FLUCTUATION IN OPOSSUM POPULATIONS ALONG THE NORTH BANK OF THE TARAMAKAU CATCHMENT AND ITS EFFECT ON THE FOREST CANOPY

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(Received for publication 10 August 1979)

ABSTRACT

Fluctuations in density patterns of opossum populations were studied by faecal pellet counts, along the North Bank of the Taramakau catchment from 1970 to 1977. The study area contained two major vegetation associations, rata/kamahi forest and red beech forest. Variations in density patterns over the years indicated that peak population numbers in the beech forests were approximately half those in the rata/kamahi forests. The upper transitional forests above both major forest types, however, reached similar peak densities. Canopy defoliation was studied by aerial photography in 1960 and in 1973. Within 13 years over 40% of the canopy in these protection forests was defoliated. This large-scale defoliation coincided with a build-up and peaking of the opossum population.

In the winter of 1974 the whole area was poisoned by air with 1080 (sodium monofluoroacetate) impregnated carrot. Approximately 85% of the opossum population was removed by this operation. The greatest decline in pellet densities was recorded in the lower and mid-forest strata.

INTRODUCTION

A study on the dynamics of opossum populations was initiated by Bamford in 1970 along the north bank of the Taramakau River, Westland (Bamford, 1972). Faecal pellet lines established by Forest Research Institute staff in April 1970 were remeasured in April 1974, 1975 and 1977. The area was aerially poisoned by the Forest Service in June 1974. The follow-up study reported here was aimed (1) at assessing the spatial and temporal fluctuations of opossum populations from 1970 to 1977 as interpreted from pellet densities and (2) defining what effect these fluctuations had on the forest canopy.

THE STUDY AREA

The study area includes some 19 km of the forested frontal faces on the north (true right) bank of the Taramakau River, between Inchbonnie corner in the west and Taveners Creek in the east (Fig. 1). Hillsides are generally steeply inclined, particularly in the west, where the study area approaches to within one kilometre of the main alpine fault. The bedrock undermass is represented by rocks of the Haast schist group, which grade eastward from granitiferous quartzofeldspathic schist near the alpine fault, through progressively lower grade schists, into non-schistose greywacke and argillite.

The vegetation in the study area is transitional between the mixed rata/kamahi forest of central Westland and the beech forest of north Westland (see Fig. 1). It can be sub-divided into three broad classes, based on the dominance of different major canopy species (Holloway, 1966; Wardle and Hayward. 1970; Wardle, 1972; James *et al.,* 1973; and Franklin, 1974).

CLASS I: *General hardwoods.* Altitudinal range 200-700 m. It consists of kamahi (*Weinmania racemosa*)/*Quintinia acutifolia*/southern rata (*Metrosideros umbellata*) and lowland short-scrub hardwood associations (as defined by Wardle and Hayward, 1970).

CLASS II: *Beeches.* Altitudinal range 200-700 m. A low to mid-altitude forest consisting of red beech (*Nothofagus fusca*)/kamahi/*Quintinia acutifolia* associations with scattered podocarps at lower levels and lowland short-scrub hardwood associations.

CLASS III: *Rata/totara Forest.* Altitudinal range 600-870 m. Frequently forms the tree-line and consists mainly of rata/totara (*Podocarpus hallii*) associations (Wardle and Hayward, 1970, James *et al.,* 1973). Short scrub-hardwood associations, often dominated by Hoheria and associated species occur as seral vegetation on unstable sites throughout this vegetation class.

In the study area the vegetation changes at Alexander's Creek. Downstream it consists mainly of Class I rata/kamahi forests, upstream it is Class II beech dominated forests. Class III rata/totara associations occur above both major forest types.

Red deer were established in the study area in 1925-1930 (Best and Crosier, 1970). Between 1960-1969 deer densities were at their highest levels (Challies, pers. comm.) and were reported to be exerting heavy browsing pressure on the palatable species in the regenerating understorey (Wardle and Hayward, 1970). Thereafter, a marked decline in numbers became apparent associated with the increasing intensity and effectiveness of commercial venison recovery.

In 1949-50 opossums were reported to be absent from the study area (Pracy, cited by Best and Crosier, 1970). They were however well established downstream from Inchbonnie, in the Hohonu Range. In 1969 the vegetation and distribution of animals in the upper Taramakau catchment was surveyed in detail (Wardle and Hayward, 1970, and Best and Crosier, 1970), and by this time opossums occurred throughout the study area with highest densities in the vicinity of Hut Creek.* Densities decreased eastwards and were approximately 50% lower in the beech forest upstream from Alexanders Creek.

An opossum control operation commenced in June 1974 when the entire study area was aerially poisoned. It was initially pre-fed with non-toxic carrot bait at the rate of 11 kg/ha and then poisoned 2-3 weeks later with toxic bait at the rate of 45 kg/ha with a standard Forest Service toxic loading of 4.5 kg 1080 (sodium monofluoroacetate) per tonne of carrot bait.

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* Subsequent calculated densities showed that little change had taken place in opossum population levels between 1969 and 1970.

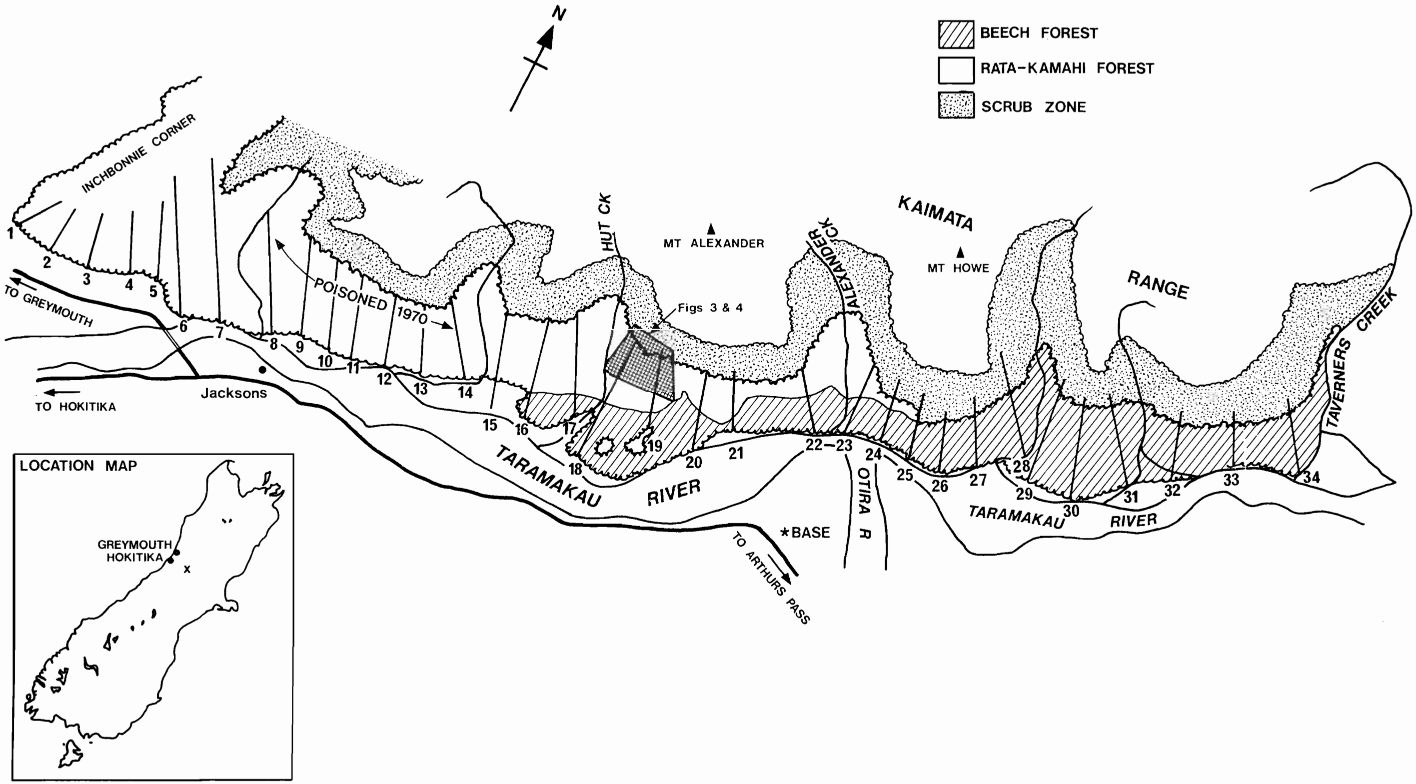

FIG. 1—Map of the study area showing the two major forest classes, the faecal pellet lines and the area poisoned in 1970. Scale: 1 cm to 1.12 km.

METHODS

Pellet Lines and Stratification

The density of opossum populations was determined from 34 faecal pellet lines established in the area in April 1970 (Fig. 1) and remeasured in April 1974 and April 1975. In April 1977, 20 of the original pellet lines were remeasured (10 in the rata/kamahi forests and 10 in the beech forests, see Fig. 5). Each pellet line consisted of a series of 80 cm radius plots (0.0002 ha) sited at 20 m intervals along a predetermined compass bearing up the hill from the lower bush-edge forest to the timberline/alpine scrub interface. The presence or absence of intact opossum pellets (as defined in Bell, 1973) on each of these plots was recorded. Pellet densities per line were calculated and a pellet density index obtained from a frequency-density transformation table (Greig-Smith, 1964). Densities reflected running means calculated from a series of three lines, the line itself and the two adjacent ones. If the 90% confidence limits of the binomial distribution of two or more pellet density estimates overlapped, the difference between these estimates was considered to be not significant. The altitudinal distribution of pellets was determined by measuring the altitude in metres at every fifth plot along each transect; altitudes for unmeasured "in-between plots" were determined by interpolation. Altitudinal strata were established to stratify pellet densities on the basis of the existing vegetation classes: Classes I and II were divided into a Lower Forest Stratum (riverbed — 399 m) and Mid Forest Stratum (400-699 m); and Class III became the Upper Forest Stratum (700-900 m).

The study area was, for the purpose of this analysis, subdivided into two blocks:

A — with Class I rata/kamahi forests in lower and mid altitudinal strata (pellet lines 11-20), and

B — with Class II beech forests in lower and mid altitudinal strata (pellet lines 23-32).

Both blocks contained Class III transitional forests above the mid forest stratum.

Canopy Damage

A study of a series of photographs from two aerial surveys (one flown on 22 February 1960, Survey No. 3680 scale 1 : 25000 and one on 19 September 1973, Survey No. 1063 scale 1 : 25000) showed that severe canopy defoliation had occurred in the rata/kamahi forests of the study area between 1960 and 1973. Areas of defoliated crowns on the 1973 series of aerial photographs were examined with a stereoscopic scanner and compared with the same areas in the 1960 series. Where an obvious and prominent change had taken place, the areas were encircled and transposed on to the map shown in Fig. 2.

Canopy defoliation was quantified in a representative face within block A (see Fig. 2). Comparable aerial photographs of this face taken in 1960 and 1973 (Figs. 3 and 4) were enlarged to a scale of approximately 1 : 6000 and examined stereoscopically. A standard dot grid analysis (Avery, 1966) was used to estimate the frequency of defoliated crowns in the canopy. Individual dots (100/sq inch) were examined independently by two observers and the crowns in the canopy under them scored as foliated, defoliated or undetermined. The undetermined category represented dots coinciding with crowns occurring in shaded areas on the photographs, or intercrown spaces. A total of 1748 dots were examined (875 in 1960; 873 in 1973) and the data subjected

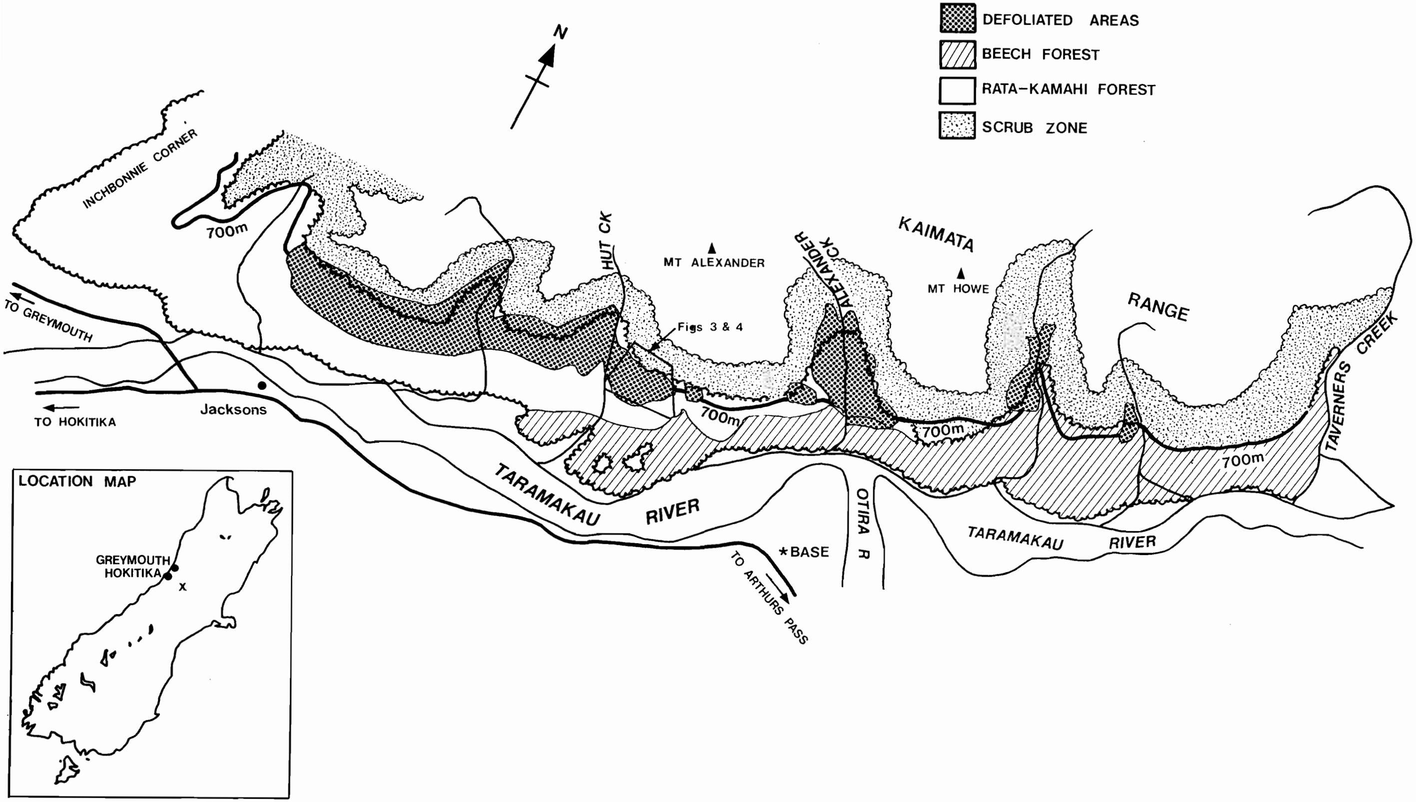

FIG. 2—Map of the study area showing the areas defoliated between 1960 and 1973 and the location of the representative face selected for more detailed study (Figs. 3 and 4). The 700 m contour line is also shown. Scale: 1 cm to 1.12 km.

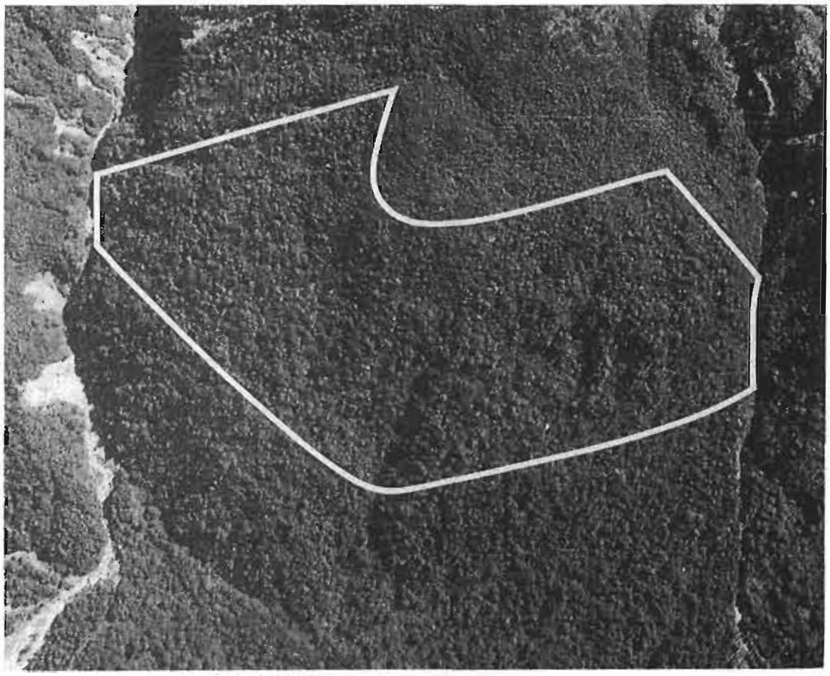

FIG. 3—Enlarged aerial photograph of representative face in block A taken in 1960. The outlined area was covered by the dot-grid analysis.

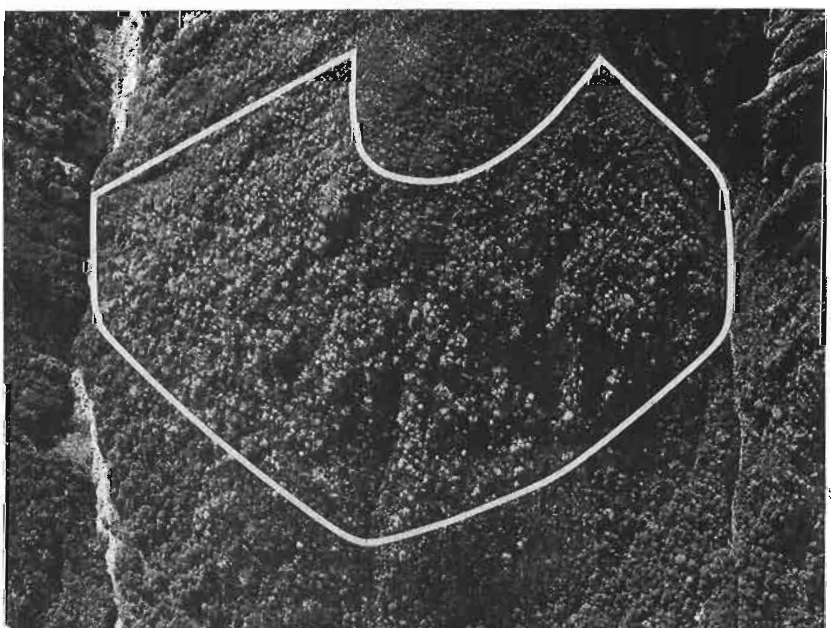

FIG. 4—Area shown in Fig. 3 photographed again in 1973.

to Fisher's exact 2 × 2 test (Sokal and Rohlf, 1969, p. 589) to test for differences between observers and years (i.e., 1960 and 1973).

An infra-red photograph taken of this face in 1974, and subsequent field assessments, confirmed that crowns scored as defoliated on the 1973 black and white aerial photograph (Fig. 4), were defoliated trees.

RESULTS

Changes in Density

The changes in opossum densities over the four sampling periods for the whole of the study area are shown in Fig. 5; those in the selected vegetation blocks in Fig. 6.

Within the pre-poison sample, pellet densities varied markedly in the rata/kamahi forests of block A. Densities declined significantly by some 45% between April 1970 and April 1974. Part of this block (transects 8-14 inclusive) had been previously poisoned with aerially sown 1080 impregnated carrots in the winter of 1970 (Bamford, 1972). However, in April 1974, 4 years after this small-scale operation, no significant difference could be detected in the decline of pellet densities between the poisoned

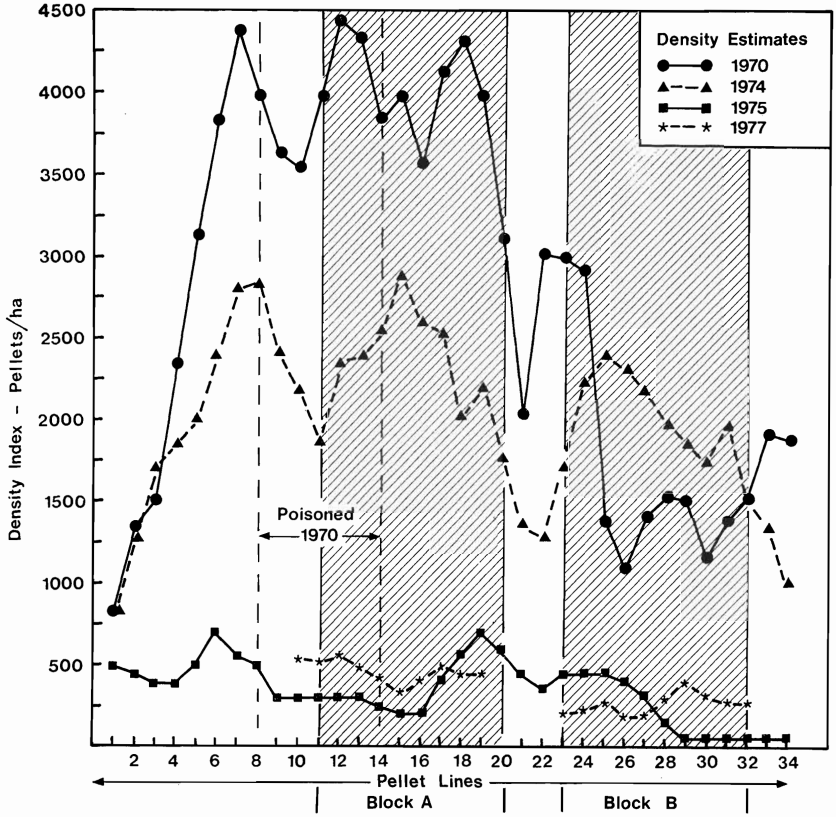

FIG. 5—Changes in population density between 1970 and 1977 for the entire study area. Location of blocks A and B are shown. Note the effects of the poison operation in July 1970 on densities measured on either side of this area in 1974.

area (transects 8-13 inclusive; 41% decline), the area containing three lines on the face upstream of the poisoned area (a buffer zone consisting of transects 15-17 inclusive; 31% decline), or in an area well away and also upstream from the poisoned area (transects 18-20 inclusive; 48% decline, see Figs. 1 and 5).

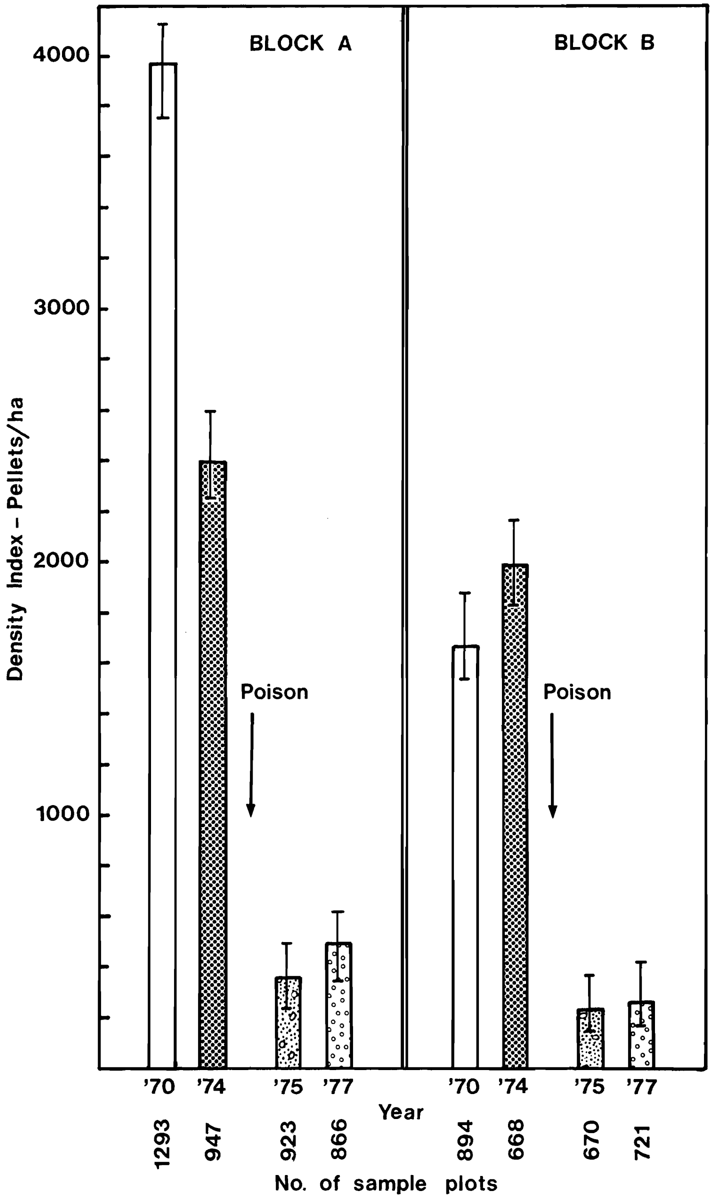

FIG. 6—Changes in population density with 90% confidence limits between 1970 and 1977 for the rata/kamahi block (A) and the beech block (B). Note the effects of the poison operation in June 1974.

In the beech block, pellet densities did not change significantly between 1970 and 1974 indicating that this area was at or close to peak carrying capacity.

The aerial poison operation in June 1974 reduced pellet densities significantly in both blocks, by 80% in the rata/kamahi forest and 88% in the beech forest (Fig. 6). In the 1975 post-poison pellet assessment no significant differences in density could be detected between the two blocks. By 1977, densities were still low and not significantly different from the 1975 assessment.

Changes in Use of Altitudinal Range

The changes in altitudinal use over the four sampling periods for both blocks were marked (Fig. 7). In 1970, the distribution of pellets in the rata/kamahi block (A) was uniformly high throughout the three altitudinal strata, and indicated the distribution of an opossum population at peak density levels (Bamford, 1972). In 1974 after the population had declined naturally by approximately 45% throughout its altitudinal range and prior to the large-scale "control" operation, the biggest decrease in density of pellets (64%) was measured in the mid altitudinal forest. In the beech block (B) pellet densities were similar in 1970 and in 1974 as already described (Fig. 6); they increased significantly with altitude however (Fig. 7). This pattern was not apparent in block A in 1970.

Major differences occur then, in the carrying capacities of lower and mid altitudinal forest in both blocks, when these were estimated to be carrying their peak populations (see highest densities measured in both blocks in Fig. 7). This is no doubt related to the vegetation occurring in these strata: Class I and II forests respectively in blocks A and B. The upper forest "rata belt" (representing Class III forests in both blocks) however, was capable of sustaining similar high densities of opossums.

Canopy Damage in Upper Forest Zone

Figure 2 shows areas in the study area (especially in the rata/kamahi forests of block A) where the most dramatic canopy changes took place between 1960 and 1973. Most of the prominent and therefore severe canopy defoliation occurred around 700 m altitude, in the Class III forests. The dot grid analysis indicated that there was a highly significant difference ($P > 0.01$) in the proportions of foliated and defoliated crowns scored in 1960 and 1973. Variation between the two independent observers however, was not significant ($P < 0.05$) and amounted to less than 10%, showing the relative ease and consistency with which defoliated crowns may be detected on aerial photographs. On the selected representative face in block A (Figs. 3 and 4), 41% of the canopy cover in the protection forests had been defoliated within the 13-year period. The defoliation of canopy crowns was greatest in the upper forest zone where 53% of the canopy was affected. This large-scale defoliation coincided with a build-up and peaking of opossum numbers in the study area. Among the canopy-forming species in the upper forest stratum defoliation was most severe in rata (68%) followed, in order of severity, by totara (15%) and kamahi (5%) (L. Burrows, unpubl.). Similar damage in this zone has been described in other mixed forest areas in Westland by Holloway (1959, 1966), Wardle (1972), James *et al.* (1973), and Pekelharing and Reynolds (1979).

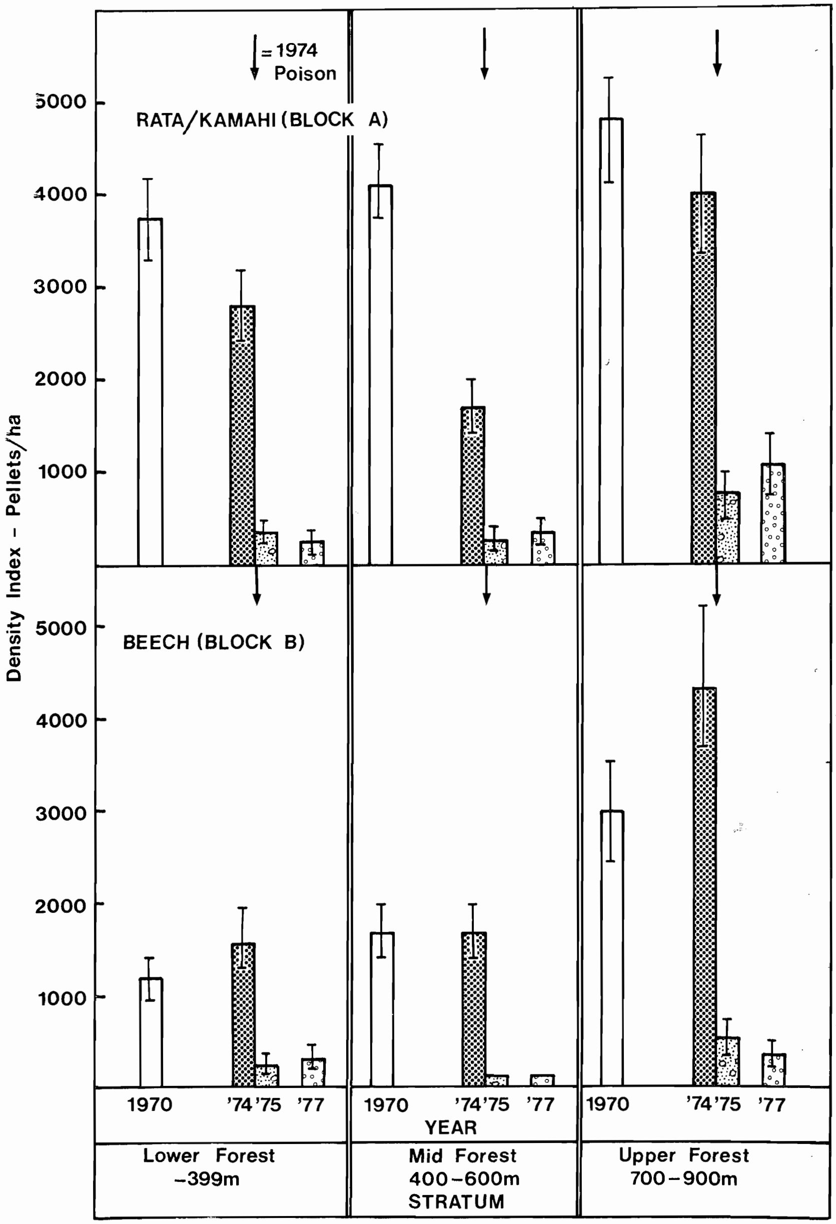

FIG. 7—Changes in altitudinal distribution with 90% confidence limits of the opossum population between 1970 and 1977. Note highest densities measured in block B in lower and mid forest zones in 1970 and 1974 in relation to those in block A.

DISCUSSION

Past survey results of animal densities in mixed forest areas have indicated that highest concentrations of deer and/or opossum faecal pellets occur in the upper forest stratum (Best and Crosier, 1970; Pekelharing, 1973; Pekelharing and Reynolds, 1979), and this study is no exception. Pekelharing and Reynolds (1979) and Pekelharing (in prep.) showed that there was no significant difference in the disappearance rates of opossum faecal pellets with altitude in the rata/kamahi forests of Westland National Park. This result therefore suggests that the altitudinal variations in pellet density measured in this study were directly related to animal density, and thus were associated with population status and habitat type. Bamford (1972) provided evidence that peak populations inhabitated block A in 1970. Presumably peak populations inhabitated block B at least in 1974. No significant increase in density of pellets was measured in this area between 1969-70 and 1974. Additionally the high kill in this block (88%) is considered symptomatic of high density populations (Bamford and Martin, 1971; Bamford, 1972). Peak populations in block B were approximately half those in block A (Fig. 6), the beech dominated vegetation in lower and mid forest strata therefore must have been a significant limiting factor.

The decline in pellet densities recorded in part of block A between 1970 and 1974 (see also Bamford, 1972) was the result of the small scale trial poison operation in July of the winter of 1970. However, natural mortality apparently accounted for a similar reduction in the adjoining unpoisoned peak "high density" populations as earlier described and shown by the 1974 density distribution (see Figs. 1 and 5).

The canopy defoliation recorded in this study is not unusual. It is not known what proportion of the defoliated trees will die or are dead and what eventually recovers. Presumably this will be determined by the decline or continuation of browsing pressure. It is certain however, that many of the trees do die (see also Meads, 1976) as a result of repeated defoliation. This is clearly shown in a tributary of the Hokitika River (the Kokatahi catchment), where large tracts of defoliated canopy photographed in 1959 (J. Johns in Travers, 1964) had collapsed and disappeared by 1979 (Pekelharing, unpubl.). Vegetation studies (James *et al.,* 1973) in catchments where opossum populations achieved their peaks, and then declined naturally, approximately 20 years earlier than those in the Taramakau, i.e., the Kokatahi and Styx catchments, show that the species composition of the impaired Class III forests is modified to resemble more closely that of a scrubland community. In the Kokatahi where the forests have lost around 70% of their basal area, following 20 years of high opossum numbers, the tree line has dropped 300 m (James *et al.,* op. cit.).

Southern rata is known to be a highly favoured food of opossums (Pracy and Kean, 1969). Although no quantitative studies have been carried out to determine the relative proportions of tree species browsed by opossums in the mixed rata/kamahi forests of the South Island, southern rata was probably at least as prominently represented in the diet of the opossums in the Taramakau population as northern rata was in the diet of a population studied in the Orongorongo valley (see Fitzgerald, 1976, and Meads, 1976). Circumstantial evidence presented in this report indicates that the canopy defoliation described in this study was mainly caused by opossum browsing. It coincided with heavy browsing of the understorey by deer.

On the steep glaciated slopes of Westland's main river valleys located within the rata/kamahi protection forest zone, the upper forests help protect the precariously placed soils and weathered rock materials from erosion and landsliding. In those parts of the valleys of the Styx, Kokatahi and Taramakau rivers where populations of red deer and opossums peaked approximately 30 years ago, severe accelerated erosion and landsliding has become evident presumably following the widespread death of the forest trees.

Overall, slope instability appears to be most severe in the biotite schist zone which forms a narrow band parallelling the alpine fault from the Arawata River in the south to the Haupiri River in the north and which lies in the study area roughly between Inchbonnie corner and Hut Creek (see Geological map of New Zealand. sheet 17, 1967). It is probable that the biotite schists are inherently more erodible than the less metamorphosed greywackes and argillites and possibly the chlorite schists east of the biotite schist zone (see Thompson and Adams in McSaveney, 1978). Generally, the biotite schist zone occurs upstream from the frontal gorges of most of Westland's rivers, where average slopes are very steep and where, according to data presented by McSaveney (1978), rainfall exceeds 5000 mm to 6000 mm per year. It is not surprising, therefore, that slope response to widespread death of the canopy trees in this region of high erosional stress has been marked if not spectacular. Accounts of the forest conditions and their influence on slopes and the general hydrological conditions are given by Wallis and James (1972), James (1973), Cunningham and Stribling (1978), Mosley (1978), and Pearce and O'Loughlin (1978) and for the Hokitika catchment by Holloway (1959, 1966) and James (1973).

More recently the forested slopes of the Taramakau catchment within the biotite zone between Inchbonnie corner and Hutt Creek (Block A) are beginning to show obvious signs of accelerated landsliding and gully formation. Here, deer and opossum populations attained peak levels in the late 1960s, approximately 20 years after the peaking of populations in the Hokitika catchment. Aerial photographs taken in 1960 show that landslides and gullies were generally absent from this area 18 years ago.

This change in slope stability is not apparent during the same time interval in the "control" area upstream from Alexanders Creek (Block B), where the vegetation is mainly beech and the bedrock ranges from semi-schistose greywacke to greywacke and argillites.

It is likely that the deteriorating trend in the protection forests of the Taramakau will continue in the future. Response of the vegetation following the reduction in deer and opossum numbers will vary with altitude. It will be slow in the upper forest stratum. Replacement of dying, defoliated canopy species in this area may well take in excess of 100 years.

ACKNOWLEDGMENTS

Many people have helped in the pellet counting. Mr K. Platt of FRI helped in the dot grid analysis, and Drs J. Coleman, C. O'Loughlin and J. Wardle read and commented on the manuscript. N.Z. Aerial Mapping Ltd provided the black and white aerial photo enlargements shown in Fig. 3 and 4.

REFERENCES

AVERY, T. E. 1966: Foresters guide to aerial photo interpretation. Agriculture handbook 308. U.S. Dept. of Ag. and Forest Service.

BAMFORD, J. M. 1972: The dynamics of possum (**Trichosurus vulpecula** Kerr) populations controlled by aerial poisoning. Ph.D. Thesis, University of Canterbury, Christchurch.

BAMFORD, J. M. and MARTIN, J. T. 1971: A method for predicting success of aerial poison campaigns against opossums. **N.Z. J. Sci. 14:** 313-21.

BELL, D. J. 1973: The mechanics and analysis of faecal counts for deer census in New Zealand. **N.Z. For. Serv., For. Res. Inst., Prot. For. Rep. 124** (unpubl.).

BEST, L. W. and CROSIER, P. S. 1970: Report on the animals within the Taramakau Catchment **N.Z. For. Serv., For. Res. Inst., Prot. For. Rep. 74** (unpubl.).

CUNNINGHAM, A and STRIBLING, P. W. 1978: The Ruahine Range A situation review and proposals for integrated management of the Ruahine Range and the rivers affected by it. **Water and Soil Techn. Publ. No. 13.**

FRANKLIN, D. A. and NICHOLLS, J. L. 1974: Forest Service Mapping Series 6, Sheet No. 18, Grey.

GEOLOGICAL MAP OF N.Z. Sheet 17, Hokitika 1967: New Zealand Geological Survey, Department of Scientific and Industrial Research.

GREIG-SMITH, P. 1964: "Quantitative Plant Ecology." 2nd ed. Butterworths, Washington, D.C. 256 pp.

HOLLOWAY, J. T. 1959: Noxious animal problems of the South Island alpine watersheds. **N.Z. Sci. Rev. 17:** 21-8.

——— 1966: Report on the Hokitika catchment 1957/58. **N.Z. For. Serv., For. Res. Inst., Prot. For. Rep. 30** (unpubl.).

JAMES, I. L. 1973: Mass movements in the upper Pohangina catchment, Ruahine range. **N.Z. J. Hydrol. 12:** 92-102.

——— 1973: The forests and sub-alpine scrublands of the Hokitika catchment. **N.Z. For. Serv., For. Res. Inst. Prot. For. Rep. 116** (unpubl.).

McSAVENEY, M. J. 1978: The magnitude of erosion across the Southern Alps. In: Proceedings of the Conference on erosion assessment and control in N.Z. N.Z. Association of Soil Conservators.

MEADS, M. J. 1976: Effect of opossum browsing on northern rata trees in the Orongorongo Valley, Wellington. **N.Z. J. Zool. 3:** 127-39.

MOSLEY, M. P. 1978: Erosion in the south-eastern Ruahine Range: its implications for downstream river control. **N.Z. J. For. 23(1):** 21-48.

PEARCE, A. J. and O'LOUGHLIN, C. L. 1978: Hydrologic and geomorphic processes on forested lands — A selective overview. In: Proc. of the conference on Erosion Assessment and Control in N.Z. N.Z. Association of Soil Conservators.

PEKELHARING, C. J. 1973: Status of introduced mammals in the Hokitika catchment, Westland. Section A: Distribution and density. Section B: Growth rate and condition of deer. **N.Z. For. Serv., For. Res. Inst., Prot. For. Rep. 122** (unpubl.).

PEKELHARING, C. J. and REYNOLDS, R. N. 1979: Status of Introduced Animals in Westland National Park. **N.Z. For. Serv., For. Res. Inst., Prot. For. Rep. No. 168** (unpubl.).

PRACY, L. T and KEAN, R I. 1969: The opossum in New Zealand. Habits and trapping. N.Z. Forest Service Publicity Item No. 40. 52 pp.

SOKAL, R. R. and ROHLF, F. J. 1969: "Biometry", W. H. Freeman & Co. San Francisco, U.S.A.

TRAVERS, W W. G. 1964: Animal Control in Westland Protection Forests. **N.Z. J. For. 9:** 1.

WALLIS, F. P. and JAMES, I. L. 1972: Introduced animal effects and erosion phenomena in the Northern Urewera Forests. **N.Z. J. For. 17:** 1.

WARDLE, J. and HAYWARD, J. 1970: The forests and scrublands of the Taramakau and the effects of browsing by deer and chamois. **Proc. N.Z. Ecol. Soc. 17:** 80-91.

WARDLE, J. 1972: The composition and structure of the forests and shrublands of the Grey catchment headwaters and the influence of introduced mammals. **N.Z. For. Serv., For. Res. Inst., Prot. For. Rep. 112** (unpubl.).