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Seasonal Changes in Composition, Abundance and Foraging Behaviour of Birds in the Snowy Mountains

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Summary: The composition, relative abundance and foraging behaviour of birds were recorded in subalpine and alpine environments in the Snowy Mountains throughout the period 1977–1988. The numbers of species and individuals recorded decreased markedly with increasing altitude, with 63 species being observed regularly in the subalpine zone and 29 of these also occurring in the alpine zone. Bird populations showed a marked decline during autumn and winter, particularly after snow cover was established. All birds left the alpine zone for at least part of the winter period, and only six species remained throughout winter in the subalpine zone. Extensive snow-cover modified bird foraging behaviour by preventing feeding in the shrub layer and at ground level, thus restricting feeding to the trunks and foliage of snow gums and to the surface of the snow. This led to a reduction in bird diversity when compared to nearby snow-free montane habitats. In late winter and early spring an increase in arthropod fall-out on the remaining snow and flowering by the bird-pollinated shrub *Grevillea victoriae*, provided additional food for insectivorous birds and nectar feeders. With increased availability of food resources and foraging niches during spring and early summer high numbers of migratory birds were attracted to the region.

Introduction

Although the high mountain areas of south-eastern Australia have attracted considerable interest from scientists and naturalists, recent studies that have concentrated on the dynamics of bird communities in the Eastern Highlands have been conducted at tableland (Recher *et al.* 1983; Recher & Holmes 1985) and montane altitudes (Lamm & Wilson 1966). There has been little attempt to describe the seasonal dynamics of bird communities in the areas affected by permanent winter snow-cover, the subalpine and alpine zones.

McEvey (1962) provided an annotated bibliography relating to birds of the Victorian High Plains and Gall & Longmore (1978) presented similar information on the Snowy Mountains area in New South Wales. Unfortunately, many of the papers mentioned in these studies lack information that enables the species recorded to be correlated with particular environments or altitudes. In the Snowy Mountains area detailed site specific surveys of subalpine and alpine birds have been made only by Gall & Longmore (1978), Osborne *et al.* (1978) and Green & Osborne (1979). The overall conclusions from these studies are that there is a decrease in the number of species with increasing altitude, and a marked decline in the numbers of species and individuals present in winter. The reasons for this are not known, but are thought to relate to the increasing severity of the weather at higher altitudes.

Winter snow-cover exerts a profound influence on terrestrial fauna, particularly on those species unable to hibernate or live beneath the snow (Formosov 1946). Although the effect of winter snowfall on bird numbers has been recorded for lower altitude forest at Mt. Wellington in Tasmania (Thomas 1987), we know of no study that examines the influence of snow on the ecology of birds in mainland Australia. The present study describes the subalpine and alpine avifaunal communities of the Snowy Mountains and examines the foraging patterns and migratory behaviour of birds in relation to winter snow-cover and seasonal abundance of food resources.

Study area and methods

The study area was situated in the Snowy Mountains in Kosciusko National Park (Fig. 1). Observations were made throughout the Snowy Mountains but three areas were chosen for detailed study: (1) the alpine Main Range lying between South Ramshead and Dicky Cooper Bogong; (2) White's River valley north of Guthega Power Station; and (3) Twin Valleys near Thredbo (Fig. 1).

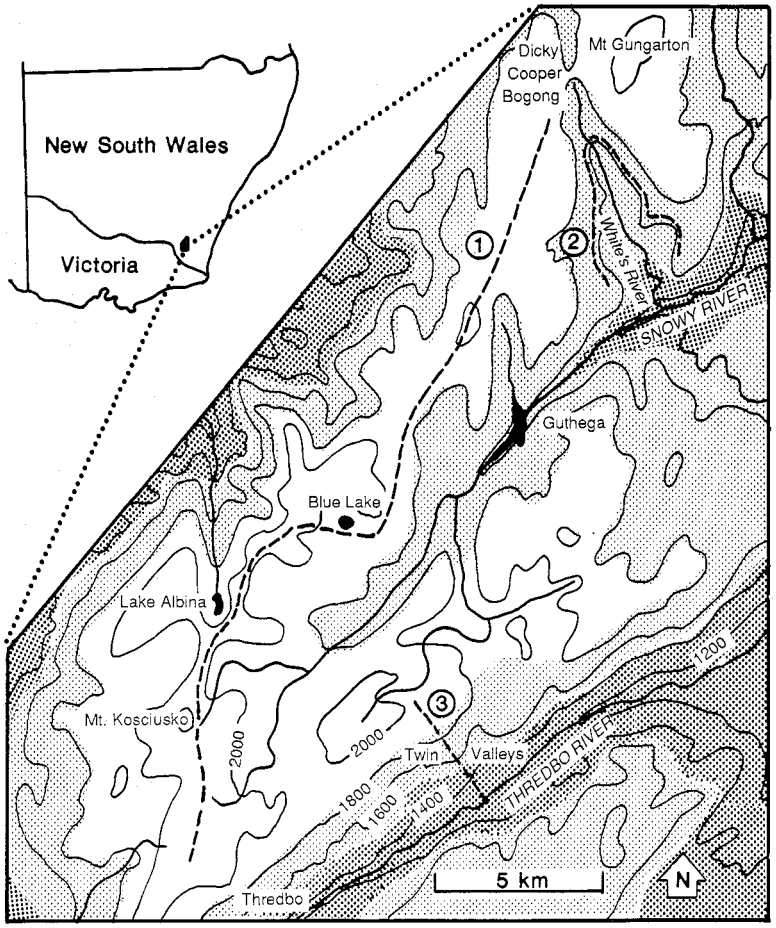

Figure 1 Location of the study area in the Snowy Mountains, NSW. Dark stippling indicates the approximate extent of the montane zone; light stipling, subalpine zone; unshaded, alpine zone. Contour interval = 200 m. Dashed lines indicate bird observation transects: 1, alpine Main Range; 2, Munyang Valley; 3, Twin Valleys.

The Snowy Mountains region includes montane (1000-1530 m asl), subalpine (1530-1800 m asl) and alpine environments (above about 1800 m asl) (Costin 1954). The alpine zone is the area above the physiological limit of tree growth (the treeline). It is characterised by a continuous snow cover for at least four months of the year and six to eight months with minimum temperatures below freezing (Costin 1957). The subalpine zone is more sheltered, lying between the treeline at its upper limit and the level of the winter snowline at its lower limit. It is characterised by a continuous snow cover for one to four months per year with minimum temperatures falling below freezing for about six months per year. The winter snowline is defined by the presence of a continuous snow cover for at least one month per year (Costin 1957). The extent of the subalpine zone is approximated by the occurrence of snowgum *Eucalyptus pauciflora* woodland. Below this is the montane zone which is often marked by a change from snowgum woodland to taller eucalypt forest (Costin 1954). Precipitation is in the range of 770-2000 mm per year with 120 to 140 days of precipitation in an average year (Costin 1957). Further descriptions of the climate, soils and vegetation of this area are given by Costin (1954) and Costin *et al.* (1979).

Visits were made to subalpine and alpine environments in the Snowy Mountains during most months each year for the period 1977 to 1988 inclusive. On many occasions we camped for extended periods, both in winter and summer, and undertook extensive walking trips which enabled us to observe birds throughout the study area. Over 800 observer days were spent undertaking field observations.

Records were made of all birds encountered, includ-

ing notes on relative abundance, evidence of breeding, foraging behaviour and the substrate where feeding occurred. Methods for recording feeding behaviour generally follow Recher *et al.* (1985) with the exception that for each individual encountered only the first foraging attempt was recorded. Foraging substrates recognised were: rock outcrop, tree trunk, major tree branches, tree foliage, shrubs, ground, snow, meltback (an area within general snow cover which had thawed) and the air (Fig. 2). Evidence for breeding included observation of the following (in decreasing order of certainty): eggs, nests, fledglings, birds visiting tree hollows, adults carrying nesting material and adults carrying food for presumed nestlings or juveniles.

The influence of increasing altitude on bird numbers and diversity was examined at Twin Valleys in the Thredbo Valley where a steep topographic gradient allowed comparisons to be made between montane, subalpine and alpine habitats (Fig 1). A disused and partly overgrown chairlift line at Twin Valleys gave access to sites between 1300 m and 1960 m ranging from dense *E. delegatensis–E. dalrympleana* montane forest, *E. pauciflora* subalpine woodland to alpine heathland and herbfield. Further details of the vegetation of this region are given by Cooper *et al.* (1984). Because of the steepness of the terrain it was not possible to use a transect strip method for censusing birds. Instead, a point count method (Pyke & Recher 1984) was adopted at intervals along the transects. At each of 13 bird count sites evenly distributed along the 3 km transect (approximately 200 m intervals), all birds seen or heard within 40 m of the centre of the site were recorded during a 20 min observation period. This area was censused once in December 1981 by WSO during fine weather when wind disturbance was low to absent.

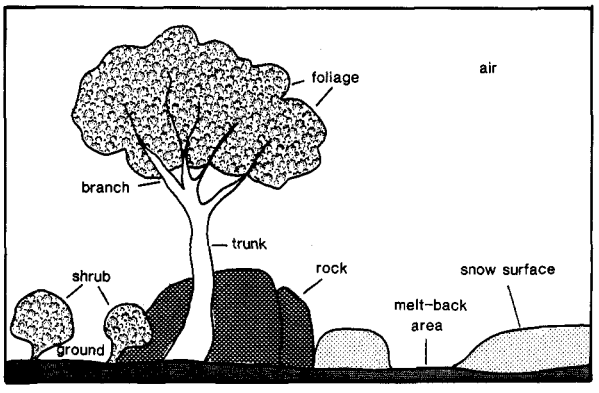

Figure 2 Habitat structural positions used to record bird foraging behaviour.

Visits to the alpine zone generally involved following the 8-km route of the alpine walking track between Mt. Kosciusko and Blue Lake (11 counts on snow-free days in summer and four counts in winter when snow cover was extensive); however, on two occasions in January and two occasions in July the entire alpine transect from South Ramshead to Dicky Cooper Bogong (Fig. 1) was walked or skiied. When skiing, an attempt was made to travel at walking pace and to make frequent stops to allow for careful observation. All birds seen or heard within 100 m of the transect were recorded.

Seasonal changes in relative abundance were assessed in the subalpine zone from July 1982 to May 1984. A 10 km long walking track which followed approximately along the 1600 m contour on either side of the White's River valley (Fig. 1) was used as a transect. The transect passed through dense subalpine *E. pauciflora* woodland along most of its length. The understorey in this woodland varied from localised forb-rich grassland to extensive areas of dense and diverse heath up to 2 m in height. The tall heath was dominated by the shrubs *Bossiaea foliosa*, *Phebalium squamulosum*, *Prostanthera cuneata*, *Baeckea utilis*, *Callistemon sieberi*, *Grevillea australis*, *Grevillea victoriae* and *Tasmannia xerophila*. The ground cover consisted of low shrubs (mainly Fabaceae and Epacridaceae) and herbs. The transect was surveyed by the same observer (WSO) at approximately monthly intervals. All birds seen or heard within about 30 m of the transect centre line were counted. All counts were made between one hour after sunrise and midday, during fine weather when wind disturbance was low or absent. Although changes in abundance also can be due to changes in detectability rather than changes in actual numbers, the low height of the trees (< 15 m) in the study area, and the increased visibility of birds in winter when shrubs are snow-covered, should have compensated for any decrease in detectability due to reduced calling by birds. Thus, the seasonal trends reported here should provide a reasonable indication of gross changes in relative abundance.

A qualitative record was made of the extent of flowering by shrubs observed along the transect on each trip. Because the exact dates of commencement and completion of flowering were not known, these were recorded as being mid-way between sampling trips. Changes in insect abundance were measured between July 1982 and May 1983 using 20 pitfall traps set in subalpine *E. pauciflora* woodland. Pitfall traps consisted of white

Table 1 Residency status, relative abundance, and breeding records for birds observed in the alpine and subalpine zones of the Snowy Mountains between 1977 and 1988. Residency status: R = present throughout year; S = present during snow-free months only; O = occasional occurrence during snow-free months. Breeding recorded = (B). Relative abundance: S = scarce, < 10 individuals recorded during entire study; U = uncommon, 10 - 50 individuals recorded; C = common, 50 - 100 individuals recorded; A = abundant, > 100 individuals recorded. * introduced species.

Species	Residency status		Relative abundance	
	alpine	subalpine	alpine	subalpine
Emu *Dromaius novaehollandiae*	—	O	—	S
Australasian Grebe *Tachybaptus novaehollandiae*	S	S	U	U
Great Cormorant *Phalacrocorax carbo*	O	S	U	U
Little Pied Cormorant *Phalacrocorax melanoleucos*	O	O	S	S
Pacific Heron *Ardea pacifica*	O	O	S	S
White-faced Heron *A. novaehollandiae*	O	O	S	S
Pacific Black Duck *Anas superciliosa*	S	S	C	C
Maned Duck *Chenonettta jubata*	O	S	U	U
Black Shouldered Kite *Elanus notatus*	S	S	S	S
Brown Goshawk *Accipiter fasciatus*	S	S	U	U
Wedge-tailed Eagle *Aquila audax*	S	S	U	U
Peregrine Falcon *Falco peregrinus*	O	O	S	—
Australian Hobby *F. longipennis*	O	O	S	S
Brown Falcon *F. berigora*	O	S	S	S
Australian Kestrel *F. cenchroides*	S	S	C	U
Stubble Quail *Coturnix pectoralis*	O	S	S	S
Masked Lapwing *Vanellus miles*	S	S	S	S
Latham's Snipe *Gallinago hardwickii*	S	S	U	U
Common Bronzewing *Phaps chalcoptera*	—	O	—	S
Brush Bronzewing *P. elegans*	—	S	—	S
Yellow-tailed Black Cockatoo *Calyptorhynchus funereus*	—	R	—	C
Gang-Gang Cockatoo *Callocephalon fimbriatum*	—	R	—	C
Crimson Rosella *Platycercus elegans*	—	R (B)	—	A
Fan-tailed Cuckoo *Cuculus pyrrhophanus*	O	R (B)	S	C
Shining Bronze-Cuckoo *Chrysococcyx lucidus*	O	R (B)	S	C
White-throated Needletail *Hirundapus caudacutus*	S	S	A	C
Skylark* *Alauda arvensis*	S	S	S	S
Welcome Swallow *Hirundo neoxena*	S	S (B)	S	U
Richard's Pipit *Anthus novaeseelandiae*	S (B)	S (B)	A	A
Black-faced Cuckoo-shrike *Coracina novaehollandiae*	—	S	—	U
White's Thrush *Zoothera dauma*	—	S	—	S
Pink Robin *Petroica rodinogaster*	—	S (B)	—	S
Flame Robin *P. phoenicea*	S (B)	S (B)	C	A
Olive Whistler *Pachycephala olivacea*	S	S (B)	U	A
Golden Whistler *P. pectoralis*	—	S	—	U
Rufous Whistler *P. rufiventris*	—	S	—	U

Continued next page

Table 1 Continued.

Species	Residency status		Relative abundance	
	alpine	subalpine	alpine	subalpine
Grey Shrike-thrush *Colluricincla harmonica*	—	W(B)	—	C
Satin Flycatcher *Myiagra cyanoleuca*	—	S	—	S
Grey Fantail *Rhipidura fuliginosa*	O	S (B)	S	A
White-browed Scrubwren *Sericornis frontalis*	S (B)	R (B)	C	A
Brown Thornbill *Acanthiza pusilla*	S (B)	R (B)	C	A
Striated Thornbill *A. lineata*	—	S (B)	—	C
White-throated Treecreeper *Climacteris leucophaea*	—	R	—	C
Red Wattlebird *Anthochaera carunculata*	O	S (B)	S	A
Yellow-faced Honeyeater *Lichenostomus chrysops*	O	S (B)	U	A
White-eared Honeyeater *L. leucotis*	—	S (B)	—	C
Brown-headed Honeyeater *Melithreptus brevirostris*	O	S	S	U
White-naped Honeyeater *M. lunatus*	O	S	S	C
Crescent Honeyeater *Phylidonyris pyrrhoptera*	O	S	U	A
Eastern Spinebill *Acanthorhynchus tenuirostris*	O	S (B)	U	C
Spotted Pardalote *Pardalotus punctatus*	—	S (B)	—	U
Striated Pardalote *P. striatus*	—	S	—	C
Silvereye *Zosterops lateralis*	S	S	A	A
Goldfinch* *Carduelis carduelis*	—	S	—	U
Red-browed Firetail *Emblema temporalis*	—	S	—	U
Common Starling* *Sturnus vulgaris*	S (B)	R (B)	C	C
Australian Magpie *Gymnorhina tibicen*	S	R (B)	U	U
Pied Currawong *Strepera graculina*	O	R (B)	S	C
Grey Currawong *S. versicolor*	—	R (B)	—	U
Australian Raven *Corvus coronoides*	S	R	U	U
Little Raven *C. mellori*	S	R (B)	A	A

plastic disposable drink cups of 70 mm diameter filled partly with a preservative (Green 1982). The traps were cleared at monthly intervals (Green 1988).

Results

Composition of the avifauna

Sixty-one species of birds were found regularly at altitudes above 1530 m asl in the Snowy Mountains (Table 1). Thirty-six species were recorded in the treeless alpine zone and these, with a further 25 species, occurred also in the subalpine zone. Evidence of breeding was found for five species in the alpine zone and 23 species in the subalpine zone (Table 1).

The birds most frequently observed in the alpine zone during the snow-free months were Richard's Pipit *Anthus novaeseelandiae* (recorded on 79% of visits), Little Raven *Corvus mellori* (68%) and Australian Kestrel *Falco cenchroides* (49%). Less frequently observed in the alpine zone were Pacific Black Duck *Anas superciliosa* (16%) (usually present in small flocks on the alpine lakes), Australian Magpie *Gymnorhina tibicen* (16%) and the introduced Common Starling *Sturnus vulgaris* (19%). At lower levels in the alpine zone, tall heath vegetation growing in sheltered situations supported low numbers of Brown Thornbill *Acanthiza pusilla* (11%), White-browed Scrubwren *Sericornis frontalis* (5%) and Silvereye *Zosterops lateralis* (5%). Other species observed less frequently in the alpine

zone included Wedge-tailed Eagle *Aquila audax*, Black-shouldered Kite *Elanus notatus*, Stubble Quail *Coturnix pectoralis*, Latham's Snipe *Gallinago hardwickii*, White-throated Needletail *Hirundapus caudacutus*, Flame Robin *Petroica phoenicea* and Australian Raven *Corvus coronoides* (Table 1).

In winter, when deep snow covered the ground in the alpine zone, birds were seen infrequently with only occasional records of Little Ravens being made. During the two July counts along the entire alpine transect no birds were recorded.

Many more species of birds were recorded in the subalpine zone (Table 1). Over the two years of study in the Whites River area the birds most commonly observed were Brown Thornbill, Crescent Honeyeater *Phylidonyris pyrrhoptera*, White-browed Scrubwren, Yellow-faced Honeyeater *Lichenostomus chrysops*, Grey Fantail *Rhipidura fuliginosa*, Silvereye, Olive Whistler *Pachycephala olivacea*, Crimson Rosella *Platycercus elegans*, Flame Robin, Eastern Spinebill *Acanthorhynchus tenuirostris*, Little Raven, Red Wattlebird *Anthochaera carunculata*, White-throated Treecreeper *Climacteris leucophaea*, Grey Shrike-thrush *Colluricincla harmonica*, Striated Pardalote *Pardalotus striatus*, Striated Thornbill *Acanthiza lineata*, White-eared Honeyeater *Lichenostomus leucotis* and Pied Currawong *Strepera graculina* (Fig. 3).

Although most of the birds recorded were found in subalpine woodland, some, such as Australian Kestrel, Richard's Pipit, Common Starling, Australian Magpie and Little Raven, were seen most frequently in open areas such as grassland, herbfield and heathland. Many other bird species were recorded in the subalpine zone (Table 1) but they were observed less frequently than the birds mentioned above. Several occurred in very low numbers but, because they were recorded regularly over the years, they were considered to be a part of the avifauna. These included uncommon species such as the Emu *Dromaius novaehollandiae* and Australian Hobby *Falco longipennis*, as well as birds that are relatively common at lower altitudes. This latter group includes the Australasian Grebe *Podiceps novaehollandiae*, Little Pied Cormorant *Phalacrocorax melanoleucos*, Pacific Heron *Ardea pacifica*, Black-shouldered Kite *Elanus notatus* and Brush Bronzewing *Phaps elegans*. Species that were recorded on very few occasions, and were probably vagrants from nearby montane areas, included the Eurasian Coot *Fulica atra*, Australian Owlet-nightjar *Aegotheles cristatus*, Galah *Eolophus roseicapillus*, Sulphur-crested Cockatoo *Cacatua galerita*, Laughing Kookaburra *Dacelo novaeguineae*, Pilotbird *Pycnoptilus floccosus*, Noisy Friarbird *Philemon corniculatus* and Olive-backed Oriole *Oriolus sagittatus*.

Some of the uncommon birds were associated with particular localised habitats. Latham's Snipe were observed only in fen, bog and other marshy habitats, Stubble Quail were recorded during late summer in grassland and Pink Robins *Petroica rodinogaster* were found only in sheltered, densely-vegetated subalpine and montane valleys. In contrast, White-throated Needletails, a trans-equatorial migrant to Australia (Frith 1976), were observed occasionally flying at subalpine and alpine altitudes during the summer months.

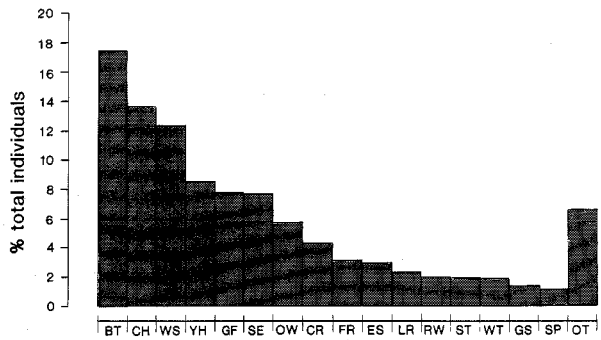

Figure 3 Relative abundance of common birds (n = 2719) recorded over 24 counts of subalpine birds in the White's River valley between July 1982 and May 1984. Bird species abbreviations are as follows: BT, Brown Thornbill; CH Crescent Honeyeater; WS, White-browed Scrubwren; YH, Yellow-faced Honeyeater; GF, Grey Fantail; SE, Silvereye; OW, Olive Whistler; CR, Crimson Rosella; FR, Flame Robin; ES, Eastern Spinebill; LR, Little Raven; RW, Red Wattlebird; ST, Striated Thornbill; WT, White-throated Treecreeper; GS, Grey Shrike-thrush; SP, Spotted Pardalote; OT, all other species combined.

Influence of altitude and season

The numbers of birds observed decreased markedly with increasing altitude. This was reflected in both the total number of species recorded utilising the subalpine zone (61) and alpine zone (36), and in the numbers of species and individuals recorded during counts made between altitudes of 1300 and 2000 m asl in the Thredbo Valley (Fig. 4). Only Little Raven and Richard's Pipit, species generally associated with treeless habitats, were more abundant in the alpine zone than the subalpine zone.

The total numbers of birds detected during monthly counts in the White's River area showed marked seasonality, declining from November 1982 to June 1983

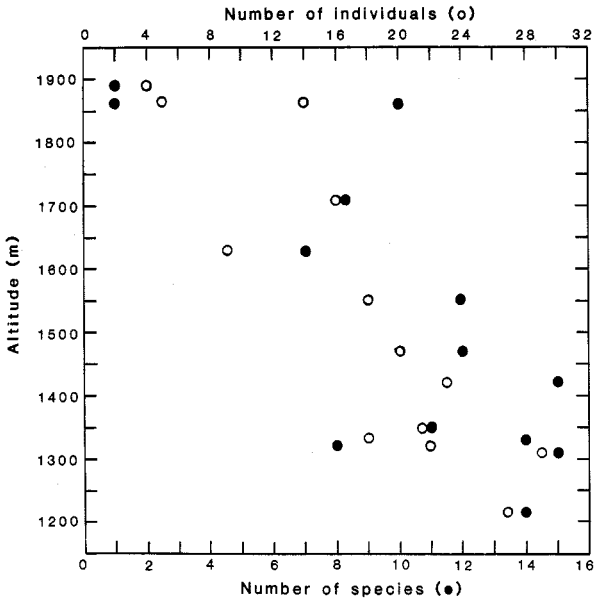

Figure 4 Relationship between altitude and the numbers of individuals (r = –0.77, $F_{1,11}$ = 16.04, P < 0.01) and species (r = –0.0.77, $F_{1,11}$ = 16.76, P < 0.01) recorded during a single survey of 13 points along a transect at Twin Valleys in the Thredbo Valley.

and, in the following spring, increasing to November 1983 before declining again (Fig. 5). The birds exhibited three main seasonal responses: some species were present in the area throughout the year, other species left the region during the colder months and some species appeared to be nomadic without regular seasonal behaviour (Fig. 6). The resident species were Crimson Rosella, Olive Whistler, Grey Shrike-thrush, White-browed Scrubwren, Brown Thornbill and White-throated Treecreeper. Apart from Grey Shrike-thrush and White-throated Treecreeper, which were uncommon in all months sampled, numbers of these birds were greatly reduced in winter, indicating that at least part of the population leaves the area. Yellow-tailed Black Cockatoo *Calyptorhynchus funereus*, Gang Gang Cockatoo *Callocephalon fimbriatum*, Striated Thornbill and Little Raven were sometimes observed during winter but were not recorded in all months of each year of the study and may have been locally nomadic.

Foraging observations

Feeding records were obtained for most species; however, many were isolated recordings and results have been used only where more than 25 records were available. The birds were divided into two groups: residents and summer migrants. In winter, the main foraging substrates were rock, tree trunk and tree branches, whereas in summer the main foraging positions were tree foliage, shrubs, ground and air, with early spring arrivals such as Flame Robin, Richard's Pipit and Little Raven also feeding on snow and meltback areas (Table 2).

During winter when snow cover was extensive birds such as White-browed Scrubwren and Olive Whistler, that fed on the ground and in the shrub layer, generally were restricted to lower altitude areas where shrubs still projected through the snow. Other resident species that did not move altitudinally utilised the trunk, branches and foliage of snowgums as feeding sites (Table 2). Larger birds such as Little Raven and Australian Magpie preyed on invertebrates caught on the snow surface

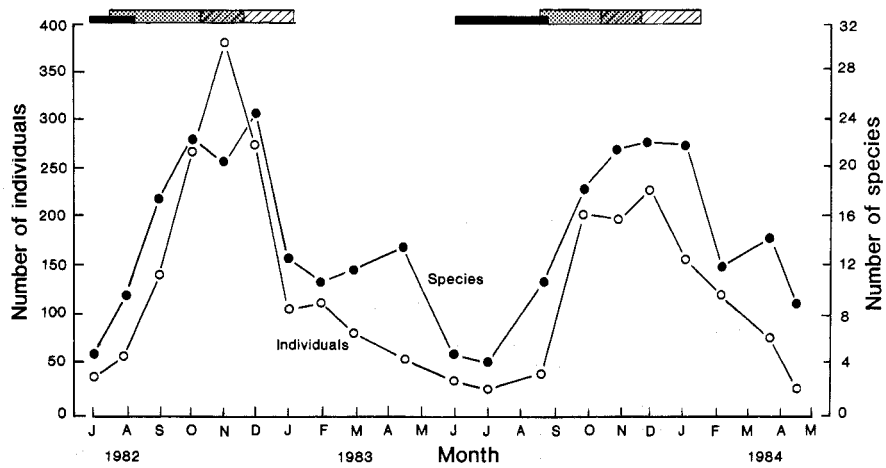

Figure 5 Total numbers of individuals and species counted at approximately monthly intervals along a 10 km transect through subalpine woodland at 1600 m altitude in the White's River valley. Bars at the top of the graph indicate the following: solid bar, period when snow cover was extensive and buried understorey shrubs; stippled bar, period during which the shrub *Grevillea victoriae* flowered; hatched bar, period during which other common shrubs were flowering.

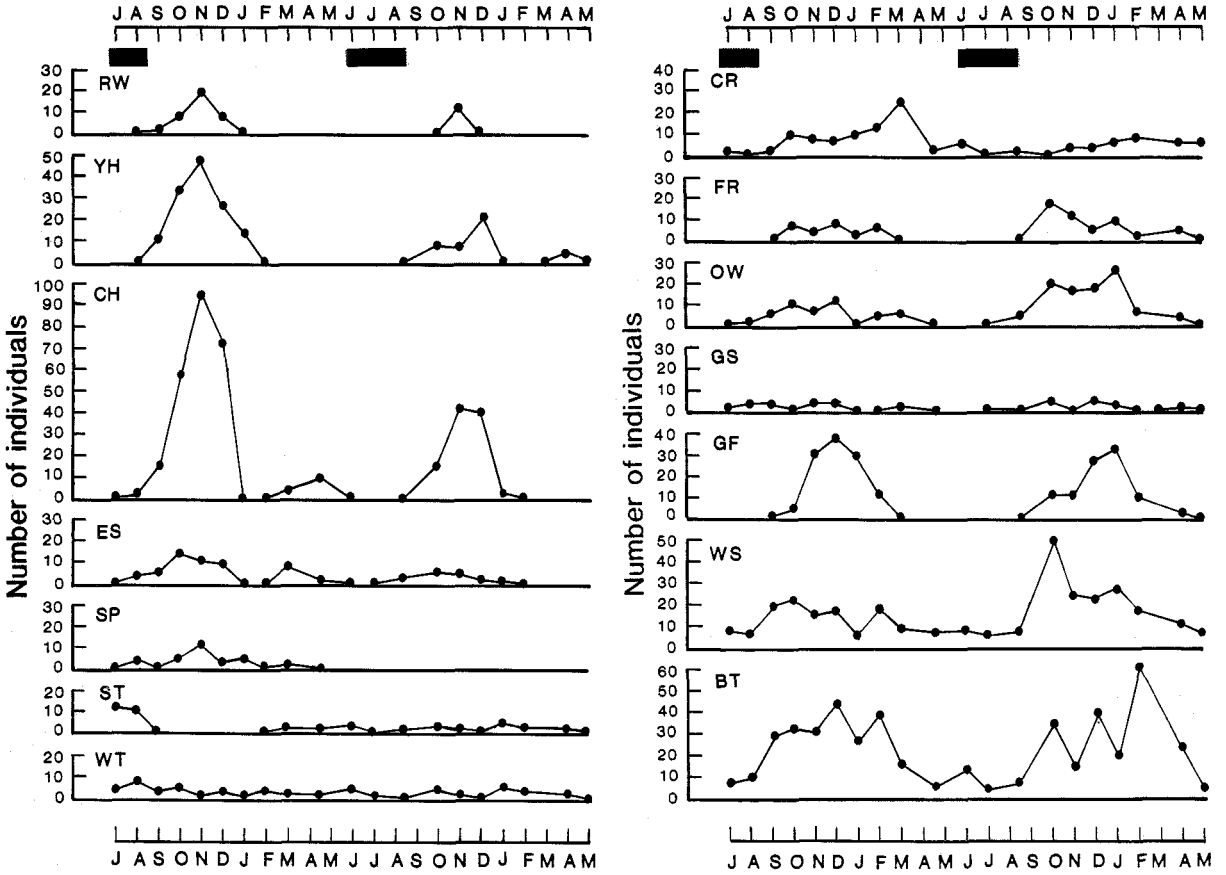

Figure 6 Total number of individuals counted at approximately monthly intervals along a 10 km transect in the White's River valley. Bird species abbreviations as for Figure 3. Solid bars at the top of the graph indicate the period when snow cover was extensive and buried understorey shrubs. See Figure 5 for further details.

and on human refuse. Crimson Rosella and Gang Gang Cockatoo fed on the mature fruit and galls of snowgums and Yellow-tailed Black Cockatoo extracted wood-boring larvae from tree trunks and branches, and thus were able to use the subalpine woodlands to some extent throughout the year.

In early spring the numbers of birds detected increased rapidly (Fig. 5) coinciding with the arrival of migrating Bogong Moths *Agrotis infusa* into the area and the early flowering of the shrub *Grevillea victoriae*. The moths were trapped in large numbers on the snow-surface and provided food particularly for Flame Robins and Little Ravens. Later in the summer the moths provided an abundant food source for large flocks of Little Ravens which undertook daily flights up into the treeless alpine areas to visit moth aestivation sites. Because of the close proximity of one of our regular campsites to a moth aestivation site, we obtained high numbers of foraging observations for this species (n = 3412). It was not unusual to observe many hundreds of birds walking amongst boulders and even climbing into rock fissures in search of the aestivating moths which were usually present in huge numbers. When disturbed by the activities of ravens, or other animals, the moths frequently spilled out of the rock fissures and then were easily captured. When Bogong Moths began leaving the mountains in late February Little Raven numbers declined and the remaining birds foraged on the ground where they captured grasshoppers.

The earliest Crescent Honeyeaters arrived when *G. victoriae* commenced flowering, even when snow cover

Table 2 Foraging substrates of common birds observed feeding in the Snowy Mountains. Numbers of observations are expressed as percentage of individuals recorded (a) during the snow-free months and (b) during periods when snow cover was extensive (in brackets). Foraging guilds follow Recher *et al.* (1985). See Figure 2 for an explanation of the foraging substrates. n_{sf} = number of records obtained when snow cover was patchy or absent; n_s = number of records obtained when snow cover was extensive.

	Rock	Trunk	Branch	Foliage	Shrub	Ground	Snow	Meltback	Air	n_{sf} (n_s)
SEED EATERS										
Yellow-tailed Black Cockatoo		55	33 (100)		12					40 (5)
Gang-gang Cockatoo				62 (100)			38			68 (6)
Crimson Rosella			47	3 (70)	11 (30)	36	3	< 1		370 (20)
AERIAL FORAGERS										
Grey Fantail					1	2			97	80
BARK FORAGERS										
Tree trunks										
White-throated Treecreeper		100 (100)								26 (7)
Loose bark										
White-eared Honeyeater		8 (100)	69	15						26 (1)
FOLIAGE FORAGERS										
Olive Whistler		7	7	7	57		14	7		28
Grey Shrike-thrush		4	9	17	34	17	17			23
White-browed Scrubwren	(26)	32 (29)	(5)	6 (26)	39 (14)	13	1	10		72 (42)
Brown Thornbill		41 (25)	5	22(63)	18 (13)		5	7	3	151(8)
Brown-headed Honeyeater			37	20	43					30
Straited Thornbill		5		93 (89)	2 (11)					56 (9)
Striated Pardalote		3		94		3				31
Silvereye		5		14	34		32	15		130
NECTAR FEEDERS										
Red Wattlebird			29	8	63					24
Yellow-faced Honeyeater		2	2	11	44	2			39	61
Crescent Honeyeater		3		12	76				9	34
GROUND FORAGERS										
Richard's Pipit					13	51	36			53
Flame Robin		6	1	1	4	8	56	15 (100)	9	268 (61)
Australian Magpie						67	27	6(100)		61 (7)
Little Raven	86		< 1			9	1(100)	2		3412(14)
Common Starling						100				36

beneath the shrubs was extensive. Later, the highest numbers of honeyeaters of all species were recorded when this shrub was in flower in 1982 and 1983 (Fig. 6). The commencement of flowering of the shrubs in autumn 1983 attracted small numbers of Crescent Honeyeaters to the study area prior to the winter snow fall. In spring, stands of *G. victoriae* proved to be particularly attractive and at the peak of flowering each stand supported a number of species of honeyeater. Because of reduced snow cover in 1982 (Green 1983), flowering by these shrubs commenced earlier resulting in the recording of more honeyeaters than in 1983 when flow-

ering was later (Fig. 6). This trend was also reflected in the lower total number of individuals and species recorded in 1983 (Fig. 5).

Numbers of insectivorous birds were also high in spring and early summer, apparently reflecting the increase in invertebrates at this time (Green 1989). There was a significant correlation ($r = 0.654$, $P < 0.05$) between the numbers of pitfall-trapped invertebrates over the period July 1982 to May 1983 (Green 1989) and monthly numbers of birds. The shrubs *Bossiaea foliosa, Hovea purpurea, Phebalium ovatifolium, Phebalium squamulosum* and *Olearia phlogopappa* attracted insects which probably provided prey for honeyeaters and other insectivorous species.

Discussion

Composition of the avifauna

The avifauna of the subalpine and alpine zones of the Snowy Mountains is similar to that recorded in other high-mountain environments in mainland south-eastern Australia (see references in McEvey 1962). There are no species confined to the mountains. Nevertheless, a characteristic of the avifauna is the absence of many species which are found nearby at lower altitudes. These include owls, frogmouths, kingfishers, lyrebirds, warblers and woodswallows, groups which in this study were not recorded at subalpine and alpine altitudes, except as vagrants or when accidently blown to higher altitudes during storms. In fact, of the 64 families recorded for the highlands of south-eastern Australia (Frith 1976) only 26 occur above 1530 m (approximate winter snowline) in the Snowy Mountains.

Despite general agreement on the composition of the avifauna of the mountain environments, several studies in subalpine woodland list at least some species which we did not regularly observe above 1530 m. For example, in Victoria Loyn (1985) listed Horsfield's Bronze-Cuckoo *Chrysococcyx basalis*, Laughing Kookaburra, Superb Lyrebird *Menura novaehollandiae*, Eastern Yellow Robin *Eopsaltria australis*, Pilotbird and Buff-rumped Thornbill *Acanthiza reguloides* as occupants of snowgum woodland, but we do not consider them to be components of the subalpine avifauna in the Snowy Mountains (Table 1). Such differences may have arisen where studies were conducted in environments with less-severe climatic conditions below the level of the winter snowline, or in situations where birds could easily move from nearby sheltered montane habitats.

Confusion over what are representative alpine species also can occur. Longmore (1973) observed 33 species of birds in the alpine zone at Kosciusko, however we consider that ten of these were vagrants. Of the birds listed by Longmore we did not observe Black Swan *Cygnus atratus*, Singing Bushlark *Mirafra javanica*, Willie Wagtail *Rhipidura leucophrys* or Scarlet Robin *Petroica multicolor* in the alpine zone. Other species observed in the alpine zone by Longmore including Shining Bronze-Cuckoo, Yellow-tailed Black Cockatoo, White-naped Honeyeater *Melithreptus lunatus*, Yellow-faced Honeyeater and Red Wattlebird, were observed more commonly in the subalpine zone but infrequently strayed into the alpine zone or flew across this region. Differences such as those discussed above emphasise the importance of providing precise information on the environment and conditions associated with published records of birds.

The reduced numbers of birds observed in the alpine zone, when compared to the subalpine zone, may be a result of the reduced structural diversity of the vegetation and hence fewer feeding positions. However, the reduced numbers of species in the subalpine zone when compared to nearby montane habitats is not as easily explained. The following birds are found at montane altitudes throughout the year (Lamm & Wilson 1966) but generally avoid the subalpine and alpine zones: Wonga Pigeon *Leucosarcia melanoleuca*, Southern Boobook *Ninox novaeseelandiae*, Laughing Kookaburra, Australian Owlet-nightjar, Superb Lyrebird, Eastern Yellow Robin, Crested Shrike-tit *Falcunculus frontatus*, Spotted Quail-thrush *Cinclosoma punctatum*, Eastern Whipbird *Psophodes olivaceus*, Superb Fairy-wren *Malurus cyaneus*, Pilotbird, Red-browed Treecreeper *Climacteris erythrops* and Satin Bowerbird *Ptilonorhynchus violaceus*. Although other features of the subalpine woodlands, such as the absence of tall, rough-barked trees, may be important, we suggest that the presence of an extensive cover of winter snow is the main factor restricting the foraging opportunities available to these birds. In other areas where they occur these species are comparatively sedentary, selecting sites that meet their requirements throughout the year. A more obvious influence of snow on foraging by birds is provided by four species which were recorded in the subalpine zone throughout the year, except when extensive snow covered all shrubs. These were Olive Whistler, White-browed Scrubwren, White's Thrush *Zoothera dauma* and Eastern Spinebill; all species which apparently over-wintered in nearby snow-free

habitats and returned as soon as the understorey shrubs were free of snow.

That snow-cover has a major influence on bird populations is supported by studies elsewhere (e.g. Child 1978; Smith & Andersen 1985; Heil *et al.* 1988); however, there have been no comparable studies undertaken in Australia. In montane forest on Mt. Wellington in Tasmania, Thomas (1987) recorded a reduction in the number of birds on a transect from 135 to 62 after snow had fallen, followed by an increase to 121 after the snow had melted. The birds most affected were dependent on insect prey and included mainly whistlers, robins, honeyeaters and pardalotes; species which also retreat from the Snowy Mountains in winter.

Seasonal migration, foraging strategies and the influence of snow

Frith (1976) notes that migration is a prominent feature of the avifauna of the south-eastern Australian highlands. Quantitative studies of bird populations at tableland (Recher *et al.* 1983) and montane (Lamm & Wilson 1966) altitudes confirms the importance of migration away from these environments in winter. Above 1530 m in the Snowy Mountains, seasonal migration is even more apparent; out of the 62 species that have been recorded in summer, only 12 species are resident throughout the year. A similar number of wintering species (11) was recorded in the subalpine zone at Falls Creek in Victoria by Marsland (1977). He, however, recorded the Olive Whistler (not regarded as a complete winter resident above 1530 m in the Snowy Mountains) as a winter resident and, surprisingly, failed to record the Brown Thornbill, which is present throughout winter in the Snowy Mountains.

There is some evidence that birds that were not major latitudinal migrants (see Recher & Holmes 1985) but that still moved away from the high-country during the cooler months, may have moved to nearby tableland locations. Recher *et al.* (1983) noted that flocks of Crimson Rosellas and Gang Gang Cockatoos moved into their study area near Bombala in late autumn and winter. Further north, in the Canberra region, numbers of Gang Gang Cockatoos, Richard's Pipits, Flame Robins, Golden Whistlers *Pachycephala pectoralis*, White-eared Honeyeaters, Crescent Honeyeaters, Eastern Spinebills, Spotted Pardalotes *Pardalotus punctatus*, Striated Pardalotes and Silvereyes are much higher in winter (Taylor 1983), suggesting a movement of these species into the region from higher altitudes.

Rowley (1971) carried out banding studies on Little Ravens in the subalpine zone near Mt. Kosciusko. His studies indicated that most immature birds move towards the inland plains in the winter, with some individuals also moving to the Monaro Plains near Cooma. They apparently avoid coastal areas. The movements of adults are poorly known but Rowley notes that the same adults return to breeding territories that they occupy for about three months each year. Banding studies carried out with Pied Currawongs in the montane zone some 20 km east of Mt. Kosciusko (Wimbush 1969) have also revealed that subadults disperse up to hundreds of kilometres away, mainly northwards. Unfortunately, the geographic extent of the annual movements of most other species is poorly known and more research, similar to that described above, is needed.

The reduced numbers of some resident species during winter is of interest. Such partial residency is a feature of birds in Scandinavia and in the European alps, where often only older birds or older males stay behind, with less experienced individuals and females avoiding the harshest conditions (M. Lenz pers. comm.). Similar patterns may operate in the Australian mountains (see Lamm & Wilson 1966) but banding studies are required from higher altitudes to confirm this.

Not surprisingly, seasonal changes in the abundance and availability of food resources coincided with changes in the size of bird populations (see also Recher *et al.* 1983). In late winter, the presence of insects on the snow surface (see below) was of great importance, attracting the early arrival of species such as Flame Robin and Little Raven (see also Edwards 1973). The timing of the annual migration to the mountains of other species appeared to be determined in part by the spring snow thaw when areas free of snow became available for feeding and nesting. This was particularly noticeable with Richard's Pipit that moved into the alpine zone as soon as areas of ground become exposed on ridges, often before the ground was exposed in the subalpine zone. Snow melt also exposed the flowers of the shrub *Grevillea victoriae* which attracted honeyeaters.

Cold weather during winter, combined with a shortened day-length, also undoubtedly influences bird populations by reducing the numbers of invertebrates in the foliage of snow gums (Morrow 1977) and in the leaf litter layer (Green 1989) (see also Recher *et al.* 1983). Insects provided a particularly important food for birds. There was a significant correlation between monthly numbers of birds and the numbers of pitfall-trapped invertebrates, perhaps reflecting the activity of invertebrates in the foliage of shrubs and trees (Morrow 1977).

Recher *et al.* (1983) found that bird migration at lower altitudes (850 m asl) was tied to seasonal changes in the numbers of invertebrates.

Bird species that wintered (Table 1) were either generalist feeders such as the Little Raven, or birds that took a significant proportion of their food from tree trunks and branches, substrates where the few available invertebrates were accessible to birds but had some protection from the weather. By contrast, birds not present in winter but visiting in summer mainly fed in shrubs or on the ground, foraging substrates inaccessible in winter, or in positions which in winter were unsuitable for insects, such as in the air and amongst the foliage of trees. Two species, Crimson Rosella and Gang Gang Cockatoo, were able to remain during winter by feed ing on the mature fruit and insect galls present on snow gums. The snow surface became a profitable foraging substrate only in spring when insects metamorphosing at lower altitudes were raised on air-currents into the mountains and became trapped on the snow (Edwards 1973). Such insect fall-out on the snow in early spring provides an abundant food source for early migrants such as Flame Robins and Little Ravens. Utilisation of such resources by birds has also been observed elsewhere (Mani 1962; Pattie & Verbeek 1966).

In conclusion, whilst cold undoubtedly reduces food availability and places a major physiological demand on birds in this region, it is likely that winter snow-fall, through its depressing influence on the extent and availablity of winter foraging niches, further reduces bird populations below those of nearby montane habitats. Whilst the foraging behaviour and seasonal changes in the abundance of populations of birds in the region have now been the subject of a number of detailed studies, information on the nature and extent of altitudinal and latitudinal movements by species in response to the changing availability of their food resources is lacking. Further co-ordinated studies covering broad geographic areas are needed to improve our understanding of the seasonal dynamics of birds in this region.

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References

Child, P. 1978. Fluctuations in birdlife in a subalpine basin. Notornis 25, 71-83.

Cooper, M.G., Osborne, W.S. & Shepherd, T.G. 1984. The natural resources of the Crackenback Management Unit. Consultants report, NSW National Parks and Wildlife Service, Kosciusko National Park.

Costin, A.B. 1954. A Study of the Ecosystems of the Monaro Region of New South Wales. Government Printer, New South Wales.

Costin, A.B. 1957. The high mountain vegetation of Australia. Australian Journal of Botany 5, 173-189

Costin, A.B., Gray, M., Totterdell, C.J. & Wimbush, D.J. 1979. Kosciusko Alpine Flora. CSIRO/Collins, Sydney.

Edwards, J.S. 1973. Insect fallout on snow in the Snowy Mountains, New South Wales. Australian Entomological Magazine 1, 57-59.

Frith, H.J. (ed.) 1976. Birds in the Australian High Country. Reed, Sydney.

Formosov, A.M. 1946. Snow cover as an integral factor of the environment and its importance in the ecology of mammals and birds. Translation by W. Prychodko and W.O. Pruitt, Occasional Paper No. 1, Boreal Institute, University of Alberta, Edmonton

Gall, B.C. & Longmore, N.W. 1978. Avifauna of the Thredbo Valley, Kosciusko National Park. Emu 78, 189-196.

Green, K. 1982. Notes on winter-active invertebrates beneath the snow. Victorian Naturalist 99, 144-146.

Green, K. 1983. Alternative strategies in the life cycle of alpine grasshoppers (Orthoptera:Acridoidea). Proceedings of the Ecological Society of Australia 12, 125-133.

Green, K. 1989. Altitudinal and seasonal differences in the diets of *Antechinus swainsonii* and *A. stuartii* (Marsupialia: Dasyuridae) in relation to the availability of prey in the Snowy Mountains. Australian Wildlife Research 16, 581-592.

Green, K. & Osborne, W. 1979. A summer vertebrate fauna survey above 1530 m in the Gungarton region of Kosciusko National Park. Victorian Naturalist 96, 176-184.

Heil, S.J., Verner, J. & Balda, R.P. 1988. Weather and bird populations in true fir forests of Sierra Nevada, California. Condor 90, 561-574.

Lamm, D.W. & Wilson, S.J. 1966. Seasonal fluctuations of birds in the Brindabella Range, Australian Capital Territory. Emu 65, 183-207.

Longmore, W. 1973. Birds of the alpine region, Kosciusko National Park. Australian Birds 8, 33-35.

Loyn, R.H. 1985. Ecology, distribution and density of birds in Victorian forests. Pp. 33-46 in Birds of Eucalypt Forests and Woodlands: Ecology, Conservation and Management. Eds A. Keast, H.F. Recher, H. Ford & D. Saunders. RAOU and Surrey Beatty & Sons, Sydney.

Mani, M.S. 1962. Introduction to High Altitude Entomology. Methuen, London.

Marsland, A. 1977. Birds in winter in the Kiewa Valley, Victoria, above 1530 metres. Emu 77, 33.

McEvey, A. 1962. Zoology of the High Plains: Part II birds and mammals. Proceedings of the Royal Society Victoria 75, 315-317.

Morrow P.A. 1977. Host specificity of insects in a community of three co-dominant *Eucalyptus* species. Australian Journal of Ecology 2, 89-106.

Osborne, W., Preece, M., Green, K. & Green, M. 1978. Gungarton: a winter fauna survey above 1500 metres. Victorian Naturalist 95, 226-235.

Pattie, D.L. & Verbeek, N.A.M. 1966. Alpine birds of the Beartooth Mountains. Condor 68, 167-176.

Pyke, G.H. & Recher, H.F. 1984. Censusing Australian birds: a summary of procedures and a scheme for standardisation of data presentation and storage. Pp. 53-63 in Methods of Censusing Birds in Australia. Ed. S.J.J.F. Davies. RAOU Report No. 7.

Recher, H.F., Gowing G., Kavanagh, R., Shields, J. & Rohan-Jones, W. 1983. Birds, resources and time in a tablelands forest. Proceedings of the Ecological Society of Australia 12, 101-123.

Recher, H.F., Holmes, R.T., Schultz, M., Shields, J. & Kavanagh, R. 1985. Foraging patterns of breeding birds in eucalypt forest and woodland of southeastern Australia. Australian Journal of Ecology 10, 399-419.

Recher, H.F. & Holmes, R.T. 1985. Foraging ecology and seasonal patterns of abundance in a forest avifauna. Pp. 79-96 in Birds of Eucalypt Forests and Woodlands: Ecology, Conservation and Management. Eds A. Keast, H.F. Recher, H. Ford & D. Saunders. RAOU and Surrey Beatty & Sons, Sydney.

Rowley, I. 1971. Movement and longevity of ravens in southeastern Australia. CSIRO Wildlife Research 16, 49-72.

Smith, K.G. & Andersen, D.C. 1985. Snowpack and variation in reproductive ecology of a montane ground-nesting passerine, *Junco hyemalis*. Ornis Scandinavia 16, 8-13.

Taylor, I. 1983. Annual bird report: 1 July 1981 to 30 June 1982. Canberra Bird Notes 8, 5-52.

Thomas, D.G. 1987. The effect of hard weather on bird abundance. Tasmanian Bird Report 16, 17-20.

Wimbush, D.J. 1969. Studies of the Pied Currawong, *Strepera graculina*, in the Snowy Mountains. Emu 69, 72-80.

RECORDS WANTED OF VAGRANT BIRDS IN SEYCHELLES

A Records Committee has been established to collate data on birds in the Republic of Seychelles, which also includes the coral limestone atolls of the Amirantes, Providence, Farquhar and Aldabra groups. It will assess and publish records of vagrants, as well as monitoring the populations of breeding species and migrants, with the ultimate aim of producing a full check-list. The members are Ian Bullock, Chris Feare, James Ferguson-Lees (chairman), David Fisher, Ron Gerlach, John Phillips and Adrian Skerrett (secretary), all of whom have spent much time in the islands. Past and present observations are needed of any species that have been reported less than annually. Lists are available from Adrian Skerrett, P.O. Box 336, Victoria, Mahe, Seychelles, to whom all observations should be sent.