WINTER USE BY TAKAHE *(NOTORNIS MANTELLI)* OF THE SUMMER-GREEN FERN *(HYPOLEPIS MILLEFOLIUM)* IN RELATION TO ITS ANNUAL CYCLE OF CARBOHYDRATES AND MINERALS

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SUMMARY: The winter diet of the takahe *(Notornis mantelli),* an endangered flightless gallinule, which inhabits the mountain grasslands and forests of the Fiordland region of southwestern New Zealand is described. A close correlation exists between their use of rhizomes of the summer-green fern *(Hypolepis millefolium),* a major item in the winter diet, and the peak in the rhizomes' annual cycle of carbohydrates and certain minerals. It is suggested that the high carbohydrate concentrations in the rhizomes are required by the birds to meet the metabolic requirements of thermoregulation in the subfreezing temperatures of mid-winter. The likely adverse effects of competition from introduced red deer *(Cervus elaphus),* both directly in limiting the extent to which the winter diet of takahe can be supplemented with other favoured plants, and indirectly in reducing availability of *Hypolepis* rhizomes by increasing the incidence of soil freezing through depleting subcanopy layers of the evergreen *Nothofagus* spp. forest, are also discussed.

INTRODUCTION

The takahe *(Notornis mantelli),* an endangered flightless gallinule now restricted to a small area within Fiordland National Park in the southwestern corner of New Zealand, has a diet which is mainly confined to five plant species but among them there are marked seasonal preferences (Mills and Mark, 1977). In the snow-free period (September-May) the birds inhabit the low-alpine snow tussock grasslands, located between tree line (*c.* 1110 m) and high-alpine fellfield (*c.* 1430 m), where the dominant tall tussock grasses *Chionochloa pallens, C. flavescens,* and C. *crassiuscula,* form the main food. This is supplemented with a mountain daisy *(Celmisia petriei)* and, when available, grain of the irregularly flowering tall tussocks and a range of small grasses. In late autumn the rhizomes of the summer-green fern *(Hypolepis millefolium)* begin to be eaten and by mid-winter they form a major part of the diet. Takahe remain in the alpine grasslands for as long as snow conditions permit but by June the snow cover usually prevents feeding above tree line and the birds are forced to move down into the adjoining evergreen beech *(Nothofagus* spp.) forest where they remain until the spring thaw in September-October.

In the beech forest the takahe diet consists of 60-80% *Hypolepis millefolium* rhizomes. Other winter foods eaten in smaller amounts include the leaf bases of some forest grasses *(Chionochloa conspicua),* sedges *(Uncinia affinus, U. davata, Carex coriacea)* and rushes *(Juncus gregiflorus)* but the availability and abundance of these alternative foods vary within the region, largely as a result of differential grazing pressure or recovery from grazing by introduced red deer *(Cervus elaphus).*

This study, conducted from May 1976 to January 1978 in the Murchison Mountains (Fig. 1), was undertaken to assess the chemical composition of the winter food of takahe and to compare the birds' seasonal preference for *Hypolepis millefolium* with seasonal changes in the chemical composition of the rhizomes. The investigation forms part of a study into a recent decline in takahe numbers and the nutrient requirements of the bird. A previous food habit study (Mills and Mark, 1977) concentrated on the summer diet.

Hypolepis millefolium occurs most commonly in open forest and clearings but in the low-alpine zone above tree line it often dominates avalanche chutes and snow-slide areas. Usually it is found in patches consisting of an extensive network of creeping rhizomes 2 to 4 cm beneath the soil surface. In mid-summer the fronds are bright green but these die back when frosted in autumn and from then until approximately six weeks before new fronds

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appear above ground in mid-November, the underground rhizomes are foraged for by takahe.

When feeding on *Hypolepis,* takahe leave easily recognisable sign. The rhizomes are excavated with the beak and conspicuous unearthed patches of *Hypolepis* are left. The faeces produced at this time are blackish and fine textured, obviously different from the coarse stramineous product associated with their summer diet of grass. Evidence of feeding on the rhizomes outside the late autumn-early spring

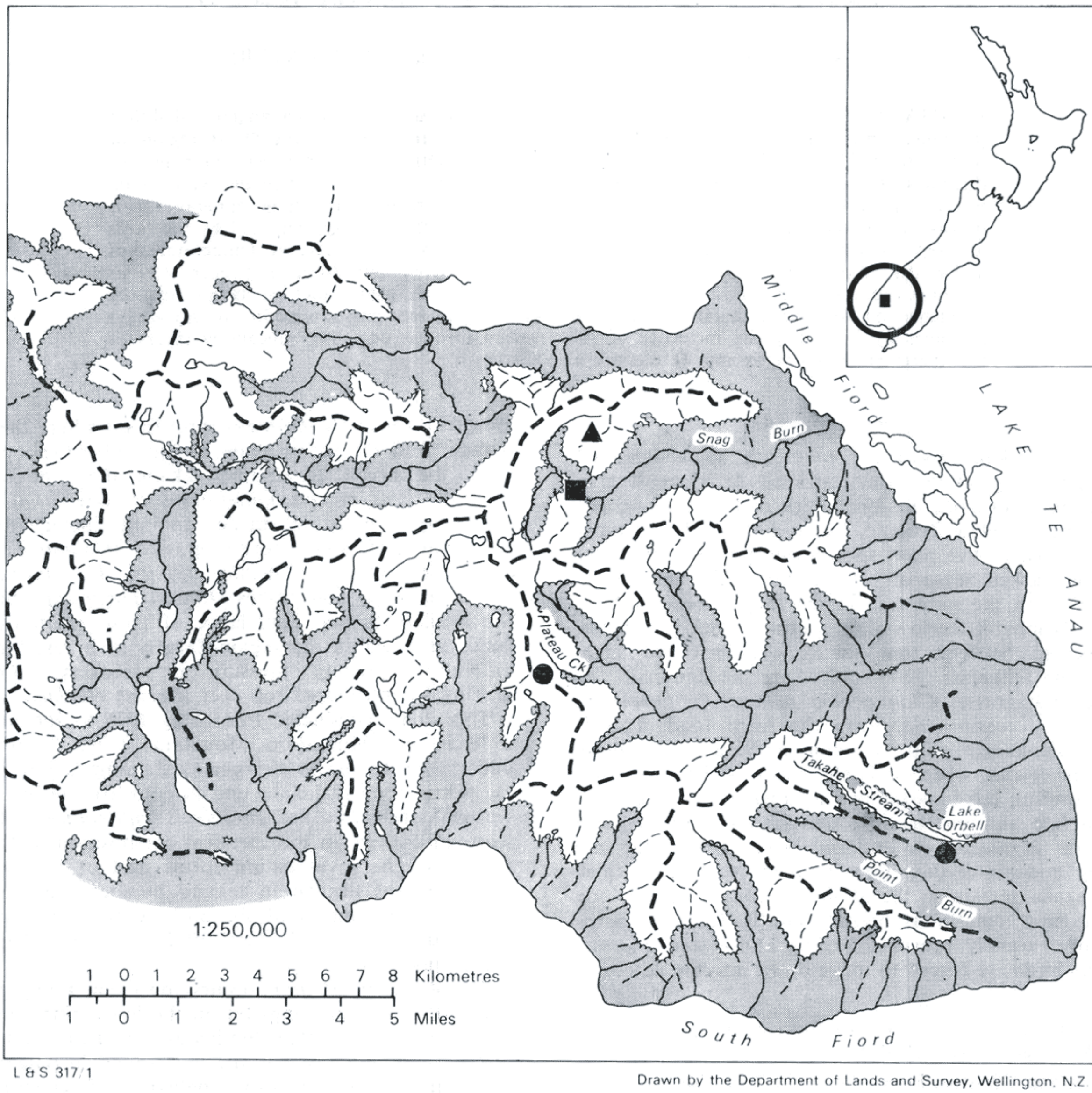

FIGURE 1. *Map of the Murchison Mountains, Fiordland, showing the localities where* Hypolepis (●), *and other winter foods of the takahe (tall tussocks* Chionochloa *spp. and* Celmisia petriei *from the low-alpine grassland* ▲; *sedges, grasses and rushes from the silver beech* (Nothofagus menziesii) *forest* ■) *were collected.* — — — *major ridges;* ——— *minor ridges;* ▒ Nothofagus *spp. forest.*

period (late March-October) was rarely observed. In the alpine grasslands foraging for *Hypolepis* begins shortly after the fronds succumb to frosting in late March. It is not until approximately a month later that takahe eat *Hypolepis* to any extent in the adjoining evergreen *Nothofagus* forests.

METHODS

Samples of *Hypolepis millefolium* rhizomes were collected from three localities in the Murchison Mountains for analysis of carbohydrates, lipid and nutrient (N, P, Mg, Ca, K, Na, S) levels. In Takahe Valley (Fig. I) under mountain beech *(N. solandri* var. *cliffortioides)* forest (9 10 metres above sea level), samples were taken from a 10 X 10 m site at the beginning of each month from May 1976 until January 1978. Similarly, from an avalanche chute in the low-alpine zone of Plateau Creek (1130 m a.s.l.) (Fig. 1), where feeding on *H. millefolium* begins about a month earlier than in Takahe Valley, samples were collected in March, April and May 1977.

The nutritive value of other foods eaten in winter was assessed from samples collected within silver beech *(N. menziesii)* forest, of the upper Snag Burn (520 m a.s.l.) in August 1977 (Fig. 1). Methods of chemical analysis were described in Mills and Mark (1977).

RESULTS

The annual cycle of carbohydrates and nutrients in Hypolepis millefolium *rhizomes and their use by takahe*

Carbohydrates in the rhizomes are mostly in the form of starch (Fig. 2) which peaks during winter, declines rapidly with the emergence of new fronds in spring, and remains at low levels while the fronds are growing in November and December. It then increases sharply in March, following cessation of leaf growth. By contrast, sugar and lipid levels are low and their seasonal variations are relatively slight (Fig. 2).

The levels of the elements phosphorus, sulphur, magnesium and sodium in the rhizomes fluctuated irregularly, whereas nitrogen, calcium and potassium generally attained their highest concentrations during the period of dormancy and declined during the growing period (Fig. 3). Mineral and carbohydrate contents of the rhizomes increased a month later within the subalpine beech forest than in the low-alpine grasslands, presumably because the evergreen forest canopy insulated the ferns from early frosts.

Takahe began feeding on *Hypolepis* rhizomes in Takahe Valley in late April, continuing through winter until late September. During this period these rhizomes constitute *c*. 60-80% of the diet. Use of rhizomes thus coincides with the increase in carbohydrate and nutrient content (Fig. 2b and Fig. 3b, d).

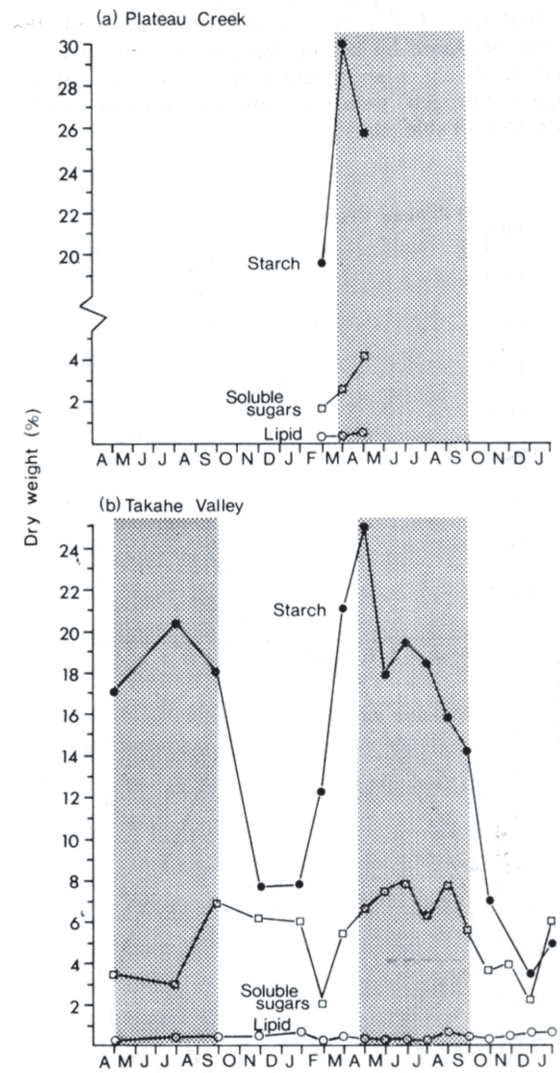

FIGURE 2. *Seasonal changes in the carbohydrate and lipid contents of* Hypolepis millefolium *rhizomes collected from the low-alpine zone in Plateau Creek (a), and beneath the subalpine beech* (Nothofagus *spp.) forest in Takahe Valley (b). The shaded area indicates the period when takahe were feeding on* Hypolepis *rhizomes.*

Feeding began when the starch content increased markedly and just preceded the increase in nitrogen content in May. At Plateau Creek, use of *Hypolepis* began a month earlier than in Takahe Valley but still coincided with the increase in both starch and nitrogen levels (Fig. 2a and Fig. 3a, c).

Analyses of *H. millefolium* rhizomes and the faeces produced by takahe feeding on them, indicate that relatively high proportions of starch, soluble sugars, nitrogen, potassium and phosphorus can be extracted (Table 1).

Nutritive content of other plants eaten in winter

Analyses of the leaf bases of other plants eaten in winter are given in Table 2. *Carex coriacea* and *Chionochloa conspicua* appear to provide excellent food, containing high levels of phosphorus, magnesium and potassium. *Carex coriacea* also has comparatively high levels of nitrogen, soluble sugars and lipid. *Juncus gregiflorus,* on the other hand, has relatively high levels of soluble sugars and sodium.

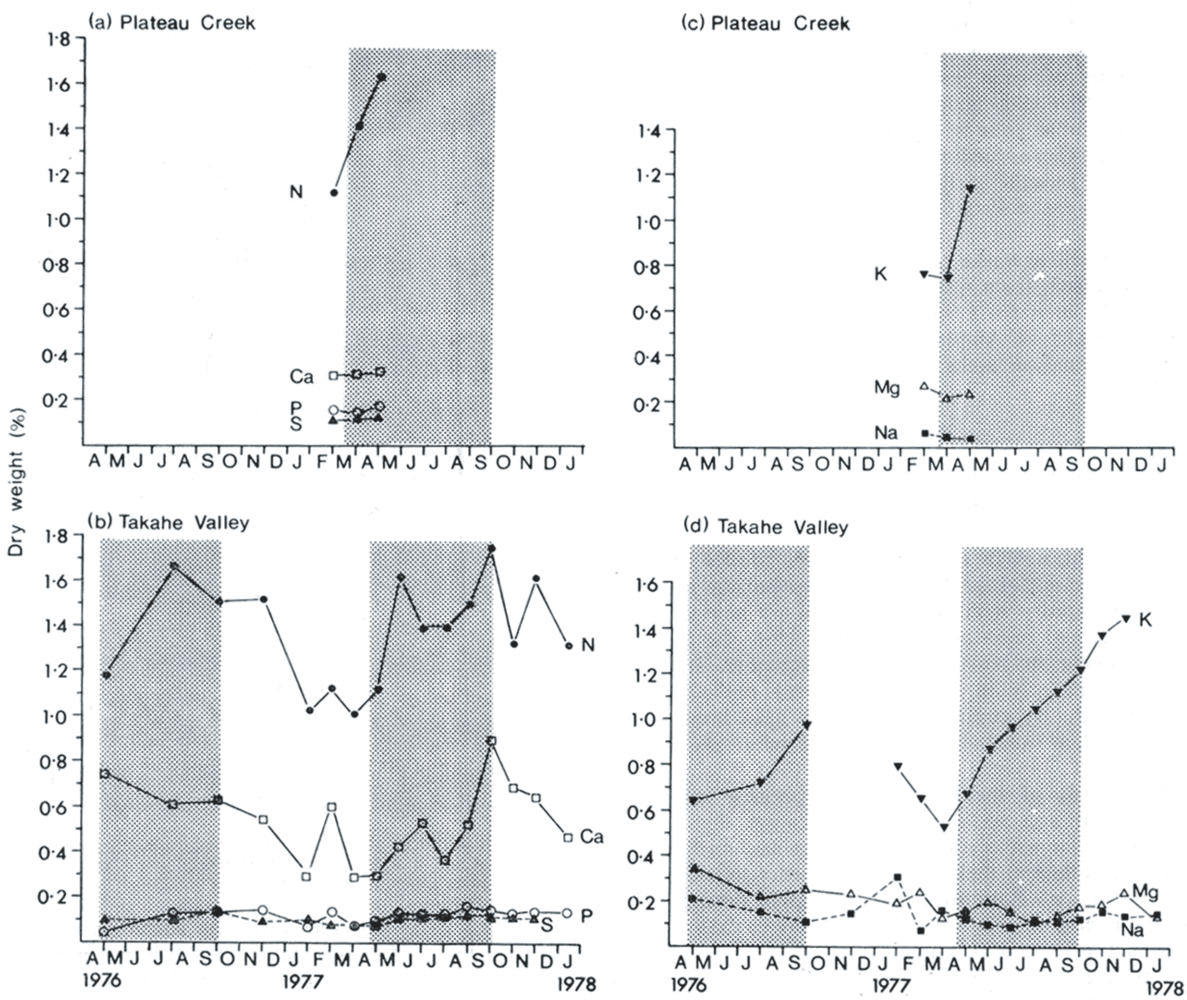

FIGURE 3. *Seasonal changes in the mineral composition of* Hypolepis millefolium *rhizomes collected from the low-alpine zone in Plateau Creek (a) and (c), beneath the subalpine beech* (Nothofagus *spp.) forest in Takahe Valley (b) and (d). The shaded area indicates the period when takahe were feeding on* Hypolepis *rhizomes.*

When snow conditions permitted feeding in the low-alpine grasslands during winter, a preferred tussock was *Chionochloa flavescens*. Although nothing conclusive can be derived from the small series of samples collected from the low-alpine grasslands (Table 2), the preference may be related to the superior levels of N and P and slightly higher soluble sugar content in C. *flavescens* compared with the other tall tussock species present.

DISCUSSION

Selection For Carbohydrates In Late Autumn And Winter

In a previous study of the food habits of takahe (Mills and Mark, 1977) *it* was shown that, from spring through to autumn the *birds* selected both amongst and between tall tussock *(Chionochloa)* species *for* those plants containing the highest phosphorus content. In the present study the initiation of feeding on *Hypolepis millefolium* rhizomes occurred when their starch and nitrogen levels were increasing. When rhizomes were eaten as a preferred food, starch constituted one fifth of their dry weight and they appeared to be one of the best available sources of carbohydrates and other nutrients. Moreover, faecal analyses have shown that the birds are able to extract relatively high proportions of starch, soluble sugars, nitrogen, potassium and phosphorus from these rhizomes.

The other plant species eaten during winter may be taken *for* their particular nutrient values. *Chionochloa conspicua* and *Carex coriacea* contain

TABLE 1. *Comparison of the major nutrient. carbohydrate and lipid contents (percentage dry weight) of* Hypolepis millefolium *rhizomes and of the faeces of takahe feeding predominantly on them. The major nutrient and lipid determinations were from three samples collected in August 1976 in the Snag Burn. while the carbohydrate analysis was performed on a sample collected in August 1974 in Takahe Valley.*

	H. millefolium rhizomes		Takahe faeces	
Constituent	Mean	S.D.	Mean	S.D.
N	1.95	0.24	1.12	0.05
S	0.12	0.02	0.11	0.02
P	0.20	0.07	0.13	0.05
Mg	0.22	0.03	0.31	0.20
Ca	0.57	0.19	0.51	0.19
Na	0.063	0.075	0.063	0.005
K	0.93	0.19	0.63	0.14
Lipids	0.37	0.06	0.93	0.31
Fructose*	1.9		0.1	
Glucose*	1.0		0.6	
Sucrose*	3.0		0.2	
Starch*	22.6		4.6	

S.D. Standard deviation.
* Data from Mills and Mark (1977).

TABLE 2. *Comparison of the major nutrient. carbohydrate and lipid contents (percentage dry weight) of winter foods eaten by takahe.* Hypolepis *values are for rhizomes.* Uncinia, Carex, Juncus, Celmisia *and* Chionochloa *spp. for leaf bases. and* Schoenus *for leaf blades. Collected August 1976 and 1977 in Snag Burn. Murchison Mountains. Fiordland.*

	N	S	P	Mg	Ca	Na	K	Soluble Sugars	Starch	Lipids
(a) Forest species										
Uncinia clavata	1.68	*	0.33	0.16	0.29	0.0]	3.39	9.9	1.65	0.49
Juncus gregifiorus	0.70	0.08	0.15	0.05	0.26	0.10	1.06	17.4	3.53	0.32
Schoenus paucifiorus †	1.12	0.07	0.05	0.12	0.29	0.04	0.50	2.58	2.03	0.45
Carex coriacea	1.82	0.18	0.34	0.13	0.26	0.07	2.02	7.7	1.13	1.10
Chionochloa conspicua †	1.68	0.15	0.32	0.20	0.23	0.02	4.25	*	2.30	0.54
Hypolepis millefolium †	2.11	0.13	0.20	0.20	0.37	0.03	0.99	2.78	20.56	0.35
(b) Low-alpine grassland species										
Chionochloa pallens	1.88	0.14	0.17	0.13	0.25	0.25	3.06	18.2	3.20	0.74
C. *flavescens*	2.80	0.10	0.19	0.10	0.29	0.04	3.13	19.4	1.94	0.64
C. *crassiuscula*	1.12	0.15	0.10	0.07	0.20	0.11	2.05	14.2	1.65	0.40
Celmisia petriei	1.37	0.10	0.12	0.10	0.70	0.32	2.07	*	0.21	1.75

* value not determined.
† sample collected 1976.

higher levels of phosphorus, potassium, magnesium and soluble sugars than *Hypolepis,* while *funcus gregifliorus* has higher amounts of soluble sugars and sodium than *Hypolepis*.

Carbohydrates, however, are probably more important than minerals during late autumn and winter because a high energy source would be needed to meet the metabolic requirements of thermoregulation in the sub-freezing temperatures of the mid-winter habitats occupied by takahe (temperatures of -15 °C have been recorded). A similar pattern of selection for starch was found when takahe were feeding on *Chionochloa pallens* in late summer and late autumn (Mills and Mark, 1977). A highly significant positive correlation occurred between the use of individual C. *pallens* plants and their starch content in late summer, and just fell short of statistical significance in late autumn (Mills and Mark, 1977).

Hypolepis millefolium may be one of the few local plants able to satisfy the high carbohydrate need in winter because the marked seasonal fluctuations and winter accumulation of carbohydrate reserves that characterise herbaceous plants from severe environments with short growing seasons abroad (Mooney and Billings, 1960) apparently is not a strategy used by alpine forbs or grasses, including the tall tussocks, in New Zealand (Hadley and Rosen, 1974; Payton and Brasch, 197&r In other species which live in an extremely cold winter environment, e.g. Icelandic ptarmigan *(Lagopus mutus)* (Gardarsson and Moss, 1970) and redpolls *(Acanthis* spp.) (White and West, i977), a high carbohydrate content of the diet is also considered important for winter survival.

Ecological implications of regional differences in the availability of alternative foods

Although *Hypolepis* rhizomes are a valuable source of starch, nitrogen and phosphorus, they may not be sufficient for a balanced winter diet. In some parts of the Murchison Mountains only minor supplementation is possible in winter because *Chionochloa conspicua* and *Uncinia* spp. have been either eliminated or severely depleted through heavy grazing by introduced red deer. In general, floristic diversity and abundance of the beech forest understorey on the Murchison Mountains declines with precipitation towards the east. This could be due to differences either in the density of present or past populations of red deer or to a slower recovery in the drier eastern region associated with recent deer reduction operations by the New Zealand Forest Service (Mills and Mark, 1977). This difference in availability of alternative winter foods may in part account for differences in the biology of takahe populations between the eastern and western sections of the Murchison Mountains. In the Takahe Valley area, which is in the eastern sector, adult survival, adult weights and chick survival are all much lower than in the west (Mills, 1975). The condition in which the birds emerge from winter may ultimately affect the breeding condition and the quality of the egg which is laid, and hence the breeding success. Studies on the red grouse *(Lagopus s. scoticus)* (Jenkins *et al.,* 1965), the herring gull *(Larus argentatus)* (Parsons, 1970) and the woodpigeon *(Columba palumbus)* (Murton *et al.,* 1974) showed that egg size was an important factor determining survival after hatching, with small eggs producing proportionately fewer surviving chicks.

Another consequence of the understorey depletion by deer is that in severe winters the forest soils of the eastern sector of the Murchison Mountains freeze more readily, thereby frustrating or seriously handicapping the effort of takahe to unearth *Hypolepis* rhizomes.

ACKNOWLEDGEMENTS

We are grateful to Mr J. L. Grigg and his colleagues of Invermay Agricultural Research Station, Ministry of Agriculture and Fisheries for analysing major nutrients and Mr P. W. Shaw and Rangers of Fiordland National Park for field assistance. Cawthron Institute determined the carbohydrate content. Generous support from the World Wildlife Fund (NZ) is gratefully acknowleged. Dr G. R. Williams commented on the manuscript. We are indebted to Messrs B. K. Bradley and D. W. Parker of the Cartographic Branch, Lands and Survey Department for preparing the map of the Murchison Mountains.

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