S4 (1), P6 (1). 1986, A7 (2).

Single birds were seen hunting in shallow water on coral reefs in 1984 and 1985 and only grey forms were observed. On Anak Krakatau in 1986 the two birds seen were white. Both morphs were seen on Sertung and Rakata by Bush & Newsome. Status: occasional shorebird of unknown breeding status.

4. Brahminy kite *Haliastur indus*. 1984, R3 (1).

A single individual was observed soaring 300 m above Zwarte Hoek (R1) on 16 September 1984. Status: rare, breeding\*, present status unknown.

5. White-bellied sea-eagle *Heliaeetus leucogaster*. 1979, R, (B+N). 1982, A (Ibkar). 1983, R, S, P (B+N). 1984, R coast (2)  $\times$  2 (3), S2 (2), P6 (3). 1985, R6 (2), S3 (2), A1 (2), A5 (1)  $\times$  3. 1986, A5 (3), S4 (1).

In 1985 two immatures were observed on Anak Krakatau and one on Rakata; in 1986 another was seen on Sertung. A large nest was seen in a casuarina on southeast Panjang in 1984. Status: moderately common, widespread, breeding\* $\dagger$  resident landbird.

6. Black eagle *Ictinaetus malayensis*. 1983, R (B+N). 1984, R2 (1)  $\times$  2, R3 (1\*), P6 (1\*). 1985, R6 (4\*) (1), R1 (1), 3 (1), S1 (1\*) (1), S3 (1\*)  $\times$  2, S4 (1\*)  $\times$  3, P6 (1), P5 (1\*)  $\times$  3.

Frequently heard and seen soaring low over the forest canopy. On 22 September 1985 one was seen at R6 attacking a *Varanus salvator* about one metre long and attempting to fly off with it. When startled, it dropped the monitor, which then rushed to shelter beneath roots of a tree. Status: moderately common, widespread, resident landbird; breeding presumed.

7. Oriental hobby *Falco severus*. 1986, A3 (1)  $\times$  2, A4 (2), A5 (2).

On 25 September 1986 a bird was seen being mobbed by six *Artamus leucorhynchus*; it returned 20 min later and was mobbed again. On 26 September 1986 a pair was seen mobbing a white-bellied sea-eagle. Alain Compost (personal communication) saw this species flying and hovering round Rakata's summit in 1982. Status: occasional, restricted, resident landbird; breeding presumed.

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8. White-breasted waterhen *Amaurornis phoenicurus*. 1982, A (Ibkar). 1984, A1 (1\*) × 3. 1985, A1 (1) × 4 (1\*) × 5. 1986, A1 (2), A2 (2).

Despite living very close to our camp-site on Anak Krakatau this furtive species was rarely seen. The 'chuck' warning calls could occasionally be heard during the day and the raucous song heard for a few minutes each evening. An almost complete skeleton was found some 50 m up the slope of Anak Krakatau at A1 in 1985, and the bones of two legs at A5 in 1986. Recordings. Status: rare and very restricted, occasional, breeding\* resident landbird.

9. Greater sand-plover *Charadrius leschenaultii*. 1984, R1 (1), S11 (1).

Status: rare, migratory shorebird.

10. Common sandpiper *Actitis hypoleucos*. 1979, R (B+N). 1983, R, S (B+N). 1984, R17 (1) × 2, S11 (1). 1985, S1 (2), P5 (1), A3 (1). 1986, A1-3 (1).

Status: occasional migratory shorebird.

11. Great thick-knee *Esacus magnirostris*. 1979, R (B+N). 1982, A (Ibkar). 1983, R, S, (B+N). 1984, R17 (2), S11 (3) (1) (2), A1-4 (2) × 2 (1). 1985, S1 (1), A1-4 (1\*) (3) × 3. 1986, A1-4 (2) × 4.

Foot prints of the thick-knee were seen on most beaches and on Anak Krakatau birds were seen on the ash slope more than 400 m above the beach both in 1985 and 1986. Their melodious piping calls were recorded several times on Anak Krakatau (A1) at dusk. Recordings. Status: moderately common, breeding\* shorebird.

12. Whiskered tern *Chlidonias hybridra*. 1979, (B+N). 1983, (B+N).

Not seen by us. Status: wandering seabird.

13. Common tern *Sterna hirundo*.

A beach-washed specimen, found on the northern tip of Sertung on 12 September 1984, was deposited at the Museum Zoologicum Bogoriense. Status: rare, restricted, migratory, non-breeding seabird.

14. Roseate tern *Sterna dougallii*. 1983, (B+N).

Several were observed sitting on Bootsmanrots on 20 September 1984. Status: occasional, restricted, wandering non-breeding seabird.

15. Black-naped tern *Sterna sumatrana*. 1982 P (Ibkar).

Observed on Bootsmanrots on 20 September 1984. Status: rare, restricted, wandering non-breeding seabird.

16. Bridled tern *Sterna anaethetus*.

Several were seen 5 km east off Rakata on 9 September 1984. Status: rare, restricted, wandering non-breeding seabird.

17. Sooty tern *Sterna fuscata*. 1983, (B+N).

We did not sight this species. Status: rare, wandering seabird.

18. Little tern *Sterna albifrons*. 1979, (B+N). 1983, (B+N).

Not seen by us. Status: wandering seabird.

19. Great crested tern *Sterna bergii*. 1982, A (Ibkar).

Frequently observed feeding near Bootsmanrots; about 10 individuals were observed sitting there on 20 September 1984. Status: moderately common, restricted, wandering, non-breeding seabird.

20. Pink-necked pigeon *Treron vernans*. 1982, P (Ibkar). 1984, R2 (1) × 2, S1 (1), S6 (1). 1985, R16 (1) × 2, S1 (1) × 3, P4 (2). 1986, A1 (3) × 2 (1), A5 (1).

This species was found in *Casuarina* and *Neonauclea* forest on Rakata, *Casuarina* and *Timonius*



forest on Sertung, *Dysoxylum* forest on Panjang and on the eastern foreland of Anak Krakatau. In 1986 a pair and one immature were regularly seen together on Anak Krakatau; two skeletons were found in the valley between the outer and inner cones. We did not learn the call, hence it is probably more numerous than it appears. Status: common, widespread, breeding† resident landbird.

21. Black naped fruit dove *Ptilinopus melanospila*. 1984, R2–3 (1) (2) × 3. 1985, R6 (1), R12 (1), P5 (1).

On 16 September 1984 a female was captured at R3: her primaries were being replaced, with number 5 four-fifths grown. Status, moderately common, restricted, resident landbird, breeding presumed.

22. Green imperial pigeon *Ducula aenea*. 1983, R, S, P, (B+N). 1984, R17 (7), P1 (4). 1985, P5 (2).

All our observations were made on the coast near tall fringing trees. On 14 September 1984 a pair was observed in aerial display in the exact manner described by Smythies (1981). Status: occasional, restricted, resident landbird; breeding presumed.

23. Pied imperial pigeon *Ducula bicolor*. 1982, P (Ibkar). 1983, R, P (B+N). 1984, R15–17 (15) (12) (5), S5 (2) × 3 (4). 1985, R7 (4), S5 (30–40), P6 (10). 1986, P1 (2).

Individuals of this conspicuous species were usually seen from a boat offshore as they perched on or flew from the tops of tall trees. They were never far from the sea. Recordings. Status: locally common, widespread, wandering landbird; breeding presumed.

24. Sunda island cuckoo-dove *Macropygia phasianella*. 1982, P (Ibkar). 1983, R, S (B+N). 1984 R1 (2), R2 (1) × 2, S5 (1). 1985, R7 (1), R8 (1), R12 (1\*), S1 (1), P3 (1), P5 (2) (1\*), A1 (2). 1986, A1 (1\*), A1–2 (3) × 2, (2) × 2.

On 15 September 1984 in *Dysoxylum* forest on Sertung (S5) a bird was seen sitting on a nest with one fresh egg. In 1986 a pair of adults with an immature were seen several times on Anak Krakatau, and on two more occasions the pair were seen courting. Three skeletons were found at A8 in 1986. Two specimens were mist-netted on Rakata in 1984: one at R2 was regrowing secondary number 6, the other, captured at R3, was not examined for moult. Status: moderately common, widespread, breeding\*† resident landbird.

25. Green-winged pigeon *Chalcophaps indica*. 1984, R2 (1), S1 (1), P2 (2). 1985, R13 (1), S1 (1), P5 (1).

In 1984 two males and three females were mist-netted on Rakata (R1); three showed no wing-moult and one was regrowing primary number 10; one was not scored. Feathers from a corpse were found on Panjang. In 1985 two were mist-netted on Rakata (R5) but moult was not scored. Status: moderately common to common, widespread, breeding\* resident landbird.

26. Lesser coucal *Centropus bengalensis*. 1982, A, P (Ibkar). 1984, S1 (1), A1 (1\*) × 2. 1985, A1 (1) (2\*), A2 (3\*), A4 (2). 1986, A1 (1) (2\*), A4 (1\*).

The species is restricted to grasslands, mostly *Imperata cylindrica* and *Ischaemum muticum*. In 1984 calls of several birds were recorded on Anak Krakatau but no birds were sighted there; in 1985 three were flushed on Anak Krakatau. A pair of *Pachycephala cinerea* was seen mobbing one individual. Status: occasional, very restricted, breeding\* resident landbird.

27. Barn owl *Tyto alba*. 1982, R6 (1); A (Ibkar). 1985, S1 (1). 1986, A1 (1\*) × 4, A7 (2) (1, 2\*) (1\*).

In November 1982 Professor I. W. B. Thornton (personal communication) saw a masked owl from close range one night on Rakata (R6); he identified it as a barn owl. In June 1982 the call of a barn owl was heard by an Indonesian expedition camped on Anak Krakatau (Ibkar-

Kramadibrata *et al.* 1986). On 19 August 1985 a fleeting glimpse of a barn owl was made by two non-ornithologists on Sertung north of S1. Owl pellets and uric acid stains were found on Anak Krakatau (A7) on the 1984, 1985 and 1986 expeditions; on each occasion there were about twenty-five pellets, mainly consisting of fur and skeletal remains of *Rattus rattus*. The pellets were collected for detailed analysis. Two feathers, an eighth primary and an auxiliary were found at A8 and A1, respectively, and later matched to a skin in the Bogor Zoological Museum. The frequent observations on Anak Krakatau in 1986 suggest the presence of one pair. Status: rare, widespread, landbird of unknown breeding status.

28. Savanna nightjar *Caprimulgus affinis*. 1982, A (Ibkar). 1984, A1 (1). 1985, R1 (1\*), S1 (1\*), P5 (1\*), A1 (5) (1) × 2 (3) (4) (1\*). 1986, A1 (2), A2 (3).

Every dusk and dawn on Anak Krakatau nightjars could be heard and seen flying. Five was the most seen at one time; occasionally they would land on the ground. One was captured in a mist net on the beach at A1 in 1986. Recordings. Status: moderately common, widespread, breeding\* resident landbird.

29. Edible-nest swiftlet *Collocalia fuciphaga*. 1984, R1 (6), S1 (4), S3 (5), P3 (10), A1–3 (4) (1). 1985, P4 (8), A2 (1) (10). 1986, A4 (3), A3 (1).

A small dark swiftlet with dark underparts was often seen flying high above the shore and was assumed to be this species. Status: common, widespread, resident landbird; breeding presumed.

30. White-bellied swiftlet *Collocalia esculenta*. 1985, R6 (6–10), P5 (about 40).

A dark swiftlet with a pale belly and assumed to be *C. esculenta* was seen on two occasions in 1985; each time close, clear views were obtained. A very small empty nest of fibrous material was found on a ledge at the front of a large cave on Panjang, south of site P5. On 25 August 1985 about 40 swiftlets were seen flying low over the sea near the beach on Panjang (P5), occasionally touching the surface with their beaks. Status: moderately common, restricted, breeding† resident landbird.

31. House swift *Apus affinis*. 1984, R2 (8), R17 (2), S1 (c.5), P1 (1), A5 (6). 1985, R5 (3), S4 (15), A5 (5).

This white-rumped swift was distinguished from *Apus pacificus* by the slightly forked tail and the conspicuous rattling trill made by birds as they left their roost on the cliff face of Rakata (R2). This was one of the few birds flying about the outer cone of Anak Krakatau. Status: moderately common, widespread, resident landbird; breeding presumed.

32. Collared kingfisher *Halcyon chloris*. 1979, R, (B+N). 1982, P, A (Ibkar). 1983, R, S, A (B+N). 1984, R1 (3) × 2 (1), R2 (2) (3) (1), R3 (1), S1 (3), S9 (1), S10 (1), P2 (3), A1 (3) × 2. 1985, R1 (1\*), R6 (1\*) (1), R17 (2) (1\*), S1 (3), P2–3 (4), P5 (1), A1 (3) × 2 (1), A2 (1). 1986, A1 (2) × 4, A3 (3), A4 (1), A7 (2).

This, the only kingfisher on the Krakataus, was extremely conspicuous and was not recorded every time it was seen. It was the first bird seen and heard at almost every site below 250 m, above which it was not found; it was never seen diving into the sea. Most of the termite nests (*Nasutitermes matangensis*) had nesting holes. Thirty-four birds were caught in mist-nets and moult scored in 16: thirteen showed no wing moult, two were regrowing primaries numbers 2 and 3 and one was regrowing secondary number 3. Recordings. Status: very common, widespread, breeding\*†, resident landbird.

33. Brown-capped woodpecker *Picoides moluccensis*. 1984, S9 (1). 1985, S5 (1), P4 (1) (1\*) × 2.

This inconspicuous woodpecker was seen high on the trunks of trees deep inside both *Timonius*

and *Dysoxylum* forest. Drumming was heard frequently on Panjang (east of P5). Status: occasional, restricted, resident landbird; breeding presumed.

34. Barn swallow *Hirundo rustica*. 1984, P1 (1), A1 (2) (1). 1985, R5 (c.6), A5 (2). 1986, A1 (1), A4 (1).

Barn swallows were seen gliding over the coast, over the exposed summit of Rakata, and over the outer cone of Anak Krakatau. Status: occasional, restricted, migrant.

35. Pacific swallow *Hirundo tahitica*. 1984, R17 (2), S3 (3), A1 (3), A5 (4). 1985, R17 (14), A1–3 (2) (1).

Most birds were seen on the coast, often perching in casuarinas; several were seen gliding along the outer cone of Anak Krakatau (A5). Status: occasional, restricted, resident landbird; breeding presumed.

36. Pied triller *Lalage nigra* 1985, R17 (1), P3 (1), P5 (1).

Two males and a female were sighted, each time in casuarinas along the coast. Status: rare, restricted, resident landbird; breeding presumed.

37. Yellow-vented bulbul *Pycnonotus goiavier*. 1982, P, A (Ibkar). 1983, A (B+N). 1984, R1 (1) × 2, R2 (2) (1), R4 (1) × 3, R5 (1\*) (1), R17 (20), S1 (1), S5 (1), S6 & 7 (1), S8 (1), P2–3 (1), A1 (1) × 2. 1985, R5 (1\*, 1 × 3), R9 (1\*), R11 (1\*), R12 (1\*), S1 (4) (1) × 2, S5 (2), P2–4 (1), P5 (1\*) × 2, A1 (1\*) (1) × 3, A2 (2) (3) (1\*), A4 (1\*). 1986, A1 (2) × 5 (1) × 2, A2 (1) (2), A3 (3) × 3.

This was the most widespread, conspicuous and common bird on the Krakataus. It occurred in all habitats on all islands and was found from the coast to the summit of Rakata. It was so frequently encountered that its occurrence and numbers were not always recorded. Communal song displays, in which up to 40 birds would assemble and sing, occurred at dawn and dusk. In 1984 13 birds were mist-netted, one of which, on Anak Krakatau, was an immature. Eight of these birds had wing moult: five were regrowing early primaries and three regrowing secondaries. In 1985 12 birds were captured, nine of which were in moult (eight were moulting primaries, including one growing number 10 and number 4; two were regrowing secondaries). In 1986 14 were mist-netted on Anak Krakatau. Recordings. Status: very common, very widespread, breeding\* resident landbird.

38. Olive-winged bulbul *Pycnonotus plumosus*. 1984, R1 (1), S1 (1).

This was only seen twice, on Rakata in the *Terminalia*–*Barringtonia* coastal formation on 10 September 1984 and on Sertung in *Casuarina* forest on 12 September 1984. Status: very rare, very restricted, resident landbird; breeding presumed.

39. Black-naped oriole *Oriolus chinensis*. 1982, A (Ibkar). 1983, A (B+N). 1984, R1 (1\* × 3) (1\*) × 2 (1), S1 (1, 1\* × 2), S6 (1) (1\*), P2–4 (1\* × 2) (2) × 2, A1 (1) (2) (2). 1985, R10 (1\*), R17 (1\*) (1\* × 2), S1–5 (1\*) × 3, P2–4 (1\* × 3) (2) × 2 (1), P5 (2), A1 (1\*), A2 (1\*). 1986, A1 (3).

The melodious calls could be heard from the coastal fringes up to 640 m on Rakata although they became less frequent with altitude. Orioles frequented tree tops and their calls, which were heard throughout the day, were not always recorded. On Anak Krakatau they mobbed a pair of *Corvus macrorhynchos*, driving them away from certain casuarinas where they possibly had a nest; in 1986 a pair and young male were banded. Recordings. Status: common, widespread, breeding\*† resident landbird.

40. House crow *Corvus splendens*. 1986, A1 (1).

This single individual stayed very close to the camp site and was thought to be a straggler. It

ate kitchen scraps and was seen to eat a fig. The bird perched on the mast of the fishing boat at anchor and when the expedition left the island, it flew several times between boat and shore, finally returning to the island. Status: very rare, restricted, ?straggler.

41. Large-billed crow *Corvus macrorhynchos*. 1983, R, A (B+N). 1984, A1 (2) × 3.

One pair was seen on each of three visits to Anak Krakatau in 1984. Courtship billing and allopreening were observed. On 13 September 1984 one had primary number 6 or 7 missing. They were frequently chased by *O. chinensis*. None were observed in 1985 or 1986. Recordings. Status: very rare, very restricted, resident landbird; breeding presumed for previous years but not for 1985 or 1986.

42. Magpie robin *Copsychus saularis*. 1982, P, A (Ibkar). 1983, R, S (B+N). 1984, R2 (1) × 2, S1 (2), S5 (2), S8 (2), P2 (2), A1 (2). 1985, S1 (1), P4 (1) (1\* × 3), P5 (1\*) × 2, A1 (1) (1\* × 3), A2 (2 × 2), A3 (1\*). 1986, A1 (1) (2), A2 (1) × 2, A3 (1) (1\*).

Three individuals captured in 1984 had no wing moult; of two caught in 1985 a female was regrowing primary number 5. In 1986 four were mist-netted on Anak Krakatau, one of which was a re-trap colour banded on the island in 1985. There was much more singing, including counter singing, in 1985 than in 1984. The robin was not found above 150 m. Recordings. Status: common, widespread, breeding† resident landbird.

43. Chestnut-capped thrush *Zoothera interpres*. 1984, R16 (1). 1986, A1 (1).

A female was caught in a mist-net on 19 September 1984 in *Neonauclea* forest 300 m inland from the coast of Rakata at site R16. The specimen is now lodged in the Museum Zoologicum Bogoriense. It was not in breeding condition, with an ovary of 8 mm × 4 mm and the largest follicle < 1 mm. No other individuals were seen or heard in 1984 or 1985. In 1986 a single individual was seen walking through the *Casuarina* woodland of Anak Krakatau. Status: very rare, restricted, landbird; breeding presumed.

44. Flyeater *Gerygone sulphurea*. 1984, R1 (1), R3–4 (1\*), S1 (1), P1 (1) (1\* × 2), P4 (1) (1\*) × 2, A1 (1) (1\*) × 3. 1985, S1 (1\*), P4 (1, 1\*) (1\* × 2), P5 (1\*) × 2, A1 (2) (1\*) (1, 1\*), A2 (5\*), A3 (1\*). 1986, A1 (2) × 5, A2 (2) × 4, A3 (2) × 5.

On 20 September 1984 a nest with three warm eggs was found on Anak Krakatau; on 13 August 1985 several nests were again found on Anak Krakatau including one with three young about 6 days old; three empty nests were found in 1986. The species was common wherever there was *Casuarina* and the warble could be heard throughout the day. A few giant relict casuarinas on the cliff of Rakata (R3–4) account for one being heard at 350 m, otherwise the species was coastal in distribution. One bird was mist-netted and had secondaries number 7 and number 9 in pin (20 September 1984). Six were netted on Anak Krakatau in 1986. Recordings. Status: very common, restricted, breeding†, resident landbird.

45. Leaf-warbler *Phylloscopus* sp. 1983, A (B+N).

Not seen by us. King *et al.* (1975) record only two species, *P. coronatus* and *P. trivirgatus*, whose range includes the Sunda Strait. Status: unknown.

46. Mangrove blue flycatcher *Cyornis rufigastra*. 1982, P, A (Ibkar). 1983, R, S (B+N). 1984, R1 (1 × 3) (3) (1) × 2, R2 (2) (1) × 2, R3 (1), R4 (1), R5 (1), R16 (1) (2), S1 (1), S5 (1), S7 (1), S8–9 (1), P2–3 (2) × 3, A1 (1). 1985, R5 (1), R6 (2) × 2 (1\*), R8 (1), R11 (1\*), R16 (1) × 2, S1 (1), P3 (2), P4 (2, 2, 1\* 1), P5 (1\*), A1 (1) (1\* × 2). 1986, A1 (3) (1) × 4, A2 (3) (1).

Four spotted immatures were seen (at R1, R5 and S1 in 1984, and A1 in 1986). Of 16 birds captured in 1984 and 1985, six were in wing moult; three were regrowing primaries and six

regrowing secondaries. One specimen was regrowing four primaries and three secondaries simultaneously. In 1986 six were netted on Anak Krakatau, including a recapture banded on the island in 1985. This tame species was observed at almost every site from the coast to the summit of Rakata where an immature was observed. Recordings. Status: very common, very widespread, breeding\*† resident landbird.

47. Mangrove whistler *Pachycephala cinerea*. 1984, R1 (1 × 2) (2), R2 (1\*) (1) × 3, R3 (1), R4 (1), R16 (1), S1 (1), S6–7 (1), S8–9 (1), S10 (1), P2–4 (1\* × 2 1 × 2), A1 (1) (2 1\* 1\*) (1) (2) × 3. 1985, R8 (1\*), R11 (1\*), R12 (1\*), R16 (1), S1 (4) × 2 (2), S4 (2), P3 (1), P4 (2) (1) (1\* × 2), P5 (1\*), A1 (1\*) (1), A2 (1\*), A3 (1\*). 1986, A1–3 (many observations of single birds and pairs).

Thirty-seven were mist-netted in 1984 and another 15 in 1985, making this species by far the most frequently caught on the Krakataus. There were 15 and two immatures in 1984 (Anak Krakatau and Rakata) and 1985 (Sertung), respectively. Immatures had pale brown plumage with rufous-edged remiges, a pale bill and yellow gape; they were moulting secondaries numbers 7, 8 and 9. Of the 20 adults examined for moult in 1984, 12 were moulting remiges, mostly primaries number 3, 4 or 5. Seven of the 15 adults captured in 1985 were also growing remiges; primaries from number 2–10 were found regrowing in different individuals. On Anak Krakatau 27 (five immature) were caught in 1986. Mangrove whistlers were found in all habitats but were not observed above 550 m on Rakata. Observations for most sites, especially Anak Krakatau, are underestimates, as many calls and sightings were not recorded. Four immatures were collected and have been lodged in the Museum Zoologicum Bogoriense. Recordings. Status: very common, widespread, breeding† resident landbird.

48. Grey wagtail *Motacilla cinerea*. 1986, A1 (1), A2 (1), A7 (1).

Status: rare, restricted, migrant.

49. White-breasted wood-swallow *Artamus leucorhynchus*. 1982, P, A (Ibkar). 1984, R1 (1), R3 (5) (1), S1 (1+) × 2, P1 (c.10), A1 (c.6) (12) (6). 1985, R17 (4), S1 (1) × 2, P3 (1) × 2, P5 (1\*), A1 (1\*) (5) (2\*), A2 (11), A4 (1). 1986 A1 (2) (6) (1), A2 (1) (2), A3 (6) × 2.

Wood-swallows were always found perching on or soaring from casuarinas. They were coastal except for some seen round casuarinas at 300 m on the cliff of Rakata (R3). On 14 August 1984 fledglings were fed on Anak Krakatau (A3). An injured specimen, found on Rakata (R1), was collected and is now lodged at the Museum Zoologicum Bogoriense; it was not in moult. Recordings. Status: common, restricted, breeding† resident landbird.

50. Tiger-shrike *Lanius trigrinus*. 1986, A1 (1).

A single bird was netted on Anak Krakatau and released after being photographed, described and banded. Status: rare, restricted, migrant.

51. Philippine glossy starling *Aplonis panayensis*. 1982, P (Ibkar). 1983, R (B+N). 1984, R17 (1) (6–10), P1 (6), A1 (1\*). 1985, R17 (8), S5 (2), P3 (2) × 2 (5) (1\*), P5 (1\*) (1\*). 1986, A3 (1\*) × 2.

All sightings were made on the coast except on Sertung (S5), where several birds were seen in *Dysoxylum* forest. In 1983 a nest with young was seen in the trunk of a fallen coconut tree on Rakata (R1) (Bush & Newsome 1986). Recordings. Status: moderately common, widespread, breeding\*† resident landbird.

52. Brown-throated sunbird *Anthreptes malacensis*. 1982, P (Ibkar). 1983, R (B+N). 1984, R2 (1) (2), S1 (1), S5 (1), S6 (1), S7 (1), S9 (1), S10 (1), P2 (2) × 2, A1 (2). 1985, S5 (1), P3 (1) × 2 (2).

Single individuals and pairs were observed on all islands. On Rakata they were not seen above 100 m. Two were mist-netted and one found to be moulting primaries numbers 6 and 7. Status: moderately common, widespread, resident landbird; breeding presumed.

53. Olive-backed sunbird *Nectarinia jugularis*. 1984, R1 (2), S6 (1), S8 (1), P3 (2) (1), A1 (1) × 3 (2). 1985, S3 (1), P4 (2), P5 (3) (1) (10), A1 (5) (3) × 3. 1986, A1 (1) × 2 (6) (3), A2 (2), A3 (2) × 2.

Normally seen in pairs or with fledglings, but up to ten individuals would assemble each morning at certain flowering trees. A female was observed gathering nest material on Panjang (14 September 1984) and several fledglings were seen on Anak Krakatau in 1985. Two males and two females were mist-netted on Anak Krakatau in 1984; three were each moulting one primary (number 7, number 5 and number 6). In 1986 two males were captured on the island. On Rakata the species was uncommon and limited to the coast. Recordings. Status: common, widespread, breeding\*† resident landbird.

54. Scarlet sunbird *Aethopyga mystacalis*. 1979, R, (B+N). 1983, R, (B+N). 1984, R2 (1) × 2 (2), R17 (1), P3 (1). 1985, R8 (1), R11 (1), R14 (2), P4 (1).

We only saw this species on Panjang and Rakata and on the latter only at sites between 150–550 m. A pair was mist-netted on Rakata (R2); there was no wing moult. Status: moderately common, restricted, resident landbird; breeding presumed.

55. Orange-bellied flowerpecker *Dicaeum trigonostigma* 1984, R2 (1), R16 (1). 1985, R5 (1), R8 (1), R12 (1).

This species was not common and was only seen on Rakata above 150 m; it was one of the few species seen on the summit of Rakata. Status: occasional, very restricted, resident landbird; breeding presumed.

#### 4. DISTRIBUTION OF BIRDS OF THE ARCHIPELAGO

The number and species of birds previously found on the archipelago were not uniformly distributed over all four islands. There were large differences in number of species between islands for surveys made before 1984 (table 2). These differences were probably due to sampling bias, Panjang being visited less than half as much as Rakata and Sertung; it must also be noted that Anak Krakatau did not come into existence until 1930.

Our island surveys during the 1984–1986 period were more even, and clearly show little difference in the number of species on Sertung, Panjang and Anak Krakatau; Rakata, the largest island, carries about 15% more species.

TABLE 2. NUMBERS OF SPECIES OF BIRDS RECORDED ON ISLANDS OF THE KRAKATAUS PRIOR TO THE 1980s AND IN OUR 1980s SURVEYS, SHOWING NON-MIGRANT, NON-MARINE BIRDS (ALSO EXCLUDING SHOREBIRDS) SEPARATELY

survey period	visits/status	Rakata	Sertung	Panjang	Anak Krakatau	all islands
1908–1952	number of visits	15	16	6	2	—
	all species	52	56	14	12	67
	resident land birds	38	34	14	3	40
1984–1986	visits	2	2	2	3	—
	all species	38	31	31	32	49
	resident land birds	32	26	26	24	36

Although each island has a unique set of species of resident land birds, the vast majority of species is common to more than one island (tables 2 and 3). Rakata has about the same number (22–25) of species in common with all the other islands. Sertung and Panjang share slightly more species with Rakata (24, 25) and with each other (22) than they do with Anak Krakatau (20, 18). Anak Krakatau has only slightly more species in common with Rakata (22) than it has with Sertung (20) or Panjang (18).

TABLE 3. NUMBER OF SPECIES OF RESIDENT LAND BIRDS 1984–1986 IN COMMON BETWEEN ISLANDS OF THE KRAKATAUS

	Sertung	Panjang	Anak Krakatau
Rakata	24 <sup>a</sup>	25 <sup>a</sup>	22 <sup>a</sup>
Sertung	—	22	20
Panjang	—	—	18

<sup>a</sup> See table 2.

Some species of resident land birds were found only on particular islands. The brahminy kite *Haliastur indus* and orange-bellied flowerpecker *Dicaeum trigonostigma* were found only on Rakata, and the white-breasted waterhen *Amaurornis phoenicurus*, the large-billed crow *Corvus macrorhynchos* and the house crow *Corvus splendens* were recorded only from Anak Krakatau.

##### 5. DISTRIBUTION OF BIRDS BY HABITAT

The physical and vegetational features of the archipelago are summarized by Thornton & Rosengren (1988). Tables 4–7 show the habitats in which each species was recorded for Rakata, Sertung, Panjang and Anak Krakatau, respectively. The total number of species for each habitat is shown in table 8.

Bootsmansrots was the only site at which *Sterna bergii*, *S. dougallii* and *S. sumatrana* were observed roosting. Shorebirds were seen feeding on the beaches on all four islands although *Esacus magnirostris* was also seen walking high up on the ashy slopes of Anak Krakatau.

*Heliaetus leucogaster* ranged widely over sea, beach and cliff and was seen several times over the inner crater of Anak Krakatau. *Ictinaetus malayensis*, which was far more frequently observed in 1985 than in the previous year, was found in all tall forests on all islands except on Anak Krakatau where none exist. *Haliastur indus* was seen only once, soaring over the cliff at 300 m on Rakata.

The waterhen, *Amaurornis phoenicurus*, was restricted to dense, shady glades of *Ischaemum* grass on Anak Krakatau's eastern foreland.

Of the six species of pigeons recorded, *Ducula aenea* was the most restricted in habitat: on each occasion it was seen on or within 20 m of beach where tall trees fringed the shoreline. *Ducula bicolor* was seen close to the shore but was also found in large numbers on the tops of tall trees in *Casuarina* and *Dysoxylum* forests. *Treron vernans* and *Ptilinopus melanospila* were usually seen in the tall trees of *Neonauclea*, *Dysoxylum* and *Timonius* forests but did not occur above 400 m altitude on Rakata. *Chalcophaps indica* was most frequently encountered in the dense understorey of coastal *Barringtonia*–*Terminalia* associations but was also seen in *Casuarina*, *Neonauclea* and *Dysoxylum* forests. On Rakata it was not recorded above an altitude of 400 m. *Macropygia*

## BIRDS OF KRAKATAU

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TABLE 4. BIRDS RECORDED ON RAKATA IN 1984 AND 1985, BY HABITAT

(1, Sighting; 2, mist-net capture; 3, birds heard only; 4, seen in 1982.)

species	sea/ beach	<i>Casuarina</i>	<i>Barringtonia</i> / <i>Terminalia</i>	<i>Neonauclea</i> ( $< 400$ m)	<i>Neonauclea</i> - <i>Ficus</i> ( $> 400$ m)	<i>Schefflera</i> summit & cliffs
<i>Fregata ariel</i>	1	—	—	—	—	—
<i>Egretta sacra</i>	1	—	—	—	—	—
<i>Haliastur indus</i>	—	—	—	1	—	—
<i>Haliaeetus leucogaster</i>	1	—	—	—	—	1
<i>Ictinaetus malayensis</i>	—	—	1	1	1	—
<i>Charadrius</i> <i>leschenaultii</i>	1	—	—	—	—	—
<i>Actitis hypoleucos</i>	1	—	—	—	—	—
<i>Esacus magnirostris</i>	1	—	—	—	—	—
<i>Sterna anaethetus</i>	1	—	—	—	—	—
<i>Treron vernans</i>	—	—	1	1	—	—
<i>Ptilinopus melanospila</i>	—	—	1	1, 2	—	—
<i>Ducula aenea</i>	—	—	1	—	—	—
<i>D. bicolor</i>	—	1	—	—	—	—
<i>Macropygia phasianella</i>	—	—	1	1, 2	1	—
<i>Chalcophaps indica</i>	—	—	2	1, 2	—	—
<i>Tyto alba</i>	—	—	4	—	—	—
<i>Caprimulgus affinis</i>	—	—	3	—	—	—
<i>Collocalia fuciphaga</i>	1	—	1	—	—	—
<i>Collocalia esculenta</i>	1	—	—	—	—	—
<i>Apus affinis</i>	1	—	—	—	—	1
<i>Halcyon chloris</i>	—	—	1, 2	1, 2	—	—
<i>Hirundo tahitica</i>	—	1	—	—	—	—
<i>H. rustica</i>	—	—	—	—	—	1
<i>Lalage nigra</i>	—	1	—	—	—	—
<i>Pycnonotus goiavier</i>	—	1	1, 2	1, 2	1	1
<i>Pycnonotus plumosus</i>	—	—	1	—	—	—
<i>Oriolus chinensis</i>	—	—	1	3	3	—
<i>Copsychus saularis</i>	—	—	—	1, 2	—	—
<i>Zoothera interpres</i>	—	—	—	2	—	—
<i>Gerygone sulphurea</i>	—	1	—	—	—	—
<i>Cyornis rufigastra</i>	—	—	1, 2	1, 2	1	1
<i>Pachycephala cinerea</i>	—	—	1, 2	1, 2	1	—
<i>Artamus leucorhynchus</i>	—	1, 2	—	—	—	—
<i>Aplonis panayensis</i>	—	1	1	—	—	—
<i>Anthreptes malacensis</i>	—	—	—	1, 2	—	—
<i>Nectarinia jugularis</i>	—	—	1	—	—	—
<i>Aethopyga mystacalis</i>	—	—	1	1, 2	1	—
<i>Dicaeum trigonostigma</i>	—	—	—	1	1	1
total	10	7	18	16	8	6

*phasianella* was found in a variety of habitats from low *Casuarina* woodland on Anak Krakatau, to tall forests of *Neonauclea* and *Dysoxylum*. It was the only pigeon seen above 400 m on Rakata.

*Centropus bengalensis* was restricted to grassland habitats on Anak Krakatau and Sertung. It was recorded from areas of *Ischaemum* and *Imperata* but not from patches of the much taller and coarser *Saccharum*. *C. bengalensis* was the only species of bird recorded in the extensive *Imperata* grasslands on the northern foreland of Anak Krakatau.

The barn owl, *Tyto alba*, was also found in open habitats, near the beach on Rakata and Sertung, and on the bare lava and ash on the slopes of Anak Krakatau, as well as in the small



TABLE 5. BIRDS RECORDED ON SERTUNG IN 1984 AND 1985, BY HABITAT

(1, 1984 sighting; 2, 1985 sighting; 3, mist-net capture; 4, seen on nest; 5, seen in *Saccharum*, 1984.)

species	beach	<i>Casuarina</i>	<i>Dysoxylum</i> forest	<i>Timonius</i> forest
<i>Fregata ariel</i>	1, 2	—	—	—
<i>Egretta sacra</i>	2	—	—	—
<i>Haliaeetus leucogaster</i>	1, 2	—	—	—
<i>Ictinaetus malayensis</i>	—	2	2	2
<i>Charadrius leschenaultii</i>	1	—	—	—
<i>Actitis hypoleucos</i>	1, 2	—	—	—
<i>Esacus magnirostris</i>	1, 2	—	—	—
<i>Sterna hirundo</i>	1	—	—	—
<i>Treron vernans</i>	—	1, 2	—	1
<i>Ducula bicolor</i>	—	—	1	2
<i>Macropygia phasianella</i>	—	2	1, 4	—
<i>Chalcophaps indica</i>	—	1, 2	1, 2	—
<i>Centropus bengalensis</i>	—	—	—	1, 5
<i>Tyto alba</i>	—	2	—	—
<i>Caprimulgus affinis</i>	—	2	—	—
<i>Collocalia fuciphaga</i>	1	1	—	—
<i>Apus affinis</i>	2	—	—	—
<i>Halcyon chloris</i>	—	2, 3	1, 2	1
<i>Picoides moluccensis</i>	—	—	2	1, 2
<i>Hirundo tahitica</i>	1	—	—	—
<i>Pycnonotus goiavier</i>	—	1, 2, 3	1, 2, 3	1, 2
<i>P. plumosus</i>	—	1	—	—
<i>Oriolus chinensis</i>	—	1, 2	1, 2	2
<i>Copsychus saularis</i>	—	1, 3	—	1, 2
<i>Gerygone sulphurea</i>	—	1	2	—
<i>Cyornis rufigastra</i>	—	1, 3	1, 2	1, 2
<i>Pachycephala cinerea</i>	—	1, 3	1, 3	1, 2
<i>Artamus leucorhynchus</i>	—	1, 2	—	2
<i>Aplonis panayensis</i>	—	—	2	—
<i>Anthreptes malacensis</i>	—	1, 2	2	2
<i>Nectarinia jugularis</i>	—	2	1, 2	1
total	10	18	14	14

wooded area of the eastern foreland. *Caprimulgus affinis* also inhabited open areas near the beaches on all islands; on Anak Krakatau it was also seen on the ash slopes and in *Casuarina* woodland. Birds were seen settling on open bare patches among the casuarinas but most appeared to fly down each dusk from the bare slopes of the outer ash cone, where they possibly roosted.

The other aerial insect feeders, *Collocalia fuciphaga*, *C. esculenta*, *Apus affinis*, *Hirundo rustica* and *H. tahitica*, also were found in open habitats. Both *Collocalia* species were limited to areas along the shorelines, whereas the remaining species also hunted for insects on the windswept summit and cliffs.

Two resident land species, *Pycnonotus goiavier* and *Cyornis rufigastra* occupied all vegetated habitats except the expanses of grasses on Anak Krakatau. They were found at sea level among the trees fringing the coasts, in the forested ridges and gullies, and in the moss forest above 400 m and in the low scrub on the summit of Rakata.

*Oriolus chinensis* and *Pachycephala cinerea* occurred in all wooded habitats on the islands except in the summit scrub on Rakata; the former species was found in the tops of trees whereas the latter inhabited the understorey. *Halcyon chloris* and *Copsychus saularis* occupied all wooded

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TABLE 6. BIRDS RECORDED ON PANJANG IN 1984 AND 1985, BY HABITAT

(1, sighting; 2, mist-net capture; 3, birds heard only.)

species	sea/ beach	Casuarina	Barringtonia/ Terminalia	Dysoxylum	Timonius	cliffs
<i>Fregata ariel</i>	1	—	—	—	—	—
<i>Egretta sacra</i>	1	—	—	—	—	—
<i>Haliaeetus leucogaster</i>	1	—	—	—	—	—
<i>Ictinaëtus malayensis</i>	—	—	—	1	—	—
<i>Actitis hypoleucos</i>	1	—	—	—	—	—
<i>Esacus magnirostris</i>	1	—	—	—	—	—
<i>Treron vernans</i>	—	—	—	—	1	—
<i>Ptilinopus melanospila</i>	—	—	1	—	—	—
<i>Ducula aenea</i>	—	1	—	—	—	—
<i>D. bicolor</i>	—	—	—	1	—	—
<i>Macropygia phasianella</i>	—	1	—	1	—	—
<i>Chalcophaps indica</i>	—	—	1, 2	—	—	—
<i>Caprimulgus affinis</i>	—	—	3	—	—	—
<i>Collocalia fuciphaga</i>	—	—	—	—	—	1
<i>C. esculenta</i>	1	—	—	—	—	1
<i>Apus affinis</i>	1	—	—	—	—	—
<i>Halcyon chloris</i>	—	—	1, 2	1, 3	—	—
<i>Picoides moluccensis</i>	—	—	—	3	1, 3	—
<i>Hirundo rustica</i>	1	—	—	—	—	—
<i>Lalage nigra</i>	—	1	—	—	—	—
<i>Pycnonotus goiavier</i>	—	—	1, 2	1, 3	1, 3	—
<i>Oriolus chinensis</i>	—	—	1, 3	1, 3	1, 3	—
<i>Copsychus saularis</i>	—	—	1, 3	1, 3	1, 3	—
<i>Gerygone sulphurea</i>	—	1, 3	1, 3	—	1, 3	—
<i>Cyornis rufogastra</i>	—	1, 3	1, 3	1, 3	1, 3	—
<i>Pachycephala cinerea</i>	—	—	1, 2, 3	1, 3	1, 3	—
<i>Artamus leucorhynchus</i>	1	1	1	—	—	—
<i>Aplonis panayensis</i>	1	1	—	—	—	—
<i>Anthreptes malacensis</i>	1	1	—	—	—	—
<i>Nectarinia jugularis</i>	—	1	1	1	—	—
<i>Aethopyga mystacalis</i>	—	—	—	1	1	—
total	11	9	12	12	9	2

habitats except those above 250 m on Rakata. *H. chloris* was found in the more open areas, whereas *C. saularis* was more confined to dense gullies.

Four species seemed to be limited to the casuarinas and the *Barringtonia*–*Terminalia* formations that fringe the shores. *Gerygone sulphurea* was confined to casuarinas and was found wherever they occurred, even in small isolated trees on the slopes of Anak Krakatau. *Artamus leucorhynchus* and *Aplonis panayensis* were normally found perching in tall casuarinas although the latter would also frequent the inland forests, where it foraged in the tops of trees. Finally, on each occasion that *Lalage nigra* was seen, the bird was perched or feeding in a *Casuarina*, twice above a cliff, and once above the shore.

Of the three sunbirds on the Krakataus, *Nectarinia jugularis* occupied the coastal formations of *Casuarina* and *Barringtonia* – *Terminalia*; *Anthreptes malacensis* occurred in the lower forests, and *Aethopyga mystacalis* occupied all forests including those above 400 m, but was not seen in the scrub on the summit of Rakata.

Three species evidently have restricted distributions. The woodpecker, *Picoides moluccensis* was confined to tall trees deep inside *Dysoxylum* and *Timonius* forests on Sertung and Panjang. The pair of crows, *Corvus macrorhynchos*, seen regularly on Anak Krakatau in 1984, were found

TABLE 7. BIRDS RECORDED ON ANAK KRAKATAU IN 1984–86 BY HABITAT

(1, sightings and vocalizations; 2, mist-net capture; 3, vocalizations only; 4, skeletal remains; 5, regurgitated pellets; 6, feathers.)

species	sea beach	ash-lava desert	<i>Casuarina</i> woodland	<i>Imperata</i> grassland
<i>Fregata ariel</i>	1	—	—	—
<i>Egretta sacra</i>	1	—	—	—
<i>Haliaeetus leucogaster</i>	1	1	—	—
<i>Falco severus</i>	—	1	1	—
<i>Amaurornis phoenicurus</i>	—	4	1, 3	—
<i>Actitis hypoleucos</i>	1	—	—	—
<i>Esacus magnirostris</i>	1	1	3	—
<i>Treron vernans</i>	—	4, 6	1	—
<i>Macropygia phasianella</i>	—	4, 6	1	—
<i>Centropus bengalensis</i>	—	—	1, 3	1, 3
<i>Tyto alba</i>	—	1, 3, 5, 6	1, 3, 6	—
<i>Caprimulgus affinis</i>	1, 2	1, 3	1, 3	—
<i>Collocalia fuciphaga</i>	1	—	—	—
<i>Apus affinis</i>	—	1	—	—
<i>Halcyon chloris</i>	—	1	1, 2, 3	—
<i>Hirundo tahitica</i>	1	1	—	—
<i>H. rustica</i>	1	1	—	—
<i>Pycnonotus goiavier</i>	—	—	1, 2, 3	—
<i>Oriolus chinensis</i>	—	—	1, 2, 3	—
<i>Corvus macrorhynchos</i>	1	—	1	—
<i>C. splendens</i>	1	—	1	—
<i>Copsychus saularis</i>	—	—	1, 2, 3	—
<i>Zoothera interpres</i>	—	—	1	—
<i>Gerygone sulphurea</i>	—	—	1, 2, 3	—
<i>Cyornis rufigastra</i>	—	—	1, 2, 3	—
<i>Pachycephala cinerea</i>	—	—	1, 2, 3	—
<i>Motacilla cinerea</i>	1	1	—	—
<i>Artamus leucorhynchus</i>	—	—	1	—
<i>Lanius tigrinus</i>	—	—	2	—
<i>Aplonis panayensis</i>	—	—	3	—
<i>Anthreptes malacensis</i>	—	—	1, 3	—
<i>Nectarinia jugularis</i>	—	—	1, 2	—
total	12	13	23	2

in the tall casuarinas or on the beach. Finally, the thrush *Zoothera interpres* was caught in a mist net on Rakata in lowland *Neonauclea* forest with a dense understorey of saplings and rattan, but, surprisingly, was also seen on Anak Krakatau in the *Casuarina* woodland in 1986.

The data do not allow a rigorous comparison between habitats, but some features are obvious. For example, in the *Neonauclea* forests of Rakata there is only half the number of species above 400 m that there is below this height; there are even fewer species on the summit itself (table 8). This, no doubt, is partly a result of sampling bias in which a total of 79 man-hours of survey were spent below 400 m and only 33 man-hours above that level. On 23–24 August 1985 we recorded birds on the eastern ascent, summit and descent of Rakata and spent approximately equal time (5 h) below and above 400 m in *Neonauclea* forest and on the summit; we counted seven, eight and six species, respectively (Thornton 1986). These data suggest that the altitudinal differences in species number (table 8) are artefacts of sampling. The almost monotypic stand of *Imperata cylindrica* on Anak Krakatau's northern foreland is not a rich habitat for birds: *Centropus bengalensis* appeared to be the only inhabitant and other birds recorded there were associated with the odd *Casuarina* or small fig tree.

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TABLE 8. NUMBER OF SPECIES OF BIRDS RECORDED IN VARIOUS HABITATS ON THE KRAKATAU ISLANDS

habitat	Rakata	Sertung	Panjang	Anak Krakatau	Bootsmansrots
oceanic rock outcrop	—	—	—	—	3
sea/beach	10	10	11	12	—
<i>Casuarina</i> woodland/forest	7	18	9	23	—
<i>Barringtonia</i> – <i>Terminalia</i> association	18	—	12	—	—
<i>Neonauclea</i> forest < 400 m	16	—	—	—	—
<i>Neonauclea</i> forest > 400 m	8	—	—	—	—
summit-cliffs	6	—	2	—	—
<i>Timonius</i> forest	—	14	9	—	—
<i>Dysoxylum</i> forest	—	14	12	—	—
<i>Imperata</i> grassland	—	1	—	2	—
ash-lava desert	—	—	—	13	—

TABLE 9. MIST-NET CAPTURE RATES BY ISLAND, SITE, HABITAT AND YEAR

(Capture rate is expressed as the number of captures in square metres of net per rain-free hour during which the nets were set, multiplied by 1000. Sites are shown in figure 2. a, average of first two day's trapping.)

island	site	habitat	capture rate		
			1984	1985	1986
Rakata	1	<i>Barringtonia</i> – <i>Terminalia</i> coastal forest	9.0	—	—
	2, 3	<i>Neonauclea</i> forest	19.0	—	—
	16	<i>Neonauclea</i> forest	7.0	17.1	—
Sertung	1–3	<i>Casuarina</i> forest	—	25.4	—
	4	<i>Dysoxylum</i> forest	0.0	8.2	—
Panjang	2, 3	<i>D.</i> forest	11.0	17.2	—
Anak Krakatau	1–3	<i>Casuarina</i> / <i>Ischaemum</i> / <i>Saccharum</i>	27.0	—	12.8*

Further comparison between habitats is complicated by the unique assemblages of birds on each island and the fact that most forest types were not found on all islands. Thus *Neonauclea* forest occurs only on *Rakata* and *Dysoxylum* forest is limited to Sertung and Panjang (Whittaker & Flenley 1982; Whittaker *et al.* 1984). Although casuarinas are present on all islands, the only stands more than a few hectares in extent were found on the Sertung spit and Anak Krakatau.

Estimates of bird abundance can be made from the capture rates by mist-net (table 9). The capture rates were highest for the *Casuarina* forests and woodlands on Sertung and Anak Krakatau. The rates for *Barringtonia*–*Terminalia*, *Neonauclea* and *Dysoxylum* forests varied considerably, depending to a large extent on the location of the net, and the year the nets were set. Nets set on passes over high ridges had good returns (1984 *Neonauclea* sites 2 and 3) whereas those set low down in gullies (1984 *Neonauclea* site 16) were less successful.

Furthermore, the returns were higher for the same sites in 1985 than in 1984 (Sertung site 4 and Panjang sites 2 and 3); this may be because the breeding season was incomplete in August 1985, although it was completed for most species when we visited in September 1984. The high returns for *Casuarina* forests and woodlands may be partly because of sampling bias because the nets, which reached a height of 3 m above ground, sampled a greater portion of the vertical stratification of vegetation in *Casuarina* (< 15 m) than in the other forests, where the upper canopy could be 20–30 m or more above ground. Despite this bias, the *Casuarina* forests and woodlands appeared to be the habitat richest in both species and numbers. A more rigorous estimate of species diversity and bird density must await future studies.

## 6. DISCUSSION

In the early 1980s, about a hundred years after the destructive eruption of 1883, 55 species of birds were recorded on the Krakataus. Of these, four seabirds and a *Phylloscopus* leaf-warbler were recorded by Bush & Newsome in 1983 and were not seen by us. Thirty-six species may be considered resident land birds, that is, they probably depend on the islands exclusively for their survival and reproduction. The remaining species are either sea birds, shorebirds or migrants that are on the islands temporarily and breed elsewhere, or represented by solitary individuals regarded as stragglers. Eight species are here recorded on the islands for the first time and six of these are considered resident land birds. In addition, two land-bird species first recorded in 1979 and 1983 by Bush & Newsome were confirmed. There are many new records for individual islands, especially for Panjang and Anak Krakatau; these islands were largely ignored by previous surveys. Our results contradict the impression gained from previous surveys that Panjang and Anak Krakatau are impoverished, and show that all four islands have similar numbers of species, although of course not exactly the same species complement. This is of particular interest in the case of Anak Krakatau, where the vegetated area is but a very small fraction of that on Panjang, the next smallest island. The birds of Anak Krakatau will be the subject of another paper.

Although our surveys have been more intensive and extensive than those of previous expeditions they suffer from a number of limitations. First, we surveyed only during August and September; this is at the end of the breeding season (Hoogerwerf 1953*b*) and before the migrants from the north can be expected. Consequently, many migrants and some species inconspicuous outside breeding may not have been detected. Secondly, we probably under-sampled the difficult and sometimes inaccessible terrain, especially that on southern Sertung. Additions to the species list may come from this location, if sampled by future expeditions. Another limitation was the small number of species collected (five species in total) for positive identification in museums; the results rest entirely on sightings and sound recordings of free-flying birds, photographs and written descriptions of captured birds, feathers and skeletal remains.

In the subsequent discussion we consider the new records for the islands in the 1980s and compare our results with those of the last survey made by Hoogerwerf in 1951–52, paying special attention to those species we failed to find. We conclude with a comparison of the avifauna on the Krakataus with those known on two adjacent islands in the Sunda Strait, Sebesi and Panaitan.

(a) *New records for the archipelago*

Six of the 14 species first recorded in the past decade are seabirds. *Fregata minor* and *Sterna fuscata* were first recorded by Bush & Newsome (1986) and *Sterna albifrons* and *Chlidonas hybrida* in 1983 by the same authors. Ibkar-Kramadibrata *et al.* (1986) were the first to record *Fregata ariel* in 1982; we saw it at close range on four of the seven occasions that we saw it, so that its identification is beyond doubt. Frigates were also seen in 1919 and 1933 but identification was not possible; Dammerman (1948) concluded that they were probably *F. ariel* because this is the most commonly observed species in the Sunda Strait area. *Sterna hirundo*, recorded from an individual washed up on the beach, is a widespread species that migrates regularly from its breeding sites in northern Asia to overwinter on the coasts of eastern Australia from September to April (Pizzey 1980).

*Corvus splendens* was first seen in 1986, on Anak Krakatau. The species is known to hitch rides on sea-going vessels (Ryall 1986). Another single sighting in 1986 was *Lanius tigrinus*, the tiger shrike (Smythies 1981).

Since 1952 two new avian predators have evidently colonized the archipelago: the black eagle, *Ictinaetus malayensis*, first seen in 1983, and the barn owl, *Tyto alba*, first recorded in 1982.

In 1984 the eagle was recorded four times whereas in 1985 it was recorded 14 times, including from Sertung. Consequently, we assume that it has increased in numbers and possibly in range in the intervening 11-month period. Alternatively, it may simply be more active and conspicuous in August than in September, although this is less likely. The eagle is primarily a nest robber (Hoogerwerf 1970) and an inhabitant of primary rainforest (Hoogerwerf 1971). It appears to be well established on the Krakataus and is possibly extending its feeding niche because it was seen attacking a large monitor on Rakata. The source of this species is speculative: none was recorded from Sebesi, the island closest (18 km north) to the Krakataus, by Chasen (1937), nor was the species present on Panaitan (44 km south) (Hoogerwerf 1953*b*) in 1951. The eagles were rare in Ujung Kulon (Hoogerwerf 1971) but seen at Carita high above a large nest in 1984 by R. A. Z. and M. V. W. and again by R. A. Z. in 1985. One of us (G. W. D.) also saw them in southern Sumatra (Tanjungkarang) in 1984. The species appears to have increased its range in the west Java area.

The barn owl, *Tyto alba*, has been on the Krakataus since at least 1982. It was heard on Anak Krakatau in 1982 and sighted on Rakata in the same year. A bird was seen on Sertung in 1985, and a pair regularly seen and heard on Anak Krakatau in 1986; they approached the loud speaker once when their call was played back. The number of pellets found on Anak Krakatau in 1984, 1985 and 1986 suggests at the very least that an owl or owls make regular visits to the island. Most of the pellets contained the remains of a *Rattus rattus*, and one rat is sufficient to sustain an owl for one day (Morton & Martin 1979). The population of rats on the island was extremely low in August 1985 (Thornton 1986) and 1986. It is possible they have been hunted out by owls, which have returned to other islands, such as Sertung, where rats were plentiful in both 1984 and 1985 on the northern spit, the open habitat of which would facilitate hunting by owls. Nevertheless, in 1986 owls were observed almost nightly on Anak Krakatau.

The occurrence of the owl on the Krakataus is consistent with its recent spread from Java to Sumatra and on to the Malay Peninsula. In Sumatra where the first barn owl was heard in 1974 (Yaffle 1985), the spread is associated with the clearing of forests, and in Malaysia with the establishment of oil palm estates (Lenton 1984). The owl population on the Krakataus must have a tenuous future given the very limited amount of open habitat available for hunting, the low density of rats on Anak Krakatau, and the uncertain future of the *Casuarina* spit on Sertung (Bird & Rosengren 1985; Thornton & Rosengren 1988).

The house swift, *Apus affinis*, seen on eight occasions, is a new record for the archipelago. The many high, rocky cliffs should provide adequate sites for breeding. The species could have reached the Krakataus from either Ujung Kulon (Hoogerwerf 1970) or Panaitan Island to the southeast, or from Sumatra to the west (G. W. Davison, in preparation).

The chestnut-capped thrush, *Zoothera interpres*, may not be as rare as it appears because it is shy and silent, and lives in shady, dense thickets (Hoogerwerf 1970). It may have been overlooked by previous surveys in which mist-nets were not used. The melodious song is diagnostic but the size of the ovaries in the specimen we captured in September 1984 show that it was not breeding and accounts for the fact that we did not hear it. Its recent unexpected

sighting on Anak Krakatau (one individual) follows the early development of mixed forest there in recent years.

The green imperial pigeon, *Ducula aenea*, is evidently recently established on the Krakataus, being found only along the coastal forests and in very low numbers. It was first seen on Rakata, Sertung and Panjang in 1983 and may have arrived from the Ujung Kulon peninsula or Panaitan Island where the species is a quite common inhabitant of primary rain forest (Hoogerwerf 1953*b*, 1971). There are no records for Sebesi (Chasen 1937) or southern Sumatra (G. W. Davison, in preparation).

The scarlet sunbird, *Aethopyga mystacalis*, was first identified on the islands in 1979 by Bush & Newsome (1986), but it may have arrived before 1951, as Hoogerwerf (1953*a*) records specimens of *Aethopyga* that he could not identify because they were in non-breeding plumage. It is reasonable to assume that he saw *A. mystacalis*; the only other likely species, *Aethopyga siparaja*, has never been recorded on the islands previously, neither was it seen on our expeditions. *A. mystacalis* probably colonized from Java rather than Sumatra. Although it is recorded from both Java and Sumatra, it occurs at Ujung Kulon (Hoogerwerf 1970) and Carita (personal observation by first author), but is not recorded from Panaitan Island (Hoogerwerf 1953*b*) or Sebesi (Chasen 1937).

The leaf-warbler seen on Anak Krakatau in 1983 (Bush & Newsome 1986) was not identified to species. We did not see it, in spite of a thorough survey of that island in 1986, and its establishment must be doubted. The sighting was probably of a winter visitor; many leaf-warbler species winter in Indonesia and breed elsewhere.

(*b*) *Species previously recorded but not found 1984–85*

We failed to find five species of resident land birds seen by Hoogerwerf (1953*a*) on the Krakataus in 1951–52. This does not prove extinction from the islands but at the least suggests that populations are extremely low.

The crested serpent-eagle, *Spilornis cheela*, was recorded twice by Hoogerwerf in October 1951 in the southeast corner of Rakata. We spent considerable time in that region during two expeditions but failed to sight it; however, we saw several black eagles, *Ictinaetus malayensis*, at that site.

We did not record the peaceful dove, *Geopelia striata*, in 1984–86, although Hoogerwerf heard it in August 1952. This species has a loud, diagnostic call with which we were familiar and as it is a conspicuous bird (Adhikerana 1985), it is unlikely that we missed it. The dove feeds on fallen seeds from grasses and sedges (Frith 1982) in open habitats that have now largely disappeared from the Krakataus as a result of succession (Whittaker & Flenley 1982). The dove was always rare on the Krakataus, having been seen only once in 1919 (Dammerman 1923); it is probably now extinct.

Between 1919 and 1934 the koel, *Eudynamys scolopacea*, was known from all islands of the archipelago but Hoogerwerf (1953*a*), who thought he heard it on Rakata in October 1951, did not see the species. We did not detect the species although we were all familiar with its diagnostic call. The species is secretive outside the breeding season and is not easily detected until it calls. At Ujung Kulon it calls in September, October, November and January, so that had it been present on the Krakataus in the 1980s it is likely that we would have heard it. Even if the koel is still present on the islands it probably no longer breeds there since its primary host, the large-billed crow, *Corvus macrorhynchos*, appears to be on the verge of extinction.

The crow was common and found on all islands during the early period of revegetation (Dammerman 1948); by 1951 it was limited to a few pairs on Sertung (Hoogerwerf 1953a), although Bush & Newsome (1986) recorded it also from Rakata in 1983. In 1984 we regularly saw one pair on Anak Krakatau, often being pursued by *Oriolus chinensis*, as the crow is a frequent nest-robber. No crows were seen in 1985 or 1986 and because they prefer open habitats (King *et al.* 1975) and are conspicuous, it can be assumed that the species has now disappeared from the islands. The decline and probable extinction of the crows follows the gradual loss of its preferred open habitats, with Anak Krakatau providing the last, but insufficient, refuge.

Hoogerwerf (1953a) sighted one other species not seen by us, the silver-rumped swift, *Rhynchidura leucopygialis*. This was the first sighting of the species on the Krakataus and it is possible that, like the house crow, *Corvus splendens*, seen on Anak Krakatau in 1986, the birds were incidental stragglers or representatives of very small populations that had temporarily colonized the islands. It is also possible that we missed the species; Hoogerwerf saw it flying high on Rakata's cliff in 1951.

(c) *Comparisons with Panaitan and Sebesi islands*

It is of interest to compare the avifauna of the Krakataus with those of two other islands in the Sunda Strait in order to assess the extent of recolonization and as an indication of what might eventuate on the Krakataus in the future. Panaitan is 7 km north of the coast of the Ujung Kulon peninsula and 44 km south of the Krakataus; Sebesi is 12 km south of the coast of Sumatra, and 18 km from Rakata (figure 1). Both islands suffered extensively from the 1883 eruption but sufficient vegetation survived on steep slopes on high ground to provide habitats for rapid recolonization. Bartels & Siebers (Dammerman 1923; Chasen 1937) visited Sebesi in 1919 and Hoogerwerf (1953b) surveyed Panaitan in 1951; more recent bird lists, unfortunately, do not exist. The comparison is complicated by the fact that the islands are of different areas, at different distances from the mainland, and were differentially affected by the 1883 eruption. Finally, surveys of their avifaunas were conducted many years apart and thus represent different stages of the recolonization process. Table 10 lists species found on Sebesi and Panaitan that are not found in comparable habitats occurring on the Krakataus. Thus species found in cultivated areas, freshwater habitats and mangroves, habitats not occurring on the Krakataus, have been omitted.

There is considerable overlap in species between habitats I and II of table 10 on all three islands, suggesting that the recolonization of these habitats on the Krakataus is now complete. This is not surprising because these are likely to have been the first habitats to be revegetated after the eruption. We have no explanation for the failure of *Orthotomus sepium* and *Arachnothera longirostris* to exploit these, and other suitable habitats, on the Krakataus.

Open country habitats and grasslands (habitat III, table 10) have been maintained and extended by human settlement on Sebesi and Panaitan, whereas on the Krakataus these habitats and their associated avifauna have all but disappeared from Rakata and Panjang as a result of ecological succession. They are now represented on the Krakataus only by the *Casuarina* woodland and grasslands on the Sertung spit and on the northern foreland of Anak Krakatau. Both areas, and their associated avifauna, have an uncertain future: the spit has diminished greatly in size and shape because of erosion (Bird & Rosengren 1985) and the habitat on Anak Krakatau is under constant threat of destruction from volcanic eruption



TABLE 10. SPECIES RECORDED ON SEBESI AND PANAITAN ISLANDS THAT ARE NOT FOUND IN COMPARABLE HABITATS ON THE KRAKATAUS

habitat <sup>a</sup>	Sebesi	Panaitan
I shore and reefs	8 species <sup>b</sup>	22 species <i>Ardea sumatrana</i> <i>Ichthyophaga ichthyaetus</i> <i>Pandion haliaetus</i> <i>Falco peregrinus</i> <i>Numenius madagascariensis</i>
II <i>Barringtonia</i> – <i>Casuarina</i> coastal formation	14 species <i>Orthotomus sepium</i> <i>Arachnothera longirostris</i>	10 species <i>Orthotomus sepium</i> <i>Aethopyga siperaja</i> <i>Arachnothera longirostris</i>
III open habitats including grassland	7 species <i>Orthotomus sepium</i> <i>Munia punctulata</i>	11 species <i>Turnix suscitator</i> <i>Streptopelia bitorquata</i> <i>Caprimulgus macrurus</i> <i>Cypsiurus parvus</i> <i>Hemiprocne longipennis</i> <i>Coracina novae-hollandiae</i> <i>Cisticola exilis</i> <i>Orthotomus sepium</i> <i>Corvus enca</i> <i>Erythrura prasina</i>
IV secondary monsoon forest	14 species <i>Cacomantis merulinus</i> <i>Chalcococcyx basalix</i> <i>Orthotomus sepium</i>	7 species <i>Orthotomus sepium</i> <i>Dicaeum trochleum</i>
V lower strata of primary monsoon forest	17 species <i>Copsychus malabaricus</i> <i>Orthotomus sepium</i>	14 species <i>Gallus gallus</i> <i>Dicrurus hottentottus</i> <i>Dryocopus javensis</i> <i>Pycnonotus atriceps</i> <i>Copsychus malabaricus</i> <i>Orthotomus sepium</i> <i>Muscicapa banyumas</i> <i>Hypothymis azurea</i>
VI crowns of primary monsoon rain forest	0 species	9 species <i>Otus bakkamoena</i> <i>Anthracoceros undulatus</i> <i>Anthracoceros malabaricus</i> <i>Dryocopus javensis</i> <i>Mulleripicus pulverulentus</i> <i>Gracula religiosa</i>

<sup>a</sup> Species found in freshwater habitats and cultivated areas have been omitted since they are absent from the Krakataus. Adopted from Chasen (1937) and Hoogerwerf (1953 *a, b*).

<sup>b</sup> Number of species is total recorded in each habitat on Sebesi and Panaitan.

(Thornton & Rosengren 1988). The open habitats on Sebesi (as at 1919) and the Krakataus have been colonized by a similar set of species, although *Orthotomus sepium* and the granivorous finch *Munia punctulata* failed to establish on the Krakataus. In contrast, *Geopelia striata*, the only granivorous bird even to colonize the Krakataus, evidently had failed to colonize Sebesi by 1919.

The recolonization of open habitats on the Krakataus and Panaitan has been quite different: although Panaitan carried ten species in 1951 that have not yet colonized the Krakataus (table 10, habitat III), there are eight species on the Krakataus that had not been established on

Panaitan by 1951. In two cases different congeners have become established on the two islands: *Caprimulgus macrurus* and *Corvus enca* on Panaitan, and *Caprimulgus affinis* and *Corvus macrorhynchos* on the Krakataus, and these may be cases of ecological species replacement.

As expected, quite similar sets of species occur in the extensive secondary forest on the Krakataus (table 10, habitat IV) as in this habitat on Sebesi and Panaitan. In contrast, large differences exist between the species of primary lowland forest (habitat V), as this habitat is as yet absent from the Krakataus. Nevertheless, species have recently colonized the Krakataus that normally live in the primary forests of Panaitan and Ujung Kulon. These include *Ducula aenea*, *Ptilinopus melanospila*, *Chalcophaps indica*, *Zoothera interpres*, *Pycnonotus plumosus*, *Cyornis rufigastra*, *Pachycephala cinerea* and *Dicaeum trigonostigma*. None of these species, however, can be regarded as an obligate inhabitant of primary monsoon forest. Those species that cannot live outside primary forest have not yet established on the Krakataus. They are listed in table 10 (habitats V and VI), and can only be expected to occur on the Krakatau islands when the slow ecological succession to primary forest (Whittaker *et al.* 1984) has proceeded further.

We thank Professor I. W. B. Thornton, who conceived this project and led both expeditions, for inviting us to participate. We thank Dr S. Adisoemarto (Director, Museum Zoologicum Bogoriense, Indonesia) for allowing two of us (A. S. A. and D.) to join the expeditions and also for providing access to the museum's bird collection. Dr T. R. New, Dr M. Bush, Dr C. Tidemann and Professor I. W. B. Thornton supplied us with their observations on Krakatau birds. We are grateful to the many financial supporters of the expeditions (see Thornton & Rosengren 1988) and to Lembaga Ilmu Pengetahuan Indonesia (L.I.P.I.) and Lembaga Biologi Nasional (L.B.N.) for permission to work on the islands. Professor I. W. B. Thornton and two referees made helpful comments on drafts of this paper.

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