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LAGOMORPH ABUNDANCE AROUND YELLOW-EYED PENGUIN (*MEGADYPTES ANTIPODES*) COLONIES, SOUTH ISLAND, NEW ZEALAND

Summary: Predation of yellow-eyed penguin (*Megadyptes antipodes*) chicks may be reduced by removing stock around penguin breeding sites because long grass may reduce lagomorph abundance and hence small mammal predators. This study tests this hypothesis in the South Island, New Zealand. The abundance of lagomorph faeces (mainly rabbit *Oryctolagus cuniculus,* but some European hare *Lepus europaeus*) was used as an index of relative abundance of lagomorphs at 16 penguin breeding sites in winter 1991 and 37 sites in 1992/93. There was no evidence that lagomorph pellet abundance was reduced where vegetation was ungrazed. Lagomorph sign was widespread throughout ungrazed areas indicating that the entire ungrazed area and not merely the edge was used by lagomorphs. Lagomorph pellet abundance was higher on sand dunes than elsewhere. Retirement from grazing by stock may help protect and provide nesting habitat for penguins, but does not decrease lagomorph abundance close to nesting sites. It is not yet known whether high lagomorph abundance leads to increased or decreased predation on penguin chicks. The habitat should not be modified ostensibly to reduce lagomorph abundance until the effect on predation is known.

Keywords: Yellow-eyed penguin; *Megadyptes antipodes*; lagomorphs; rabbits; *Oryctolagus cuniculus*; hares; *Lepus europaeus*; vegetation buffer zones; predation; conservation; faecal pellets; Gibb score.

Introduction

Populations of yellow-eyed penguins (*Megadyptes antipodes* Hombron and Jacquinot) are considered to be declining on the South Island of New Zealand (Seddon, van Heezik and Darby, 1989). Predation by feral cats (*Felis catus* L.), ferrets (*Mustela furo* L.) and stoats (*Mustela erminea* L.), has been identified as an important cause of chick mortality (Darby and Seddon, 1990; Moller, Ratz and Alterio, 1995).

The maintenance of "vegetation buffers" around penguin breeding sites has been suggested as a relatively cheap, long-term and potentially effective means of reducing the predation of yellow-eyed penguin chicks (Department of Conservation, 1989). Vegetation buffers are grass strips that are fenced to prevent grazing by domestic stock (usually sheep and cattle). Lagomorphs are important prey items for feral cats, ferrets and stoats (Gibb, Ward and Ward, 1978; Smith *et al*., 1995; Alterio and Moller, 1997) and modification of ground cover by retirement from grazing may exclude rabbits (*Oryctolagus cuniculus* L.) and hares (*Lepus europaeus* de Winton). This in turn is thought to reduce predator numbers which reduces chick predation (Darby and Seddon, 1990).

Buffer zones hold potential as an extremely cost-effective solution to the predation problem. However, if buffer zones do not reduce lagomorph abundance and consequently chick predation, there is a danger from relaxation of conventional predator control measures which could potentially increase rates of predation on chicks. In addition, increased predation on chicks may result if buffer zones actually increase lagomorph abundance. Alternatively, the presence of more lagomorphs within the buffer zones may reduce predation of chicks by providing predators with other prey.

Hitherto, vegetation buffer zones have been widely adopted to reduce predation on yellow-eyed penguin chicks with no assessment of their impact. This study tests the hypothesis that lagomorph abundance is reduced in and around ungrazed penguin breeding sites.

Methods

Study sites

Sixteen yellow-eyed penguin breeding sites were surveyed between late August and early September 1991 and 37 more sites between late December 1992 and early January 1993. All sites were situated in either the Moeraki area, Otago Peninsula or the Catlins, in south-east Otago, South Island, New Zealand (between 45°25'S and 46°39'S).

Comparison of lagomorph pellet abundance between sites

The abundance of lagomorph faecal pellets was assessed using Gibb scores (Gibb *et al.*, 1969) in and around penguin breeding sites. Up to ten line transects were placed through grass areas around penguin nests and extended up to 100 m depending on the size of the site. A single Gibb score was assigned to each transect by averaging the score for each 25 m segment. Where possible, sign was scored for 10 transects in grazed (by sheep and/or cattle) areas and 10 in ungrazed areas at each site. Ungrazed areas usually consisted of long rank grass, reeds and lupin scrub while grazed pasture consisted of close-cropped grass (<10 cm). The transects were spaced evenly thoughout available habitat, while ensuring that they were at least 20 m apart. In 1991, average vegetation height was estimated in a 5 m radius plot every 25 m along each transect.

Transects were classified as 'dune' or 'non-dune', and two-way ANOVAs tested pellet abundance against dunes and grazing.

Gibb score calibration

Thirty-six 100 m transects spanning two penguin breeding sites (Double Bay and Lupin Block) at Boulder Beach, Otago Peninsula in 1991 were used to calibrate the Gibb scores against the number of lagomorph pellets. A Gibb score was allocated to each transect by inspecting the whole of the transect before counting all pellets present in 2 m radius plots at 10 m intervals along the transect. We attempted to get ten transects for each Gibb score but this was not possible for every score. The two sites consisted of ungrazed dune and non-dune areas and vegetation types were representative of all the sites. The Gibb scores and corresponding pellet counts were then examined using a simple regression.

Results

Gibb score calibration

The Gibb scores were closely related to pellet numbers ($r^2 = 0.86$; Fig. 1), which offers a reliable index of the number of pellets. This calibration equation ($y = 1.281x^2 + 6.370x - 1.038$) was used to predict pellet abundance before comparing differences between sites.

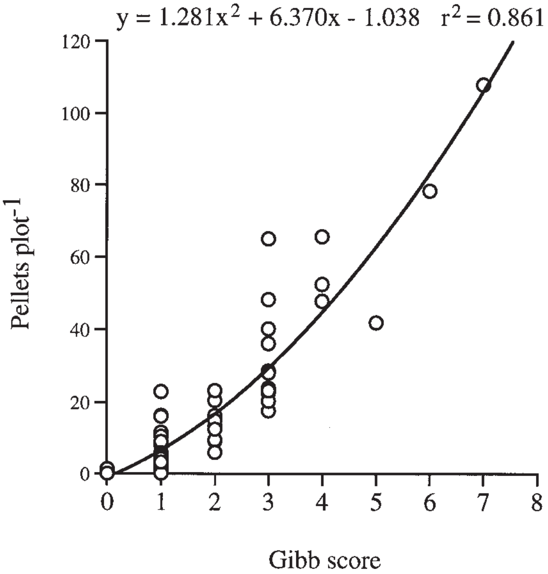

Figure 1: *Relationship between Gibb score assigned and absolute number of lagomorph pellets counted at Double Bay and Lupin Block, Boulder Beach, in 1991. The fitted line is a second order polynomial regression; the plot was a circle of 2 m radius.*

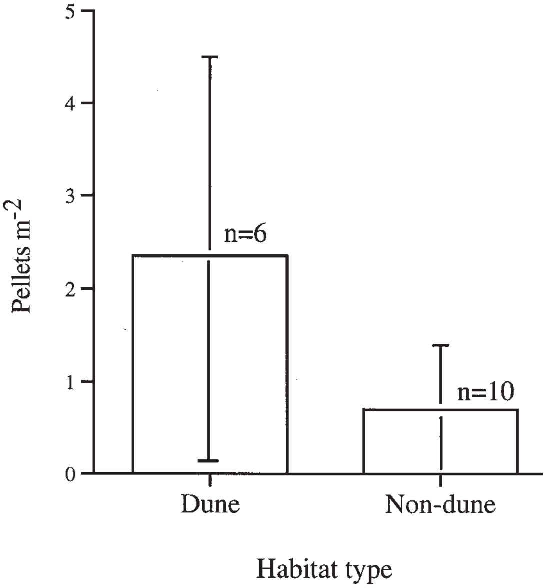

Figure 2: *Average number of lagomorph pellets per m^2 (± 95% CI) in dune and non-dune areas of yellow-eyed penguin breeding sites on Otago Peninsula in 1991. n = number of breeding sites.*

Comparisons of pellet numbers between sites

1991 season

The predicted mean number of pellets was higher at penguin breeding sites associated with sand dunes than at those without dunes (P=0.035; Fig. 2). No significant difference in pellet numbers was detected between grazed and ungrazed areas (P>0.6; Fig. 3). No significant interaction was detected between dune and non-dune versus grazed and ungrazed sites (P>0.1).

Gibb scores for sites surveyed in 1991 were almost significantly correlated with average vegetation height (simple regression, P=0.074). Gibb scores generally increased with increasing vegetation height but also became more variable with increasing vegetation height (Fig. 4).

1992/93 season

As there are no dune areas at the penguin breeding sites in the Catlins, we compared pellet numbers only between regions (Otago Peninsula and Moeraki versus Catlins) and between grazed and ungrazed sites. On average, there were four times as many pellets in the more northerly region than at the Catlins (P=0.087). There was little apparent difference in pellet numbers between grazed and ungrazed areas (P=0.74), nor did the effects of grazing vary between the regions (P=0.88) (Fig. 5).

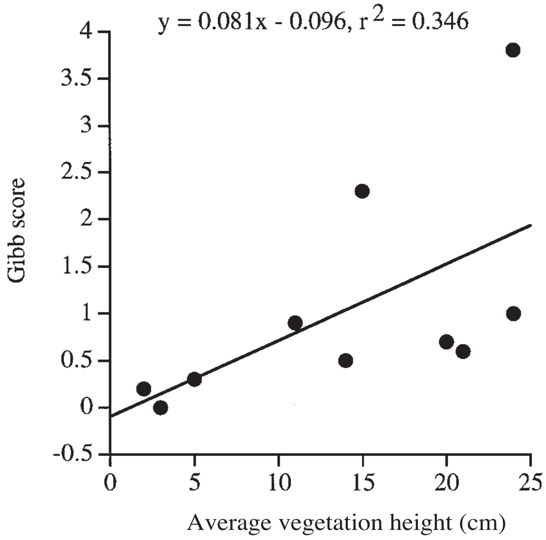

Figure 4: *Relationship between lagomorph pellet abundance and average vegetation height around non-dune yellow-eyed penguin breeding sites on Otago Peninsula in 1991.*

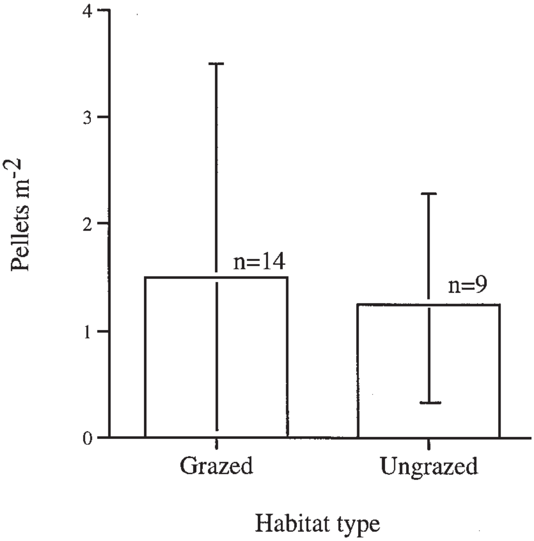

Figure 3: *Average number of lagomorph pellets per m^2 (± 95% CI) in grazed and ungrazed areas of yellow-eyed penguin breeding sites on Otago Peninsula in 1991. n = number of breeding sites; seven of the 16 breeding sites had both grazed and ungrazed areas.*

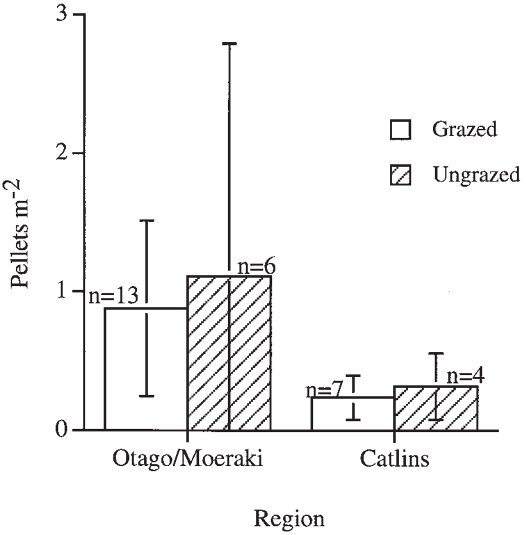

Figure 5: *Average number of lagomorph pellets per m^2 (± 95% CI) in grazed and ungrazed yellow-eyed penguin non-dune breeding sites in Otago/Moeraki and Catlins regions in 1992/93. n = number of breeding sites.*

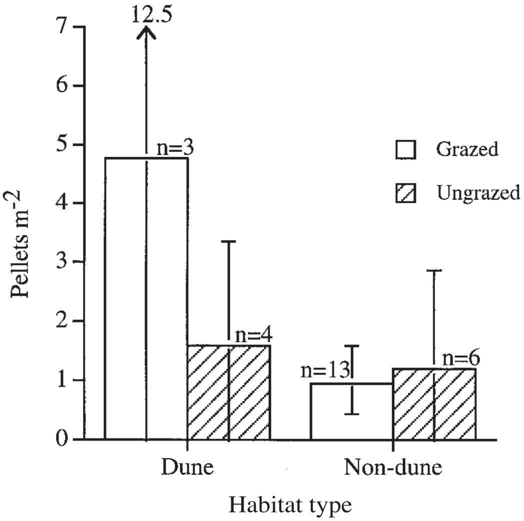

Figure 6: *Average number of lagomorph pellets per m^2 (± 95% CI) in grazed and ungrazed areas of yellow-eyed penguin breeding sites on dune and non-dune areas in Otago Peninsula and Moeraki in 1992/93. n = number of breeding sites.*

Using the Otago Peninsula and Moeraki data only, dunes had higher pellet counts than non-dunes (P=0.005). Grazed areas on average contained more pellets than ungrazed areas (P=0.044) but the effect varied between dunes and non-dunes (P=0.024; Fig. 6).

Discussion

Rabbits and hares probably used the sites in different ways and had different patterns of distribution but it was not possible to differentiate between rabbit and hare pellets. In fact, captive hares and rabbits on the same diet produce identical pellets (Flux, 1990). However, nearly all the lagomorphs seen in the study areas were rabbits (Bruce, 1991; Alterio, 1994; *unpubl. obs.*).

Pellets were more visible and easily counted in the grazed areas, so there may have been more pellets in the ungrazed areas than were detected. Taylor and Williams (1956) recorded higher pellet decay rates under bushes or tall grass than on short grass or bare ground, which may further underestimate pellet density in ungrazed areas. In addition, it is unknown whether lagomorph defecation rates vary between grazed and ungrazed habitat. Alterio (1994) found that pellet scores gave similar results to counts of rabbit scrapes and burrows in comparing habitats which suggests that our pellet counts were broadly reliable to indicate lagomorph abundance. However, only approximate comparisons of lagomorph abundance can be inferred from the pellet scores, and biases may underestimate apparent abundance in long grass.

We suggest that lagomorph abundance may not be greatly changed by retiring pasture from grazing, at least on non-dune areas. This corroborates the findings from more intensive sampling of lagomorph sign at Boulder Beach (Moller *et al.,* 1995). If detectability of pellets was impaired significantly on ungrazed areas and decay rates are faster in long grass, then there may have been even more lagomorphs in ungrazed than grazed pasture. In coastal Spain, Rogers and Myers (1979) recommended relieving fragile pasture on dunes from livestock to prevent local extinction of rabbits. Ungrazed coastal pasture in New Zealand is unlikely to be lush enough to become unsuitable for rabbits, and exclusion of stock may increase food availability for lagomorphs. Thus, establishing buffer zones is unlikely to reduce rabbit or hare abundance. This negates the value of continued purchase and de-stocking of large tracts of coastal farmland to establish vegetation buffer zones.

A potential decrease in lagomorph abundance with removal of grazing from dune areas is signalled by Fig. 6 and our significant interaction term (P=0.024). However, only three grazed dune areas were sampled, all close together, and all in the most northerly region. Accordingly, we urge further study on a wider area to evaluate this potential effect. If proven, the buffer zone concept may have some utility on dune land.

A second, potentially important finding is that sand dunes promote the number of rabbits present. In coastal Spain, rabbits thrive best where sandy ridges suitable for warrens adjoin moist feeding grounds (Rogers and Myers, 1979). Rabbits prefer free-draining soils and moderately elevated areas for warrens and burrows (Rogers, 1981). Drowning of young in breeding stops limits rabbit populations in New Zealand (Robson, 1993). Therefore, the presence of free-draining dunes is likely to determine rabbit density.

Lagomorph pellets were widespread throughout the ungrazed sites at Boulder Beach, dispelling suspicions that lagomorphs (particularly rabbits) may use only the periphery of ungrazed areas for shelter and access to close-cropped pasture. Pellet counts corrected for decay rates for differing micro-habitats suggest rabbits use “closed micro-habitat” more frequently than “open micro-habitat” (Simonetti, 1989). The widespread distribution of lagomorph sign inside ungrazed areas suggests that rabbits use these areas extensively for cover and feeding.

There have been no systematic studies to determine whether high lagomorph abundance increases or decreases chick predation, though Moller *et al.* (1995) found that prey and predator numbers were higher in vegetation buffers than elsewhere; or whether more lagomorphs and predators around penguin breeding sites actually increases chick predation. It is not known whether predation on chicks is causing a putative decline in yellow-eyed penguin, but predation has been identified as the main land-based cause of death (Darby and Seddon, 1990; Moller *et al.*, 1995).

Even if retirement from grazing and establishment of vegetation buffers does not reduce predation of penguin chicks, the provision of nesting habitat free from livestock trampling may be important in protecting the species. Research is needed to test the effect of modifying the vegetation around penguin nesting sites on lagomorph abundance. Priority needs to be given to determine the relationship between chick predation and lagomorph abundance. Additional habitat modifications to manipulate lagomorph abundance should not be carried out until the effect of these manipulations is clarified.

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References

Alterio, N. 1994 (unpublished). *Diet and movements of carnivores and the distribution of their prey in grassland around yellow-eyed penguin* (Megadyptes antipodes) *breeding colonies.* M.Sc. Thesis, University of Otago, Dunedin, New Zealand. 120 pp.

Alterio, N.; Moller, H. 1997. The diet of feral house cats (*Felis catus*), ferrets (*Mustela furo*) and stoats (*Mustela erminea*) in grassland surrounding yellow-eyed penguin (*Megadyptes antipodes*) breeding areas. *Journal of Zoology (London)*. 243: 869-877.

Bruce, L. 1991 (unpublished). *Lagomorph abundance and distribution around yellow-eyed penguin* (Megadyptes antipodes) *breeding colonies on the Otago coast of New Zealand.* Wildlife Management Report No. 13, University of Otago, Dunedin, New Zealand. 33 pp.

Darby, J.; Seddon, P.J. 1990. Breeding biology of yellow-eyed penguins (*Megadyptes antipodes*). *In:* Davis, L.S; Darby, J.T. (Editors), *Penguin Biology*, pp. 45-62. Academic Press, San Diego, U.S.A.

Department of Conservation 1989. *Species Conservation Strategy: Yellow-eyed Penguin* (Megadyptes antipodes). Department of Conservation, Dunedin, New Zealand. 61 pp.

Flux, J.E.C. 1990. Brown Hare. *In:* King, C.M. (Editor), *The handbook of New Zealand mammals,* pp. 160-172. Oxford University Press, Auckland, New Zealand.

Gibb, J.A.; Ward, G.D.; Ward, C.P. 1969. An experiment in the control of a sparse population of wild rabbits (*Oryctolagus cuniculus*) in New Zealand. *New Zealand Journal of Science 12*: 509-534.

Gibb, J.A.; Ward, G.D.; Ward, C.P. 1978. Natural control of a population of rabbits (*Oryctolagus cuniculus*) for ten years in the Kourarau enclosure. DSIR Bulletin 223, Department of Scientific and Industrial Research, Wellington, New Zealand. 89 pp.

Moller, H.; Ratz, H. and Alterio, N. 1995. *Protection of Yellow-eyed Penguins* (Megadyptes antipodes) *from predators.* Wildlife Management Report Number 65, University of Otago, Dunedin, New Zealand. 56 pp.

Robson, D.L. 1993. Natural mortality of juvenile rabbits *(Oryctolagus cuniculus),* in North Canterbury, New Zealand. *Wildlife Research 20:* 815-831.

Rogers, P.M. 1981. Ecology of the European wild rabbit, *Oryctolagus cuniculus* in Mediterranean habitats. II Distribution in the landscape of the Camargue, Southern France. *Journal of Applied Ecology 16:* 355-371.

Rogers, P.M.; Myers, K. 1979. Ecology of the European wild rabbit, *Oryctolagus cuniculus* in Mediterranean habitats. I Distribution in the landscape of Coto Donana, Southern Spain. *Journal of Applied Ecology 16:* 691-703.

Seddon, P.J.; van Heezik, Y.M.; Darby, J.T. 1989 (unpublished). *Inventory of Yellow-eyed Penguin* (Megadyptes antipodes) *mainland breeding areas, South Island, New Zealand*. Report commissioned by the Yellow-eyed Penguin Trust and the Otago Branch of the Royal Forest and Bird Protection Society of New Zealand Inc. 116 pp.

Simonetti, J.A. 1989. Microhabitat use by *Oryctolagus cuniculus* in central Chile: a reassessment. *Mammalia 1 53:* 363-368.

Smith, G.P.; Ragg, J.R.; Moller, H.; Waldrup, K.A. 1995. Diet of feral ferrets (*Mustela furo*) from pastoral habitats in Otago and Southland, New Zealand. *New Zealand Journal of Zoology 22:* 363 - 369.

Taylor, R.H.; Williams, R.M. 1956. The use of pellet counts for estimating the density of populations of the wild rabbit, *Oryctolagus cuniculus* (L.). *The New Zealand Journal of Science and Technology 38:* 236-256.