AGE AND SEX DETERMINATION OF KAKERORI *Pomarea dimidiata*

By H.A. ROBERTSON, J.R. HAY and E.K. SAUL

ABSTRACT

The Kakerori, or Rarotonga Flycatcher, of the Cook Islands has two distinctive colour forms: orange and grey. Our colour-banding study showed that colour is simply related to age, not to sex as described earlier. When fledglings leave the nest their body is covered in grey down, and their wings and tail are still growing. Orange juvenal plumage is attained about one month after fledging. Despite having similar orange plumage, yearlings can be distinguished from 2 year-old birds on the basis of bill colour and wing and tail lengths. Third-year birds have elements of both main colour phases. Once the definitive basic plumage is attained in the fourth year, the age of grey birds cannot be determined. Wing and tail lengths apparently increase at each successive moult until the definitive basic plumage is reached. Males are larger than females, with bill length being the best discriminator.

The progressive colour change recorded here parallels that described for three of the four other species of *Pomarea* flycatcher in eastern Polynesia, but colour variation in the other species, and in some other monarch flycatchers in the Pacific, needs critical examination.

The ability to distinguish three cohorts of Kakerori is useful in measuring annual variations in productivity, survivorship, and age structure of the population.

INTRODUCTION

The Kakerori, or Rarotonga Flycatcher, is an endangered monarch flycatcher endemic to the island of Rarotonga in the Cook Islands. *Pomarea* flycatchers, or monarchs, are small insectivorous forest birds found in eastern Polynesia, especially on high-altitude volcanic islands. All five species within the genus *Pomarea* are regarded as endangered, rare or vulnerable (IUCN 1990).

In the literature there is considerable confusion over the basis for the colour variation within the Kakerori. As its specific name *dimidiata* implies, the species has two distinctive colour forms. On the basis of three grey males and three "rufescent fulvous" females collected by Andrew Garrett, Hartlaub & Finsch (1871) originally described the Kakerori as being sexually dichromatic: "The totally different coloured female, as is usual in the members of this genus, resembles very much the female of *Monarches* [= *Pomarea*] *niger* [of Tahiti]...". Gill (1885), in documenting the decline of land birds on Rarotonga last century, referred to two species of "kakirori", presumably the two colour forms. DuPont (1976) followed Hartlaub & Finsch in describing and illustrating the male Kakerori as being grey and the female rufous. Holyoak (1980), after observing Kakerori in the field, noted that adult males are grey, whereas adult females and immature males are rufous: this model was followed by Pratt *et al.* (1987), except that they depicted all immatures as being rufous.

In 1983, David Todd (pers. comm.) found pairs of grey birds breeding, and this led Hay (1986) to note that the colour phases may not be related to sex or age. Just before our study began in 1987, Suzanne Mitchell (*in litt.*) noted a grey pair and also an orange pair and thought that plumage colour was most likely controlled genetically, as a polymorphism such as known for Fantail *Rhipidura fuliginosa* (Craig 1972) and Variable Oystercatcher *Haematopus unicolor* (Baker 1973).

Among the other *Pomarea* flycatchers in eastern Polynesia a variety of plumage patterns are described (Murphy & Mathews 1928). Two species, *P. nigra* of Tahiti and *P. whitneyi* of Fatu Hiva, Marquesas Group, have sexes similar (cf. Hartlaub & Finsch 1871 for *P. nigra* of Tahiti), but the immature form is distinctively different from the adults; in *P. mendozae* of Mohotani (Motane), Nuku Hiva and Ua Pu, Marquesas Group, adult males and females differ, and females vary from island to island in the amount of white and buff, and the immature form is distinctly different from adult patterns; in *P. iphis* of Eiao and Ua Huka, Marquesas Group, adult males are described (Murphy & Mathews 1928, Pratt *et al.* 1987) as being black and white, whereas females and immatures are both brown above and pale tawny below, with only slight differences between them. In this group of *Pomarea* flycatchers, plumage change with age appears to be characteristic and birds are capable of breeding before the definitive basic ("adult") plumage is attained (Murphy & Mathews 1928).

During a conservation programme aimed at saving the Kakerori from extinction, we individually colour-banded a large portion of the population and determined the basis of the colour variation in the species, and also differentiated the sexes from measurements.

METHODS

Each spring (August to early October), from 1987 to 1992, HAR mist-netted Kakerori in the forested interior of the southern part of Rarotonga, Cook Islands. The colour form of each bird was noted, and the colour of the bill was noted irregularly in 1987 and 1988, but regularly from 1989 onwards. Each bird was weighed and up to five linear measurements were recorded: wing, tail, tarsus, exposed bill and head & bill. All birds were marked with a unique combination of coloured plastic bands. Each spring, HAR used taped calls of Kakerori to help make a "roll-call" of colour-banded birds and he noted the colour form of each bird. These records were supplemented by observations of bill colours, moult, and plumages of fledglings in summer (November to February).

Comparisons of measurements were made with analysis of variance (ANOVA) and Tukey multiple comparisons were used to test for differences between age classes.

RESULTS

A total of 60 Kakerori were caught, measured and colour-banded during the study. Of these, 42 (84%) of 50 birds caught up to 1991 were resighted in subsequent years, sometimes up to five years in a row (Table 1). Three colour-banded birds (two males and one female) have now been recorded to

TABLE 1 — Plumage changes of 29 Kakerori between successive years after colour-banding; for example, three birds progressed right through all plumage patterns from Oy to G. Oy = orange plumage, yellow bill, Ob = orange plumage, blue bill, M = mixed plumage, G = grey plumage.

No. of Birds	Plumage Sequence
12	Oy → Ob
6	Oy → Ob → M
3	Oy → Ob → M → G
2	Ob → M
4	Ob → M → G
2	M → G

Note: All grey birds, including 13 originally banded as grey, remained grey in subsequent years (n = 60 bird years).

follow the complete plumage sequence from 1st year to 4th + years described below.

Ageing

Except for fledglings, the timing of moult and plumage change is not known precisely because birds were handled and observed systematically only in the spring. From the evidence available, we consider that there is a single moult each year. Adults moulting wing and tail feathers were recorded by EKS towards the end of the breeding season in January and February (when observations normally finished each year). The moult is apparently complete before June, because none of eight grey birds was moulting when handled by JRH and Gerald McCormack in June 1984. No birds handled by HAR between August and October were noted to be moulting. The terminology for the hypothesised moult sequences follows Humphrey & Parkes (1959).

All colour-banded birds, both male and female, changed plumage and bill colours in a standard pattern according to age. When the young left the nest they were still covered in grey-brown down, and had short, but growing, wings and tail. The juvenal orange (rufescent fulvous) plumage was attained by different birds from 2 to 8 weeks after fledging, presumably through the progressive loss of natal down from the feather tips: the last down to be lost was from the belly and flanks. Observations of birds through the breeding season by EKS indicated that the bill colour of first-year birds had generally changed to the second-year type at about 12 months (November). In the

TABLE 2 — Wing and tail lengths of Kakerori recaptured in subsequent years. The measurement is given under the appropriate colour phase (Oy = orange, yellow bill, Ob = orange, blue bill, M = mixed, G = grey), and so captures and recaptures of grey birds are given in two columns headed "G". All measurements were made by HAR with a stopped metal ruler.

	Wing (mm)					Tail (mm)				
Band	Oy	Ob	M	G	G	Oy	Ob	M	G	G
W-G	76	81				64	65			
W-BR	76	83				62	66			
-YB	77	83				61	64			
-GW	77	82				62	65			
W-WB	80	86				65	66			
-WG	77		82			62		66		
B-R		82	84				68	66		
R-G				86	85				69	68
W-YW				84	85				69	69
G-B				83	82				65	65

TABLE 3 — Sequence of plumage and bill colour changes in Kakerori.

Age (months)	Plumage Type	Bill	Plumage Colour
0 - 1	Natal	black, yellow base	grey-brown
1 - 15	Juvenal	black, yellow base	orange
15 - 27	1st basic	blue, black tip	orange
27 - 39	2nd basic	blue, black tip	mixed orange and grey
39 +	Definitive basic	blue, black tip	grey

first prebasic moult, at about 15 months of age (February), the orange plumage colour did not change appreciably, but wing and tail feathers were longer than in their juvenal plumage (Table 2). A mixed grey and orange plumage was adopted in the second prebasic moult at approximately 27 months, and the body of mixed-plumage birds became progressively greyer through the next year as the orange tips of the body feathers became worn

to expose the subterminal grey portion of the feathers. The definitive basic plumage, which is grey above and pale grey below, was finally reached at about 39 months, when wing and tail moult was noted towards the end of the breeding season. This sequence of plumage and bill-colour patterns for Kakerori is summarised in Table 3.

Field descriptions

Fledglings: Bill black with base of lower mandible prominently yellow to orange. Body covered in grey-brown down with a light grey (sometimes light yellow) head when they first leave the nest. Short wings and tail.

1st year: Bill black, with base of lower mandible pale yellow; upperparts orange; underparts pale orange, becoming paler towards the centre of the belly; wing feathers blackish-brown with pale orange outer edges; tail feathers pale orange, with blackish-brown centres to terminal quarter.

2nd year: Bill pale steel blue, with darker tip to the upper mandible; plumage similar to 1st-year bird's.

3rd year: Bill similar to 2nd-year bird's. Plumage highly variable, but always including some elements of grey and orange feathering. In oranger forms, grey most prevalent on forehead, crown and nape; greyer forms can be similar to 4th + year birds but always retain traces of orange on wings and/or tail, occasionally on forehead.

4th + year: Bill similar to that of 2nd- and 3rd-year bird's; upperparts grey; underparts white to very pale grey, extending as a collar onto the sides of the neck, and under the eye forwards to the base of the bill; wing and tail, dark grey.

We could not separate age classes once birds had attained the definitive basic plumage in their fourth year, but there seemed to be some consistent individual variation in the shade of grey, some birds being consistently darker or paler than most others.

Wing and tail lengths and weights increased with age in both males and females, and did not appear to be related to differences in feather wear, but the three skeletal measurements (bill, head & bill, and tarsus) showed no consistent variation with age (Table 4). From three recaptures of grey birds in subsequent years (Table 2), it appears that wing and tail lengths stopped increasing once the definitive basic plumage was attained.

Sexing

Within 17 of the 18 breeding pairs where both birds were colour-banded (Table 5), the two birds differed markedly in the three skeletal dimensions (bill, head & bill and tarsus) which did not vary systematically with age. In the field the clearest difference was in bill length, which had a bimodal distribution pattern (Figure 1). The exception was a pair in which both birds had bill lengths 13.5 mm or less, and we suspect that the measurement of the bill for the "male" was recorded incorrectly. In the 17 pairs, the bird with the longer bill (> 13.5 mm) was generally more aggressive and vocal,

TABLE 4 — Measurements of Kakerori presented as mean ± s.d. (n). Includes measurements of birds recaptured in a different plumage form from when first captured. Oy = 1st year. Ob-M = 2nd and 3rd years combined, G = 4th+ year. Vertical lines connect pairs of means that are significantly ($P<0.05$) different (ANOVA: Tukey multiple comparisons).

	♂	♀
Bill		
Oy	14.00 ± 0.54 (16)	13.10 ± 0.26 (17)
Ob-M	14.08 ± 0.61 (10)	12.80 ± 0.55 (5)
G	13.98 ± 0.29 (13)	12.98 ± 0.05 (4)
Head & bill		
Oy	39.38 ± 0.55 (16)	38.08 ± 0.66 (17)
Ob-M	39.51 ± 0.78 (9)	37.66 ± 0.56 (5)
G	39.31 ± 0.70 (11)	38.43 ± 0.41 (4)
Tarsus		
Oy	25.02 ± 0.34 (16)	24.38 ± 0.50 (17)
Ob-M	25.25 ± 0.44 (10)	24.06 ± 0.39 (5)
G	25.00 ± 0.52 (13)	24.43 ± 0.70 (4)
Wing		
Oy	78.38 ± 1.78 (16)	76.41 ± 1.70 (17)
Ob-M	83.42 ± 1.44 (12)	79.60 ± 1.52 (5)
G	85.08 ± 1.44 (13)	82.25 ± 1.89 (4)
Tail		
Oy	62.44 ± 1.26 (16)	63.24 ± 1.60 (17)
Ob-M	66.17 ± 1.59 (12)	64.00 ± 3.16 (5)
G	67.15 ± 1.91 (13)	66.50 ± 0.58 (4)
Weight		
Oy	22.19 ± 0.68 (16)	20.60 ± 1.20 (17)
Ob-M	23.67 ± 1.83 (12)	21.36 ± 1.10 (5)
G	23.48 ± 1.27 (13)	22.75 ± 1.11 (4)

Results of ANOVA on differences between males and females:

Bill: $F = 72.5$, $P<0.001$ H&b: $F = 51.2$, $P<0.001$ Tarsus: $F = 35.6$, $P<0.001$
Wing: $F = 38.2$, $P<0.001$ Tail: $F = 1.91$, $P=0.171$ Weight: $F = 18.8$, $P<0.001$

and in two pairings, the bird with the longer bill was known to be a male from its position during copulation with its two successive mates, one mate in 1987-89 and the other in 1989-90. We therefore concluded that males have longer bills than females and that the birds with a bill measurement greater than 13.5 mm are very likely to be males. When we sexed birds by their behaviour or bill length (if they were not territory holders), males were significantly heavier, and significantly larger for all linear measurements, except tail length (Table 4).

TABLE 5 — Bill, head & bill (H&B), and tarsus measurements of 18 pairs of Kakerori. Note that seven birds had two or more partners that were measured during our study. Wing length, tail length and weight were related to age and so could not be used.

Band combination		Bill (mm)		H&B (mm)		Tarsus (mm)	
"♂"	"♀"	"♂"	"♀"	"♂"	"♀"	"♂"	"♀"
G-Y	Y-G	13.8	13.0	38.6	37.6	24.6	24.0
R-Y	Y-G	13.8	13.0	38.8	37.6	24.9	24.0
R-Y	W-Y	13.8	12.8	38.8	37.9	24.9	24.6
-GY	YG-	13.9	12.0	40.1	37.3	25.3	24.6
-GY	W-G	13.9	13.2	40.1	37.1	25.3	23.9
-WG	-BY	13.9	12.7	39.3	37.3	25.0	24.2
-WG	R-B	13.9	13.4	39.3	37.3	25.0	24.2
-WG	G-G	13.9	12.6	39.3	37.6	25.0	24.0
G-W	B-G	14.3	13.2	39.3	38.3	24.9	24.5
-YR	B-G	14.2	13.2	39.3	38.3	25.0	24.5
-WY	W-WG	14.1	12.8	39.7	38.2	24.8	25.1
Y-B	W-WG	14.0	12.8	39.5	38.2	25.6	25.1
Y-B	-WR	14.0	13.0	39.5	37.2	25.6	23.4
Y-W	R-R	14.6	13.0	40.2	37.9	25.9	24.1
R-W	-RY	14.3	13.0	-	38.3	24.8	23.8
B-R	Y-R	13.0	13.5	38.7	38.6	24.7	24.1
W-BR	-RG	13.9	13.5	39.4	38.1	25.6	24.4
R-G	W-YG	14.2	13.0	40.2	38.8	25.4	24.4

"T-test" results (mean ± s.d. (n)

Bill: ♂ 14.00 ± 0.38 (13); ♀ 12.98 ± 0.38 (15); t = 7.04, P< 0.001
H&B: ♂ 39.43 ± 0.55 (12); ♀ 37.83 ± 0.54 (15); t = 7.50, P< 0.001
Tarsus: ♂ 25.12 ± 0.40 (13); ♀ 24.22 ± 0.40 (15); t = 5.85, P< 0.001

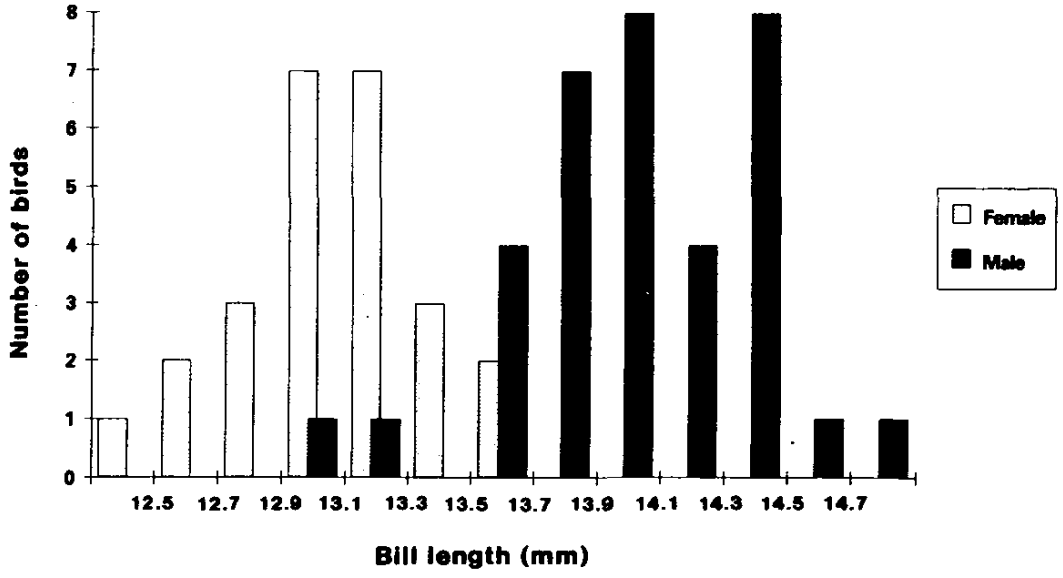

FIGURE 1 — Bimodal distribution of bill length of Kakerori

DISCUSSION

Based on a small sample of museum specimens and no previous field studies, the published descriptions of plumages of Kakerori are incorrect. In hindsight, it appears that the original collection of three grey birds and three orange birds, described by Hartlaub & Finsch (1871), was composed of three adult males, two 2 year-old females "bill hornish black" and a yearling female "bill black, base of mandible yellow". The "females" depicted by DuPont (1976) and by Pratt *et al.* (1987) are 2nd-year birds with the entirely dark bill.

Among the other four *Pomarea* flycatchers in eastern Polynesia, three (*P. nigra*, *P. mendozae* and *P. whitneyi*) show similar changes in colour with age as we have found in the Kakerori, with young generally being an orange - brown colour. Murphy & Mathews (1928) even noted that nestlings or early fledglings of *P. mendozae* and *P. whitneyi* are darker than later juvenals and that this change was apparently due to feather wear. The number of years before definitive basic plumage is attained is not known in any other *Pomarea* flycatcher. We therefore suggest that in the few remaining viable populations, field studies with colour-banded birds are needed to determine the pathway and time from juvenal to definitive basic plumages.

For the remaining species, *P. iphis* of Eiao and Ua Huka, Marquesas Group, Murphy & Mathews (1928) examined 16 males and 12 females (including juveniles) as the basis for describing age and sex variation in the species. It seems unusual that one species out of five in the genus would have a pattern of plumage variation completely different from the others and similar to that hitherto described for Kakerori, and so we suggest that a critical examination of the species in the field is necessary. In the original description by Murphy & Mathews (1928), the adult female of *P. iphis iphis* of Ua Huka was noted to have "pileum and nape olive-brown, *with a few interspersed black feathers on the forehead and crown, and around the eye...*" (our italics), which makes us suspect that all the females examined were in predefinitive basic plumages and that the plumage being described is like our mixed (3rd year) Kakerori.

Several other monarch flycatchers of the genera *Metabolus* and *Monarcha* in the South West Pacific seem to display changes from juvenal to adult plumages similar to those we have noted for Kakerori. The most striking is the Truk Monarch *Metabolus rugensis*, in which the female depicted in Plate 25 of Pratt *et al.* (1987) is similar in general appearance to a 3rd-year Kakerori, i.e. with a mixture of juvenal and definitive basic features; again a field examination is warranted.

The ageing and sexing of *Pomarea* flycatchers have been complicated by the fact that all species are capable of breeding before the definitive basic plumage is attained (Murphy & Mathews 1928; this study). The acquisition of definitive basic plumage is unusually protracted in this group and is, we believe, unique among passerines. Not only does it take four years for the definitive colour to be attained, but during this time, the wings and tail seem to become progressively longer at each moult. It is not unusual for first-year birds to have shorter wings than older birds (e.g. Svensson 1984) or for juvenal feathers to be soft and wear faster than subsequent feathers (Prater *et al.* 1977), but we are not aware of other passerines increasing wing and tail lengths progressively over four years.

In our conservation programme for Kakerori, being able to distinguish three cohorts plus one age class (4+ years) in the field has helped us to evaluate the success of the programme as the population has increased from a low of 29 birds in spring 1989 to 56 in spring 1992. Although we have not been able to colour-band every bird, we have been able to determine accurately the changing patterns of annual recruitment, the age structure of the population, and the age-specific mortality rates in response to different management regimes, based on the geographic distribution of sightings of different-aged birds each year.

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HUGH A. ROBERTSON & J. ROD HAY, *Science & Research Division, Department of Conservation, P.O. Box 10 420, Wellington, New Zealand;*
ED K. SAUL, *Conservation Service, P.O. Box 371, Rarotonga, Cook Islands*