Fluctuations in possum numbers in the Pararaki Valley, Haurangi State Forest Park

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Abstract

Each year from 1965 to 1997, brushtail possums (*Trichosurus vulpecula*) were recovered from permanently marked trap lines in the Pararaki Valley, Haurangi State Forest Park, to document long-term changes in their life history statistics, and to determine if the population had reached equilibrium (stability) with its environment 70–80 years after initial colonisation. Each trapping comprised 80 leg-hold traps run for 3 nights. Each year, the total catch was recorded, and all the possums captured were scored for their physical condition, age, maturity, and reproductive condition. Analysis of these data indicated that the population had declined in numbers by about 2% per annum over the period of our study, and by about 50% of the rate of decline measured in the same area in the late 1940s and 1950s. In addition to the overall decline, the population crashed in 1977 and in 1996, to 60–70% of that recorded in the previous year. At the time of these crashes, the possums taken on our trap lines appeared to be starving. Concurrent measurements of body condition, age, maturity, and the time of breeding changed significantly, although almost all females continued to breed. Overall, these occasional population crashes (but not the overall rates of decline) follow similar trends documented for the possum population studied for a similar length of time in the nearby Orongorongo Valley, and suggest that the same population-regulating mechanism operated in both areas, 30 km apart. It appears that possums in our study area have yet to reach any long-term stability with their environment, and while continuing to decline in numbers, suffer occasional dramatic declines apparently initiated by shortages in food. Our results suggest that there are real conservation gains likely through more cost-effective possum control if possums are targeted when their populations are declining naturally.

1. Introduction

The trends in numbers of possums in the Pararaki Valley, Haurangi State Forest Park, Wellington, and related changes in their life history statistics from 1965 to 1997 inclusive have been reviewed by Landcare Research for the Department of Conservation (DOC). This review summarises annual possum-trapping and necropsy data collected, and compares the patterns observed with similar data gathered elsewhere in New Zealand.

1.1 BACKGROUND

After c. 150 years of colonisation, brushtail possums (*Trichosurus vulpecula*) now occupy about 95% of New Zealand (Parkes *et al.* 1997) and are absent only from high alpine areas, the most remote parts of Fiordland, and some offshore islands. Apart from high alpine areas, remaining unoccupied areas are under threat of colonisation or recolonisation.

Possum numbers in New Zealand were estimated at c. 68 million in the late 1980s (Batcheler & Cowan 1988, cited in Department of Conservation 1994), and while this figure is an approximation, their numbers and impacts are such that possums are now rated as New Zealand's most significant vertebrate pest. This is firstly because, through their folivory and predation, uncontrolled possum populations pose serious threats to the health and diversity of New Zealand's flora and fauna—currently about $12m is spent annually in protecting conservation values (Parkes *et al.* 1997). Secondly, possums act as a source of infection of bovine tuberculosis (Tb) to livestock and put at risk market access of New Zealand's exports of beef, dairy and venison products. Control of possums for the elimination of bovine Tb cost $18.3m in 1997/98 (Animal Health Board 1998). Often this control also provides considerable benefits for conservation.

The assisted introduction of mammalian herbivores into New Zealand—a land largely free of competing herbivores and predators, but with an abundance of palatable native forests and grasslands—created a situation rarely encountered elsewhere in the world in recent times. Most liberated species spread rapidly, apparently radiating out in a wave (Riney 1963) from each liberation point to progressively occupy all areas of suitable habitat. The wave crest, representing the population at its maximum, was preceded by a rapidly increasing population, followed by one in decline. Riney, when studying colonising populations of red deer (*Cervus elaphus*) in New Zealand, recognised four stages in this 'irruptive oscillation', viz.

- population growth when food resources are greater than food demands,
- a slowing of population growth as food resources and animal condition decline,
- population decline with high mortality arising from severe depletion of food resources, and
- population adjustment to a much reduced but fluctuating carrying capacity.

This phenomenon has also been recognised in colonising possum populations, as they also appear to be regulated in a density-dependent way (Fraser 1979, Thomas *et al.* 1993). These authors broadly conclude that possum populations at different densities across an irruptive oscillation display demographic characteristics typical of increasing, peak, and declining populations.

This report deals with the nature of the adjustments of one possum population to reduced and changing habitat carrying capacity, i.e. with Riney's fourth stage. Unlike Fraser's study, which sampled populations at different locations over one instance of time, our study examines the phenomenon of population adjustment over 32 years at the same location.

Only two studies in New Zealand have attempted to monitor the post-irruptive fluctuations of possum numbers and life history statistics. Both are built on annual trapping surveys undertaken over c. 30 years. The first study was based in the Orongorongo Valley near Wellington and has been reported several times (e.g. Bell 1981, Brockie 1992). The second—our study—was also in the lower North Island, and has also been the subject of earlier reports (Batcheler *et al.* 1967, Thomas *et al.* 1993).

This report summarises data on possum numbers and life history statistics of possums taken in the Pararaki Valley from 1965 to 1997, and relates these data to similar information gathered in the Orongorongo Valley. It extrapolates the temporal trends observed to current management strategies used to control possums to protect conservation values and livestock.

1.2 OBJECTIVE

- To document temporal changes in the density and life history statistics recorded over 30 years of possums in the Pararaki catchment, Haurangi State Forest Park.

2. Methods

2.1 STUDY AREA

Our study area has been detailed previously (Thomas *et al.* 1993). It comprises forested leading spurs in the centre of the Pararaki Valley, a steep-sided coastal catchment ranging from 100 to 500 m a.s.l. in Haurangi State Forest Park, Wellington (Fig. 1). The vegetation has been described by Wardle (1967). It is dominated at low altitude by mahoe (*Melicytus ramiflorus*), hinau (*Elaeocarpus dentatus*), and rewarewa (*Knightia excelsa*). On the higher slopes, black and silver beech (*Nothofagus solandri* var. *solandri* and *N. menziesii*) are dominant. The canopy is presumably modified by possums throughout, and is broken by windthrow on the ridge crests. The understorey is dominated by species unpalatable to deer, such as pepper tree (*Pseudowintera colorata*), and by tree ferns (*Cyathea* spp.) and beech seedlings. This forest tier is now considerably more dense than it was in the 1950s (L.T. Pracy, unpubl. data), when red deer, goats (*Capra hircus*), and wild sheep (*Ovis aries*) were common and had removed most palatable understorey species.

Possums were liberated within 13 km of our study area in 1920 and 1921 (Pracy 1962), and presumably occupied it soon after. The study area has been closed to commercial harvesting since 1965. Limited commercial trapping and small-scale aerial-baiting trials were undertaken there from 1949 to 1957. Neither of these activities appears likely to have had any effect on the possum population during our study.

2.2 DATA COLLECTION AND ANALYSIS

Possum abundance was assessed from the catch on four permanently marked leg-hold trap lines. All were established in 1965 and trapped annually ever since (except in 1979 and 1987). Each trap line (1–4) extended from the valley bottom up to the nearest ridge crest (Fig. 1). Each line consisted of 20 permanently sited gin traps set at c. 60 m intervals on the ground on what was deemed in 1965 by one of us (L.T.P.) to be 'good' possum sign. Each year, in July or August, all traps were set unlured for 3 consecutive fine nights, weather permitting. Each following day, all traps were visited and any possums captured were humanely killed and necropsied. For each carcass, its sex, maturity (determined from the size of the testes (males) and from the presence of a pouch (females)), body weight, total length (nose to tail tip), and the reproductive status of females (determined from the presence or absence of pouch young and/or lactation) was noted. Body condition was assessed from 1978 onwards from the weight of the excised mesenteric fat depot (Bamford 1970), while age was determined from 1975 onwards from cementum annuli in extracted second and third mandibular molars (Pekelharing 1970). The time of breeding was determined from the head lengths of pouch young, using a regression generated from known-aged pouch young (Bell 1981). Annual comparisons of demographic data were biased towards immature/young possums, because their demography more accurately reflects changes in environmental conditions than those of adult possums.

The annual trap success of possum per line (numbers caught per trap night) were compared using data from 1965 to 1997. Trends in annual trap success were modelled using the approach of Link & Sauer (1997), where the repeated counts on each line were taken as over-dispersed Poisson random variables. Mean annual decreases in trap success were analysed on the log scale and were corrected for bias arising during data transformation, using the Delta method (Seber 1982). Separate ANOVA were used to compare annual changes in mean body weight, possum age (following log transformation), mesenteric fat, time of breeding, and productivity.

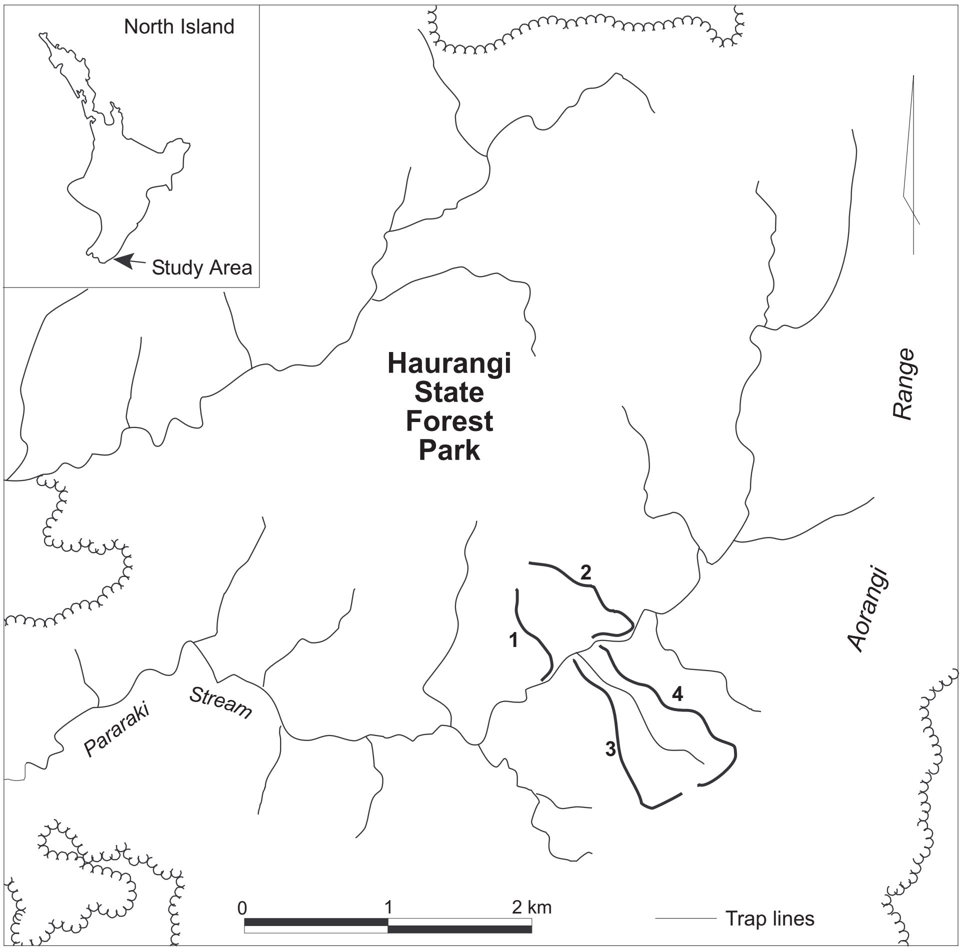

FIGURE 1. THE STUDY AREA IN THE PARARAKI VALLEY, HAURANGI STATE FOREST PARK, SHOWING THE LOCATION OF THE ANNUALLY TRAPPED LINES.

3. Results

3.1 TRAP SUCCESS

The annual trap success of possums taken from lines 1–4 appeared highly variable but peaked at 4- to 6-year intervals (Fig. 2). Catches were greatest from 1965 to 1976 (40–80% per trap line per night), fell by about 70% in 1977 to c. 20% per trap line per night, rose to more modest levels from 1981 to 1995 (c. 45% per trap line per night), and fell again in 1996. Overall, the trap success declined during the period of our study by 2.0 ± 0.31% (S.E.) per annum on average. However, because of the sharp decline in the trap success in 1977, the data are inadequately represented by a simple linear model (AIC = 879.70). The model that provided best fit to changes in trap success over time (Fig. 2, AIC = 834.33; a considerable improvement over linear model, AIC = 879.70) was one that suggested no change within the trappable population (i.e. a slope of 0) prior to the sudden decline in success in 1977, a sharply increasing success over the period 1978 to 1982, a further period of no change from 1982 to 1995, and another sudden decline thereafter. Comparisons of trap success prior to 1977 with those for the period 1982–95 indicated that during the two periods of apparent population stability, the trappable population differed significantly ($\chi_1^2 = 13.42$, $p < 0.001$).

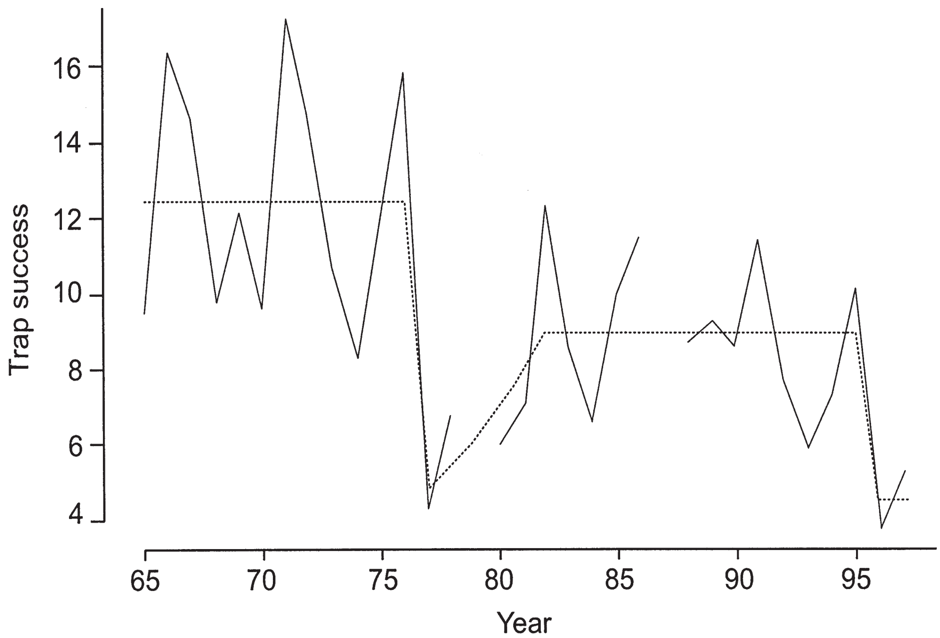

FIGURE 2. OBSERVED (—) AND FITTED (....) ANNUAL PERCENTAGE TRAP SUCCESS, POSSUMS TAKEN ON LINES 1-4 FROM 1965 TO 1997. THE LINES WERE NOT TRAPPED IN 1979 AND 1987.

3.2 DEMOGRAPHY

Because of the dramatic declines in the trap success recorded in 1977 and 1996, comparisons of indicators of possum population well-being were focused about these two years.

Body weights of adult possums varied annually (Fig. 3; $F_{30,2964} = 17.55$, $p < 0.0001$). Highest weights were recorded in 1978 and 1997 immediately following population declines. Weights in these years increased significantly from those recorded 1 year earlier, i.e. in 1977 and 1996 respectively, which were years characterised by marked population declines (see Fig. 2), i.e. 1977–78 ($F_{1,2964} = 22.07$, $p < 0.0001$); 1996–97 ($F_{1,2964} = 26.31$, $p < 0.0001$). Body weights of adult possums before the population decline in 1977 (i.e. 1965–76) were significantly lighter than after it (1978–96), i.e. 2.004 kg v. 2.120 kg; ($F_{1,2964} = 71.89$, $p < 0.000$).

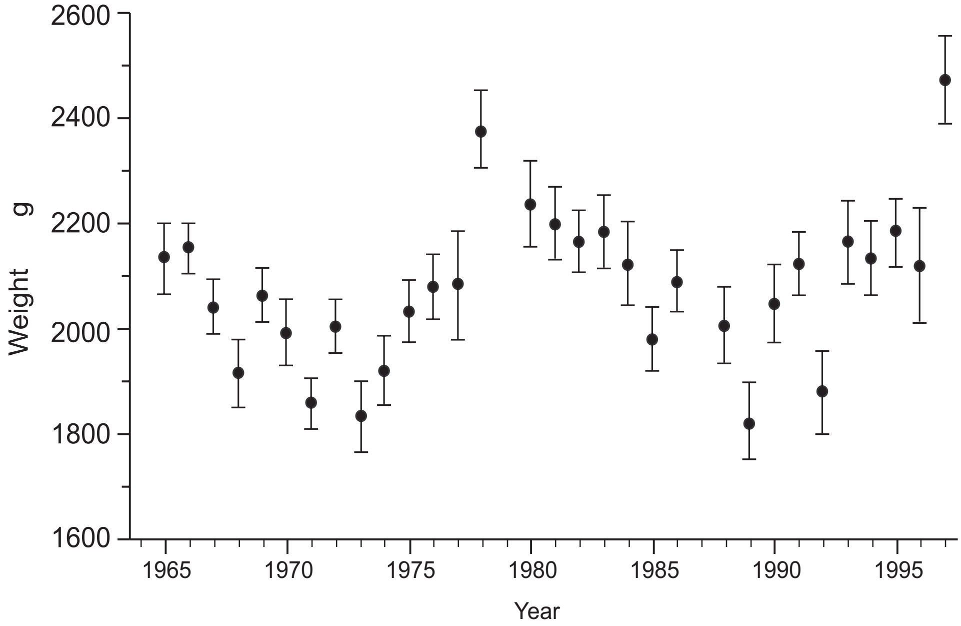

FIGURE 3. MEAN BODY WEIGHTS OF ADULT POSSUMS (± 95% CONFIDENCE INTERVALS) TAKEN FROM LINES 1–4 FROM 1965 TO 1997 (BUT EXCLUDING 1979 AND 1987).

Body weights for adult male and female possums showed similar patterns to those of the sexes combined. Highest weights were also recorded in 1978 and 1997 following population declines, and increased significantly from 1 year earlier, i.e. males: 1977–78 $F_{1,1555} = 16.06$, $p < 0.001$; 1996–97 $F_{1,1555} = 11.85$, $p = 0.0006$; females: 1977–78 $F_{1,1377} = 7.92$, $p = 0.005$; 1996–97 $F_{1,1377} = 14.7$, $p = 0.0001$. However, females were heavier on average than males ($F_{1,2932} = 13.34$, $p = 0.0003$), although this difference varied with year ($F_{30, 2932} = 1.507$, $p = 0.0379$).

Body weights of juvenile possums also varied between years ($F_{29,527} = 4.268$, $p < 0.0001$), but unlike those of adults, weights in 1976, just prior to the population decline (1977), were significantly higher than in 1975 ($F_{1,527} = 4.37$, $p = 0.006$), and 1974 ($F_{1, 527} = 16.68$, $p < 0.0001$ using post-hoc contrasts). However, there was no increase between 1993 and 1994 ($F_{1, 527} = 0.004$, $p = 0.95$) or between 1994 and 1995 ($F_{1, 527} = 0.0467$, $p = 0.829$) leading up to the 1996 decline.

The condition of adult possums, as indicated by indices of either body weight/total length or mesenteric fat also varied each year ($p < 0.0001$). In particular, the weight/length index increased significantly in years immediately following population declines, i.e. 1977–78 ($F_{1,1685} = 9.1797$, $p < 0.002$) and 1996–97 ($F_{1,1685} = 46.44$, $p < 0.0001$). However, comparisons of data from all years sampled prior to (i.e.

1965–76) and after the decline in 1977 (1978–96), showed no such difference ($F_{1,1685}$ = 0.0230, p = 0.88). Differences were also recorded from mesenteric fat weights taken in 1996 and 1997 ($F_{1,129}$ = 164.2, p < 0.0001), but not between 1977 and 1978.

The mean age of adult possums varied between years (Fig. 4; $F_{20,1641}$ = 7.327, p < 0.0001). Ages fell significantly between1976 and 1978 ($F_{1,1641}$ = 7.43, p = 0.006), remained stable but low from 1980 to 1983, and then rose and stabilised from 1984 to 1993. Another sharp decrease in age occurred following the population decline in 1996 ($F_{1,1641}$ = 4.17, p = 0.041). Thus, mean age in adults appeared to broadly decline as the size of the population declined, remained low during periods of population recovery, and was highest during periods of population stability. The sharp decline in mean age recorded in 1993–94 (Fig. 4) clearly does not fit this pattern.

Age patterns were strongly influenced by the numbers of juveniles in the trapped sample. While the percent of juvenile possums varied each year ($F_{30,93}$ = 5.99, p < 0.0001), no juveniles whatsoever were trapped in 1978 (Fig. 5), immediately after the

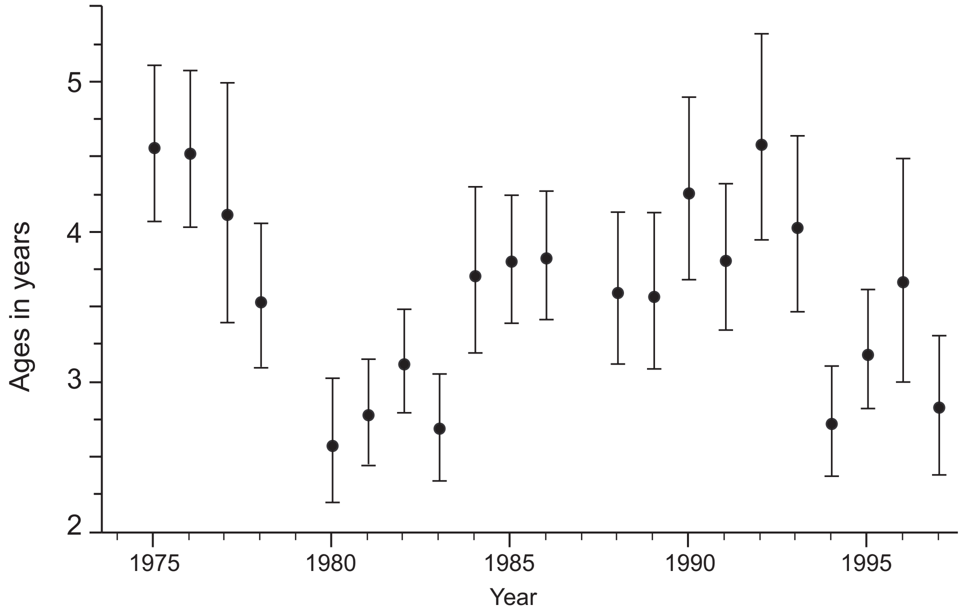

FIGURE 4. MEAN AGE OF ADULT POSSUMS (± 95% CONFIDENCE LIMITS) TAKEN FROM LINES 1–4 FROM 1975 TO 1997 (BUT EXCLUDING 1979 AND 1987).

population decline of 1977. Juvenile possums were also under-represented in the trapped sample in 1985, in 1993–94, and in 1997, and each of these periods also followed years in which the population declined (Fig. 2).

Annual variations in the proportion of juvenile possums should be reflected in the proportion of adult females carrying pouch young trapped in the previous year. Although this ratio varied throughout the study ($F_{30,93}$ = 6.00, p < 0.0001), data from years immediately before or after population declines did not differ from the population mean. This result may well have been an artifact of sampling—the timing of annual trapping varied slightly each year, but it always included some animals still to breed or pregnant.

The recruitment of young (one-year-old) possums into the Pararaki population was low in both 1977 and 1996 (Fig. 6). However, it was also low in most years after 1975

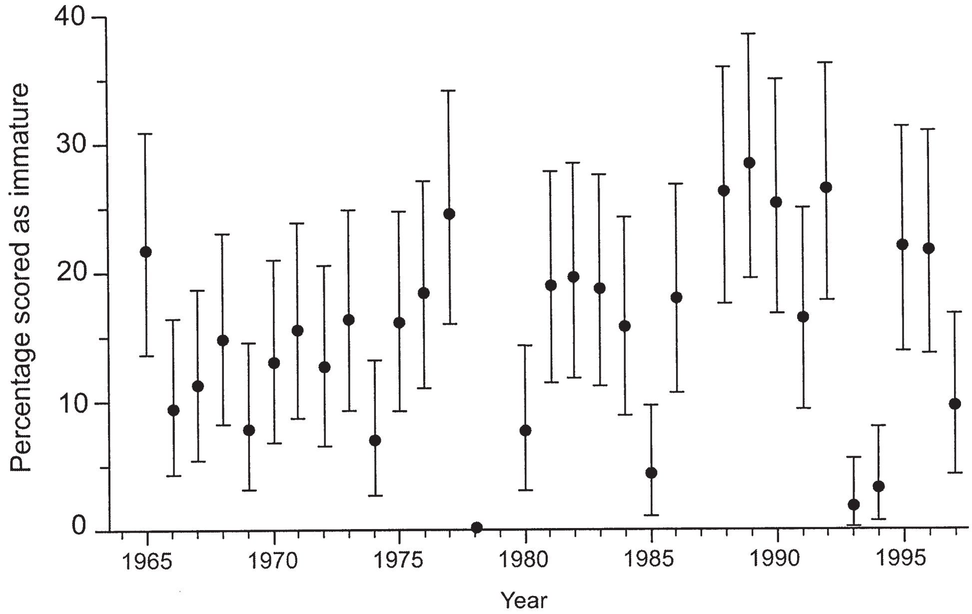

FIGURE 5. PROPORTION OF JUVENILE POSSUMS (± 95% CONFIDENCE LIMITS) TAKEN FROM LINES 1–4 FROM 1965 TO 1997 (BUT EXCLUDING 1979 AND 1987). THE LARGE CONFIDENCE LIMITS REFLECT THE SMALL NUMBER OF INDIVIDUALS IN EACH SAMPLE.

(when pouch young were first recorded) in which the trap success fell sharply below the fitted model of the mean trap catch (e.g. 1984, 1992, 1993; see Fig. 2). Clearly, poor recruitment of one-year-old possums in any one year is usually sufficient to result in significant declines in trap catch in that year.

The birth date of young possums also varied annually ($F_{19,681}$ = 7.5206, p = 0.000). Possums gave birth significantly later in 1977 compared with 1976 ($F_{1,681}$ = 7.2941, p = 0.007), and again in 1996 compared with 1995 ($F_{1,681}$ = 5.2454, p = 0.022). In contrast, in intermediate years, possums appeared to breed earliest in years when the trap success was lowest (see Fig. 2).

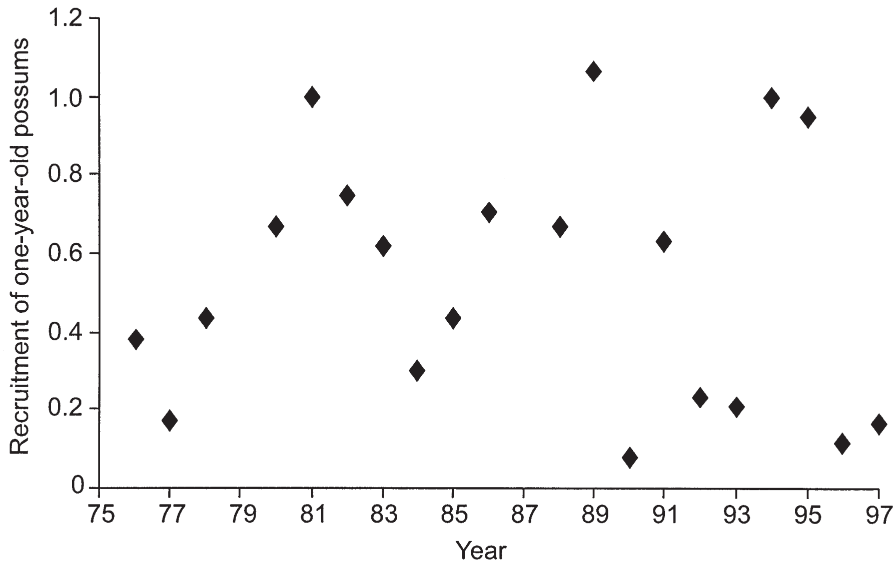

FIGURE 6. ANNUAL RECRUITMENT OF YOUNG POSSUMS INTO THE TRAPPED POPULATION, BASED ON AN INDEX OF THE NUMBER OF ONE-YEAR-OLDS TRAPPED IN THAT YEAR DIVIDED BY THE NUMBER OF POUCH YOUNG PRESENT IN THE PREVIOUS YEAR. AN INDEX OF 1 INDICATES 100% RECRUITMENT, AN INDEX OF 0 INDICATES ZERO RECRUITMENT.

4. Discussion

Possum populations in the Pararaki Valley were apparently at peak numbers in 1948–49, following colonisation in 1920–21 from nearby liberation sites (Thomas *et al.* 1993). Numbers in the valley were monitored in 1945 and 1951 (Batcheler *et al.* 1967), 1956, 1959, and 1965 (L.T.P) on now abandoned trap lines. Data from these lines indicate that possum numbers seemingly declined by about 80% or roughly 4% per annum in the 1950s, apparently due to shortages of food: they were commonly observed at that time by one of us (L.T.P.) to be in extremely poor condition and feeding during daylight hours on highly unpalatable plant species. In 1965, the four trap lines that provided the data for this report were established in the area. Data from these lines confirm the declining population trends established on the original lines, although the rate of decline (about 2% per annum) is now much reduced. Trapping success on these lines also indicated the population peaked at 4- to 6-year intervals, with the peaks at lower amplitude during the second half of our study. The reason for these peaks is unclear. We believe they may also be driven by variations in food availability, but we have no measure of this parameter from this study to support our contention.

In addition to overall patterns of population decline and annual variation, our data and the model of best fit to our percent trap success (and earlier observations by L.T.P.) suggest that this possum population also suffered two dramatic population crashes in 1977 and 1996, when between 60% and 70% of the trappable population vanished, followed by progressive population recovery. In the first of these crashes, 1977, and in no other year, possums on and about our trap lines showed clear outward signs of starvation and impending death, including dying in the traps from exposure, disoriented feeding during daylight hours, and extreme emaciation. Comparisons of body condition, age, and recruitment data collected in 1976, 1977, and 1978 in particular support these observations.Thus, coincident with the real population decline and recovery at that time, we recorded significant losses and recoveries in body weight by both juveniles and adults, and similar significant changes in two indices of body condition: weight/length and mesenteric fat. At the same time, possum age declined and juveniles were under-represented or absent (1978) from the population (few appeared to survive beyond early independence). Both measures remained low during population recovery. There appeared to be no depression of breeding, and even in years associated with population declines, most females continued to breed and to carry pouch young. Declines in trap success at other times were smaller and they occurred over two or more years, i.e. 1967–68 and 1972–74, and were not similarly accompanied by declines in most other population parameters.

Similar crashes late in 1977 were recorded from cyanide paste lines on nearby farmland (L.T.P.), and in 1977 and 1996 in possum trap success in the Orongorongo Valley, about 30 km away (Efford 1991, 1997). These events suggest the same population-regulation mechanism is working in all three areas. The decline in the Orongorongo Valley occurred despite the population there remaining stable, near a density of 8–10/ha over the last 30 years. In the Orongorongo Valley, the 1977 crash followed two years of below-average temperature and above-average rainfall (Brockie 1992), which was assumed to contribute to significant food shortages. We believe that the nearby Pararaki population, which lives in similar forest and under similar climate, suffered similar adverse weather patterns and was similarly and coincidentally limited by food supplies.

Fifty years after reaching peak numbers and promptly crashing, possums in the Pararaki catchment (in contrast to those in the Orongorongo Valley, M. Efford, pers. comm.) are still declining in numbers, and although showing occasional dramatic year-to-year perturbations, show little evidence of having reached any real balance with their new environment. This imbalance is likely to be true of most uncontrolled post-peak possum populations elsewhere in New Zealand, and is reflected in the ongoing degradation of the botanical integrity of many of New Zealand's forests (Department of Conservation 1994). Such trends may be halted or even reversed temporarily following possum population crashes (e.g. rata mortality in the Orongorongo Valley, Cowan *et al.* 1997), but these events are unlikely to change the broad pattern of ongoing possum-induced forest decline. Unsustained one-off possum control options mimic natural population crashes, but appear likely to provide only similar short-term gains in forest health.

Population crashes of possums may provide new opportunities for improved possum management. The targeting of possum populations recently reduced by toxic baiting to artificially low levels, by immediate further baiting, has been suggested to be a more cost-effective strategy for possum control than the traditional approach of initial control followed by periodic maintenance control (Department of Conservation 1994). In a similar way, the recognition of natural population crashes and their integration into ongoing control programmes could also improve the cost-effectiveness of current possum management, with the relative acceptance of novel foods (i.e. toxic bait) by possums influenced by animal condition and hunger (Bamford 1970). Compared with declining populations, post-crash populations are younger and in better condition and able to recover rapidly to former population levels. The use of natural population crashes for improved possum management relies on the recognition of climatic cues which, acting through food, trigger crashes similar to those documented in our study.

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