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Population densities and detectability of 3 species of Fijian forest birds

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Abstract Three endemic forest bird species, masked shining parrot *Prosopeia personata*, giant forest honeyeater *Gymnomyza viridis*, and golden dove *Chrysoenas luteovirens* were surveyed using distance sampling from forest tracks at 4 sites on Viti Levu, Fiji. Repeat surveys were made at 1 site to better understand the factors affecting detectability. Seasonal changes in detectability reflected the number of calling birds and were almost certainly linked to breeding. The highest mean densities (41 masked shining parrot km^{-2} (birds), 33 giant forest honeyeater km^{-2} (calling birds) and 14 golden dove km^{-2} (calling males)) were found in low- to mid-altitude old-growth forest. Densities in degraded re-growth forest and mahogany plantations were about 30% and 50% lower, respectively. Densities in upland forest were very low for masked shining parrot (2.5 km^{-2}), but moderate for giant forest honeyeater (21 km^{-2}) and golden dove (8 km^{-2}). Provisional population estimates of 50,000 pairs of masked shining parrot, 70,000 pairs of GFH and 60,000 pairs of golden dove were made though attention is drawn to the limitations and uncertainties of these estimates. In common with many Pacific Islands, the endemic avifauna of Fiji is threatened by forest loss and degradation and a lack of protected areas. This study could assist in the design of effective protective areas as well as being a baseline for future surveys.

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Keywords Fiji; island endemic; forest bird; masked shining parrot; golden dove; giant forest honeyeater; bird detectability; population estimate

INTRODUCTION

Despite the many conservation threats to the endemic forest bird faunas of the Pacific islands there have been few quantitative studies of their abundance. Such information is important for estimating population size and trends, identifying conservation priorities, designing protected areas and making accurate IUCN threat assessments. The islands of the Fiji archipelago (177°E-178°W 16-19°S) are no exception. Of the 28 endemic forest bird species in Fiji, none has published estimates of population density.

This paper records the 1st attempt to estimate the densities of 3 species, each from a different family; the masked shining parrot (MSP) *Prosopeia personata* (Psittaciformes), the golden dove (GD) *Chrysoenas luteovirens* (Columbiformes) as and the giant forest honeyeater (GFH) *Gymnomyza viridis* (Passeriformes). These are known locally as *kaka, ko* or *bunako,* and *sovau*, respectively (Watling 2001). These species were chosen because they are endemic species of high conservation interest (MSP and GFH are currently listed as Vulnerable (BirdLife International, 2000)). Although all these species can be difficult to see, at certain times at least, they are easily detected by their highly distinctive, and relatively far-carrying, calls.

Some data were also collected at the same time on 2 regionally endemic doves, the many-coloured fruit-dove (MCFD) *Ptilinopus perousii* and friendly ground-dove (FGD) *Gallicolumba stairi,* and results for these species are also presented where possible.

The aims of this study were to develop a survey method that is practical in the Fijian terrain and habitats, to examine seasonal, time-of-day, and weather-related effects on bird detectability, to estimate bird densities in relation to forest type and altitude, and to combine the density results with estimates of habitat availability to calculate approximate population sizes.

The survey work reported here focused on a few sites in detail that were surveyed in a standardised way using the relatively advanced survey methods known as distance sampling (Buckland *et al*. 2001). The work compliments recent basic bird surveys by BirdLife International - Fiji (hereafter, *BirdLife*) over many forest sites in Fiji as part of a project to identify

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Important Bird Areas (Dutson & Masibalavu 2006). The results of the present study are interpreted in the context of these *BirdLife* surveys.

MATERIALS AND METHODS

Bird species

The focal species of the study are all medium-sized birds restricted to forest or scrub habitats.

Masked shining parrot The MSP is restricted to Viti Levu and is a typical large (*c.* 47 cm), mostly bright green, parrot that uses all forest layers, and nests in tree hollows. They are commonly seen flying over or through the canopy and give a range of distinctive loud calls (Watling 2001).

Giant forest honeyeater This large (*c.*27 cm) olive-green honeyeater is shy and mainly uses the upper canopy levels though it does descend to lower levels to visit suitable flowers. The Viti Levu race (*G. v. brunneirostris*) differs slightly from the Vanu Levu and Tavenui race (*G. v. viridis*) and is much more vocal (Watling 2001).

Doves The GD (*c.* 20 cm) is shy and is restricted to Viti Levu. It frequents mainly dense shrubbery and the lower forest canopy. Although males are bright yellow and females green, their reclusive behaviour means they are difficult to see. However, males are easily detected when they are calling. The similarly-sized MCFD occurs in Fiji, Tonga, and Samoa and the male has a striking cream, green, and purple plumage. It is found mainly in the upper canopy, often in small flocks, and feeds on figs. The slightly larger and mostly brown FGD mainly lives on the forest floor and is distributed widely in the region. On Viti Levu it is shy and hard to see although elsewhere it is more confiding (Watling 2001).

Survey sites and habitats

The study took place on Viti Levu, the largest island in the Fiji archipelago. Most of the southern and eastern parts of the island, and the central uplands, are covered with wet tropical forest and large plantations of mahogany. Bird surveys were conducted in 4 widely-separated areas: Savura (178°26′E 18°3′S); Namosi (178°10′E 18°5′S), Serua (177°50′ E 18°10′ S); and Monasavu (178°1′ E 17°42′ S) (Fig. 1).

Savura The Savura study area consisted of the catchment of the Savura Creek and the eastern foothills of Nakobalevu Hill (Fig. 1). The area had a rugged landscape that is typical of much of the eastern half of Viti Levu, i.e. ridges and steep slopes (average slope 18°) reaching up to 400 m a.s.l., and dissected by many creeks. The area had about 90% forest cover, consisting of a mixture of re-growth and old-growth forest and was at the edge of an area of forest that extended westwards more or less continuously for 85 km. Parts of the area are designated as a water catchment reserves. To the east was a semi-mature 6 km^2 mahogany plantation (which was also surveyed), and a mixture of forest fragments and agricultural land.

Namosi The Namosi study area was located c.30 km west of Savura (Fig. 1). It was part of the same large forest block and had a similar topography. The areas surveyed were predominantly covered in natural forest but 1 survey line was through the centre of a 17 km^2 recently-established mahogany plantation. In this plantation old-growth forest had been removed or poisoned and mahogany planted about 5 years before the survey. The habitat consisted of dead native trees, sapling mahogany, and areas of dense shrubland.

Serua The Serua study area (inland from Naboutini) was a further 35 km west of Namosi and again was part of the same forest block as the preceding sites (Fig. 1). However, the vegetation of this area had been converted to mahogany plantation and the topography was slightly less rugged. The mahogany plantation covered 51 km^2 and was mostly semi-mature (25+years old). The area surveyed formed a band through the centre of the plantation and was mostly at least 1 km from the plantation edge. Relict natural forest remained along steep creeks though this was estimated to amount to < 10% of the area.

Monasavu The Monasavu area was on the undulating central plateau area c. 850 m a.s.l. (Fig. 1). The natural forest here was of lesser stature and consisted of mainly rather small, close-growing trees. The central plateau has a noticeably cooler climate than that at lower altitudes.

Habitat areas

The extent of natural forest habitats and plantations on Viti Levu was estimated from the 1990-1993 Fiji National Forest Inventory survey map (NFI) (Fiji Department of Forestry 1995), which was based on satellite imagery. To ensure that our bird population estimates were conservative, the extent of natural forest at the time of our surveys was assumed to have declined by 10% since the NFI survey. This was equivalent to the 0.5-0.8% annual loss rate estimated by Classen (1991). The map of NFI habitat categories was examined for each study site and compared to the habitats observed there to produce a simplified habitat classification. For our analyses, NFI categories 'dense forest' and 'medium dense forest' <600 m were classified as 'low-medium altitude natural forest', 'scattered forest' <600 m as 'low-medium altitude degraded or re-growth forest', and all natural forest at >600 m was classified as 'upland forest'.

Survey method

The steepness of the terrain and density of the forest meant it was only practical to survey birds from existing tracks and paths. Following a 2-week

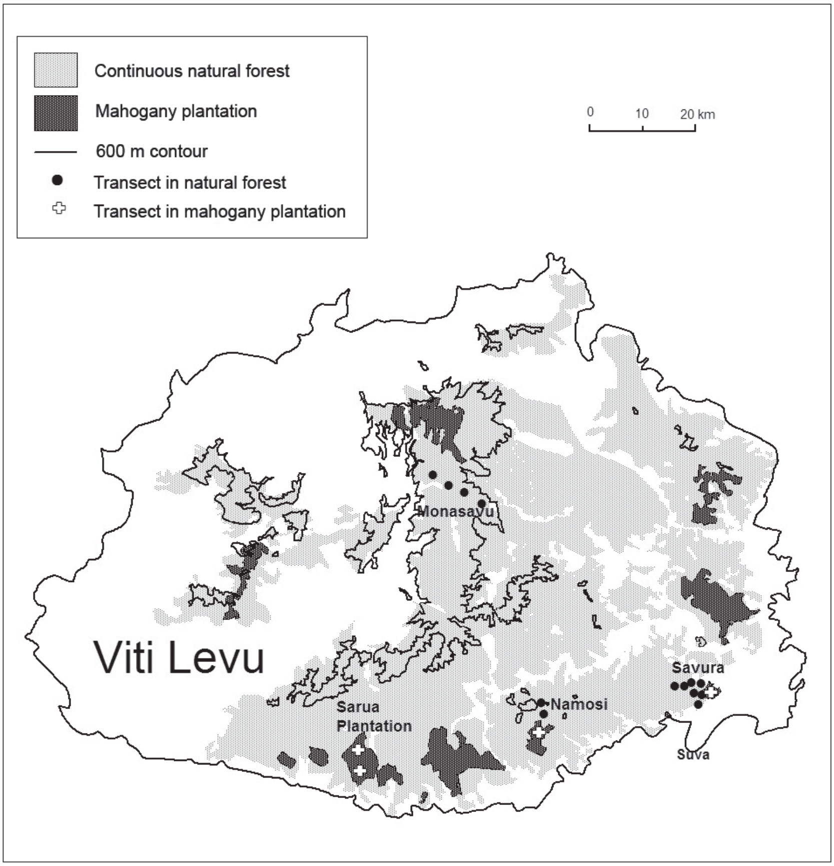

Fig. 1 Map of Viti Levu, Fiji Is, showing the locations of bird surveys, and extent of natural forest, mahogany plantations, and land over 600 m.

pilot study to develop the method, surveys were conducted along 18 transects totalling 42.7 km. Transects were more or less straight and, depending on availability of suitable tracks, 1.1-3 km long. Most followed a valley or a ridge. Ten transects were in low- to mid-altitude forest (<400 m), 4 in upland forest (>500m), and 4 in mahogany plantations at various stages of maturity (all <250 m a.s.l.). A more detailed study was done in the Savura study area. The 7 low- to mid-altitude transects in this area were surveyed at about fortnightly intervals from Jul to Dec 2003. The other 11 transects were each surveyed once (9), or twice (2), between mid-Sep and mid-Nov 2003, which coincided with the breeding seasons of these species.

The transects were traversed at *c*.1 km h^{-1}. This meant that most individual birds were in potential hearing range for about 15 min and, with their usual call rates, were likely to be heard at least once. Surveyors alternated walking short stretches (*c*.150 m) with stops of 5 minutes; this resulted in less confusion than walking continuously and made it easier to hear and locate distant birds. Except for some of the Savura transects, surveys started 15-45 min after sunrise, in fine (no rain), relatively still (wind <15km h^{-1}) conditions. The wet-tropical climate meant that some rain during surveys was inevitable; surveying was halted temporarily during showers and abandoned if continuous rain developed. Poor weather conditions prevented survey work on *c*.20% of mornings.

For MSP all birds seen or heard giving the various distinctive *squawk* calls were recorded. GFH records were restricted to birds giving the loud and frequent (typically every ±2 min) prolonged 'car-alarm' call and any birds that were seen. The other vocalisations of this species were considered too similar to those of wattled honeyeater *Foulehaio carunculata* (common at all sites) to be identified with certainty. Only adult male GDs were recorded, either birds seen or those giving the continuously repeated 'bark' call. The vocalisations of all 3 species could normally be heard at up to *c*. 250 m. For MCFD and FGD, all sight and aural records were recorded.

For every eligible bird or group detected the magnetic bearing (Silva 54B sighting compass) and distance from the observer's position (hand-held GPS unit using Fiji national grid co-ordinates) was recorded. If a bird was seen to fly to a new position,

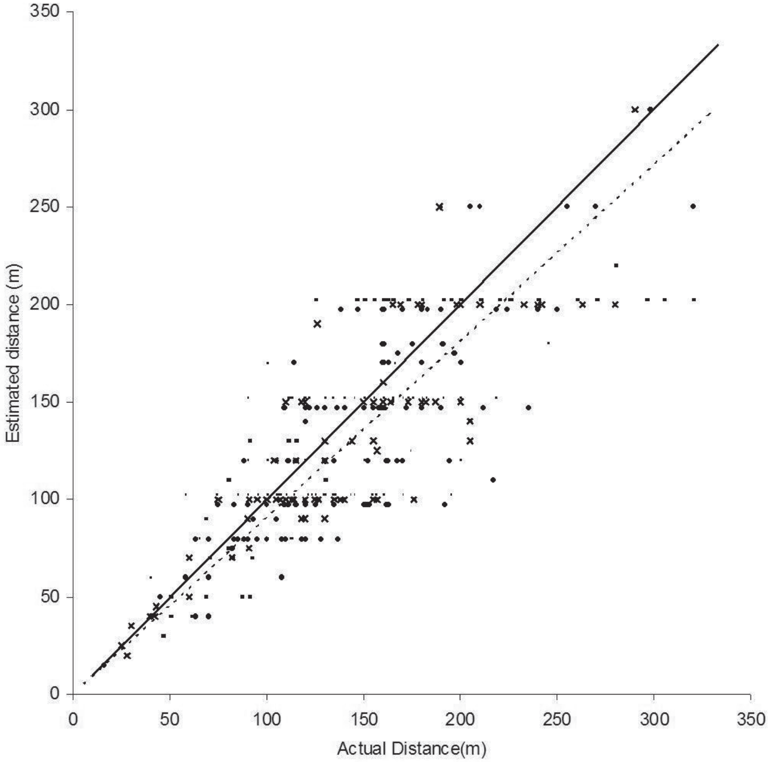

Fig. 2 Comparison of estimated distances with actual distances determined by direct measuring or trigonometry, during standardised surveys, Viti Levu, Fiji. X, masked shining parrot (*n*=78); ●, giant forest honeyeater (*n*=113); ‐, golden dove (*n*=128). Some points have been offset slightly to prevent overlap. Solid line, line of equality; dotted line, line-of-best-fit.

this was also recorded to prevent repeated records. Similarly, if what was believed to be the same bird or group was detected from a different observation point the position was recorded again and the record noted accordingly. MSPs (but not GD or GFH) were often in small groups. If birds were seen, group size was counted directly. For about 25% of heard-only records (*n*=702) a minimum count was possible; such instances were denoted by a '+' suffix to the count value. Birds that over flew the area being surveyed, or flew in from outside it, were excluded (applied only to 26 MSP records).

Distances to birds that were seen (MSP: 46% of 1115 records; GFH: 7% of 1405 records; GD: 3% of 531 records) could be estimated using a 1:10,000 topographical map, or if close to the track, measured by pacing. Distances to birds that were not seen but were heard from 2 or more locations >100 m apart were retrospectively calculated by triangulation (20% MSP; 40% GFH; 70% GD records). The GDs often called continuously from the same location for many minutes, which facilitated location by triangulation. Distances to birds that were heard from a single location only (the remainder) were estimated using the map, taking into account call direction, volume, attenuation, and perceived suitability of habitat.

Distance sampling requires that distances be known accurately so that the distance detection function can be correctly modelled. The accuracy of a sample of estimated distances was checked in 2 ways: when possible, visually estimated distances were measured by pacing; and compass bearings to a bird were taken from 2 (or more) locations that were a known distance apart (typically *c.*200 m) and the observer's estimate compared to that obtained by trigonometry. This was done either by a single observer taking 2 fixes at a short time interval, or as a specific validation exercise when both observers took simultaneous bearings.

During surveys, observers noted any signs of breeding activity (e.g., adults visiting nests or feeding young, and recently fledged juveniles).

Data handling and analyses

Co-ordinates on the Fiji national grid system were computed for each record by trigonometric calculation in an Excel® spreadsheet. The results for each survey visit were printed as a map (scatter-plot chart in Excel®) showing the estimated positions of all birds and their record identification number, observation positions, and the transect-line. Each map was checked against the field data to ensure locations were plotted correctly and to identify any instance of double records. Records of the same species <75 m apart on the plots and not recorded from the same location were assumed to be the same bird(s) unless evidence to the contrary had been recorded.

Table 1 Summary of records for masked shining parrot (*Prosopeia personata*; MSP), giant forest honeyeater (*Gymnomyza viridis*; GFH), golden dove (*Chrysoenas luteovirens*; GD), many-coloured fruit dove (*Ptilinopus perousii*; MCFD), and friendly ground dove (*Gallicolumba stairi*; FD) recorded during surveys in the areas of Viti Levu, Fiji, shown on Fig. 1, in 2003. % "seen", percentage of records in which bird seen; % "heard", percentage of records in which bird heard; % transects, percentage of 18 transects in which taxon recorded.

Taxon	No. records	No. individuals	(% "seen")	(% "heard")	(% transects)
MSP	1115	1806	45.7%	96.1%	94.4%
GFH	1481	1492	8.0%	99.1%	100%
GD	544	545	2.9%	98.7%	88.9%
MCFD	23	25	26.1%	95.5%	44.4%
FGD	4	4	25.0%	75.0%	22.2%

For the distance sampling analyses, only the position of the 1st record of an individual/group was selected. For these records, the perpendicular distance between the mapped position the transect-line was measured on the map to 1 mm, equivalent to <10 m on the ground.

Conventional Distance Sampling software (Distance 4.1®) was used to estimate density (Thomas *et al*. 2003). Perpendicular distances were pooled into 5 categories (0-44 m, 45-89 m, 90-139 m, 140-189 m, 190-239 m, 240-280 m) to reduce problems associated with inaccurate measurements (Buckland *et al*. 2001). Data for all species were right-truncated at 280 m to prevent the few most distant records unduly influencing the distance detection model (Buckland *et al*. 2001). The final model chosen was that which gave the minimum AIC information value.

For MSP, a correction was applied to the 16% of records where only minimum group size was known. This correction was based on the assumption that the frequency distribution of groups of known size (remaining 84% of records) should be the same as that for records where only minimum group size was known. In practice, it was found that the simplest way to achieve this match was to increase the group size value for every 3rd record (i.e. quasi-randomly) by 1.

The validation checks on the accuracy of estimated distances (i.e. those not directly measured or determined by triangulation) indicated that although some individual estimates were subject to moderate errors, overall there was a very strong correlation between the estimate and the measured distance (Fig. 2). On average, observers tended to slightly underestimate distances. The average degree of underestimation (*c*.9%) was the same for all 3 species (Fig 2). All estimated distances were multiplied by a factor of 1.1 to correct for this bias.

RESULTS

In general, MSP, GFH, and GD were common in the survey areas and in most instances all 3 species were recorded few to many times during each transect visit (Table 1). Factors affecting the detectability and apparent density of these species are examined below. MCFD and FGD were recorded only rarely (Table 1), so analyses attempted on data for these species were more limited. Apart from 1 juvenile GFH, all birds seen well during survey work appeared to be in adult plumage, although the juveniles of all specie surveyed are relatively difficult to distinguish in the field except by observing their behaviour (G. Dutson, *pers. comm.*).

Factors affecting bird detectability

The effects that rain, wind, time-of-day, and time-of-year had on the number of birds recorded were examined using data from the 7 Savura transects visited repeatedly from Jul to Dec. The 5 transects >2 km long were divided into even halves. This gave 12 *c*.1-km survey sections, each representing *c*.1 h of survey effort. The conditions during each visit to these sections were summarised by a single value for rain, wind, and time. The number of birds recorded on a visit was converted to an index (to reduce survey-section specific effects) by dividing it by the mean number for all visits to that section.

Weather On average the number of birds recorded on visits during which it rained for >20% of the time declined by about ⅔rds for MSP, ½ for GD, and by ⅓rd for GFH, compared to visits with little or no rain (Fig. 3). Rain for <20% of the survey period (e.g., showers) appeared to make no difference to the detectability of the 3 species. The lower recording rate during persistent rain probably reflects a combination of reduced bird activity (especially for parrots) and the greater difficulty in hearing birds.

At the time of surveys, it was obvious that vegetation noise resulting from winds > Force 3 made it difficult to hear birds, to the extent that observations were not attempted. Light winds (Force 2 or 3) prevailed on 20% of the Savura survey visits. In comparison to results in still air conditions (Force 0 or 1) they appeared to have no effect on the detectability of either MSPs and GFHs, but reduced by *c*.30% the number of GDs detected (Fig. 4).

Time of day For each visit to each of the 12 survey sections, the index of birds recorded was plotted

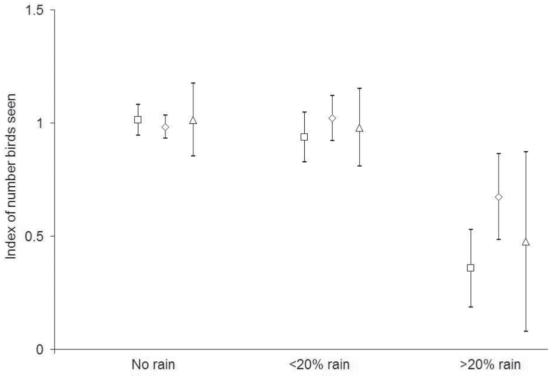

Fig. 3 Effect of rain on mean bird detectability, during standardised surveys, Viti Levu, Fiji: □, masked shining parrot; ◊, giant forest honeyeater; △, golden dove. Error bars ±2SE$_{mean}$.

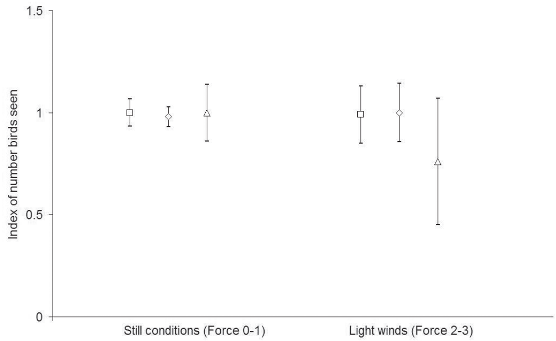

Fig. 4 Effect of wind on mean bird detectability, during standardised surveys, Viti Levu, Fiji. Symbols and error bars as in Fig. 3.

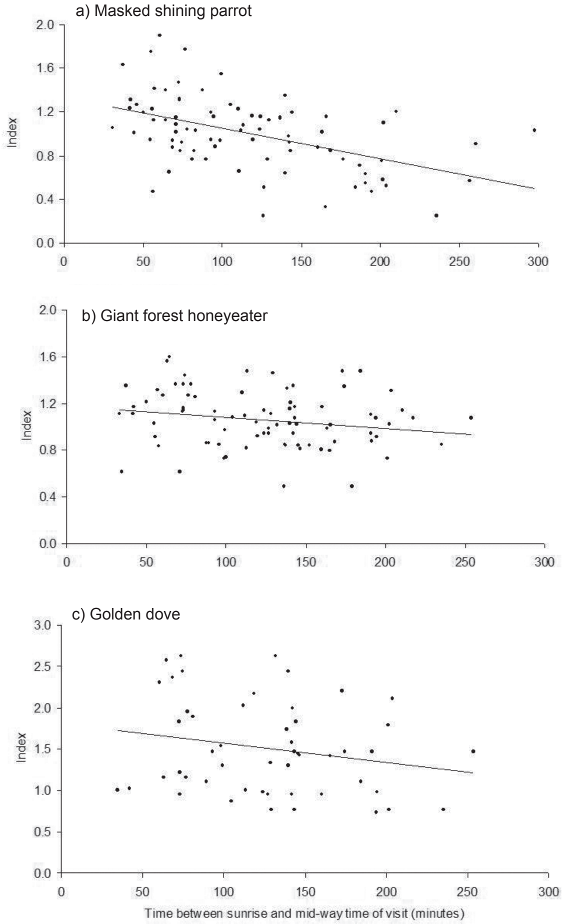

Fig. 5 Effect of time after sunrise on number of birds recorded during standardised surveys at 12 forest sections at Savura study area, Viti Levu, Fiji: (a) masked shining parrot (number of birds detected declined significantly during the morning; R^2 = 0.248, $F_{1,80}$ = 25.5, P=<0.001); numbers of (b) giant forest honeyeaters and (c) golden doves detected did not decline significantly (R^2= 0.043, $F_{1,81}$ = 3.65, P=0.06); R^2= 0.045, $F_{1,49}$ = 2.32, P=0.134, respectively).

against the interval between sunrise and the time at halfway through the visit (c. 30 min after beginning) (Fig. 5). Visits with >20% rain, and, for GFH and GD, all visits before mid-Jul, and 26 Aug, respectively (see below), were excluded from the analysis.

For GD and GFH, the number of birds detected showed only a slight, insignificant, tendency to decline through the morning period (GD R^2= 0.045, $F_{1,49}$=2.32, P=0.134; GFH R^2= 0.043, $F_{1,81}$ =3.65, P=0.06). In contrast, the number of MSP detected declined significantly (R^2 = 0.248, $F_{1,80}$ = 25.5, P=<0.001) during the morning (Fig. 5a), amounting to *c*.13% h^{-1} (Fig. 5a). In the usual clear weather, the increase in insect noise beginning *c*.3 h after sunrise probably made it harder to hear birds and contributed to the reduced detection rate for all 3 species.

Seasonality and evidence of breeding Before examining the effect of the time of year, the index values for MSP were adjusted to take account of the 13% decline h^{-1} in detection related to time of observation.

Through the survey period (early Jul to early Dec) the number of MSP recorded during surveys did not change (Fig. 6a) (R^2 = 0.02, $F_{1,122}$ = 2.70, P=0.103). A pair of MSP was seen entering and leaving a tree hollow twice in Jul but the stage of the breeding cycle was not established.

The number of GFH recorded increased significantly through the survey period (Fig. 6b). (R^2 = 0.27, $F_{1,113}$ = 41.1, P=<0.001). This amounted to an average increase in records of about 9% each successive month, though after mid-Sep there were insufficient data to be sure if the increase had peaked. The only direct evidence of GFH breeding was a recently-fledged juvenile seen in mid-Nov.

The number of GD recorded changed significantly through the study period (Fig. 6c) (linear regression of quadratic-transformed data,

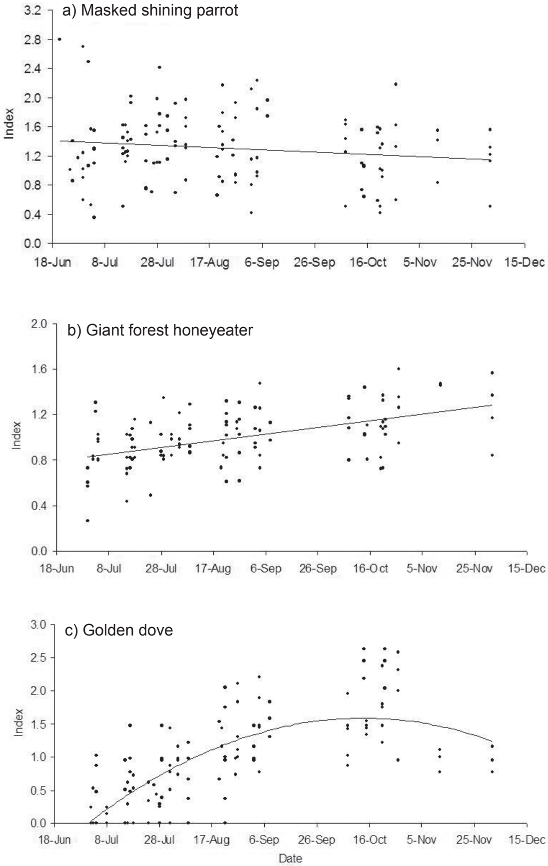

Fig. 6 . Changes over a 5- month period in the number of birds recorded during standardised surveys at 12 forest sections at Savura study area, Viti Levu, Fiji. Numbers of (a) masked shining parrots recorded did not change with date ($R^2 = 0.02$, $F_{1,122} = 2.70$, P=0.103), whereas numbers of (b) giant forest honeyeater ($R^2 = 0.27$, $F_{1,113} = 41.1$, P=<0.001) and (c) golden dove (linear regression of quadratic-transformed data, $R^2 = 0.49$, $F_{1,114} = 107.6$, P=<0.001) recorded both changed significantly, apparently reflecting breeding activity.

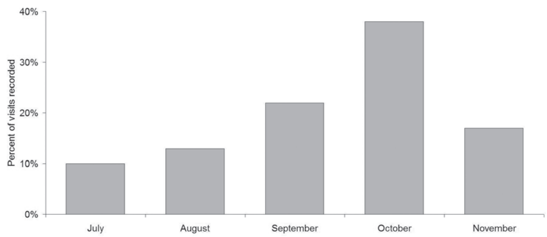

Fig. 7 Monthly pattern of all records of many-coloured fruit doves during survey work in Viti Levu forest, [n= 23 records (6 visual, 17 heard only), during 65 survey visits].

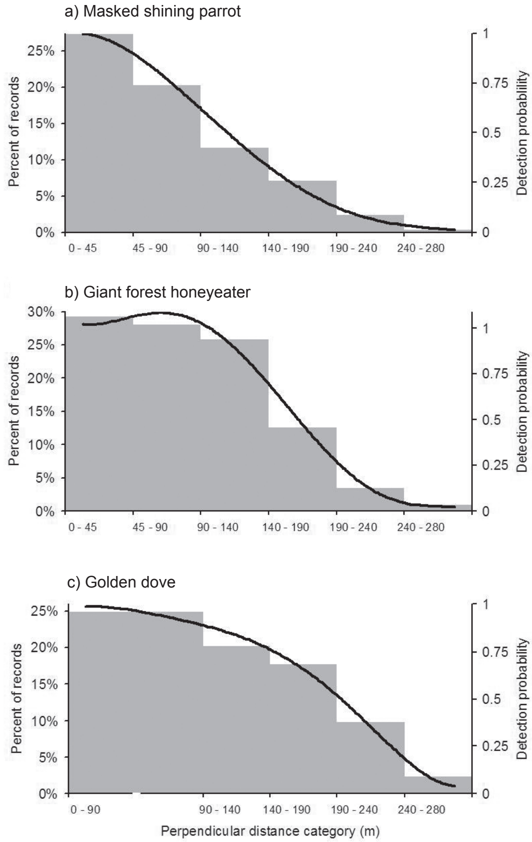

Fig. 8 Distance detection histograms and modelled detection curves for masked shining parrot, giant forest honeyeater, and golden dove, on Viti Levu, Fiji, based on results from Distance 4.1® software.

$R^2 = 0.49$, $F_{1,114} = 107.6$, P=<0.001). Numbers recorded increased steadily to reach a peak in Oct, and slowly declined thereafter. In Jul, and to a lesser degree in Aug, it was not uncommon for no GDs to be heard during a survey, but this was never so after 25 Aug. Two active GD nests were found in Oct.

The few records of MCFDs also showed evidence of a seasonal pattern; they increased steadily from Jul (recorded on 10% of visits), peaked in Oct (38% of visits), and declined thereafter (Fig. 7).

Group size

All GD (n=531) and 99% of GFH (n=1405) records were of single birds, the other 1% were instances of 2 birds only:63% (n=1115) of MSP records involved more than 1 bird and single birds were often within 100 m of another bird. At least 50% of MSPs recorded were with 1 other bird, either together or within 100 m. The true figure is probably greater because it is

Table 2 Summary of results of distance sampling surveys of masked shining parrot (*Prosopeia personata*; MSP), giant forest honeyeater (*Gymnomyza viridis*; GFH), and golden dove (*Chrysoenas luteovirens*; GD) in various forest habitats at 4 study sites on Viti Levu, Fiji, in 2003. Only survey results from visits when a species had a high level of detectability are included. Codes, Transet codes; D, population density; E, eligible visits.

					MSP			GFH			GD		
Site	Forest/plantation type	Alt (m)	Codes	Length (km)	E	D (km^{-2})	95% CI	E	D (km^{-2})	95% CI	E	D (km^{-2})	95% CI
Savura	Re-growth with *Merremia* vine	70	S1	2.6	7	29.0	*21.6 - 38.9*	4	18.8	*12.5 - 28.2*	3	7.8	*5.7 - 10.6*
Savura	Old-growth	160	S2	2.4	8	42.3	*33.3 - 53.6*	5	30.0	*23.3 - 38.4*	4	9.7	*6.5 - 14.3*
Savura	Mainly old-growth	185	S3	1.1	7	49.6	*38.3 - 64.3*	6	23.9	*17.2 - 33.0*	4	15.0	*7.5 - 30.2*
Savura	Old-growth	195	S4	2.2	9	39.7	*34.4 - 45.9*	6	37.7	*32.3 - 44.0*	3	11.4	*9.0 - 14.5*
Savura	Re-growth and farmland	245	S5	1.9	5	27.5	*19.6 - 38.5*	6	31.1	*22.1 - 43.8*	3	13.0	*5.8 - 29.1*
Savura	Mainly re-growth	315	S6	2.2	11	36.9	*31.3 - 43.5*	6	26.3	*21.2 - 32.6*	3	9.6	*7.1 - 13.1*
Savura	Old-growth	360	S7	1.1	7	60.9	*48.3 - 76.8*	5	52.3	*43.8 - 62.6*	4	22.8	*16.8 - 30.9*
Namosi	Re-growth and old growth	210 - 455	N1, N2, N3	2.1, 2.7, 2.1	3	25.1	*6.3 - 100*	3	32.2	*22.2 - 46.9*	3	14.2	*6.9 - 29.2*
Central Plateau	Upland	820 - 870	U1, U2, U3, U4	2.1, 2.9, 3, 2.7	4	2.5	*0.3 - 25.0*	3	21.1	*14.3 - 31.0*	3	8.3	*2.8 - 24.8*
Namosi	Sapling mahogany <6 yrs	219	P2	2.0	1	26.7	*13.6 - 52.5*	1	42.6	*28.5 - 63.9*	1	6.9	*2.9 - 16.3*
Savura	Semi-nature mahogany, *c.* 25-year-old	185	P1	2.5	2	22.1	*3.2 - 154*	2	5.1	*0.5 - 53.1*	2	15.1	*10.7 - 21.4*
Sarua	Mature mahogany, *c.* 40-year-old	230-235	P3, P4	2.7, 2.4	2	20.4	*13.3 - 31.3*	2	23.2	*19.8 - 27.1*	2	0.8	-

Table 3 Summary of results of distance sampling surveys of masked shining parrot (*Prosopeia personata*; MSP), giant forest honeyeater (*Gymnomyza viridis*; GFH), and golden dove (*Chrysoenas luteovirens*; GD)in various forest habitats at 4study sites on Viti Levu, Fiji, in 2003. Only survey results from visits when a species had a high level of detectability included. TL, total length of transects (km); E, eligible visits; D, density (km^{-2}).

			MSP				GFH				GD			
Habitat	Alt (m)	Transect codes	TL	E	D	95% CI	TL	E	D	95% CI	TL	E	D	95% CI
Degraded and regrowth forest	70-245	S1, S5, N1	29.6	13	29.3	*24.3 - 35.3*	25.5	12	24.6	*18.5 - 32.7*	15.6	7	10.4	*4.2 - 25.7*
Old-growth forest <600 m	160-455	S2, S3, S4, S6, S7, N2, N3	81.5	44	41.1	*36.6 - 46.2*	54.0	30	32.8	*27.5 - 39.0*	36.0	20	13.7	*5.6 - 33.2*
Upland forest >600m	820-870	U1, U2, U3, U4	10.4	4	2.5	*0.3 - 24.9*	8.2	3	21.1	*14.3 - 31.0*	6.0	3	8.5	*2.9 - 24.8*
Mahogany plantations (all ages)	217	P1, P2, P3, P4	12.1	5	22.2	*18.0 - 27.3*	12.1	5	18.8	*7.3 - 48.5*	7.4	5	6.5	*1.8 - 23.5*

Table 4 Indicative size of Viti Levu, Fiji, populations of masked shining parrot (*Prosopeia personata*; MSP), giant forest honeyeater (*Gymnomyza viridis*; GFH), and golden dove (*Chrysoenas luteovirens*; GD), based on mean densities calculated in main forest types and approximate areas of forest types. Estimates should be seen as indicative only because the few sites surveyed were unlikely to be representative. D, population density; IPS, indicative population size.

		MSP		GFH		GD	
Habitat	Area (km^2)	D (km^{-2})	IPS	D (km^{-2})	IPS	D (km^{-2})	IPS
Degraded and regrowth forest <600 m	1000	29.3	29300	24.6	24600	10.4	10400
Old growth forest <600 m	2800	41.1	115080	32.8	91840	13.7	38360
Upland forest >600m	854	2.5	2135	21.1	18019	8.5	7259
Mahogany plantations	388	22.2	8614	18.8	7294	6.5	2522
Totals			155129		141754		58541

very likely that a 2nd bird would not be recorded if it was hidden or remained silent. It seems likely, therefore, that MSPs spend most their time with another bird, presumably their mate.

Loose gatherings of MSPs (groups ≥3) were also recorded, typically comprising up to 9 individuals, but exceptionally as many as 15. These aggregations were temporary and dynamic, with individuals or pairs joining or leaving at any time. The birds in aggregations were normally highly vocal and chasing was observed frequently. Although aggregations were recorded throughout the survey period, they were much more frequent in late Jun and Jul (encountered on 60% of visits) the period that apparently coincided with the start of the breeding season (Jackson & Jit 2004), and declined steadily thereafter (to 25% of visits in Nov-early Dec). This could indicate that the aggregations may be associated with acquiring and maintaining breeding territories.

Distance sampling density estimates

The distance sampling was aimed at estimating population densities, so analyses were restricted to data collected when detection rates were high, when probably almost all individuals in the closest distance zone (see below) were detected. For all species, data from visits with >20% rain were excluded. For MSP only data from visits begun within 60 min of sunrise were included, whereas for GFH and GD data were restricted to visits made from Sep onwards, and from Sep to mid-Nov, respectively. There was no evidence that species differed in detectability between transects or study areas, therefore a single distance detection-function was used for each species (Fig 8). For the analysis of GD records data for the 2 shortest distance categories (0-44 m, 45-90 m) were pooled because birds tended to avoid the immediate vicinity of tracks, resulting in about 20 % fewer records than expected for the closest distance category.

Density estimates calculated for each of the transects at the Savura study area accorded multiple visits, and for each major forest types for the remaining study areas are given in Table 2. Habitat specific densities computed with results pooled across study areas are given in Table 3. Estimated densities between transects of a given forest type and altitudinal zone were broadly consistent (Table 2).

The highest densities of all 3 species occurred along transects with predominantly old growth forest, with average densities of 41 MSP km^{-2}, 33 GFH km^{-2}, and 14 male GD km^{-2} (Table 3). Densities of all three species averaged *c*.25% lower in regrowth and disturbance forest than in old growth. The average density of MSP in upland forest (2.5 birds km^{-2}) was only 6% of that in old growth forest at lower altitude. The only 2 transects in the study where MSP were not recorded were both in upland forest. Average densities of GFH (21 birds km^{-2}) and GD (9 males km^{-2}) in upland forest were *c*.40% lower than in lower altitude old growth forest.

On average, the population density of all 3 species in mahogany plantations was *c*.50% that for old growth forest at equivalent altitudes (Table 3). Although relatively little time was spent in surveys in areas of mahogany, GFH and GD densities did seem to be affected by plantation maturity. In particular, GDs appeared to avoid mature stands of mahogany, which lack a significant shrub under storey. All 3 species were common in the single survey site in young (pre-closed-canopy stage) mahogany plantation, although the distance to the plantation edge against old-growth forest from the transect line at this site was only 0.5-1.5 km.

Indicative population sizes and caveats

The density estimates were combined with the estimated extent of the forest habitats on Viti Levu to provide a crude estimate of total population size for MSP, GFH, and GD (Table 4). These estimates should be treated only as indicative of the approximate population size because they were based on few survey areas. Confidence limits have deliberately not been calculated for the estimates in Table 5, as this would imply that they encompassed the true

Table 5 Comparisons of encounter rates (birds seen or heard 10 h^{-1} survey effort) for 5 species of forest birds (masked shining parrot (*Prosopeia personata*; MSP), giant forest honeyeater (*Gymnomyza viridis*; GFH), golden dove (*Chrysoenas luteovirens*; GD), many-coloured fruit dove (*Ptilinopus perousii*; MCFD), and friendly ground dove (*Gallicolumba stairi*; FGD), on Viti Levu, Fiji, during surveys conducted by *BirdLife* and this study (2003). Values >1 are to nearest whole number. E, effort.

Site	Month(s)	E (h)	MSP	GFH	GD	MCFD	FGD
***BIRDLIFE* SURVEYS**							
Lowland sites (<600 m)							
Bovitu	Feb	14	17	23	33	4	0.7
Garrick	Oct	13	27	21	21	11	0
Korobaba	Feb	12	26	18	25	0	0
Laselevu	Jun	13	19	23	3	0	0
Medrausucu	Mar	16	17	38	27	3	0
Nabukelevu, Serua	July	24	25	22	6	0.8	0
Nakauvadra	Jun	12	2	4	17	3	0
Nakavika	Sep	6	120	125	16	16	11
Namosi[1]	Dec	14	3	31	13	0	0
Naraiyawa	Aug	7	57	78	11	0	0
Navua	April	9	12	16	1	0	0
Sovi	May, Oct	51	12	18	11	0.8	0.6
Wainadawa	Mar	13	3	7	3	5	0
Wainikatama	Sep	7	89	101	25	5	5
Lowland sites mean			**31**	**37**	**15**	**3**	**1**
Upland sites (>600 m)							
Wabu	Nov, Aug	23	3	22	18	0.9	0
Monasavu	Nov, Aug	20	0.5	49	15	0	0
Vaturu	Apr	18	19	16	9	15	4
Upland sites mean			**8**	**29**	**14**	**5**	**1**
THIS STUDY							
Savura study area	Jul-Dec	160	67	71	22	0.9	0.1
Namosi study area[1]	Oct-Nov	9	46	78	41	8	1
Mahogany plantations	Sep-Nov	13	39	52	12	0	0
Monasavu area (>600 m)	Sep, Nov	7	3	70	24	4	1

[1] The areas at Namosi surveyed by *BirdLife* and this study were several km apart.

population size. Nevertheless, it may be noted that the confidence limits of the density estimates (Table 4) suggest that, if the survey sites are representative, the 95% confidence limits on the population estimates are about ±15% for MSP, ±20% for GFH, and ±60% for GD. Furthermore, no attempt has been made to account for any of the factors discussed that may have caused the density estimates to be too high or too low as the biases are in both directions and are likely to at least partly cancel each other. For example, the mean density estimates for GFH and GD are suggested to be too low (see Discussion) because on average a significant proportion of the birds were not calling on a visit (even during favourable conditions), but comparison with *BirdLife* data (Table 5) suggests that the study areas were probably slightly better for these species than average.

The indicative population estimate for the masked shining parrot was 155,000 individuals. Large parrots typically do not breed until several years old (Juniper & Parr 1998), so the population could be expected to include many non-breeding immatures. If ⅓rd of individuals were non-breeding immatures, the breeding population might be *c*.50,000 pairs.

The estimate of *c*.142,000 giant forest honeyeaters was basically that of the number of calling birds (most survey records). Unfortunately it is not known whether females call too. During the surveys, it was common for 2 birds to be heard calling close to each other, though it could not be demonstrated whether these were instances of pair members, or neighbouring males, or both. Using a conservative approach, assuming that both males and females called, and that as calling birds probably held a territory, it is likely all were breeding individuals. If these assumptions were true, the breeding population for the Viti Levu subspecies would be *c*.70,000 pairs.

The estimated population of golden dove was for calling males. The number of breeding pairs would be similar, i.e. approaching 60,000 pairs, but the confidence intervals for this species were large so the estimate should be treated with caution.

DISCUSSION

Comparison with *BirdLife surveys*

The *BirdLife* encounter rate data (Table 5) were collected by a different and much less standardised method, and so are not directly comparable with the data from this study (G. Dutson, *pers. comm.*). In particular, observers tended to proceed more slowly, recorded all bird species (so inevitably devoted less attention to the 3 focal species of this study), did not map where birds were detected, and often recorded from within dense forest and not from on a wide track. This last results in greatly reduced detectability, in part as a result of the inevitable noise made by observers. Furthermore, *BirdLife* observations were not restricted to times and conditions of high bird detectability. For example, surveys were conducted later into the morning (up to 1000 h), in the late afternoon, and at all times of year. These differences can be expected to have resulted in lower average encounter rates, particularly for MSPs, in comparison to the results presented here.

Unfortunately, apart from 1 transect at Monasavu, none of the *BirdLife* surveys was in the locations surveyed in this study, so direct comparisons are not possible. The *BirdLife* survey mean encounter rates for MSP, GFH, and GD were generally 25-50% lower than those recorded in equivalent forest in this study (Table 5). The extent to which low encounter rates at some sites reflect low density or simply reflect low recording rates for the reasons already listed is unknown, but probably both contribute.

Given these differences in methods, it would be wrong to assume that the *BirdLife* survey data can be used to infer bird densities at these other sites. However, they do demonstrate 4 valuable points. First, although there were large site-to-site variations, MSP, GFH, and GD were widespread (all 3 species were recorded at all sites) and generally common in natural forest habitats on Viti Levu. Second, although they averaged higher, with the exception of GD, the encounter rates in the present study were well within the range of encounter rates found by *BirdLife* observers from a larger sample of sites, which shows that our sites did not have exceptionally high densities. On balance, the comparison suggests, perhaps, that the 2 low-mid altitude forest study areas (Savura and Namosi) had slightly higher than average population densities of these 3 species. Third, the *BirdLife* survey encounter rates for MSP in the central uplands (Monasavu and Wabu) were very low, which our findings corroborate. Interestingly, however, at the single site (Vaturu Dam) surveyed by *BirdLife* observers in the much more restricted uplands of western Viti Levu, MSP were encountered at rates similar to those in lowland forest sites. The difference may be linked to the much lower rainfall, and generally higher diversity and greater stature of the forest in the western uplands in comparison to forest on the central plateau. Fourth, the *BirdLife* survey results were also corroborated by the MCFD and FGD results from this study, which show that both species were patchily distributed and generally uncommon (Table 5).

In conclusion, comparison of our data with the *BirdLife* surveys generally supports the notion that the areas we surveyed were broadly typical of the large forest areas remaining in central, southern, and eastern Viti Levu.

Bird detectability

Repeating surveys at the Savura study area regularly over a 6-month period enabled us to examine the factors affecting detectability. This in turn enabled our survey methods to be refined (i.e. limiting survey work to times when bird detectability was highest), ultimately, we contend, resulting in more accurate and precise density estimates. The procedure also tested, at least for the 3 focal species, the validity of widely believed — but seldom tested — assertion that surveys are more accurate when performed in fine conditions early in the morning. We found that broadly this was true, especially for the MSP, for which detectability declined steadily in the few hours after dawn. Marked changes in detectability as the morning progresses have been found for other species of tropical parrot and for New Zealand kaka *Nestor meridionalis* (Marsden 1999; T. Greene, *pers. comm.*).

Variations in the numbers of individuals recorded along a transect (during periods and conditions conducive to high detectability) have implications for the accuracy of the density estimates. The visit-to-visit variations in records of GFH and GD were almost certainly caused mainly by differences in calling activity, rather than by variation in the numbers of individuals present. For both species, but especially GDs, calling by an individual appeared to stimulate neighbours to call, leading to a weak all-or-none effect. This suggests that on most (and perhaps all) visits not all birds present were calling and, therefore, that the mean density was underestimated. The mean difference between the mean and peak numbers of birds detected on visits to the Savura transects within the period of high detectability showed the likely extent of any underestimation was 30% for GFH and 28% for GD.

For MSP, differences in the numbers recorded probably resulted from real variation in the number of birds near the transect line and the density estimates are likely to be accurate. In comparison with GD and GFH, MSP appeared to be mobile and were often seen to make flights of up to several hundred metres (Jackson & Jit 2004). MSP were also frequently seen in aggregations of up to 10+ birds, with individuals having moved several hundred metres (Jackson & Jit 2004). It seems likely that such aggregations, social or otherwise, close to a transect could temporarily inflate the number of birds present in the detectable distance range, whereas gatherings just outside the detectable range could cause a temporary depletion. The lack of seasonal differences in the number of parrots recorded suggests that the population living in the Savura study area did not change markedly during the survey period.

Perhaps more surprisingly for the tropics was the strong seasonal pattern in detectability demonstrated for 3 species. The seasonal increase in the numbers of GFHs and GDs recorded almost certainly reflects an increase in the proportion of individuals calling (rather than an influx of birds) and coincided with the breeding season of these species. Seasonal variation in tropical forest bird detectability is, perhaps, under-appreciated yet would have major implications for the timings and interpretation of survey work. Seasonality in detectability in tropical systemsmerits further study.

Distance sampling

This study demonstrates that it is practical to undertake distance sampling of bird populations, at least for some species, in Fijian forests. The assumptions of distance sampling (Buckland *et al*. 2001) could be broadly met; any violations were minor and could not have significantly affected the final density estimates. The biggest difficulty encountered, that of estimating distances accurately, has been discussed already[1]. The validation tests conducted showed that observers were able to estimate distances with sufficient accuracy to support the results and that underestimation of distances balanced overestimation. There was no evidence that birds made evasive movements before being recorded or that the transect lines were not representative of the study area. The fact that most transects tended to follow valleys or ridges might be expected to have caused mid-slope forest to be under sampled. This is, however, unlikely because the distance from ridge tops to valley bottoms was typically <400 m and mid-slope habitat was usually well within the detection range for a species.

Distance sampling yielded significantly more information than simply recording the presence of birds, although it was much more time-consuming both in the field (as distances and bearings had to be measured) and, especially, during the analysis. It meant that the results were expressed as a density (usually with confidence limits), rather than an index value, and therefore could be used to calculate population size. Perhaps of even greater importance for conservation studies is that distance sampling can be used to show the population trend over time in a relatively unbiased way. Even though distance sampling in tropical forest is not without problems and takes longer to achieve, the results – quantitative densities that can be used to estimate population size – are a significant advance on the informed guesses of experts, which constitute the bulk of the information available at present. In this study, the main shortcomings in the population estimates are likely to arise from the limited number of sites surveyed and not in the distance sampling method itself.

The population density estimates for MSP in forests below 400 m obtained by distance sampling in this study are similar to those of 32-51 birds km^{-2} reported for the closely-related red shining parrots (*P. tabuensis*) on 'Eua in Tonga (Rinke 1988).

Conservation implications

The indicative population estimates produced for MSP, GFH, and GD showed that all 3 have substantial populations, each probably well in excess of 100,000 individuals. Despite uncertainty in the confidence intervals, these populations undoubtedly greatly exceed the IUCN threshold of <10,000 individuals to qualify for the threat listing of 'Vulnerable' on the basis of small population size. If it could be shown that numbers had declined by more than 30% in 3 generations, a threat listing of Vulnerable might still be applicable (BirdLife International 2000). However, this seems unlikely given the present rate of forest loss and that all 3 species use degraded forest and, at least under some conditions, mahogany plantations. Based partly on the present study, Dutson & Masibalavu (2006) recommended that GFH is re-categorised from Vulnerable to Least Concern and MSP from Vulnerable to Near Threatened. GD remains at the Least Concern level.

The 3 focal species were found in moderate densities in degraded and re-growth forest and in mahogany plantations. This suggests that these species could be resilient to some degree of habitat change, which would bode well for their long term future given that further losses and degradation of old growth forest are predicted and indeed inevitable (Classen 1991; D. Watling, *pers. comm.*).

[1]Note added in proof: Use of a handheld rangefinder would have further facilitated distance measurement, for birds seen. DBJ has since used this equipment, with very good results.

However, our results may give a false impression of the apparent value of degraded forest and, particularly, mahogany plantations as it remains to be demonstrated that birds living in these habitats are equally successful as those in old-growth habitats, or even that they are residents.

For example, the MSP requires large tree cavities for nesting, and these modified or novel habitats may be of low conservation value because of a shortage of suitable nest sites (Jackson & Jit 2004). The ecologies of MSP, GFH, and GD in mahogany stands need to be investigated. In this study most of the MSP and GFH recorded in mahogany plantations were in pure stands, and not in relict areas of natural vegetation. Although this suggests that mahogany trees themselves are used by these species, it is likely the areas of relict natural vegetation within plantations and nearby surrounding natural forest are very important to the survival of these species in plantations. The basic habitat of GD appears to be the native understorey shrub layers. Such undergrowth is cleared routinely from mahogany plantations, which could explain why GD were scarce in stands of semi-mature and mature mahogany.

It was not possible to estimate population sizes for MCFD or FGD because we recorded only small numbers of individuals. The paucity of records may reflect the soft vocalisations that are difficult to detect (G. Dutson, *pers. comm.*), but it is also likely these 2 species are generally scarce and patchily distributed in Viti Levu. MCFD is suspected to be semi-nomadic (Watling 2001); if so, it would make survey and monitoring more difficult. In contrast to the more optimistic view of the status of the 3 target species, the apparently low densities of these 2 species revealed by this study, and by the *BirdLife* surveys, should give cause for concern, especially as both have declined elsewhere in their restricted ranges (Watling 2001).

Field surveys are the basis for assessments of the status of forest birds and informing conservation decisions. It is therefore important that surveys are well-designed, well-executed, and thoughtfully interpreted. In the tropical forests of Pacific Is where the ecologies of most if not all species are generally poorly known, and resources and capacity for studies are often limited, it can be difficult to balance the conflicting demands of scientific rigour and the need to provide information that identifies conservation problems and can be a basis for conservation priorities. The Fiji Is have a high rate of avian endemism, accompanied by significant conservation threats, yet very little quantitative information exists to inform conservation measures that both the Fiji Government and NGOs are starting to develop. Our results suggest that targeted research such as this, can provide such information and demonstrate that the use of methods that go beyond simple bird recording add significant value to the affordable research that will be fundamental to maintaining as much as possible of the avian diversity of the archipelago.

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