SEASONAL AND DIURNAL TIME BUDGETS AND FEEDING INTENSITY OF THE WHITE-FACED HERON IN PASTURE

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ABSTRACT

Time-activity budgets and feeding rates were compiled for White-faced Herons *(Ardea novaehollandiae)* on pasture near Pukepuke Lagoon, Manawatu, from March 1980 to February 1981. Indices of the hourly strike, catch and step rates were calculated. The direction of the bill during strikes was recorded to indicate the kind of prey being hunted.

Time spent foraging increased from summer through to spring. Feeding rates were highest in spring, less in summer and winter, and lowest in autumn. Herons fed most actively early and late in the day. Adults were more efficient at foraging than juveniles. Herons spent longer foraging and fed at a faster rate when energy demands were high owing to cool temperatures, breeding or moult, and when more food was available.

Areas of pasture in which herons fed, and some that they avoided, were sampled with a sweep net and soil quadrat to determine the seasonal availability of potential prey. Earthworms were most abundant in winter and scarcest in summer, whereas larger insects were common in summer and autumn. Herons fed on whatever prey was most available, taking earthworms in winter and less often in autumn and spring, but concentrating more on insects in summer and autumn.

INTRODUCTION

The White-faced Heron *(Ardea novaehollandiae)* is widely distributed over the south-west Pacific (Hancock & Elliot 1978). After reaching New Zealand from Australia before the mid-1800s (Carroll 1970), it remained sparse until the 1940s, increased rapidly to a peak in the 1960s, and then stabilised. It is now widespread in coastal and inland habitats to 330 m a.s.l. and is the most common heron in New Zealand. It is unusually versatile, exploiting estuarine, freshwater, and pastoral habitats, hunting slowly and methodically for a wide variety of prey.

Carroll (1967) analysed the stomach contents of 89 White-faced Herons collected around New Zealand, and the behaviour, feeding methods and diet of the herons in coastal districts have been studied by Spurr (1967a, b), Louisson (1972) and Moore (1984) in New Zealand, and by Lowe (1983) in Australia. Recher & Recher (1980) briefly discussed its ecological niche in Australia in a broader discussion of resource partitioning by herons. For herons in general, Kushlan (1978) reviewed the literature on feeding behaviour, foraging methods and food habits, but noted a need for time-budget studies.

This paper reports on work aimed primarily at better understanding the seasonal and diurnal time-activity budget of White-faced Herons on pasture, where they have not previously been studied. A secondary aim is to provide indices of the intensity and success of feeding, and to relate these to the levels of some potential prey in coastal Manawatu pasture.

STUDY AREA

The study was made between March 1980 and February 1981 on farmland near Pukepuke Lagoon (40° 20'S, 175° 16'E), 30 km west of Palmerston North and 3 km from the coast. The original sand plains are now under ryegrass/clover *(Lolium/Trifolium)* pasture, which includes scattered artificial ponds for stock, with interconnecting drains, and stands of pine trees (*Pinus* spp.).

The region lacks sharp seasonal contrasts in climate. During the study, mean air temperature varied from 19.0 °C in January to 6.7 °C in July, but rainfall differed markedly from the average seasonal pattern (NZ Meteorological Service, Ohakea). March and September to November 1980 were unusually wet, and from June to November 1980 many fields had extensive areas of surface water. Other months were drier than normal. The prevailing west-northwesterly winds can be strong at times, especially in spring.

METHODS

Observations were made for two or three days each week on the largest group of herons located on pasture near Pukepuke Lagoon, at five sites within a 2.5 km radius. Observations at roosts and nest sites were not included.

Time-budget data were collected from scan samples (Altmann 1974) at 5-minute intervals, when the activity of each heron was recorded. Implicit assumptions were that a 5-minute interval did not match any natural periodic behaviour in the herons, and that each individual was observed for the same brief time (Fordham 1978).

The activities of the herons were ascribed to six broad categories:

Foraging :	Searching for, striking at, and swallowing prey.
Looking :	Resting and looking about (but not in an agonistic context) while standing or walking.
Body care :	Maintenance and comfort actions such as preening, scratching, washing and stretching.
Flying :	All flying except aggressive pursuits.
Agonism :	All intraspecific threat and appeasement displays.
Miscellaneous :	Infrequent behaviour such as drinking and courtship.

The low-frequency categories of flying, agonism and miscellaneous were grouped as 'other activities'.

We measured feeding rates by observing individual herons for 1-minute periods during which we counted the number of strikes made at prey (strike rate); the number of successful strikes (catch rate) when the bird swallowed immediately after striking; and the number of steps taken (step rate). These data were taken only from herons already foraging but were discarded if a bird stopped for more than 5 seconds. The feeding rate of any one heron was recorded only once in any 5-minute interval.

Feeding and stepping rates were combined with the time-budget data to calculate two indices of feeding *intensity* and an index of the area searched. We calculated strike, catch, and step indices by multiplying each rate by the proportion of time (in minutes) spent foraging for a particular diurnal period or season to get the total number of strikes, catches, and steps made per hour on average by a foraging heron.

The direction of the bill during strikes was scored to indicate the kind of prey being hunted. Horizontal strikes (with the bill directed 0°-30° below the horizontal) indicated attacks on more mobile prey, such as flies, on or above the ground, and vertical strikes (with the bill directed 30°-90° below the horizontal) suggested attacks on slow-moving prey, such as earthworms, on or in the ground.

Daylight was taken as being from half an hour before sunrise to half an hour after sunset and was divided into six equal parts for each month and season: autumn (March-May), winter (June-August), spring (September-November), and summer (December-February).

The potential prey in heron feeding areas was assessed weekly by sweep net and turf-soil samples. Sweep net samples, which we took while walking, consisted of 100 sweeps brushing the pasture. From these samples we counted and identified the insects according to CSIRO (1970). Turf-soil samples comprised five 0.05 m^2 x 7.5 cm quadrats, which amply covered the depth penetrated by the bill. Following Edwards and Lofty (1977), we handsorted the samples, identified the animals, and obtained their dry weights by heating at 80 °C to a constant weight. Earthworms were identified from Martin (1977). From July 1980 to February 1981 (except December), we took an additional monthly sample close to the current feeding area to compare areas in which herons fed with those they consistently avoided, which tended to be slightly higher and therefore drier.

Seasonal and diurnal changes in time given to an activity and rates of feeding were analysed by analysis of variance, with tests by orthogonal coefficients (Meddis 1975) for linear and quadratic trends to the diurnal data. Data on prey sampling, and on feeding rates between pairs of seasons, and adults and juveniles were compared by Mann-Whitney U-tests. For these tests significance was set at the 0.01 level.

RESULTS

Seasonal and diurnal time budgets

During 668 hours of observation we made 38 011 bird recordings. Overall, herons spent 68.7% of their time foraging, 19.1% in looking, 8.7% on body care and 3.5% on other activities (3.1% flying, 0.3% agonism, 0.1%

miscellaneous). The proportion of time spent on each of the four main activity categories varied significantly ($P < 0.01$) over the year (Fig. 1). Foraging dominated the time budget throughout the year, and the proportion of time spent feeding increased significantly from summer through to spring. In contrast, the time spent looking was least in spring and most in autumn. Body care took up little time, except in summer. Flying was most frequent in winter, and agonism from May to July.

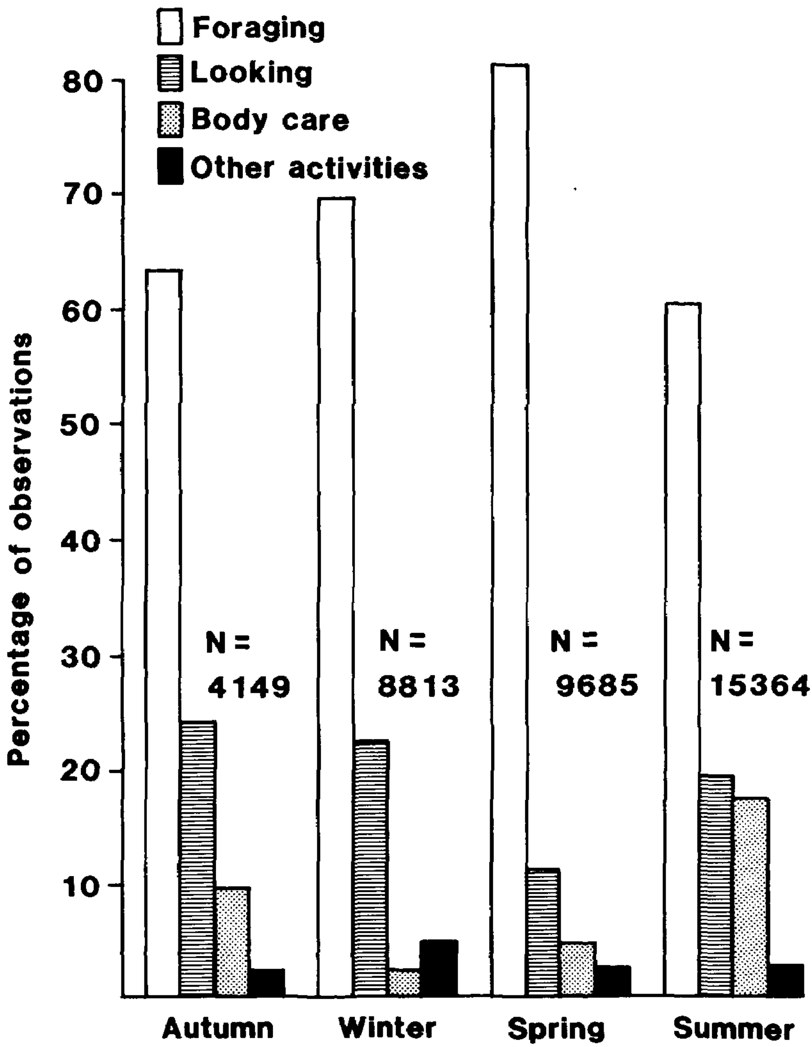

FIGURE 1 — Seasonal time-activity budget of White-faced Herons in coastal pasture, Manawatu

The diurnal trends for each activity were significantly different (Fig. 2). The foraging pattern was significantly bimodal with one peak in the early morning and a higher one in the evening. The pattern was similar in each season except spring, when foraging tended to increase over the day without a morning peak (for full quantitative data see Lo 1982). In all seasons foraging increased strongly from early afternoon onwards.

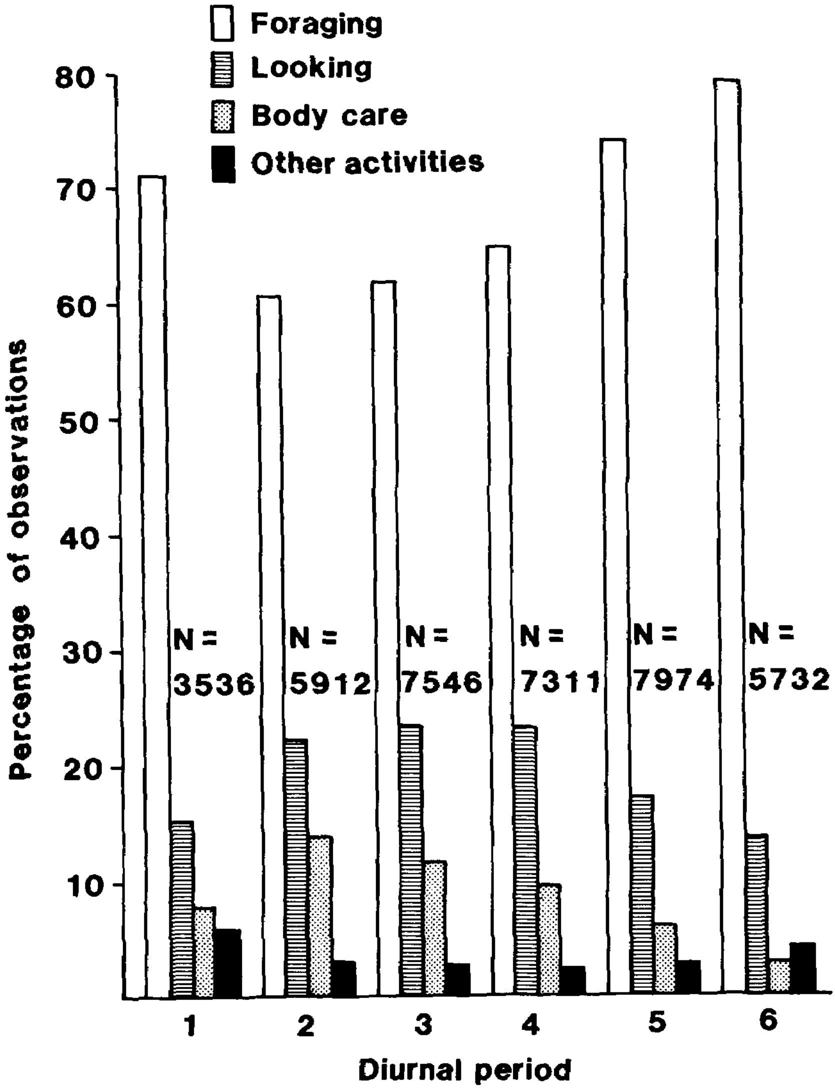

FIGURE 2 — Diurnal time-activity budget of White-faced Herons in coastal pasture, Manawatu

The frequency of looking was significantly greater in mid-morning and early afternoon than earlier or later in the day. In autumn and winter the proportion of time spent looking doubled from about 15% to 33% between early and late morning, and then decreased gradually over the afternoon. This contrasts with spring and summer, when looking tended to occupy a similar proportion of time over most of the day, being low in spring and higher in summer.

Time allocated to body care showed an early peak, and then a significant steady decline. In winter and spring, little time was spent preening during any part of the day, whereas in summer, body care was most frequent in mid-morning and occupied about 17% of time until the evening. Similarly, in autumn, body care occurred most frequently between mid and late morning, before declining over the afternoon as in the other seasons.

Other activities were significantly more frequent at the beginning and end of the day, when the birds flew more. Agonism was infrequent and even throughout the day, and a similar pattern occurred in each season.

Seasonal and diurnal feeding rates

From a total of 4813 measured rates of feeding, herons averaged 5.2 strikes and 3.5 catches per minute, which was equivalent to capturing prey on 67.3% of strikes. The step rate averaged 38.8 steps per minute. The overall feeding indices (time spent foraging x feeding rates) showed that herons made on average 218 strikes, 147 catches and 1590 steps every hour. There were significant seasonal and diurnal variations in all these measures.

Seasonal: Feeding rate data (Table 1) showed that changes in strike and catch rates were similar, except from autumn to winter when the strike rate rose but the catch rate fell. Herons fed at significantly higher rates in spring and summer than in autumn and winter. They were much more likely to be unsuccessful with a strike in winter than in the other seasons, and their horizontal strikes were much fewer in winter and spring than in summer and autumn.

The strike index (time spent foraging x strike rate) was significantly higher in spring than in winter and summer, which were both higher than autumn (Fig. 3). Herons captured significantly more prey per hour in spring and summer than in autumn and winter. The peak of prey numbers caught in spring was shown more clearly when examined month by month. The catch index doubled between September and October (135 to 272 catches per hour), remained high in November (206), and then decreased by half in December (102). The step index showed that herons covered the greatest area when foraging in winter and spring, and the least in summer (Fig. 3).

Diurnal: Herons struck at prey more often towards the end of the day (Table 1), but only the step rate and the strike and step indices varied significantly over the day. The strike and catch rates for summer and autumn were low early in the day and higher over the afternoon. In contrast, winter and spring both had bimodal patterns with higher rates at the beginning and end of the day. The percentage of successful strikes varied markedly over the day only in winter, when the birds were significantly more successful up until mid-morning than afterwards. The ratio of horizontal to vertical strikes did not change over the day in winter and spring, but in summer and autumn the proportion of horizontal strikes increased during the middle of the day. The step rate was highest early in the morning, levelling off around midday. In summer it continued to decrease over the afternoon, whereas in the other seasons it increased slightly.

TABLE 1 — Seasonal and diurnal feeding rates for White-faced Herons: strikes, catches and steps per minute; and the percentage of strikes directed horizontally and vertically

Season	Strike rate	Catch rate	% Successful strikes	Step rate	% Horizontal: vertical strikes
Autumn	4.0	2.9	72.3	41.0	21 : 79
	*	N.S.		*	
Winter	4.9	2.6	52.6	44.8	2 : 98
	*	*		*	
Spring	6.2	4.2	68.1	34.8	3 : 97
	*	*		*	
Summer	5.9	4.5	76.2	29.6	69 : 31
	*	*	*	*	
Diurnal period					
1	4.8	3.3	69.6	52.4	14 : 86
2	4.7	3.3	71.7	40.3	26 : 74
3	4.8	3.4	69.0	35.1	33 : 67
4	4.9	3.2	62.9	34.2	23 : 77
5	5.8	3.9	66.0	34.5	25 : 75
6	6.1	4.1	67.0	36.1	19 : 81
	N.S.	N.S.	N.S.	**	

Diurnal period data are means of the seasonal values. N.S. = not significant, **=P<0.01, *=P<0.001, Mann-Whitney U Test between pairs of seasons, ANOVA (F ratio) for seasonal and diurnal variations.

Over the day, herons had a bimodal pattern of feeding intensity, as indicated by the three indices (Fig. 4). After a small early peak in attempts to catch prey, the feeding rate increased from early afternoon onwards. Except in spring, when there was a marked drop around midday, the seasonal patterns were similar to the overall pattern. The step index shows that the area searched by herons was greatest in the early morning, least around midday and increased to a lower peak in the evening.

A total of 104 feeding rates for juvenile herons was recorded in March 1980 and from August 1980 to February 1981. Compared with data from adults in the same months, juveniles had statistically similar strike and step rates, but their catch rate of 2.8 per minute (adults 4.0) was significantly lower. Similarly their percentage of successful strikes (53.9) was significantly less than that of adults (69.5).

Availability of prey in pasture

In 56 sweep net samples from feeding areas, seven orders of insects and spiders were recorded (Table 2). Diptera were by far the most numerous, comprising mainly small acalypterate flies. Most of the larger insects collected were also from dipteran families – Anthomyiidae, Muscidae and Sarcophagidae. Most samples had a few Hymenoptera (mainly small wasps), Hemiptera (aphids and shield bugs), small Coleoptera and spiders, but few insects of other orders were collected. Other insects occasionally found were damselflies, crane flies, chironomids, and small butterflies. Significantly more insects were collected in summer and autumn than in winter and spring. Feeding and non-feeding areas had a similar range of families and number of insects (299 and 244 per sample respectively), except that grasshoppers (Orthoptera) were not recorded in feeding area samples.

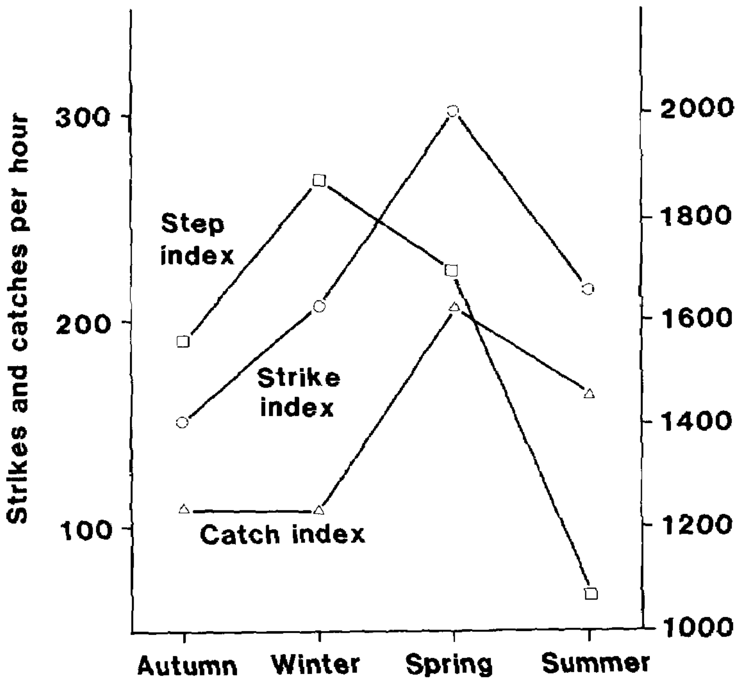

FIGURE 3 — Mean seasonal indices of strikes, catches and steps by White-faced Herons in coastal pasture, Manawatu

The 56 turf-soil samples from feeding areas produced 7816 earthworms (206.0 g dry weight, n = 6214), and the larvae of seven Tipulidae, two unidentified Scarabaeidae, three grass grubs (*Costelytra zealandica*) and 96 slugs (*Deraceros* spp.). The slugs were most abundant in autumn, and scarce in spring and summer. Four species comprised 89.6% of the number and 98.6% of the dry weight of earthworms; the remainder were small unidentified immature worms (Lo 1982). In number and dry weight *Allolobophora caliginosa*, *A. longa* and *Lumbricus rubellus* were roughly of equal ranking and were much more important than the fourth species, *Eiseniella tetraedra* which, although common, was much smaller. Earthworms were numerous in autumn and winter, and became significantly scarcer in spring and summer (Table 3). The mass of worms was greatest in winter

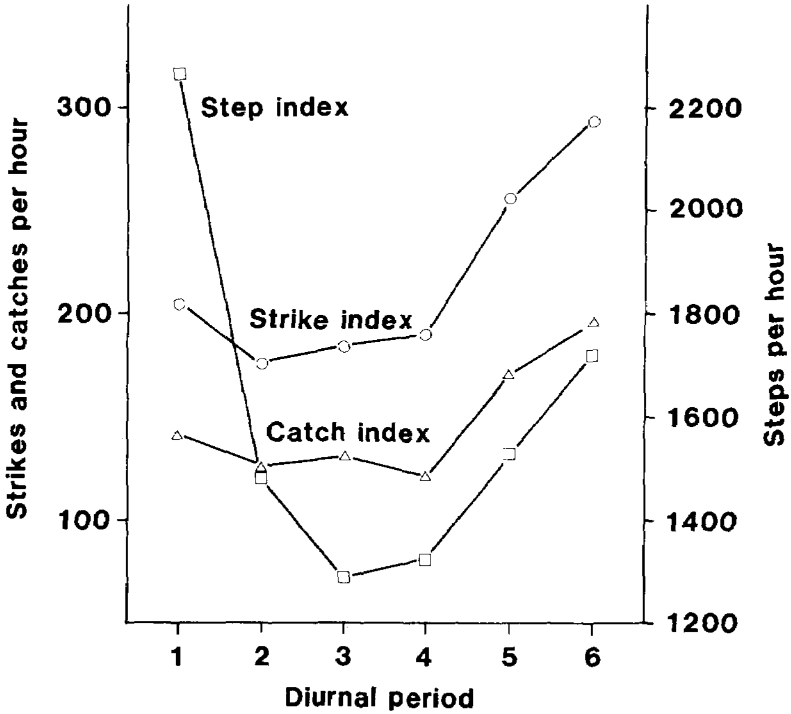

FIGURE 4 — Mean diurnal indices of strikes, catches and steps by White-faced Herons in coastal pasture, Manawatu

TABLE 2 — Seasonal catches of invertebrates per sample by sweep netting from coastal pastures in which White-faced Herons fed, March 1980-February 1981

Order	Autumn	Winter	Spring	Summer
Hemiptera	7.7	1.4	1.8	0.4
Coleoptera	4.9	1.6	0.3	1.2
Diptera	449.6	168.5	265.0	633.2
Hymenoptera	51.4	1.4	1.3	19.3
Odonata, Neuroptera, and Lepidoptera	2.1	0.1	0.3	0.4
Araneae	17.7	5.2	0.5	2.2
Unidentified	6.2	1.6	1.1	2.9
TOTAL	539.6	179.8	270.3	649.6
	* (Autumn–Winter)	N.S. (Winter–Spring)	* (Spring–Summer)	
Samples	10	16	19	11

*=P<0.01, Mann-Whitney U Test between pairs of seasons, N.S. = not significant.

and spring and significantly less in summer. Earthworms were more abundant in heron feeding areas than in places not used for feeding (Table 3), but the differences were not significant for both numbers and dry weights. In the seven samples from non-feeding areas, *A. caliginosa*, *A, longa* and *L. rubellus* comprised 94.9% of the 508 worms collected and 99.2% of the 19.0 g total dry weight.

TABLE 3 — Seasonal abundance of earthworms in turf-soil samples from White-faced Heron feeding areas in coastal pasture, March 1980-February 1981, and from feeding and non-feeding areas, July 1980-February 1981

Season	(Samples)	Number of worms per m^2		Dry weight (g) per m^2	
Autumn	(10)	787		14.6	
			N.S.		N.S.
Winter	(16)	876		21.9	
			**		N.S.
Spring	(19)	380		19.9	
			*		**
Summer	(11)	196		6.0	
Feeding areas	(39)	464		16.8	
Non-feeding areas	(7)	290		10.8	

*=$P<0.01$, **=$P<0.001$, Mann-Whitney U Test between pairs of season, and feeding and non-feeding areas, N.S. = not significant. Autumn dry weight comprises 2 samples.

DISCUSSION

Seasonal ecology

The time budget in autumn, when resting and preening occupied a comparatively large proportion of the day, reflected the lack of extra demands (e.g. breeding or moult) on the herons above basic self-maintenance. Because both insect and ground prey were abundant, the low feeding rate suggests that the herons could easily satisfy their energy demands.

In winter herons spent proportionately more time foraging, at the expense of body care, and increased their foraging effort. They made the highest number of strikes and steps per prey item caught, indicating that food was hard to get. In winter, insects, especially large ones, became scarce, although earthworms were abundant, and the herons responded by striking more at the ground. Except for the occasional frog, the only prey large enough to be identified by direct observation were earthworms about bill length (7 cm) or longer. Because more earthworms were identified as prey in winter (18.5% of prey captured) than in autumn (4.1%), spring (5.1%) or summer (1.0%) (Lo 1982), the average size of prey taken was probably greatest in winter. Presumably this compensated for increased metabolic demands in winter when the number of prey taken was similar to that taken in autumn.

Cattle Egrets *(Bulbulcus ibis)* in southern Africa similarly ate earthworms most during winter and least in summer according to their greater availability (Siegfried 1972).

In spring, when foraging most dominated activities, the birds collected large quantities of food from smaller areas than those covered in winter. Earthworms remained abundant, and aquatic prey such as beetles, tadpole shrimps *(Lepidurus apus)* and backswimmers (*Anisops* spp.) were readily available in ponds, drains and surface water, although large insects remained scarce. This feeding peak coincided with the breeding season from August to December (Lo 1984). Most young were raised in October and November, when the increased demand for food led to higher catch indices for these months than in September, when few chicks had hatched, and December, when the young had fledged.

In summer, with breeding completed and the post-nuptial moult advancing, herons spent less time foraging and more resting and preening. Feeding continued at a high rate, however, with birds striking mainly at above-ground prey, taking large numbers of insects but few earthworms, which were scarce. High ambient temperatures should have reduced energy demands, but the herons took more prey than in autumn, suggesting that they had to recover condition after breeding and to cope with the demands of moulting. The high feeding rate in summer may have been partly due to their mainly insectivorous summer diet, insects probably having a lower net energy return than earthworms.

White-faced Herons foraging on farmland at Pukepuke probably had the least food available in summer, when large prey such as earthworms, tadpole shrimps and tadpoles (*Litoria* spp.) were scarce. This shortage may explain the summer movement of many White-faced Herons to harbours and estuaries around New Zealand (Carroll 1970, Pierce 1980, Moore 1984), including the Manawatu estuary (L. J. Davies, pers. comm.), and in Australia (Lowe 1983). This movement is reversed in winter as birds move back on to wet inland pastures.

Diurnal ecology

The bimodal pattern of foraging in the White-faced Heron is typical of ardeids, which generally forage most near dawn and dusk and rest around midday (Kushlan 1978). The early morning peak in time spent foraging and area searched was probably due to a combination of hunger, cool conditions and more accessible earthworms. With warmer temperatures during the middle of the day, the herons fed less and spent more time resting or preening. In spring, however, under the heavy demands of breeding, the herons continued foraging into the midday "rest" period. In summer any peak of resting would have been obscured by increased preening. As with looking, body care occurred when feeding was less urgent, the most convenient time being just after the morning peak of foraging.

Feeding activity increased over the afternoon as herons spent longer foraging and searched progressively smaller areas for each item. The proportion of earthworms in the prey became less as the day went on, indicating a drop in their availability between morning and evening. Despite this, catch rates increased throughout the afternoon in all seasons, even when insects were scarce, perhaps because the herons fed less selectively towards evening to get as much food as possible before roosting.

Adult and juvenile foraging success

That adult herons are more efficient than juveniles in food collecting has been demonstrated in the Little Blue Heron *(Florida caerula)* (Recher & Recher 1969), Cattle Egret (Siegfried 1971, 1972) and Grey Heron *(Ardea cinerea)* (Cook 1978). Adult White-faced Herons also were better than juveniles at gathering food. The inefficiency of juveniles at capturing prey means that they must forage longer and expend more energy obtaining an equal quantity of food. The much higher death rate of first-year herons than of older birds (Kahl 1963) must at least partly be caused by this lack of experience.

Prey sampling

Herons preferred to forage in wet pasture and avoided dry pasture, which had fewer earthworms, although the difference in worm abundance was marginally non-significant. A high water table brings earthworms to the soil surface (Edwards & Lofty 1977), and so they were available to herons most in winter, less in autumn and spring, and least in summer. This was confirmed by the seasonal percentages of prey we recognised by direct observation as earthworms.

In summer, drier pastures had fewer ground and aquatic prey than in other seasons but insects became abundant. Although many of the insects collected in sweep net samples were too small to be taken by herons, larger ones, including damselflies, shield bugs, beetles, flies and bees were found in regurgitated pellets (Lo 1982). Grasshoppers, which herons ate also, were not recorded in feeding area samples, which illustrates the limitations of the sweep net method and the somewhat arbitrary distinction between feeding and non-feeding areas.

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SHORT NOTE

T. R. Hacket and the Okarito kiwis

Thomas Ridge Hacket (c.1830-1884) was the son of Dr Thomas and Amelia Hacket. He had experience as a mining engineer in England and Europe before migrating to New Zealand, arriving in October 1857. His brother James Henry and his sisters Harriet and Mary Elizabeth joined him in Nelson, where he was employed as manager of the Dun Mountain Company's copper mine. He lost his job when the company went broke, but he remained in Nelson and showed Hochstetter over the workings in 1859. Dr (later Sir) David Monro wrote of "young Hacket" at that time; he was about 29 years old. In 1860 he joined the surveyor John Rochfort on an expedition to the mouth of the Buller River, thence overland to the Grey, inspecting the coal outcrops there. Rochfort married Elizabeth Hacket in 1863, but she died in 1864.

Hacket turned up next (1863) at Oamaru, meeting Dr James Hector and getting a job as assistant geologist in the Geological Survey of Otago, with R. B. Gore, clerk and meteorologist, J. Buchanan, draughtsman and botanist, and William Skey, laboratory assistant, as his colleagues. From Queenstown in 1864 he did the first climb of Double Cone on the Remarkables and sounded Lake Wakatipu. At the Dunedin Exhibition in 1865 Hacket served as a Juror for nine classes of exhibits of varying descriptions: gold ores, chemical substances and products, vegetable