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PROCEEDINGS OF THE FIRST SYMPOSIUM ON

MARSUPIALS IN NEW ZEALAND

EDITED BY
BEN D. BELL

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Proceedings of the First Symposium on

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ABSTRACT

At this symposium convened by the Zoology Department, Victoria University of Wellington, twenty papers on the research and management of marsupials in New Zealand are presented, most of them referring to the common brushtail possum *Trichosurus vulpecula*. The Keynote Address on advances in marsupial biology reviews 25 years of research. Seven papers report basic research on the possum, covering such aspects as reproduction, social behaviour, movements, feeding, condition and population dynamics. In the section on applied research and management one paper deals with zoo maintenance of wallabies, three consider diseases of possums, three examine possum population assessment, two describe possum damage to farm crops, pasture and erosion-control plantings and three refer to control of possum populations.

Full reports of workshop discussions provide a range of opinions on anaesthesia and handling marsupials; diseases and risks to humans and domestic stock; housing and management of captive marsupials; techniques of sequential fractional analysis and protein electrophoresis; population assessment; impact on vegetation; exploitation for fur and meat; side-effects of control on non-target species and the environment; offshore island possums; the choice of the vernacular names 'possum' or 'opossum'; communication amongst research and management interests; funding of marsupial research in New Zealand.

A survey of symposium delegates' views on research priorities indicated most, on average, gave priority to research on population assessment techniques, and on evaluating the efficiency of control, though research on control techniques and on diseases, parasites and health also ranked highly.

PREFACE

One of my first editing tasks was to reach a decision on the names to be used for the various marsupials referred to in these Proceedings, and especially on which vernacular name should be used for *Trichosurus vulpecula*. Recent New Zealand policy has been to call this well-known Australian marsupial the 'brush-tailed opossum' though 'Australian opossum', 'Australian phalanger', 'common possum' are some other names that have been used. 'Brush-tailed opossum' is now enshrined in numerous New Zealand scientific and management publications as well as in national legislation. By contrast in Australia the name 'possum' is used to describe *Trichosurus* and its allies, and the vernacular name for *T. vulpecula* used by authorities such as Ride (1970) and Tyndale-Biscoe (1973) is simply 'brush possum'. Dr Tyndale-Biscoe and many overseas authors use the term 'opossum' in reference to New World polyprotodont marsupials such as *Didelphis*, a useful convention to differentiate them from the Australian diprotodont 'possums'. In 1980 the Australian Mammal Society Vernacular Names Committee published a list of recommended names for Australian mammals: *Trichosurus vulpecula* is referred to as the 'Common Brushtail Possum'.

In these Proceedings I have decided to use the term 'possum' rather than 'opossum' for *Trichosurus vulpecula*, being guided by the majority wish of the symposium delegates: 67 percent voted for 'possum', 23 percent voted for 'opossum' and 10 percent abstained. After careful consideration I have avoided use of 'brush-tailed possum' or 'brush possum' for the specific name: given a decision for change I felt it preferable to follow the recommendation of the Australian Mammal Society and use, where necessary, the name 'common brushtail possum'. Hopefully this name will become widely accepted in the New Zealand literature for the need for sensible rationalisation of this relatively minor matter is long overdue. Partly to avoid further delays in production of these Proceedings, I have not adopted the suggestions of the Australian Mammal Society in their entirety - for instance the initial letters of the free-standing words are not capitalised (as in 'Common Brushtail Possum'), and the term 'possum' rather than 'brushtail' is often used in general text references to the species. The matter of using 'possum' or 'opossum' is pursued further in Dr Tyndale-Biscoe's Keynote Address and in Workshop Topic 10. Finally, the nomenclature of other native Australian mammals referred to in these Proceedings also follows the Australian Mammal Society recommendations.

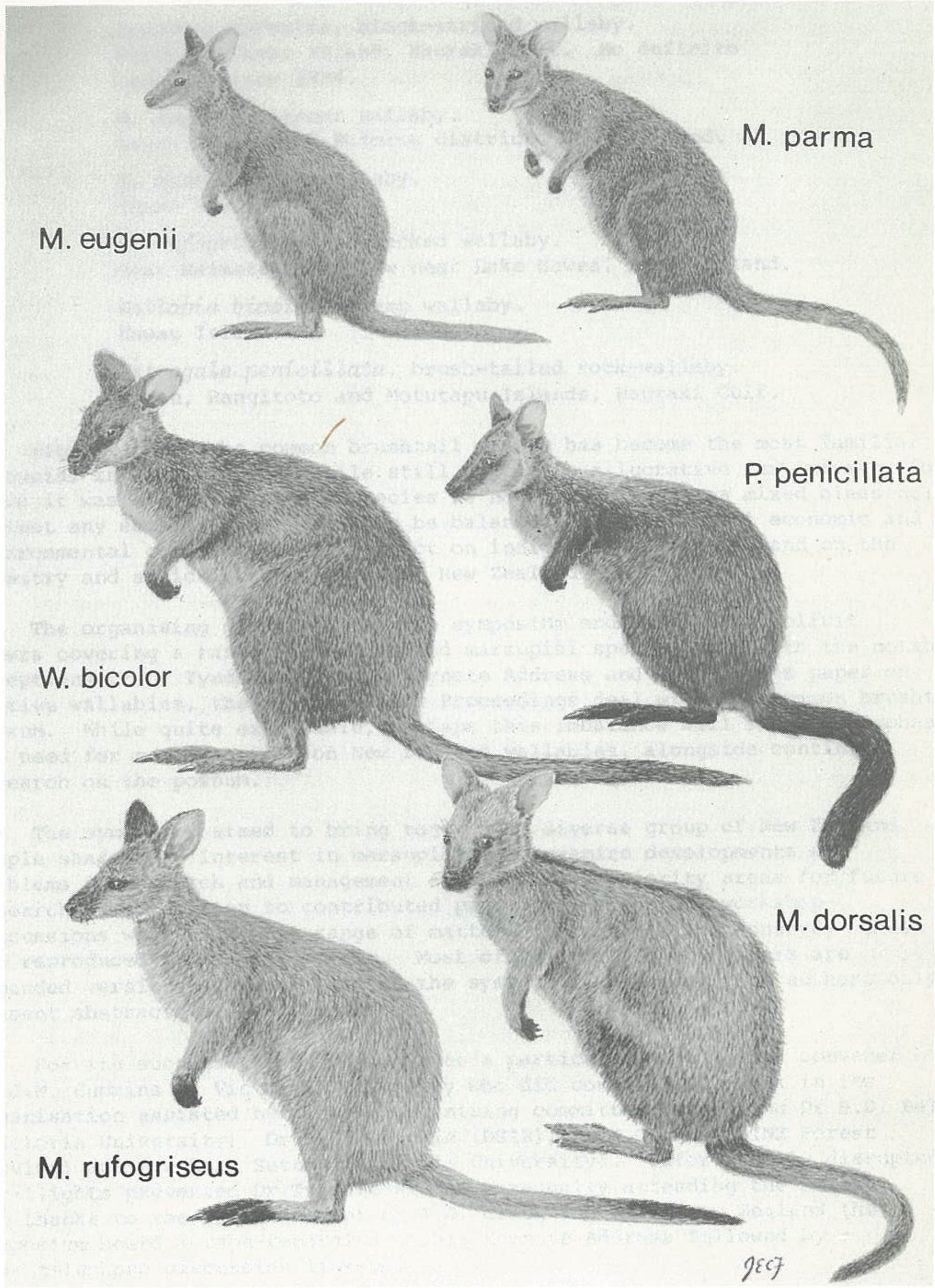
After introduction from Australia during the mid to late nineteenth century, the New Zealand marsupial fauna now comprises six or seven species, mostly wallabies. The following species list includes information on distribution from Gibb and Flux (1973):

CLASS MAMMALIA

Order Marsupialia

Family Phalangeridae

Trichosurus vulpecula, common brushtail possum.
Abundant and widespread throughout most of New Zealand.



The six species of wallaby found in New Zealand drawn to scale by Dr J.E.C. Flux. Reproduced with the artist's permission from WODZICKI, K. & FLUX, J.E.C.F. 1967. Guide to introduced wallabies in New Zealand. *Tuatara 15*: p. 51.

Family Macropodidae

Macropus dorsalis, black-striped wallaby.
Formerly Kawau Island, Hauraki Gulf. No definite records since 1954.

M. eugenii, tammar wallaby.
Kawau Island and Rotorua district, North Island.

M. parma, parma wallaby.
Kawau Island.

M. rufogriseus, red-necked wallaby.
Near Waimate and a few near Lake Hawea, South Island.

Wallabia bicolor, swamp wallaby.
Kawau Island.

Petrogale penicillata, brush-tailed rock-wallaby.
Kawau, Rangitoto and Motutapu Islands, Hauraki Gulf.

Without doubt the common brushtail possum has become the most familiar marsupial in New Zealand. While still supplying a lucrative fur industry for which it was introduced, this species is now recognised as a mixed blessing: against any economic gains have to be balanced the substantial economic and environmental costs due to its impact on indigenous vegetation and on the forestry and agricultural sectors in New Zealand.

The organising committee for the symposium endeavoured to solicit papers covering a range of New Zealand marsupial species, but with the notable exceptions of Dr Tyndale-Biscoe's Keynote Address and Mr Meadow's paper on captive wallabies, the bulk of these Proceedings deal with the common brushtail possum. While quite explicable, perhaps this imbalance will serve to emphasise the need for more research on New Zealand wallabies, alongside continued research on the possum.

The symposium aimed to bring together a diverse group of New Zealand people sharing an interest in marsupials, to examine developments and problems in research and management and to define priority areas for future research. In addition to contributed papers two afternoon workshop discussions were held on a range of matters of interest and concern; these are reproduced in an edited form. Most of the contributed papers are expanded versions of those read at the symposium, although five authors only present abstracts of their papers.

For its success the symposium owes a particular debt to its convener Dr J.M. Cummins of Victoria University who did considerable work in its organisation assisted by a small organising committee comprising Dr B.D. Bell (Victoria University), Dr R.E. Brockie (DSIR), Dr W.Q. Green (NZ Forest Service) and Mrs K.B. Sutton (Victoria University). Unfortunately disrupted air-flights prevented Dr Tyndale-Biscoe personally attending the meeting, but thanks to the assistance of Mr I.G. Crook and Radio New Zealand the symposium heard a tape-recording of his Keynote Address followed by a live telephone discussion link-up.

As editor, I have endeavoured to maintain an accurate record of the Proceedings, despite considerable difficulties with certain parts of the discussion due to technical problems in tape-recording. Some of the gaps were filled by consulting the speakers involved, although if in doubt I have omitted sections rather than risk misrepresentation.

It is my pleasure to thank Fletcher Timber, Apex Pest Control NZ Ltd., Consolidated Traders Ltd., the National Parks Authority of New Zealand, the New Zealand Forest Service, Medical Supplies NZ Ltd., and Selby-Wilton Scientific Ltd. for generously sponsoring the symposium.

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Ben D. Bell
Editor

May 1981

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ADVANCES IN MARSUPIAL BIOLOGY - A REVIEW OF 25 YEARS' RESEARCH

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I must preface this paper by saying how much I appreciated the invitation to attend this first symposium on marsupials in New Zealand and to deliver this address. My own interest in marsupials began in New Zealand and I was looking forward keenly to meeting all of you today. It is a very great disappointment that I cannot be at the symposium and can only participate as a disembodied voice.

When I was asked to give this address I thought I should review the most salient features of marsupial research over the last 25 years. It soon became obvious, however, that it would be quite impossible to do this and I have chosen, instead, to trace the way in which our attitudes to marsupials have changed and how these attitudes colour the research we do. Science like religion satisfies a deep need to find order in a chaotic world, and scientific theories that provide a simple, clear arrangement are often held tenaciously long after their usefulness has passed. This idea has been very well developed recently by Professor Hayes (1977) in relation to the development of molecular biology, and I think it may be instructive to apply it to marsupial biology.

Twenty-five years ago the prevailing view about marsupials was essentially still T.H. Huxley's view that they are physiologically intermediate between reptiles and higher mammals and that their present distribution in only two of the southern continents is because they were driven to the remote corners of the world by later evolved, superior mammals and saved from extinction by isolation there. If there was any merit in studying them it was for the light that might be shed on the evolution of higher mammals. As a consequence, virtually nothing was known about the physiology, ecology or reproduction of any Australian marsupial 25 years ago, despite the fact that some species, such as the red kangaroo *Macropus rufus* in Australia and common brushtail possum *Trichosurus vulpecula* in New Zealand, were becoming serious economic pests.

The person who was largely responsible for changing this attitude in Australia was Harry Waring who came to the Chair of Zoology in Western Australia in 1948, bringing the outlook of a comparative physiologist and the conviction that the study of marsupials was intrinsically worthwhile (Waring 1956). The group he attracted to Perth from other parts of Australia and New Zealand concentrated their attention on the quokka *Setonix brachyurus*, a small wallaby common on Rottnest Island, and in February 1954 preliminary notices of the first two important discoveries were published in *Nature*. These were the phenomenon of delayed pregnancy or embryonic diapause (Sharman 1954) and the ruminant-like digestion and metabolism (Moir *et al.* 1954) of the quokka. Both phenomena were subsequently found to be shared by most or all the Macropodidae and profoundly influenced the subsequent direction of research in reproduction and metabolism respectively. Other work by this group on temperature regulation and water metabolism of the quokka and other desert-living macropods indicated regulatory capacities quite the equal of desert-adapted eutherian mammals.

About the same time in the mid-1950's research programmes were begun by several state and commonwealth bodies on the ecology of the large kangaroos in response to the growing public concern at the adverse effects these species were having on the pastoral industry. For instance, in north western Australia the marginal lands were carrying increasing numbers of kangaroos while sheep numbers steadily declined. It soon became evident that this was due to the better physiological adaptation of the kangaroos to the country and to their opportunistic breeding strategies. So almost from the beginning basic and applied research on macropods proceeded simultaneously and knowledge is now much more advanced about this than any other family of marsupials. Also as a result of these interrelated studies across the country a new appreciation of marsupials developed so that in the preface of our review (Waring *et al.* 1966) published in 1966 we felt constrained to say of 'the old and recurrent notion that marsupials are inferior mammals. That among other things we think this review kills that superstition.' We hoped to establish a new view of marsupials as the equals of other mammals, not from misplaced chauvanism but because the older view was arbitrary and restrictive. While the new view certainly influenced thinking in Australia the rest of the scientific world took little heed and even as recently as January this year *Nature* carried a commentary by Cox (1977) entitled 'Why marsupials can't win'.

In Australia, however, the new attitude to marsupials in its turn canalised thought and obscured truth. In the middle 60's evidence from several independent groups began to be gathered that indicated a basal metabolic rate different from that of eutherians. The first species reported was the eastern pygmy-possum *Cercartetus nanus* (Bartholomew and Hudson, 1962) in which the basal metabolic rate was 70% of that predicted for its body size from the 'mouse-elephant curve' of eutherian species. At the time this was explained as being probably due to the hibernating habit of the species. But the results of studies in Perth on nitrogen metabolism in several macropods showed all of them to have remarkably low minimum nitrogen requirements. Since minimum heart rate and metabolic rate are correlated, Kinnear and Brown (1967) examined the heart rate of 14 species of marsupial and found the relationship to body size in all of them was half that for eutherians (Fig. 1). Two years later two papers appeared simultaneously (MacMillen and Nelson 1969; Dawson and Hulbert 1969) reporting that the basal metabolic rate, derived from measurements of oxygen consumption,

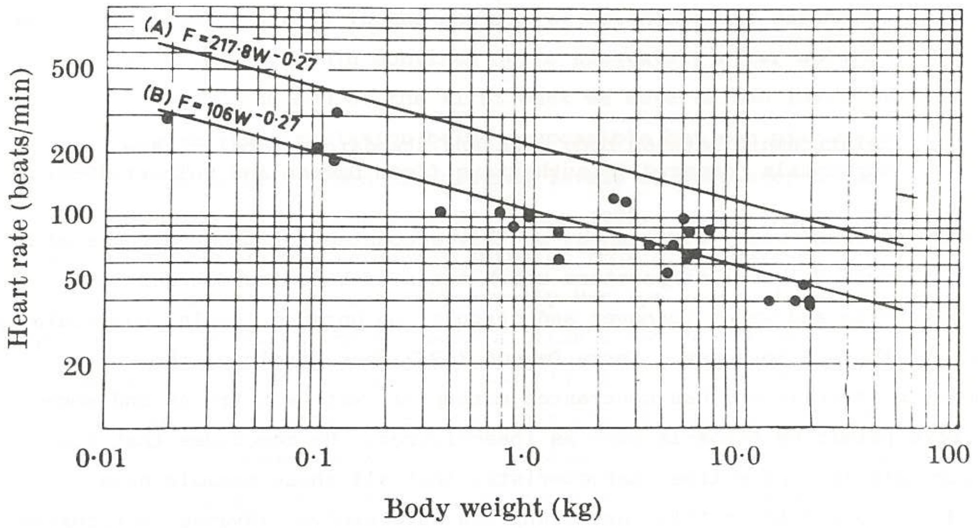

Fig. 1. Relationship between body size and minimum heart rate in marsupials compared to eutherians (from Kinnear and Brown 1967)

of marsupials ranging from 9 g to 54 kg body weight was 69% of the eutherian rate reported by Kleiber (1961) (See Fig. 2).

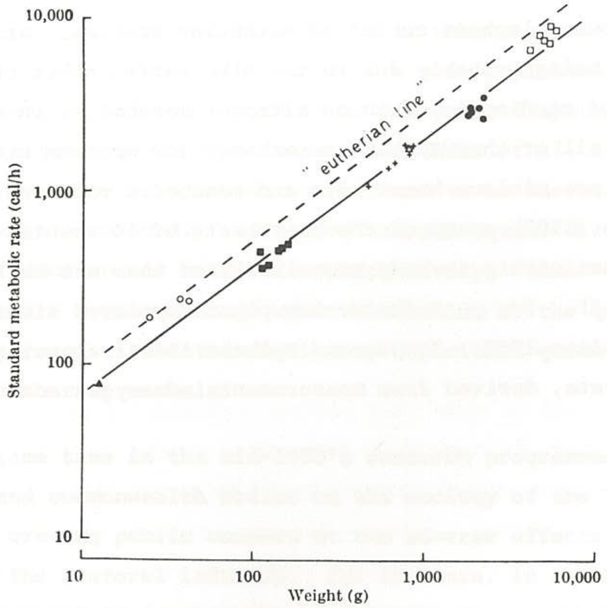

Fig. 2. Relationship between body size and standard metabolic rate in marsupials compared to eutherians (from Dawson and Hulbert 1969)

These results found ready acceptance, as they accounted for other aspects of physiology, such as basal temperature which tends to be a few degrees lower than in Eutheria and water turnover and circulating hormone levels, particularly adrenal and thyroid hormones. Terry Dawson (1972) has developed the hypothesis most fully and has contrasted marsupials with monotremes and some of the more primitive Eutheria such as insectivores. He concludes that low metabolic rate is a primitive characteristic that all these mammals have retained, but overlaid on this the marsupials have evolved advanced mechanisms of temperature regulation, kidney function and digestion. Indeed the low metabolic rate may have pre-adapted the macropods to desert conditions as they require less water and less protein nitrogen. However, Victor Macfarlane (1971) has challenged this whole concept; he considers the double log relationship of body weight to metabolic rate obscures substantial differences between the species of one taxon and that the marked difference reported between Eutheria and marsupials can be partly accounted for by the fact that Kleiber used largely temperate zone species while the Australian studies used almost exclusively desert or semi-desert species. When the water turnover of rodents, antelope or dasyurid marsupials from different climates are compared the desert-evolved species generally have lower metabolic rates than those species from cool temperate climates. The generalization that marsupials have a fundamentally different rate setting, which affects all their physiological functions, has been a very useful and stimulating concept for almost a decade, but like its predecessors it may have outlived its use and we should now be ready to modify it.

Let us turn now to another field of study and another example where prevailing attitudes influenced thought. Sharman's discovery of embryonic diapause in the quokka provided a powerful impetus to research in reproduction because it afforded such a beautiful experimental model with which to examine the endocrine and other control mechanisms operating in marsupials. Nevertheless, with hindsight I can see that we were heavily conditioned in our thinking by the attitude that the marsupial pattern would be a simplified eutherian plan with the placenta playing little or no part. Since pregnancy is accommodated within a single oestrous cycle of one month's duration and the corpus luteum of pregnancy does not have an extended life, we assumed that its role in the control of pregnancy was paramount. When in 1963 I found that pregnancy would continue quite adequately after ablation of the corpus luteum at the end of the first week we entertained ideas about long-acting hormones in circulation being responsible but not placental involvement. Ten years later when circulating levels of progesterone were measured in the tammar wallaby *Macropus eugenii* (Lemon 1972), which indicated differences between pregnant and non-pregnant animals, none of us were yet convinced that the placenta was responsible. Eventually Marilyn Renfree's (1972) work showing differences in the endometrial tissue and secretions of the two uteri, convinced some of us that the yolk sac placenta was having a local stimulatory influence on the pregnant uterus but this idea is only now gaining general acceptance. Contemporaneously other studies indicated differences in response of the myometrium of the pregnant and non-pregnant uterus to oxytocin and now finally the placenta of the tammar and quokka have been shown to have the capacity to synthesise progesterone. If our minds had been less prejudiced the evidence was at hand 15 years ago.

The discovery of the role of the pituitary in diapause is also interesting in the same way. During diapause the corpus luteum is small and follicle growth is suppressed. By analogy with the rabbit and rat it was assumed that the suckling stimulus caused reduced secretion of gonadotrophin and raised the levels of prolactin. Prolactin in rats is luteotrophic, but clearly it was not having a luteotrophic effect in the quokka; so we supposed that this might be because insufficient was available to stimulate both the mammary glands and the corpus luteum. When John Hearn (1973) hypophysectomised tammars however, the results were quite unexpected for the corpus luteum immediately reactivated and pregnancy proceeded, which clearly showed that the pituitary exercises a tonic inhibition of the corpus luteum, which is otherwise autonomous. Subsequent experiments have shown that gonadotrophin levels are unchanged in diapause and pregnancy and that the corpus luteum inhibitor is prolactin, a corpus luteum stimulator in rats. It now appears likely that prolactin is the hormone that suppresses the return to oestrus in lactating cows and causes lactational amenorrhoea in women.

Ecological thinking about marsupials was dominated in Australia until quite recently by kangaroos of the arid and semi-arid zones and some of the most stimulating ideas are currently being generated by this work. In his recent review, Alan Newsome (1975) marshalled the results of 20 year's research on red kangaroo and common wallaroo *Macropus robustus* to develop the thesis that the huge increases in populations of these two species early this century were the result of the removal of the primeval constraints of fodder and water shortage when stock were introduced. A succession of droughts through the 1940's took heavy toll of stock and red kangaroos but the wallaroos were able to exploit the ravaged country because of their less demanding dietary requirements (Fig. 3). He predicted that red kangaroos may never again reach the level of the earlier years wherever there is competition with any two introduced herbivores, cattle, sheep or rabbits. He also suggested that similar sequences of sudden abundance and subsequent collapse also befell the small marsupials of the grasslands but much earlier when the first introduction of stock converted tall grasslands to close cropped pasture. The relevance of this to our present meeting is that when their habitat was profundly altered these species behaved like invaders in a new territory. I understand that there is evidence in New Zealand that some possum populations may be undergoing this sort of sequence. If so the population densities of more than 10 adults per hectare recorded in New Zealand forests (Crawley 1973), which are 20 times the densities recorded in Australian forests, may be a transient phenomenon.

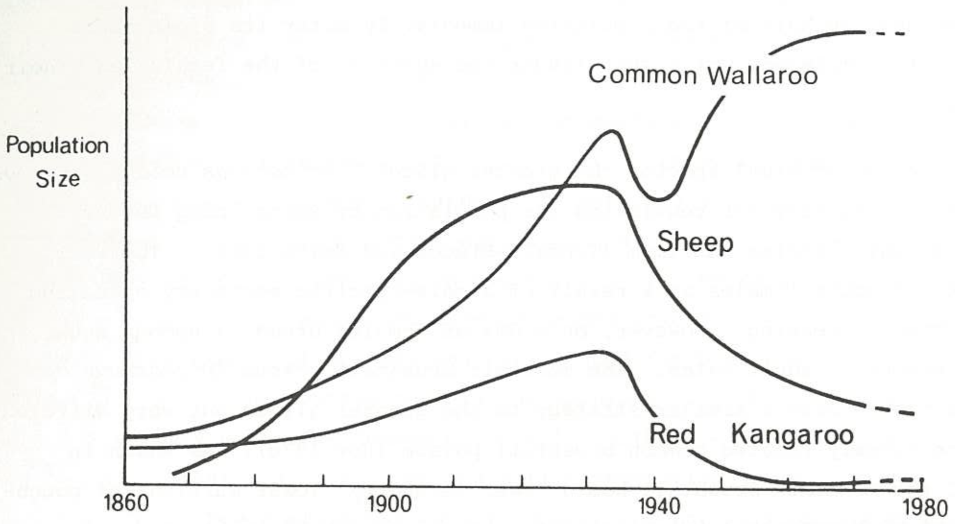

Fig. 3. Schematic population trends of three competing herbivores in north-western Australia (from Newsome 1975)

Research on forest-dwelling marsupials has a short history in Australia and only began in earnest after the growth of public interest in forest conservation in the 1970's. At present the only completed studies were all initiated in universities as graduate student projects. Nevertheless the ideas that have arisen from these may have more relevance to our deliberations, since almost all the marsupial species now in New Zealand originated from this habitat.

The forests of the eastern seaboard harbour a greater diversity of mammals than any other part of Australia and were, until recently, the least affected by European settlement. The radiation of marsupials across Australia and New Guinea probably began in forests like these and, from the few studies done so far, it is apparent that the present day inhabitants show adaptations for the regulation of their populations at low densities, which do not conform to the conventional theories derived from fecund species of the northern hemisphere. Males of several species of *Antechinus* die immediately after the breeding season, while the females give birth and support a litter of young for several months, and these young then become the breeding population of the next year. The cause of the male die-off is complex (Lee *et al.* 1977); an androgen-driven aggressive behaviour pattern with prolonged bouts of copulation is associated with high plasma concentrations of free cortisol, negative nitrogen balance and increasing susceptibility to diverse pathogens. Selection may have favoured aggressive behaviour but it has also removed one half of the population immediately after its biological function is completed, which must favour the survival of the females and their progeny.

Among the arboreal species the greater glider *Schoinobates volans* displays a different strategy for regulating the population by maintaining fecundity below the physiological maximum (Tyndale-Biscoe and Smith 1969). The adult sex-ratio favours females as a result of a male-specific mortality operating at the time of weaning. However, only 60% of females breed, a number equal to the number of adult males. The mountain brushtail possum *Trichosurus caninus* appears to exercise a similar strategy to the greater glider but very different from the closely related common brushtail possum (How 1978). As shown in Table 1 the mountain brushtail has a lower fecundity, lower survival of pouch-young but much greater survival at the weaning and sub-adult stage due to a much longer association with the mother. Sexual maturity is not attained until the third year. There is also evidence of close overlap of home-ranges of particular male and female pairs, which suggests that the species may be monogamous and that the adults have a high attachment to their territory which is held exclusively. Where the two species are sympatric, the common brushtail is excluded from rain forest or wet sclerophyll forest by the mountain brushtail, but is more abundant in open or drier habitat. In Tasmania, where the mountain brushtail is absent, the common brushtail occupies the wet sclerophyll forest. So far as I can gather from Pracy's (1962) account, the mountain brushtail was never introduced to New Zealand but it is interesting and not entirely academic to speculate from current knowledge on what might have happened if it had been. It is likely that it would have excluded the common brushtail from the high rainfall forests and would have occupied them at low density as it does in eastern Australian rain forests. However, had we been able to advise the Acclimatisation Societies of 100 years ago to liberate the mountain brushtail it would not have commended itself to people concerned to populate the forests of New Zealand with a good fur bearer as quickly as possible. It is interesting to read the opinions of Cockayne and Kirk, both eminent botanists, on the common brushtail. Both were in favour of its spread and believed that its effects on the native vegetation would be negligible. Now opinion in New Zealand has wholly changed and the serious and seemingly intractable problems raised by this highly adaptable species will engage most of our attention at this meeting.

Table 1. Comparison of two species of possum in northern New South Wales (From How 1978)

	Trichosurus vulpecula	*T. caninus*
Season of birth	April - October	March
Productivity (Young/female)	1.4	0.5
Mother-young association (days)	175	250
Dispersal age (years)	0.5 - 1.5	1.5 - 2.5
Sexual maturity (years)	1	2 - 3
Male-female association	polygamous	probably monogamous

It would be a pity if the pressing urgency of the problems caused by the common brushtail possum should lead to the view that all liberations of marsupials in New Zealand were an unmitigated disaster, for in the small but established populations of tammar wallabies near Rotorua, in the wallabies on Kawau, Rangitoto and Motutapu Islands and in the red-necked wallaby *Macropus rufogriseus* in South Canterbury (Wodzicki and Flux 1967), New Zealanders have the opportunity to make important contributions to marsupial biology and shape new ideas. Ideas which may also contribute to a better understanding of the common brushtail. In applied research no less than in basic research we must beware of the seductive charm of prevailing attitudes and hypothesis, and be ready to entertain heterodox ideas from wherever they come. Of course it is axiomatic that for new ideas to emerge the results of all research must be open to critical appraisal by the whole scientific community. Nowadays the major problems in any field of research can only be adequately tackled by government-funded organisations able to deploy substantial resources over a long time. A disadvantage of this is that it imposes the constraint of definite objectives which may be political or economic as well as scientific.

University research groups provide an important dialectic; they are not thus constrained and graduate students seem to be more ready to entertain heterodox ideas than their seniors and the best of these ideas get tested out in their projects. Some are fizzlers but a few transform the subject. As I prepared this talk I was impressed by how many of the new directions in thought about marsupials during these last 25 years have begun with a graduate student's research.

It is most appropriate that the organisers of this symposium are providing time in the programme for discussion on the universities' role in research on marsupials. I hope that our deliberations, or the published proceedings, may stimulate more students to seize the real opportunities New Zealand offers for research in this field of biology.

The organising committee deserve our thanks for conceiving the idea to hold this symposium and the response to it is evidence that they were right; it is a splendid opportunity for all of us engaged in research on marsupials to share experiences and problems in the certain expectation that this way leads to new ideas and better research.

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GENERAL DISCUSSION

CATT. Have you noticed a change in the appearance of the corpus luteum in the tammar during seasonal quiescence?

TYNDALE-BISCOE. There is no apparent change during quiescence but there does seem to be a change in the power of inhibition by the pituitary. We are studying this at present and we think the level of inhibition by prolactin may vary, so it is possible to trigger off reactivation more easily at certain times of the year.

B.D. BELL. You mentioned lower productivity, a shorter breeding season and a later maturity in the mountain brushtail *Trichosurus caninus* when compared with the common brushtail *T. vulpecula*. In New Zealand results from the Orongorongo Valley study, at least, suggest *T. vulpecula* tends towards the situation you describe for *T. caninus* - we have recorded low productivity, reduced breeding and delayed maturity there. I wonder to what extent the environment is influencing the pattern in *T. vulpecula*?

TYNDALE-BISCOE. That is a good question. In How's study there was a clear difference between the two species. One could carry out a parallel study in Tasmania where *caninus* does not occur and *vulpecula* occupies forest which is more similar to New Zealand forest. It is interesting that *vulpecula* might show this kind of strategy in the Orongorongo Valley since there the peak population density is probably past. We might be getting a situation where the more K-selected pattern is developing. The other aspect of *caninus* is that the association of the young with the mother is much longer, up to 250 days, as compared with 175 days for *vulpecula*. Do you have similar observations for possums in the Orongorongos?

B.D. BELL. Your figure of 175 days strikes me as low for *vulpecula*. I calculated a period of 170 days to the end of pouch-life and there is association with the mother for a period after that, in cases for at least a further six months.

TYNDALE-BISCOE. So your population of *vulpecula* is getting close to the pattern that How described for *caninus*.

B.D. BELL. Yes in some individuals, while others fall between the period 175 to 250 days.*

TYNDALE-BISCOE. Is the Orongorongo possum population now lower than 1966-1968 when Dr Crawley made his study?

B.D. BELL. The population has fluctuated over the years rather than showing a conspicuous downward trend.

GREEN. I think we are all impressed by the examples you gave of how our current thinking can influence the interpretation of results. I quite often hear the possum referred to as a dumb animal, so perhaps you might have some comments on the intelligence of marsupials in general?

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* Refer also to abstract of paper by J.N. Jolly, later in this issue - Editor.

TYNDALE-BISCOE. That's a very difficult question. I believe various marsupials have been the subject of standard psychological tests, with for instance Skinner boxes, but I would be rather sceptical about interpreting the results. When marsupials are presented with such situations they tend to perform less well than, say, laboratory rats. But they are not in a normal environment, not in the situation which is of significance in their survival so I'm not sure how one would go about testing their innate intelligence.

CUMMINS. In New Zealand we are concerned with disease in possums, especially leptospirosis and bovine tuberculosis. Have you any observations on diseases of forest dwelling marsupials in Australia?

TYNDALE-BISCOE. After a request from Dr Brockie two years ago I did make enquiries but came up with little recent information. However the earlier literature cites reports of epidemic-type diseases going through koala *Phascolarctus cinereus* populations and other marsupials. None of these were properly authenticated and most people tended to dismiss them. In defence, there were attempts to explain the sudden disappearance of many of the smaller marsupials. I think the hypothesis I mentioned in my address has more substance - an abnormal increase in their numbers initially, and then a subsequent crash when the habitat was no longer suitable. Most of the disease reports have little evidence and I'm not aware of anything in Australia resembling your outbreak of bovine tuberculosis.

WODZICKI. Many of us working on the possum in New Zealand are concerned with the problem of their control, and they have continued to spread since you left the country. Could you comment on how we might attack this problem over the longer term?

TYNDALE-BISCOE. I think it is the toughest problem that New Zealand biologists working on marsupials have got to face, and we have nothing like it in Australia. Given the idea that populations will ultimately stabilise at a lower level, then it follows there will be a natural adjustment. When deciding when to interfere with the situation, one has got to look at the life-cycle of the animal to see at what point control measures can be most effectively applied. In other words, if one were to attack the animal during the breeding season or just afterwards, one might have more effective control of the population than if it were applied later in the year when juveniles are already becoming independent.

KEBER. Is there any possiblity of biological control, such as with myxomatosis in the rabbit?

TYNDALE-BISCOE. Given that myxomatosis caused little problems with the endemic cottontail *Sylvilagus braziliensis* in South America, but was virulent in our rabbit *Oryctolagus cuniculus*, then I suppose New Zealand biologists could collect a variety of South American marsupial species and test any pathogens against brushtail possums. I believe some South American marsupials are considered reservoirs of viruses which affect humans, horses and cattle. It is a possible line of attack.

CUMMINS. It has been suggested the possum may be rather deficient in cell mediative immunity, and one idea is that instead of trying to eradicate tuberculosis in possums one should be spreading it!

TYNDALE-BISCOE. I thought that in general their immune response was pretty good and that it developed at quite an early age in pouch-life. This is work which as far as I know has not been published. There was some work done in New England on I think the development of the immune response in the possum.

SPURR. I don't know if you're going to bite at this one. We want an opinion on the nomenclature 'possum' versus 'opossum'.

TYNDALE-BISCOE. I thought that might come up! I've prepared a photocopy from a book by Grzimek called 'Mammals and Man' and there is reference to the marvellous American opossum *Didelphis* which has spread through California and recently to New Zealand where it now occurs in many millions and is causing much damage to the forests! This indicates the desirability of trying to keep one common name for the American animals and distinguishing the Australian animal by a different vernacular name. 'Opossum' has become well-established in New Zealand which I think is unfortunate because it is generally used outside our countries by people to represent the American animal.

CUMMINS. I think it is very courageous of you as a New Zealander to point out this conservatism. On behalf of the meeting I would like to thank you very much for your stimulating address.

CONTRIBUTED PAPERS

SESSION I - BASIC RESEARCH

Chairman: K.M. Moriarty

Massey University, Palmerston North

SPERM MATURATION IN THE POSSUM *TRICHOSURUS VULPECULA*: A MODEL FOR COMPARISON WITH EUTHERIAN MAMMALS

J.M. Cummins

Victoria University of Wellington*

ABSTRACT

In eutherian mammals, sperms passing through the epididymis undergo subtle morphological and biochemical changes which culminate in the capacity to fertilise. In contrast, the pattern of sperm maturation in the possum is extremely elaborate and overt. The spermatozoa undergo marked contraction and loss of cytoplasm. Structural elements are elaborated in the midpiece and they progressively acquire the potential for motility. Unlike the eutherian, these changes are easily studied using light microscopy. As well as being an inherently interesting picture of cell differentiation, sperm maturation in the possum also provides a useful model for looking at the relative importance of testis *versus* epididymis in the evolution of male reproduction. Far from being a 'primitive' system, sperm maturation in the possum epididymis appears to be more elaborate and specialised than in comparable Eutheria. These findings are discussed in the light of experiments to determine the endocrine control of epididymal function in the possum.

INTRODUCTION

In this paper, I intend to outline the process of sperm maturation in the epididymis of the common brushtail possum *Trichosurus vulpecula*, and I hope to show how a study of this process may help to illuminate the selection pressures behind the evolution of the male tract in modern eutherian mammals, as well as in the marsupials.

FUNCTION OF THE EPIDIDYMIS IN EUTHERIAN MAMMALS

Embryologically, the epididymis derives from the mesonephric duct (Wolffian Duct) which has lost its original urinary function and now serves to convey the gametes from the testis to the vas deferens (Romer 1960).

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However, it is not a simple connecting tube, for it serves both to concentrate the spermatozoa and to enable them to complete the process of maturation which starts in the seminiferous epithelium. That spermatozoa do not acquire fertility until they have passed through the epididymis was first shown by Young (1929 a,b, 1931) and Young and Simeone (1930), in work on the guinea-pig. Since those early experiments, a variety of studies has shown this to be true for a number of laboratory and domesticated species, and presumably for all eutherian mammals. The significance of the epididymis is thus well established (Hamilton 1972; Bedford 1975).

The acquisition of fertility during epididymal maturation is not precisely related to any particular change in sperm structure, but rather to physiological and biochemical changes - particularly in membrane structure and composition - which presumably render the spermatozoa capable of effecting fertilization. Some morphological changes do occur, however, notably contraction of the acrosome and distal migration of the cytoplasmic droplet; and these changes are accompanied by increases in specific gravity (Lindahl and Kihlström 1952; Lavon *et al*. 1966). This general pattern is now fairly well established, at least for the domestic and laboratory species (Glover 1974; Bedford 1975; Prasad and Rajalakshmi 1977), and it appears to be under the control of the epididymis, which is in turn dependent upon an adequate level of androgens (Hamilton 1972; Glover 1974; Prasad and Rajalakshmi 1977).

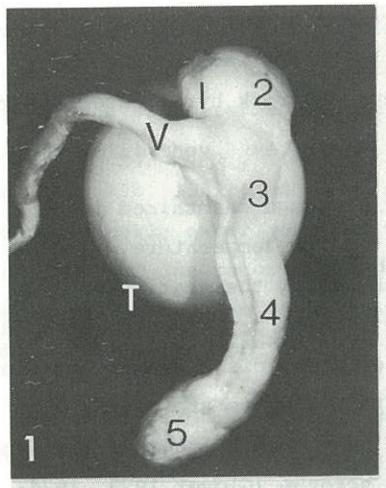
The epididymis is usually described, in gross anatomical terms, in relation to its attachment to the testis; thus we have the caput, corpus and cauda epididymidis; or 'head', 'body' and 'tail'. Unfortunately, there are considerable differences between species in the cytology of these regions, and it seems unlikely that the gross anatomy of the epididymis is related to function in any but the most general terms. Glover and Nicander (1971) proposed a uniform classification for the eutherian epididymis, based upon histology and a study of gross maturational changes in spermatozoa. They described three distinct regions: the Initial Segment, characterized by a high degree of fluid resorption from the testicular exudate; the Middle Segment, where sperm concentration continues and maturation is completed; and finally a Terminal Segment, where the mature spermatozoa are stored in an inactive state before ejaculation. In most species, the Terminal Segment corresponds to the cauda epididymidis, but there may be considerable variation in the positioning of the other regions in terms of gross anatomy. The situation is especially complicated when we consider species which have abdominally situated testes, in which the Terminal Segment may be at a considerable distance from the testis, close to the surface of the body; for example, in the elephant *Loxodonta africana* and rock hyrax *Heterohyrax brucei* (Glover 1973).

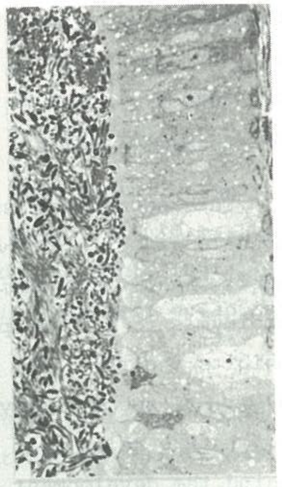
The spermatozoa in the Terminal Segment, although maintained in an immobile state, are nevertheless highly sensitive to temperature. In the rabbit *Oryctolagus cuniculus*, for example, subjecting the testis and epididymis to body temperature by means of artificial cryptorchidism rapidly inhibits the fertility of sperm in the cauda epididymidis (Cummins and Glover 1970). It seems likely that the need to maintain a sperm store at a temperature below that of the body cavity may have been a powerful influence behind the development of a thermo-regulatory scrotum (Glover 1973, 1974; Bedford 1977), and this intriguing possibility will be dealt with later.

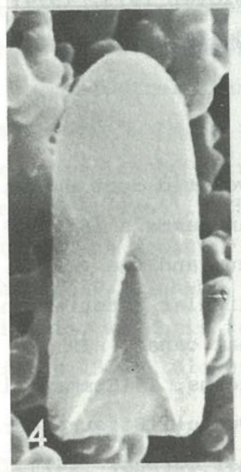
STRUCTURE OF THE POSSUM EPIDIDYMIS

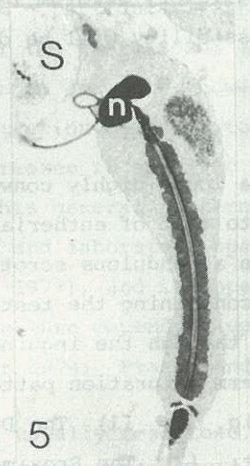
The epididymis of the possum is a long, highly convoluted duct which, in gross appearance, is very similar to that of eutherian mammals (Fig. 1). The testes and epididymides lie within a pendulous scrotum and the vasa deferentia and the vascular pedicles containing the testicular arteries and veins lie close together when passing through the inguinal canal. In analysing epididymal structure and sperm maturation patterns, I (Cummins 1976) divided the duct into five regions (Fig. 1): (1) The Ductuli Efferentes and Proximal Caput; (2) The Distal Caput; (3) The Proximal Corpus; (4) The Distal Corpus; (5) The Cauda and commencement of the Vas Deferens.

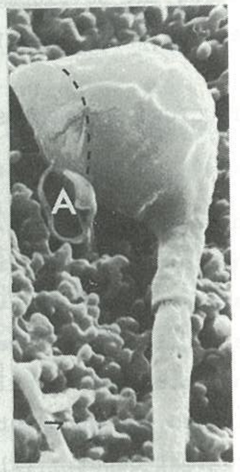
The cytology of the tract also bears remarkable similarity to that of eutherian mammals. Thus, regions 1 and 2 have high columnar epithelium with prominent stereocilia, enclosing an irregularly shaped lumen with relatively few spermatozoa (Fig. 2). Regions 3 and 4 have lower epithelium, with a heterogeneous cell population and active secretion of PAS-positive material (Fig. 3). Region 5 has low, almost cuboidal epithelium enclosing a wide lumen densely packed with spermatozoa; in the terminal region approaching the caudal flexure and merger into the vas deferens, the lumen becomes large enough to be seen with the naked eye (Fig. 1). Sperm concentration increases progressively in descending the tract, reaching a maximum in Region 4.

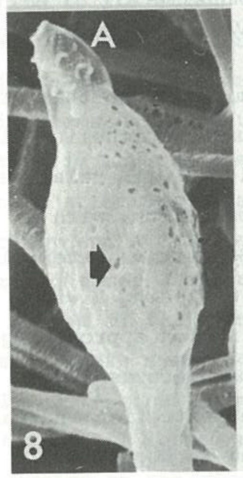


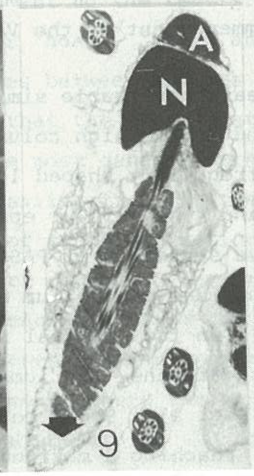


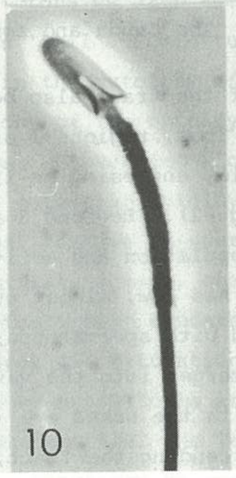


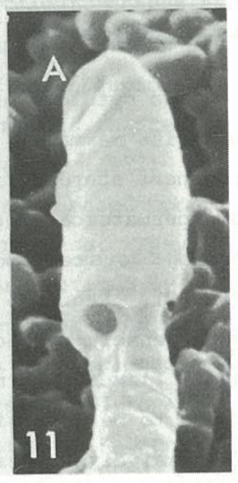












EXPLANATION OF FIGURES 1-11

An idea of the magnifications in Figures 4-11 will be given by the fact that the sperm nucleus is approximately 5 micrometers (.005 mm) long.

Fig. 1. The testis (T) and epididymis removed from the scrotum and displayed. Epididymal regions 1-5 are numbered (see text). The vas deferens (V) runs along the side of the 'corpus' (3 and 4) and leaves the scrotal sac in close association with the testicular artery and vein.

Fig. 2. Light micrograph of a section of epididymal region 2. Note the high columnar epithelium rich in lipid droplets, and the sparse luminal contents. The spermatozoa are recognizably immature, with large cytoplasmic droplets.

Fig. 3. Epididymal region 4. The spermatozoa are now nearly all morphologically mature, and have become densely packed. The epithelium shows several different cell types.

Fig. 4. Scanning electron micrograph (SEM) of a naked nucleus, showing the ventral groove. The background is a Millipore filter.

Fig. 5. Transmission electron micrograph (TEM) of the possum testis, showing a spermatozoon at the point of liberation from the Sertoli cell (S). The bowl-shaped acrosome sits on the anterior third of the nucleus (n), and is still filled with the Sertoli cell process. Note the large cytoplasmic droplet, with reticular channels running the length of the midpiece.

Fig. 6. Phase-contrast light micrograph of immature sperm from epididymal region 1. Note the perpendicular head-neck angle, the large cytoplasmic droplet around the neck, and the protruding acrosome (A).

Fig. 7. SEM of immature sperm from epididymal region 1. The position of the nucleus within the cytoplasmic droplet is indicated by a dotted line. Note the bowl-shaped acrosome (A).

Fig. 8. SEM of condensing sperm from epididymal region 2. The acrosome (A) is collapsing, with the loss of membranous vesicles from its surface, and the cytoplasmic droplet has a pitted appearance (arrowed).

Fig. 9. TEM of sperm section. The cell is at approximately the same stage in maturation as that shown in Figure 8: the nucleus (N) is starting to straighten out on the neck, the cytoplasmic droplet is losing much of its internal organization, and the fibrous sheath interspersed with invaginations has appeared in the distal midpiece (arrowed).

Fig. 10. Phase contrast micrograph of mature spermatozoon from epididymal region 5. The acrosome and cytoplasmic droplet have fully contracted, and the head and tail are in line, presenting a streamlined appearance.

Fig. 11. TEM of mature sperm, showing the fully contracted acrosome (A). This specimen was air-dried, which caused some contraction of membranes permitting observation of the mode of insertion of the neck into the nuclear groove (here viewed side-on).

CHANGES IN POSSUM SPERMATOZOA DURING EPIDIDYMAL TRANSIT

A number of recent papers have been published on the ultrastructure and maturation of possum spermatozoa (Harding *et al.* 1975, 1976 a, b; Olson 1975, Cummins 1976; Temple-Smith and Bedford, 1976). I shall concentrate here on the major features of possum sperm maturation with a view to comparing it to the eutherian pattern.

The nucleus of the sperm is shaped rather like a human glans penis, with a prominent groove running for about half the length of the 'ventral' surface (Fig. 4). The axoneme is inserted into the anterior end of the groove, and thus virtually into the centre of gravity of the nucleus, rather than into the posterior border of the nucleus as in Eutheria. The attachment point is reminiscent of a ball-and-socket joint, in that the nucleus appears to be free to swivel on the axoneme. In fact, this swivelling is one of the most striking features of maturation: the sperm is released from the seminiferous epithelium with the nucleus nearly perpendicular to the neck (Figs. 5 and 6), and during maturation, the neck becomes pulled into the groove until in the mature sperm the long axis of the nucleus is in line with the flagellum (Figs. 10 and 11). This streamlining of the sperm coincides with contraction of the cytoplasmic droplet around the neck. However, the nuclear-axonemal junction seems to stay quite flexible, for dead sperm in mature populations frequently show retroflexion of the nucleus into the immature position. Although such retroflexion is usually a post-mortem artefact, the impression has persisted in the literature that marsupial sperm heads are 'free' to pivot on the neck (see for example Austin 1976).

The change in the head-neck angle is the most easily observed maturational change in possum sperm, and three stages of maturation can be recognized by this parameter (Cummins 1976). The bulk of the sperm population passes through these three stages within regions 1-3 of the epididymis, and by region 4, the majority are morphologically mature and have developed the potential for progressive motility.

Ultrastructural studies show that the straightening out of the head and tail of the sperm is accompanied by striking changes in the acrosome, the cytoplasmic droplet and the midpiece. In the testis and upper regions of the epididymis, the acrosome is a bowl-shaped structure sitting on the anterior 'dorsal' third of the nucleus (Figs. 5, 6 and 7). It acquires this shape during the latter stages of spermiogenesis through an interaction between the circumnuclear ring, and a process of the Sertoli Cell which appears - at least to this author - actively to extrude the sperm from the seminiferous epithelium (Harding *et al.* 1976 a; see also Fig. 5). During maturation, this bowl-shaped acrosome collapses into an inconspicuous button-shaped structure (Fig. 11), and contraction is accompanied by striking vesicles of plasma membrane which appear to bud off the overlying surface. At the same time, the initially large cytoplasmic droplet contracts and loses much of its internal complexity, and this is also accompanied by pitting and vesiculation of the plasma membrane (Figs. 8 and 9).

The contraction of the acrosome and cytoplasmic droplet occurs largely in epididymal regions 2 and 3. As this is also where the sperm mass is becoming progressively more concentrated (Figs. 2 and 3), it is possible that the contraction of the sperm cytoplasm is a response to the increasing concentration of the epididymal plasma caused by fluid resorption across the epithelium. However, whether the vesiculation and pitting of the sperm plasma membrane is simply an osmotic phenomenon is a question which requires further experimentation.

As well as contraction of the acrosome and cytoplasmic droplet, possum sperm also show dramatic changes in the ultrastructure of the midpiece during maturation. In the immature spermatozoon, the space between the mitochondrial sheath and the overlying plasmalemma is filled with a network of membranous cisternae reminiscent of smooth endoplasmic reticulum; this system communicates anteriorly with similar structures in the cytoplasmic droplet (Fig. 5). While the spermatozoa are passing through epididymal regions 2 and 3 (see Fig. 1), the cisternae are replaced by a spiral fibrous sheath underlying the plasma membrane of the posterior two-thirds of the midpiece. The gyres of the sheath run counter to the gyres of the mitochondrial spiral, and are interspersed with caveolae-like invaginations of the plasma membrane (Fig. 9). This structure appears at the same time in maturation as the acrosome and cytoplasmic droplet contract. Although its composition is not known, differential extraction techniques indicate that it may be a sulphydril-bond-rich protein similar to the keratinoid proteins which fortify eutherian sperm tails (Calvin and Bedford 1971; Calvin 1975; Temple-Smith and Bedford 1976). Exactly how it gets laid down in the sperm midpiece in such a precise manner remains a mystery. Protein synthesis would be extremely surprising in the genetically inactive spermatozoon, and furthermore, there is no histochemical evidence of RNA in the developing sperm midpiece (Cummins unpublished). It is conceivable that the sheath may arise by increasing sulphydril bonding within a pre-existing pattern of polypeptides. However, ultrastructural evidence of any such pattern in immature spermatozoa remains elusive. The spiral fibrous sheath of marsupial spermatozoa seems to be the first described example of a major structural feature appearing in mammalian spermatozoa *after* they leave the seminiferous epithelium, and as such, is of great interest.

The caveolae-like invaginations of the plasma membrane presumably serve to increase the surface area overlying the mitochondrial sheath. Although they are reminiscent of pinocytotic vesicles, there is no evidence of any time-related uptake of markers such as horseradish peroxidase (Cummins 1977). It is interesting that a number of related marsupial species possesses a fibrous sheath in their spermatozoa, but not all show the membrane invaginations (Harding, Carrick and Shorey 1977). The structural and physiological significance of these features of the marsupial sperm midpiece must remain open questions.

HOW DOES THE PATTERN OF SPERM MATURATION IN THE POSSUM COMPARE WITH THAT OF EUTHERIA?

It is necessary at this stage to point out that knowledge of sperm maturation in the possum is based purely on morphology: nothing is known, as yet, about the acquisition of fertilizing ability. Nevertheless, a comparison with the 'typical' eutherian pattern raises some fascinating questions about the evolution of the epididymis and scrotum. Firstly, there are some obvious basic similarities in the process; for example, in the progressive condensation of excess sperm cytoplasm and in the increasing disulphide bonding within structural proteins. There is also the fact that in both models the sperm mass undergoes progressive concentration as it passes through the epididymis, and this indicates that fluid resorption is a major feature of both the marsupial and eutherian epididymis. A minor difference here is that the fluid resorption seems to occur over a relatively greater proportion of the duct in the possum, but this impression requires further investigation. Finally, it is also clear that the epididymis of the possum, as in eutherian mammals, is under androgenic control, for castration and treatment with androgen antagonists such as diethylstilboestrol cause regression of the duct and disruption of the pattern of sperm maturation (Cummins 1977, and in preparation).

Despite these similarities, it is clear that possum sperm maturation possesses some unique features. The complex acrosomal changes involving loss of plasma membrane vesicles, the pitting and vesiculation of the cytoplasmic droplet, and the elaboration of the midpiece fibrous sheath are all examples of morphological modification occurring within the epididymal lumen, which in comparable Eutheria, one would expect to have been completed by the time the spermatozoa had left the seminiferous epithelium. The overwhelming impression is that possum sperm are liberated in a much more immature state than are the sperm of comparable eutherian mammals, and that the epididymis has consequently assumed greater control over the development of the mature gamete.

EVOLUTION OF THE MALE REPRODUCTIVE TRACT IN MODERN MAMMALS

Evolutionarily, the ancestral stocks of eutherian and marsupial mammals are thought to have diverged about 130 million years ago (Lillegraven 1974, 1975). Despite this long era of separate development, the male reproductive systems in the two groups of mammals show some striking similarities, which indicates that they have probably evolved in response to similar selection pressures. I have already compared the process of sperm maturation in the possum with that found in the Eutheria, and I should like now to use this as a basis for speculation about those very selection pressures, concentrating on three main aspects of the male system, which seem to be most worthy of study: the thermoregulatory scrotum; the epididymis; the role of sperm production in mating systems.

The reasons for the evolution of a thermoregulatory scrotum are intriguing and elusive. Both marsupials and Eutheria show the tendency for testes to move into an outpouching of the peritoneum, yet this has obviously developed after divergence, for not all species develop a scrotum, and in those that do, there are fundamental embryological differences in the mode of descent between the two groups of mammals (Eckstein and Zuckerman 1956; Sharman 1970). Although there is little doubt that testicular function in those animals that have a scrotum is rapidly impaired by raising the testes to the temperature of the body, this may simply reflect secondary adaptation of testicular function to a lower temperature. Carrick and Setchell (1977) have surveyed a wide range of mammals with different degrees of elaboration of a scrotum, and have found little relationship between the effectiveness of spermatogenesis and testicular temperature. In view of this, attention has now swung away from the testis to the epididymis, and Glover (1973, 1974) and Bedford (1977) have examined in detail the possibility that a major factor in the evolution of the scrotum has been the need to provide a cool storage zone for the mature spermatozoa. It is noteworthy that the Terminal Segment (or cauda epididymidis) invariably lies in the coolest extremity of the scrotum. Although this idea clearly needs further study, it has nevertheless refreshed our interest in the selection pressures behind the evolution of the modern male tract.

When considering the epididymis, it is clear that again there are marked similarities between eutherian and marsupial mammals, although, as yet, data for marsupials are scanty. I have shown here that in the common brushtail possum, as in Eutheria, we can clearly identify an Initial Segment concerned with fluid resorption, a Middle Segment where spermatozoa complete maturation, and a Terminal Segment where the mature gametes are stored (Glover and Nicander 1971). The area in which the possum seems to be unique seems to be that of sperm maturation, for the degree of morphological modelling of the spermatozoa which occurs in the epididymis is much greater than that seen in Eutheria.

It is impossible to consider the factors behind the evolution of the scrotum and epididymis without studying the roles of those structures in sperm production. Yet, when we examine the facts of sperm production in mammals, we are confronted with what seems to be a paradox: males in general produce far more spermatozoa than are needed to effect fertilization, and yet the female tract has evolved a number of mechanisms designed to prevent too many spermatozoa from reaching the ova and thus increasing the risks of polyspermic fertilization (see Cohen 1969). What are the reasons for this seeming wastage of gametes? The answer most probably lies in the reproductive strategies evolved by males to ensure breeding success. Although an examination of the evolution of reproductive behaviour is beyond the scope of this article (see Wilson 1975), it is clear that the ability to produce extremely large numbers of spermatozoa must have been a successful trait in early mammals, otherwise it would not have persisted. In mammalian breeding systems, there is considerable division of labour between the sexes, with the females carrying the major energy-consuming tasks of gestation, lactation and caring for offspring (Dawkins 1976; Grodzinski 1975).

Clutton-Brock and Harvey (1978) have pointed out that in such breeding systems, the reproductive success of females is limited by the number of young they can produce, while the success of males is largely limited by competition between them to impregnate females. Thus, mammals on the whole tend to be polygynous rather than polyandrous, and competition between males tends to select not just for vigour in breeding behaviour, but also for the ability to produce large numbers of fertile spermatozoa. The energy demands of mammalian sperm production *per se* are not known, however they are probably minor in terms of overall energy budgets (Sadleir 1969). In contrast, female mammals invest a large proportion of their energy budget in breeding; small rodents, for example, need to increase metabolic effort by about 60% during gestation and lactation (Grodzinski 1975). In evolutionary terms, the advantages to males of producing large numbers of spermatozoa must have outweighed the disadvantages of 'wastage' of excess gametes.

If these suppositions are correct, then the need to produce excesses of spermatozoa must have placed increasing metabolic and mechanical demands upon the testis; demands accentuated by the increasing importance of the testis as an endocrine gland. These stresses could be eased, and sperm output maximized, if spermatozoa could be released from the testis shortly after the completion of meiosis, with a minimum of maturation. I suggest that the epididymis, in the evolution of modern mammals, played an increasingly important part in overseeing the final steps of sperm maturation; a maturation which, in turn, was becoming biochemically more complex as the spermatozoa faced the rigours of an extensive female tract designed for viviparity.

Viewed in this context, we can now see that the epididymis of the possum would appear to have assumed greater control over sperm maturation than in comparable eutherian mammals. Certainly the morphological changes are much more overt and dramatic, and this should ease the way for investigations into factors which control the process. A side issue of this observation is that the reproductive tract of the possum can in no way be considered 'primitive', for it may in some ways be even more complex than that of the supposedly more 'advanced' Eutheria. Whether or not the reproductive biology of marsupials is in general 'primitive' is still a matter of hot debate. Lillegraven (1975) inclines to the view that, in general, it is, or at least that it is less evolutionarily flexible than that developed by placental mammals. On the other hand, several recent authors have pointed out that in many ways, the marsupial pattern of viviparity, with a short gestation and long lactation, is a highly successful strategy which minimises risk to the mother and also makes best use of potentially variable supplies of nutrition (Gould 1977; Kirsch 1977; Parker 1977).

The suggestion that the marsupial epididymis may be relatively more important in sperm maturation than that of eutherian mammals is still only an hypothesis. In order to test it, there seem to be three main areas where research should be directed: first, the relative durations of spermatogenesis and sperm maturation; second, the biochemical changes occurring in the epididymal plasma around the maturing spermatozoa; and third, the nature of the changes in the spermatozoa and their control. Some data are already available to show that the timing of spermatogenesis and epididymal transit in marsupials may be comparable to that of Eutheria (Setchell and Carrick 1973; Carrick and Setchell 1977), but in general the field for experimentation is virtually untouched.

CONCLUSIONS

I have attempted here to outline what is known about sperm maturation and epididymal function in the common brushtail possum with a view to comparing it with the pattern for eutherian mammals. There are striking similarities in the structure of the epididymides, although relatively more of the possum epididymis appears devoted to progressive sperm concentration and fluid resorption than is normally seen in eutherians. In terms of morphological changes in the spermatozoa, again the picture for the possum appears basically similar to the eutherian pattern, but the changes are far more dramatic, and - unlike Eutheria - involve shedding of membranes by the sperm as well as elaboration of at least one major structural feature: the midpiece fibrous sheath.

I have also speculated as to how these contrasts may illuminate the selection pressures behind the evolution of the scrotum and epididymis in present day mammals. Clearly these pressures have produced some remarkable parallel developments in the marsupials and placentals. Among the more important pressures would appear to be the need for males to produce large excesses of fertile sperm in competition for breeding success; the increasing endocrine role of the testis; the increasing biochemical demands on sperm imposed by the adoption of internal fertilization and viviparity; and the problems of storing mature spermatozoa in a fertile state for prolonged periods. The storage problem would appear to have been eased in both groups of mammals by the evolution of the thermoregulatory scrotum for cooling the sperm accumulated in the distal portion of the epididymis. I suggest that the proximal regions of the epididymis have progressively assumed greater control over the final stages of sperm maturation in order to ease the demands on the testis, and if this is so, then the epididymis of the possum would appear to have specialized further along this path than is the case for eutherian mammals.

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GENERAL DISCUSSION

MORIARTY. Could you give some indication of the time sequence required for this dramatic change in sperm morphology to take place?

CUMMINS. We have some indication that the time period from spermatogenesis to release of ejaculate is about two weeks. This is comparable to most eutherian mammals of the same weight and size. So it takes some two weeks for sperm to pass through the epididymis and I would estimate that they probably remain viable in the tail of the epididymis for up to 2 or 3 weeks.

BROCKIE. How long do you think the sperm could remain viable in the vagina of the female?

CUMMINS. I really do not know. We have kept them in culture for up to 48 hours. My guess would be 24 hours maximum.

ANONYMOUS. Do you find sperm is released into the urine?

CUMMINS. The sperm is normally released into the urine in the possum. At one time it was thought that in eutherian mammals the sperm is absorbed when not ejaculated. I think the idea has largely gone by the board. For example rams that are not allowed to mate will pass into the urine daily amounts of sperm equivalent to the daily testicular sperm production. So it happens in eutherians as well as in marsupials.

GREEN. Does your work suggest that chemo-sterilant control is a viable possibility sometime in the future, or would you look rather to the female from this point of view.

CUMMINS. If I were attempting to devise a strategy I think I would look at the female, but I think the male must not be ignored. If we look at chemosterilants in the male we must look at the prostatic secretions - that is something that will affect the sperm once they have been ejaculated. While in the epididymis they are pretty untouchable.

GREEN. Are you going on to look at this aspect?

CUMMINS. Yes, I hope we will.

BROCKIE. Would I be right in thinking the sperm is produced regularly throughout the year without seasonal variation?

CUMMINS. Yes. The evidence for the possum is that there is no seasonal variation in sperm output or testis weight, though there is seasonal variation in prostate weight. Certainly we have found no seasonal variation in sperm quality in the animals we have examined.

BROCKIE. So seasonality in the reproductive cycle will depend on the female rather than the male?

CUMMINS. Yes, I think so.

WODZICKI. The work of Dr Cummins has described demonstrates how easy it is in New Zealand to carry out not only applied but fundamental work on marsupials. I remember Dr Tyndale-Biscoe had to travel hundreds of miles to obtain a few tammar wallabies, while here if we wish to study wallabies we can get them in hundreds. The same is of course true of the possum. There is a great prospect for university zoology departments to contribute to fundamental studies of these marsupials. Also Dr. Cummins has shown that the reproductive system is not at all antiquated or primitive, but rather that the marsupials have successfully evolved during the long time they have been in Australia.

MORIARTY. I am sure that the message will come from this symposium that we are sitting on a gold-mine of experimental material.

SOME EFFECTS OF THE FEEDING HABITS OF THE POSSUM *TRICHOSURUS VULPECULA*

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ABSTRACT

Possum foods have been examined since about 1920 though more scientific research did not begin until 1946-47. The results of both incidental observation and detailed research have many aspects in common and a few which show peculiarities restricted to certain localities or types of habitat. An overall picture of the food of possums and their feeding habits is covered in this paper. Food habits of *Trichosurus vulpecula* in New Zealand are compared with those in Australia.

TRICHOSURUS VULPECULA IN AUSTRALIA

In Australia, the common brushtail possum *Trichosurus vulpecula* is not often regarded as a pest. It occurs in South Queensland, New South Wales, Victoria and Tasmania. The distribution of *T. vulpecula* overlaps narrowly with that of the mountain brushtail possum *Trichosurus caninus*, generally in dry sclerophyll forests which have an unusually dense under-storey. Broadly, *T. vulpecula* is restricted to dry sclerophyll forest but it is also a common suburban dweller, while *T. caninus* is largely restricted to wet sclerophyll, sub-tropical or rain forest (Owen and Thomson 1965). *T. vulpecula* feeds mainly on eucalypt leaves, which may form 66% of its diet (Freeland and Winter 1975), as well as on a variety of indigenous and exotic shrubs. It is primarily arboreal, while *T. caninus* feeds mainly on ground or under-storey plants; there is little or no evidence of seasonal variety in the diets of either species (Owen and Thomson 1965). Mature leaves are preferred by both species so that food availability is constant all the year round. Nest sites of the two species differ; *T. vulpecula* mostly up trees, *T. caninus* in fallen logs or hollow stumps. *T. caninus* is more tolerant of wet conditions than the mainland *T. vulpecula*, and is probably more terrestrial.

Trees in exotic plantations (mostly *Pinus radiata*) may be attacked by both species of *Trichosurus* but also by *Rattus fuscipes*[1], *Wallabia bicolor*, and occasionally by the common wombat *Vombatus ursinus* and the rabbit *Oryctolagus cuniculus* (McNally 1955). The bark of the trees is removed by all these species, with a typical pattern for each. *T. vulpecula* strips off the bark and eats the soft cambial flesh, and there is not much sign of bark in the stomachs. *W. bicolor* and *R. fuscipes* eat both stripped bark and apical portions. Both *T. vulpecula* and *T. caninus* may girdle the trees, which

[1] formerly *Rattus assimilis*

causes either tree malformation or death. With *T. vulpecula* the damage is often much more difficult to detect because it occurs higher up in the trees. There may be repetitive attacks on particular trees. In four plantations sampled for possum damage, only 20% of the trees remained untouched (McNally 1955).

In Tasmania, *Eucalytpus regnans* (mountain ash) is browsed by *T. vulpecula* (Cremer 1969), as are *Acacia* and *Pomaderris* species. The main damage is done to trees up to about 1 metre, and it is uncertain what part of the damage is attributable to *T. vulpecula* and what is caused by other browsing species (e.g. wallabies). Petioles of *E. regnans* are eaten by *T. vulpecula*, with leaves appearing to be eaten mostly in autumn and winter. However, this may be an erroneous observation because it is then that browsed foliage would be least likely to be hidden quickly by new growth. Tasmanian plant species seem able to recuperate from browsing more readily and in more months of the year than most New Zealand species.

Some workers (e.g. Green 1974) consider that *T. vulpecula* is primarily a ground feeder in Tasmania and that it has a liking for a wide variety of food, including meat. Though formerly restricted to dense sclerophyll forest in Tasmania, it is now much more widely distributed, and despite its mortality from hunters it has increased and is now plentiful.

Troughton (1941) says that though *T. vulpecula* is specialised for an arboreal existence, it thrives in comparatively treeless areas, making dens in rabbit warrens, etc., as readily as in trees. He considers that in the wild state its food is variable, and includes many species of eucalypt. In Australia generally, *T. vulpecula* is thought to be rarely responsible for other than localised damage. The Tasmanian *T. vulpecula*, thought by Troughton to be a separate species (*T. fuliginosus*), is much heavier than its mainland grey-furred counterpart, and has much denser, longer fur which is more commonly brown.

HISTORICAL BACKGROUND OF *TRICHOSURUS VULPECULA* IN NEW ZEALAND

Trichosurus vulpecula was initially introduced into New Zealand from the Australian mainland and Tasmania in the mid-nineteenth century, but did not become established successfully until about the end of the century. Thomson (1922), quoting F. Hart of Southland, wrote that the food of the possum was chiefly seeds of broadleaf, kamahi, panax, maple (*Pittosporum*), fuchsia, and makomako, rata blossoms and supplejack berries, and practically all seeds that grew in the bush. The possum was not considered to be a grass-eating species, though it would eat red and white clover and sweet-briar shoots. The damage that the animals could do when running at large was thought by Thomson to be very little, seeing that they never came out into open country.

Perham (1924) said that in a search for damage by possums that might be construed as materially affecting the forest, results had not been very fruitful - in fact only one instance of extensive bark-biting had been found. Perham considered that their leaf-eating habit, if moderate (as had been the case up until then), would have no bearing on the welfare of the forest "as trees have been subjected to and withstood such from pigeons through many centuries". Where death of one or two specimens of some tree species (e.g. northern rata *Metrosideros robusta*) was evident, the theory was that the tree had reached its allotted span and was dying away. Other similar examples were quoted.

Cockayne (1928) thought that if the possum was doing noticeable damage, the forests would unmistakeably point to this in their dead trees. But the forest, according to Cockayne, was untouched by damage from possums : "If damage of any kind there be, it is so slight as to be negligible". Nor did he consider that the animals affected the all-important floor covering or reduced the seed crop to any great extent. "At any rate, if it is proved eventually, which is most unlikely, that opossums are a menace to forests, their skins are so valuable that at any time the animals can be reduced in numbers to the extent desired without any cost. Unlike deer, it would pay handsomely to keep the opossum under strict control".

However, Kirk and Bendall (1919) were much more concerned about the possums' effect on Kapiti Island. Damage to kohekohe *Dysoxylum spectabile*, mahoe *Melicytus ramiflorus*, passion-flower *Tetrapathaea tetrandra*, and fuchsia *Fuchsia excorticata* was noticeable, and these authors thought that the only safe aim was the absolute extinction of the possum on Kapiti Island.

SOME CONSEQUENCES OF INCREASED NUMBERS OF *TRICHOSURUS VULPECULA*

Zotov, in the early 1930s, noted damage done by possums and other browsing or grazing animals in the Tararua Ranges, though he did not publish this information until 1947. By this time the complacent attitude that had prevailed in the earlier part of the century was giving way to very great concern. Most of this concern stemmed from survey work done by the Wildlife Section of the

Department of Internal Affairs and the New Zealand Forest Service. It was highlighted that in New Zealand most plant species have very little resistance to browsing or grazing animals, though there were some areas where the impact of the possum was minimised because the vegetation and geology differed significantly from that found in most areas occupied by the animal (Holloway 1959). It was Holloway's opinion that, particularly in the South Island, spectacular erosion had occurred even before the introduction of browsing or grazing animals, and that even now the removal of all animals from such areas would not prevent continuing instability.

Kean and Pracy (1949) and McKelvey (1959) thought that large possum populations could occur only in forests where the shrub tier and the forest floor cover had been reduced or practically eliminated by hoofed animals, principally deer (*Cervus* sp.). Possums apparently colonise an area with greater ease if under-cover is naturally sparse, or where sparseness is induced. If this theory is accepted as a generalisation, then the damage by possums must be superimposed on that of deer and goats *Capra hircus*, the possums defoliating the canopy above a depleted shrub layer. This type of damage is usually most severe in mixed hardwood-podocarp forest, but serious damage is sometimes confined to scrubby hardwoods that often dominate the valley bottoms and gullies. Heavy browsing on this type of vegetation can create areas of weak vegetation which run along main drainage patterns and culminate in zones of geological instability at sites which are most vulnerable to slipping (McKelvey 1959). Regeneration of the original scrub species is generally prevented by continued browsing, and those species which do regenerate successfully are the ones which are unpalatable to possums and deer. If any one species predominates, this species may in turn become vulnerable to insect pests that can then reach epidemic proportions sufficient to kill even the unpalatable species, e.g. geometrid moth larvae (*Pseudocoremia rudisata*) on *Brachyglottis repanda* and *Olearia* species (M.J. Meads pers. comm.). Any agent that defoliates and reduces vegetative cover minimises natural control of water runoff.

In the North Island there is a broken chain of steep, mainly forested ranges 1000-2000 m high, principally of readily fractured greywacke with frequent shatter zones and active fault lines. The central part is veneered with volcanic Taupo pumice. Protection forests in this part receive in excess of 2500 mm of rainfall per year, and the presence of dense forest prevents catastrophic floodwaters from reaching the fertile plains. However, in the Ureweras (for example) the grazing and browsing of ungulates and possums has destroyed much of the vegetation, and this and the presence of feral pigs *Sus scrofa* prevents regeneration of some species. In some places the ground becomes bare and compacted, while in others abnormal slips have been induced (McKelvey 1959), sometimes dislodging the more porous pumice mantle and leaving areas of more vulnerable greywacke. Though deer culling has reduced much of the deer damage, the impact of the possum in this and other areas is still great.

In general, however, it is difficult to differentiate between the effects of different browsing animals - even canopy damage may be caused by defoliating insects. The general forest deterioration is caused by the combined effects of deer, goats, cattle, pigs, and possums. Many plant species have been either eliminated or drastically reduced in abundance: kamahi *Weinmannia racemosa*, northern rata *Metrosideros robusta*, fuchsia *Fuchsia excorticata*, makomako *Aristotelia serrata*, pate *Schefflera digitata*, mahoe *Melicytus ramiflorus*, and some of the *Pseudopanax* species.

It appears that deer and possums cannot reach equilibrium with the environment without further undesirable results. Even if stability is reached, the end result will be a depleted forest which will contain fewer species and be much less efficient in controlling runoff. Besides introducing a number of undesirable mammals to New Zealand, man has converted vast areas of lowland forest to land suitable for grazing sheep and cattle. The topography and altitude of the remaining forest render it especially vulnerable to the pressure of browsing or grazing animals, aggravating the consequences of their feeding habits.

FEEDING HABITS OF *TRICHOSURUS VULPECULA*

Possums in particular show very pronounced preferences for some plant species, and this intensifies their impact. Kean and Pracy (1949) listed 70 or so species eaten by the possum, and ascribed to them an order of preference shown by the animals. Subsequent work on the food of possums has largely substantiated this list and quantified some aspects of the diet (Mason 1958, Gilmore 1967, Fitzgerald 1976), but the habitats and areas studied by the more intensive method of stomach or faecal analysis have been more restricted than those covered by Kean and Pracy.

From all the work done on the food of possums in New Zealand, the same species occur regularly and reliably in the diet: fuchsia, rata (*Metrosideros robusta* or *M. umbellata*), kamahi, fivefinger *Pseudopanax arboreus*, kohekohe, makomako, titoki *Alectryon excelsus*, and toro *Myrsine salicina*. Where bush borders farmland the choice offood is widened to include grasses and clover.

However, the order of preference by possums is not always consistent. For each species mentioned as highly preferred there may be exceptions where these species are virtually ignored, and others where species normally considered unpalatable are preferred despite the presence of so-called highly preferred plants. The reasons for these exceptions, and for that matter the reasons for preference of any species, are not clear. Information on species eaten in Australia suggests that the leaves of these plants are highly sclerophyllous; this probably indicates that a large amount of food must be eaten in order to extract the nutrients required. Lipid content in eucalypt species is quite high, as it is in *Metrosideros* spp. - particularly *M. fulgens* during the months that it occurs most frequently in the diet of possums in the Orongorongo Valley (Fitzgerald 1978). Just how much of this lipid is or can be used by possums is not known.

Other preferred species in New Zealand seem to have amounts of protein and carbohydrates that are comparable with the amounts in those species which are not generally eaten. Plant toxicity (or lack of it) is another feature which may determine the possums' choice of food, but it is well known that possums can and do eat - with apparent immunity - leaves of *Coriaria* species which are actively toxic to cattle. Fluctuations in the presence and abundance of fruit may also alter the possums' dependence on leaves and change their selection patterns.

Our feeding trials with captive possums have suggested reasons for both preferential selection of some plant species and seasonal selection of others, but we do not yet know the habitats or nutritional plane necessary for possums to breed twice a year. More work which will throw light on the nutritional requirements of possums may help to sort out some of the management problems of possum control.

A comparative study of some aspects of the ecology of the possum in two different-aged stands of *Pinus radiata* has recently been completed (M. Clout, pers. comm.). One stand was planted in 1960, the other in 1971. Stomach analyses showed that, in the older stand, the possums ate pine foliage mainly in the autumn, when it formed up to 50% of the diet and was supplemented with female strobili. From June to September large quantities of male strobili were eaten and formed about 70% of the diet by August. Bibionid larvae (*Insecta : Diptera*) were also eaten, often in considerable numbers, from April to October. During late spring and summer, stomach contents consisted mostly of leaves of lower-storey shrub species with some ferns. The switch from this mixed diet in spring/summer to one comprising predominantly pine was quite abrupt.

In the 1971 stand the diet was more varied, less predictable, and with less seasonal pattern. Reproductive parts of the pines were not available, but pine foliage was still eaten in small amounts and bark was eaten mainly in winter and spring. Grass was an important food throughout the year; though dicotyledons formed a small proportion of the vegetation, they often accounted for about 40% of the stomach contents. Fern was also eaten in this habitat.

Possums in the two ages of pine stands thus had strongly contrasting diets, particularly in winter, largely as a result of the presence or absence of strobili. This difference in diet, with other variables possibly associated with the differences in the age of the two pine stands, produced quite marked differences in body weight and fecundity between the two groups of possums. Other such studies (*e.g.* Bell this symposium) together with laboratory experiments may eventually allow us to predict with confidence the response of the possum to its habitat and food supply.

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GENERAL DISCUSSION

COOK. During which months were rata trees eaten?

FITZGERALD. In the Orongorongo Valley northern rata *Meterosideros robusta* was eaten in all months of the year. Over the whole year this species comprised about 30% of the diet.

CHARLESTON. Do they more than accidentally eat insects? Having kept the old possum I found them willing to eat almost anything and they just loved meat.

FITZGERALD. Yes, that is right, they will eat practically anything. Dr Ben Bell has done some work on possums eating puriri moths. When these moths are in season he found them taken in large numbers by possums when attracted to a light. He had the moths analysed and they had a high lipid content. Mick Clout's example I cited was not just a case of a few odd larvae in the gut - the dipterous bibionid larvae were there in considerable numbers, something like 1,800 in one stomach. To a very large extent these larvae came through the gut intact.

PEKELHARING. Is there totara *Podocarpus totara* in the Orongorongo Valley and, if so, do possums eat it?

FITZGERALD. Yes, it is there and they eat it, but it is not in their first 14 choices of tree species.

BROCKIE. Mistletoes were once widespread through New Zealand but have been disappearing at an alarming rate. One species *Trilepidea* (*Elytranthe*) *adamsii* was confined to the Coromandel district and is now thought to be extinct because possums have eaten it out. This is the one and only New Zealand native species that seems to have become extinct on the mainland, and possums seem to be the culprit. It looks as though other mistletoe species are heading in the same direction and very rapidly.

FITZGERALD. This is an interesting point. Dr Given has produced a recent paper* on rare and endangered plant species and it would be worth checking - presumably you could make some intelligent guesses about other species likely to become extinct like the mistletoes.

ANONYMOUS. The reverse is reported from South Australia where mistletoe is alleged to be spreading through the lack of possums.

FITZGERALD. I think Sir Charles Fleming noted that pollen analyses indicate species such as *Meterosideros* were quite widespread in parts of Australia, but no longer occur there.

MIERS. Kamahi and fuchsia were also in a similar category in Australia.

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A PROGRESS REPORT ON THE MOVEMENTS OF POSSUMS *TRICHOSURUS VULPECULA* BETWEEN NATIVE FOREST AND PASTURE

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ABSTRACT

A major study was started by F.R.I. in 1975 to investigate the daily and seasonal movement patterns of possums within rata/kamahi forest and their movements onto adjacent pasture land. This paper is a progress report based on 20 months of trapping records.

Nearly 1000 possums were live-trapped within a 2 square km area that varied from pasture through lowland forest into alpine scrub, in the study area at Lake Haupiri, Westland. Movement patterns vary considerably between individual animals. Nonetheless animals resident in different forest zones tend to have different movement patterns. Hence the alpine scrub animals move the least, while animals resident within 800 m of the pasture tend to move the most. The lush pasture forage draws animals from unexpectedly long distances in the forest; most of these movements appear to be via ridges. Fixed trap lines provide minimum estimates of long-distance movements and are a poor guide to the total home-ranges animals occupy. Hence these trap estimates are now being supplemented by an extensive radiotelemetry study of selected tagged possums over the entire study area.

It is already clear from trap data that possums will move several hundreds of metres to feed on pasture, and may do so quite frequently. This may place deep-forest possums at risk as potential bovine tuberculosis vectors and control programmes in tuberculosis problem areas should be reassessed accordingly.

INTRODUCTION

The common brushtail possum *Trichosurus vulpecula* has long been recognised as a harmful browsing species in New Zealand's indigenous forest. In addition, in the last decade it has been identified as both a vector and reservoir of two diseases of farm stock, namely bovine tuberculosis and leptospirosis, and to be an important competitor of farm stock for both pasture and fodder crop species.

The control of possums foraging out onto farmlands relies heavily on the extensive use of compound 1080 applied to vegetable baits and sown throughout adjacent forests. The dramatic rise in control costs (see Coleman, this symposium) increases the need to maximise the percent kill; in particular the need to control that proportion of the possum population which is most "at risk" to Tb. infection. A more efficient approach to aerial control with 1080 clearly requires better information on the ecology of possums in forest/pasture margin situations. With this control objective in mind we started studying the foraging patterns of possums with the intention of defining the zone of contact on forest/pasture margins between possums and stock, and thus delimit more accurately the width of the adjacent forested slopes requiring control.

The study discussed here is continuing on the slopes of Mt Bryan O'Lynn near Lake Haupiri in central Westland, and involves possums on a 800 m wide strip of land extending from improved stocked pasture at 230 m to alpine grasslands at 1350 m altitude. In this paper we discuss the broad patterns of population movements between forest and pasture, and the implications of these movements from a control perspective. Further seasonal details of movements, other aspects of possum biology, and the interaction between possums and rata/kamahi (*Metrosideros/Weinmannia*) forest will be published at the completion of the study.

METHODS

Seven trap lines have been established; the lowest traverses the forest/pasture margin, the highest traps the alpine scrub zone (Fig. 1). The upper lines run between two adjacent ridge systems and all lines are aligned so as to intersect the numerous forest-to-pasture possum runs. Two hundred and fifty wire-mesh, live-capture traps are permanently positioned on sites with favourable possum sign. These traps have been set for three fine nights per month since August 1975, and produce monthly catches of between 250 and 350 animals.

Newly captured animals are anaesthetised with ether, identified with an ear tag and tattoo number on the inner ear, then weight, length, reproductive status and condition of teeth are recorded. On subsequent captures we weigh animals and determine their reproductive status without using anaesthetic. Non-kill snares have also been set in the lower regions of the hill at different times.

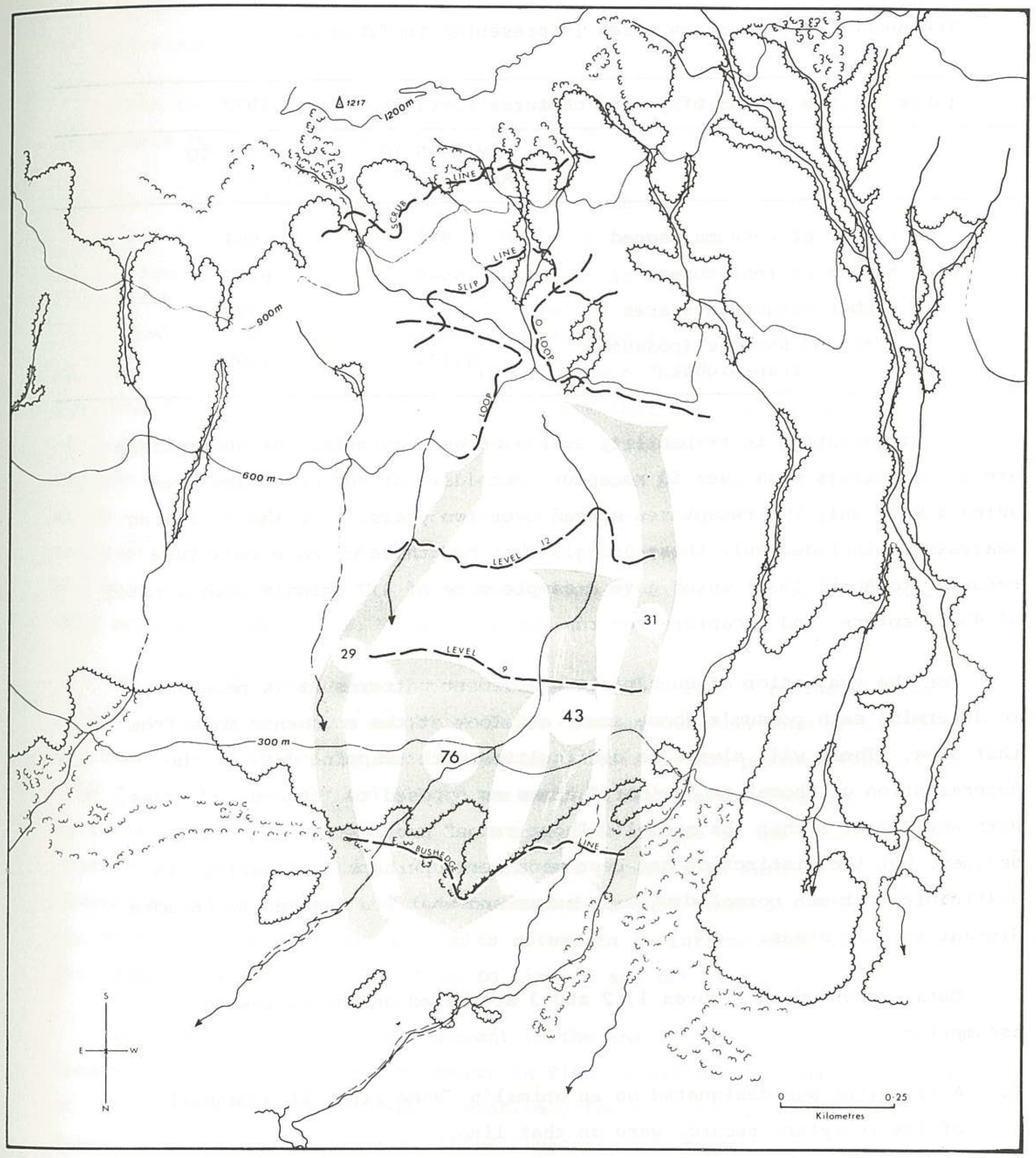

Fig. 1. Percentages of forest-dwelling possums trapped at least once on pasture on the bush edge line. Arrow widths are proportional to total catch and also to Fig. 2 arrows.

RESULTS

The number of possums captured is presented in Table 1.

Table 1. The number of possum captures May 1975-October 1977

		MAY 1975 TO APRIL 1977	MAY 1975 TO OCT 1977
Number of possums tagged	=	877	964
Number of recaptures	=	4545	6237
Number caught in snares	=	177	177
Trapping success (possums/ trap/night)	=	0.376	0.390

Great variation in trapability exists between animals. At one extreme are a few animals with over 50 recapture records; at the other are some animals with only two recaptures spread over two years. For the following analysis we included only those animals that had three or more recapture records (to April 1977) which gave a sample size of 412 animals with a total of 4521 capture and recapture records.

For the evaluation of bush/pasture movement patterns it is necessary to determine each possum's "home area" and look at the movements made from that area. There will always be difficulties with trapping data in the determination of "home" or "primary" areas as opposed to "secondary" areas. Both would fall within the animal's "home-range" area as it is normally defined, but the distinction has been made here, perhaps arbitrarily, to distinguish between normal den site areas and what are assumed to be more distant feeding areas.

Data presented in Figures 1, 2 and 3 are based on the following assumptions:

1. A trap line was designated as an animal's "home line" if a majority of its recapture records were on that line.
2. Residents of the pasture-margin habitat appear to feed in the vicinity of the pasture and are unlikely to venture long distances into the forest. At the same time many forest nesting animals are likely to forage down on the pasture. Consequently forest residents are more likely to be caught in pasture traps than are pasture animals in the forest traps. Therefore, when recapture records for an animal were evenly balanced between two or more lines, the line furthest into the forest was designated the "home line". (Subsequent radio-telemetry data have supported this assumption.)

When the 412 animals had been assigned to "home lines" the distribution of animals per line was as follows:

Bush-edge and pasture = 96 Line 9 = 68
Line 12 = 81 O Loop = 51
J loop = 21 Slip line = 62
Scrub line = 33

Downhill movements of possums are presented in Fig. 1, uphill movements in Fig. 2. The pool of animals assigned to each "home line" was considered in turn and the number of animals from that line that had been caught, at least once, on each of the other six lines was calculated. These numbers are expressed as percentages in Figs. 1 and 2, or can be estimated since the width of the arrows in the figures are proportional to each other. It is important to stress that Figs. 1 and 2 do not give frequencies of movements but only a minimum estimate of the proportion of animals from any given line that moved, at least once, to other lines.

Thus Fig. 1 shows that of the animals for whom line 9 is their "home line", 76% have also been caught at least once on the bush-edge or pasture. The remaining 24% have not been caught any closer to the pasture than on line 9. Similarly, 29% and 31% of the animals that have J loop and O loop as their respective "home lines" have also been caught on the bush edge or pasture. Since our primary interest in this paper is in bush-to-pasture movements, Fig. 1 shows only the movements from each "home line" down to the bush-edge/pasture traps and omits movements to intermediate lines; for example, movements from O loop to line 12 are not shown.

Despite the difficulties inherent in the analysis of trap data some interesting comparative points emerge in Figs. 1 and 2. The "magnet effect" of the pasture is most obvious; relatively few possums in the low or mid forest are captured above their "home lines" compared with the larger proportions that travel down to the pasture. We have even caught two of the 60 "slip-line animals" in pasture traps (not shown in Fig. 1). The pasture feeders from the low-forest area (Level 9, Level 12) are moving 400-700 m from their den site areas. Pasture feeders from the mid-forest J and O loop areas have to cover, on average, 1200 m ground distance and a vertical drop

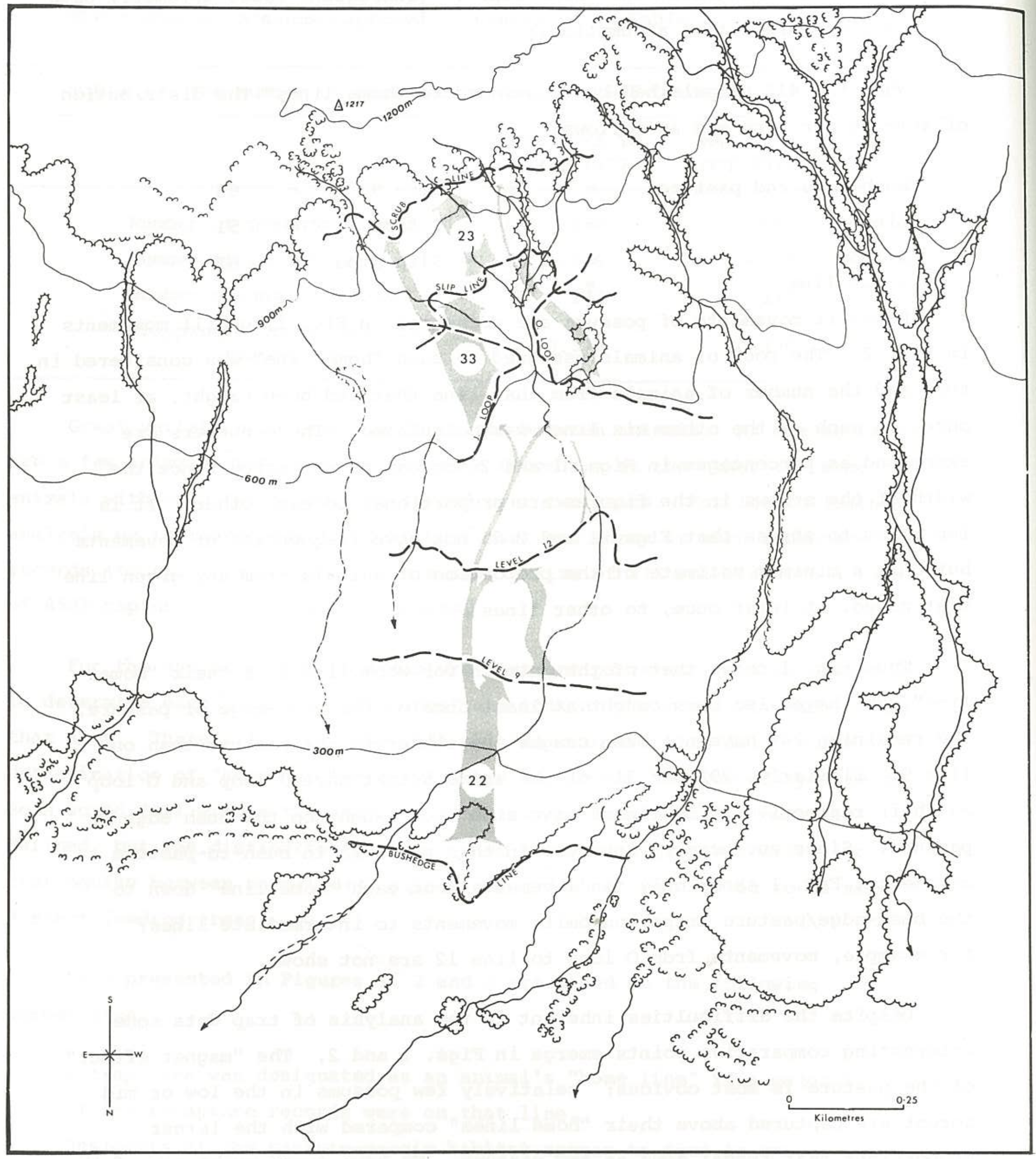

Fig. 2. Percentages of possums trapped at least once on lines deeper into the forest than their "home line". Arrow widths are proportional in Figs. 1 and 2.

of 350 m during their travels to the bush-edge. As these animals generally return to den sites the same night then the total distance for one pasture feeding excursion may exceed 2.5 km through mature rata/kamahi forest and some dense cutover vegetation adjacent to the bush-edge.

Two features of the uphill movement patterns are worth comment. First, the low occurrence of uphill movements when compared with downhill movements has already been mentioned. Secondly, there is a virtual absence of uphill movements in the mid-forest zone, particularly by Level 9 and Level 12 possums. One explanation for this discontinuity may be that dietary requirements of low-forest animals are fully met by species in their immediate or pasture environment.

The recapture data can also be used to give some indication of the *frequency* of movements between lines whereas Figs. 1 and 2 only show the *proportion* of animals that move between lines. Hence Fig. 1 suggests 76% of level 9 animals forage out onto pasture but does not indicate if these animals travel to pasture every night or once a month. An estimate of movement frequencies was obtained by summing the capture/recapture records for resident animals of each "home line" and calculating the percentage of captures that were made on other lines. The results for bush to pasture movements are shown in Fig. 3 by the solid arrows; dotted lines give Fig. 1 data for comparison. The pattern for uphill movement changes in a similar manner and is not presented here.

Frequency data suggest the amount of travel between lines represents 10%-25% of the activity of possums that make such moves. As might be expected O and J loop animals are less likely to travel to pasture when compared with Level 9 and 12 animals. Only if possums are equally trapable in both "home line" areas and pasture areas will these data accurately reflect the frequency of travels to pasture. Further analysis of trap data does not test this assumption and only through methods such as radio-telemetry tracking can we begin to resolve the problem.

DISCUSSION

Preliminary investigations of the foraging movements of possums on Mt Bryan O'Lynn suggest quite different patterns exist for peripheral and deep forest-dwelling animals. While the majority of possums denning within 700 m of adjacent pasture make frequent return forages out to the pasture

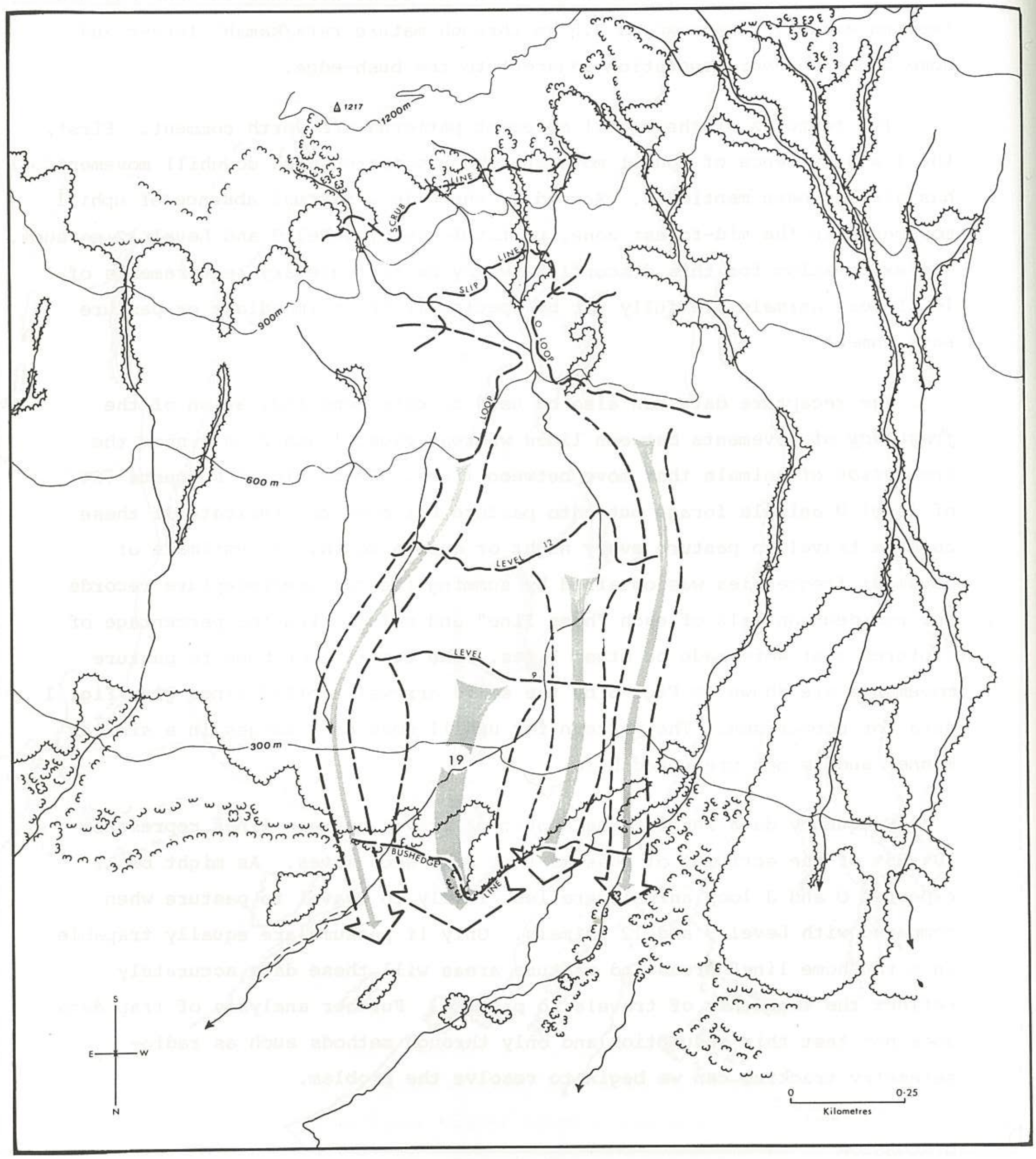

Fig. 3. Captures made on pasture or the bush edge line as a percentage of all capture records for forest-dwelling possums. Arrow widths are proportional; Fig. 1 data are given by dashed arrows for comparison.

and back, other possums denning between 700 and 1200 m from the pasture come out less frequently. Possums denning in deeper forest rarely make such extended journeys and in contrast to possums denning near to pasture, have local home ranges. Overall, there is a great deal of individual variability in the foraging patterns of possums; a few animals nest within 300 m of the pasture and yet ignore it, while a few that den between 700 and 1200 m seem to feed on the pasture almost every evening.

Direct comparisons with other published movement studies should be treated cautiously. Winter (1963) worked in a forest remnant habitat close to urban areas and estimated range sizes of 1.1 ha for males and 2.1 ha for females, but recognised that these were underestimates because of movements into surrounding scrub areas. In an area of indigenous forest in the Orongorongo Valley Crawley (1973) estimated that range sizes were slightly smaller; around 0.9 ha for males and 0.6 ha for females. Crawley also gives figures for the average distances moved from the initial point of capture. For males 95% of the movements were less than 115 m; the corresponding value for females was less than 90 m. Dunnet (1956, 1964) reported larger range areas, 3 ha for males and 1 ha for females, in open eucalypt forest near Canberra. These values are similar to Jolly's (1976) estimates for a Banks Peninsula population (males, up to 3.6 ha, females, up to 1.2 ha) in a mixed pasture, bush and scrub habitat.

The Bryan O'Lynn population is a markedly more mobile population than any previously studied; especially when the animals within 700 m of the forest/pasture margin are considered. Range movements are five to ten times longer than those for Orongorongo Valley animals (Crawley 1973) and home range areas are several times larger. Jolly (1976) reports range movements for males that approach the corresponding values for Bryan O'Lynn animals, but in a habitat of widely scattered food sources. In fact, previous workers had not studied populations occupying indigenous forest adjacent to pasture, despite the ubiquitous nature of this habitat throughout New Zealand. The disparities in movement between the populations in these various studies exemplify, once again, the remarkable adaptive abilities of the possum to a diversity of habitats.

The striking difference in mobility between the Orongorongo and Bryan O'Lynn animals in indigenous forest might be explicable entirely in terms of the attraction of the pasture forage at Bryan O'Lynn. However, just as colour and size differences distinguish these two populations, so might more subtle genetic differences be having an effect on the behavioural responses of the respective populations. There are no data to test this hypothesis at present.

Radio-telemetry studies are now underway on selected Bryan O'Lynn possums which will contribute significantly to our further understanding of movement patterns. Nonetheless we can suggest, with some confidence, the width of the zone that will require control in forest/pasture margin situations. Elimination of a majority of the pasture foraging animals should follow from a control operation on a 1200 m wide forest zone starting at the pasture margin. Successful control of this zone would create a buffer zone between stock and the deep forest possum population. The long-term effectiveness of this buffer zone will depend on the rate of reinvasion of the area from peripheral possum populations and on the amount of dispersal and successful establishment by sub-adult animals from the deeper forest.

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GENERAL DISCUSSION

PRACY. Am I right in assuming that you accept that the habitat was a good one with good condition animals?

GREEN. Yes, certainly the animals were in good condition for their mean weight was 3 kg or more, and many males weighing 4 kg were caught. The condition of animals varied with their position on the hill. Those in the middle region tended to be in poorer condition than those nearer the pasture edge. I would say the habitat is good at this stage compared with many other West Coast areas nearby.

PRACY. Would this be in relation to food availability?

GREEN. Yes.

PRACY. The reason I asked the question is that it is not uncommon for established possum populations to move distances of 1 km or more from forest to pasture margin, but I have never seen it with a colonising population.

GREEN. Clearly the food supply has changed a great deal from the peak population time. I am not suggesting it is as good as it used to be, but to the eye there is still a great amount of greenery which we normally class as palatable.

MORIARTY. Would you be prepared to guess how frequently a possum might journey down to the pasture and back again?

GREEN. We certainly have had some animals in the mid-hill zone caught on the pasture edge and then up in their forest area two nights later - some 1200 m away. Whether they do it nightly or whether they 'stopover' I cannot say until we have done radio-telemetry work. I would not be surprised if some do it nightly.

YOUNG. You have not opened up tracks on the slope which would facilitate possum movement?

GREEN. No, only in the alpine scrub zone did we actually cut a track. We have been well aware of the danger of influencing movements through cutting tracks. We have not really opened up the understorey to any extent.

WODZICKI. Many of your possums are coming to the grass, which is a renewable crop, and you actually find that they do not do much damage. What would be their range inside native forests? Do they do the damage they might have been expected to do had they not moved but had remained in their one area of native forest?

GREEN. It is a difficult argument because one would have to show that the numbers would be as high if there was no pasture. If there was no pasture then presumably it would be a more difficult habitat for them and numbers might be therefore lower. So I cannot follow that argument through to say that if they did not have the grass they would be wiping out all the forest.

B.D. BELL. In the Orongorongo study we have no evidence of such long movements in the adult animals. For 3½ years we trapped possums in two lowland forest areas on river terraces some 3 km apart and there was no evidence of lateral movement between areas. There is some evidence of dispersal by younger animals, of both sexes, up to distances of

10.5 km. Within the forest study areas on reaching maturity the possums appear to settle into discrete home-ranges of a few hectares, perhaps making periodic excursions of only a hundred or so metres. We have little evidence of vertical movements from higher altitudes down to the river terraces, although only a little trapping has been carried out above our main study areas.

GREEN. This more sedentary pattern would suggest what? The drawing power of our pasture, or the food supply in the Orongorongo forest?

B.D. BELL. I think it likely that your pasture draws the possums down hill. In our area the Orongorongo river bed is relatively sparsely vegetated, and is possibly less of a draw being mostly visited by possums living in the immediate vicinity. However more extensive studies of movements would be worthwhile in the Orongorongos to clarify the situation.

AGE STRUCTURE AND MORTALITY OF POSSUM *TRICHOSURUS VULPECULA* POPULATIONS FROM NEW ZEALAND

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ABSTRACT

The age structure of samples of possums from 11 areas in New Zealand varied seasonally, mainly in response to the major birth pulse in May. Between May and September, 1-2 year-olds predominated in trapped or poisoned samples. Between October and early January, 6-12 months-old animals usually predominated. Animals under 2 years old provided the bulk of most samples. Of 2492 females aged by counting annual cementum layers on teeth, 4 reached the age of 14 years. On leaving the pouch, possums in the Orongorongo Valley, Wellington, had a life expectancy of about 6 years, mortality being lightest in the animals 2-4 years old. The average annual mortality rate of adult and subadult animals in the Orongorongo Valley was about 15%. Males outnumbered females in the 0-2 year age classes in 9 of 12 samples analysed and, in pooled samples, 0-1 year-old males outnumbered females by 135-100. This disparity is attributed to a greater proportion of males in the pouch and a trapping and poisoning bias in favour of males. Females increasingly outnumbered males in the over-7-year age classes. In the Orongorongo Valley 44% of natural deaths of adults and subadults occurred between June and August and the number of animals found dead or dying ranged from 4 to 62 in their best and worst years.

INTRODUCTION

Tyndale-Biscoe (1955) first investigated the age structure of common brushtail possum *Trichosurus vulpecula* populations. Using epiphysial fusion of the tibiae as a criterion he divided 120 Banks Peninsula animals into three age classes, the youngest of which were sexually immature and probably under a year old. Between May and August the proportion of 0-1 year olds fell from 48% to 23%. In one area with a history of severe trapping, young animals comprised one third of the sample whereas in another undisturbed area they comprised only 8% and those over 4 years comprised 55%. This implies that adult animals lived on average for more than six years (Tyndale-Biscoe 1975).

In 1953, 1449 possums were taken from the Orongorongo Valley, Wellington and, using tooth wear and skull sutures as an aging technique Kean (1975) estimated that 52.9% were over 4½ years old.

Pekelharing (1970) developed a reliable method for allotting possums to annual age classes based on the deposition of cementum layers of the molars. Earlier techniques could be misleading (B.D. Bell, A.J. White, unpubl.).

Throughout this paper, animals without an inner cementum layer on the lower first molar are classed as 0-1 year olds. More precisely their age lies between about 6 months, when they first leave the pouch (and are first liable to be poisoned, trapped or shot) until they lay down their first layer of cementum. This is customarily thought to occur at 12 months, but the first layer may be deposited from about 10 months onward (See Discussion). Summarising:

No cementum layer = 0-1 year old
1 cementum layer = 1-2 years old
2 cementum layers = 2-3 years old
etc.

This definition is necessary because some authors group results on another basis, e.g. Bamford (1972) divided his samples into "pivotal" age classes - a pivotal age of 1 including animals between six and eighteen months, a pivotal age of 2 including animals between eighteen and thirty months old, etc. Because of this, Bamford's results cannot always be incorporated into our analyses.

Since Pekelharing (1970) first developed his aging technique, several workers have sampled possum populations and analysed them according to this method. The samples are very uneven, having been gathered for various purposes. Some were gathered within a day or two, other samples accumulated over several years. Some came from a small area, others over large areas. Most were poisoned, trapped or shot; one sample was found dead or dying. Fragments of history or recent reproductive performance are known for some samples. Little of the information has been published, most of it appearing in internal government reports or student theses. Enough analyses have now been made to look for useful generalisations and to try to explain differences and similarities between populations.

Bamford (1972) aged 1356 possums from an area stretching 19 km along the north bank of the Taramakau River, Westland. 686 were taken in 1970 from 3 areas where he thought the possums were on the increase, static or in decline. He may have been right about the status of these populations but the age structure of the three populations is statistically homogeneous (chi square test) and affords no evidence of differences (Fig. 4a). An additional sample of 237 animals was gathered over the same ground a year later after it had been poisoned with aerially distributed chopped carrot impregnated with 1080 poison and another sample of 196 from an unpoisoned area. Bamford showed that one-year-old animals were significantly under represented in the poisoned sample ($\chi^2_1 = 4.8$, $p < 0.02$). Bamford suggested that, as the poison was laid when the young were still in the pouch (August), the sucklings may have succumbed to doses which left their mothers unaffected but passed to them in their mother's milk; or at weaning, the young may be possibly more susceptible to traces of 1080 than adults. Another possibility is that sublethal doses of 1080 stopped the flow of milk and the young starved to death.

Boersma (1974) poisoned, trapped or shot 1001 female and 1176 male possums over a large area of the Hokitika River catchment. Only the 213 males without cementum layers were aged. The females were divided into annual age classes. He found mortality was high in the first year of life and again increasingly so after the fifth year. Between 2 and 4 years his females enjoyed a low death rate. Earlier control programmes appeared to have left no mark on the age structure of the Hokitika animals.

Cook (1975) investigating the incidence of bovine tuberculosis among possums of the Hohonu Forest, Westland, estimated the ages of 1203 animals by dental cementum layers. He interpreted an excessive number of 7-8 year old animals as reflecting the introduction of tuberculosis to the area 7 or 8 years earlier.

Clout (1977) studied possums in young and old pine forest near Tokoroa and estimated the age of 244 animals excluding pouch-young. He interpreted the large proportion of 3-4 year-old males in one sample as reflecting the clearing and burning of the site 4 years earlier.

Crawley (1970) reported that the oldest of 218 possums, tagged and recaptured in the Orongorongo Valley between 1956 and 1970, was in her twelfth year.

Fraser (1979) working in the Copland Valley, South Westland, found that males dominated the younger age classes, females the older age classes.

SAMPLES

The following samples of possums have been included in this survey:

1. Hokitika River catchment, October-December 1970. After Boersma (1974).
2. Kapiti Island, June 1968. 56 animals were gin-trapped by commercial hunters in the bushed central part of the island along the Trig and McKenzie tracks, leading from Rangatira flats to the summit. These animals had been subject to moderate annual trapping for many years.
3. (a) Waitotara (6 km N.E. of Waverley, Wanganui) July-October 1970. Control operations had been withheld on this farm of 242 ha for at least two years previously as the Patea-Waitotara Pest Destruction Board was conducting a mark-recapture trial there. But in 1970 the Board attempted to exterminate possums with prolonged and intensive poisoning, trapping and shooting. Most of the animals were killed in the first month (July) of this operation. The flat pastureland was intersected with scrub and bush-choked gulleys and, although 406 possums were taken from the farm, some survived in the more inaccessible cover.
   (b) Waitotara, 7-25 February 1974. The same farm was poisoned and trapped again and 88 possums collected.
4. Hohonu State Forest, Westland. Between January 1973 and February 1974, Dr B.R. Cook, livestock officer of the Ministry of Agriculture and Fisheries and Dr J. Coleman of the N.Z. Forest Service collected 2269 possums at two-monthly intervals. 1203 of these were aged by sectioning teeth. The animals were trapped and poisoned from pastureland at the edge of the bush to a distance of 3.6 km into the forest (Cook 1975).
5. Tokoroa, September 1974. Clout (1977) poisoned 111 possums in a 3-year-old pine plantation and aged the animals by sectioning teeth.
6. Tokoroa, December 1974. Clout poisoned 133 possums in a mature *Pinus radiata* forest, 10 km away from the young plantation.
7. Orongorongo Valley, southern Rimutaka Range, 16 km east of Wellington, 1970-1973. 103 possums found dead on the ground or dying in cage traps were collected from broadleaf-podocarp forest near the mouths of Greens Stream and Woottons Stream (see Crawley (1970)). These animals were found during a capture-recapture study running since 1966 (Bell, this symposium) and are presumed to have died of natural causes.
8. Tennyson Inlet, Marlborough Sounds, 1971-75. 68 possums were trapped over five years by Drs R. Bray and G. Struik in bush-covered hills.

9. Wainuiomata Valley, 26 February-5 March 1976. Officers of the Ministry of Agriculture and Fisheries poisoned 280 possums with cyanide along the bush edge bordering the southern Wainuiomata Valley, along the "5-mile track", and up the Peak and Dick Streams, Orongorongo Valley. These populations had been occasionally poisoned and trapped for many years.
10. Ashley Forest, North Canterbury, May 1975-May 1976. Warburton (1977) gin-trapped 472 possums in *Pinus radiata* forest at fortnightly intervals.
11. Copland Valley, South Westland, January-February 1978. Fraser (1979) sectioned teeth of 185 animals poisoned with cyanide.
12. Between 1966 and 1977, 670 adult or subadult possums were trapped, marked and released in 14 ha of bush adjacent to the DSIR field station in the Orongorongo Valley and most of these were recaptured at monthly intervals for several years (see Bell, this symposium). Detailed dossiers on many animals were built up. A sample of 100 males and 100 females, having been repeatedly recaptured over a three-year period, some time between 1966 and 1973, and therefore considered to be permanent residents in the study area, disappeared from the records or were found dead before 1973. Six years elapsed without further trace of these 200 animals so they are presumed to have died. The date on which they were found dead or the date of their last capture is noted in Table 6.

METHODS

A molar tooth was taken from the lower jaw by various authors, ground down, stained, and examined by X40 microscopy to reveal annual layers of cementum as described by Pekelharing (1970).

RESULTS

Table 1 summarises the age structure of samples collected in the Hokitika catchment (1970), Kapiti Island (1968), Waitotara (1970 and 1974), Hohonu Forest (1973-74), Tokoroa (1974), the Orongorongo Valley (1966-1974), Tennyson Inlet (1971-75), Wainuiomata Valley (1976), Ashley Forest (1975-76) and Copland Valley (1978). Table 2 summarises results obtained in the Taramakau Valley in 1970 and 1971 by Bamford (1972). Data from Tables 1 and 2, converted to percentage frequency of occurrence, are summarised in Figures 1-4.

Table 1. Age structure of possum populations. Data from the Hokitika River Catchment from Boersma (1974); from Tokoroa after Clout (1977); Tennyson Inlet from Dr R. Bray and G. Struik; Ashley Forest from Warburton (1977); the Copland Valley after Fraser (1979); Hohonu Forest from Dr B.R. Cook.

LOCATION AND DATE OF COLLECTION	SEX	YEARS OLD															TOTAL	MEDIAN AGE CLASS (YEARS)	SEX RATIO ♂ ♀
		0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 11	11 - 12	12 - 13	13 - 14	14 - 15			
Styx, Kokatahi and Toaraha Streams, Westland. October 1970	♀	92	55	52	43	34	34	15	11	4	8	4	4	0	0		356	2-3	1:1.20
Mungo and Hokitika Streams. November 1970	♀	24	27	23	20	26	16	18	13	6	4	1	2	1	1		182	3-4	1:0.99
Whitcombe Stream, frontal country between Kokatahi and Toaraha Streams and between Toaraha and Hokitika rivers. December 1970	♀	119	60	59	58	53	40	28	13	11	10	7	5	0	0		463	2-3	1:1.17
Kapiti Island. June 1968	♂	1	16	6	4	3	2	0	0	2	1	0					35	1-2	
	♀	2	5	4	4	3	0	0	1	1	0	1					21	2-3	1:1.67
	♂+♀	3	21	10	8	6	3	0	1	3	1	1					56	2-3	
Waitotara farmland. July-October 1970	♂	29	68	30	10	5	6	6	5	5	1	0	2				167	1-2	
	♀	21	60	52	27	22	14	14	9	5	7	4	4				239	2-3	1:0.70
	♂+♀	50	128	82	37	27	20	20	14	10	8	4	6				406	2-3	
Waitotara farmland. February 1974	♂	12	7	14	6	4	0	1	1	0							45	2-3	
	♀	11	6	9	4	4	3	3	2	1							43	2-3	1:1.04
	♂+♀	23	13	23	10	8	3	4	3	1							88	2-3	
Hohonu Forest, Westland January 1973-February 1974	♂	219	135	87	58	34	17	30	29	14	9	3	3	1	2	0	641	1-2	
	♀	136	92	76	57	36	34	29	36	24	14	13	8	4	1	2	562	2-3	1:1.14
	♂+♀	355	227	163	115	70	51	59	65	38	23	16	11	5	3	2	1203	2-3	
Tokoroa. Young pine plantation. September 1974	♂	2	13	10	17	12	2	2	0	0	1						59	3-4	
	♀	4	18	14	6	7	1	0	2	0	0						52	2-3	1:1.13
	♂+♀	6	31	24	23	19	3	2	2	0	1						111	2-3	
Tokoroa mature pine forest. December 1974	♂	24	7	6	4	5	5	3	2	1	0	1	0				58	1-2	
	♀	20	13	10	6	9	4	5	3	0	3	1	1				75	2-3	1:0.77
	♂+♀	44	20	16	10	14	9	8	5	1	3	2	1				133	2-3	
Orongorongo Valley, Wellington. 1966-1974	♂	6	5	4	2	7	9	1	6	3	2	4	3	3	1		56	5-6	
	♀	7	5	0	1	5	3	4	3	4	3	3	4	1	4		47	6-7	1:1.19
	♂+♀	13	10	4	3	12	12	5	9	7	5	7	7	4	5		103	5-6	
Tennyson Inlet Marlborough Sounds. 1971-75	♂	3	27	4	3	1	1	2	2	1	2	0					46	1-2	
	♀	4	11	3	2	0	0	0	1	0	1	1					23	1-2	1:1.20
	♂+♀	7	38	7	5	1	1	2	3	1	3	1					69	1-2	
Wainuiomata Valley farmland. February-March 1976	♂	24	56	16	12	13	11	10	8	2	2	0	0	0	0		154	2-3	
	♀	16	50	10	13	8	6	5	3	5	4	0	3	1	2		126	1-2	1:1.22
	♂+♀	40	106	26	25	21	17	15	11	7	6	0	3	1	2		280	1-2	
Ashley Forest, Canterbury. May 1975-May 1976	♂	95	81	29	12	17	10	8	6	3	2						263	1-2	
	♀	71	62	22	13	13	12	3	6	4	3						209	1-2	1:1.26
	♂+♀	166	143	51	25	30	22	11	12	7	5						472	1-2	
Copland Valley. January-February 1978	♂	19	17	16	16	5	7	3	3	1	2	0	0				89	2-3	
	♀	5	9	17	15	20	10	8	7	3	1	0	1				96	4-5	1:0.93
	♂+♀	24	26	35	31	25	17	11	10	4	3	0	1				185	3-4	

Table 2. Age structure of seven possum samples from the Taramakau Valley, Westland, 1970 and 1971. From Bamford (1972).

LOCATION AND DATE OF COLLECTION	SEX	"PIVOTAL" AGE IN YEARS													TOTAL	MEDIAN AGE (years)
		1	2	3	4	5	6	7	8	9	10	11	12	13		
Taramakau Valley, May-June 1970																
Block 1 "Declining"	♂+♀	32	27	24	23	22	18	16	10	5	4	2	0	1	184	4
Block 2 "Static"	♂+♀	52	46	38	39	26	19	15	10	5	1	2	2	0	247	3
Block 3 "Increasing"	♂+♀	57	39	35	20	24	18	13	17	7	10	4	3	0	255	3
Taramakau Valley, May-September 1971																
Block 1 (b)) Poisoned previous year	♂+♀	6	14	10	12	11	10	8	5	2	2	1	1	0	82	4
Block 2 (b)) Poisoned previous year	♂+♀	9	18	9	12	9	8	9	4	8	4	4	1	0	95	4
Block 3 (b)) Poisoned previous year	♂+♀	11	9	11	7	7	3	2	2	3	1	2	2	0	60	3
Block 3 (c) Not poisoned control area	♂+♀	37	36	28	30	21	17	12	5	1	4	2	3	0	196	3
Total		204	189	155	193	120	93	75	53	31	26	17	12	1	1119	4

The effect of the May birth pulse on age structure

Treating each sex as a separate subsample, six of the nine collections made between October and early February (at Hokitika, Tokoroa, Waitotara and Copland Valley) revealed a modal age of 0-1 year (Fig. 1a-1d). All but one of the 8 samples collected between late February and September revealed a modal age of 1-2 years - the exception being from the pine stand burned over at Tokoroa four years previously (Fig. 2a-d).

This change in the modal age of samples can be explained as the effect of the main birth pulse of May moving through the population. Animals born in May remain in the pouch until about September. Until that date they are classed as pouch-young and do not figure in these samples. From October to early February the 0-1 year-olds dominate most samples. In late February, a transformation apparently occurs as the first layer of dental cementum becomes distinguishable, that is, at the age of 10 or 11 months. From late February on, these over-ten-months-old animals, with their first distinguishable cementum line, are classed as 1-2 year-olds and their numbers dominate the age classes until September or October when a new crop of 0-1 year-olds displaces them as the modal age class.

Exceptions to this pattern (the 1974 male sample from Waitotara, the Sept. male sample from Tokoroa, and the female sample from the Copland Valley) which display unexpected peaks in the 2, 3 and 4 year-old age classes, are considered in the Discussion.

Sex-ratios in increasing age classes

Males outnumbered females in 10 of the 14 samples listed in Table 1 but their contribution to different age classes varied greatly. In 9 of the 12 samples, males dominated the 0-2 year age class.

Table 3 is based on nine pooled samples and reveals the males dominated the 0-1 year class by 100 females:135 males. The ratio rises to 100:141 if the large Hokitika and Hohonu samples are added. The 1-2 year-old class is also dominated by males (100 females:124 males). From the age of 2-9 years the sex-ratio remained about equal but, over the age of 9 years, females outnumbered males by 38:14, or 19:3 over the age of 10 years.

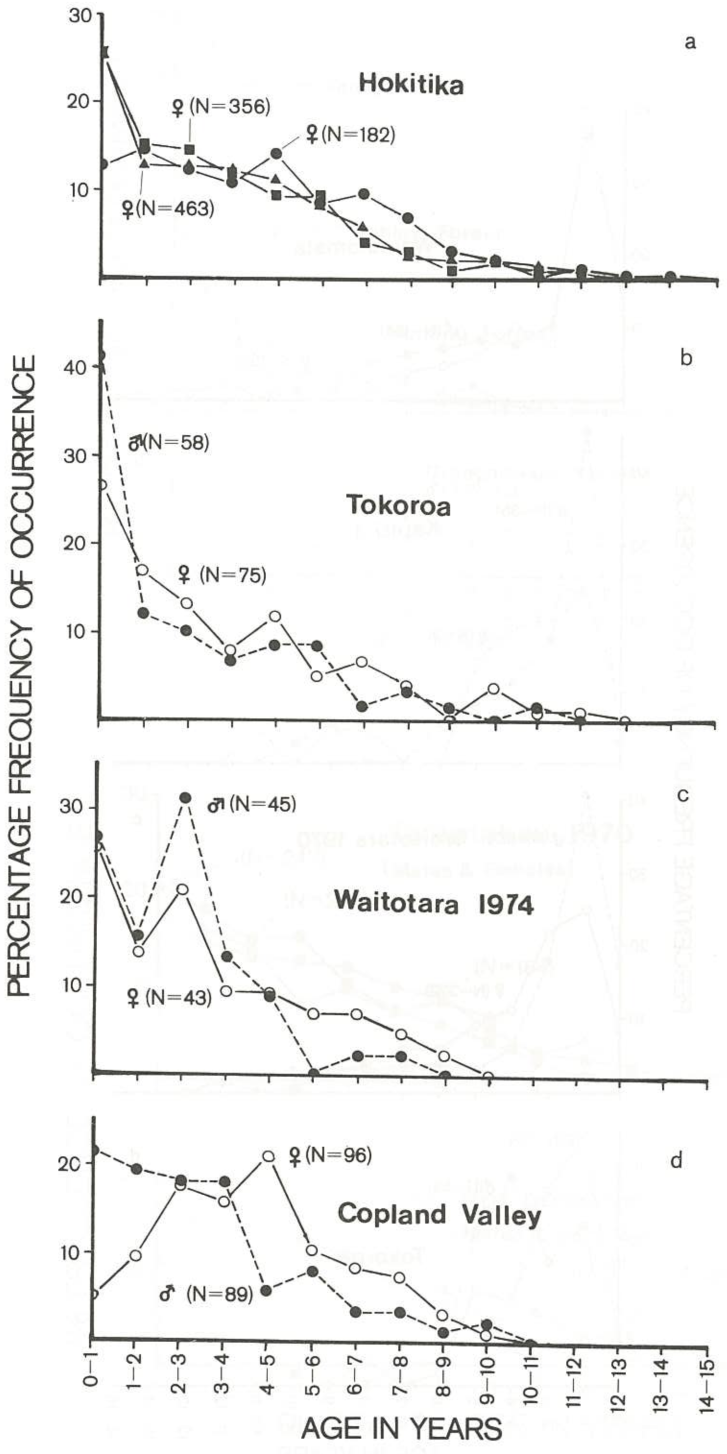


Fig. 1

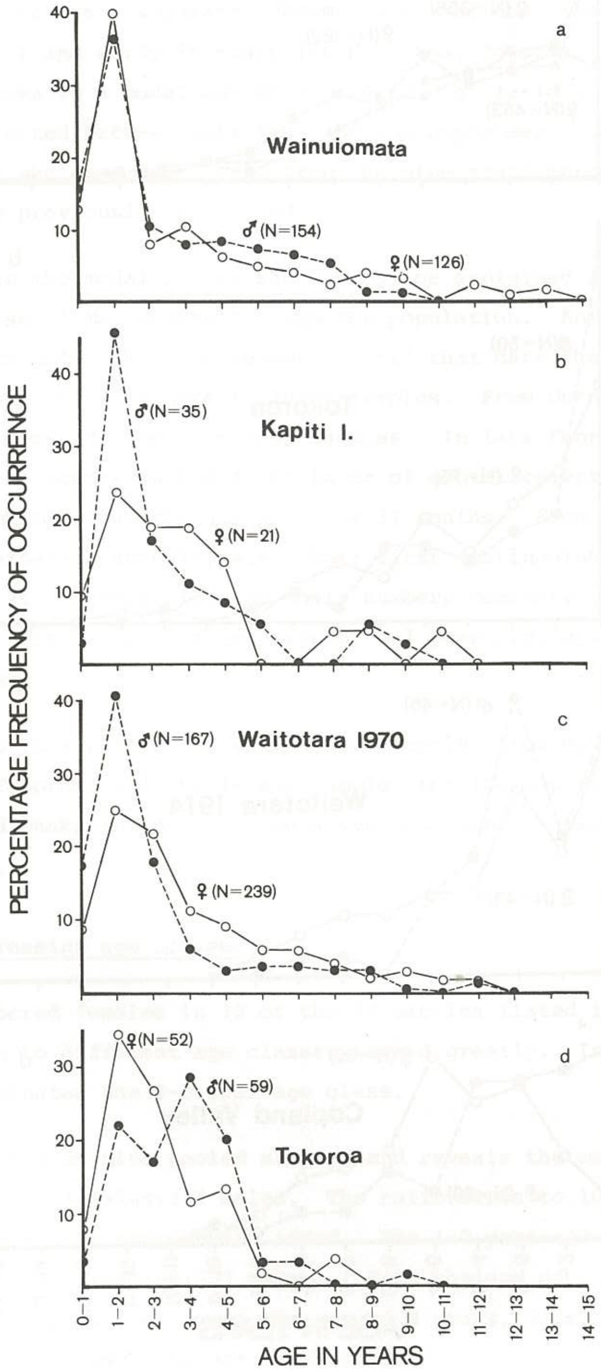
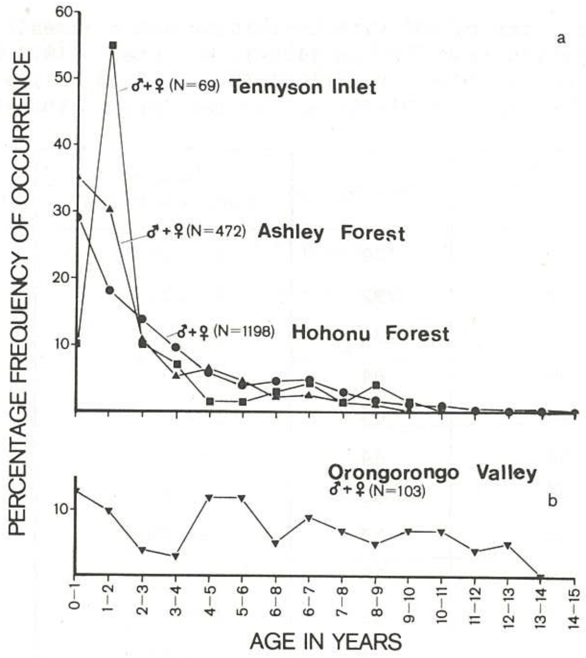
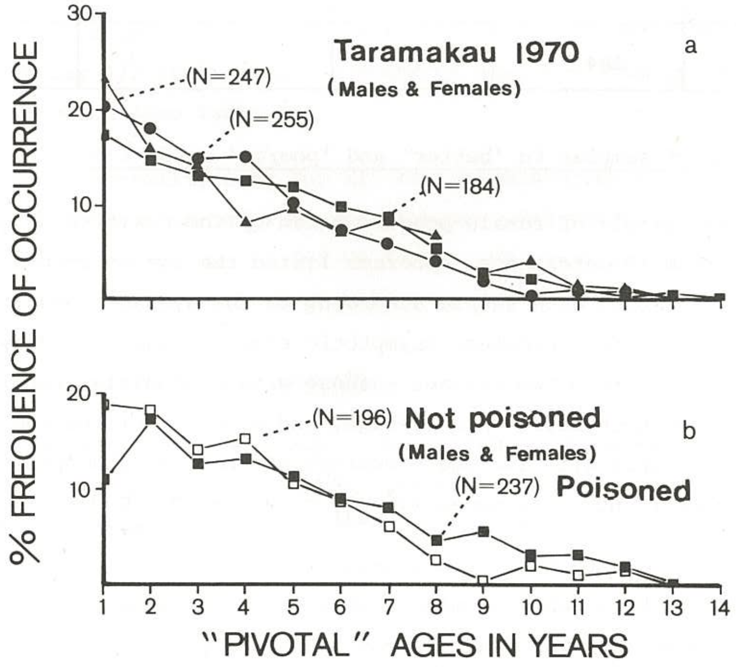

PERCENTAGE FREQUENCY OF OCCURRENCE
a
Wainuiomata
♂(N=154)
♀(N=126)
b
♂(N=35)
Kapiti I.
♀(N=21)
c
♂(N=167)
Waitotara 1970
♀(N=239)
d
♀(N=52)
♂(N=59)
Tokoroa
40
30
20
10
0–1
1–2
2–3
3–4
4–5
5–6
6–7
7–8
8–9
9–10
10–11
11–12
12–13
13–14
14–15
AGE IN YEARS

Fig. 2


PERCENTAGE FREQUENCY OF OCCURRENCE
a
♂+♀ (N=69) Tennyson Inlet
♂+♀ (N=472) Ashley Forest
♂+♀ (N=1198) Hohonu Forest
Orongorongo Valley
♂+♀ (N=103)
b
60
50
40
30
20
10
0–1
1–2
2–3
3–4
4–5
5–6
6–7
7–8
8–9
9–10
10–11
11–12
12–13
13–14
14–15
AGE IN YEARS


% FREQUENCE OF OCCURENCE
Taramakau 1970
(Males & Females)
a
(N=247)
(N=255)
(N=184)
(N=196) Not poisoned
(Males & Females)
b
(N=237) Poisoned
30
20
10
1
2
3
4
5
6
7
8
9
10
11
12
13
14
"PIVOTAL" AGES IN YEARS

Figs. 3 & 4

Table 3. Changing sex ratios with increasing age classes. Pooled information from Tokoroa (1974), Waitotara (1970 and 1974), Wainuiomata (1976), Kapiti (1968), Copland Valley (1978), Tennyson Inlet (1971-75) and Ashley Forest (1975-76).

Age class (years)	Females	Males	Ratio Females/Males	Statistical Significance
0- 1	154	209	1:1.35)	$\chi^2 = 7.1$
1- 2	234	292	1:1.24)	$p < 0.01$
2- 3	141	131	1:0.92	n.s.
3- 4	90	84	1:0.93	n.s.
4- 5	86	65	1:0.76	n.s.
5- 6	50	44	1:0.88	n.s.
6- 7	38	35	1:0.92	n.s.
7- 8	34	27	1:0.79)	
8- 9	19	15	1:0.79)	
9-10	19	11	1:0.57)	
10-11	7	1	1:0.14)	$\chi^2 = 4.166$
11-12	9	2	1:0.22)	$p < 0.05$
12-13	1	0	1:0)	
13-14	2	0	2:0)	
Total	884	916		

Age structure of samples in 'better' and 'poorer' condition

The large sample of female possums taken up the Hokitika River by Boersma (1974) came from 19 catchments. Boersma listed the age structure of each of the 19 samples and ranked each sample according to the average condition of the animals (based on fat reserves, asymptotic size, k, and fecundity). We have regrouped his data into two classes - those with a condition ranking above the average 9.6 and those below this average, and have calculated the age structure of each group (Table 4). The age structure of 'better' and 'poorer' samples showed no significant differences ($\chi^2_{(13)} = 19.62$; $P > 0.05$).

Table 4. Age structure of female possums from the Hokitika catchment, 1970. Animals in 'poorer' and 'better' condition compared. The condition was calculated on the basis of fat reserves, asymptotic size, k and fecundity by Boersma (1974).

Condition of possums	Years old														
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	Total
Animals in 'poorer' condition	95	35	51	45	50	32	24	14	7	6	5	2	1	1	368
Animals in 'better' condition	140	107	82	76	63	58	37	22	15	17	7	8	0	0	632

Life expectancy and survivorship

The 103 possums found dead or dying in the Orongorongo Valley between 1966 and 1974 form a useful mortality series. Converted to a life table (after Ilersic 1970) they reveal that, of 1000 animals which left the pouch, 47 could be expected to survive until their 13th year. The mean life expectancy on leaving the pouch was 6.2 years. At 3-4 years of age, the animals could expect to live another 5 years (See Table 5).

The mean annual mortality rate for all the animals which left the pouch is 14.9%. The mortality rate varied with age, however, 0-2 year-olds suffering a 11.1-12.6% loss; 2-4 year-olds a 3.9-5.0% loss; and animals over 4 years old losing 10.3-45.3% of their age class annually.

Annual and seasonal differences in mortality

Those resident adult possums known to have died or disappeared from the 14 ha study area of the Orongorongo Valley between 1966 and 1973 are listed in Table 6. Deaths and disappearances occurred more frequently in 1967 and 1968 than in the other years while very few animals died or disappeared during the warm winter of 1971. The number of resident animals found dead or disappearing from the study area fluctuated 15-fold (from 4 to 62) between the best and worst years.

Table 5. Life table of Orongorongo possums, based on 103 animals found dead or dying 1966-1974.

AGE IN YEARS	FREQUENCY OF OCCURRENCE	NO. OF SURVIVORS AT BEGINNING OF AGE INTERVAL OF 1000 BORN l_x	MORTALITY RATE NO. DYING IN 1 YEAR OF 1000 BORN d_x	YEARS LIVED BY ALL POSSUMS IN AGE GROUP	YEARS LIVED AFTER x	EXPECTATION OF LIFE OR MEAN LIFETIME REMAINING TO THOSE ATTAINING AGE INTERVAL e_x	% ANNUAL MORTALITY
0- 1	13	1000	126	937	6210	6.2	12.6
1- 2	10	874	97	825.5	5273	6.0	11.1
2- 3	4	777	39	757.5	4447.5	5.7	5.0
3- 4	3	738	29	723.5	3690	5.0	3.9
4- 5	12	709	117	650.5	2966.5	4.2	16.5
5- 6	12	592	117	533.5	2316	3.9	19.8
6- 7	5	475	49	450.5	1782.5	3.8	10.3
7- 8	9	426	87	382.5	1332	3.1	20.4
8- 9	7	339	68	305	949.5	2.8	20.1
9-10	5	271	49	246.5	644.5	2.4	18.1
10-11	7	222	68	188	398	1.8	30.6
11-12	7	154	68	120	210	1.4	44.2
12-13	4	86	39	66.5	90	1.0	45.3
13-14	5	47	47	23.5	23.5	0.5	-
Total	103	6710	1000	6210		$\left(\frac{\Sigma d_x}{\Sigma l_x}\right) = 14.9$	

Table 6. Possum mortality. Seasonal and annual distribution of possums found dead or dying and resident animals known to have disappeared permanently from trapping grids in the Orongorongo Valley, Wellington.

YEAR		J	F	M	A	M	J	J	A	S	O	N	D	TOTALS	
1966	♂									2	1	1	2	6	8
	♀											1	1	2	
1967	♂	1	2	1	6	2	3	3	3	1	1	3	2	28	46
	♀	1	3		3	1		2	3	2	1	2		18	
1968	♂	3	3	1	3		3	10		3	1	1		28	62
	♀	3	2		5		6	5	6	2	2	2	1	34	
1969	♂	2			1			2	1	1			1	8	17
	♀	1		2	1				3	1			1	9	
1970	♂					2	1	1	2	3				9	16
	♀				1	2	2				1		1	7	
1971	♂						1			1				2	4
	♀	1					1							2	
1972	♂		2			2	4	2	2			1		13	33
	♀		1				3	7	3	4	1		1	20	
1973	♂						1	2	2				1	6	14
	♀		1				1	3	1	1			1	8	
TOTAL	♂	6	7	2	10	6	13	20	10	11	3	6	6	100	
	♀	6	7	2	10	3	13	17	16	10	5	5	6	100	
TOTAL		12	14	4	20	9	26	37	26	21	8	11	12	200	
		SUMMER (Dec-Feb)			AUTUMN (Mar-May)			WINTER (June-Aug)			SPRING (Sept-Nov)				
		♂ 19		♀ 19	♂ 18		♀ 15	♂ 43		♀ 46	♂ 20		♀ 20		
			38			33			89			40			

Over the eight-year period, the greatest number of deaths occurred in July and fewest in March. Seasonally, 44.5% of deaths and disappearances occurred in winter, 20% in spring, 19% in summer and 16.5% in autumn.

DISCUSSION

Sampling distortions

The samples considered in this paper were collected in many ways and for diverse purposes. They present a heterogeneous base on which to build any sort of speculative analysis. The main inadequacy is that we know little or nothing of the stability or instability of the populations.

Collections of possums made over several months or years, although useful for investigating, for example, age-specific fecundity or the life expectancy of older animals, are of little use in reconstructing the recent history of the population. So many events and processes, acting separately or in concert, overtake the population during the period of collection as to make interpretation difficult or impossible.

'Instantaneous' samples make it possible to date the effect of recent events on the age structure with some accuracy.

The patterns of age structure were more regular in the female than in the male component in most samples. Males showed greater variations from the expected patterns, presumably because they were less sedentary than the females and because of their greater vagility - young males probably moved quickly to fill depopulated areas and distorted samples because they were more vulnerable to traps, poisons and guns.

Seasonal change in age structure

Two main patterns of age structure have emerged - that prevailing from October to early February, with a predominance of 0-1 year-olds, and a late February to September pattern, with a modal age of 1-2 years.

The 'February' transition comes unexpectedly early as the main birth peak for most New Zealand possums occurs in May (Brockie *et al.* 1979) and animals should not graduate into the 1-2 year class until May of the following year. The Wainuiomata sample (Fig. 2a) shows that the bulk of the animals had developed their first layer of dental cementum by late February or early March when they were probably 10-11 months old; more known-age yearlings must be

examined to resolve this point and more field samples collected between February and May are required to date the transition in other localities.

Three notable exceptions to these age structure patterns require explanations. The Waitotara (1974) sample has a bimodal pattern peaking in the 0-1 year, and the 2-3 year age classes; and males in the Tokoroa sample of September 1974 have a peak in the 3-4 year age class. Clout (1977) explains the large number of 3-4 year old males in the September Tokoroa sample as being due to an influx of young males to fill gaps left by the clearing and burning operations 4 years earlier. The Waitotara animals were subjected to a drastic control program 3½ years previously and the large number of 2-3 year olds in the later sample is also probably due to the rapid influx of one-year olds to fill the gap. The Copland Valley males reveal the usual October-February age structure but the females are quite anomalous (Fig. 1d) with a predominance of 4-5 year olds - cf. 5 males and 20 females in this age class. Fraser (1979) does not attempt to explain this anomaly but it appears as though the population was disturbed in 1973 or 1974 and that it affected males more than females. Other possibilities are that few female young were produced in 1974-77, or that young females were subject to greater mortality than males during those years.

The large number (58.7% of males and 47.8% of females) of 1-2 year-olds from the Tennyson Inlet sample is not approached by any other sample. The trapped area consisted of a narrow strip of seaside forest at the back of which lay an extensive bushed hinterland. The high proportion of 1-2 year-olds probably resulted from the continued but light trapping over a small area, providing empty living space which was continually refilled with youngsters dispersing in from the hinterland. The ranger on Kapiti Island (Peter Daniel, pers. comm. 1978) reported a somewhat similar pattern. Over 18 months he shot some 130 possums near his house at Rangatira Flat. After the first 100 animals, almost every new animal shot was a young male.

Sex-ratio and age classes

The excess of males in the 0-2 year age class of most samples is probably caused by two factors:

1. Excess of males in the pouch.
   Caughley & Kean (1964) confirmed that males slightly outnumbered females in 908 possum pouches, in the ratio of 100 females:114 males.

2. Sampling bias. Young animals, especially young males, experience a dispersal phase in the first year or two of life (Dunnet 1964). Males also exploit a larger home-range than females (Ward 1978) so, moving more widely, are more likely than females to encounter traps, poison or spotlight shooters, a point also made by Fraser (1979).

Table 3 shows that females dominated all 12 age classes over the age of two years. Without further pooling the differences in the sex-ratio are too small to sway tests of statistical significance but their consistency is impressive.

Over the age of 9 years females dominate the pooled samples by 38:14 and by 19:3 over the age of 10 years. This excess of females in very old age classes is not exceptional in mammals. Dall sheep *Ovis dalli*, Orkney voles *Microtus orcadensis* and humans show the same tendency (Caughley 1966).

The high mortality rate of 2 year-old males may be attributed to the extra hazards they meet while dispersing and their continuing decline after the age of 3 years may be caused by their having to maintain a larger home-range than females with its attendant extra demands. Another possibility is that male possums share the kind of reproductive stress shown by the brown antechinus, *Antechinus stuartii*, which goes into a general decline after mating. The metabolic rate of the male *Antechinus* shifts up during the breeding season and the animals move into a negative nitrogen balance in April, unlike the females which remain in a positive nitrogen balance during the winter (Woollard 1971). Our records from the Orongorongo Valley and Kapiti Island show that most males lose considerable weight in the winter whereas females generally maintain or increase their body weight (see Bell, this symposium).

The greater longevity of females does not show up in the sample of animals dying natural deaths in the Orongorongo Valley, despite the four thirteen-year-old females. The small size of the over-eight-year-old samples precludes statistical tests of significance.

Mortality rate and life expectancy

The calculations on mortality rate and life expectancy of possums in the Orongorongo Valley (Table 5) give a spurious appearance of accuracy and may be wide of the mark because (1) the sample size is so small, (2) both sexes are run together in the calculations but there is every possibility that the sexes suffer differential mortality rates, and (3) the table assumes a constant population density before and during the period of collection. We have evidence, however, that possum numbers rose from about 7 to about 15 animals per hectare in 1972 and fell away again after that date (unpublished data). The calculations therefore give a clue to mortality rates and life expectancy but the details are open to question.

However, Boersma (1974), who also supposed his mixed samples were from a stationary population, obtained rather similar results. He calculated that females suffered high mortality in their first year, a reduced rate between their first and fourth years and an increased rate after the age of four. These similarities between very different populations perhaps give some plausibility to the calculations.

We must concur with Caughley (1974) that the age structure of possum populations is of little value in estimating whether a population is on the increase or decrease. Age-specific birth and death rates, the incidence of double breeding and spring births, the migration or dispersal of certain age classes, overwhelming degradation or improvements in the habitat, control operations, food crop successes or failures, and perhaps predation and disease, shape the pattern of age structure. Add to these factors the bias of most sampling methods and the usual demographic changes which overtake an animal population from month to month, and the hazards of interpretation become apparent.

Age estimation is nevertheless a valuable exercise as it throws light on the age of maturity, age-specific reproductive performance and mortality, the potential and actual rates of increase, the age-specific effects of diseases and control operations.

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GENERAL DISCUSSION

FORDHAM. Nearly four years after you had cleared the Waitotara population you still had animals of 4 years and more in the population. This suggests an ability to disperse is not restricted to one-year-olds. What do you know about the inequalities of these animals apart from that related to sex? Do you have data comparable to that collected from small mammal studies?

BROCKIE. We know rather little about these aspects of the animals we studied.

ANONYMOUS. Winter has got some information in his thesis about changes in the home-ranges of adult animals.

B.D. BELL. Much home-range data has been collected in the Orongorongo live-trapping study and I feel sure this could throw further light on differences and relationships between animals and on changes throughout the life-history of individual possums. Regarding the Waitotara kill in 1970, while it may have been quite a good one I do not think the population was entirely cleared, so there would presumably be residual animals of all ages left.

SPURR. I have also been looking at age structure between different possum populations. When you say that you have compared age structures statistically and do not obtain significant results, what do you mean?

BROCKIE. We tested statistically using χ^2 tests.

SPURR. Do you have age structure data for the live Orongorongo possums?

BROCKIE. We have a fairly good measure of the age structure of the resident animals but we have less information on the transient animals which pass through our study areas.

FITZGERALD. You suggested that by controlling one and two-year-olds you may make drastic inroads into your population if the animals are not in very good condition. I think this is a debatable point. A high fat index does not necessarily mean the animal is in good condition for all purposes. If you have animals in what we call 'not such a good condition' which will not breed until their second or third year, then by removing your one and two-year-olds you are not going to eliminate your breeding animals. So really the impact of such removals depends to some extent on the condition of your animals.

BROCKIE. Mine was a wide generalisation and I agree it may need qualifying along the lines you suggest.

FITZGERALD. Any inroads into the population would not be permanent would they?

BROCKIE. No.

FITZGERALD. So it would only be a temporary situation rather than a permanent control measure?

BROCKIE. Yes, you would have to come back in later years and do the same thing. Mind you, you might have fewer animals then.

KEBER. But with large scale movement and dispersal that may make up for any loss.

YOUNG. Auckland wouldn't believe that.

BROCKIE. It would depend on a variety of factors, including the scale of the operation. It would only work if you could work on a large area so that relatively few animals would be moving in.

YOUNG. I think we shall need a workshop discussion because we must differentiate between established animals and home-ranges as opposed to your first and second age class groups which are wandering and subject to greater mortality. The mortality younger animals suffer may only be because they cannot become established due to the adult population already there.

CUMMINS. I'm intrigued that a major controlling influence on the population seems to be the New Zealand winter. Has there been any research into the possible effects of for example the effects of detergents on thermo-regulation? I know this has been done in birds but it seems we might very well look at this in terms of the possum losses.

BROCKIE. I can't quite follow the mechanics of this.

CUMMINS. Detergents reduce the insulating qualities of the fur.

KEBER. There is no oil in the fur anyway so you would not be gaining much from it. The animals are very susceptible to wetting with water.

CUMMINS. So we need to increase the rainfall even more!

HATHAWAY. You mentioned a population of good-conditioned animals had a high mortality rate?

BROCKIE. Yes, this was the study of Boersma on the West Coast and referred to mortality in the first year of life.

HATHAWAY. Is it possible that your good-conditioned animals entered the ranks of the poor-conditioned animals after a hard year or winter? They swell the ranks of the poor-conditioned animals so this group appears to have high mortality but in fact there is a change in the composition of the population of good-conditioned to poor-conditioned ones.

BROCKIE. If I understand you right, that could be a possibility. My remarks regarding the West Coast study were an over-simplification. There are many catchments and tributaries to the Hokitika River. Some populations have been poisoned there for 10 years almost regularly while others have been poisoned occasionally, so there is a mosaic of different sub-samples.

BREEDING AND CONDITION OF POSSUMS *TRICHOSURUS VULPECULA* IN THE ORONGORONGO VALLEY, NEAR WELLINGTON, NEW ZEALAND, 1966-1975

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ABSTRACT

In possum populations studied in the Orongorongo Valley, near Wellington over 1966-75, 99% births occurred in late autumn or early winter (April-June); spring births were rare. Yearling females rarely bred and failed to rear pouch-young. Overall about 60% two-year-olds and 85% older females bred; both age groups reared just over half their pouch-young. Annual recruitment of young barely compensated for mortality of older possums. There was variation in female breeding success between two areas of lowland forest and in both the productivity was low compared with populations studied elsewhere.

In the main study area there was marked annual variation in breeding productivity correlated with changes in female body weight; in years of higher mean weight of females births tended to be earlier, more females bred and more of their young survived. This probably reflects annual variations in weather, food supply and possum density, although the interplay of the factors affecting the productivity and numbers of the possum population is not fully understood.

INTRODUCTION

The present paper is concerned with the recruitment rate of young common brushtail possums *Trichosurus vulpecula* into a population, how this relates to the age and physical condition of the female and, ultimately, to annual variations in density, climate and food-supply. Live-trapping data for the decade 1966-75 are the basis for this analysis. Previous information on the breeding biology of possums in the Orongorongo Valley is given by Kean (1959, 1967, 1971, 1975, unpublished), and by Crawley (1970, 1973) who initiated aspects of the present study over 1966-68. The investigation has continued since 1975 as part of a long-term study of possums by the Ecology Division of D.S.I.R.

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STUDY AREAS

Location

The study was carried out in the southern Rimutaka Range forests some 17 km S.E. of Wellington. Two study areas were selected along the middle stretch of the Orongorongo River where it runs N.E. to S.W. between steep ridges rising to 941 m in the east and 706 m in the west (Fig. 1).

The main study area (area A) also used by Crawley (1973) was on the east bank of the Orongorongo River between two tributaries - Brown's and Green's streams. Area A at 100-160 m a.s.l. extended over approx. 14 ha. of lowland podocarp-broadleaf forest mostly on gently sloping fan material and along the base of steeper slopes behind. The second study area (area B) covering approx. 12 ha. was in a broadly similar situation 3 km downstream of area A near Wootton's Stream at 70-120 m a.s.l. (Fig. 1).

Weather

Annual rainfall over 19 years in area A averaged 2420 mm, ranging from 1363 mm to 3662 mm. Rainfall is fairly evenly distributed over the year but with a maximum in winter and a minimum in summer. The mean winter and summer temperatures over 1969-71 averaged 6.7°C and 15.5°C respectively. The mean winter minimum was 2.8°C, frosts being unusual and generally light. The maximum summer temperature over 1969-71 was 32.1°C with a mean daily maximum of 19.4°C. (D.J. Campbell pers. comm.; Ecology Division, D.S.I.R. 1980).

Continuous weather records for 1966-75 were not available from the study areas so a measure of local weather trends over this period was obtained from rainfall and temperature data at Kelburn, Wellington (17.5 km N.W., 126 m a.s.l.) and on rainfall data from the Orongorongo Weir (7.5 km upstream of area A at ca. 240 m a.s.l.). Annual and seasonal weather trends are considered in the Discussion section of this paper (Tables 10 and 11).

Vegetation

The vegetation of area A outlined by Crawley (1973) is described more fully by Fitzgerald (1976). Comparative data from area B is based on a survey in January 1977 by A.E. Fitzgerald and J.A. Foggo, supplemented by personal observations (over 1970-75) and by information in unpublished Ecology Division reports (Waddington *et al.* 1980; R.E. Brockie, P. Cowan,

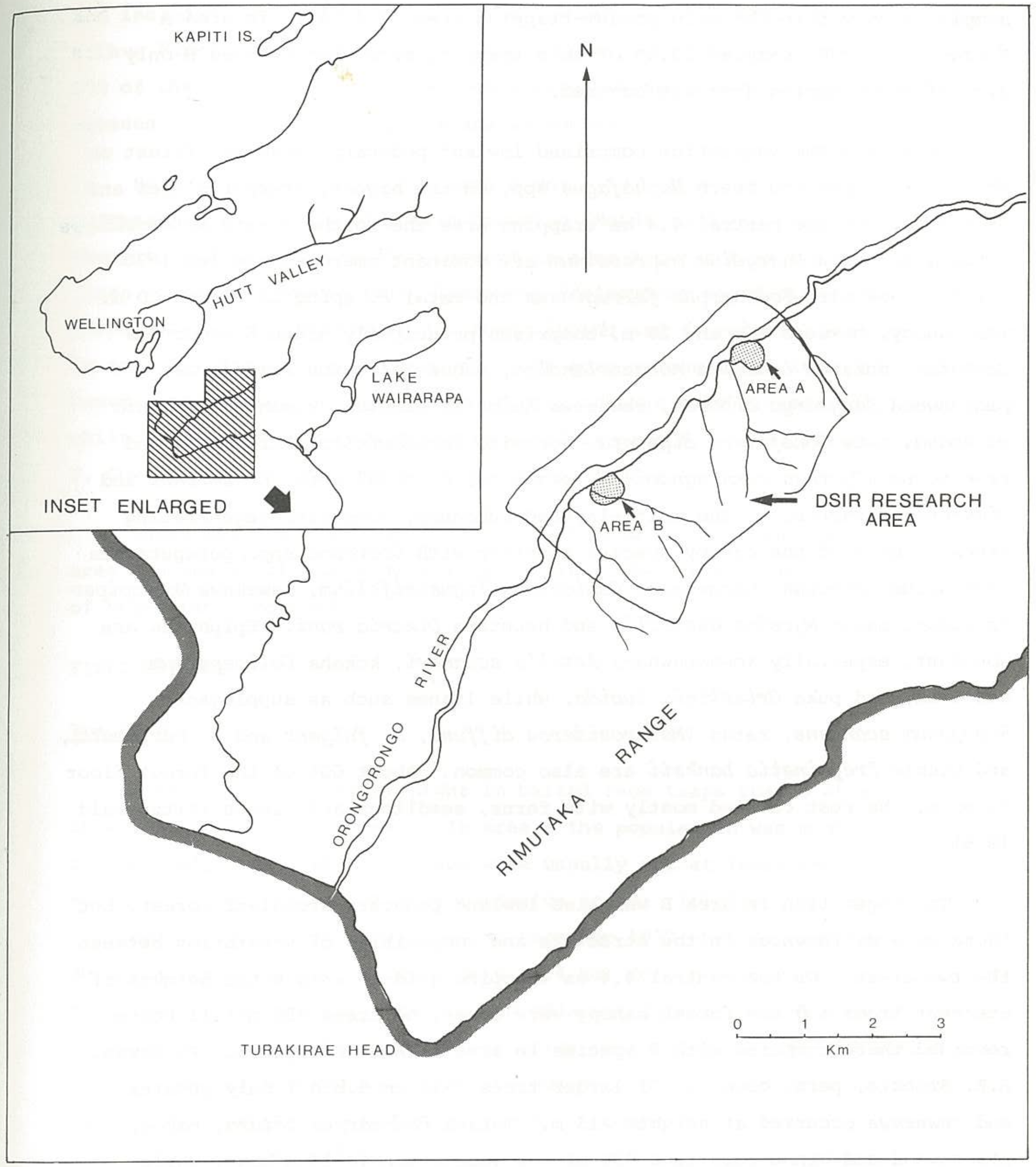

Fig. 1 Location map of the two study areas situated within the DSIR forest research area in the Rimutaka range, east of Wellington at the south end of the North Island.

A.E. Fitzgerald, pers. comm.). Vegetation surveys in each area were based on sample plots within the main possum-trapping area (4.4 ha); in area A Fitzgerald (1976) sampled 13.5% of this trapping area, but in area B only 3.3% of the trapping area was covered.

In area A the vegetation comprised lowland podocarp-broadleaf forest on the lower slopes and beech *Nothofagus* spp. on the higher, steeper slopes and on ridges. On the central 4.4 ha trapping area the northern rata *Meterosideros robusta* and rimu *Dacrydium cupressinum* are dominant emergent species (>30 m tall); some miro *Podocarpus ferrugineus* and matai *P. spicatus* exceed 20 m. The canopy, between 6 m and 20 m, comprises principally hinau *Elaeocarpus dentatus*, pukatea *Laurelia novaezelandiae*, mahoe *Melicytus ramiflorus*, pigeonwood *Hedycarya arborea*, rewarewa *Knightia excelsa*, kamahi *Weinmannia racemosa*, pate *Schefflera digitata*, horopito *Pseudowintera axillaris*, and tree ferns (*Cyathea cunninghami*, *C. dealbata*, *C. medullaris*, *C. smithii* and *Dicksonia squarrosa*). The multi-layered subcanopy comprises regenerating trees of most of the canopy species together with *Coprosma* spp., putaputaweta *Carpodetus serratus*, hangehange *Geniostoma ligustrifolium*, kawakawa *Macropiper excelsum*, mapau *Myrsine australis* and heketara *Olearia rani*. Epiphytes are abundant, especially kowharawhara *Astelia solandri*, kokaha *Collospermum hastatum*, and puka *Griselinia lucida*, while lianes such as supplejack *Ripogonum scandens*, ratas (*Meterosideros diffusa*, *M. fulgens* and *M. perforata*), and kiekie *Freycinetia banksii* are also common. About 60% of the forest floor is open, the rest covered mostly with ferns, seedlings and kiekie (Fitzgerald 1976).

The vegetation in area B was also lowland podocarp-broadleaf forest, but there were differences in the structure and composition of vegetation between the two areas. On the central 4.4 ha trapping grid in area B the heights of emergent trees and the forest canopy were lower, no trees >20 m tall being recorded there compared with 7 species in area A (A.E. Fitzgerald, P. Cowan, R.E. Brockie, pers. comm.). Of larger trees (>10 cm d.b.h.) only pukatea and rewarewa occurred at heights >15 m. Totara *Podocarpus totara*, mahoe, pigeonwood and hinau comprised 93% of the vegetation 10-15 m high, while mahoe, pigeonwood and kawakawa represented 79% of trees in the 5-10 m height class, other species including kaikomaka *Pennantia corymbosa*, kanuka *Leptospermum ericoides*, tawa *Beilschmedia tawa*, putaputaweta, totara, matai and miro. Kawakawa, pigeonwood and mahoe comprised the 2-5 m height class.

Epiphytes and lianes were conspicuous throughout the area B survey area and included puka and kokaha as epiphytes and *Meterosideros* spp., supplejack, kaihua *Parsonsia heterophylla* and kohia *Passiflora tetranda* as lianes. About 50% of the ground was vegetated comprising 30% seedlings, 51% ferns, 14% grasses, 3% nettle *Urtica ferox* and 2% mosses.

Northern rata occurred in area B until 1970 when the last tree died, presumably as a result of possum browsing (Meads 1976 and pers. comm.). Horopito and kamahi were also present in area A but not in area B, while hinau, heketara, mapau, pate, lemonwood *Pittosporum eugenioides*, nikau *Rhopalostylis sapida*, karamu (*Coprosma lucida* and *C. robusta*) were more scarce in area B. Species present in area B or more common there included totara, kanuka and nettle. Amongst lianes supplejack was more widespread in area A, while kaihua and kohia were only recorded in area B (A.E. Fitzgerald, P. Cowan, R.E. Brockie, pers. comm.; pers. obs.).

There was relatively more grazing and browsing by sheep and cattle in area B compared with area A, especially in 1970-71 when extensive trampling of vegetation occurred.

FIELD METHODS

Trapping

Possums were caught at night in baited cage traps spaced at regular intervals through the forest. In area A the population was monitored continuously over 1966-75; traps were usually set at least one night per month, with two periods of more intensive study: (i) 1966 to 1968 described by Crawley (1973); (ii) May 1970 to December 1973 when 64 traps were set at 30 m intervals on a 210 x 210 m grid (4.4 ha) for four successive nights each month, with supplementary trapping in adjacent forest for 2-4 nights every 3-4 months. In area B a parallel trapping regime to that used in area A was adopted, 64 traps being set on the ground on a 210 x 210 m grid during the same nights each month from June 1971 to December 1973, (then less intensively until September 1974).

Animal examinations

To facilitate examination and measurement, many possums were immobilised using succinylcholine chloride (Taylor and Magnussen 1965); others, mostly retrapped males, did not require detailed examination at each capture so were simply identified, weighed and released. Free-ranging possums were individually marked with a numbered tattoo and a fingerling tag in the ear; pouch-young up to about 30-40 days were too small to mark; from then until about 90 days they were marked by cutting small notches in up to three positions on the ear margin; from about 80 days they could be ear-tagged; they were not ear-tattooed until they were free-ranging (>170 days).

Animals were weighed on at least the initial capture each trapping-month and only this initial weight was used in the present analysis. Those immobilised were measured externally following Lyne and Verhagen (1957): total length was taken by running a flexible tape mid-dorsally along the body contours from tip of tail to tip of snout. Pouch-young measurements comprised head length, tail length and, in smallest young, crown-rump length (Lyne and Verhagen, 1957); they were only weighed after they had voluntarily released the teat; except for smaller young, all were sexed, and when evident, fur-colour was recorded. During the potential breeding season (March-November) females were immobilised and examined every month, but at other times of year pouches were usually checked without drugging the animals.

ANALYTICAL METHODS

Only some of the conventions adopted in the analysis are outlined here; others will become evident in the Results section that follows.

Definition of seasons

Throughout this paper the following groupings of months into seasons are used: December-February = summer; March-May = autumn; June-August = winter; September-November = spring.

Age classes and age determination

Four main age-groups are differentiated in the analysis: (i) pouch-young; (ii) yearling; (iii) two-year-old; (iv) adult.

(i) Pouch-young

For analyses of pouch-young survival, the arbitrary end to pouch life was assumed to be 170 days, (although emergence from the pouch is a gradual process, Crawley (1970) noting ages of 137 and 175 days for earliest pouch emergence and latest pouch occupation respectively). While many young were seen with females beyond 200 days, the more

conservative limit of 170 days was chosen to minimise misinterpretation of records of absent young: through most of the pouch-life this was confidently assumed to be due to mortality, but increasingly during the 'back-young' phase absent young were found later again with their mothers, some even with foster-mothers (Bell 1974). The 170 days figure is based mainly on data from the study area, especially Crawley (1970), supplemented with those of Dunnet (1956), Lyne and Verhagen (1957), Gilmore (1966), Smith *et al.* (1969), How (1974) and Kean (1975).

Birth dates were estimated by aging pouch-young on head length and/or tail length measurements using linear regression lines from a sample of newly born young measured at intervals during their pouch-life (Crawley 1970, Bell, unpubl.). For head length and tail length the length (Y) on age (X) regressions[1] were, respectively: $Y = 0.3430X+7.1736$ and $Y = 0.7984X + 2.6113$; age (X) was determined using the reciprocal of Y on X following Simpson, Roe and Lewontin (1960).

(ii) Yearlings

These are animals in the first calendar year after their year of birth, representing ages from about 7½ to 19½ months. Each year newly caught yearlings were identified by comparing their body measurements with those of known-age yearlings known as pouch-young the previous year. The term 'juvenile' was also occasionally used to designate those young caught alone at the end of their year of birth prior to their entering the 'yearling' age-class in January.

(iii) Two-year-olds

These are animals in the second calendar year after their year of birth representing ages from about 19½ to 31½ months. Most (89%) were formerly trapped as yearlings; the rest were aged by comparison with body dimensions of known two-year-olds.

(iv) Adults

Adults comprise all possums approx. 2½ years or older, i.e. those in the third calendar year after their year of birth onwards. This amalgamation of all adult year classes was necessary since in the initial phases of the

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[1] For head length on age regression: sample size 23, standard error of estimate 2.0879, correlation coeficient 0.9941 ($p<0.001$); for tail length on age: sample size 18, standard error of estimate 2.9731, correlation coefficient 0.9948 ($p<0.001$). The head length regression was based on young up to 170 days old, the tail length regression on young up to 100 days old.

study none could be aged more precisely. Twelve females caught as either two-year-olds or adults could not be aged with confidence on body measurements so were excluded from analyses involving age.

Female breeding histories

Analysis of life-history records enabled investigation of female breeding histories. The amount of information per female per year depended largely on her capture rate. Overall, breeding histories of 268 area A females and 108 area B females were checked. Since many possums were caught over successive seasons a combined total of 1,067 breeding histories was compiled, comprising 854 from area A (1966-75) and 213 from area B (1971-74). Higher capture rates enabled good documentation of breeding for 421 histories (49.3%) in area A and 101 (47.4%) in area B; less complete breeding data were obtained for a further 230 (26.9%) histories in area A and 51 (23.9%) in area B; for the remaining cases (203 area A, 61 area B) the breeding performances could not be assessed since captures were too infrequent.

Females of known breeding history were categorised as:

(i) non-breeders (those evidently having no pouch-young);
(ii) those having young but losing them before 170 days;
(iii) those successfully rearing pouch-young over 170 days.

RESULTS

Seasonal distribution of births

In the Orongorongo Valley most births occur during April-June (Fig. 2) as noted by Kean (1971, 1975) and Crawley (1973), the mean date of birth for 494 pouch-young over 1966-75 being 15 May (median 18 May). Only 3 births (0.6%) were recorded in spring (i.e. after 1 September). During 1971-74 mean birth dates in areas A and B were 15 and 13 May respectively, and were not significantly different.

In both study areas females raising pouch-young had earlier mean birth dates than those which lost their young. However while the differences were significant in area A (dates 13 May and 1 June, $t = 6.451$, $p<0.001$), they were not so in area B (dates 6 and 14 May).

Mean birth dates for yearling and 2 year-old females were later than for those 3 years old and over.

Number of young

Females gave birth to only single young and no twins were recorded; Kean (1971) found only one set of evident twins during 1946-61 out of a sample of 8,000 Orongorongo females. In October-November 1972 two females carried fostered young in their pouches in addition to their own progeny (Bell 1974); all four young were furred, weights of the progeny being 220 g and 258 g compared with corresponding weights of 150 g and 230 g for fostered young. No cases of double-breeders, as reported for other areas (Kean 1971), were detected during 1966-75; but one was recorded in area A in 1978 (R.E. Brockie, pers. comm.).

Breeding success

Overall trends

In general most females gave birth to young each year (Table 1), and the birth rate over 1971-74 was not significantly different between the two areas ($\chi^2_1 = 3.1810$, $0.10>p>0.05$). Many young died in the pouch. Over 1971-74 the survival rate in area B (42%) was significantly lower than in area A (58%) ($\chi^2_1 = 4.1489$, $p<0.05$).

The timing of the disappearance of pouch-young was estimated very approximately as the mid-point between their last sighting and the date the pouch was first found prematurely empty; mean dates were 7 September (area A) and 17 August (area B), while corresponding mean ages of young (±S.E.) were 95.4 ± 3.5 days (n = 107) and 97.9 ± 7.7 days (n = 33).

The estimated rates at which young surviving the pouch-phase were produced (i.e. birth rate x survival rate) were only 38% and 33% for areas A and B respectively. So although most females had young, their final productivity was low compared with some other reports (e.g. Dunnet 1964, Kean 1971).

Grey-coloured females predominated over blacks in area A (60:40) but not in area B (46:54); the difference between areas was significant ($\chi^2_1 = 5.8615$, $p<0.05$). There were no significant differences in the measures of breeding success of the two colour morphs (χ^2_1 0.000 to 0.5109).

Age and Breeding success

The ages at which females first produced young were determined for 41 animals of known age and breeding history in area A:

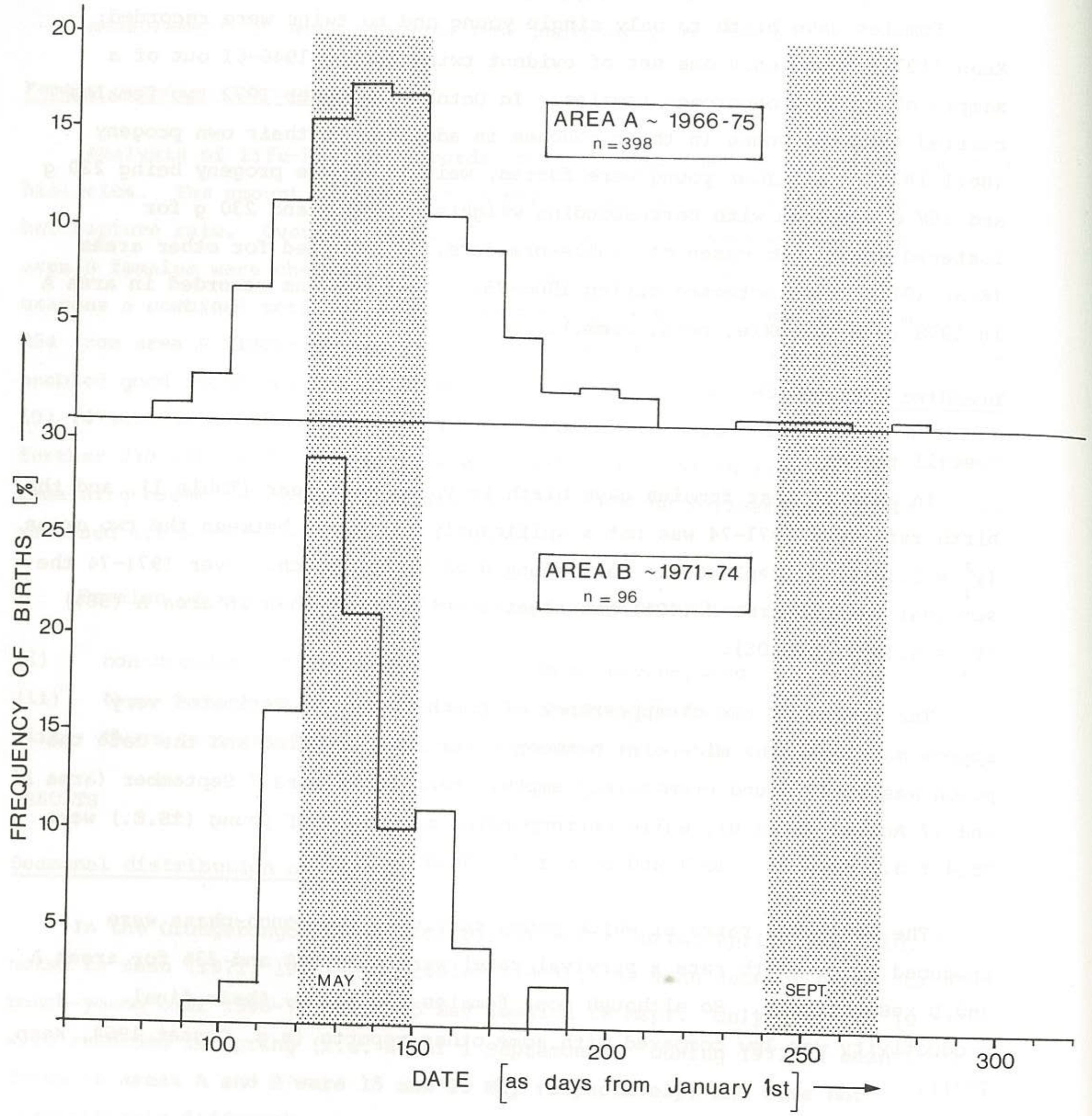


Fig. 2 Seasonal distribution of possum births in the two study areas. The date of birth is scaled as 10-day intervals from January 1st with the months of May and September indicated by stippling.

7 (17.1%) first bred as yearlings;
23 (56.1%) at two years;
9 (22.0%) at three years;
and 2 (4.9%) at four years.

The mean age of first breeding was 2.15 years with no significant difference between blacks and greys ($\chi^2_3 = 1.3274$. $p>0.10$).

Data from a larger sample (Table 1) show for area A over 1966-75 only 8% of yearling females gave birth, and none reared pouch-young successfully; no area B females gave birth as yearlings.

Approximately 60-65% of two-year-old females had young, birth rates between areas differing significantly over 1971-74 ($\chi^2_1 = 4.222$, $p<0.05$). None of their young survived in area B, however, but 47% did in area A during 1971-74 (and 52% over 1966-75). Thus while no two-year-old females were known to rear young in area B, 34% did so over the same period in area A (Table 1).

The birth rate was significantly greater in adults than two-year-old females in both area A ($\chi^2_1 = 11.6710$, $p<0.001$) and area B ($\chi^2_1 = 9.8776$, $p<0.01$); it was also greater in adults in area B (93%) compared with area A (81%) during 1971-74 ($\chi^2_1 = 8.3811$, $p<0.01$).

The 'adult' category (Table 1) comprised all animals three or more years old. Data for a more limited sample of precisely-aged possums are given in Table 2; sample sizes for older age classes (>5 years) are unfortunately limited. As seen in Table 1 the birth rate increases dramatically between yearling and two-year-old possums ($\chi^2_1 = 48.8057$, $p<0.001$). Significant increases in birth rate also occurred between years 2 and 3 ($\chi^2_1 = 5.3171$, $p<0.05$) but thereafter there were no significant differences between successive years except years 5 and 6 ($\chi^2_1 = 5.2179$, $p<0.05$). An explanation, at least in part, for the lower birth rate of five-year-olds is evident when these age-specific breeding data are related to breeding success in different years of the study: most data on five-year-olds came from 1973 and 1975, two years when the birth rate was relatively low (see Fig. 3).

The survival rate of pouch-young increased significantly between yearlings and two-year-olds; the young of four-year-olds survived significantly better than those of either three or five-year-olds ($\chi^2_1 = 8.7273$-9.3818, $p<0.01$). Over the first six years therefore, the highest female productivity occurred in four-year-olds, 91% producing young that survived the pouch-phase. The

Table 1. Overall breeding success of female possums in relation to age, colour and area.

		AREA A (1966-1975)								Area A (1971-1974)[2]								AREA B (1971-1974)							
		1 yr old		2 yr old		Adult		TOTAL		1 yr old		2 yr old		Adult		TOTAL		1 yr old		2 yr old		Adult		TOTAL	
		%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n
BIRTH RATE																									
Percent of females known to have young	Blacks	5.9	34	59.1	22	83.9	192	71.0	248	6.7	15	70.0	10	85.2	81	72.6	106	0	8	60.0	5	92.8	69	81.7	82
	Greys	10.4	48	65.6	32	83.5	278	72.1	358	17.4	23	73.7	19	79.5	117	69.8	159	0	10	50.0	2	92.5	53	76.9	65
	TOTAL[1]	8.2	85	63.6	55	82.8	482	70.9	622	13.2	38	72.4	29	80.9	204	70.5	271	0	20	57.1	7	92.6	122	78.5	149
SURVIVAL RATE OF POUCH-YOUNG																									
Percent of breeders rearing their pouch-young	Blacks	0	2	45.5	11	56.3	87	54.0	100	0	1	33.3	6	60.0	40	59.6	47	0	0	0	2	42.9	35	40.5	37
	Greys	0	3	57.1	14	54.9	133	54.0	150	0	2	55.6	9	62.7	51	59.7	62	0	0	0	0	44.4	27	44.4	27
	TOTAL[1]	0	5	52.0	25	55.7	221	54.2	251	0	3	46.7	15	62.0	92	58.2	110	0	0	0	2	43.5	62	42.2	64
PRODUCTIVITY RATE																									
(Birth rate x survival rate of pouch-young)	Blacks	0		26.9		47.2		38.3		0		23.3		51.1		43.3		0		0		39.8		33.1	
	Greys	0		37.5		45.8		38.9		0		41.0		49.8		41.7		0		0		41.1		34.1	
	TOTAL[1]	0		32.8		46.1		38.4		0		33.8		50.2		41.0		0		0		40.3		33.1	

[1] includes some extra animals whose coat colour was not recorded.

[2] although included in the 1966-75 figures, area A data are expressed separately for 1971-74 to facilitate comparison with area B data from the same period.

Table 2. Breeding success of known-age area A females in successive years of life.

		AGE IN YEARS									
		1	2	3	4	5	6	7	8	9	10
BIRTH RATE	%	8.2	63.6	85.0	90.6	71.9	100.0	91.7	75.0	100.0	100.0
	N	85	55	40	32	32	15	12	4	5	2
SURVIVAL RATE OF POUCH-YOUNG	%	0	52.0	63.6	100.0	63.6	66.7	25.0	50.0	100.0	0
	N	5	25	22	21	11	9	8	2	1	2
PRODUCTIVITY RATE OF FEMALES	%	0	32.8	54.1	90.6	45.7	66.7	22.9	35.5	100.0	0

perceptible decline in success after the fourth year is in part due to increasing numbers of poor-conditioned females in the samples. Those females known to have died in area A from natural causes showed a marked decline in breeding success in their last year (Table 3); the differences in birth rate and survival rate between the last two years of life were highly significant (χ^2_1 = 11.35 and 12.37 respectively, $p<0.001$); differences between other years were not significant. At death some females had lost their young, others still retained them; often their poor condition resulted in unclean, smelly pouches and conspicuously undernourished young.

Table 3. Breeding success of area A females up to and including the year of death.

	YEAR DIED		PREVIOUS YEARS					
			1		2		3	
	%	N	%	N	%	N	%	N
BIRTH RATE	48.3	29	91.7	24	93.3	15	93.8	16
SURVIVAL RATE OF POUCH YOUNG	0	14	63.6	11	66.7	9	80.0	10
PRODUCTIVITY RATE OF FEMALES	0		58.3		62.2		75.0	

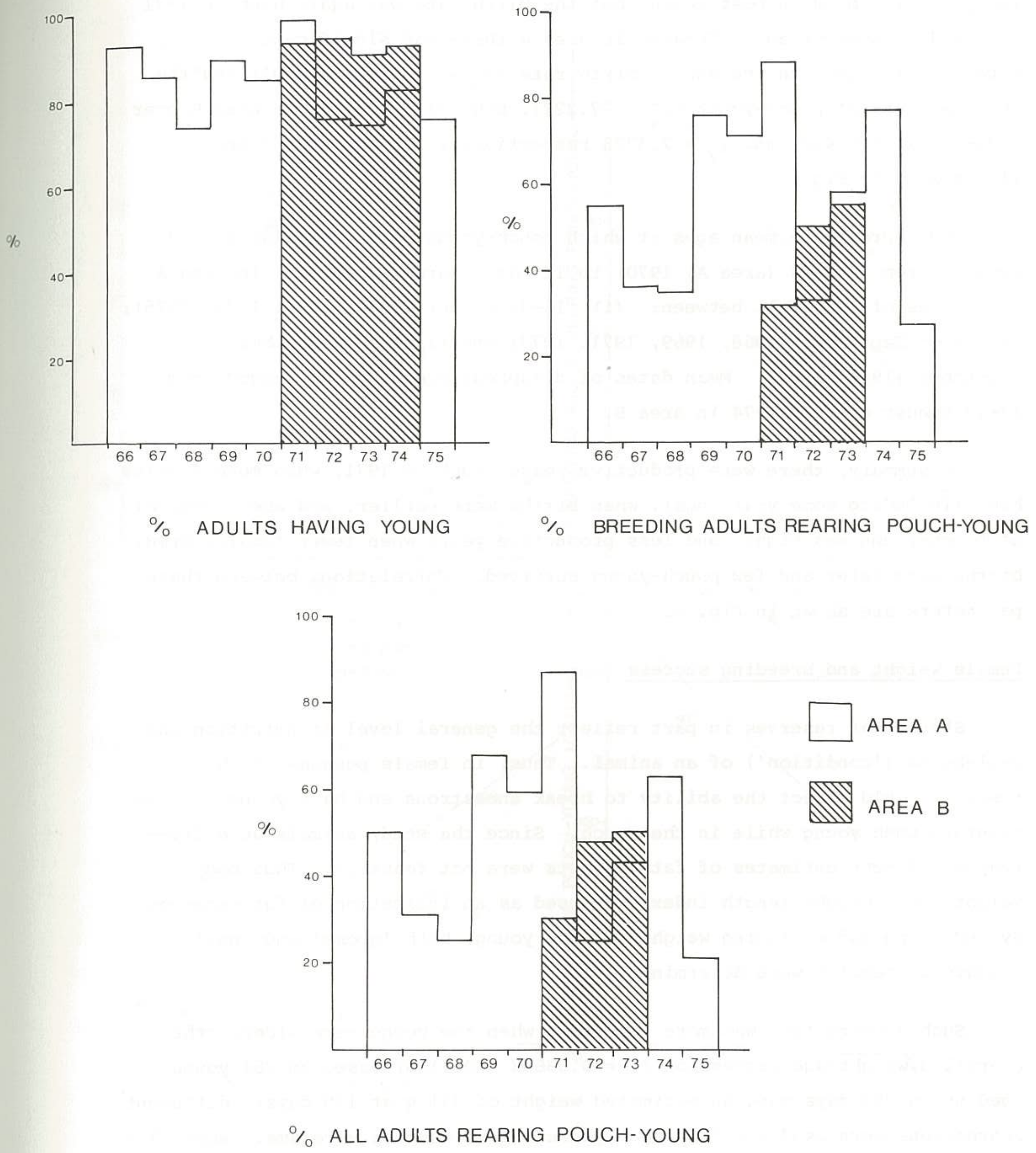
Although slightly more one and two-year-old greys had young compared with blacks, no significant age-specific differences in breeding success were found between the two colour morphs in area A (Table 1; χ^2_1 = 0.5241 and 0.2387 for yearlings and two-year-olds respectively, $p>0.10$).

Annual fluctuations in breeding success

There was marked variation in the onset and median dates of birth between years. The median date of birth in area A was especially early in 1971 (19 April); in other years median birth dates fell later as follows: 2 May (1966), 10 May (1969), 15 May (1970), 18 May (1974), 19 May (1967), 21 May (1972), 24 May (1973), 25 May (1968), and 4 June (1975). In area B the dates were 7 May (1971), 8 May (1972), 11 May (1974) and 15 May (1973). These annual fluctuations were also reflected in breeding trends of the same female over consecutive years. Spring births (after 1 September) occurred only in area A and in 1967 (1) and 1971 (2).

Table 4. Breeding success in yearling and two-year-old females, 1966-75.

		BIRTH RATE (Proportion known to have pouch-young)		SURVIVAL RATE OF POUCH-YOUNG (Proportion of breeders known to rear pouch-young)	
		YEARLING	2 YEAR OLD	YEARLING	2 YEAR OLD
AREA A	1966	0/7	0/0	0/0	0/0
	1967	0/10	6/9	0/0	2/5
	1968	0/5	1/5	0/0	1/1
	1969	2/12	0/1	0/2	0/0
	1970	0/12	6/10	0/0	3/4
	1971	5/16	8/8	0/3	3/4
	1972	0/11	9/15	0/0	3/8
	1973	0/5	3/4	0/0	1/2
	1974	0/6	1/2	0/0	0/1
	1975	0/1	1/1	0/0	0/0
AREA B	1971	0/6	1/1	0/0	0/1
	1972	0/6	2/4	0/0	0/1
	1973	0/6	0/1	0/0	0/0
	1974	0/2	1/1	0/0	0/0



% ADULTS HAVING YOUNG

% BREEDING ADULTS REARING POUCH-YOUNG

% ALL ADULTS REARING POUCH-YOUNG

Fig. 3 Annual variation in breeding success of adult females in the two study areas.

Among younger females, yearlings bred in area A in 1969 (2) and 1971 (5); two-year-olds bred in most years, but the birth rate was again high in 1971 (Table 4). Amongst adult females in area A there was significant heterogeneity in both the annual birth rate ($\chi^2_9 = 23.8998$, $p<0.01$) and the survival rate of pouch-young ($\chi^2_9 = 37.2221$, $p<0.001$), but not in area B over 1971-74 ($\chi^2_3 = 0.4005$ and $\chi^2_2 = 2.3723$ respectively). These trends are illustrated in Fig. 3.

The approximate mean ages at which pouch-young were lost also varied, ranging from 74 days (area A, 1970) to 127 days (area A, 1966). In area A mean dates of loss fell between: (i) 16-31 August (1970, 1972, 1974, 1975); (ii) 1-15 September (1968, 1969, 1971, 1973) and (iii) 16 September - 1 October (1966, 1967). Mean dates of disappearance of young ranged from 13-19 August over 1971-74 in area B.

In summary, there were productive years, such as 1971, when more females bred (including some yearlings), when births were earlier, and when survival of pouch-young was high; and less productive years when fewer females bred, births were later and few pouch-young survived. Correlations between these parameters are shown in Fig. 4.

Female weight and breeding success

Stored fat reserves in part reflect the general level of nutrition and well-being ('condition') of an animal. Thus, in female possums, such reserves could affect the ability to break anoestrous and have young, and to maintain such young while in the pouch. Since the study animals were live-trapped, direct estimates of fat-deposits were not feasible. Thus body weight (or a weight/length index) was used as an indication of fat reserves. By including and excluding weights of the young, both 'gross' and 'net' weights of females were determined.

Such a correction was more important when the young were older; the overall $\sqrt[3]{\text{weight}}$/age regression ($Y = 0.0365X + 0.7150$) based on 264 young aged up to 250 days gave an estimated weight of 331 g at 170 days; different regressions were used for different years unless samples were small when this overall regression was used. Since young remain attached to the teat during early pouch-life, no weight data were available from the study areas; data from 52 young ranging from 0.7 g to 85.5 g (mean 29.1 g) from Waverley, N.Z. were therefore incorporated into the predictive growth curve; this was

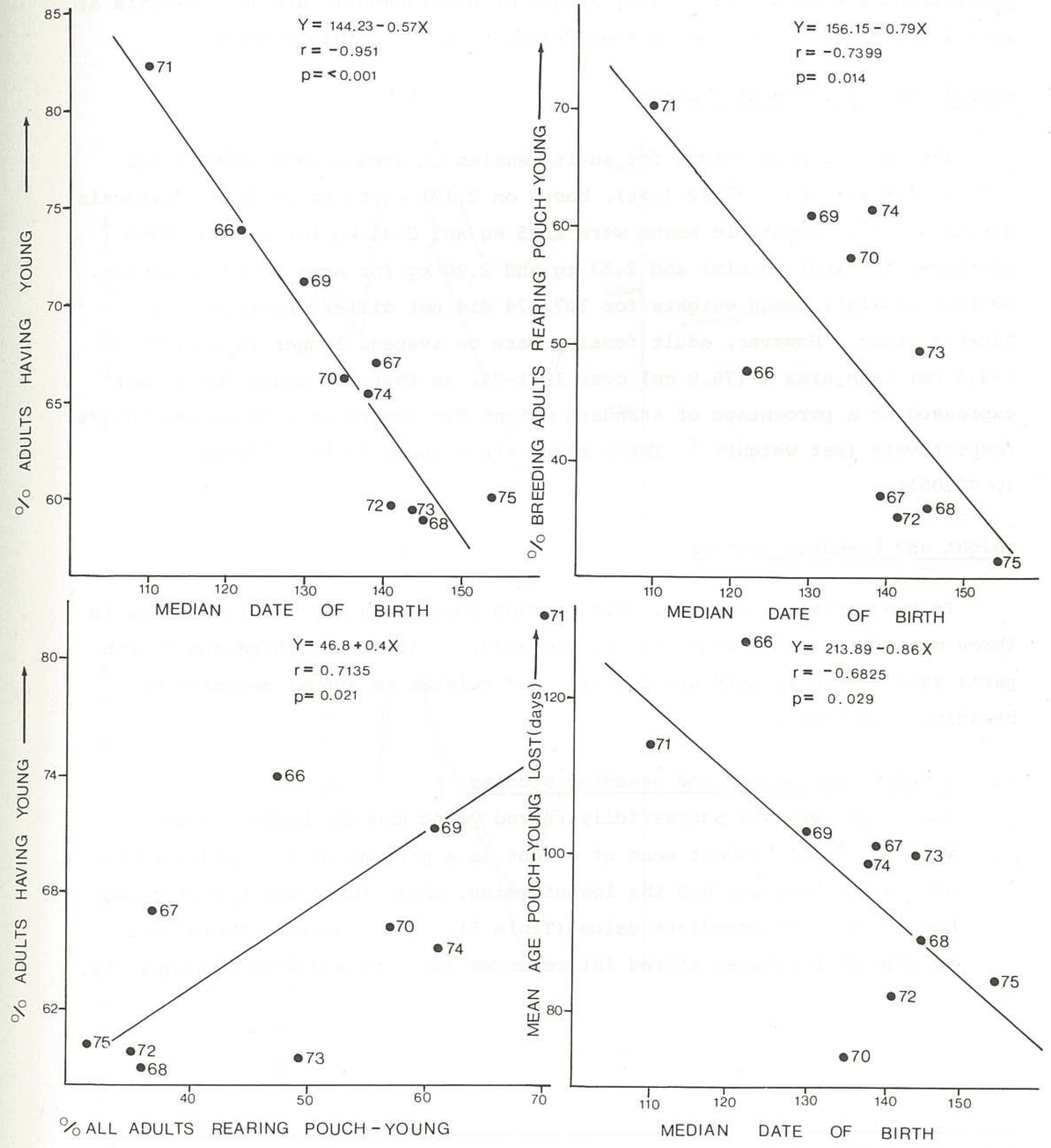


Fig. 4. Linear regressions and correlations between annual breeding parameters for adult females, area A (1966-75).

The proportion of adults breeding and the proportion rearing pouch-young are as defined in Fig. 3 but with arcsin transformation of the percentages.

considered justifiable since: (i) differences in growth rate between populations are less during early stages of development; and (ii) weights at such a stage are in any case a tiny fraction of the female's weight.

Overall mean weights of females

The overall mean weight for adult females in area A over 1966-75 was 2.32 kg (gross) and 2.27 kg (net), based on 2,191 captures of 207 individuals; during 1971-74 comparable means were 2.35 kg and 2.31 kg for area A (1960 captures, 108 individuals) and 2.33 kg and 2.20 kg for area B (606 captures, 89 individuals); mean weights for 1971-74 did not differ significantly between areas. However, adult females were on average longer in area B (78.7 cm) than area A (76.8 cm) over 1971-74, so that the means for weight expressed as a percentage of standard weight for length were 98.2% and 105.7% respectively (net weight).[1] These means are significantly different ($p < 0.001$).

Weight and breeding success

In the first two parts of this section mean weights of adult females in three major breeding categories are compared, while in the third and fourth parts annual mean weights are compared and related to annual measures of breeding performance.

(i) Overall mean weight and breeding success

Adult females that successfully reared young had the highest mean weight and the highest mean of weight as a percent of standard weight; adults not breeding had the lowest means, while those which lost young had means of intermediate value (Table 5). This suggests there is a relationship between stored fat reserves (weight) and breeding capacity.

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[1] This expression follows Bamford (1970) and is based on a pooled regression of log weight and log total length, the curve having the form W = 0.0163 $\ell^{2.72}$ where W = weight (g) and ℓ = total length (cm); a similar regression of log weight and log body length (computed from total length-tail length) was not used since the correlation coefficient was lower. For Westland possums Bamford's regression curve was W = 0.0125 $\ell^{2.81}$; he found for each sex that weight as a percent of standard weight was highly correlated with the proportion of total body fat.

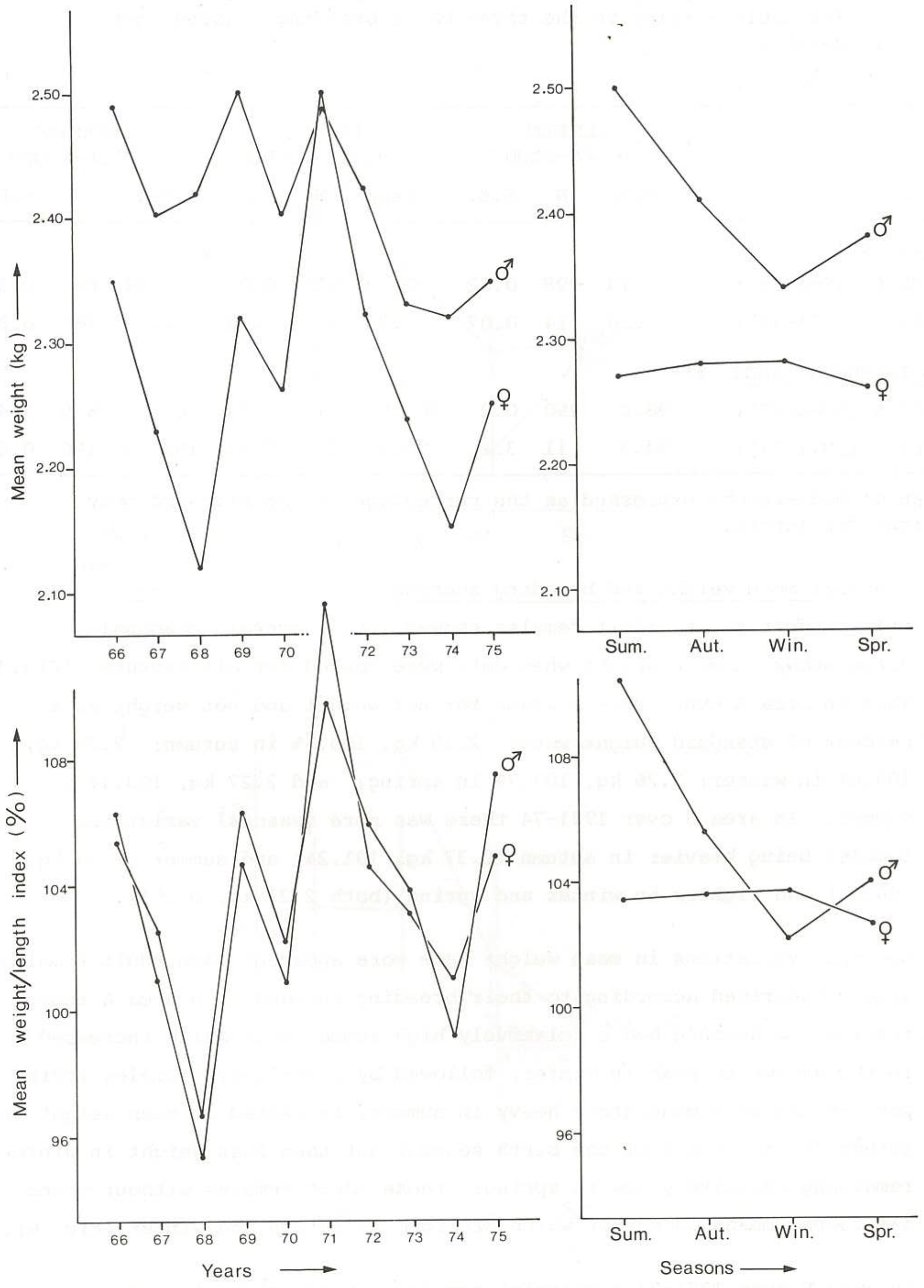

Fig. 5. Overall annual and seasonal mean weights and mean weight/length indices for adult males and females area A (1966-75).

For clarity standard errors are omitted; for mean weights their range was 0.01-0.04 kg (males) and 0.01-0.03 kg (females); for mean weight/length indices 0.7-1.9% (males) and 0.7-1.1% (females). Only net weights of females are illustrated.

Table 5. Overall mean body-weights and mean body-weight/length indices for adult females in the three major breeding classes (net weights).

	WITHOUT POUCH-YOUNG			LOSING POUCH-YOUNG			REARING POUCH-YOUNG		
	Mean	N	S.E.	Mean	N	S.E.	Mean	N	S.E.
<u>WEIGHT</u> (kg)									
AREA A (1966-75):	2.13	298	0.02	2.19	519	0.00	2.34	663	0.01
AREA B (1971-74):	2.20	14	0.07	2.22	213	0.02	2.38	160	0.02
<u>WEIGHT/LENGTH INDEX</u> (%)*									
AREA A (1966-75):	98.0	290	0.8	101.5	511	0.54	105.9	639	0.47
AREA B (1971-74):	94.3	11	3.2	95.9	213	0.82	101.7	160	0.61

* mean of body-weight expressed as the percentage of the standard body weight for length.

(ii) <u>Seasonal mean weight and breeding success</u>

Unlike adult males, adult females showed little overall seasonal differences in mean weight when data were pooled for all captures (Fig. 5). Thus in area A over 1966-75 means for net weight and net weight as a percent of standard weight were: 2.28 kg, 103.5% in autumn; 2.28 kg, 103.6% in winter; 2.26 kg, 102.7% in spring; and 2.27 kg, 103.4% in summer. In area B over 1971-74 there was more seasonal variation, females being heavier in autumn (2.37 kg, 101.2%) and summer (2.33 kg, 100.2%) and lighter in winter and spring (both 2.23 kg, 95.5%).

Seasonal variations in mean weight were more apparent when adult females were categorised according to their breeding success. In area A those rearing pouch-young had a relatively high summer mean which increased in the autumn to peak in winter, followed by a decline; females losing pouch-young were moderately heavy in summer, increased in mean weight in autumn (at the onset of the birth season) but then lost weight in winter, remaining relatively low in spring; those adult females without young had lowest means in summer which declined in autumn and winter (Fig. 6).

In area B over 1971-74 successful females gained weight in autumn as in area A, but then weights declined; those losing young were relatively heavier than the area A females in summer and autumn, but there was a marked decline by winter and a further decline in spring. As in area A, non-breeding adults weighed less than those with young, and weights again

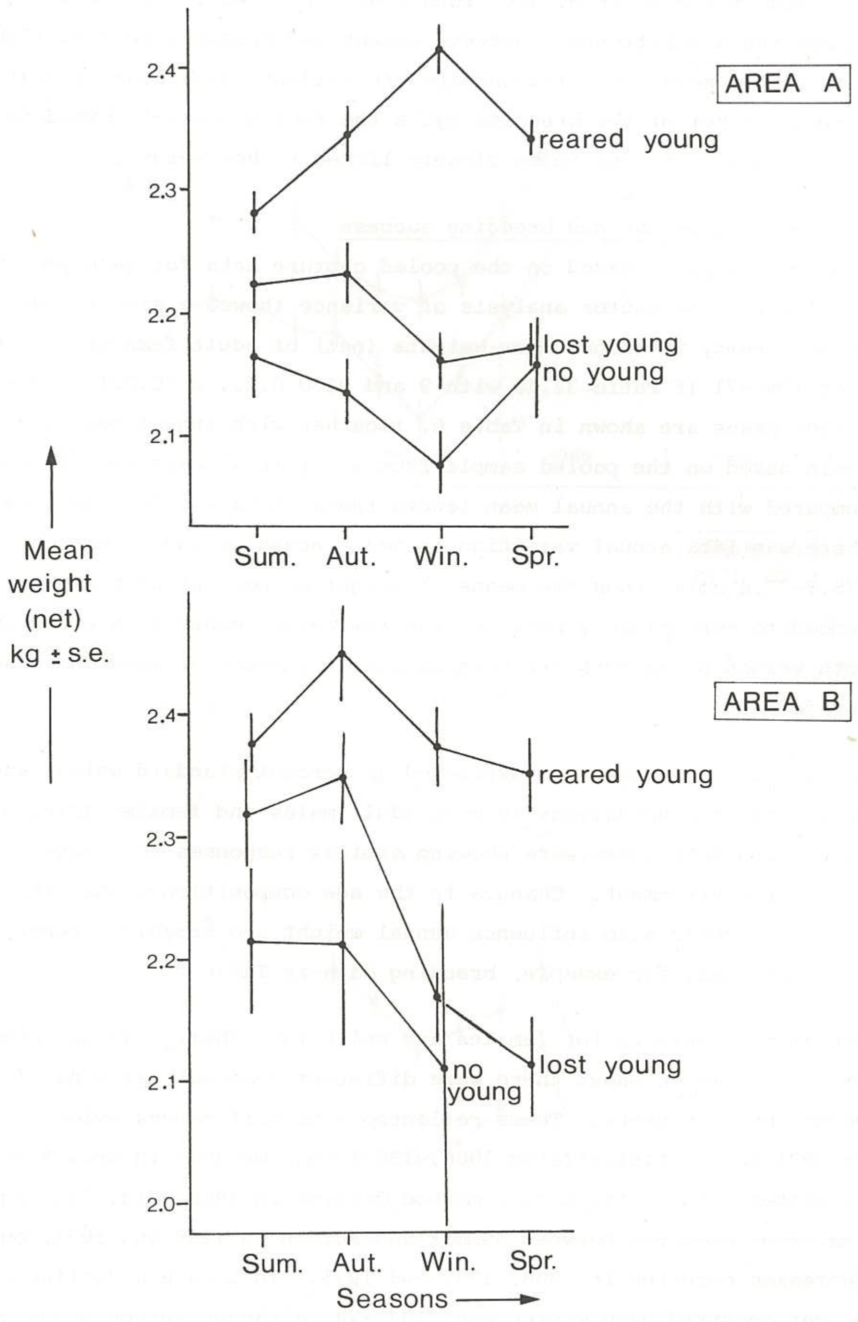

Fig. 6. Seasonal mean weight trends in adult females of different breeding histories.

Comparable trends were evident when weight was expressed as a percentage of the standard weight for length.

Data for area A covers 1966-75; for area B 1971-74.

declined in winter (Fig. 6). Thus apart from the overall results suggesting a relationship between weight and breeding success (Table 5), more subtle seasonal relationships are evident which suggest that through various phases of the breeding cycle the female possum's breeding performance continues to be closely linked to her weight.

(iii) Annual mean weight and breeding success

When mean weights based on the pooled capture data for each year were examined, a one-factor analysis of variance showed a significant heterogeneity in annual mean weights (net) of adult females in area A over 1966-71 (F ratio 32.49 with 9 and 2180 d.f., $p < 0.001$). The annual weight means are shown in Table 6, together with annual mean lengths, again based on the pooled sample from all initial captures per month. Compared with the annual mean length range in males (76.0-79.8 cm), there was less annual variation in mean length of adult females (75.7-77.4 cm); thus the means of weight as percent standard weight tended to more closely parallel the raw weight means (Table 6), so both weight parameters are used as annual indices of mean fat reserves for females.

Annual weight means, when expressed as percent standard weight showed very similar fluctuations in both adult males and females (Fig. 5), suggesting both sexes were showing similar responses to annual changes in their environment. Changes in the age composition within the 'adult' age class could also influence annual weight and breeding trends, however; see, for example, breeding data in Table 2.

Annual mean weights for females are split into their seasonal components in Fig. 7, which shows there were different seasonal patterns of mean weight between years. These reflected some differences evident in Fig. 6. In 1971 in particular (also 1966, 1969) mean weights in area A increased in winter - in contrast to a marked decline in 1968 (Fig. 7). Again, increases occurred between summer and autumn in 1969 and 1971, but decreases occurred in 1968, 1973 and 1975. In area B a decline in mean weight occurred each winter over 1971-74, although autumn means were relatively high in most years (Fig. 7).

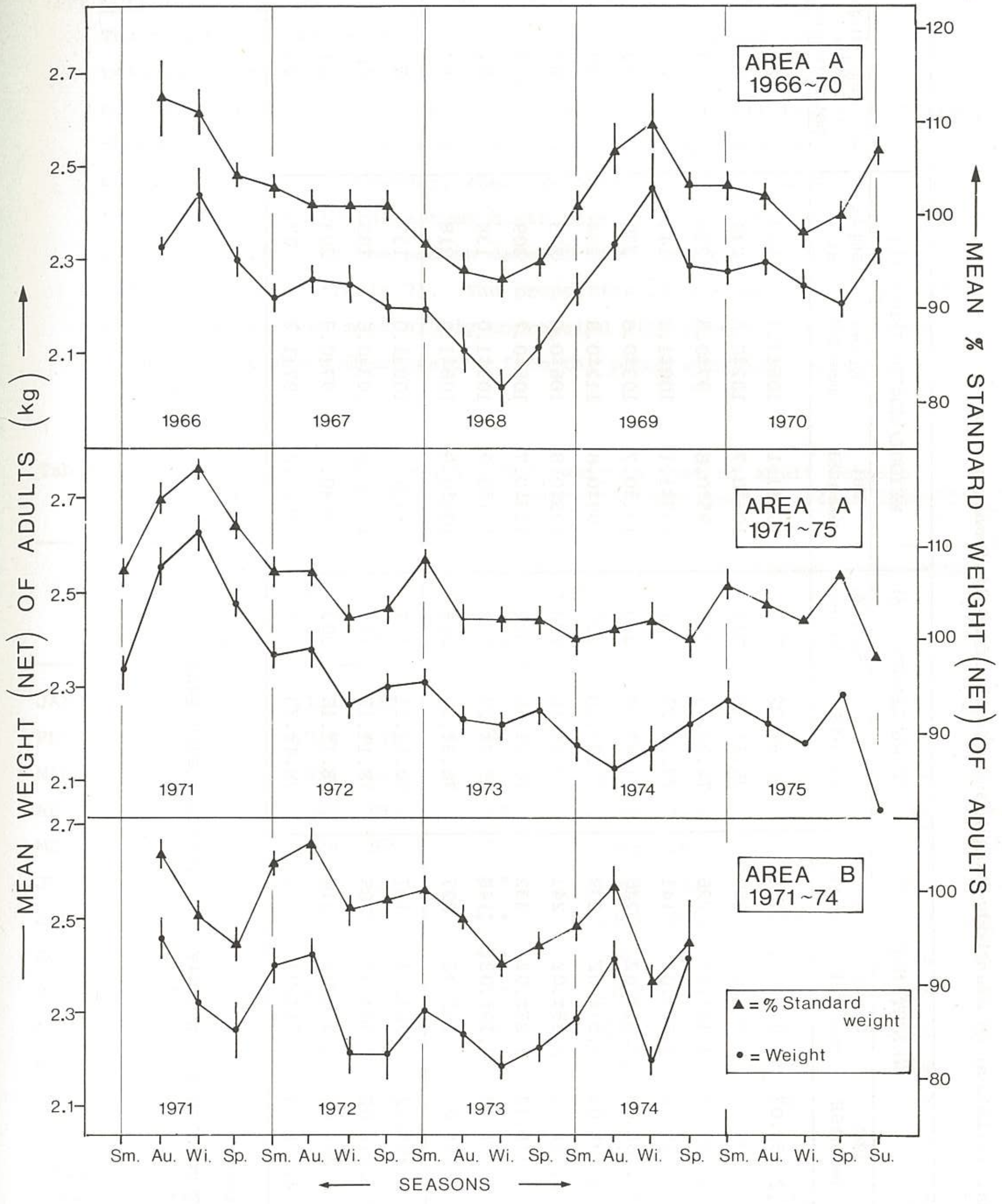

Fig. 7. Seasonal trends in mean weights of adult female possums: 1966-75.

Weights are given as means for consecutive 3-month periods (± 1 standard error). Note general similarity of pattern between the 2 expressions of weight, and the variation between years, seasons and areas.

Table 6. Annual variation in mean body-weight and length of adult female possums[1]

		WEIGHT (kg)			TOTAL LENGTH (cm)		WEIGHT/LENGTH INDEX (%)			No. weighings including pouch-young
		Net mean±SE	Gross mean±SE	Sample size	mean±SE	Sample size	Net mean±SE	Gross mean±SE	Sample size	
AREA A	1966	2.35±.02	2.42±.03	138	76.9±.22	136	104±1.1	106±1.1	167	65
	1967	2.23±.02	2.26±.02	259	76.9±.18	249	101±0.7	102±0.8	249	93
	1968	2.12±.02	2.16±.02	226	77.3±.17	226	95±0.8	97±0.9	226	75
	1969	2.32±.02	2.40±.03	141	77.2±.21	141	105±1.1	108±1.3	141	61
	1970	2.26±.02	2.31±.02	240	77.4±.18	239	101±0.7	103±0.8	239	99
	1971	2.50±.02	2.57±.02	239	77.3±.18	228	109±0.8	112±0.9	234	139
	1972	2.32±.02	2.35±.02	241	77.2±.16	233	105±0.8	106±0.8	233	97
	1973	2.24±.02	2.27±.02	332	76.5±.16	309	103±0.7	105±0.7	309	107
	1974	2.15±.03	2.19±.03	148	75.7±.25	138	101±0.9	103±1.0	138	54
	1975	2.25±.02	2.28±.02	227	76.3±.22	218	105±0.9	106±1.0	218	57
AREA B	1971	2.35±.02	2.38±.02	137	79.1±.21	137	99±1.0	100±1.0	137	71
	1972	2.33±.02	2.36±.02	185	78.1±.18	185	101±0.8	103±0.8	185	66
	1973	2.24±.01	2.27±.02	214	78.7±.16	203	96±0.7	97±0.7	203	67
	1974*	2.30±.03	2.31±.03	70	79.4±.33	67	96±1.2	97±1.2	67	22

* up to September

[1] based on combining all monthly estimates for each year

(iv) Correlations between annual weight and breeding performance

The breeding performance of adult possums each year was significantly related to their mean annual body weight (Fig. 8). A comparison of the monthly mean weights of females and their breeding performance each year showed no correlations were evident over the summer months prior to breeding (Table 7). However, their weights over March and April, immediately prior to the autumn birth peak (Fig. 2), were significantly correlated with both the median date of birth and the proportion of females that bred (Table 7). The proportion of possums rearing pouch-young each year was most highly correlated with June to September mean weights, most young disappearing from the pouch over late August and September.

Table 7. Correlation of mean monthly body-weights (net) of adult females each year with breeding performance in those years, area A 1966-75.

	MEDIAN DATE OF BIRTH			PERCENT FEMALES BREEDING			PERCENT POUCH-YOUNG SURVIVING		
	Significance[1]	r	df	Significance[1]	r	df	Significance[1]	r	df
JAN	NS	.111	180	NS	.029	180	NS	.053	166
FEB	NS	.014	146	NS	.059	146	NS	.066	130
MAR	***	.451	103	**	.301	103	NS	.138	87
APR	***	.248	193	**	.192	193	NS	.096	169
MAY	**	.238	165	*	.169	165	*	.199	139
JUN	***	.439	181	***	.364	181	***	.363	165
JUL	***	.362	205	***	.323	205	***	.243	196
AUG	***	.513	163	***	.442	163	***	.366	136
SEP	***	.432	203	***	.381	203	***	.308	190
OCT	NS	.103	165	NS	.056	165	NS	.141	149
NOV	*	.144	235	NS	.057	235	**	.214	202
DEC	NS	.082	226	NS	.042	226	NS	.023	211
WHOLE YEAR	***	.269	2187	***	.194	2187	***	.194	1962

[1] NS = not significant; * = $p<0.05$; ** = $p<0.01$; *** = $p<0.001$

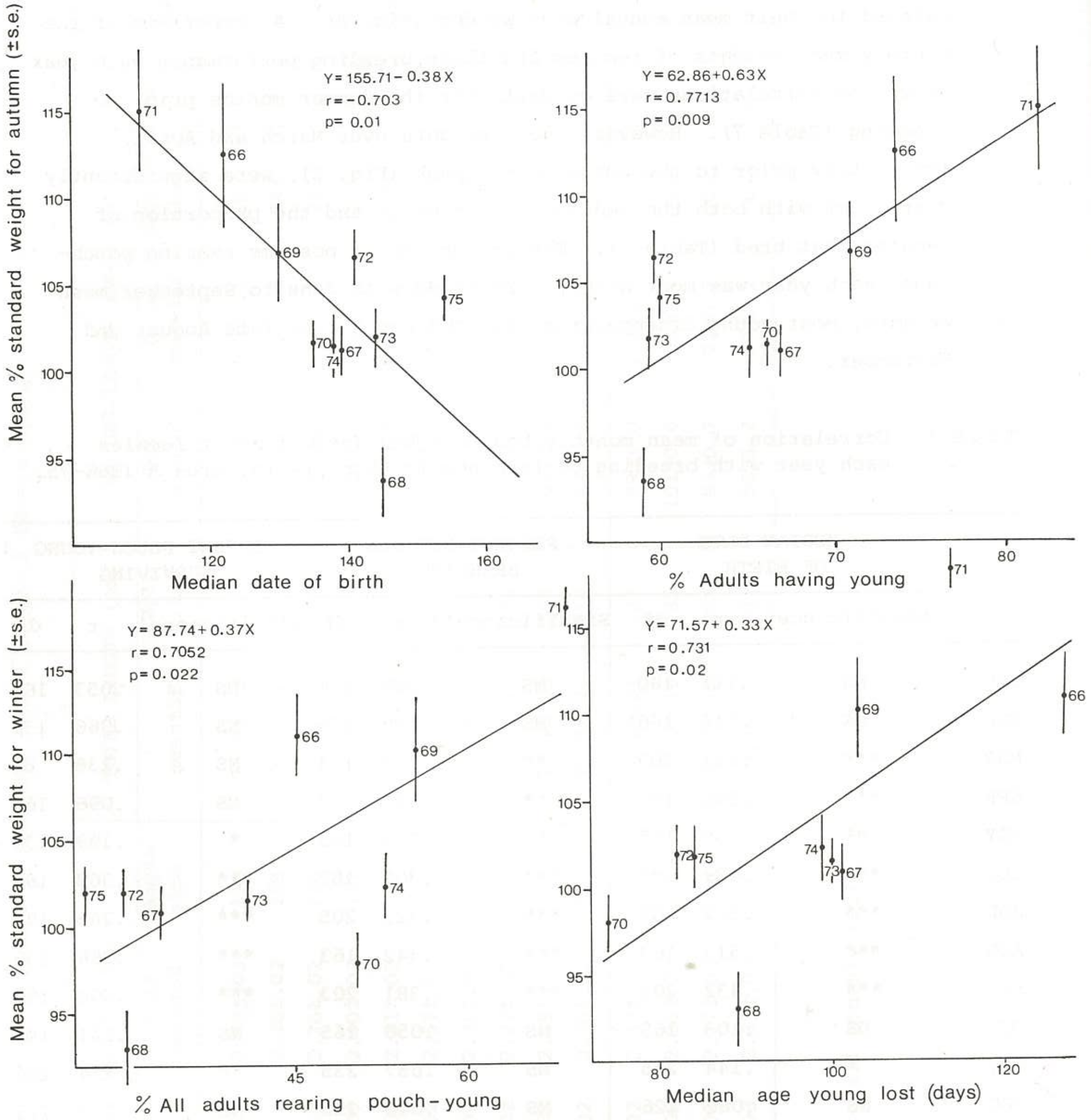

Fig. 8. Linear regressions and correlations between annual breeding performance and seasonal weights for adult female possums in area A (1966-75). Arcsin transformation for percent adults with young and percent rearing young.

Even though most births occurred in May (Fig. 2), the correlations continued over June to September between mean monthly weights of females and both the proportion of them rearing pouch-young and the median date of birth (Table 7). This seems due to annual weight differences, already apparent in autumn, being even more marked and closely correlated in winter. The females' seasonal weight trends (Fig. 7) tend to support this: high weights in the autumns of 1966, 1969 and 1971 were even higher in the following winters; conversely, low weights in the autumns of 1968, 1970 and 1973 were lower by winter.

It was noted earlier that yearling females attempted to breed only in certain years (Table 4). In autumn yearlings averaged 1.23 ± 0.03 kg in area A but (like adults) the mean annual weights (± S.E.) fluctuated from 0.83 ± 0.13 kg (1974) to 1.55 ± 0.04 kg (1971). These yearlings' weights (Table 8) were correlated with adult female weights in autumn (Fig. 9). This suggests the factors affecting the condition of adult females during the birth season also influence the later development of young in their first year.

Table 8. Annual variation in mean autumn body-weights of yearling possums.

	AREA A			AREA A		AREA B	
YEAR	MEAN ± SE(g)	N	YEAR	MEAN ± SE(g)	N	MEAN ± SE(g)	N
1966	1225±78	8	1971	1547±43	20	1293±97	7
1967	967±33	3	1972	1119±35	27	1282±72	14
1968	1083±87	6	1973	1058±123	6	1169±58	16
1969	1417±91	9	1974	825±132	5	1450±85	6
1970	1350±100	7	1975	979±161	6	-	

Weights of pouch-young

The earliest a pouch-young was recorded free of the teat was at 53 days weighing 23 g (July 1972); of 443 weighings up to one year of age, only six were of young less than 90 days old. At 170 days, the assumed end of pouch-life, mean weights for 194 young up to 200 days old were estimated as:

(i) 316 g using an age (X) and log weight (Y) regression $Y = 0.0205X + 2.2741$ ($r = 0.8889$);

(ii) 328 g using an age (X) and cube root weight (Y) regression $Y = 0.0383X + 0.3809$ ($r = 0.8673$).

Estimated weight at 170 days varied from year to year. Adopting the log weight regression (i) above, in area A, estimated weights were relatively high in 1969 (439 g), 1971 (369 g) and 1970 (352 g); were low in 1973 (264 g), 1974 (259 g) and 1972 (229 g); and nearer the overall area A mean (321 g) in 1975 (327 g), 1966 (310 g) and 1968 (297 g); only three young (mean 427 g) were weighed in 1967. In area B over 1971-73 the 170 day estimate was 291 g compared with 300 g for area A over the same period; annual means were 284 g (1971), 333 g (1972) and 256 g (1973). In area A over 1966-75 weight estimates at 170 days were correlated with the winter mean weight of 150 adults known to successfully rear pouch-young (Fig. 9). Thus years when female weights were higher were those when pouch-young weights were higher also.

DISCUSSION

Limitations of the data

Not all breeding-histories were fully documented because some females were caught infrequently (some perhaps not at all). Since the more frequently captured females contributed most to the analysis, it could be argued that the results do not represent the population as a whole. This is an inherent sampling difficulty using such a live-trapping approach; Dunnet (1964) points to other problems with live-trapping. However, the recapture rate was relatively high compared with some other species (Brown 1962); about half the breeding-histories were fully documented and a further quarter partially so. Nevertheless on the assumptions that more frequently caught possums may have been in poorer condition (see Bamford 1971) or that frequent captures (especially winter) might reduce condition, then breeding success (especially survival rates of young) may have been underestimated. Certainly mean weights of less frequently caught adults with young of unknown fate were closer to means of the successful than the unsuccessful breeders, which indicates such a bias.

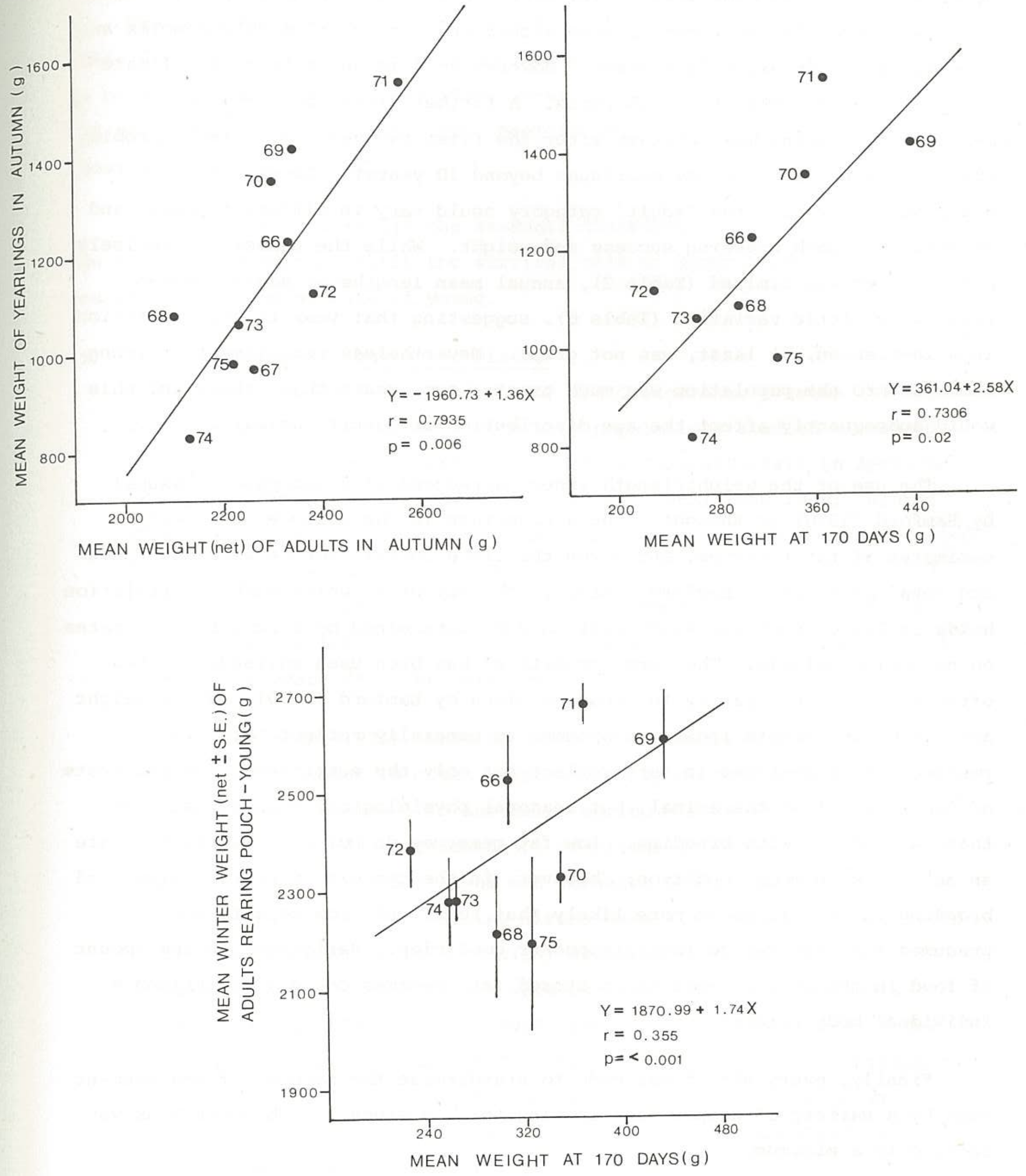

Fig. 9. Linear regressions and correlations between annual mean weights of pouch-young, yearlings and adult females in area A (1966-75).

Both breeding and weight data are based, in many cases, on successive observations on the same individuals over a period of months or years. This has statistical implications in some situations e.g. when monthly samples are combined as in annual weight means. However this is unlikely to invalidate the major conclusions of the analysis. A further limitation was the inadequacy of aging most possums after the first two years of life (a problem that is easing as the study continues beyond 10 years). Age-class distributions within the 'adult' catagory could vary in different years, and so influence both breeding success and weight. While the number of precisely aged females was limited (Table 2), annual mean lengths of adults showed relatively little variation (Table 6), suggesting that year to year variation in size-classes, at least, was not great. Nevertheless recruitment of young animals into the population was much greater some years than others and this would subsequently affect the age distribution of 'adult' animals.

The use of the weight/length index introduced (for autopsied possums) by Bamford (1970) is thought to be appropriate in the absence of direct estimates of fat reserves, and given the close correlation between the index and total body fat in Bamford's study; the extent to which such a correlation holds in the Orongorongo study will only be determined by direct fat estimates on autopsied animals. The term 'condition' has been used advisedly or has often been avoided, partly for reasons given by Bamford (1970). While weight and the weight/length index are assumed to generally reflect total fat reserves, such reserves in turn reflect not only the nutritive plane and state of 'well-being' of the animal, but seasonal physiological changes, such as those associated with breeding. Low fat reserves do not necessarily indicate an animal is in poor condition; however, in the context of poor survival and breeding sucess, it seems more likely that relatively low weights and presumed fat reserves do indicate poorer condition. Variations in the amount of food in the gut, as well as in stored fat reserves could also influence individual body weights.

Finally, every effort was made to standardise the methods of measurement used by a variety of people contributing to this study, so observer bias was reduced to a minimum.

Breeding pattern in Orongorongo Valley and elsewhere

The breeding performance of possums in the Orongorongo Valley over 1966-75 was generally poorer than most other populations studied to date in both Australia (e.g. Dunnet 1956, 1964; Smith *et al.* 1969; How 1972, 1974), and New Zealand (e.g. Gilmore 1966, Bamford 1972, Boersma 1974, Jolly 1976, Clout 1977, Warburton 1977).

This was manifest in (i) the seasonal distribution of births; (ii) the age of first breeding; (iii) the survival rate of pouch-young; and (iv) the resulting recruitment rate of young.

(i) The seasonal distribution of births

The overall median date of birth for the Orongorongo possums (18 May) was relatively late compared with many populations studied elsewhere. Most medians for autumn births recorded in Australia fell in April or early May (Dunnet 1956, 1964; Smith *et al.* 1969; How 1972; Winter 1976), while in New Zealand medians in April or early May were recorded for Banks Peninsula (Gilmore 1966; Jolly 1976), Tokoroa (Clout 1977), Ashley (Warburton 1977) and the Taramakau (Bamford 1972); on Kapiti births were earlier in 1975 (Bell and Atkinson 1976) but generally not so in later years (R.E. Brockie, pers. comm.).

As noted by Kean (1971), Crawley (1973) and others, the autumn birth period of the possum is often supplemented by another in spring that involves fewer females. In Australia spring births occurred in most populations studied and reached 30% of births in Canberra (Bolliger 1942; Dunnet 1956, 1964; Lyne and Verhagen 1957; Smith *et al.* 1969; How 1972; Winter 1976). Spring births have also been widely reported in New Zealand and, as in Australia, appeared most prevalent in populations where autumn births were earlier e.g. Banks Peninsula (Tyndale-Biscoe 1955; Gilmore 1966, 1969; Jolly 1976), some of the Hokitika (Boersma 1974) and at Tokoroa (Clout 1977). Spring births were virtually absent in the Orongorongo Valley over 1966-75 (Fig. 2) only three occurring, two in 1971 when, significantly, autumn births were unusually early (median 19 April).

The same populations with early autumn breeding and a high proportion of spring births were also those in which some females evidently reared young in both autumn and spring. Kean (1971) concluded that such animals occur only when densities are low and food supplies are plentiful. However, he considered such conditions would not always result in double-breeding, but potential expansion of population was a common factor. Boersma (1974) indicated some possums in the Hokitika catchment with spring births had bred twice; spring births there only occurred in populations with high fat reserves and high asymptotic weights.

In the Orongorongo Valley, Kean (1971) expected sustained gin-trapping during 1953-61 would lead to the emergence of double-breeders in better locations, but this did not evidently occur, even when possums near the field station were given supplementary food - though an isolated female showed oestrous behaviour in November (Kean unpubl.). Kean (1971) concluded a high incidence of double-breeders required selection for appropriate genotypes, and could not be induced somatically. Nevertheless, the present study illustrates the possible importance of localised environmental factors in determining the reproductive capabilities and success of the Orongorongo female possums; such environmental constraints may well have still been operating to some degree when the population had formerly been reduced in Kean's experiment.

(ii) Age of first breeding

Most Orongorongo females did not have young until at least 2 years old; the few records of yearlings breeding occurred only in 1969 (2) and 1971 (5). This contrasts with many other study areas where yearling females usually have young, as at Canberra (Dunnet 1956, 1964), in New South Wales (Smith *et al.* 1969, How 1972), on Banks Peninsula (Gilmore 1966; Jolly 1976), in parts of the Hokitika catchment (Boersma 1974) and in Ashley Forest (Warburton 1977).

(iii) Survival rate of pouch-young

Despite their close association with the female, only about half of the pouch-young (52%) survived in the Orongorongo Valley over 1966-75. This ranks as a poor survival rate compared with some other reports. For instance in Canberra Dunnet (1964) found survival in the pouch was very high, while Kean (1971) concluded in an earlier study that most Orongorongo females had reared young. There was marked variation in pouch-young survival between years, areas and age-classes. In area A no yearling females reared pouch-young, while in area B neither yearling nor two-year-old females did so (Tables 1,2,4). Adult females raised only 30-50% of their pouch-young in area B, while in area A there was marked annual variation in pouch-young survival ranging from 30% (1975) to 90% (1971).

(iv) Recruitment rate of young

The inter-correlation of annual measures of breeding performance in the Orongorongo Valley over 1966-75 is emphasised in this paper; similar relationships are evident when the breeding productivity is compared between different study areas. Broadly, areas with earlier autumn breeding, such as Canberra and Banks Peninsula (Tyndale-Biscoe 1955; Dunnet 1956, 1964; Gilmore 1966, 1969; Jolly 1976) are those with highest rates of spring births and double-breeding, with more yearling breeders and with high survival of pouch-young, so the resultant breeding productivity is much higher. Kean (1971) indicated such populations occur where food supplies are relatively good and densities are low; by contrast Orongorongo possums are at higher density (Crawley 1973), are depleting their food species (Mason 1958; Fitzgerald 1976, 1978; Meads 1976) and are subject to marked annual variation in productivity, which in general is low.

Assuming 20% of females are between one and two years old, the estimated annual production of independent young was 1.16 per female in Canberra (Dunnet 1956, 1964; Brockie *et al.* 1979). The overall production rate for Orongorongo females over 1966-75 (derived from data in Table 1) was only 0.37 young per female. This has interesting demographic implications when related to available data on mortality of the study population.

Brockie *et al.* (this symposium) estimate survivorship rates from a sample of 103 possums found dead in the study area over 1966-74. These data are combined with breeding data from Table 1 in Table 9; age classes follow Brockie *et al.* except all animals 3 years and over are combined as 'adults'. Using a Leslie projection matrix (Leslie 1945, Lefkovitch 1965, Williamson 1972) on the available data, the finite rate of natural increase (λ) is estimated as 1.01 (using either assumed sex-ratio and with either the unadjusted mortality series or with mortality series smoothed by fitting quadratic curves - see Snedecor & Cochran 1967). This estimate indicates the population is producing just enough young to counter mortality losses in older animals. However survival

Table 9. Summary of annual recruitment and survival of possums, Orongorongo Valley 1966-75.

AGE CLASS[1] (years)	BREEDING RATE[2]	MALE SURVIVAL[1]	FEMALE SURVIVAL[1]	EXPECTED NO. MALE OFFSPRING[3]	EXPECTED NO. FEMALE OFFSPRING[3] (FERTILITY RATE)
0 - 1	0	0.893 (0.821)	0.851 (0.831)	0 (0)	0 (0)
1 - 2	0	0.900 (0.876)	0.875 (0.884)	0 (0)	0 (0)
2 - 3	0.303	0.911 (0.914)	1.000 (0.922)	0.155 (0.151)	0.148 (0.151)
Adults	0.449	0.805 (0.831)	0.833 (0.849)	0.230 (0.225)	0.219 (0.225)

[1] Derived from Brockie, Bell & White (this symposium), tables 1 and 5; alternative survival values in parentheses are those from smoothed curves (Snedecor and Cochran 1967).

[2] Derived from Table 1, combining all females from both areas.

[3] Based on sex-ratio of 43 ♂♂: 41♀♀ for young at end of pouch-phase (Bell, unpubl.); alternative values assuming 1:1 sex-ratio are given in parentheses.

rates may be overestimated; losses between the end of pouch-life (170 days) and the young becoming free-ranging (and at risk of 'entering' the life-tables) are not included in estimates of recruitment rates. Thus it appears that the population may barely be capable of maintaining its numbers without net immigration from outside, although in reaching such a conclusion some inadequacies of the data need to be borne in mind (see Brockie *et al.* this symposium, also earlier Discussion).

Growth, weight and breeding

The directions of annual fluctuations in breeding productivity in the Orongorongo Valley were reflected in various measures of possum growth and body weight. These were: (i) adult weight trends; (ii) pouch-young growth; and (iii) juvenile growth. Compared with areas of high productivity, such as Canberra and Banks Peninsula (Dunnet 1956, 1964; Gilmore 1966, 1969, Jolly 1976), growth rates and relative weights of Orongorongo animals were depressed, suggesting lower growth rates delay the onset of breeding and that females in poorer physical condition (as reflected by depressed body weight) breed less successfully.

(i) Adult weight trends

Data on seasonal weight trends in adult females (Fig. 6) suggest more successful breeders increase their fat reserves during autumn and into winter, though a decline occurs in late winter or spring, probably related to the maximal demand of lactation (Gilmore 1966, Kean 1971, Crawley 1973). Kean (1971, unpubl.) in 1953-61 and Crawley (1973) in 1966-68 found fat reserves/mean weight increased in winter. Kean (unpubl.) described 72% of August females in 1953 as well conditioned (as opposed to lean) but by September the proportion dropped to 47% (when of 34 animals 5 had no fat, 13 a trace of fat, 6 were in good condition and 10 were very fat). It is evident seasonal weight trends varied between years; so although on average winter weights increased during 1966-68 (Crawley 1973) over ten years (1966-75), different years tended to cancel each other out and overall there was no significant seasonal effect.

Gilmore (1966) found on Banks Peninsula (where spring births occurred) female weights and fat reserves peaked in autumn and remained relatively high in June and July, and a similar pattern was evident there more recently (J.N. Jolly, pers. comm.). Bamford (1970) found females from the lower Styx Valley, Westland, had highest fat reserves in June compared with March, September and December, while in exotic pine forest near Tokoroa female fat reserves and weights again peaked in winter (M.C. Clout, pers. comm.). Thus, despite some minor regional variation, it appears females, where possible, lay down fat reserves in autumn and early winter, but that these reserves are utilised during late winter or early spring when pouch-young approach their periods of maximum growth (Kean 1975), and demands of lactation are higher (Gilmore 1966, Kean 1971, Crawley 1973). The present study suggests that some females are unable to metabolise fat reserves in this way and either do not have young (perhaps because they do not return to oestrous in autumn) or are unable to sustain a developing and suckling pouch-young through the winter.

(ii) Pouch-young growth

Orongorongo pouch-young attain relatively low annual mean weights (229-439 g) by the end of pouch-life. Possums near Canberra (Dunnet 1956) were much heavier (ca. 900 g) at 170 days; Lyne and Verhagens' (1957) nomogram indicates a weight of almost 600 g for other Australian data; Gilmore (1966) recorded a mean of 860 g for Banks Peninsula possums at 5-6 months. Kean (1975) found captive possums in the Orongorongo area over 1953-61 weighed 240-580 g at the end of pouch-life (ca. 170 days). His calculated growth rate of wild pouch-young, based on a field collection of 811 individuals, evidently underestimated their mean weight at 170 days; the estimate (198 g) was lower than any comparable figure for 1966-75 and is hard to reconcile with a juvenile weight of 850-900 g in November-December 1953 (Kean 1975 - Fig. 5). These juvenile means were higher than those in this study which averaged (± S.E.) 464 ± 17 g in November and 648 ± 31 g in December.

(iii) Juvenile growth

Growth of the juvenile over the months after leaving the pouch also varied markedly between years as evident from mean weights of yearlings which ranged from 0.83-1.55 kg in area A and 1.17-1.45 kg in area B (Table 8). While no yearling females bred in area B, some did in area A in the two years when mean weights were highest (1969, 1971). Higher growth rates and yearling weights were noted in other studies, for instance by Lyne and Verhagen (1957) and Dunnet (1964) in Australia and by Gilmore (1966) in New Zealand.

Factors influencing annual variations

The annual variations in the weights and breeding performance of the possums suggest annual variations occur in their forest environment. These could involve intrinsic factors usually associated with animal behaviour patterns and population structure, and extrinsic factors such as weather, food-supply and disease. It could be simplistic and misleading to assume cause-and-effect relationships between the possums and any one of these possible checks to increase. The interplay between the individual possums and between the possums and their environment is still under investigation and some of these inter-actions are not yet fully understood. Thus any correlations evident up to 1975 should be regarded as only indicators, and as starting points in our interpretation of some of the inter-actions involved.

Four of the more likely factors influencing annual variations will now be examined.

(i) Population density

Annual estimates of population density in area A over 1966-75 were compared with breeding and weight data to see if any density-dependent trends were evident. The population density was approximately estimated by determining the number of possums known to be alive in the trapped area each year; this ranged from 150 (1975) to 217 (1967). There were no significant correlations between the current (annual) population density and the annual weight and breeding performance (Fig. 10). Had increasing density depressed weights and breeding output, then negative correlations with adult birth rate, pouch-young survival rate and adult winter weight would be expected, while the date of birth would be positively correlated. There is evidence of such trends in some of the graphs if one ignores the less typical years of 1971 and 1975.

If the population density the *following* year is compared with certain breeding and weight data then significant correlations did occur (Fig. 11). Contributing to this delayed effect is the fact that most young were not trapped as free-ranging animals until the calendar year following birth. It is to be expected that a year of improved breeding success would contribute more young to the population. This, combined with better adult winter survival in such years, seems to be the basis for the observed correlations.

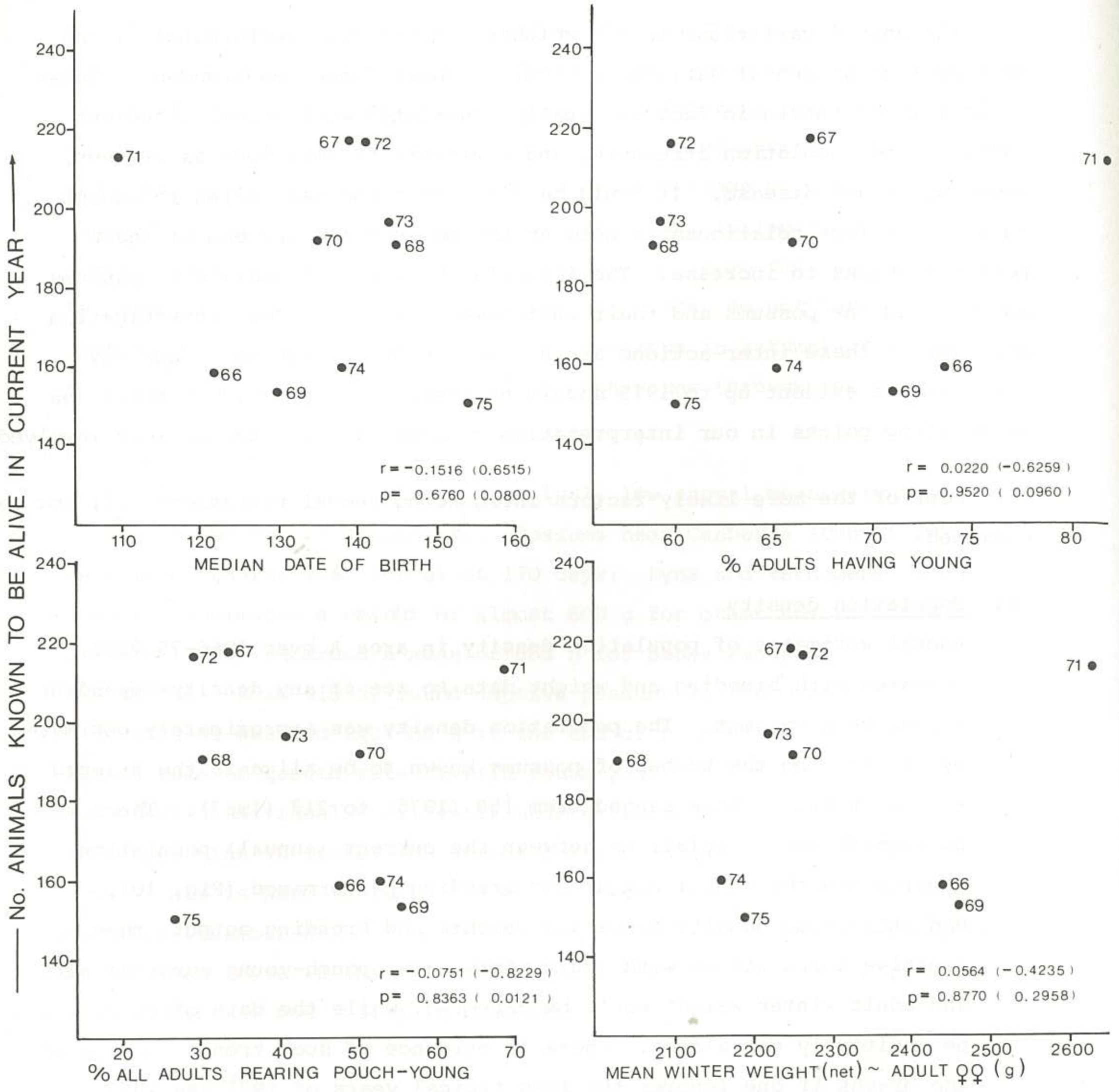

Fig. 10. The current annual population level (minimum no. known alive) in relation to annual breeding and weight parameters, area A (1966-75). Arcsin transformations for percent adults with young and percent rearing pouch-young. Correlation coefficients (r) and significance levels (p) are given for all 10 years and (in brackets) for the 8 years excluding the 'extreme' years of 1971 and 1975.

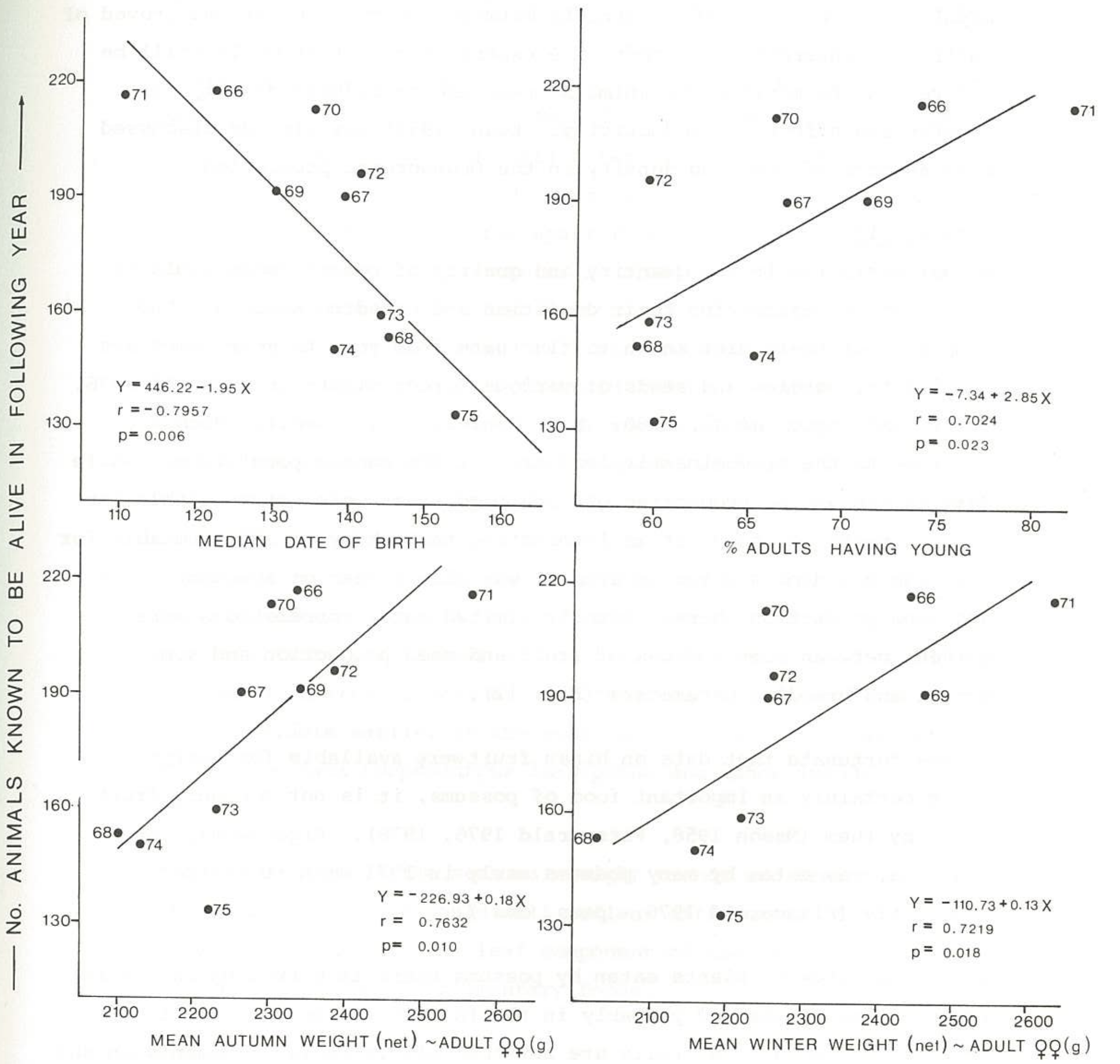

Fig. 11. Linear regressions and correlations between certain annual breeding and weight parameters and the number of possums known to be in the population the subsequent year, area A (1966-75). Arcsin transformation for percent adults with young.

The area B study was initiated with the aim of investigating the effects of an experimental reduction in population density on the surviving population. However, the contrasts between the two populations proved of sufficient interest to postpone the experiment; but it would still be interesting to monitor the animals' response to reduced density and observe its effect on productivity. Kean (1971) has already discussed some aspects of reducing density in the Orongorongo population.

(ii) Food supply

Annual variation in the quantity and quality of possum foods could be important in determining their condition and breeding success. One component of their diet known to fluctuate from year to year comprises the fruits, berries and seeds of various forest plants (Fitzgerald 1976, 1978; Waddington *et al.* 1980; M.J. Daniel, pers. comm.). Such food supplements the predominantly leaf diet of the possum population. While data on the annual production of such food items were not available for earlier years of study, it is interesting that the year 1971, notable for the high breeding success in area A, was also a year of abundant fruit and seed production there. Despite limited data, correlations were evident between some indices of fruit and seed production and some weight and breeding parameters (Fig. 12).

It was fortunate that data on hinau fruitwere available for analysis; while certainly an important food of possums, it is not the only fruit taken by them (Mason 1958, Fitzgerald 1976, 1978). Pigeonwood, for instance, was eaten by many possums early in 1971 when it fruited abundantly (Fitzgerald 1976; pers. obs.).

Among the range of plants eaten by possums there is marked variation in reproductive cycles and probably in the factors influencing fruit production. Also such fruits are not the only variable components in the diet - possums take leaves and flowers of a variety of species, as well as invertebrate foods at times (Fitzgerald 1976, 1978; pers. obs.). This variation in the quality and quantity of food available for the possums therefore seems to have been important in influencing annual fluctuations in weight and breeding performance, especially in years like 1971 when area A possums bred most successfully.

Comparison between study areas

There were differences in the composition and condition of vegetative cover in the two study areas; for example virtually all northern rata trees, a known food species, were dead in area B by 1971, unlike area A (Meads, 1976; pers. comm.). More detailed comparative vegetation surveys were not completed until after 1974, when live-trapping in area B was halted (A.E. Fitzgerald, pers. comm.). However, it was apparent that a number of food species apart from northern rata (*e.g.* kamahi) were absent or reduced in numbers in area B, possums having heavily browsed them (see earlier description of study areas). Supplementary foods such as buds, flowers, fruit and seeds occurred commonly in the diet of possums in area A (Fitzgerald 1976); a comparison of fruit, flowers and seeds in the litterfall suggests area A produces a much greater annual crop of such foods compared with area B (Waddington *et al.* 1980). Not only is area A vegetation more diverse but there are marked differences in those species whose fruit is taken by possums (A.E. Fitzgerald, pers. comm.). The 4 species probably contributing most of the fruit eaten in area A - hinau, pigeonwood, pate and supplejack - bear ripe fruit over autumn and winter. Only pigeonwood and supplejack are common in area B, most of the other species of fruits eaten there being available earlier in the year (up to April) *e.g.* kaikomaka, kawakawa, karaka *Corynocarpus laevigatus* and mahoe (Waddington *et al.* 1980).

Thus differences in the seasonal weight trends and breeding productivity between areas A and B could well reflect differential food supplies, differing not only in the leaf component of the diet but in the timing and availability of supplementary foods.

(iii) Weather

Since continuous weather records were not available from the study areas over 1966-75 N.Z. Meteorological Service data from Kelburn, Wellington and the Orongorongo Weir are used to summarise annual and seasonal fluctuations in rainfall and temperature over the study period (Tables 10 and 11). Kelburn recorded about half the amount of annual rainfall as the study areas, while at the Orongorongo Weir it was about 400 mm (14%) more. Over 1969-71 mean winter and summer temperatures at Kelburn were milder than area A by 2.6°C and 1.2°C respectively.

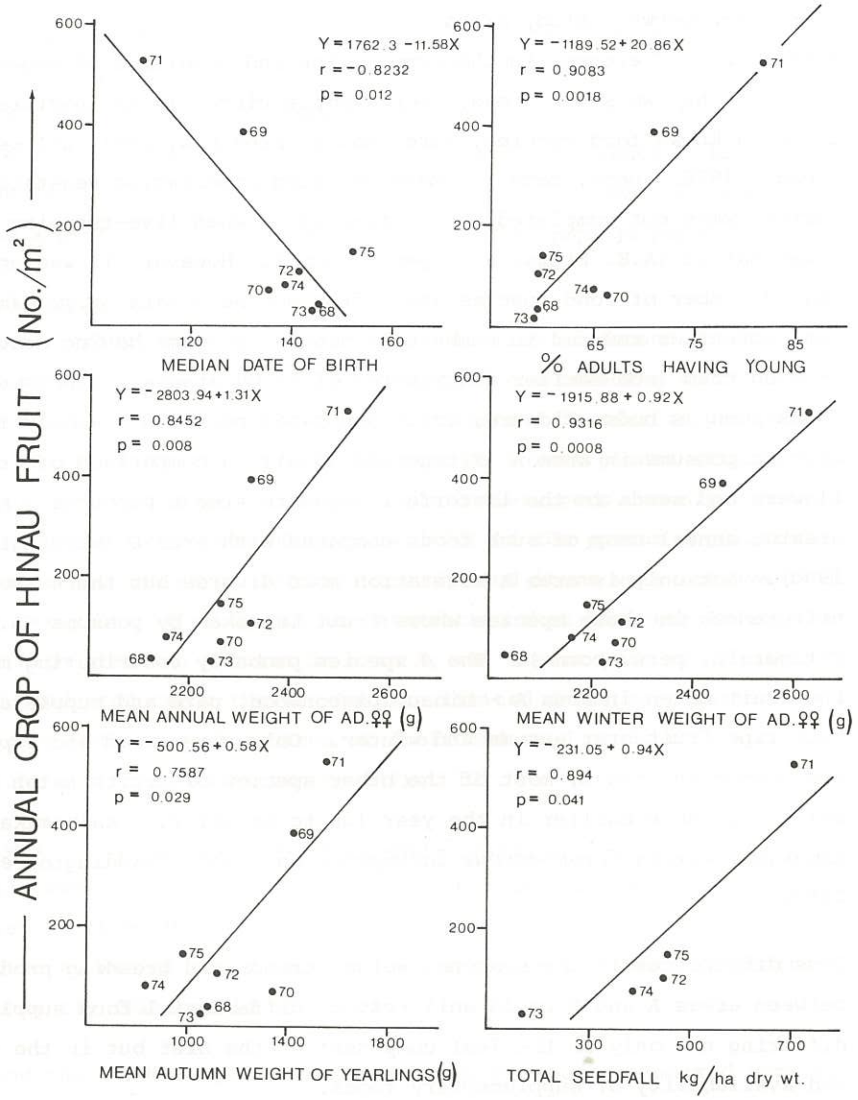

Fig. 12. Linear regressions and correlations between the annual crop of hinau fruit and various annual breeding and weight parameters in area A.

While hinau is but one of the fruits eaten by possums, there is a correlation between the annual hinau crop (no. fruits/m²) and the annual crop of all fruits and seeds collected in the area (measured as kg/ha, dry weight - see Daniel 1975 for methods). Although data are limited, this suggests hinau cropped heavily in concert with some other species in years like 1971 (see Figure, lower right based on 1971-75 data).

For percent adults with young arcsin transformation.

Table 10. Annual rainfall and temperature data from Kelburn, Wellington (1966-75) and the Orongorongo Weir (1966-74).

	Total rainfall per annum				Total raindays per annum				Mean daily temperature per annum	
	Kelburn		Orongorongo		Kelburn		Orongorongo		Kelburn	
	Total (mm)	% deviation from mean*	Total (mm)	% deviation from mean*	No. days	% deviation from mean*	No. days	% deviation from mean*	Mean (°C)	% deviation from mean*
1966	1447	+15%	3738	+29%	169	+7%	212	+5%	12.2	-4%
1967	1251	- 1%	2665	- 8%	151	-4%	209	+4%	12.4	-3%
1968	1364	+ 8%	c.3061	+ 6%	168	+6%	c.212	+5%	12.5	-2%
1969	933	-26%	2059	-29%	137	-13%	178	-11%	12.5	-2%
1970	1246	- 1%	2949	+ 2%	153	-3%	183	-9%	13.2	+4%
1971	1231	- 2%	2534	-12%	151	-4%	c.191	-5%	13.5	+6%
1972	1029	-18%	2416	-16%	164	+4%	214	+6%	12.4	-3%
1973	1039	-18%	2425	-16%	151	-4%	203	+1%	13.0	+2%
1974	1706	+35%	4206	+45%	166	+5%	c.210	+4%	12.8	+1%
1975	1372	+ 9%	-	-	165	+4%	-	-	13.0	+2%
Mean for period	1262 (1966-75)		2895 (1966-74)		158 (1966-75)		201 (1966-74)		12.8 (1966-75)	

* Annual deviations from the mean value for the whole period of observations are expressed as percentages of that mean value (given at bottom of table).

Table 11. Seasonal rainfall and temperature data from Kelburn, Wellington (1966-75), expressed as percentage deviations from overall seasonal means for the 10 year period*

	TOTAL RAINFALL (mm)				TOTAL RAINDAYS (no. days)				MEAN DAILY TEMPERATURE (°C)			
	SUM	AUT	WIN	SPR	SUM	AUT	WIN	SPR	SUM	AUT	WIN	SPR
Mean for 1966-75	220	334	412	297	28	38	51	41	16.4	13.7	8.8	12.1
1966	+37	+31	-8	-25	+21	-3	+2	-7	-1	-2	-6	-6
1967	+61	-18	0	-2	+32	-13	-12	+2	-6	-3	-1	-2
1968	+6	+15	-4	+19	+7	+21	-2	+10	-1	+4	0	-7
1969	+16	-7	-43	-40	+11	-13	-18	-20	-6	-5	-8	+3
1970	-23	-3	+16	+7	-4	-3	0	-5	+5	-1	+10	+4
1971	-15	-32	+7	+17	-25	-8	-6	+15	+6	+6	+15	+1
1972	-20	-10	-13	-29	+4	-13	+14	-2	-3	+2	-10	+6
1973	-55	-27	-19	-2	-18	+16	+2	-2	-4	0	+2	+3
1974	+10	+72	+17	+60	-25	+11	+10	+7	+2	-7	+2	+2
1975	-19	-20	+47	-6	-4	-3	+10	+2	+10	+8	-1	-6

* see Table 1 for calculation of percentage deviations

Annual mean daily temperatures at Kelburn (Table 10) were highest in 1971 (13.5°C) and 1969 (13.2°C) and lowest in 1966 (12.2°C), 1967 and 1972 (12.4°C).

The summer and autumns of 1975 and 1971 were especially mild, while those of 1969, 1967, and 1966 tended to be coolest (Table 11). The winters of 1971 and 1970 were relatively mild, while those of 1972 and 1969 were cooler. Spring temperatures were highest in 1972 and lowest in 1968, 1966 and 1975 (Table 11).

Rainfall data show the years 1974, 1966 and 1968 to be the wettest, while 1969 was especially dry (Table 10). Seasonally the summers of 1967 and 1966 were wettest; the 1973 summer had the lowest rainfall, while the summers of 1971 and 1974 had the longest dry periods (fewer raindays). Heaviest autumn rainfalls occurred in 1974 and 1966, the most sustained rain occurring in 1968. Conversely, lightest falls occurred in the autumns of 1971 and 1973, with least sustained rain in 1967, 1969 and 1972. In winter most rainfall occurred in 1975 but was most sustained

in 1972. The driest winter was 1969. Spring was wettest in 1968, 1971 and 1974 and driest in 1969 and 1966 (Table 11).

An analysis of Kelburn weather records and possum weights showed adult female summer and autumn weights were correlated with prevailing weather; the animals weighed more in drier, warmer seasons. Also the mean daily summer temperature was correlated with mean weights one year later - possibly a spurious result, although an indirect, delayed effect through, say, the growth of possum food plants could be indicated. Lack of some local meteorological data made study of immediate weather and possum weight and breeding data difficult; very poor, wet weather reduced the numbers of possums caught, and a sustained period of bad weather could curtail feeding and reproductive activity and so contribute to reduced breeding; such may have been the case in the 1968 autumn and winter (refer Fig. 7); further, many of the possums found dead or comatose were trapped in cold and wet weather. Thus despite limitations in data, it appears that for 1966-75 weather fluctuations probably directly or indirectly influenced the possums and their food supply, and so may ultimately have influenced possum weight and breeding success.

(iv) Pathological factors

Autopsies were limited to those animals found dead or dying and little information was obtained on diseases and parasites.

At a time of heavy adult mortality in winter 1972 the cestode tapeworm *Bertiella trichosuri* Khalil was found in 5 dead possums examined; a further 2 cases occurred in winter 1973 (A.J. White, pers. comm.). Clark (1977) reports lower weights and low birth rates in females infected with this parasite in Taranaki. Some Orongorongo possums had heavily abraded fur due to irritation from the ectoparasite mites, *Atellana papilio* and *Trichosuro laelaps crassipes*; animals in poor condition were most heavily infected, and were severely scratched on the rump. Whether poor-conditioned animals were more prone to infection or whether the parasites contributed largely to their poor condition is not known.

Bovine tuberculosis *Mycobacterium bovis*, reported from New Zealand possums (Ekdahl *et al.* 1970; see also Julian, this symposium), was not observed in the study area during a 1976 survey (A.J. White, pers. comm.); advanced stages of infection characterised by external lesions at the lymph nodes would be evident in regularly trapped animals.

High infection rates of leptospirosis have been found in New Zealand possums (de Lisle *et al.* 1975; Hathaway, this symposium). A 1975 survey of urine samples from the Orongorongo study population revealed an infection rate of 10 percent (R.E. Brockie, pers. comm.), but any relationship between leptospore infection and breeding performance has yet to be established.

The study in perspective

The success of the common brushtail possum, both as an introduced species in New Zealand (Pracy 1962, 1974) and as a coloniser of disturbed habitats in Australia, reflects its demographic adaptability (Bell *et al.* 1979). Populations in the Orongorongo Valley at moderate densities contrast with those studied near Canberra and on Banks Peninsula where growth rates and breeding productivity are much higher (Tyndale-Biscoe 1955; Dunnet 1956, 1964; Gilmore 1966, 1969; Jolly 1976). The history of the Orongorongo populations has been a changing one both over the long and short-term.

Over the long-term there is evidence of marked depletion of selected food resources since possums were introduced last century (Mason 1958; Kean 1971, 1975, unpubl.) and such trends continue (Fitzgerald 1976, 1978; Meads 1976). Comparison with Kean (1971, 1975, unpubl.) suggests mean weights and breeding productivity have also declined since the 1950s.

Over the short-term (1966-75) the possum population exhibited marked annual changes. This may simply be a reflection of a variable environment, although it could (but not necessarily does) imply more than this - the study animals may now be near to the limits of their resources - near to their 'bread-line' - so that they are more sensitive to, and respond conspicuously to seasonal and annual fluctuations in their physical and social environment. Such marked fluctuations have not been recorded elsewhere, although it should be noted that no other studies on *Trichosurus vulpecula* have continued as long as the present one (e.g. see birth dates in Brockie *et al.* 1979).

Climate is important in directly influencing possum activity and health and through indirect effects on their food resources. Annual and seasonal fluctuations in food-supply, especially supplementary foods such as fruits and berries, seem to be important in determining variations in female weight and productivity. There is also evidence of density-dependent relationships in at least less 'extreme' years which require closer investigation. In the 'extreme' years factors such as food-supply and weather may have such a marked effect on productivity that they modify relationships between population density and productivity.

The regressions presented in this paper suggest a variety of predictions involving weight, breeding performance, population level and food supply. A start can now be made in developing a dynamic model of the climate-vegetation-possum complex of interactions in the Orongorongo study area, although with continuing study predictive equations will require updating and modification. The relationship of some of the components discussed in this paper is illustrated diagrammatically in Figure 13.

Bamford (1971) has already discussed the importance of assessing the fat levels of a possum population before implementing control operations, and he illustrated how, in one area, the success of such control could be predicted using a weight/length index (Bamford 1970). The present study demonstrates that, within some areas, the average annual body weight can vary markedly from year to year, and so the inferred fat-reserves. This too could have possible application to planning control in situations like the study area - a higher kill would be expected (from Bamford's data) in years when weights were lower.

Over 1966-75 there was little clear evidence of a marked rise or fall in possum numbers (if anything, they declined); rather, their numbers fluctuated as a consequence of annual variations in recruitment rate, mortality and dispersal, causing dynamic changes in their age-structure over the years. In the lowland podocarp-broadleaf forest of the Orongorongo Valley the possum is therefore maintaining moderately high densities, at least in the short-term (and notwithstanding the rigorous natural checks to breeding productivity and to population increase described here).

In general the possum is still in a phase of adjustment to its relatively new environment in New Zealand and without human intervention the carrying capacity of the Orongorongo forest will probably decline further as more food resources are depleted through selective browsing by possums and other herbivores. My analysis of the first ten years of population study has drawn attention to the dynamic nature of the possum-vegetation-climate interactions, emphasising some demographic consequences of temporal changes in the possums' physical and perhaps social environment. In a population with a life-expectancy on leaving the pouch of about 6 years (Brockie *et al.* this

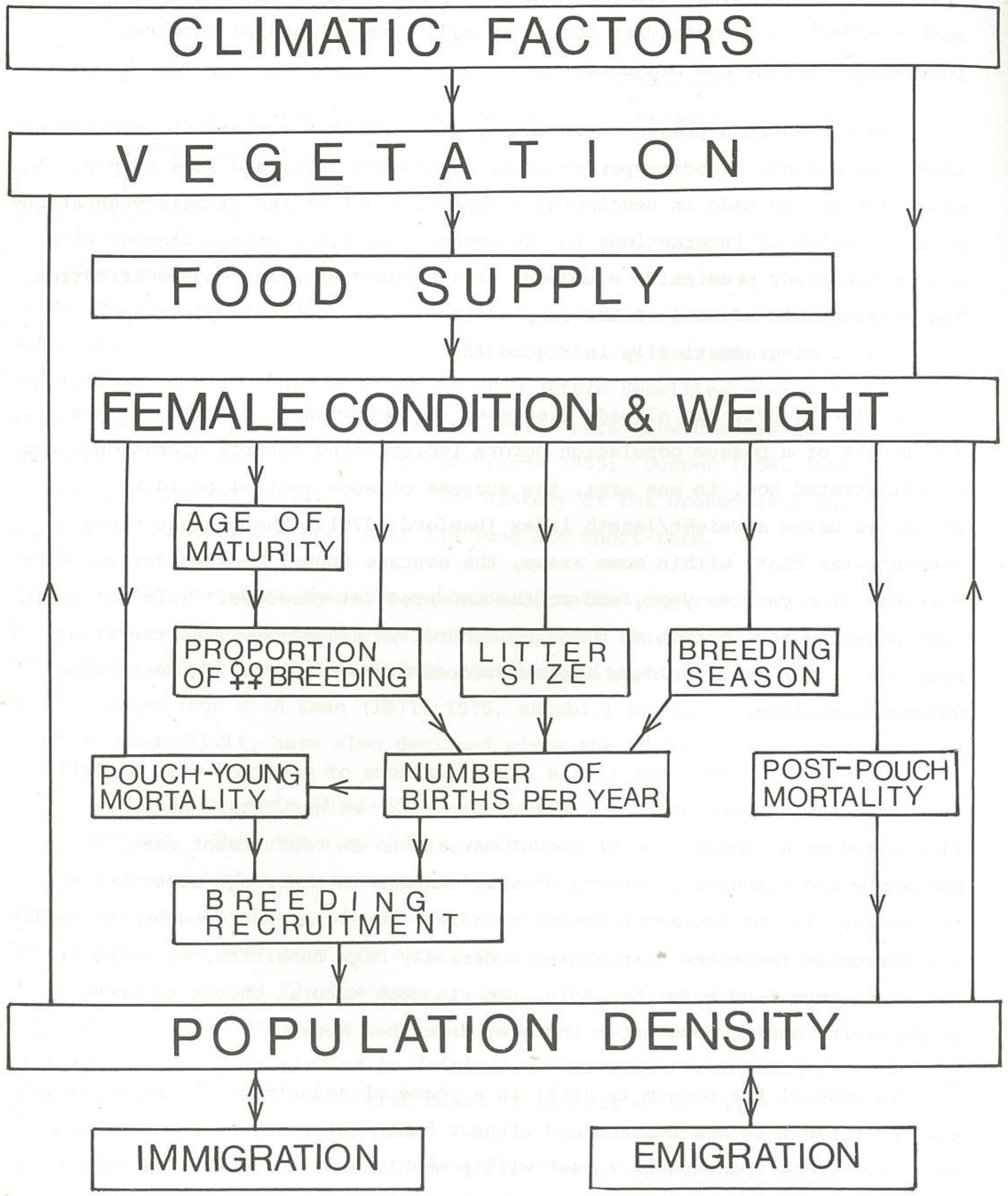

Fig. 13. A hypothetical model of the possum-vegetation-climate complex of interactions in the Orongorongo forest, with emphasis on aspects relating to female breeding productivity. 'Post-pouch mortality' refers to all deaths after the pouch-young phase of development, and to both sexes including females as indicated.

symposium), studies need to continue well into the future if the nature and rate of the longer-term population changes are to be adequately documented and more clearly understood.

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GENERAL DISCUSSION

WAGSTAFF. Dr Bell, you said that the security of the young depends to a large extent on the female. David Pepper-Edwards of the Auckland Zoo says that female wallabies often eject their joeys when disturbed or handled. Have you noticed this with the possums you've handled? When you weigh possums do the females take back their young or tend to eject them?

B.D. BELL. Most animals we handle are used to being caught and examined in cage traps so are relatively quiet during the handling process. The exceptions are generally new animals or those only caught a few times previously; the occasional individual remains excitable despite being caught many times. Generally we drug the female before examining her pouch and young and any young that are free of the teat are accepted back without difficulty - we have no evidence of pouch young being ejected or affected adversely by the female. Certainly it can be physically a little difficult to return older back young into the pouch, and those that are released riding on the back of the mother are occasionally knocked-off by vegetation, *e.g.* supplejack, as she runs away. However, the young is generally found again by the female.

COLEMAN. I noticed in 1968 your possums' breeding success and general weights were down. In 1968 in the South Island there was a very rugged winter with very poor success also. Last year there was very heavy snow on the West Coast and very poor survival. There were just no possums around when traps were out and there was no sign of them - they were probably holed up.

B.D. BELL. Dr Crawley was operating in the 1968 autumn of the Wahine storm - from all accounts the rainfall was higher than usual that autumn.

FITZGERALD. With the correlations you have run, have you in fact done anything in relation to the effect of rainfall?

B.D. BELL. There were few significant correlations between various rainfall parameters taking the monthly average. However a closer look at rainfall over the few days prior to capture, for instance, is worth doing. We know heavy rainfall can markedly affect the activities of the possum, so a period of sustained wet weather could be deliterious, especially if cold also.

YOUNG. You demonstrated the range of variation in productivity of your adult age class of possums. There must then be an extraordinary variation in the productivity of one and two year olds.

B.D. BELL. Yes, indeed, there is considerable variation in the first and second year age classes in terms of breeding performance. 1969 and 1971 were the only years in which first years ever attempted to breed and those two were the 'better' years generally.

MEADOWS. Can you give me any figures on the maturity of the males?

B.D. BELL. On external criteria - scrotal development of males and pouch development of females - the two sexes evidently mature about the same time. Most are not sexually mature at the end of their first year in the Orongorongo study but the situation may be different in other areas of New Zealand.

ASPECTS OF THE SOCIAL BEHAVIOUR OF THE POSSUM *TRICHOSURUS VULPECULA*

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ABSTRACT

Seventy eight possums were individually marked and observed by dimmed spotlight in a pastoral habitat in Birdling's Valley on Banks Peninsula, New Zealand, between October 1972 and February 1974.

A distinct change occurred only in male behaviour at the beginning of the breeding season. Males made all the approaches during the breeding period. Females were initially antagonistic to males, but gradually became more tolerant. Promiscuity was not observed within a given breeding season and a short-term pair-bond was established. However, partners did change between breeding seasons.

Young first emerged from the pouch when about five months old but remained closely associated with their mothers until 8-9 months old. There was some evidence that young of both sexes dispersed when 11-12 months old.

Tracks were used communally and even the intensively used parts of both male and female ranges overlapped. It is possible that occupied den sites were defended and that an individual-distance system of spacing between animals, maintained by scent-marking, occurred. The type of social organisation found in possums is compared with that of other mammals.

GENERAL DISCUSSION

CLOUT. Is there any evidence of a dominance hierarchy amongst the adult males in terms of mutually exclusive home-ranges?

JOLLY. We did not find this at Birdling's Valley. The only suggestion of any kind of dominance was in an adult female. However even she had a range which overlapped considerably with others in the autumn and she showed no sign of aggression to other animals there.

SUTTON. You said males follow the females at night. Are they responding to a scent secreted from some gland?

JOLLY. I am not sure, though their behaviour suggested they might be following a scent.

SUTTON. I wonder if it might be secreted during a threat posture?

JOLLY. It was not necessarily secreted during a threat display. Certainly the male followed nose-to-ground in situations where no threats were given.

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<u>B.D. BELL</u>. Have you any evidence that the repertoire of vocalisations varies between different possum populations. While I regularly heard the loud alarm or chatter call in Western Hutt, I have seldom noted it in the Orongorongo Valley forest.

<u>JOLLY</u>. I have only worked in the one study area so I cannot really comment on comparisons between different populations. The "kaa-kaa-kaa" chatter call you mention appears to be associated with a general alert situation, and it seemed to have some effect on other animals nearby. They would sit up on their haunches and look around and sometimes would even run up a tree.

<u>WODZICKI</u>. From your comments on behaviour it would seem to me that pherenomes may play a role - they have been shown to be important in our understanding of breeding behaviour and may have application in control work. I feel this is an area deserving more research attention as soon as practicable.

SOME CONTRASTS BETWEEN POPULATIONS OF THE POSSUM *TRICHOSURUS VULPECULA* IN DIFFERENT AGED STANDS OF *PINUS RADIATA*

M.N. Clout

University of Auckland*

ABSTRACT

Possums were studied by live-trapping and poisoning in young (2-4 year old) and middle-aged (13-15 year old) plantations of *Pinus radiata* near Tokoroa. In the latter area animals grew to a larger size and some females produced two young a year, contrasting with the single breeding season in young stands. These differences are discussed in relation to the winter foods available in the two habitats.

GENERAL DISCUSSION

<u>KEBER</u>. I am not sure what you attribute the difference in the size of possums between your areas to. I found there was an increase in size with altitude and I notice this happens in Kaingaroa.

<u>CLOUT</u>. Well, if anything, it would be the reverse trend in my two areas for the younger stands of trees had the smaller animals but were at a slightly higher altitude.

<u>KEBER</u>. In your case one area is a cut-over tawa *Beilschmedia tawa* forest and the other is one that has been in *P. radiata* for some years. In Kaingaroa both areas were second rotation *P. radiata*.

<u>CLOUT</u>. So you are implying differences in habitat quality?

<u>KEBER</u>. Yes.

<u>FITZGERALD</u>. Do you know if there was any difference in the rainfall between the two areas?

<u>CLOUT</u>. It would have been higher on the Mamaku Plateau in the younger trees.

<u>COLEMAN</u>. You mentioned females producing two young a year and in an earlier paper J. Jolly mentioned that young were dependent on the mother for about 8 months. This suggests such females must be suckling two young. Also I think males have been found in greater numbers than females in the pouch-young in any population studied in this country at least. This would support your findings.

<u>CLOUT</u>. I think the excess of males in my younger pine stand was due to greater dispersal of young males into the area rather than to a greater number of males born there. There seems to be a difference in dispersal patterns between the sexes during their immature phase, when about one year old or less.

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COLEMAN. Regarding fat estimations, you no doubt know that Dr Bamford in his paper* applied regression constants but these only referred to Westland populations.

CLOUT. Yes, I got different regression constants worked out from my own data.

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* BAMFORD, J. 1970. Estimating fat reserves in the brush-tailed possum, *Trichosurus vulpecula* Kerr (Marsupialia: Phalangeridae). *Australian Journal of Zoology 18*: 415-425.

CONTRIBUTED PAPERS

SESSION II - APPLIED RESEARCH AND MANAGEMENT

Chairman: J.M. Cummins
Victoria University of Wellington

SOME ASPECTS OF THE MANAGEMENT AND DISEASES OF CAPTIVE WALLABIES AT THE AUCKLAND ZOO

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ABSTRACT

Of the six species of wallaby feral in New Zealand, four have been held in captivity at the Auckland Zoo since 1970. These are the tammar wallaby *Macropus eugenii*, the parma wallaby *M. parma*, the red-necked wallaby *M. rufogriseus*, and the brush-tailed rock-wallaby *Petrogale penicillata*. In addition a colony of the agile wallaby *M. agilis* has been maintained.

The main factors in successful management are careful acclimatisation of new arrivals, the avoidance of stress, attention to the quality of the environment and to the materials used, strict attention to nutrition and diets, and an established preventative medicine programme. Regular recording and data collection are essential, and all animals are individually identified to facilitate these procedures.

The main disease problems have been the occurrence of *Fusiformis necrophorus* infection ("lumpy jaw" syndrome) and a predisposition to primary or secondary pneumonia. Ecto- and endo-parasitism is not a problem but nevertheless the animals are treated regularly with an anthelmintic as part of the preventative medicine programme.

Successful breeding colonies have been established for all species, using either wild-caught or captive-bred animals.

The wallaby species feral in New Zealand have a definite place in captivity, not only for exhibition purposes, but also as reproductive colonies providing opportunity for research and animal studies.

INTRODUCTION

Of about twelve species of marsupial introduced into New Zealand between 1858 and 1870, only the common brushtail possum *Trichosurus vulpecula* and six species of wallaby became successfully established (Wodzicki and Flux 1967). In some areas the latter multiplied to such an extent that in 1956 wallabies were classified as noxious animals, but eradication programmes against the red-necked wallaby *Macropus rufogriseus** had commenced as early as 1947 in the Waimate area.

Apart from the black-striped wallaby *M. dorsalis* which is now very rare if not extinct, these species provided the nucleus from which animals have been caught for display or research purposes in New Zealand, and hundreds have been exported.

Four of the six species have been held at the Auckland Zoo since the beginning of 1970. These are:

Red-necked wallaby *M. rufogriseus*
Tammar wallaby *M. eugenii*
Parma wallaby *M. parma*
Brush-tailed rock-wallaby *Petrogale penicillata*

In addition, a colony of the agile wallaby *M. agilis* has been maintained.

DEVELOPMENT AND MAINTENANCE OF COLONIES

Records are incomplete prior to 1975, but from information available it is clear that only in the last few years have viable and expanding colonies been established. Stock losses from disease or injury were substantial until the introduction of new management and feeding techniques, and the application of a strict preventative medicine programme. Figures for additions through importation and births, and for losses from disease or injury are shown in Table 1.

Two encouraging factors emerge from these figures. Firstly the incidence of death from disease has fallen dramatically between 1971 and the present, as has the incidence of disease occurrence itself. During the last eighteen months only three animals have required treatment, and none has died. Secondly, the number of births has risen, and within the four established colonies there have been twelve pouch-young from fifteen females since May 1976. Our definition of a successful birth is the first appearance of a pouch-young,

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* Editor's note: to maintain consistency throughout these Proceedings vernacular and scientific names follow those recommended by the Australian Mammal Society in 1980 - see also Preface.

Table 1. Additions and losses of wallaby stocks at Auckland Zoo 1968-1977 - all species included.

YEAR	IMPORTS	BORN	TOTAL ADDITIONS	DEATHS INJURY	DEATHS DISEASE	TOTAL LOSSES
1968	3	n.r.	3	n.r.	n.r.	3
1969	25	n.r.	25	n.r.	n.r.	26
1970	0	n.r.	0	n.r.	n.r.	13
1971	23	2	25	12*	18	30
1972	7	1	8	0	6	6
1973	1	3	4	0	8	8
1974	1	2	3	0	5	5
1975	9	2	11	8*	1	9
1976	23	4	27	6†	0	6
1977 to May	7	8	15	3*	0	3

* killed by dogs

† 4 dead on arrival from Australia
2 died after capture and translocation

n.r. no records.

Table 2. Number of wallabies displayed at Auckland Zoo (1 May 1977).

Species	No. ♂♂	No. ♀♀	No. ? sex	TOTAL
Agile	2	4	2	8
Parma	0	1	0	1
Red-necked	3	5	0	8
Rock	3	4	0	7
Tammar	1	4	1	6
Total	9	18	3	30

usually at about three to four months after birth has actually taken place. These two factors have resulted in an overall increase in the wallaby population, and this has been supplemented by the translocation of rock-wallabies from Motutapu Island and red-necked wallabies from the South Island.

Deaths from injury are tabled separately to highlight the disastrous results that attacks by feral dogs can have on wallaby colonies. In 1971 and 1975 twenty wallabies were either killed outright or died shortly after attack from injuries received or from shock. Only eight days ago a further three suffered the same fate. Although the Zoo has a three metre perimeter fence surrounding it and all precautions are taken to prevent entry of dogs through open gateways, it has proved impossible to entirely eliminate the risk, and dog traps are now set every evening as a precautionary measure. Any animal caught is destroyed. In our experience attacks have been by two or more animals acting together, and any organisation considering setting up colonies for display or research purposes should be aware of the danger, particularly in urban areas where roaming dogs are liable to form packs.

The numbers of each species currently held are shown in Table 2.

MANAGEMENT

Translocation and acclimatisation

The first consideration in acclimatisation is to place the animals in a stress-free environment. The stress involved in the capture and/or shipping of animals, particularly those which are wild caught, or species, such as the agile wallaby, which are naturally of a nervous disposition, is considerable (Meadows, unpublished). The six deaths in 1976 all occurred during or immediately after translocation - four out of a shipment of eight agile wallabies were dead on arrival at the Zoo, post mortem examination showing the cause of death to be cardiac tamponade induced by the psychogenic stimulation of loading in Australia. The other two deaths were of brush-tailed rock-wallabies which had been caught and translocated to the Zoo as part of a research project. One animal died from injuries sustained in its violent attempts to escape while recovering from the influence of a neuroleptanalgesic, and the other died from shock.

Incoming animals are placed into the quarantine area for a minimum of seven days, regardless of their origin. During this period the animals are observed several times a day, routine faecal egg counts are carried out for

the detection of parasite burdens, and routine anthelmintic treatment given with the food.* As soon as possible after arrival animals are weighed, sexed and identified by means of ear-nicking (Karsten 1975).

The quarantine buildings and yard are entirely surrounded by a three metre concrete block wall, and covered with a roofing of wire mesh. Thus animals contained within the quarantine area are unable to see anyone except the staff assigned to look after them, and stress from sight and sound of humans is minimal. Only assigned Zoo staff, the veterinarian and Department of Agriculture inspectors are allowed access.

Animals are allowed free access from a 5 x 4 metre loose box to an outside concrete yard measuring about 15 x 5 metres. The concrete floor of the loose box is covered with a layer of hay or straw, and several bales of hay are placed to form small hideouts for the animals.

Animals adapt quickly to the presence of a quiet human being, and stress is thus kept to a minimum. However, wild-caught animals and nervous species require quiet handling throughout their lives. Food is provided in the form of a zoo-animal cake containing 14% protein, fed at a rate of approximately 2 kg cake per 100 kg animal. A small amount of lucerne chaff is given, and hay and water provided *ad lib*. With such a dry feeding regime, no nutritional scour has been noted.

Once animals have become reasonably quiet, are eating well and are cleared by the veterinarian as being free from disease they are transferred to their outside enclosure.

Handling and Restraint

Animals are caught by one of two methods. The most common is the use of a large catch net. This is made of double strands of 3 mm brushed nylon cord with a mesh of about 8 cm square and is 2 m high and 10 m long. It is laid on the ground and the animal to be captured is driven quietly across it. As the animal passes over, the net is lifted and the animal tangled in the mesh. Hoop nets may be used but are less satisfactory. Quiet animals can be caught by hand at the base of the tail.

Once caught, animals are restrained by placing them into a sack, or if they are reasonably quiet they are carried on one arm by placing the forearm

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* Equizole - Merck, Sharpe and Dohme

across the top of the animal's body and then between its hind legs, gripping the base of the tail, the animal facing the operator. Once held like this a wallaby can be carried with little stress to either itself or the operator.

Enclosures

These should be as spacious as possible. Although animals have bred in enclosures of about 6 x 3 metres, at least three times these dimensions are recommended (Bergin 1976). The enclosure sizes at Auckland have been a minimum of 20 m x 10 m, and two years ago three enclosures were made into one large one for the exhibition of a mixed group. After enlargement the measurements were 40 m x 20 m. Currently this contains 1 eastern grey kangaroo *Macropus giganteus*, 9 common wallaroo *Macropus robustus*, 8 agile wallaby, 1 parma wallaby and 6 tammar. The move has been very successful, and interspecific interaction has so far been confined to periodic sparring matches between a male agile wallaby and the second oldest male wallaroo, who despite his greater size usually is the first to break contact.

Perimeter fences are a minimum of 2.5 m high - more to keep out feral dogs than to keep in the wallabies.

When new animals are introduced into an enclosure wire fences are made more visible by hanging them with hessian as panicky animals will bound straight into a wire fence.

The floors of most enclosures are sanded to a depth of at least 20 cm. Earth and grass floors are not favoured except for large enclosures on a hillside in which are kept two colonies of rock-wallaby. The extensive nature of these ensures the preservation of adequate ground cover.

Enclosures should be well planted with trees and shrubs protected by guards. These not only give shade, but allow escape and afford protection from animal interactions. They are also aesthetically pleasing, and Auckland enclosures have been planted out with Australian native plants to represent more fully the Australian zoogeographical region.

If adequate trees, shrubs, rocks and logs are provided there is no need for formal shelters. However, in the mixed exhibit there are two large shelters, each 4 x 3m, in which food troughs are placed in summer, and into which hay is placed in winter as bedding material (small amounts being added daily until the bed is up to 30 cm thick by 3 months at which time it is all

cleared out). Provided that an adequate amount of fresh hay is added daily, no disease problems arise, and the animals enjoy the warmth and comfort of the bed.

Enclosures are cleaned every morning. Faeces are picked up by brush and shovel wherever practical, and sanded enclosures are thoroughly raked to expose any contaminants to the actions of sunlight and wind.

Food and water bowls and troughs are cleaned daily.

Feeding

Animals are fed once daily, in the afternoon, using the same system as for the quarantine animals. In addition occasional green food is given, such as grasses, tree or shrub leaves, bamboo, green vegetables, *etc*. Lettuce should be fed sparingly as it predisposes to diarrhoea. All food is placed in troughs to reduce the possibility of ingestion of parasitic ova or other contaminants. Water is provided by automatic drinking bowls placed about 30 cm above ground level. From time to time a young animal may need to be hand-reared (Wilson 1971) and for this a lactose-free diet should be used to avoid the occurrence of nutritional diarrhoea or cataract formation (Stephens 1976, Finnie 1976).

Breeding

The tammars mature sexually at about two years in males and at about one year in females, which continue to breed throughout life. They are seasonal breeders and in the southern hemisphere produce young in January (Barker 1971). Parma wallabies breed mainly in the spring, while red-necked wallabies breed all year round. The present colony of agile wallabies appears to be exhibiting similar behaviour to the tammar wallabies.

Currently no selective breeding is carried out, and any male may serve an oestrous female of the same species. Eventually selection will be carried out for females by the removal of male pouch-young, a technique used successfully at Adelaide Zoo (Dunn 1972).

DISEASES

In the past colonies have suffered from two main disease problems - the first, lumpy jaw, has been a common problem in many zoos (Wallach 1971, Barker, Calaby and Sharman 1963) and is now known to be caused by *Fusiformis* *necrophorus* with secondary infection by a large range of bacteria. While the disease appears refractory to most forms of treatment, Vibramycin has been effective in at least one case at the Auckland Zoo (Smith, pers. comm.). The second, pneumonia, has been a salient post-mortem finding in many instances, and is thought to have been induced by lowered bodily resistance resulting from stress or sub-clinical infections. Many cases occurred shortly after translocation, but no common organism was isolated.

Preventative Medicine

The current disease prevention programme is based on accurate observation and recording by well trained staff, and has virtually eliminated disease problems during the last two years. Every animal is closely inspected each day, as routine, and any change in behaviour or illness is reported immediately. Keepers' observations are recorded in a daily diary kept at the feed shed, and include group behaviour as well as individual. Each animal has its own record card, on to which are transposed all relevant observations, including matings, changes in habit, sighting of pouch-young, dietary changes or illness, treatment, and transfers. Regular collection of faecal samples for examination for oocysts and for worm egg counts, plus routine treatment with anthelmintics at three-monthly intervals has completely eliminated intestinal parasitism. Coccidiosis has never been diagnosed, and no coccidiostat is added to the food. No other vaccinations or procedures are carried out, except that whenever practical animals are weighed.

Treatment

Any animal appearing sick, or showing loss of weight, is transferred to an isolation pen where regular attention can be given without stress, either to the individual animal or to the composite group.

THE VALUE OF CAPTIVE COLONIES

Although in many areas the wallaby is a pest, it certainly does have a place in New Zealand. It has a value as a tourist attraction in reserves such as Kawau Island, and in captivity it makes an attractive, interesting and educational exhibit in zoos and wildlife parks. No major exhibition of wildlife would be complete without at least one colony of wallabies, and because of their size they are easy to keep and handle. Tame animals can be successfully incorporated into a walk-through or contact area.

Captive colonies have proved popular for research purposes in Australia and have been used in America (Barker 1971). An Auckland Zoo colony of the rock-wallaby is currently under post-graduate study by the University of Auckland in order to obtain some basic information on territorial and agonistic behaviour prior to a field study on Motutapu Island, and the other colonies are used by undergraduates from various faculties for behavioural study. Plans for a study programme by Zoo staff are currently under way.

Between the two extremes of attitude to the wallaby there must be a compromise, and I suggest that the animal not only has a future as part of New Zealand's mammal fauna, but also makes a most interesting subject for research and a pleasing and entertaining exhibit. It should not be forgotten that the "rediscovery" of the parma wallaby on Kawau Island led to export of stock from New Zealand which established the species in many parts of the world in an attempt to prevent its extinction. Currently the rock-wallaby, a subject of extermination on Motutapu Island, is reported as becoming rare in parts of Australia (Bucher pers. comm.) and certain universities and wildlife parks are currently negotiating the capture and translocation of these animals from the island. Control measures are necessary, but should only be carried out after all aspects have been studied, and this indicates a need for closer communication between those who are interested in captive propagation and the government departments with an interest in wallabies.

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GENERAL DISCUSSION

CUMMINS. During a visit to Australia last December I learnt of a research grant into work on the reproduction of macropods that exceeded six figures, so there is a lot of money involved in such research there.

LEES. Mr Meadows, first I would like to congratulate you for helping us realise there are other marsupials apart from possums. I have two points, the first regarding ear-nicking of wallabies - we found regrowth of the ear could occur after about 2 years. The second and most interesting point concerns lumpy-jaw - do you really think you have got on top of it? If so, we will be putting our animals on sand.

MEADOWS. On your second point, yes I believe we have got lumpy-jaw beaten. We have been careful with diets and whether or not by using sand we have eliminated *Fusiformis* from the environment I don't know. I tend to think we have. Regarding ear-nicking, yes I agree one does get regrowth and we will either have to re-nick or probably also tattoo the ear. There should be another method for you also get tearing of the ears with fighting so it may be difficult to distinguish such tears from an ear-nick.

LEES. In the case of lumpy-jaw, we have animals that may need treatment time and time again. Is it worth continuing to inject them?

MEADOWS. I have not been in a position of having to do this myself, but I'm tempted to say no because it is claimed that there is no satisfactory cure. Vibramycin had been found to cure it in one case only but that was before my time. I think it is generally accepted that it is extremely difficult to cure. When you look at the bone erosion that occurs and the secondary infections, such as lung infections, I think it is very doubtful that one should treat it, apart from the fact that you may still have the organism being spread. I think there should be isolation to start with.

ANONYMOUS. Could you comment on the accumulated hay bedding in some shelters which are cleared out every 3 months.

MEADOWS. In the summer rocks and shrubs provided much of the shelter. In the winter last year we tried the hay bedding system in a fairly large house which the animals shared. We simply built up a hay (not straw) floor and this was added to daily. We did not clean it out - faecal and urine matter within the bedding broke down but the top of the bed was completely dry and remained clean for 3½ months. We were told this was not the right thing to do, so we are keeping our fingers crossed. Rightly or wrongly we got through and we did this with ungulates as well. We shall try again next winter.

LEPTOSPIROSIS IN THE POSSUM *TRICHOSURUS VULPECULA*

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ABSTRACT

The common brushtail possum has been established as a primary host reservoir for *Leptospira balcanica* (subgroup *Hebdomadis*) in New Zealand, and evidence of infection was present in over 80% of mature adults in this survey. The presence of *balcanica* has not been established in domestic stock or man in New Zealand to date, however with definitive reference laboratory typing of isolates, *Hebdomadis* infections diagnosed in these species may be found to be mainly due to *balcanica*.

Extensive wildlife surveys in East Europe and throughout the world have failed to identify *balcanica* in wildlife species. Therefore, the possum is the only reported wildlife reservoir of this organism in the world.

INTRODUCTION

Leptospiral organisms are classified by division into serogroups and within serogroups, serovars, on an international basis. There are twelve main serogroups and contained within these groups are more than 130 serovars. In New Zealand, six leptospiral serovars have been isolated, *viz.*: *ballum*, *pomona*, *copenhageni*, *tarassovi*, *hardjo* and *balcanica* (Table 1). Of these, *hardjo* and *balcanica*, which are antigenically very similar, belong to the *Hebdomadis* serogroup.

Leptospiral infections are very common in domestic stock in New Zealand, with several serovars being represented. *Hebdomadis* serogroup infections are most relevant to this discussion and have been demonstrated by serology in cattle, sheep and horses. Serovar *hardjo* has been isolated from cattle (Lake 1973), and it has been assumed that this serovar has been the most prevalent of the *Hebdomadis* organisms infecting domestic stock.

The *per capita* prevalence of leptospirosis in humans in New Zealand is amongst the highest in the world (20 cases: 100,000 c.f. U.K. 0.1 : 100,000 and U.S.A. 0.02 : 100,000) and *Hebdomadis* serogroup infections are the most common. Serovar *hardjo* has been isolated from humans by Christmas *et al.* (1974).

Recently, *hardjo* was reported as being isolated from the common brushtail possum *Trichosurus vulpecula* in New Zealand (Brockie 1975; de Lisle *et al.* 1975).

Table 1. Leptospires isolated in New Zealand.

SEROGROUP	SEROVAR	HOST SPECIES	FIRST REFERENCE
Pomona	L. pomona	Bovine	1954
		Porcine	1976
		Feline	1970
		Human	1952
Hebdomadis	L. hardjo	Bovine	1973
		Human	1974
		Possum*	1976
	L. balcanica	Possum	1976
Ballum	L. ballum	Bovine	1973
		Human	1967
		Hedgehog	1976
		Rat	1976
		Mouse	1977
Icterohaemorrhagiae	L. copenhageni	Bovine	1960
		Rat	1951
Tarassovi	L. tarassovi	Porcine	1976

* Not subjected to cross-absorption identification procedures

In 1975 the author made a single isolation of *balcanica* from a possum in the Pohangina Valley. Serovar *balcanica* had only previously been isolated from a man in Bulgaria (Janev, *cit.* Babudieri and Mateev 1961) and from cattle and a pig in Russia (Semenova 1965).

Serovars *hardjo* and *balcanica* are within the same antigenic subgroup as determined by factor sera analysis (E. Kmety pers. comm.) and as such the only means of differentiating between these organisms is by isolation of the organism in pure culture and examination by cross-absorption studies on specific antisera of all serovars within the *Hebdomadis* serogroup. This is a complicated procedure and is performed at W.H.O. reference laboratories. Consequently, the agglutination test used routinely on sera in this country will identify infection due to organisms from a particular serogroup, but will not identify

specific serovars. Similarly, any isolated cultures from animals with leptospirosis can only be identified as to serogroup without definitive typing.

Bearing these facts in mind, a survey was undertaken in the southern half of the North Island to determine the prevalence of *Hebdomadis* serogroup infections in pastoral possum populations, and to identify the specific serovars involved.

MATERIALS AND METHODS

Field samples were collected by night shooting and trapping from four pastoral localities where possums were of moderate to high population density. Following bleeding, sex and age-group were determined and the animal tagged for identification. Animals were divided into juvenile, transitional-stage adult and mature adult groupings. Differentiation was made on sexual maturity parameters: juveniles had testes lengths < 18 mm (males) or had undeveloped pouches (females); transitional-stage adults were sexually mature but weighed less than 2.4 kg and lacked the conformation of fully grown adults; mature adults weighed 2.4 kg or more and had fully mature head and body conformation.

Sera were tested by the microscopic agglutination test (M.A.T.) against reference antigens *ballum*, *pomona*, *copenhageni*, *tarassovi*, *hardjo* and *balcanica*. The reciprocal of the final dilution of serum that agglutinated 50% of the test antigen was taken as the titre of that serum.

Kidneys were aseptically removed within 3 hours of death and cultured. A 'Coleworth Stomacher[1]' was used to homogenate whole kidneys and three serial ten fold dilutions were inoculated into EMJH[2] semisolid media.

RESULTS

A high prevalence of *Hebdomadis* serogroup reactions was revealed in the pastoral possum populations sampled, with 60 of 127 sera (47%) positive to *Hebdomadis* antigens. Serovar *hardjo* antigen gave a consistently higher titre when compared with *balcanica* antigen in all sera tested. No cross-reactions were seen with antigens from other serogroups.

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[1] Coleworth Stomacher 400, A.J. Seward and Co. Ltd., 6 Stamford Street, London, SE 19 UG, England.

[2] Bacto-Leptospira Medium Base EMJH, Difco Laboratories, Detroit, U.S.A.

There was a marked age differentiation in serological prevalence with mature adults having the highest prevalence, and only one juvenile animal being positive at a low titre (Table 2).

Table 2. Serological and cultural prevalence by age and sex of serogroup *Hebdomadis* leptospiral infection in possums from four pastoral localities.

SUBGROUP	NO. COLLECTED	NO. SEROPOSITIVE TO *HEBDOMADIS* ANTIGEN	(%)	NO CULTURE POSITIVE	(%)	NO. SERO. AND/ OR CULTURE POSITIVE	(%)
Mature male	32	25	(78)	23	(72)	28	(86)
Mature female	32	22	(69)	18	(56)	26	(81)
Trans. stage male	15	7	(47)	4	(27)	7	(47)
Trans. stage female	18	5	(28)	3	(17)	5	(28)
Juvenile male	15	0	(0)	0	(0)	0	(0)
Juvenile female	15	1	(7)	0	(0)	1	(7)
Total	127	60	(47)	48	(38)	67	(53)

Leptospiral isolations were made from 48 of 127 animals sampled (38%). All were typed against standard antisera in our laboratory as belonging to the *Hebdomadis* serogroup. Eight isolates were forwarded to the W.H.O. Reference Laboratory in Atlanta, U.S.A. for serovar identification. All eight isolates were found to be serovar *balcanica*.

A marked age differentiation was seen in cultural prevalences with all isolations being from sexually mature adults (Table 2). Isolates were obtained from 41 of 64 mature adults (64%) and from 7 of 33 transitional-stage adults (21%).

DISCUSSION

These results demonstrate that leptospiral infections of pastoral possums in New Zealand are very common with over 80% of mature adults showing serological and/or cultural evidence of infection at the time of collection. The recovery and definitive identification of *L. balcanica* from possums establishes this animal as a primary host reservoir for this organism. The origin of this infection in possums in New Zealand is unknown as this organism has only previously been isolated from domestic stock and man in East Europe. Other wildlife species including rats, mice, hedgehogs, *Mustelidae*, pukekos and ducks have been investigated in New Zealand for *Hebdomadis* infections (unpublished data) but no cultural or serological evidence has so far been found.

Isolations were made in all cases from sexually mature adults, and serological reactions were also restricted to this group. This pattern has been reported in other species of wildlife in leptospiral surveys overseas (Ferris *et al*. 1961; Wolf and Bohlander 1965; Shotts *et al*. 1975) and may be a feature of endemic host-adapted leptospiral infection in wild animal populations.

Two earlier reports of leptospiral infections in possums (Brockie 1975; de Lisle *et al*. 1975) provisionally diagnosed the organism involved as being *hardjo*. Without the use of cross-absorption tests, it is not possible to distinguish between *balcanica* and *hardjo*. In light of the results of the present survey it is more likely that the organisms isolated were in fact *balcanica*. The fact that possums infected with *balcanica* give a higher serological titre against *hardjo* antigen compared with homologous antigen is being further investigated.

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GENERAL DISCUSSION

MIERS. Do you get any regional differences in the infection rate of possums?

HATHAWAY. I have only sampled in the southern half of the North Island. However we have differentiated between different habitats such as pastoral, forest margin and deep forest. We found leptospiral infection in forest up to 5 miles from the forest margin so it seems capable of residing in the deep forest populations.

B.D. BELL. Have you examined isolated populations, such as the possums on Kapiti Island?

HATHAWAY. Mr A.J. White has been collecting urine from possums in the Orongorongo Valley forest and the organisms appear to occur through the year at a rate of about 10-20% of the possums examined.

KEBER. Could you speculate on how this serotype has become so infective in the possum in New Zealand?

HATHAWAY. I can speculate. In New Zealand all our ground mammals were introduced, and these included species in which the infection could have evolved. So you could speculate that the organism was introduced to possums after European settlement in New Zealand, or was introduced with the brushtail possum from Australia and that in New Zealand we have a specific ecological situation which has allowed *balcanica* to become endemic.

TUBERCULOSIS IN THE POSSUM
TRICHOSURUS VULPECULA

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ABSTRACT

Since tuberculosis was first reported in possums in New Zealand in 1970 field surveys and experimental work have contributed significantly to our understanding of the epidemiology and pathology of the disease.

Infected possum communities have been discovered in 23 general localities throughout New Zealand. There is compelling evidence linking tuberculosis in possums to high and persistent reactor rates in cattle in the same environment.

The possum is very susceptible to the effect of infection with *Mycobacterium bovis* and will develop a progressive and fatal disease with wide dissemination of lesions. The lesions are characterised by a limited cellular response, extensive tissue necrosis and a high rate of multiplication of the bacilli.

It is highly probable that tuberculosis can maintain itself in a population of possums and serve as a continuing source of re-infection for cattle and as a risk to people handling possum carcases.

INTRODUCTION

Tuberculosis is caused by acid-fast bacilli in the genus *Mycobacterium*, principally by *M. tuberculosis*, *M. bovis* and *M. avium* (the human, bovine and avian strains respectively).

Although recognition of tuberculosis in wild brushtail possums *Trichosurus vulpecula* is a relatively recent event, tuberculosis in captive animals has been recognised for sixty years. Moore (1903) noted "an enlargement of one of the stifle joints exactly in the nature of a strumous enlargement or abcess sometimes found in sheep. Post-mortem examination showed the lungs one mass of tubercles." These lesions were seen in 1895 in a young possum held in captivity. Subsequently tuberculosis was reported in a possum held in a zoological park (Scott 1928).

Tuberculosis in wild possums was first reported in 1970 (Ekdahl *et al.* 1970), and this report was an outcome of a growing awareness of an association between the persistence of tuberculosis in cattle in a tuberculosis control area and tuberculosis in possums in the same environment. The distinctive lesions of tuberculosis due to *Mycobacterium bovis* in the possum have been described

(Ekdahl *et al.* 1970, Smith 1972) and Smith (1972) drew attention to the large numbers of organisms which may be present in these lesions.

There is now compelling circumstantial evidence linking tuberculosis in possums to a high and persistent reactor rate in cattle sharing the same environment and, although a number of feral or wild species may be infected with *M. bovis*, only the tuberculous possum appears to have attributes of a significant reservoir of infection for cattle (Animal Health Division 1976).

The susceptibility of the possum to *M. tuberculosis* and *M. bovis* infections has been established experimentally (Bolliger and Bolliger 1948). Intraperitoneal and intramuscular injections of tubercle bacilli resulted in death in 2 to 5 weeks and natural transmission of *M. bovis* from an experimentally infected possum to a cage mate was demonstrated.

CLINICAL EFFECTS

No detailed clinical observations have been made on tuberculosis in the possum. Wild possums with advanced tuberculosis have occasionally been observed wandering about in the open during daylight hours. They appear dazed and do not respond to the approach of man.

Following experimental infection with *M. bovis* the onset of the illness was quite abrupt. The possums became quiet, less responsive to stimuli and less resistant to handling. They lost their appetite and body condition: the degree of loss being dependent on the duration of illness. Clinical signs were observed for approximately 14 days prior to death regardless of the length of the premonitory period (O'Hara *et al.* 1976).

GROSS LESIONS

The distribution of gross lesions as seen at post mortem of poisoned wild possums in three surveys is given in Table 1. These figures show that the lungs are the most commonly affected site (202/327 - 61.8% of cases). The superficial lymph nodes were affected on 203 occasions. As some possums would have lesions in more than one superficial lymph node the total number of possums with lesions in these sites would be somewhat less than 62.7%. Nevertheless, superficial lymph nodes would be the second most common site affected.

Table 1. Distribution of gross lesions in poisoned wild possums.

SITE	A.		B.		C.		TOTALS	
	No	%	No	%	No	%	No	%
Lung	21	80.1	81	55.1	100	65	202	61.8
Liver	12	46.2	28	19.0	20	13	60	18.3
Spleen	2	7.7	14	9.5	9	5.8	25	7.6
Kidney	2	7.7	18	12.2	6	3.9	26	7.9
Adrenal	2	7.7	3	2.0	-	-	5	1.5
Axillary lymphnodes	2	7.7	46	31.3*	81	52.6*	129	39.4
Inguinal " "	4	15.4	17	11.6+	28	18.2+	49	14.9
Mediastinal " "	3	11.5	8	5.4^{o}	30	19.5^{o}	41	12.5
Mesenteric " "	7	26.9	27	18.4	31	20.1	65	19.8
Gastric " "	4	15.4	2	1.4	1	0.6	7	2.1
Hepatic " "	3	11.5	14	9.5	14	9.1	31	9.4
Iliac/sublumbar lymphnodes	1	3.9	5	3.4	5	3.2	11	3.3
Peripharyngeal/ cervical lymphnodes	-	-	3	2.0	22	14.3	25	7.6
Total No. of possums	26		147		154		327	

A Possum tuberculosis survey - Waikato region 1974 (Lake 1974)
B Possums from Hohonu Mountain 1974 (Animal Health Division 1974)
C Possums from Buller and Inangahua counties 1974 (Cook 1974)

* Axillary and post scapular lymph nodes
\+ External iliac lymph nodes
o Mediastinal and bronchial lymph nodes

Lesions have also been recorded in splenic and renal lymph nodes, prostate and mammary glands, stomach, intestine and heart (Animal Health Division 1974, Cook 1974, Lake 1974). Bone infections also occur occasionally.

The distribution of lesions in experimentally infected possums is shown in Tables 2 and 3. Following subcutaneous inoculation on the medial aspect of the left thigh the nature and distribution of lesions at post-mortem resembles those seen in naturally infected wild possums. Intranasal instillation produced a less widespread distribution of lesions with involvement of somatic lymph nodes confined to the head and neck only (O'Hara *et al.* 1976).

Table 2. Distribution of gross lesions in subcutaneously infected possums (O'Hara *et al.* 1976).

Lesions present*

Dose (mg)	Inoc. Site	Inguinal LN	Axillary LN	Head LN	Hepatic LN	Mesenteric LN	Iliac Sublumbar LN	Lung	Liver	Kidney	Spleen	Adrenal
0.2	3/3	6/6	2/6	0/3	3/3	3/3	3/6	6/6	3/3	4/6	3/3	0/6
0.6	2/2	4/4	4/4	1/2	2/2	1/2	0/4	4/4	2/2	2/4	2/2	1/4
1.0	2/2	2/4	2/4	0/2	2/2	1/2	1/4	4/4	2/2	2/4	2/2	1/4

* Expressed as $\frac{\text{no. sites with lesions}}{\text{no. sites examined}}$

Table 3. Distribution of gross lesions in intranasally infected possums (O'Hara *et al.* 1976).

Lesions present*

Inoc. site	Inguinal LN	Axillary LN	Head LN	Hepatic LN	Mesenteric LN	Iliac Sublumbar LN	Lung	Liver	Kidney	Spleen	Adrenal	Intestine
0/4	0/8	0/8	4/4	3/4	4/4	0/8	7/8	3/4	1/8	3/4	0/8	1/4

* Expressed as $\frac{\text{no. sites with lesions}}{\text{no. sites examined}}$

Somatic lymph node lesions are typically a soft fluctuating abscess with a diameter up to 4 cm containing a semi-liquid lime green pus. On occasions these abscesses open and form sinus tracts, discharging their contents. White to yellow nodules up to 2 cm in diameter are the most commonly seen lesions in visceral organs and lymph nodes. They may be multilobular and have a more caseous centre than a somatic lesion. In some possums miliary white lesions will be seen in the lungs, liver, spleen or kidneys. The lungs of other possums may have generalised grey-white consolidation of part of a lobe or lobes.

HISTOPATHOLOGY

Histologically the lesions can vary from typical tubercle formation to poorly organised lesions composed mainly of necrotic tissue.

Lake (1974) describes the typical areas of nodular consolidation as being composed of granulomatous tissue, with no distinctive fibrous capsule and with varying amounts of amorphous eosinophilic debris centrally. Reactive infiltrating cells included lymphocytes, plasma cells, an occasional eosinophil, macrophages, giant cells and many neutrophils. Neutrophils were in greatest concentration around the area of caseous material. No mineralisation was observed. Acid-fast bacteria were often present in large numbers; both free and phagocytosed in macrophages. Smith (1972) described the reaction as being mainly suppurative and estimated that approximately 5 x 10^9 organisms were present in 1 gm of tissue.

Typical tubercles with epithelioid cells, Langhans giant cells and capsule formation have been seen on rare occasions.

Preliminary observations from experimental work (O'Hara *et al.* 1976) have suggested that the earliest lesions appear to be small foci of necrosis of the invaded tissue infiltrated by neutrophils. These foci are invaded by macrophages which accumulate in considerable numbers but appear to be randomly arranged and do not organize as epithelioid cells as seen in other species. At this stage small to moderate numbers of bacilli are present. Coagulative necrosis occurs at the centre of the macrophage nodules, the necrotic tissue becomes caseous and bacilli are usually more numerous. While caseation does occur, there is usually a substantial amount of coagulative necrosis indicating that necrosis is proceeding at a rapid rate. The granuloma does not acquire a significant capsule and the formation of satellite granulomas is common. The large lesions found in the lungs and lymph nodes consist of large necrotic centres surrounded by a narrow rim of macrophages and neutrophils. Liquefaction is common in these large lesions and at this stage the number of bacilli present is reduced.

The limited cellular response, lack of organisation of the response, extensive tissue necrosis and high rate of multiplication of bacilli are the histological hallmarks of a susceptible host.

MICROBIOLOGY

Mycobacterium bovis is the most common isolate from tuberculous possums. Ninety out of one hundred and nine isolates from possums were typed as *M. bovis*. *M. vaccae* was isolated on seventeen occasions and *M. avium* and *M. fortuitum* on one occasion each (Ekdahl 1976).

M. vaccae is a rapidly growing organism and is considered to be saprophytic. It has been isolated most commonly from possums which had lesions histologically attributed to other causes although in three out of 20 cases a dual infection of *M. vaccae* and *M. bovis* was found. Experimental inoculation of possums with a suspension of *M. vaccae* failed to produce lesions (O'Hara *et al.* 1976). Thus, it appears as if *M. vaccae* is an opportunist which can colonise lesions in possums.

IMMUNOLOGY

The susceptibility of the possum to the effects of *M. bovis* infection has prompted speculation on, and some investigation into the cell mediated immunity of the species.

Artificially infected possums showed no significant hypersensitivity to intradermal tuberculin whereas BCG vaccinated possums did show a slight degree of reaction. The vaccinated possums did show an increased resistance to subsequent infection manifest by longer survival times, fewer and less widely distributed lesions and the development of fewer but larger pulmonary lesions. The latter lesions were large but discrete areas of lung replaced by caseous tissue (O'Hara *et al.* 1976). These findings suggest that the possum may be a useful model in studying the relationship between hypersensitivity and immunity as the role of hypersensitivity in the immune response of animals to mycobacteria is not completely clear (Salvin and Neta 1975, Youmans 1975).

It has been found that possum splenic leucocytes are less readily induced to transform by low levels of mitogen than are rabbit cells (Moriarty 1973). Lymphocyte transformation is one *in vitro* method of assessing cell mediated immunity.

Thus, there is some evidence that cell mediated immunity as a means of controlling tuberculosis is not as well developed in the possum as in other species.

PREVALENCE

The prevalence of tuberculosis in infected possum populations as determined by post-mortem examination of poisoned animals has varied with 20% being the highest recorded (Davidson 1976) - see Table 4.

Affected possums have most frequently been found in scrub or bush within two kilometres of cattle pastures (Davidson 1976).

Table 4. Prevalence of tuberculosis in populations as determined by post-mortem examination of poisoned, trapped or shot possums.

AREA	YEAR	NO. AFFECTED/NO. EXAMINED	PREVALENCE	SOURCE[1]
Mokihinui river	1970	not recorded	12%	(1)
Buller County	1970-71	202/4193	4.8%	(2)
Inangahua County	1970-71	89/1715	5.2%	(2)
Hohonu mountain	1973	115/1486	7.7%	(3)
Waikato	1973	2/1629	0.1%	(4)
Taumarunui & Otorohanga Counties	1974	26/1602	1.6%	(4)

[1] Sources cited: (1) Davidson 1976 (2) Cook 1974 (3) Animal Health Division 1974 (4) Lake 1974 .

EPIDEMIOLOGY

To date tuberculosis has not been recorded in wild possums in Australia so we presume that infection occurred once they became established in New Zealand. Thus there can be little doubt that the possums were originally infected from cattle. When this occurred it is impossible to say. It is likely that cattle-to-possum transmission occurred independently in widely separated areas in New Zealand (Davidson 1976).

Possum-to-possum transmission of tuberculosis has been found to occur readily under experimental conditions. It has occurred between possums in direct contact (Bolliger and Bolliger 1948, O'Hara *et al.* 1976), close contact in adjacent cages and by aerosol over distances up to 180 cm (O'Hara *et al.* 1976).

It is possible to infect possums experimentally by intraperitoneal and intramuscular injections or by feeding infected material (Bolliger and Bolliger 1948), also by subcutaneous inoculation and intranasal instillation (O'Hara *et al.* 1976). All these factors suggest that transmission of tuberculosis could readily occur in possum populations especially when possums are in close association such as in the denning site. It is highly probable that the disease can maintain itself in a wild population and, on occasions, result in spread to neighbouring populations.

There are two ways in which man can disseminate tuberculosis from one population of possums to another; by the transportation of infected carcases to a part distant from the area of collection, and by introducing tuberculous cattle into a previously uninfected possum habitat (Davidson 1976).

The potential risk of infected possums contaminating pastures which could then be grazed by cattle has been realised for some time (Ekdahl *et al.* 1970). The importance of possums as foci of infection for cattle is now more clearly understood with infected possum communities discovered in some 23 general localities in New Zealand (Davidson 1976), and compelling circumstantial evidence linking tuberculosis in possums to high and persistent reactor rates in cattle sharing the same environment (Animal Health Division 1976). The transmission between possum and cattle is presumably through contamination of cattle pasture and possibly also by investigation of possum carcases by cattle (Davidson 1976).

Possum trappers and people involved in autopsies on possums in survey work are obviously exposed to a significant health hazard (Ekdahl *et al.* 1970, Davidson 1976).

To date only one case of human tuberculosis has been ascribed to handling diseased possums, this was a case of a wound infection in a trapper (Davidson 1976). Protective clothing is made available to all people involved in survey work. Possum trappers can minimize the risk by limiting their handling of obviously diseased carcases and by maintaining good hygiene during and after handling carcases. It is important that trappers are taught to recognise lesions which may be tuberculous in possums.

DISCUSSION

The problem of tuberculosis in wild possums in New Zealand bears many similarities with tuberculosis in the badger *Meles meles* in South-west England. In 1971 *M. bovis* was isolated from a badger carcase found on a farm in Gloucestershire where bovine Tb existed in cattle (M.A.F.F. 1976). Since then studies on tuberculosis in wild badgers have been made (Muirhead *et al.* 1974, Gallagher *et al.* 1976), and experimental work on transmission of infection, viability of the bacillus and badger ecology and behaviour have been initiated (M.A.F.F. 1976).

Behavioural changes have been reported in some badgers with advanced lesions. These badgers may leave their sets in search of more easily available food supplies or they may be rejected by the remaining set occupants (Muirhead *et al.* 1974). In possums I think the former reason most likely as, at least in experimental studies, they do not appear to reject sick animals and have continued to sleep with the carcase of a recently dead animal.

Inhalation is thought to be the main route of infection in badgers because of the high prevalence of lung or pulmonary lymphnode lesions, the dusty conditions that can prevail in sets, the finding of dust aggregations in lungs and the knowledge that dust particles can render the lung more susceptible to tuberculosis (Gallagher *et al.* 1976). The possum similarly has a high prevalence of lung infections but it is unlikely that dust would be a factor in the pathogenesis of the disease. The possibility of aerosol infection directly from infected possums occupying the same denning site is obviously high.

This intimate association in the denning site may also account for the high prevalence of superficial lymph node lesions in the possum: there could be direct contamination of wounds with infection localising in the regional lymph nodes. Bite and scratch wounds inflicted during the mating season may also be a factor in this method of spread of the disease.

The kidney is considered to be a predilection site for lesions following haematogenous spread in the badger (Gallagher *et al.* 1976). Such a site has not been defined in the possum. The superficial lymph nodes have been suggested (Animal Health Division 1974). The lungs should also be considered because of the high prevalence of lung lesions in possums and the finding that lungs were always affected following subcutaneous inoculation. Unfortunately no correlations have been made between the different sites affected in possums so we do not know the usual distribution of lesions within an individual animal. This information could give some information on the method of transmission of tuberculosis in the possum.

There is similarity between the gross lesions in the two species though it appears as if the badger develops miliary lesions in the lung more often. Histologically there appears to be no great differences between the two species.

As in the possum the tuberculin test was found not to react in experimentally infected badgers (M.A.F.F. 1976). The mild cellular reaction in field cases of badger tuberculosis has suggested that the badger has a low hypersensitivity rating, that the development of lesions is likely to be slow and the clinical course more prolonged than might be expected in the bovine. This hypothesis is supported by the finding that only two-thirds of the infected badgers examined had distinct visible lesions (Gallagher *et al.* 1976). The possum could also be considered to have a low hypersensitivity rating but experimental work has shown that the clinical course of the disease is rapid following inoculation with large numbers of organisms. It will require more work to see if the above hypothesis holds true when low numbers of organisms are inoculated.

The large numbers of possums examined in surveys have precluded the practicality of examining tissues from all animals microbiologically as was done in the British survey. But, in light of their finding one-third of infected animals with no distinct visible lesions, I feel that it is now necessary for us to do such a detailed survey. This does not mean that a full microbiological examination is necessary in all surveys as infected animals without gross lesions can hardly be considered a significant source of infection for cattle. This information is necessary to better understand the pathogenesis and epidemiology of the disease.

Parallels can also be seen in the epidemiology of the disease in the two situations. Both species were most likely originally infected from tuberculous cattle and now are both maintaining the disease in their own populations and serving as a reservoir of infection for cattle. The mechanics of transmission between the wild species and cattle has been suggested to be pasture in both instances.

These comparisons have been made to give a better understanding of the problem of tuberculosis in wild animals. By pooling information from both sources one is then in a better position to formulate a policy aimed at solving such a problem.

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EPIDEMIOLOGY AND BEHAVIOURAL PATTERNS IN THE POSSUM *TRICHOSURUS VULPECULA* IN RELATION TO TUBERCULOSIS

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ABSTRACT

Epidemiology is that area of medical science concerned with the ecology of disease. Essentially it is both a descriptive and an interpretive science, placing considerable emphasis on the population dynamics, behavioural patterns and the physiology of the various species involved. This paper reports observations on the incidence of bovine tuberculosis in common brushtail possum populations in the West Coast region of the South Island and especially in the Hohonu mountain area. The following aspects of possum biology are considered in relation to tuberculosis:

(1) the condition index in different populations;

(2) age and sex;

(3) distribution in Hohonu Mountain area in terms of distance from forest-pasture margins;

(4) behaviour in relation to density, social structure and feeding.

The mean incidence of tuberculosis in the Hohonu Mountain possum population was 7.7%.

The possum is a most adaptive species, so variable in its behavioural patterns that reliable observations and conclusions from one locality may even be irrelevant when populations in adjoining localities are considered. Therefore it may be very difficult to relate observations made in the Grey County, Westland, to, say, observations in the Orongorongo Valley or the central King Country, without making unjustified assumptions.

ESTIMATING THE DENSITY OF POSSUMS *TRICHOSURUS VULPECULA*

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ABSTRACT

There are four methods which have been, or are being used by F.R.I. to measure possum populations and/or to assess the effectiveness of possum control operations.

Spot-light counts are applicable in farmland situations but become inefficient as the amount of bush or scrub cover increases. Weather markedly affects the number of animals counted.

Gin grapping, as well as contributing towards control, provides an index of animal density based on the numbers caught on successive nights. Precise estimates are dependent upon the catchability of animals remaining constant, a factor often subject to change because of climatic variations and changes in the structure of the population due to animals being removed.

Interference by possums of non-toxic baits provides an index of animal numbers and is a technique which may be applied in a wide range of habitats. The accuracy of the estimates is influenced by weather changes and changed behaviour as animals learn locations of bait stations.

Faecal pellet counting is a suitable method for sampling large areas, although dense ground vegetation limits its application. Current research is aimed at solving problems associated with variations in defecation rates and pellet decay rates.

It can be seen that there are problems associated with all techniques and that more research is required before any one of them can be unconditionally recommended for any given situation.

INTRODUCTION

In this paper I shall give an evaluation of the four most commonly used methods of assessing common brushtail possum *Trichosurus vulpecula* populations. Examples have been chosen which illustrate the type of results that can be expected when these methods are applied in their appropriate field situation. With one exception, the assessments were conducted by F.R.I. in the course of their possum research programme.

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SPOTLIGHT COUNTS

Spotlight counting is a relatively untried technique. My analysis is based on counts of possums by the M.A.F. rabbit research section, during routine counts of rabbits. In the Waikari district in Canterbury, two 27 km transects were laid out in different areas. Two men on trail bikes with helmet-mounted spotlights, each covered a transect on three or four successive fine nights, starting at dusk and finishing three to four hours later.

During a 10 month period a total of eight samples was obtained from the two areas. The 95% confidence limits of each sample averaged ± 69% of the mean, while the confidence limits of the total samples in each area were ± 27 and ± 34 percent respectively. In other words the counts did not vary much from one sample to the next, but, from night to night there was often significant variation.

Because this technique is relatively appealing to use, is not labour intensive, and because large areas can be covered, it has a high potential use in pastoral areas. While the variation between nightly counts could be reduced by increasing the number of counts and increasing the transect length, more research is required to identify the factors which influence possum activity.

TRAP CATCHES

The trap-catch model for estimating possum density was formulated from data collected in 1945 and 1951 from the Pararaki catchment in the Haurangi Forest Park (Batchelor *et al.* 1967). When the model is used in other areas the estimate must be regarded as an *index* of density because the probability of capturing animals - an important constant in the formula - may not be the same. The model's principal application is therefore in measuring the effect of control operations, using the change in the density index as a measure of percent kill.

The Pararaki population was measured again in 1975 and in 1976. Each sample consisted of four lines of 20 traps, spaced at 100 m intervals which were run for three consecutive fine nights. Density in 1975 was 11 possums per ha ± 50% and in 1976 12 per ha ± 44%. Smaller errors could be expected if the sample size was increased to six lines of 25 traps - requiring approximately 12 man-days of effort. A typical situation where the trap-catch model could be used would be an easily accessible forested area due to be aerially poisoned. Trap lines would be run before and after poisoning and the mean and 95% confidence limits of the kill assessed from the percent reduction in the density indices of individual lines. Total effort required would be about 20 man-days.

NON-TOXIC BAIT INTERFERENCE

A non-toxic bait interference method is being used in the Haupiri research area to establish the relative levels of pasture utilisation at increasing intervals from the main bush margin.

Monthly samples consist of lines, 100 m apart, which run from 250 m inside the bush to a maximum of 850 m into pasture. Bait stations consist of a small length of alkathene pipe attached to a reinforcing rod, into which is forced a plastic cap to contain the bait. These are placed at 50 m intervals along the lines and filled with a flour and soya bean oil paste. Baiting is carried out for five successive nights regardless of the weather.

Nightly patterns of baits taken are frequently irregular as a result of unfavourable weather, although in general they increase from night to night. During the 18 months of sampling the average number of baits taken has steadily increased even though other sources indicate that a small drop in animal numbers has occurred. My conclusion is that animals have learnt to associate some sign, whether it be the sight or smell of stations, with the presence of a bait which they have come to accept over the months. Because bait stations are removed at the end of a sample and replaced at the beginning of the next, the baits taken increase from night to night as their positions are discovered by animals within their particular home-ranges.

A need to modify Bamford's (1970) sample design is evident from these results. Two options are available: (1) the first to stabilise the estimate by introducing a time based factor accounting for the learning process (Jane this symposium); (2) to side-step the problem by doing a series of one-hit counts. For example, an assessment of a control operation would require before and after samples consisting of five lines of 20 baits set in different localities on three consecutive fine nights. Total effort would equal about 12 man-days. The 95% confidence limits of the estimates would be about ± 25%, depending of course, on the distribution of the population. The technique can be used in a wide range of habitats - from native forests to open pasture, but, in general, is most applicable in areas which have good access.

FAECAL PELLET COUNTS

Pellet counts have been used in many areas to estimate possum densities but, in general, the technique is most suited to bush areas where access is limited. Their most extensive application has been in the Haupiri research area where monthly assessments have been made over the period of a year.

An estimate of possum numbers is obtained by calculating the number of pellets accumulating each day in a given area and dividing this by the average number of pellets voided each day by one animal. Experience in the Haupiri indicates that to obtain a meaningful estimate, a large sample (in excess of 500 1-metre-radius plots) is necessary. Two such samples, normally one to two weeks apart, are required for a single estimate of possum density. In the first, pellet density is measured and pellets are identified in some way, such that when the second sample is run, the density of those which remain can be measured. The number of new pellets recruited into the population is basically the difference between the number of survivors and the total density in the second sample.

Although animal numbers may remain fairly static, pellet densities may fluctuate considerably. For example in the Haupiri, consecutive pellet densities fluctuated, on average by ± 42%. Wind and rain which caused, on the one hand a high rate of pellet disappearance through litter fall and mechanical breakdown, and on the other, lowered activity levels and therefore a reduction in the number of pellets being deposited, probably accounted for most of this variation.

Results from a 'one-hit' sample which do not include an estimate of pellet disappearance rate can only be interpreted in very broad terms. The animal controller who wishes to use pellet counts to measure the effectiveness of an operation is faced with a before and after survey consisting, in each case, of two pellet density estimates and a disappearance rate estimate: something like 30 man-days of effort.

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GENERAL DISCUSSION — over page.

GENERAL DISCUSSION

JANE. Do you think it is practical to use pellet counts in exotic forests when the frequency of pellet counts is about five percent?

D.J. BELL. No. At that level the errors probably make the estimate rather meaningless.

JANE. I have experienced a considerable bias in spotlight counts in estimation of density. Have you found this?

D.J. BELL. No. The results I have seen tend to indicate that you can achieve some sort of stability if you select your nights and maintain them over a period of time. I can't really comment on what bias is involved - it would depend partly on the type of control operation used.

JANE. No it is not so much the type of control operation. Rather it is due to variations in the area that is being observed with the spotlight. Where you have a number of tall stands with understorey your search area or search distance is short; in younger more open stands your search distance can increase ten-fold.

D.J. BELL. I pointed out spotlight counting was a technique with high potential for use in pastoral areas. One usually repeats the same route on a trial-bike each night so the intensity of search does not vary much from one count to another. When you get into forest areas there are many difficulties.

WODZICKI. The decay rate of pellets must vary between different environments, and are you aware of the work by Taylor and Williams* on rabbit pellet density estimates?

D.J. BELL. Actually Taylor and Williams' method is the basis for our pellet count work on possum populations. Pellet disappearance or decay is a very important factor.

WODZICKI. But have you measured decay rate in a range of possum environments?

D.J. BELL. We run a series of plots on a transect through the habitat which we want to sample and we measure the density of pellets on these plots and we also mark pellets on these very plots for decay. So on exactly the same ground that we are measuring pellet density, we are measuring their decay rate. We do this twice to get one estimate of recruitment rate, which is directly attributable to the number of animals.

KEBER. Have you ever tried calibrating these indirect methods of population assessment by say, laying cyanide out over successive nights, collecting dead animals and then calibrating the recorded fall-off in population numbers with changes in pellet density or bait interference?

D.J. BELL. Not yet. We are planning a large kill at the end of the Haupiri study when detailed information on the composition, movements, and density of the possums is available. We will probably try out such experiments there. Trap counts and pellet counts have been compared in the past and the results tend to agree fairly well.

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* 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). *N.Z. Journal of Science & Technology, Section B 38*, 236-256.

FLUCTUATIONS IN DENSITY PATTERNS OF POSSUMS *TRICHOSURUS VULPECULA* ALONG THE NORTH BANK OF THE TARAMAKAU CATCHMENT WESTLAND, NEW ZEALAND

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ABSTRACT

Fluctuations in density patterns of common brushtail possum populations were studied by faecal pellet counts along the North Bank of the Taramakau catchment from 1969 to 1975. 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 carrying capacities in the beech zone were approximately half those in the rata/kamahi zone.

The upper forest transitional zone above both major forest types reached similar peak densities. Canopy damage in this zone, which coincided with heavy use of the understorey by deer, is discussed on the basis of aerial photography runs flown over the area in 1960 and in 1973.

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

GENERAL DISCUSSION

WODZICKI. How do you assess your populations and what were the possible errors in your estimates?

PEKELHARING. I was unable to give full details due to lack of time. Basically, populations were assessed using faecal pellet surveys in plots at 20 m intervals along lines up the hill; each line probably consisted of 80 such plots and we were just scoring presence or absence of possum pellets in those plots. Using frequency/density transformations we worked out a density index which was multiplied by the plot area to give the equivalent of density of possum pellets per hectare. I have not put confidence limits on these estimates because I consider that the changes were so drastic that I feel fairly confident about the results - pellet counts ranged from about 500/ha to 4,000/ha.

YOUNG. You seem to have touched upon a very fundamental point, simply that the factors controlling the population at one density level may be quite different from those allowing the population to develop again after control. Otherwise if you don't accept this, then you must say that the population level of 1974 would have fallen naturally down to its present 1977 level without control. There must be two sets of factors operating - one at the medium density levels of 1974 and the other at the very low level immediately after this.

PEKELHARING. I did not want to complicate matters in my paper, but part of this area was poisoned in 1970 as part of Dr Bamford's work. There was quite a high kill so the population did decline quite markedly. We got the same amount of drop outside the poison area so I concluded that the population was at peak and that what was removed in the one area by the poison, was removed in the other area by natural decline.

YOUNG. The critical drop was the next one from 1974 to 1977, following poisoning. Is there any indication that the population has tried to increase again, or has tried and not succeeded?

PEKELHARING. No. After 3 years I would not say with certainty that it has increased, rather I would say it was about the same level - at least it is nowhere near the level it was formerly. Fluctuations in pellet counts make a more precise opinion difficult.

APPLICATION OF THE POISSON MODEL TO THE BAIT INTERFERENCE METHOD OF POSSUM *TRICHOSURUS VULPECULA* ASSESSMENT

G.T. Jane

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ABSTRACT

The bait interference method of possum assessment put forward by Bamford (1970) has been tested in a range of areas and the simple model found inadequate. However if time is added as a variable such that:

$$\text{Relative density} = -1/i \log_e (1-f) \times 100$$

where i is a time estimator

and f is the frequency of interference with bait stations, a stable estimate of relative density is obtained.

Sample design is strongly constrained by the method of baiting and other practical considerations. A number of problems may also arise in the design of the bait stations and choice of bait used.

INTRODUCTION

For many years it has been common practise for field officers involved in control of common brushtail possums *Trichosurus vulpecula* to estimate killing rates from the difference between takes on bait acceptance lines before and after a poison operation. Bamford (1970) developed this practise into a bait interference method which involved a device which would exclude other animals such as rats from the baits. He defined the sample strategy by drawing an analogy between the encounters with bait stations and trapping models where the Poisson model is applied to estimate density (Seber 1973):

$$\text{Relative density } d = -\log_e (1-f)$$

where f is the frequency of baits taken.

A major problem is that if bait stations are placed too close together an animal is able to follow along the lines. However Bamford (1970) showed that if bait stations are placed at distances of 40 yards there was little evidence of such contagion.

The bait interference method has been used extensively by N.Z. Forest Products Ltd. and more recently in the Wellington Conservancy of the N.Z. Forest Service to estimate poisoning success. Baiting was usually carried out nightly, over extended periods of weeks or even months. Both operators found that the frequency of baits taken rose with each assessment, with a break occurring at the date of poisoning. This led to two ways of estimating the kill rate: (1) Use of the mean number of baits taken over several days before and after poisoning, from which estimated densities were calculated; (2) Use of only those values *immediately* before and after poisoning if the rise in baits taken over successive nights prior to the kill was steep. Neither approach was very satisfactory; with the first method the frequency of baits taken was often still rising immediately before poisoning and almost always rose from the low point after poisoning - it usually gave a value well below visual estimates of kill; with the second method many data were ignored and it had characteristics of a 'shot in the dark' estimate. Neither method gave a value as high as that obtained from trapping or spotlighting where comparison could be made (Table 1). Also the larger labour content involved in baiting lines over an extended period (arising from the uncertainty of the poison date) posed a serious limitation for large operations, such as at Kaingaroa where up to 48000 ha are poisoned each year.

Table 1. Relative density[1] and percent kill estimates of possums in trials at Kaingaroa and Western Bays during 1976.

Relative density estimates:

Kaingaroa	Western Bays
38.20 (19 May)	33.40 (4 May)
74.97 (10 June)	66.85 (12 May)
——— POISONING ———	
17.43 (31 July)	11.53 (30 July)

Percent kill estimates:

	Kaingaroa	Western Bays
From bait interference:	max. 76.9% mean 69.2%	max. 82.8% mean 77.4%
From trapping	86.7%	-
From spotlighting	96.7%	-

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[1] Only a relative index of density is given, not an absolute measure of numbers per unit area; the author has subsequently compared such an index with actual animal numbers using trap density estimates - see Jane (1979).

KAINGAROA AND WEST TAUPO TRIALS

In an attempt to reduce the labour content and apparent contagion between assessments two changes were made when the bait interference method was introduced to Kaingaroa and Western Bays, Taupo in 1976: (1) baits were set out and left over *two* nights before assessment; (2) there were only two baitings before and two after poisoning, separated by at least two weeks. All baits were removed between assessments. This kept the number of visits low and aimed to reduce or eliminate the rise in baits taken between assessments. Some preliminary trials were carried out at Kaingaroa in April/May but high variability in the data made the results inconclusive, so at Kaingaroa (but not Western Bays) bait interference assessment was run in parallel with mark/recapture trapping and spotlight counts. 1200 ha were assessed at Kaingaroa and 6800 ha at Western Bays in 1976. In each area 30 lines of 20 bait stations were used, and the results are shown in Table 1.

The method was unsatisfactory in failing to give a consistent estimate of relative density over the first two (pre-kill) assessments - in both areas there was a marked increase. Moreover at Kaingaroa the percent kill derived from bait interference was lower than estimates based on trapping and spotlight counts.

A NEW MODEL

Criticism of our change from daily assessment (Bamford's (1970) recommendation) to assessment over two nights at a time led to our including time in the basic model. The density should remain constant from night to night (or at least vary randomly) so it was possible to demonstrate (Appendix) a Poisson process where:

Relative density $d_t = -1/t\ (\log_e (1-f_t))$

Where t is the time interval from the first assessment

and f_t is the frequency of baits taken at time t .

When this model was tested with several sets of available data d_t remained relatively stable.

Table 2 shows a typical data set from N.Z. Forest Products Ltd. for their 1974 poison area, and an un-poisoned control area. In column (4) d_t can be seen to vary considerably and yet shows no systematic variation. The break at the poison date is sharp and results in a new level being established.

Table 2. Data from Poison Operation - N.Z. Forest Products Ltd. - 1974

DAYS	POISONED AREA				NON-POISONED AREA				INTERVAL
	BAITS TAKEN %	Relative Density			BAITS TAKEN %	Relative Density			
t	f	d	d_t	d_i	f	d	d_t	d_i	i
1	1	1.08	1.08	1.08	5	5.13	5.13	5.13	1
2	4	4.08	2.04	2.04	5	5.13	2.56	2.56	2
3	9	9.43	3.14	3.14	7	7.26	2.42	2.42	3
4	11	11.65	2.91	2.91	14	15.08	3.77	3.77	4
36	44	57.80	1.61	11.60	43	56.21	1.56	11.24	5
38	63	99.43	2.62	16.57	57	84.40	2.22	14.07	6
41	49	65.33	1.64	9.62	50	69.31	1.69	9.90	7
42	82	171.48	4.04	21.42	67	110.87	2.64	13.86	8
48	43	56.21	1.17	6.20	57	84.40	1.76	9.38	9
49	54	77.65	1.58	7.76	51	71.33	1.46	7.13	10
Poison	Drop								
56	30	35.67	0.64	3.24	62	96.76	1.73	8.80	11
57	29	34.25	0.60	2.85	62	107.88	1.89	8.95	12
63	32	28.57	0.61	2.97	85	119.71	3.01	14.59	13
64	41	52.76	0.82	3.77	90	230.26	3.60	16.45	14
70	54	77.65	1.11	5.18	79	156.08	2.32	10.40	15
Kill %	Av. Max.	33 54	69	45					

Three estimators of relative density were calculated from the % of baits taken:

$$d = -100 \log_e (1-f/100)$$

$$d_t = -100/t \log_e (1-f/100); \quad t = \text{time interval (column 1)}$$

$$d_i = -100/i \log_e (1-f/100); \quad i = \text{no. of baitings (column 10)}$$

Av. is the kill % from the average of baits taken before and after poisoning

Max. is the kill % from density on days 49 and 56 only (*immediately* before and after poisoning).

Table 3 from 1972 data shows a similar pattern in the poisoned area data but in the control area d_t falls sharply after day 2 and even more sharply after each break in baitings. Examination of the data on interference frequency (column 4) shows that almost all baits were taken from the fourth baiting onwards however and so a limit had soon been reached. Data from this point onwards should be excluded from analysis as it is no longer possible to estimate d_t.

Further analysis of the 1976 Kaingaroa and Western Bays data (Table 4) showed difficulties with this model since d_t (middle columns) fell rapidly, with a large decline after the poison date - yet at Western Bays d_t rose again over the February baitings. If only the number of nights (i) over which the lines were baited are accumulated, then the new estimate d_i is a good fit and the estimate of kill in better agreement with that obtained from trapping.

Table 3. Data from Poison Operation - N.Z. Forest Products Ltd. - 1972

	POISONED AREA		NON-POISONED AREA	
DAYS t	BAITS TAKEN f%	DENSITY d_t	BAITS TAKEN f%	DENSITY d_t
1	24	27.4	60	96.6
2	46	30.8	82	85.7
3	52	24.5	82	57.2
4	58	21.7	84	45.8
5	70	24.1	90	46.0
Poison				
10	26	3.01	84	18.3
11	32	3.51	88	19.3
12	40	4.27	90	19.2
23	-	-	90	10.1
24	88	8.83	94	11.7
25	44	2.32	94	11.3
26	54	2.99	90	8.8

Kill % (omitting day 24) = 90.8%

See text for explanation of the data

Table 4. Data from N.Z. Forest Service Poison Operation, West Taupo and Kaingaroa - 1976

DATE	WESTERN BAYS DATA												TIME INTERVALS
	Pastoral			Bush Fringe			Bush			Totals			
	d	d_t	d_i	d	d_t	d_i	d	d_t	d_i	d	d_t	d_i	i
4/5	23.77	11.88	11.88	34.48	17.24	17.24	48.34	24.17	24.17	33.40	16.77	16.77	2
12/5	38.45	4.81	9.61	67.66	8.46	16.92	130.11	16.26	32.50	66.85	8.36	16.70	4
Poison	drop												
30/7	12.26	0.16	2.04	1.68	0.02	0.28	17.57	0.22	2.93	11.53	0.15	1.92	6
14/2	8.84	0.04	1.11	8.70	0.04	1.08	34.76	0.18	4.76	16.88	0.09	2.11	8
18/2	10.54	0.05	1.05	44.37	0.21	4.44	100.33	0.47	10.03	39.57	0.19	3.96	10
18/2[1]						(2.02)			(4.56)			(1.80)	22
Kill %	67.2	97.1	81.0	97.5	99.3	98.3	86.5	98.8	89.7	82.8	98.9	88.5	
	KAINGAROA DATA												
	Block A			Block B			Block C			Totals			
	d	d_t	d_i	d	d_t	d_i	d	d_t	d_i	d	d_t	d_i	i
19/5	13.06	6.52	6.52	72.70	36.00	36.35	56.21	28.11	28.11	38.20	19.11	19.11	2
10/6	51.08	2.32	13.24	112.39	5.11	28.76	86.75	3.94	21.69	74.97	3.41	18.74	4
Poison	drop												
31/7	21.62	0.60	3.60	10.54	0.14	1.76	18.63	0.26	3.11	17.43	0.24	2.91	6
6/9	18.90	0.04	2.36	14.31	0.13	1.79	18.63	0.17	2.33	17.43	0.16	2.18	8
16/9	18.23	0.63	7.50	22.40	0.19	2.23	52.76	0.44	2.74	27.11	0.23	2.71	10
Kill %	58.9		69.8	90.6		94.5	78.5		89.1	76.7		86.3	

Relative densities calculated as for Table 3.

[1] Revised estimate based on interval of 22 rather than 10 days - see text.

When d_i is calculated for N.Z. Forest Products data (Table 2) the fit was not good; there tended to be a rise in baits taken at the beginning of each baiting session followed by a decline. However at Kaingaroa and Western Bays baits were removed from bait stations between assessments, but at N.Z. Forest Products Ltd. baits were left and hence the total number of baited nights approximated the total time lapse. Finally it was found after analysis that at the last assessment at Western Bays baits were not removed from the bait stations between assessments and so i (the time interval) was not 10 but 8 + 14 = 22 days (as shown in Table 4 where the revised estimates of d_i are given in parentheses).

SAMPLE STRATEGY

Since d_i is a Poisson variable the lower the value of d_i the lower the variance and the smaller the sample required (Johnston & Kotz 1969). Now d_i is determined from a number of observations of baits taken (n_i) and the larger the number taken at time (i) the better the estimate of d_i. These two variables can be controlled separately. The d_i is determined by animal numbers and may be varied by changing bait station design to make the station less conspicuous and possibly by varying bait type or the use of lures. The n_i can be varied by altering the number of nights (i) the baits are set at each assessment and removing or leaving baits between assessments. Since much of the labour is in establishing bait lines it is usually more efficient to make several assessments on the same lines rather than to increase the number of bait stations. Samples of less than 100 stations however appear too small.

This requirement of 100 stations is difficult to satisfy in one line as at a spacing of 40 m between stations it represents 4 km. Such a long line of uniform habitat is usually difficult to achieve or traverse even in exotic forest. Often 1 km is a more practical distance and so sets of 20 or 25 stations are more realistic. In most areas lines will need to be grouped on the basis of uniform habitat or density. The value of this stratification is evident in the Western Bays data (Table 4) where in different habitats rates of kill and of subsequent re-invasion vary. The highest kill was obtained in the high density areas (as expected) but recolonization was also most rapid in such areas, presumably because of the high residual population in adjacent areas.

PRACTICAL PROBLEMS

At Kaingaroa, birds, including robins *Petroica australis* and possibly House Sparrows *Passer domesticus*, left bill marks in incompletely taken baits, especially in open areas. On one occasion a feral cat was observed following the person setting out the baits, undoing his work. On other occasions high levels of baits taken (often 100%) were preceded and followed by relatively low levels (*e.g.* Table 3, day 24, poisoned area). On pastoral land stray stock could be responsible for taking baits in other cases rabbits *Oryctolagus cuniculus* or deer *Cervus* sp. would seem more likely culprits. This can be minimised by designing a bait station inaccessible to other animals (*e.g.* by placing the bait platform in a tube or under low cover) and by selecting a bait which is unpalatable to say cats and rabbits (a pollard or lured jam bait may be appropriate).

DISCUSSION

The bait interference method was introduced to provide a simple and easily executed alternative to trapping for estimating possum densities. Faecal pellet counts and spotlight counts (Batcheler 1970) have also been tried in exotic forests. Low faecal pellet counts (less than 5% frequency) and highly variable decay rates have made pellet counts unsatisfactory. Spotlight counts are unsuitable due to physical constraints (need for open areas) resulting in an unrepresentative or biased sample (as indicated by the high kills estimated in Table 1). Thus the bait interference method seems to be a feasible alternative to the well-tried trapping method. The most time-consuming operation is the establishment of the trap or bait interference lines since this involves marking the lines and setting up traps or bait stations. However if there is an adequate sample intensity (as determined from binomial tables) a greater number of assessment visits (say 4 or 5) on a bait interference line will give a better estimate of kill at a lower cost. In indigenous forest tracts this advantage is very evident. Similarly in sampling small areas of say 200 ha, or in low density areas such as farmland, insufficient animals may be trapped to obtain a reliable estimate of density but it would still be possible to obtain a minimum of 100 bait station sets.

The bait interference method therefore offers an alternative or even first choice for assessment of possum density. However the sample design must be chosen with care to obtain consistent estimates of relative density and one must be sure that the possum is the sole animal using the baits.

ACKNOWLEDGEMENTS

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APPENDIX

Statistical basis for the model

From the first premise that the density and hence probability of encounter remains constant from night to night, and animals are simply remembering bait station locations, we have:

$$P_1(0) = P_2(0) \text{ --------------------------------- } = P_t(0)$$

where $P_t(0)$ is the probability of non-encounter at time t.

$$\text{Now } \frac{n_1}{N} = \frac{n_2}{n_1} \text{ ------------------------------ } = \frac{n_t}{n_{t-1}}$$

where n_t is the no. of baits remaining at night t, and N is the total bait stations set.

$$\text{Hence } \frac{n_2}{N} = \left(\frac{n_1}{N}\right)^2; \quad \frac{n_3}{N} = \left(\frac{n_1}{N}\right)^3; \quad \text{--------} ; \quad \frac{n_t}{N} = \left(\frac{n_1}{N}\right)^t$$

or $\frac{n_1}{N} = \left(\frac{n_t}{N}\right)^{1/t}$.

Now $P_1(0) = \frac{n_1}{N} = e^{-d}$

where d is a measure of density of individuals present;

hence $P_t(0) = \left(\frac{n_t}{N}\right)^{1/t} = e^{-d}$ ------------------ (1).

Thus the probability of non-encounter up to and including night t is

$$\frac{n_t}{N} = e^{-td},$$

and the probability of n encounters during the t nights can be shown to be

$$\frac{e^{-td}(td)^n}{n!} .$$

This is a Poisson process, obtained from the superimposition of several independent Poisson processes (Bailey 1964, Cox and Miller 1965). The distribution function can be regarded as a composite one of a Poisson density function and an exponential time function (Bailey 1964) representing the time between encounters.

Thus an estimate of density d_t can be obtained from (1):

$$e^{-d_t} = \left(\frac{n_t}{N}\right)^{1/t}$$

taking logs $-d_t = {}^{1}/{}_{t} \log_e \frac{n_t}{N}$

now frequency of baits taken at time t is $f_t = \frac{n_t}{N} - 1$

hence $d_t = -1/t (\log_e (1-f_t))$.

GENERAL DISCUSSION

MORGAN. Could you say how confident you are with a 40 m spacing between baits to overcome contagion?

JANE. Reasonably confident. You usually get contagion where a single animal has gone along a line, probably a larger animal.

MORGAN. Have you done any night observations at bait lines?

JANE. No I have not had the time. I gather from your own night observation work that random encounters may be involved rather more than the possum specifically following along the lines. J. Jolly mentioned earlier the scent signals left by animals, and this could draw them back to the same bait station later on.

WOOLLONS. Unless you can show the location of baits is purely random, all those equations could unfortunately be very, very biased, either way.

JANE. I think the night observation work probably helps interpretation regarding randomness. Are you worried about the successive nights being different from the initial night?

WOOLLONS. I'm worried about the basic model which you really have not changed. You have certainly made the operation far easier and that is a very good thing, but does the basic model hold? I don't think you have shown this.

JANE. Well I admit I have some rather limited data. I have incorporated bait interference lines on which are only 20 bait stations. This I feel is far too few and one probably requires nearer 100. To my mind if one carries out an operation a little more precisely, then we can probably get back to getting a reasonable linear relationship between bait interference and trapping estimates.

ANONYMOUS. In other words you are relying on trapping as your calibration. That raises the question of how reliable is trapping?

JANE. True.

DAMAGE BY POSSUMS *TRICHOSURUS VULPECULA* TO FARM CROPS AND PASTURE

E.B. Spurr and J.N. Jolly*

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ABSTRACT

This paper reviews previous reports of possum damage to crops and pasture, methods of measuring the damage, and the cost-effectiveness of control operations.

Various reports of possum damage indicate that localised serious damage can occur to crops (e.g. turnips, chou moellier, lucerne) and to pasture (clovers and grasses), particularly near forest-scrub margins.

Methods previously used to assess damage (questionnaire surveys and analysis of possum diets) are incomplete and possibly biased. The questionnaire surveys used in the past have not attempted to estimate losses, but only the type and extent of the damage. If incomplete consumption or compensatory growth occurs, loss of farm production cannot be directly extrapolated from analysis of possum diets. Assessment of economic losses must be based on measurements of yield.

Current methods used to control possums (e.g. phosphorus and 1080 poisons) are adequate to reduce possum populations locally. However, achievement of satisfactory control is limited by a lack of co-operation and co-ordination as well as shortage of finance. Research cannot be expected to solve these problems, but there is a need for research into cost/benefits and methods of improving the efficiency of control.

INTRODUCTION

If control of the common brushtail possum *Trichosurus vulpecula* on farm land is to be economic, the cost of control should not exceed the value of the damage (reduction in yield) caused by possums. Thus, assessment of the economic impact of possums is a pre-requisite for economic control. This was recognised by the Technical Advisory Committee (Animal Pests), which stated in 1969 that "while there is no evidence that opossums compete seriously with livestock for pasture on a wide scale, locally opossum grazing can appear serious enough for farmers to persuade pest destruction boards to carry out intensive control. The effects of opossums on pasture should therefore be investigated before such intensive control can be justified" (Anon 1969). This is even more crucial today because of the ever-increasing costs of control operations.

As a preliminary to any cost/benefit analysis of possum control on agricultural land, it is necessary to devise methods of measuring the damage (ultimately in terms of the market value of the units lost) and the cost-effectiveness of control. In this presentation we give:

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1. A brief review of previous reports of possum damage to farm crops and pasture;
2. An outline of the methods and problems of measuring the damage; and,
3. An outline of the problems of assessing the cost-effectiveness of control.

PREVIOUS REPORTS OF DAMAGE

Early reports on the feeding of possums were based on observations of possums in indigenous forest. They concluded that "opossums are not grass eating animals" (Mason 1958)*, and that "the opossum is not and will never become an important grassland pest" (Howard 1963). The diet of possums in pastoral districts was first analysed by Gilmore (1965a, 1965b, 1967). He found that "where root crops were grown as winter feed for stock opossums travelled long distances to feed on them" (Gilmore 1965b), and that "clover and grasses were eaten in quantity and by large numbers of opossums throughout the year" (Gilmore 1967). He speculated that "opossums may seriously reduce the carrying capacity of the land" (Gilmore 1965a). Shortly after that, Quinn (1968) reported an instance where the carrying capacity of one farm had been raised by about 1 ewe/hectare following an intensive poison campaign against the possums, but he also stated that this case "was possibly exceptional". About the same time, surveys (consisting of questionnaires supplemented by interviews and inspections) in several agricultural districts (Anon 1966, 1967a, 1967b, 1968) all indicated that possum damage to crops and pasture was of minor importance. This is illustrated by two quotations: "crops close to forest fringes were damaged to some extent but, taking cropping as a whole, the damage was not significant" (Anon 1967b) and "opossums do eat limited amounts of pasture ... but ... there is no evidence that they have affected the carrying capacity of the land generally" (Anon 1967b). More recently, Harvie (1973) published the results of stomach analyses of possums collected in 1968 and 1969 from four farms including the one reported on by Quinn (1968). She estimated that pasture formed about 30 percent of the diet of possums sampled while feeding in paddocks, and, using a figure of 43 possums/ha, calculated that the stocking rate could possibly have been increased by 2.5 sheep/ha. (Recalculation of these data indicate an increased stocking rate of 1.3 sheep/ha : Fitzgerald 1977).

From our preliminary investigations, it is evident that serious localised damage can occur, particularly near forest or scrub margins. The damage to pasture and crops (such as turnips, chou moellier, lucerne) is most noticeable when paddocks are shut-up without stock (e.g. pasture shut up in autumn for winter feed).

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* Thomson (1922) reported that "the opossum is not a grass-eating animal".

MEASUREMENT OF DAMAGE

The previous investigations have approached the problem of measuring possum damage in two ways: (i) by questionnaire surveys, and (ii) by analysis of stomach or faecal contents coupled with estimates of the density of possums. Both approaches are indirect and both contain errors. The results of questionnaires are possibly biassed from a variety of sources of error (Deming 1944, Oppenheim 1966). For example, farmers are not always aware of, or concerned about, possum damage on their properties, but this may not be apparent from their response to questionnaires. However, provided its limitations are recognised, a questionnaire survey can give a general appraisal of the situation which might serve as a guide to policy. Quantitative stomach analyses are also subject to several sources of error, including the difficulty of estimating the extent of root and tuber consumption (Vorhies and Taylor 1933), and faecal analyses require accurate determination of the differential break-down rates of plant materials (*e.g.*, Dunnet *et al.* 1973, Fitzgerald 1976). However, the most serious limitations in extrapolating from analysis of diet to loss of production are: (1) the strong dependence on accurate estimates of the density of possums feeding on an area of farm land, (2) no estimate is made of any compensatory growth by plants in response to browsing or grazing, and (3) no estimate is made of the amount destroyed but not eaten. In such cases, reliable estimates of losses to the farmer must be based on measurements of yield (various references in Chiarappa 1971).

Methods of assessing reduction in yield caused by pests have many similarities to agronomic and horticultural yield assessments, such as described by Boswell (1974).

We adapted one of these methods to estimate losses to possums, as an initial step in a cost/benefit analysis, by placing wire-netting cages in unstocked paddocks to exclude possums from small replicated plots of about 3 square metres. Each protected plot was paired with an unprotected plot (separated by only 1 m to minimise site differences), and a paired comparison t-test (Sokal & Rohlf 1969) was used to compare yield. In only one trial out of six was there a significant reduction of yield definitely attributable to possums. This was a 26% reduction in a chou moellier/swede crop, but because of the small area involved (0.4 ha), the crop lost to possums in 3 months would have supported only 336 ewe equivalents for 1 day. It was felt that these results reflect the limitations of the trials rather than a lack of significant possum damage.

The method we used has the following disadvantages:

1. It can only be used over a small area at a time.
2. It is costly, time and labour-consuming.
3. The protected (enclosed) plots probably have a modified micro-climate which may influence yield (see Lynch 1966), although if this is predictable it may be possible to correct for it.

However, it is possibly the only method suitable for use on pasture.

For crops it would be desirable to develop an alternative method to give a measure of the loss after the damage has occurred. This could perhaps be achieved by scoring the frequency of damage, and determining the dry weight yield of damaged and undamaged plants at points along a transect. Having established a quantitative relationship between the amount of damage and the resulting loss of production, it should be possible to survey the amount of damage to estimate losses on a regional basis.

CONTROL

Control of possums, when declared a pest on rateable land, is the responsibility of local Pest Destruction Boards. These Boards are elected by local ratepayers, and they employ staff to carry out control operations. Finance for this work normally comes from rates from farmers (and a 1:1 government subsidy).

Methods used to control possums on farmland are many and varied (Anon 1966). Probably the most common methods are the use of phosphorus (jam) and 1080 (jam and carrots). 1080 is probably the most effective but is not favoured in certain areas because of the risk of poisoning domestic animals, particularly farm dogs, from secondary poisoning. Individual Board operators have usually evolved techniques applicable to their particular area. Wherever possible, they make use of local features, such as laying poison around pine trees in spring or feed crops (e.g. turnips) in autumn/winter. The need to maintain full-time employment of staff means that seasonal use is often made of several techniques and that staff are usually involved in rabbit *Oryctolagus cuniculus* control as well. To estimate the cost of this control, it would be necessary to separate the various costs in Pest Destruction Board records.

Existing techniques used by Pest Destruction Boards appear to be adequate to reduce local possum populations. Examples of successful control operations can be cited in many Board areas. However, satisfactory control is seldom achieved throughout a Board's area. There are two basic reasons for this:

1. Insufficient co-ordination of activities.

Breakdowns in communication have, particularly in the past, resulted in failure or only poor success of control, e.g. when Boards have not given farmers sufficient notice to move stock, or when farmers have refused access to Board operators for various reasons, including trapping for skins, and their inability to de-stock some areas requiring control. For successful control it is essential that good co-operation exists between Boards and ratepayers. The Agricultural Pests Destruction Council has recognised this and is actively endeavouring to bridge the gap (e.g. see A.P.D.C. Annual Report 1977). It is essential that the communication be two-way, and that farmers, for example, advise the Board of any cropping and pasture development programmes.

2. Lack of finance.

Pest Destruction Boards are dependent on rates from farmers. However, the Boards are farmer-controlled, and in some cases appear reluctant to increase rate demands on fellow farmers, particularly when areas without a possum problem are included within the Board's jurisdiction. Few Boards strike differential rates. Most Boards are also reluctant to lower the level of rabbit control, which would make more money available for control of possums, for fear that rabbit populations might explode in the absence of continual control. In many cases, possums are causing more damage than rabbits, but the rabbits are still being hunted whereas the possums are not. There would appear to be a need for some form of differential rating or payment-for-service-rendered scheme.

These organisational and financial difficulties will need to be accounted for in any assessment of the cost-effectiveness of possum control.

CONCLUDING REMARKS

Previous reports and our own experience all indicate a situation typified by serious damage of a localised rather than a generalised nature. There is a definite need for research to determine:

1. The economic importance of this damage (on a local and regional basis).
2. The short and long term cost/benefits of current control practices.
3. The areas of improvement to control technology, either by attempting to increase efficiency or by development of new methods.

Research cannot be expected to solve problems associated with the organisation and financing of pest control.

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GENERAL DISCUSSION

B.D. BELL. You mentioned that control of possums on rateable pastoral land is the responsibility of the local Pest Destruction Board. Does the Board have powers to enforce possum control if it is against the wish of the farmer?

NELSON. When the possum is declared a pest of local importance then the local Board has legal right of access for control. However they generally liase with the landowner to ensure control operations phase in with his requirements and to ensure stock losses are avoided. In the interests of furthering good relations they are reluctant to push their enforcing powers.

DAMAGE BY POSSUMS *TRICHOSURUS VULPECULA* TO EROSION-CONTROL PLANTINGS

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ABSTRACT

Poplar and willow cuttings, in the form of long poles, are planted extensively on farm land in order to control soil erosion without retiring the land from grazing. Reports on possum damage to plantings have shown that considerable damage can occur over a wide area. In some areas planting programmes have been abandoned because of this damage. Possums eat leaves in spring and late summer and break leaders. Bark biting and bud removal occur in winter.

The worst damage often occurs where poles are planted near scrub-filled gullies or bush patches but can also be severe in areas without bush or scrub where plantings are small and scattered. Both these situations present possum control problems either because of the large areas involved or because low density populations can cause severe damage.

Improved control would result from better co-operation between Catchment Boards, who are the planters, and possum control operators. Research into improving methods of protecting the poles follows along three lines. The selection of less palatable pole types is continuing. Experiments will be attempted with physical barriers in the form of sleeves around the poles and with lures in the form of highly palatable bait trees or crops dispersed amongst the plantings.

INTRODUCTION

Poplar (*Populus* spp.) and willow (*Salix* spp.) trees are preferred for soil erosion control on hill country farmland primarily because of their extensive root systems and rapid growth rates, their ability to grow in poor soils and in harsh environments and their ability to strike from long poles. The last characteristic allows the young pole to grow in the presence of stock with minimal restrictions and avoids the need to retire large areas of land from grazing.

Catchment Boards have planted between 20000 and half a million poles annually over the last 20 years. It has been estimated (van Kraayenoord 1968) that a further 20 million poles will be needed in the next twenty years at a current cost of about $1.20 per pole.

This paper describes the damage to poles by common brushtail possums *Trichosurus vulpecula* and outlines research into methods of alleviating it.

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THE NATURE AND DEGREE OF POSSUM DAMAGE

There are four types of possum damage to the poles. The leaves are eaten and at the same time leaders broken, primarily shortly after leaf emergence in spring and before leaf fall in late summer. In winter possums bite off patches of bark and remove buds. As a result, some poles are killed and many others damaged to an extent that their growth is slowed or they become stunted and their effectiveness for erosion control is reduced or lost altogether.

Surveys of pole losses have illustrated the degree and extent of damage. An interdepartmental committee reported (Anon 1966) that, in the East Coast (North Island) district 6.7% of poles and trees inspected had been killed by possums and a further 21.2% damaged. A Ministry of Works survey (Anon 1970) of the Poverty Bay, Hawke's Bay, Wairarapa, Manawatu and Rangitikei catchment board districts found that 11.4% of the poles were definitely damaged by possums two years after planting. This figure is likely to be conservative because the cause of death or damage to many poles inspected some time after the damage occurred could not be determined. More recently (1974), the Rangitikei-Wanganui and Wairarapa Catchment Boards and the Waikato Valley Authority reported similar or greater possum damage (15-20% of poles lost - E.H.H. Kelman pers. comm.). They also reported that damage was so severe in some areas that planting was discontinued.

The value of poles lost to possums was estimated as $7,000 per annum in the East Coast District report (Anon 1966) and between $6,000 and $9,000 per annum for some boards in 1974. The resulting reduced effectiveness of erosion control measures makes the total cost of possum damage considerably greater.

The degree of damage by possums must be considered in relation to damage by other agents. The most important of these are believed to be desiccation and cattle rubbing and barking. No figures are available for losses due to desiccation but both surveys reported considerable cattle damage (East Coast survey: 29.5% killed by cattle; 6.7% killed by possums. Ministry of Works survey: 9.7% damaged by cattle; 11.4% damaged by possums). Although still a problem, this damage has now apparently been greatly reduced by encouraging farmers to keep cattle out of planted paddocks for the first one to two years. In addition, bark biting by stock is now largely prevented by attaching plastic netting sleeves to the poles.

POSSUM CONTROL PROBLEMS

Damage is often worse where poles are planted near scrub-filled gullies or bush patches but can also be severe in areas without bush or scrub where plantings are small and scattered. Both these situations present possum control problems, firstly because of the large areas involved and secondly because low density populations can cause severe damage.

Some improvement in tree protection would result from better co-operation between the Catchment Boards and Pest Destruction Boards. Pest Boards should be furnished with the size and siting of all erosion control measures well before planting so that they can assess the control situation. Pest Boards have sometimes been reluctant to protect poles in possum prone areas through lack of appreciation that erosion control measures can be essential in such areas. Generally co-operation is better now than in the past but could still be improved.

A second limitation to the effectiveness of current control is that the funds of Pest Boards, derived from rates on farms and a 1:1 government subsidy, are very limited. Catchment Boards cannot vote money for possum control and grants from the Agricultural Pests Destruction Council are only available for catchment control schemes, which include only a small proportion of the planting. The cost of control is high because of the large area of poles planted, the need for extensive controlled buffer zones around the plantings, and the need to reduce possum populations to very low levels. There is clearly a need for cost-benefit analyses especially in areas where low density populations cause damage to small groups of plantings.

RESEARCH OBJECTIVES

There are three approaches by which research can improve protection of the poles: the development of less palatable tree types, protection of the poles by physical barriers and the improvement of possum control techniques.

Research so far has been concentrated on breeding less palatable clones of poplars and willows. The Plant Materials Centre of the Ministry of Works and Development has had some success with willow breeding (Hathaway 1974). However, a vigorous, unpalatable, tree willow has yet to be produced (van Kraayenoord 1975). The arrival of the *Melampsora* spp. poplar leaf rusts have largely nullified the efforts with poplar breeding (van Kraayenoord 1975). All of the unpalatable clones in common use were susceptible to one or both rust species.

Development of less palatable, rust resistant clones is being attempted by the Plant Materials Centre.

Physical barriers in the form of sleeves can be attached around the trunks of the poles. The sleeve design must allow for expansion of the trunk over the critical first 4-5 years of the pole's life. They must also be designed to be recovered and re-used or to break away when their maximum diameter is reached. It is believed that metal sleeves are unsuitable because of the excessive heat transferred to the trunk of the young tree but formal trials are lacking. Several designs of both plastic and metal sleeves will be tested as barriers to possums and for any deleterious effects on the poles.

Research is also required to try to produce possum control techniques that avoid the expensive practice of blanket poisoning large areas. Highly palatable bait trees or crops dispersed amongst plantings will be assessed as lures where the possums can be subsequently poisoned in confined areas. A variety of methods of presenting the poison, such as bait stations or poison in gel form, will also be tested. There is also a need for research on poisons other than 1080 which are safer in farm land conditions, particularly in the presence of farm dogs. A lure in the form of highly palatable poles is suitable for systemic poisoning.

It is likely that only a combination of all three approaches will result in greatly reduced damage.

ACKNOWLEDGEMENTS

We are grateful to Mr E.H.H. Kelman of the Soil and Water Division, Ministry of Works and Development for providing us with unpublished reports. We would also like to thank Mr C.L. Batcheler and Dr J.D. Coleman of the Forest Research Institute for reviewing this manuscript.

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GENERAL DISCUSSION

ANONYMOUS. Could you tell us more about the heat effect of the protective bands on the trunks of the plantings?

JOLLY. I believe in trials carried out by the Plant Materials Centre, tin sleeves were found to "cook" the live pole plantings and they simply would not grow.

WODZICKI. Are you looking for a species or variety of tree that would be very unpalatable to possums, that would show less damage from them?

JOLLY. I think the Plant Materials Centre has explored the ground very thoroughly. You need a pole 3 m high that will sprout from the top so that stock cannot reach the foliage. Also you need a plant that will strike easily in tough country from such a long pole. Your choice of suitable species is limited and you come back to poplars and willows every time. The alternative is to retire land and there is probably more retirement going on in North Island hill country now than there was in the past.

FITZGERALD. The Plant Physiology Division of DSIR have been working on meristematic tissue and have developed a polar strain highly resistent to *Melampsora*. Unfortunately it is highly palatable to possums. I gather they are going on to try and find a strain resistent to both possums and *Melampsora*.

WODZICKI. How does the frequency of damage by possums to plantings vary - have you considered the matter quantitatively?

JOLLY. Most of the poles were planted in mudstone country across the central and eastern part of the North Island - from Wanganui to the Rangitikei and Manawatu catchments, then north up the east coast from Wairarapa to East Coast-Poverty Bay. The damage has been pretty bad in all the catchment districts involved. It does vary locally, in that you tend to get less damage further away from normal possum habitats; conversely in Wairarapa tussock country, lacking in scrub or forest, we found significant damage despite low numbers of possums. There is also a seasonal component - spring is probably the main period of attack, after the leaf emergence.

WARD. You have mainly referred to poles. Does this mean the damage occurs only over the first 2 or 3 years, or is it only critical then? If you can nurse your pole through this early period of establishment can it then hold its own?

JOLLY. The damage is critical over the first three to four, possibly five, years but it continues in older trees too.

BROCKIE. Dr Gibb has suggested it might be possible to incorporate a poison into a sticky glue and simply paint this in a band around a pole. As the animals climb up and down, the poison is transferred to the fur and when the possum later grooms itself the poison takes effect.

JOLLY. Yes, Dr Spurr also had the same idea. There is the prospect of applying 1080 as a gel onto the top of the pole above the height the stock can reach. I would like to do trials on this aspect.

COLEMAN. A suggestion that the N.Z. Forest Service use 1080 gel on the bark of some forest trees was turned down for on smooth-barked trees, at least, the life of the 1080 gel would be very short indeed.

ANONYMOUS. Would a band of sticky paper wrapped round the trunk be quite an effective deterrent?

JOLLY. The problem is it would have to cover every pole, which themselves cost $1.20 each now, so the catchment boards are not prepared to add to their labour costs unless satisfied it would be worthwhile. I think you need to draw the possums to a particular site and try and kill them there.

SPURR. The Plant Materials Centre has worked on repellents, ranging from rotting seaweed to mechanical devices, but so far they have turned out nothing really effective.

TUBERCULOSIS AND THE CONTROL OF POSSUMS *TRICHOSURUS VULPECULA* - AN EXPENSIVE BUSINESS

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ABSTRACT

The recent identification of bovine tuberculosis in widely scattered populations of possums throughout New Zealand has led to a re-thinking of possum control policy and control technology, and to dramatic increases in the areas under control and monies expended.

Two organisations are involved in possum control. The Agricultural Pests Destruction Council is responsible for possums on rateable lands, while the N.Z. Forest Service is responsible for those on lands of other tenure. Together, the organisations accounted for $1.38 million in direct Tb/possum control between 1972 and March 1976, and anticipated spending a further $1.3 million in the 1977-78 financial year. Even with this effort, the elimination of local foci of bovine tuberculosis has been achieved in few instances. It is apparent that a greater understanding of the epidemiology of the disease in possums is required to reduce future cattle losses and enable the best use to be made of manpower and resources.

INTRODUCTION

The common brushtail possum *Trichosurus vulpecula* has long been identified with the destruction of New Zealand's indigenous forests. More recently the species has also been blamed for economic losses in exotic plantings, in catchment plantings, and in improved pastures and fodder crops. Perhaps most devastatingly, possums have also been identified as a reservoir of leptospirosis and as both a vector and reservoir of bovine tuberculosis (Tb) *Mycobacterium tuberculosis* var. *bovis*; the latter from such scattered areas as the central North Island, Wairarapa, Westland, Methven, Banks Peninsula, and Southland (Fig. 1).

The progressive reduction of bovine Tb amongst New Zealand cattle has led inevitably to the need to "control" farm-dwelling, tuberculous possum populations. However, traditional methods of possum control have often proven unsatisfactory in the elimination of the disease from possum populations although dramatic changes in control planning have taken place.

The present paper outlines the history, function and funding of possum control agencies in New Zealand and examines the cost and success of individual control operations.

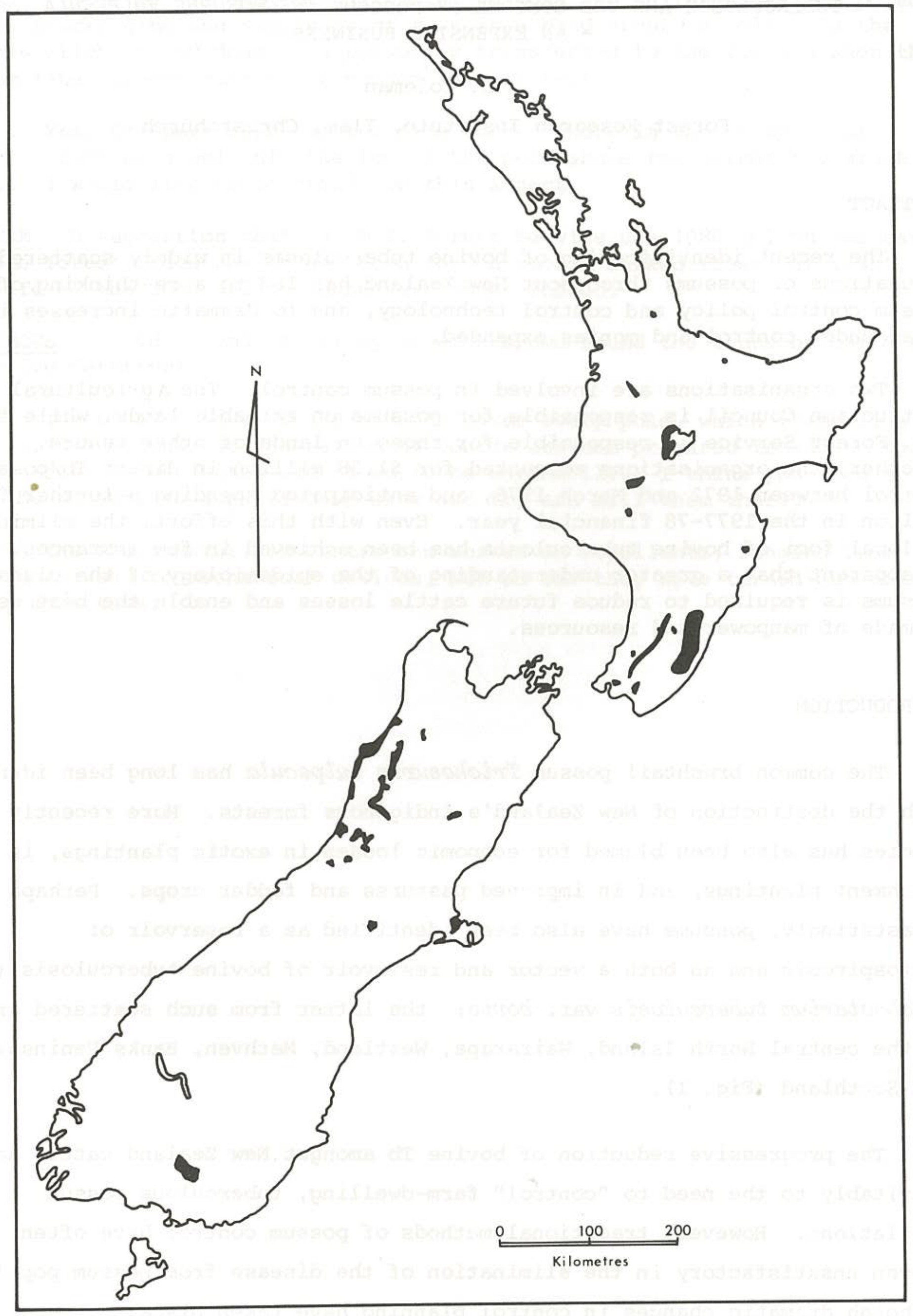

Fig. 1 Location of tuberculosis - infected possum populations in New Zealand.

THE ORGANISATION OF POSSUM CONTROL

The basis for successful possum control is adequate legislation - the Wildlife Act of 1953 contains in its sixth schedule a list of animals "declared" to be noxious (and hence to be destroyed) under the Noxious Animals Act of 1956. This list includes nine species of deer (*Cervidae*), thar *Hemitragus jemlahicus*, chamois *Rupicapra rupicapra*, goat *Capra hircus*, pig *Sus scrofa*, wallabies (*Macropodidae*) and the possum. Local efforts at the control of any of the so declared species vary markedly throughout New Zealand, but in terms both of the finance and control effort expended, the possum is now pre-eminent.

Two organisations are involved in possum control. The Agricultural Pests Destruction Council (APDC) with its associated pest boards is responsible for the control of possums on all rateable lands, while the New Zealand Forest Service (NZFS) is similarly charged on lands of other tenure, e.g. state forest, unoccupied crown lands, national parks and flora and fauna reserves.

The involvement of the APDC and of its predecessor, the Rabbit Destruction Council (RDC) in possum control began in 1958. Initial action was taken by the Banks Peninsula and Northern Hawkes Bay Pest Boards, who became alarmed at possum densities on local farmland and mounted pilot control programmes funded by direct government grants. The success of these operations, together with the concern growing for the numbers of possums present over much of New Zealand's rateable land, led in 1960 to an amendment of the Rabbit Act of 1955. Boards then became able through revised legislation, to legitimately seek revenue both from central government and from rate payers for the control of possums wheresoever they are declared "a pest of local importance". Many boards made use of this amendment - 61 had done so by 1962, and 87 out of a total of approximately 100 by August 1976 (Fig. 2). Surprisingly, possums have been declared "pests" in areas where the nature of the farmland and land management is such that the species is unlikely ever to cause serious economic losses, *viz.* boards in inland South Canterbury and Central Otago. Conversely, other boards exist which have yet to declare the possum a pest, even though they are contiguous with, or are themselves, thought to be harbouring Tb infected populations, *viz.* South Otago, Waitomo and Hutt.

The involvement of the NZFS in substantial possum control began with sodium monofluoroacetate (compound 1080) trials in 1956 in the Aorangi, Granville and Mt Bruce indigenous forests and Ngaumu exotic plantings. Subsequent control has been confined largely to populations in indigenous forests and

Fig. 2 Pest destruction districts which have yet to declare the possum a "pest of local importance" (cross-hatched areas). Data from the Agricultural Pests Destruction Council 'Bulletin to Pest Destruction Boards'.

exotic plantings within state forests, with the exception that since the early seventies and the isolation of bovine Tb from possums, some control of diseased populations on rateable lands has taken place. Involvement of the NZFS in control on rateable lands has resulted from (1) the absence of active pest boards in key Tb areas, particularly the Buller, Inangahua and Grey counties, (2) the need to control possums on non-rateable forested lands contiguous with lands of other tenure and, (3) the control experience gained in past years by its management staff.

THE COST OF TB/POSSUM CONTROL

The cost to the nation of the control of Tb/possums has steadily increased since 1970, as new areas of infection have been discovered and as larger numbers of cattle become at risk. Thus, while the NZFS and APDC together spent approximately $1.38 million in direct possum control up to March 1976 (Salisbury, MAF, pers. comm.), a further $1.3 million was requested for control in the 1977-78 financial year (from "Surveillance" 1977, No. 2, p. 13). These estimates do not include any of the substantial costs incurred by the replacement of diseased stock, herd testing, the loss of production, or the wages of NZFS staff employed in possum control.

The control activities of both the APDC and NZFS have been made possible by increased funding from central government, and made workable by close inter-organisational liaison. Finance for APDC control programmes has been derived from additional rates struck for possums, from the related increase in government subsidies, and from direct government grants. Grant monies for the control of disease-free populations increased steadily during the sixties to a high in 1967 (Fig. 3). This trend reversed in 1968 concurrent with the general economic recession of the time, but dramatically increased once again in 1976 and 1977 as the need for Tb/possum control in the North Island became apparent. Rate and subsidy monies available for Tb control have also been substantial - a total of $88,000 was spent in the 1976/77 year (P.L. Burston, APDC, pers. comm.). Thus for the period April 1976 to April 1977, the APDC spent a total of $408,000 directly on Tb/possum control, with by far the greater amount being spent in the North Island.

By contrast, control commitments of the NZFS have been greatest in the South Island, particularly in Buller and Westland. Complete costings of NZFS control operations are difficult to determine, as only the direct expenses of individual programmes are itemised. Nevertheless, approximate costings of two

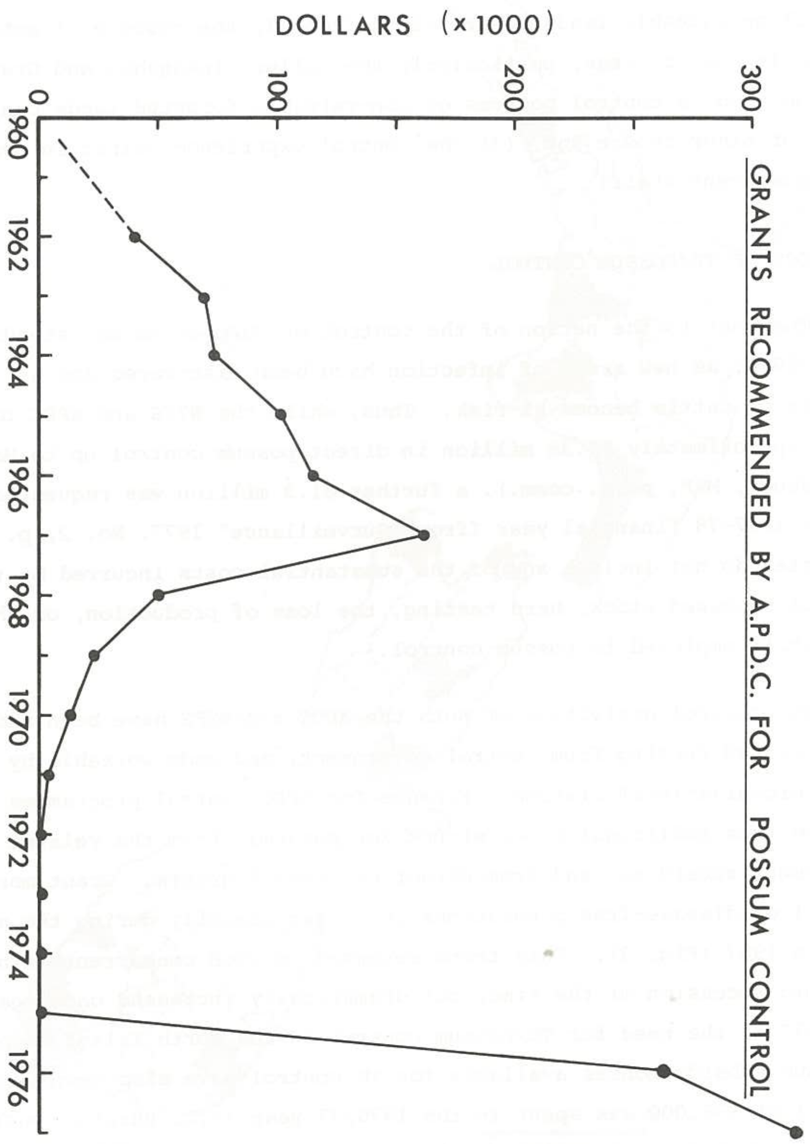

Fig. 3 Grant monies requested by the Agricultural Pests Destruction Council from central Government for the control of possums. Data from APDC and RDC reports.

typical Tb/possum control operations are presented below. The first (a) was carried out in 1974-76 in Westland by the NZFS, and the second (b) intended for the winter of 1977 in Canterbury by a local pest board.

a. Tb/possum control - Westland

"Aerial" control - 1974
  area of control = 6430 ha
  quantity of carrot bait used = 232 tonnes
  cost of aerial control = $42 000 or $6.53/ha
  cost corrected to December 1976 (consumer price index) = $55 340 or $8.60/ha
"Ground" control - 1975-76
  area of control ≈ 5000 ha
  cost of ground control = $73 850 or ≈ $14.60/ha
  total cost of control 1974-76 = $115 850
  cattle directly at risk ≈ 5000
  annual cost of control per beast ≈ $8.00
Gross annual profit margin (for Westland stock in 1977, Edwards, MAF, pers. comm.)
  dairy = $154
  beef = $30-45

b. Tb/possum control - Canterbury - June/July 1977

Total area of control = 1620 ha
  area of aerial control = 1320 ha
  area of ground control = 300 ha
Quantity of bait required = 55 tonnes
Cost of control
  aerial control = $12 470 or $9.45/ha
  ground control = $790 or $2.63/ha
Cattle directly at risk = 2000
Control cost/beast = $6.70
Gross profit margin (for Canterbury stock in 1975, from Tocker, 1975, "Farming as a business") - beef = $19/head

It is apparent that control costs vary locally, regardless of whether they are expressed in terms of cost per unit area under control, or cost per unit of stock. Aerial control for possums has been costed out at $6-8/ha in the South Island and is suggested to be a little higher in the North Island (about $8.00/ha, P. Nelson, APDC). Further, the "kill" obtained is normally in the range of 50-80% and alone is usually considered inadequate for disease control. Ground control is often equally as expensive as aerial control, as it is rarely a "one-hit" operation and may continue for several years. It is also apparent that the economics of farming beef or dairy cattle in areas under Tb control are likely to be less than profitable. Any apparent profitability is eroded further by basic farm costs such as labour expenses and mortgage repayments which are not included in the profit margins quoted above, as well as by stock replacement.

THE SUCCESS OF TB/POSSUM CONTROL

Success in Tb/possum control can ultimately only be measured in terms of a reduced incidence of tuberculosis amongst cattle herds. This has been most accurately documented for the "Block 1" test area near Westport (Fig. 4, from Stockdale, 1975, Report AH26-1175). In that area, tuberculin testing of herds at three monthly intervals revealed incidences amongst reactor and tuberculous cattle of 5-6% and 2-3% respectively. Reduced incidences of cattle of either status were obtained only with the attempted elimination of infective animals outside of individual herds. Control of possums, initially by aerially applied toxin and later by repeated ground operations has led to a steady reduction in the incidence in both reactor and tuberculous cattle. In at least two instances, *viz.* the Monument area on Banks Peninsula and the Matiri Valley near Murchison, repeated possum control has led indirectly to disease-free herds.

Long term changes in the disease status of possum populations have not been monitored. However, in the two instances quoted above - the Monument area and the Matiri valley - it is reasonable to infer that a dramatic reduction if not a total elimination of all foci of infection amongst possums occurred in each area.

Short term changes have been monitored at least once, *viz.* in the Hohonu region, central Westland, by the author. In that instance, the possum kill obtained by aerial poisoning was estimated to be 67± 14% (C.L.) while the percent incidence of tuberculous possums remained unchanged.

CONCLUSION

The eradication of the disease from dairy and beef herds remains an uphill fight, with successes such as those discussed above counter-balanced by the need for intense possum control throughout many beef and dairy farming areas of New Zealand. It is obvious that both a greater understanding of the epidemiology of the disease in possums and some revision of the traditional methods of possum control are required, to reduce further cattle losses and enable the best use to be made of the available manpower and resources.

ACKNOWLEDGEMENTS

I am indebted to J. Bell, of the Ministry of Agriculture and Fisheries and to Dr W.Q. Green of the Forest Research Institute for reviewing the manuscript.

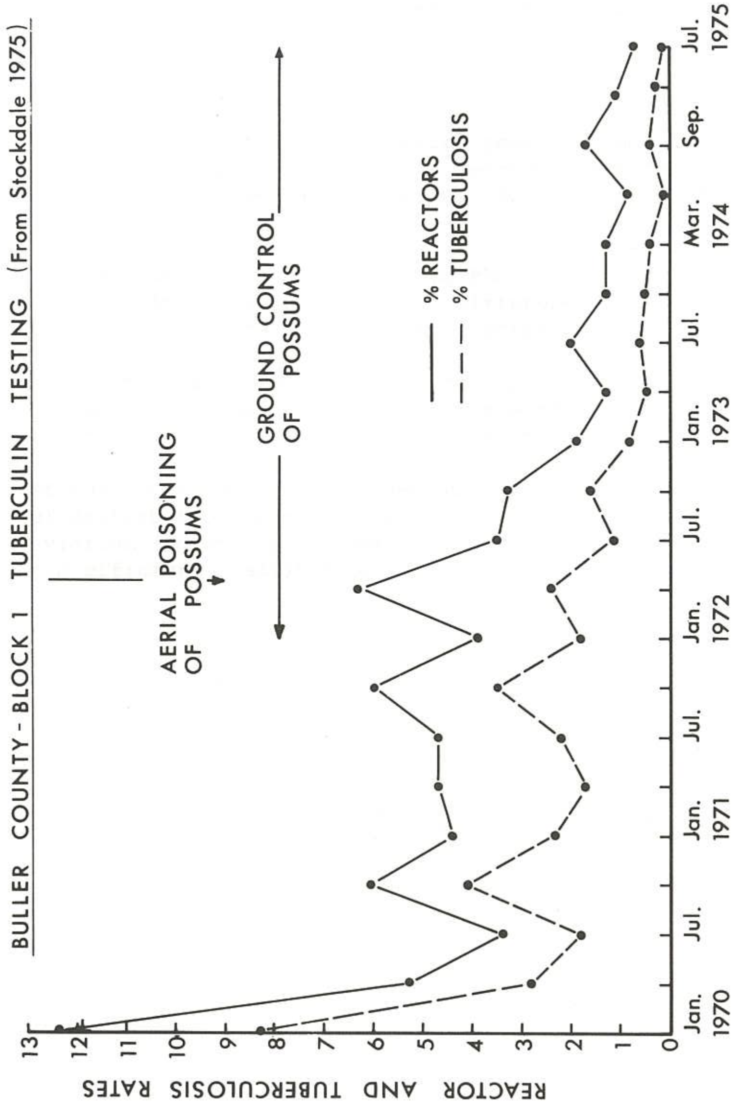

Fig. 4 Herd testing results from 'Block 1' near Westport.

CURRENT RESEARCH AND DEVELOPMENT OF BAITS FOR AERIAL CONTROL OF THE POSSUM *TRICHOSURUS VULPECULA*[1]

D.R. Morgan

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ABSTRACT

With the common brushtail possum being regarded increasingly as a pest of great importance, there is emphasis on improved methods of control, particularly by broadcast aerial poisoning. Three aspects of this approach are currently being developed:

1. Research is aimed at determining the suitability of various baits to different target populations and climatic conditions;

2. At the manufacturing level, a pilot plant has been developed to produce experimental quantities of wet-extruded pellet baits;

3. At the operational level, new techniques of distribution have been developed by the aviation industry providing for more economical and efficient distribution of baits.

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[1] A fuller account of the research topics in this paper is to be found in Branch Report No. 152, Protection Forestry Division, F.R.I., N.Z. Forest Service.

MODELLING THE EFFECTS OF CONTROL OPERATIONS ON POSSUM *TRICHOSURUS VULPECULA* POPULATIONS

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ABSTRACT

To model the effects of control operations on possum populations it was first necessary to determine the basic parameters on which the model could be based. In the absence of definitive field data, a range of parameters was used to simulate the growth of possum populations at various rates of increase. The theoretical effects of different levels of control by sterilisation and conventional killing were then calculated. The modelling shows that permanent sterilisation of both sexes is more effective than killing the same proportion of the population. Temporary sterilisation is not as effective as killing. The implications of these findings are discussed in relation to future control of possums.

INTRODUCTION

The objective of this paper is to model the effects of control by reproductive inhibition (conveniently called sterilization) compared to conventional control (killing) of the common brushtail possum *Trichosurus vulpecula*. The model used is developed from that given by Knipling and McGuire (1972), who presented a theoretical appraisal of the potential role of sterilization in suppressing rat populations.

THE BASIC MODEL

A population's pattern of growth is typically sigmoid, and may be represented by the following:

$$N_t = N_{t-1} e^{r_t} \quad \dots\dots\dots\dots \quad (1)$$

where

N = the number in the population

t = time

e = the base of the natural logarithm

r = the exponential rate of increase.

The rate of increase (e^r) is a function of reproduction and survival, and it is necessary to separate these functions when modelling reproductive inhibition of part of a population. Thus Knipling & McGuire (1972) expanded expression (1) as follows:

$$R_t = R_{t-1} e^S + 0.5 R_{t-1} e^I \quad \dots\dots\dots\dots \quad (2)$$

where

R = the size of the adult breeding population

e^S = adult survival rate from t-1 to t

e^I = the rate of recruitment to the adult population (in terms of animals recruited per adult female) and describes both birth and death rates of juveniles.

The exponents S and I are linear functions of the number in the population, so that:

$$S_{t-1} = a + b R_{t-1}$$

$$I_{t-1} = c + d R_{t-1}$$

To calculate the impact of reproductive inhibition it is necessary to further expand expression (2) (after Knipling & McGuire 1972) as follows:

$$R_t = (MN_{t-1} e^S + 0.5P_t) + (FN_{t-1} e^S + 0.5P_t) + MS_{t-1} e^S + FS_{t-1} e^S \quad . \quad . \quad . \quad (3)$$

where

P_t = $(FN_{t-1} MN_{t-1}/(MN_{t-1} + MS_{t-1}))e^I$

MN = normal males

MS = sterile males

FN = normal females

FS = sterile females

P = progeny.

PARAMETERS FOR THE MODEL

To model the rate at which a population will build up following a reduction in numbers it is first necessary to determine the parameters which could be used in the models.

To use expression (1), it is necessary to estimate the maximum rate of increase (e^{r_m}), which is observed when population numbers are minimal, by measuring the rate of increase of either

i. a newly established population, or

ii. an artificially reduced asymptotic population (and then extrapolating backward to minimal population size; see Caughley and Birch 1971).

Neither of these measurements has been made for possum populations. Bamford (1972, 1973) calculated a maximum rate of increase from a translation of the time taken to disperse a certain distance; for possums in a part of the Taramakau Valley this rate was 1.41 (i.e. a 41% increase). While there may be some dispute with the derivation of this figure, and some doubt about

liberation points and dispersal in the Taramakau Valley, a figure of 1.40 has been used as the maximum rate of increase for the model population in this paper.

To use expression (2) it is necessary to know adult survival and recruitment rates for

i. an increasing population, *and*

ii. an asymptotic population.

There are some data available for the latter but not for the former. Therefore, it was necessary to consider potential derivations of the maximum rate of increase.

The maximum annual adult survival is 100%, and the maximum annual recruitment to the adult possum population is 2 per adult female. When these are combined the maximum rate of increase is 2.0 (Table 1, Fig. 1). That is, the population doubles annually. Such a rate of increase is unlikely ever to have been reached. Some other potential rates of increase for possums are shown in Fig. 1, and their derivations in Table 1.

The maximum annual survival rate recorded for adults 1 year old and over (derived from stable age distributions presented by Bamford 1972 and Boersma 1974) is 80%. It is likely that survival rates would be higher in low density, increasing populations.

The maximum recorded rate of recruitment to an adult population (one year old and over) is 0.77 per adult female (derived from an age distribution of a harvested population as presented by Warburton 1977). This population had a fecundity or birth rate of 0.84 per female. Kean (1971) stated that double breeding (birth rate in excess of 1.0) occurs in low density populations with a good food supply. The maximum recorded birth rate (and therefore the maximum potential recruitment rate given 100% survival) is 1.8 births/female/year, recorded by Jolly (1976) on Banks Peninsula. The next highest recorded birth rates are 1.75 on Mt Egmont (Kean 1971), 1.5 on Banks Peninsula (Gilmore 1966), 1.4 on Kapiti Island (Kean 1971), and 1.2 in the Whitcombe Valley (Boersma 1974). All other birth rates recorded in New Zealand are less than 1.0 (e.g. Tyndale-Biscoe 1955, Bamford 1972, Crawley 1973, Boersma 1974, Bell this symposium).

If the maximum rate of increase of a population is 1.4, and the annual adult survival rate is in excess of 0.8, then the annual rate of recruitment to the adult population must be less than 1.2 per adult female (Table 1).

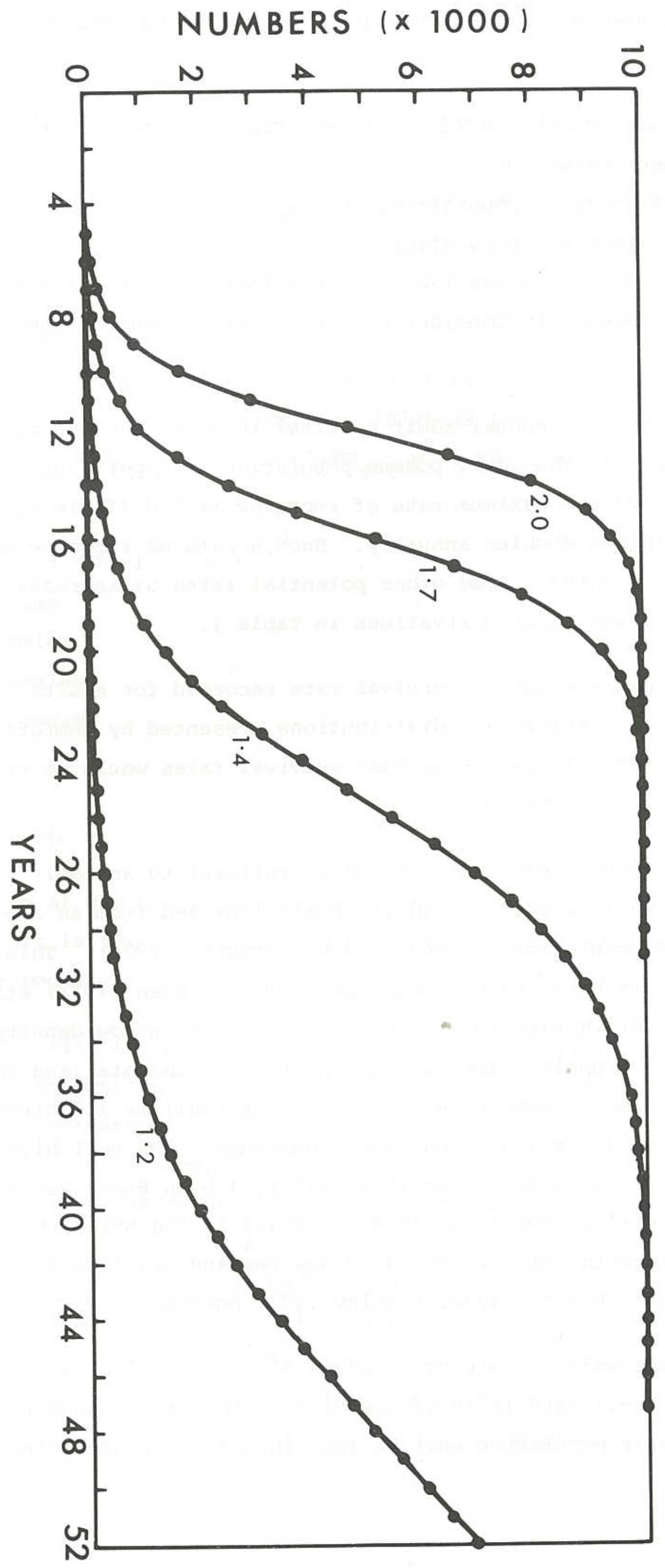

Fig. 1. Theoretical population growth curves, with the maximum rate of increase indicated beside each curve.

Table 1. Derivation of different rates of increase

ADULT SURVIVAL RATE	RATE OF ADULT RECRUITMENT PER FEMALE	POPULATION RATE OF INCREASE
1.00	2.00	2.00
.90	2.00	1.90
.90	1.80	1.80
.90	1.60	1.70
.90	1.40	1.60
.90	1.20	1.50
.90	1.00	1.40
.90	.80	1.30
.90	.60	1.20
.80	1.80	1.70
.80	1.60	1.60
.80	1.40	1.50
.80	1.20	1.40
.80	1.00	1.30
.80	.80	1.20
.80	.60	1.10
.74	.52	1.00*

* Stable population

THE MODEL POPULATION

For the purposes of this paper the model population is assumed to have a maximum rate of increase of 1.4, in which maximum adult survival is 90% and recruitment to the adult population is 1.0 per adult female. The population prior to control is assumed:

i. to be a stable population of 10 000 adult possums (1 year old and over) capable of breeding, with a sex ratio of 1:1;

ii. to be at the maximum sustainable density for the habitat;

iii. to be capable of breeding when 1 year old (and hence the adult population is 1 year old and over);

iv. to be isolated and not subject to emigration or immigration;

v. to have an annual adult survival of 74%, and an annual rate of recruitment to the adult population of 0.52 (adults recruited per adult female) which balances mortality (26%).

The figure for adult survival is taken from live-trapping studies by Crawley (1973) in the Orongorongo Valley and Jolly (1976) in Birdlings Valley. Re-working of age distributions presented by Bamford (1972) in the Taramakau Valley and Boersma (1974) in the Hokitika River catchment provide estimates of adult survival ranging from 70% to 80%.

EFFECT OF DIFFERENT CONTROL OPERATIONS

Killing removes a percentage of possums from the population. Possum numbers are reduced immediately. The survivors will have an increased reproductive and survival rate immediately after the numbers are reduced because of a reduction in density-dependent regulating factors. To calculate the theoretical rate at which a population will build up it is necessary only to impose the basic rate of increase curve on the remnant population. Following a 70% kill, a population with a maximum rate of increase of 1.4 will take a minimum of 10 years to return to 90% of its former level (Fig. 2). The increase in the first year after killing 70% of the population will be only 25% (or a rate of increase of 1.25). The maximum rate of increase of 1.40 will not be reached because population numbers have not been reduced to minimal. If the kill is 90%, the period of recovery is extended to 14 years. If the maximum rate of increase is only 1.2, the recovery time is much longer.

Inhibition of reproduction (or sterilisation) of both sexes leaves animals alive to compete for mates, food, nesting sites, and other resources, and therefore does not result in increased reproductive and survival rates of non-sterilised animals. If the sterilised animals are fully competitive and equally distributed they are theoretically capable of suppressing reproduction in non-sterilised members of the population to a degree equal to the percentage of the population sterilised. This will still apply even though possums may be polygamous, provided the same proportion of dominant individuals is sterilised as for the population as a whole.

Temporary sterilisation (i.e. sterilisation effective for only one breeding season) of 70% of the population reduces numbers only by suppression of reproduction for one breeding season. It will take a population with a maximum rate of increase of 1.4 only 3 years to reach 90% of its former level (Fig. 2).

Permanent sterilisation of 70% of the population in a single operation will suppress reproduction in the first breeding season as for temporary sterilisation, but will continue to suppress reproduction in subsequent breeding seasons,

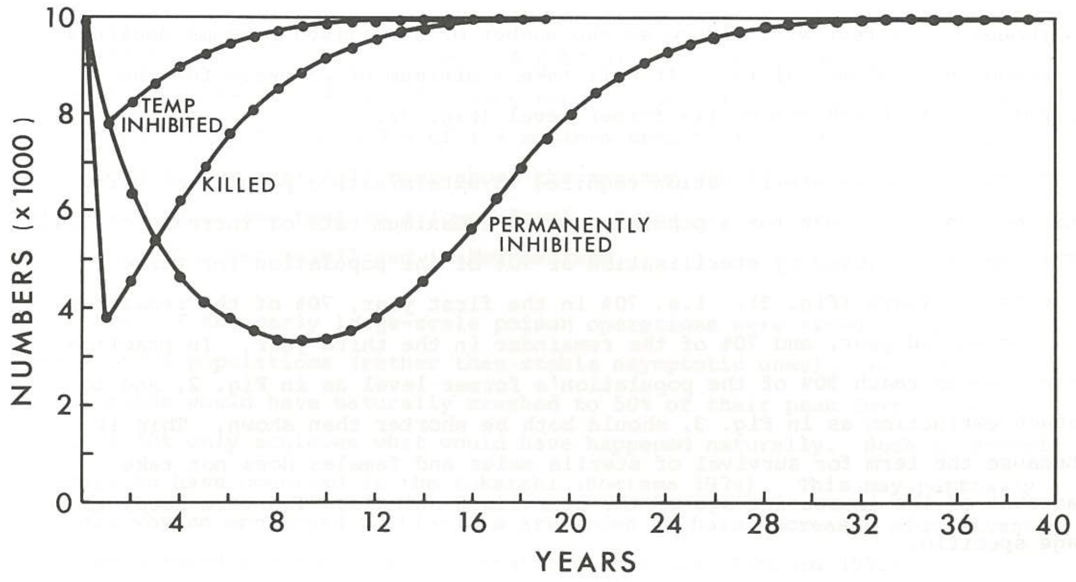

Fig. 2. Theoretical response of possum populations to 70 percent control for one year.

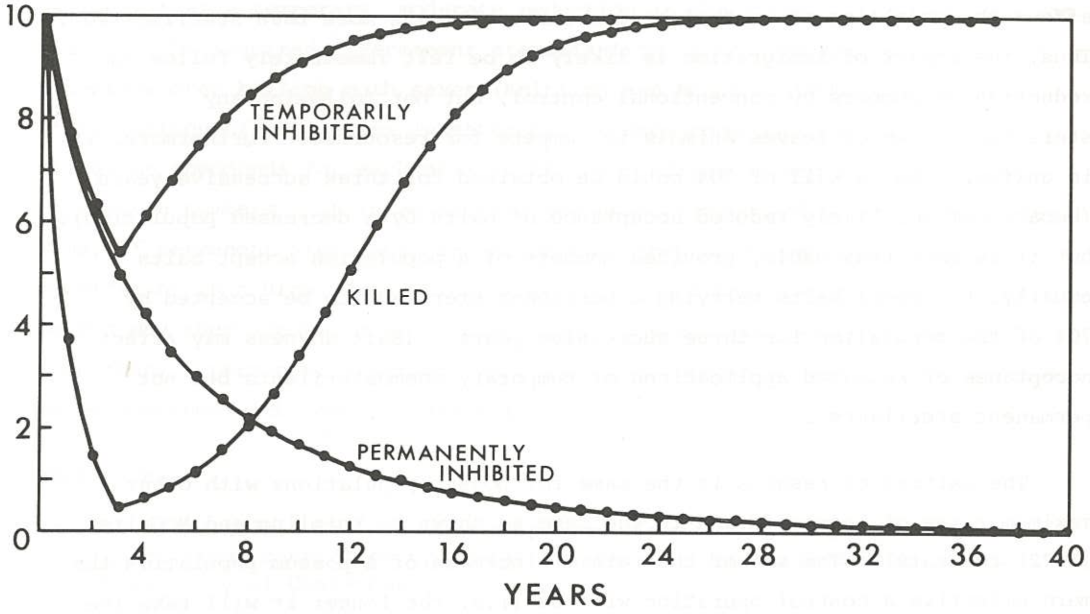

Fig. 3. Theoretical response of possum populations to 70 percent control for three successive years.

although its effect will reduce as the number of sterilised possums declines (through natural mortality). It will take a minimum of 23 years for the population to reach 90% of its former level (Fig. 2).

The degree of sterilisation required to exterminate a population using expression (3) is 97% for a population with a maximum rate of increase of 1.4. This may be achieved by sterilisation of 70% of the population for three successive years (Fig. 3); i.e. 70% in the first year, 70% of the remainder in the second year, and 70% of the remainder in the third year. In practice the time to reach 90% of the population's former level as in Fig. 2, and to reach extinction as in Fig. 3, should both be shorter than shown. This is because the term for survival of sterile males and females does not take account of the increasing age of the sterilised animals. The term needs to be age specific.

DISCUSSION

Some of the assumptions on which the modelling is based are unrealistic but necessary to compare the effect of control by killing versus reproductive inhibition. In fact, invalidity of some of the assumptions is likely to affect the modelling of control by conventional means more than sterilisation. Thus, the impact of immigration is likely to be felt immediately following reduction of numbers by conventional control, but not following any sterilisation which leaves animals to compete for resources. Furthermore, it is unlikely that a kill of 70% could be obtained for three successive years (because of the likely reduced acceptance of baits by a decreased population), but it is more reasonable, provided members of a population accept baits equally, to expect baits carrying a permanent sterilant to be accepted by 70% of the population for three successive years. (Bait shyness may affect acceptance of repeated applications of temporary chemosterilants but not permanent sterilants).

The pattern of results is the same for possum populations with other maximum rates of increase (and is the same as shown by Knipling and McGuire (1972) for rats). The slower the rate of increase of a possum population the more effective a control operation will be (i.e. the longer it will take the population to recover).

A maximum rate of increase of 1.4 is likely to be in excess of what a possum population would reach in today's modified New Zealand habitats (although it is quite possible that in the early days of colonisation such rates were reached). Starting with a population of 30 possums with a maximum rate of increase of 1.4, a colonising population is estimated (by the model) to take 23 years to reach 90% of its maximum density for the habitat. In fact populations typically over-shoot the maximum density, modify the habitat, and crash from this peak to a lower level. Pracy (1977) has noted that no population has yet stabilised in New Zealand.

Most of the early large-scale poison operations were aimed at peak or near peak possum populations (rather than stable asymptotic ones). If these populations would have naturally crashed to 50% of their peak level, then a kill of 50% only achieves what would have happened naturally. Such an example appears to have occurred in the Kokatahi (Boersma 1974). This may partially explain why no monitored populations are known to have increased significantly following large-scale poisoning operations (see also Bamford 1973).

The advantage of killing is that it gives immediate results. However, with the current use of poisons there are also problems with poisoning non-target species. Temporary sterilisation has no immediate or marked effect on a population, but is the safest for non-target species. However, it is unlikely that a temporary, moderate reduction in the numbers of a pest species will ever be required. Permanent sterilisation of one sex has no theoretical advantage over killing both sexes (Knipling and McGuire 1972). Permanent sterilisation of both sexes (whether by the same compound for both sexes or different compounds for each sex) is the most effective way of controlling population numbers. It is equally dangerous to target and non-target species. Thus, if permanent sterilants are to be used they will need to be highly specific or in a highly specific carrier-bait, and this is probably the main reason why they are not more widely used at present (see also Jackson 1972). Even then, a permanent sterilant will not give immediate results, and may need to be combined with conventional killing.

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GENERAL DISCUSSION

WODZICKI. What do you call temporary sterilisation?

SPURR. Temporary sterilisation is preventing the breeding of a female for one year only *i.e.* in subsequent years she can join the breeding population again.

CLOUT. You have not taken any account of immigration in your model. Immigration could have a major impact. Certainly I found in my studies of possums that dispersal of animals into an area that had been poisoned could raise the population level quite rapidly after control. So you present a rather simplified view.

SPURR. Yes, typically the situation will be that you have both immigration and emigration. Only if the poisoned area was sufficiently large or sufficiently isolated would you have a situation where such movements were less important.

CLOUT. It would have to be very isolated since possums can move vast distances during the dispersal phase.

KEBER. If the animals have an average life-span of say 4 years and you permanently sterilise them, then you still have them doing potential damage for several years. In my particular area of exotic forest this could mean the difference between a crop harvested or not.

SPURR. Yes, I said killing gives the only immediate relief from damage. The purpose of the whole paper was to see if there was any advantage in searching for a chemo-sterilant.

WORKSHOP DISCUSSION ON MARSUPIAL RESEARCH AND MANAGEMENT IN NEW ZEALAND

Chairman : J.M. Cummins

TOPIC 1 : ANAESTHESIA & HANDLING ANIMALS

CUMMINS. To start this discussion session, I draw your attention to the topic of anaesthesia. Those of us working on marsupials in the laboratory, and those examining them in the field require appropriate means of subduing or anaesthetising them. To start with, at Victoria University we have used a CIBA barbiturate product called Dial quite successfully for longterm anaesthesia of brushtail possums. With a dose rate of 75-80 mg/kg we get deep anaesthesia which can be maintained up to 7 hours. We use it in physiology class demonstrations and certain longterm experiments. It is not suitable for work on the central nervous system.

SUTTON. We do get deaths using this barbiturate, often at quite low dose levels. We think stress might be involved. Premedication with Ketamine-HCl does not appear to have any effect.

MORIARTY. What route were you using?

CUMMINS. Intravenous.

WHITE. At Ecology Division I have used halothane gas anaesthesia for possums. The animal is placed in a container, and halothane passes in with oxygen as the propellant. The animals are anaesthetised in about a minute, though this varies with size. I do not know the exact percentage of halothane/oxygen mix but the mixed gas is supplied at 5-6 litres down to less than 1 litre per minute. The animals can be maintained in deep anaesthesia in this way. It works well, though a few have died and I agree with Mrs Sutton that it may be due to some nervous reaction. However, it has proved the safest and fastest anaesthetic of some fifteen I have tested. The possums come round within 2-3 minutes and appear normal within 5-10 minutes. There appears to be some addiction of possums to the gas.

CUMMINS. Do you see halothane as a field anaesthetic?

WHITE. I encountered problems in the field, for instance the gas may not disperse fast enough for the operator's health.

GREEN. We have tried both halothane and ether in the field on possums. Halothane has no great advantage over ether for us, and is far too expensive for the use we require. We have had no deaths from either anaesthetic. With halothane the possums tended to come round very quickly after doing an operation like ear-tattooing; with ether recovery was a little slower and therefore better for our purposes.

CUMMINS. We have noticed some respiratory problems using ether, have you found this in the field?

GREEN. No, we operate fairly close to the 'knock-out' point and measure the animals as soon as the eyes close. We apply artificial respiration if necessary by holding them by the neck and rump and making concertina-like movements with them.

COLEMAN. We also noticed animals under halothane seemed to come out on a "high", which did not happen with ether.

FITZGERALD. How did you administer ether and halothane in the field?

GREEN. By using a 1 ft^3 ($0.3m^2$) perspex box that was applied to the end of the trap. Gas was applied using a foot pump.

FITZGERALD. So you had no control over the dose?

GREEN. No, though we can observe the animal's response.

MORIARTY. We have used halothane for many years and rarely had a death. I agree some possums do become addicted to it. The type of anaesthesia you want depends on what you do with the animal. We started using halothane to harvest lymphocytes from possum blood. It proved expensive so we used ether but found that was not suitable for good yields of lymphocytes so went back to halothane.

CUMMINS. Anaesthetics typically function by increasing the cell membrane fluidity so presumably your lympocytes were more fragile with ether.

HATHAWAY. I have done many hundreds of ether anaesthetisations but I have only lost one possum and that was due to inattention.

SUTTON. We control the level of anaesthesia with a portable anaesthetic machine that can be used in the field. We have used it for halothane and penthrane. Using penthrane the degree of analgesis is much greater and they take longer to go down - some 20 minutes. By using halothane in conjunction with scoline (succinyl choline chloride) as a muscle relaxant we find we can just keep possums down so that the central nervous system is not too depressed. This allows neuro-physiological work to be carried out. As an alternative to scoline we have used intravenous valium - which is not too expensive and since it potentiates the halothane, less halothane is needed.

MORIARTY. Would anyone accept a couple of strong men each with a pair of gloves and dispense entirely with anaesthesia?

JANE. When trapping and marking at Kaingaroa we used such a method.

GREEN. We only anaesthetise possums at the first capture for tattooing and detailed examination; all subsequent recaptures are done without anaesthetic and that includes measuring the head-lengths of pouch-young.

FITZGERALD. We have used a cylindrical retaining device made out of plastic cyclone netting through which wire pegs are inserted to secure the possum.

CUMMINS. I wonder what the field workers feel about using muscle relaxants?

WHITE. In the Orongorongo Valley we have used scoline since the beginning of studies by Dr Crawley. Despite my trials with anaesthetics I've come back to using scoline. Typically it takes only 3-4 minutes to work, the animal stays immobilised for 5-6 minutes and recovers over 5 or so minutes. We use a 10% solution of scoline. We rarely lose animals but on occasions have to apply artificial respiration.

JULIAN. We experimented with various intramuscular anaesthetics and found saffan was satisfactory for the short-term in possums, allowing both tranquilisation and cardiac punctures. We used 1-1.5 ml.

KEBER. With saffan, once the animal is disturbed it may take 15-20 minutes to take effect and there is a long period of recovery. So in the field

I am still using scoline.

MEADOWS. I have used ketamine successfully on wallabies. With a dose of 0.5-1.0 mg/kg they go under in about 30 mins. and stay under for 30-45 mins.

CUMMINS. There seems to be a difference between macropods and possums. We tried ketamine on possums and it is certainly not a long-term anaesthetic for them. Again the research group in the University of West Australia use nembutal for wallabies but in possums I found animals still crawling off the table with 2-3 times the lethal dose when injected intravenously.

FITZGERALD. Direct injection of nembutal into the liver of possums seems to be effective.

HAMILTON. For ether anaesthesia we simply put the possums in a bucket, pour ether onto cotton wool, place on a lid and wait until the animal is anaesthetised. However while ether is quite a good anaesthetic, we shifted to using saffan on advice from Wallaceville Animal Research Centre. With saffan we got a fairly good relaxation, good surgical anaesthesia and we could do cardiac punctures with no recovery problems.

RAMADASS. How do you quieten down the animals before anaesthesia?

SUTTON. We use intramuscular ketamine at 25 mg/kg.

CUMMINS. I am sure our veteran possum researchers will know that a good thick sack for half an hour can be a very effective tranquilliser. The animal can be anaesthetised through the ear merely by pulling it out of a fold in the sack.

MEADOWS. I think many people are trying to use anaesthetics or similar agents in ways which are not suitable. Many of the so-called criticisms of drugs may not be because the drug is no good but that people are not using them in the right way.

SUTTON. That could apply to saffan because it can be absorbed erratically if not used intramuscularly and so it may take longer to take effect.

WHITE. While the analgesic rompun is used on animals such as goats, on possums it is not satisfactory for they go crazy. A useful gas is nitrous oxide which only takes some 25 seconds to take effect. The animal can be kept under for your examination period and recovery takes only about 5 seconds with apparently no side-effects. However, there is a risk to the operator if the gas escapes.

CUMMINS. Nitrous oxide is quite useful to use prior to the application of halothane if trouble is encountered in inducing halothane anaesthesia.

D.J. BELL To what extent are pouch-young affected when the mother is anaesthetised?

FITZGERALD. We have no records of loss of pouch-young.

HATHAWAY. I have also had no trouble in losing small pouch young from 5g and older.

B.D. BELL. In the field we have carefully monitored survival of pouch-young and there is no evidence of increased losses of young in those females that have been immobilised more often using scoline. So with scoline, at least, there is no clear evidence of detrimental side-effects on the pouch-young.

TOPIC 2 : DISEASES & PUBLIC HEALTH

CUMMINS. Would the veterinarians present like to comment on the health and hygiene aspects of handling possums, or marsupials in general? What are the hazards and how do we get around them?

MORIARTY. The two main diseases that spring to mind are leptospirosis and tuberculosis. As a generalisation, in our area (Palmerston North) Tb is not a great health hazard, for I have not seen it on any possums we have handled. However, because of risks from an infected animal, at Massey University we have reduced the use of possums in student practicals.

HAMILTON. We had an extraordinary situation where we were actually stopped from using possums because of the health hazard. I did not think it was all that hazardous. However on examining a urine sample we found it loaded with *Leptospira*, so that convinced me that the urine could be quite a hazard to the human operator.

BLACKMORE. I agree the major diseases in possums are leptospirosis and tuberculosis but I think we have got to put it into perspective in relation to other animals we are handling. Apparently viable *Leptospira* occur commonly in most of our wild mammal species but we do not yet know the particular significance of various serotypes that have occurred in the possum. In the meantime we must consider it hazardous. Anyone carrying out postmortems on possums must therefore wear gloves, and if you know you are working in a Tb area particular precautions must be taken. However, it needs to be put into perspective - one should take sensible precautions with any wild animal for any could be transmitting disease which can be contracted by man.

CUMMINS. Yes it is worth noting that the possum is not the only villain on the scene. Do you take any prophylactic measures with your captive animals? For example at Victoria University we routinely dose them with combiotic (following Wallaceville Animal Research Centre's recommendation) before they are placed in the colony.

BLACKMORE. I just think we treat every possum as a potential disease source. We do not yet have a possum prophylactic in terms of a vaccine either for *Leptospira balcanica* or tuberculosis.

BROCKIE. As I recall there are very few substantiated cases of people being infected by possums. I think records of hospital patients on the West Coast were checked and about 10-12 trappers had got skin tuberculosis, presumably from handling possums. It was restricted to their hands and wrists. Another case was a technician who contracted leptospirosis from a rat at Massey.

BLACKMORE. We have to be careful with statistics. We have 550-odd Tb cases in humans a year but few of the mycobacteria are typed. So we don't really know how many cases were *M. bovis* (which is pathogenic to man as well as possums and cattle) or *M. tuberculosis*. Again, we need to treat every animal as suspect regarding disease risks.

CUMMINS. I think it's worthwhile that the points raised at this meeting are brough to the attention of the schools. I know possums are quite routinely trapped around Wellington for various class projects. I think it should be noted by all dealing with them that they are a potential health hazard.

BLACKMORE. I have in fact written a Health Department Bulletin pointing out the dangers of using possums in the school situation.

ANONYMOUS. Mr Chairman, I think that the Bulletin has been sent around to the teachers concerned.

MEADOWS. I would be interested to know if anybody has come across ringworm in possums. It is reported in Australia that some species around cities in particular have it, and it is one of the diseases which can be a health hazard.

BROCKIE. I've submitted 40-50 samples of possum fur to the National Health Institute. One or two with ringworm have shown up but they have not been pathogenic to humans. Nearly every other wild animal does carry ringworm that can be transmitted to humans so in a sense it was something of a disappointment. Often possums look very mangy but the cause of this is ectoparasitic mites rather than ringworm.

GREEN. If there is a potential Tb risk from handling possums in New Zealand, why have the appropriate tests for typing the *Mycobacterium* not been done?

BLACKMORE. This has been done on occasion. If a doctor sees a case of tuberculosis and feels there is something odd he will submit a culture for typing. However the doctor is usually concerned with whether it is a Tb case or not, and not so concerned as to which type of tuberculosis it might be.

WARD. Where you are handling animals and are at risk of being urinated on, what antiseptic would anyone like to recommend?

COOK. Both formalin and Savlon are contraindicated in the presence of tuberculosis. I would suggest that you use Dettol if you are going to use a disinfectant at all; merely soap and water is probably quite good.

HATHAWAY. I would react strongly regarding the use of Dettol against *Mycobacterium*, for I don't think it's very effective. Phenol derivatives are most commonly used at Massey University.

MARKHAM. I find Dettol is not so good. Medol or synthetic phenols are better for Tb. As far as leptospirosis is concerned, the organisms appear very susceptible to any of the common disinfectants; water and soap is also very good. However, leptospirosis can survive in damp conditions, so if one is urinated on use a paper-towel - get the urine off and dry oneself.

HAMILTON. Can I suggest that if anybody is worried about picking up tuberculosis from possums it's likely to be through skin infection. It would be wise to test your tubercular sensitivity first of all, and see if you are tubercular negative. The BCG vaccination would almost certainly prevent you having the skin reaction with bovine tuberculosis and it would certainly raise your resistance and diminish your chances of getting pulmonary tuberculosis.

PRACY. I think people dealing with possums especially in these informed situations know the risk and take precautions. The problem is the occasional trapper who is unaware of the risks. When skinning it is quite possible to cut through an infected lymph node. I must admit I have done this four times. Also I am in the habit when opening-up possums of holding them between the knees and this is where I think there is a danger.

HAMILTON. I would like to present to the symposium a statement on possums in virus research based on our work at the Virus Special Projects unit of the National Health Institute. We were asked by Dr R.E. Brockie if we could utilise possums discarded after his studies of *Leptospira*, ringworm, and so on. We decided to try and infect possums with human influenza viruses.

It is known that the ferret *Mustela putorius* could be infected with human influenza viruses, both type A and type B. Andrews had indeed first demonstrated the viral aetiology of human influenza, using these animals in 1933. He had previously tried a number of experimental animals without success, and it is said that his pre-deliction for blood sports determined the choice of ferrets and his access to supplies of this exotic experimental animal! Later work by Burnet demonstrated that the human influenza virus could be grown in fertile eggs utilising the amniotic cavity of 10-15 day old embryos. During adaptation to the egg, the human influenza virus undergoes a mutational change from the original (O) human phase to the derived (D) egg-adapted phase of the virus. This latter phase, D, grows faster than the O phase, and also in the allantoic cavity, which the O phase is unable to do. The important fact is that ferrets could also be infected with the D phase egg-adapted influenza virus which is completely avirulent for man. This later finding is fundamental to the ecology of human influenza viruses, for it precludes the possibility of using egg-adapted virus as attenuated live influenza virus vaccines in humans. This work of Burnet's has never been repeated except in minor ways (e.g. the virus isolated in human kidney tissue cultures seems to remain in the O phase). Thus, based on this type of thinking we attempted to infect possums with first, egg-adapted virus in high doses and later, with human throat secretions found positive for influenza virus in eggs.

Wild caught possums were obtained and bled by cardiac puncture under ether anaesthesia. When the animals recovered they were inoculated intranasally with the virus-containing inocula under light ether anaesthesia. Swabs were obtained after 3 days from the throat also under ether anaesthesia and virus isolation was attempted in eggs. A post-inoculation sample of blood was taken 14 days after inoculation , also by cardiac puncture. A large amount of blood could be obtained from a mature possum - 180 ml with recovery from cardiac puncture.

Now I shall outline the results. Two possums were infected with *Myxovirus influenzae* type A, from egg-adapted virus 1974 that had been stored at -90°C. The virus was recovered from the throat of one animal 3 days after inoculation; the serum antibody response was marked, the pre-inoculation titre of $\leq$ 1/10 going to 1/160 and 1/320 respectively in the two animals.

The possums were similarly infected with egg-adapted *Myxovirus influenzae* type B. In this case, virus recoveries after 3 days were negative; the preinoculation titre to the inoculated virus went from < 1/10 to 1/40 and 1/320 respectively in the two animals.

A young male in contact with the infected animals above did not develop antibody and attempted virus recovery was negative.

Single attempts to infect possums with human throat secretions were negative, but the stored material was not viable when simultaneously tested in eggs. Thus the results were not conclusive. A total of eight possums was used for these experiments.

To summarise, egg-adapted virus will infect possums; the antibody development could be of similar specificity to that developed in ferrets and so could be very useful for strain-specific identification of human influenza viruses.

We also carried out tissue culture studies. Kidney tissue cultures were set up in glass test-tubes as dispersed epithelial cell cultures. Fourteen specimens of influenza viruses from -90°C storage were used to inoculate fully grown tissue cultures from several animals. Cytopathogenic effects and positive haemadsorption were demonstrated with virus of egg and human origin. Thus virus could be isolated directly from human source material in possum kidney cultures.

In possum antibody studies serum from just over 100 wild caught possums was examined for antibody to human A and B influenza viruses by both a complement fixation and haemoglutination technique. No specific antibody was demonstrated. The H.I. tests were bedevilled by much non-specific inhibition, unlike sera obtained under laboratory conditions.

From these studies I conclude that possums could be very useful animals in human myxovirus research for:

(1) production of large amounts of post-infection antibody which has the promise of being highly specific;

(2) use of the kidney epithelial cell cultures for isolation and antibody studies in human infections; these promise to be better than monkey kidney cell cultures which can be infected with SV5 virus contaminant (another myxovirus);

(3) the investigation of the immunological abnormality which allows the growth of egg-adapted influenza virus could have important results in the field of live attenuated influenza viruses for human influenza immunisation;

(4) the use of possums in other aspects of human respiratory virus investigation is worthy of exploration, such as organ cultures of the trachea and the attempted isolation of other human respiratory viruses.

I gratefully acknowledge the technical assistance and expertise of Mr Maurice Wilson and Mr Norman Kuttner in this work.

TOPIC 3 : GENERAL HOUSING & HUSBANDRY OF CAPTIVE MARSUPIALS

CUMMINS. Marsupials and especially possums are going to be used more and more as laboratory animals in New Zealand. Do we have any idea on suitable housing methods, especially if we want to breed the animals. Is there any magic formula for keeping possums happy in a cage?

FITZGERALD. Not that I am aware of. At DSIR, Taita, we have been known to stock our small outside animal house with as many as 16 or 17 possums which would seem to be overcrowded; they certainly scrap a bit but we do get successful breeding. I find we can get animals through to the large pouch-young or back-young stage; then we start to get the young dying because they are not in a position where they have very ready access to the food.

CUMMINS. What sort of diet are you maintaining your animals on?

FITZGERALD. We try to keep it fairly mixed. We use a basic SG1 commercial pelleted diet and we supplement this with bread, apples, leaves, household scraps but no bones.

SPURR. The N.Z. Forest Service at Rangiora had the same problem in losing back-young in captive stock.

MEADOWS. T.J. Bergin, a zoo curator, suggests that marsupials should be in a cage eight times the length of the body (head plus body not tail); the width of the cage should be four times the body length; the height should be about 4 feet (1.2 m). In that sort of situation they seem to be maintained quite happily.

CUMMINS. So for possums that would work out at a length of about 8 ft, (2.4 m), a width of 4 ft (1.2 m) and a height of 4 ft (1.2 m).

MEADOWS. If anybody wants a reference its a refresher course for veterinarian postgraduates held at Sydney last year, no. 29.

PRACY. Is that formula for holding the possums or for reproduction?

MEADOWS. This is for reproduction. In a colony these are optimum figures. I'm not suggesting they couldn't be held in less.

PRACY. Initially in the Orongorongo Valley over 1947-60 we had trouble with females reproducing under cage conditions. We had pens 16' x 16' x 9' high (4.9 x 4.9 x 2.7 m) with good nest boxes. Initially they had earth floors but this was unhygenic and it was not until we put concrete floors in and kept them well washed that we found an improvement.

ANONYMOUS. At Massey University we kept possums in cages 3' x 2' x 2' (0.9 x 0.6 x 0.6 m) over trays.

TOPIC 4 : STATEMENTS ON THE USE OF SEQUENTIAL FRACTIONAL ANALYSIS AND PROTEIN ELECTROPHORESIS IN MARSUPIAL RESEARCH

CUMMINS. We shall now hear from two Victoria University people who are not working directly on marsupials, but who have something to say on their research programmes that might be of interest to this symposium. The first speaker is Warren Johnston of the Botany Department.

JOHNSTON. Through the good services of Dr Kear and Mrs Fitzgerald samples of forest plants have been collected every 3 months over a 2 year period. Eight of these were known to be eaten by possums, six were known not to be eaten by possums. Now any organism can only exist in an environment because of what is available to it in terms of nutrients. Now how does one analyse for available nutrients? You can do a total analysis of leaf material of any plant you like, and then quote, say, a calcium figure. That calcium figure does not mean that all calcium is available; for instance, a lot may be present as calcium oxylate which is so unavailable, it's not even funny.

To tackle this problem we have a technique we call S.F.A. - sequential fractional analysis. With this technique we run plant material through a series of fractionations in a set chemical sequence; we take each particular extract and analyse it for potassium, calcium, magnesium, sodium, iron, copper, zinc and so on. At the end we have a total figure for, say, calcium; we know, or at least we have a very good idea, that the calcium present in certain fractions is available, whereas the calcium present in other fractions on chemical grounds we believe unavailable. So therefore at the end of the analysis we can estimate how much of that calcium is available. We can arrive at this figure because digestion is a chemical process. Inorganic elements are neglected all the time in nutritional work. You will get far more work done on proteins and carbohydrates but you try to look for figures on available iron, calcium, or copper: they often just don't exist. This is because I do not think people have had a method. Now I'm not going to say that the method we use is 100% effective, but it is at least one step on the ladder, so to speak, to achieving some idea of available nutrients.

Now there are lots of things that could possibly come out of this. It would be the first time in New Zealand that anyone has sat down and analysed our native vegetation for inorganic elements; and, who knows, among the plants that the possum avoids for instance, there might be some with high nitrate content. You know as well as I do that nitrate is reduced to nitrite and this combines with haemoglobin; this has poisoned quite a few people already since civilisation started. When you look at some analyses of even common vegetables, such as celery or carrot, they're so incredibly high in nitrate that it's not even funny; there have been cases of infants poisoned for instance by carrot juice because of the high nitrate content.

So this is what we are attempting to do. I don't know how successful we will be; it may take us 18 months, or 2 years to complete analysis. To my mind this is the only way to start looking at the inorganic elements that are required by an animal.

CUMMINS. Thank you Warren, I think that will be a matter of interest to a number of people here interested in nutrition, palatability of bait, and so on. We now have Peter Harper who is doing work on protein analysis. This might be of interest to people who are looking at aspects of disease or speciation in possums or wallabies.

HARPER. I have been looking at the plasma proteins of albatrosses and petrels using acrylamide vertical-slab gel electrophoresis in conjunction with immuno-electrophoresis.* With colleagues in the Botany and Zoology Departments we have developed a technique using some relatively inexpensive components and are resolving in the order of 22-24 different proteins in this sea-bird plasma. Runs I have done on human plasma reveal quite astonishing numbers of proteins. It is a simple, inexpensive technique that gives beautifully reproductive results. I pass on the information to you in case you wish to examine genetic polymorphism in marsupials. It is a very exciting and interesting tool to use.

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* this work is now published in *NZ Journal of Zoology*, 1978, Vol. 5, 509-548 - Editor.

TOPIC 5. POSSUM POPULATION ASSESSMENT

CUMMINS. One of the main topics to come up in this symposium is possum population assessment techniques which is quite a crucial aspect. After all we are looking at an animal supposed to be one of our major pest problems, but we seem to have very little idea of how many there actually are.

MEADOWS. I feel much of the scientific work has been based on assumptions for which there is very little evidence. It's like a large building being put on very muddy ground. What evidence is there for accurate estimation?

CUMMINS. I was interested in one particular point - the quite significant loss of a possum population in an average year - some 15% of the population. Dr Brockie, did you in fact have any idea what caused this loss? Was it loss through migration, through natural death or what?

BROCKIE. In the Orongorongo Valley where we've been working there is a loss of possums through emigration, but this is compensated for by immigration; immigrants are mostly males in their first year. The dead animals were mostly found in winter on the ground by Dr Ben Bell and A.J. White. They all I understand had very low body weights and they appeared not to have died of disease or predation. By a process of elimination these animals appear to have died by starvation, through poor food supply at that time of the year. It's probably a complex situation though, with many factors contributing to it. I suspect that the cold wet weather in winter curtails the animals' feeding. There must be a cut-off point where the possums have to decide whether to stay inside their den to conserve what energy resources they have, or to take a risk and go outside to look for something with which to support themselves.

B.D. BELL. Further to what Dr Brockie has said about the Orongorongo Valley population, I examined weights of adult animals known to die and there was certainly a very marked decline in their weight prior to death. We set traps in the main study area for four successive nights each month and one needs to pose the question regarding our effect on the study population through this trapping activity. I looked at mean weight trends in animals which were successively trapped on all four nights each month or even three of those four nights; there were successive declines in mean weight, as you might expect, since over much of the night the animals could be cooped-up in a cage trap.

However, the animals which showed a serious decline in condition and became comatose or dead in the traps were generally those animals which were already in relatively poor condition and underweight; healthy animals appeared able to regain the weight-loss from successive captures. Thus I conclude that our trapping activities were not a major factor inducing low weights and deaths in the study population.

COLEMAN. To respond to Mr Meadows, I think we have got to remember that work on assessment methods is on-going. We are dealing with a generally arboreal, nocturnal, forest dwelling animal so to a large extent we are limited to indirect methods of assessment. What you use is dependent on the effort you have available and what you want to get out of it. D.J. Bell has given us an estimate of the confidence you can place on the different techniques which are available to us. If you are prepared to put the manpower into it, if you are prepared to estimate the decay rate of pellets, then you have a pretty useful tool. It's no good considering assessment in a purely cursory fashion; after one night you cannot come up with something which can stand up to close scrutiny.

CHARLESTON. Do we have any idea of how reliable ground trapping is for an arboreal animal like the possum? Until you know this, how can you say how effectively pellets estimate the population?

COLEMAN. That's not quite true. We measure pellet estimates against trapping as you say; we also measure trapping against total kill, and Mr Pracy is one who has trapped a population to extinction, and we intend to do the same in the population we've worked on. We shall trap to extinction and relate our pellet numbers to our trap catch in fact.

CHARLESTON. But you still have problems of immigration and emigration unless you have an isolated area.

CLOUT. I have computed a trapping estimate with a removal-kill estimate and I found quite good agreement.

FITZGERALD. Isn't it in fact true that by any of these methods you will never know what extinction is - you have no way of knowing when a population is extinct with any degree of certainty.

CUMMINS. Except on an island.

GREEN. I think we are trying to split a hair four ways which is really not our purpose. If one traps in an area where pellets decay mostly within a few weeks, I would submit that if one runs a pellet line in that area after you have trapped to extinction and one finds no pellets, then there are no possums. So I submit that we can probably trap to extinction with a fair degree of confidence, and by extinction I mean the animals normally resident and those passing through at the time have been killed. If you do your trapping to extinction in an area where you already have done pellet counts and have established a certain relative density, then a further pellet count provides a fairly good estimate of the effectiveness of your killing.

FITZGERALD. Yes, I feel I'm not very good at finding pellets.

YOUNG. I don't see any difference in us trying to get an estimate for possum numbers than for any other estimate we make in the field. The problem last year for the project I was involved in was estimating the numbers of a fruit-fly, and it came back to exactly the same topics. We do as many types of estimates as we can so one can check out the other. The advantages of the possum situation over the fly is that you can get a higher percentage of your animals marked in the habitat and this should give a pretty good idea of the numbers in the trapping area. I don't see why we are subject to this difficulty. Any decent study that has been run for 2-3 years comes out with a very good estimate of the numbers present, unless you talk about hypothetical aerial animals which have aerial pellets.

CUMMINS. This leads us to one of the perennial questions which is approximately how many possums do we have in this country? How many do we have to deal with? Les Pracy I've already elicited a tentative estimate from you.

PRACY. Yes, I was once directed to undertake this rather painstaking estimate. Fortunately, I had done a national survey of possums and covered some of the areas in New Zealand two or three times over. Most of this work strangely enough came back to the original population studies in the Orongorongo Valley in 1946-47 where there was a complete trap out of an area with marginal lines to stop re-infestation. There was a correlation between two methods of estimating density: the Lincoln index gave 2.2 possums per acre (5.4/ha), the trap-out gave 2.6 possums per acre (6.4/ha). There were 2 study areas and a marked difference in their carrying capacity in relation to vegetation types. Now in assessing the population for the whole of New Zealand what this meant was that you would have to assess all the various vegetation types and the carrying capacities at the time. There were 2 or 3 areas in the North Island and about 3 in the South Island where we could reckon on good reference populations. Knowing the possums' distribution and with population densities plotted as 'scattered', 'light', 'moderate', 'heavy', and 'dense', then on forest types and carrying capacity you could work out the national population. At that time, it worked out at 46 million. I didn't like this as a figure and I remember saying to Ralph Kean, "To hell with this, we'll cut it in half" so we arrived at a figure of 22 million. Now there are over 187 areas of post-peak populations, with 80 in the South Island, according to the last national survey of 1971-72.

CUMMINS. Would anybody from the Forest Research Institute like to stick out their necks on this one?

GREEN. They're not that long.

YOUNG. In regard to population estimates, our problem has not been so much to find the number in an area, but to find a geographic area to relate that number to. In fact as soon as possible we require some sort of standard technique to let us apply our trapping grid data (which simply gives a figure of animals' home ranges) to an area. Until we can do this, we don't have any density measurements that are reasonable. The standard method is to add half of the grid-spacing, but some papers don't even mention how they convert to a density. Clout working in consultation with Seber got quite different densities than if done by other methods. So this seems to me a critical issue that has to be resolved if anybody is using grids or lines as trap systems. We can get a number, and then that has to be converted to a density, and there's no realisation of how this should be done and certainly no conformity.

CLOUT. In fact I added half the estimated home range radius to the edge of my trap-revealed range area; obviously even that is going to be a gross underestimate of the area we are actually dealing with. The problem is how far are the animals moving outside of your grid-trapped area. It would be interesting if anyone else has comments.

YOUNG. It's only important because everybody quotes densities.

JANE. We did some bait interference work at Kaingaroa and two bait interference lines were separated by a road and fire-break, probably about two chains (40 m) distance. The bait line in a tall stand on one side reached a 100% take within a week, the bait line across the road reached a 5% take in three days but didn't increase beyond that. This indicates that you can get a very sharp boundary of a range in such a situation.

YOUNG. One of the standard papers everybody is using is the 1973 one of Dr Crawley*. We do not see clearly what the basis of his density figures were. Does he remember that?

CRAWLEY. Yes, at least as far as the trapping grid is concerned. I simply used half the grid spacing to increase the area around the grid. I think one can choose one of a whole variety of methods or several of these methods. It's by no means a peculiar problem to possum density estimation, or even to mammals as you've pointed out. There aren't any easy answers. I think all one can do is to apply as many methods as possible and check estimates against one another. If you can trap to extinction against a previously trapped population estimated in any other way, that's tremendous, for you can get another check there.

There has of course been a great deal done with rodents; areas have been completely cleared and then known numbers of animals introduced; systems have then been tried out to estimate what at least for a short period was a known population. Of course, knowing the propensity of rodents and similar animals to breed the population may rapidly increase, or may possibly decrease rapidly from mortality factors. But I think one can continue discussions like this to the point of sterility. You have to get on with the work.

CLOUT. I'm really concerned that most of the density estimates may be gross overestimates, for instance in the Orongorongo Valley and in my own case as well. We have heard from Dr Green about very extensive movements of possums which would not have been picked up by standard live-trapping. It seems possible that ranges may have been much larger than we had thought, so that densities are lower than have been estimated.

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* CRAWLEY, M.C. 1973. A live-trapping study of Australian brush-tailed possums, *Trichosurus vulpecula* (Kerr), in the Orongorongo Valley, Wellington, New Zealand. *Australian Journal of Zoology 21:* 75-90.

TOPIC 6 : ASSESSMENT OF POSSUM BROWSE ON VEGETATION

YOUNG. I would be interested to know of people who have been able to evaluate the techniques of assessing plant damage by possums, particularly on native vegetation. Do we have people who are routinely determining the effect of different population levels on vegetation, either immediately or over the long-term? - I mean something on paper, not just a quick assessment of dead trees.

BROCKIE. In the Ecology Division of DSIR M.J. Meads has been looking closely at the effects of possums on northern rata trees and has devised a method for measuring the amount of damage and browse on them. He has published this information in the *New Zealand Journal of Zoology**. He has attempted to apply this to other kinds of trees, but hasn't come up with the same degree of success there. It is very difficult to measure the effect on any kind of tree and put a solid figure on it.

FITZGERALD. Along with Mike Meads, I have been looking at browse on about 60 species of trees in the Orongorongo area; as Bob Brockie says, it is very difficult to try to make a quantitative assessment of damage that will stand up to the rigorous sort of statistics that seem to be required these days. Dr Ian Atkinson of Botany Division has been doing the same sort of thing on Kapiti Island and I think he and Mike Meads have used the same type of technique. Jim White has also done some research using the same techniques, so we do have some information, but apart from the Kapiti data, it all relates to the Orongorongo Valley. It probably is not all that relevant throughout New Zealand, but at least it gives you some ideas of techniques that can be used.

COLEMAN. We have done some browse work as well. In our case we were climbing some 100 rata trees for a year to mark some small branchlets. Needless to say the enthusiasm was not much initially and it waned as the study went on. I am not sure of the value of some of the information we gained.

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* MEADS, M.J. 1976. Effects of opossum browsing on northern rata trees in the Orongorongo Valley, Wellington, New Zealand. *N.Z. Journal of Zoology 3:* 127-139.

GREEN. I was particularly struck by the damage done by animals other than possums, such as invertebrates. I felt that it was extremely difficult, without much background knowledge, to differentiate possum chew from stick-insect chew, from larval chew and so on. Until someone can sort this problem out it will be difficult to correctly assess the extent to which possums contribute to observed damage.

FITZGERALD. Yes, I can substantiate that. For a long time I have called something possum damage when it was the decidious or semi-decidious nature of the particular plant species. It is just that easy to be wrong.

CLOUT. With the assistance of NZ Forest Products Ltd., we ran a trial on the effect of artificially browsing *Pinus radiata* seedings. The results will be appearing in my Ph.D. thesis*.

KEBER. I have extended Mike Clout's work on newly-planted or very small trees and I have extended it to cover bark stripping of trees of up to say 10 years old and 20 m height. Besides the simulated damage work I have marked about 800 naturally possum-damaged trees, with measurements taken yearly, to see the effect on growth. At this stage it appears that for the damage to be important the tree has to be actually killed; trees can tolerate a large degree of damage which probably makes very little difference to the growth.

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* CLOUT, M.N. 1977. The ecology of the possum (*Trichosurus vulpecula* Kerr) in *Pinus radiata* plantations. Unpublished Ph.D. thesis, University of Auckland.

TOPIC 7 : EXPLOITATION OF POSSUMS FOR FUR AND MEAT

CUMMINS. One of the main aims of the symposium organisers was to get people talking together across their particular areas of interest. There are those who regard marsupials as pests, there are those who see them as a resource, and those who are interested in them for their own sake. We have already heard about basic research, and about aspects of their management and control. Now I would like to hear the view of those concerned with the meat and fur industry. In the case of the possum, how do you feel management of the animal as a resource balances with its deleterious effect on the environment?

CAMPBELL. I see the only way you can maintain your costs without going to the country for money all the time is to join up with some commercial enterprise, and the worldwide market is there. I can't add much on the other aspect of your question, except that I don't like seeing such a gross outlay on control.

SYNNOTT. I will comment only in my own field, as a representative of Consolidated Traders Ltd. Our job is buying skins from possum trappers and preparing the skins for export. Government statistics provide export figures. In the July-June export year of 1972/73, 1,240,112 skins were exported, and the net return was just over $2,000,000. Prior to that year there were large fluctuations from year to year. In 1973/74 the figures were 1.57 million skins and $3,869,000; 1974/75 1.79 million skins and $4,637,670; 1975/76 1.58 million skins and $4,379,828; and the first 3 months of the 1976/77 year 229,000 skins and $575,000. I would anticipate that over the complete 1976/77 year the figures would again be 1.4-1.7 million skins.* These figures represent the external earning power of the skins, not the taxation power which is paid at source, unless you have a dispensation. So the possum skin is quite a profitable item for the country. As for the meat of possums, I prefer to leave that aspect wide open; we had a rabbit industry and used to export rabbits years ago, and there is still hare meat about. There is an untold potential as a meat resource if you kept the poison factor in mind and if you could get the necessary hygiene standards.

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* Corresponding figures taken from the N.Z. Official Yearbooks for 1979 and 1980 are: 1976/77 1.66 million skins and $6,632,000; 1977/78 2.72 million skins and $12,558,000; 1978/79 2.62 million skins and $13,533,000 - Editor.

CUMMINS. I got the impression yesterday that you felt the skins you were getting into the market represented only a fraction of the animals that were actually getting killed or trapped.

CAMPBELL. The average trapper would throw 10% away as being uneconomical to take out.

PRACY. A problem regarding a possum meat industry is transportation and hygiene. Access to stock is not so bad on marginal farmland but in areas of indigenous forest there are problems. Regarding hygiene, the animals have to be skinned pretty well immediately after death, but skins are not usually taken off warm possums; there would be a risk of damaging top quality skins. Then you have the problem of getting the animals from the area of recovery to a point where they can be hygienically handled under the meat regulations.

WHITE. Mr Chairman, could I ask, through you, what Consolidated Traders Ltd. think about a complete devaluation of the possum?

CAMPBELL. I am in the situation of having had a rabbit industry trade taken away from me some years ago. Yes, I think it could be on the cards, but at what expense to the country are you going to devalue? What would we be getting back for our effort on a cost/benefit basis?

CUMMINS. It does seem to me in running this symposium, we should come up with a complete balance sheet of the possum, its hazards as a pest, its damage and so on, and its potential as a market. I wonder if anyone in the N.Z. Forest Service has ideas about this?

ANONYMOUS. If I could follow on to what Mr Pracy said about not being able to get the meat out. Fairly stringent regulations were brought in concerning skinning of deer, and deer comes in with the skin on. I see no reason why possums can not be treated the same way, with heart and lungs brought in for government inspection.

PRACY. Before you can even consider devaluations you have to decide whether the possum is a pest of national importance or not. This would require pretty intensive surveys.

FRY. Who does the defining of a pest of national importance?

NELSON. The Pest Destruction Boards and numerous other people including Federated Farmers have pressurised the Agricultural Pests Destruction Council to call the possum a pest of national importance. So A.P.D.C. went to Government with such a proposal and we are now preparing to have a very hard look at the possum all over New Zealand. To this end we are circulating questionnaires to all Pest Boards and other interested people. Even if it is declared a pest of national importance I do not think there has been any intention of devaluing the possum; if there is possum damage affecting agricultural production, then it will be controlled.

McGILL. There is an obvious conflict in that any harvest assumes you get a sustained yield. This could not be tolerated in a diseased population. There is no indication that commercial hunting has anything but a very short-term effect on total numbers, so there is a conflict between commercialising animals in a disease area and control needs.

YOUNG. Is there something deeply significant about declaring an animal a pest of national importance, as opposed to simply recognising that it's a pest in the normal way that we would recognise another pest that is competing with man?

NELSON. The Agricultural Pests Destruction Council is responsible for overall small-animal control on rateable land in New Zealand. At present animals controlled are possums, rabbits, wallabies, rooks and hares. The rabbit is a *national* pest. We will destroy rabbits wherever they cause loss in agricultural production. A pest of *local* importance is declared in a district because it affects production within that district. An example would be the wallabies of Rotorua or of the Hunter Hills. It was mentioned today that approximately 90% of the Pest Boards of New Zealand have declared the possum a pest of *local* importance. It does not necessarily mean that they will be controlled. If it was a pest of *national* importance, in the event of a need they would be instructed by our organisation to carry out control, and that is the difference.

CUMMINS. Is there any need to bring possum control or exploitation under one unified control body? At the moment it appears to be under the aegis of several different government departments.

NELSON. It's only under two government departments. The N.Z. Forest Service operates on non-rateable land, state forest, scenic reserves *etc*, while Pest Destruction Boards operate on all rateable land and in some cases on unoccupied ground, Crown land, Maori land and state forest. Pest Destruction Boards work on other than rateable land only by agreement with the Forest Service state forests. They in turn will do some of our areas.

<u>CUMMINS</u>. This concerns animal control but what about possum exploitation or farming - dare I use that word?

<u>NELSON</u>. Exploitation would be covered by quite a large variety of organisations or individuals. There are some 6,000 private hunters using cyanide in New Zealand every year, so that means 6,000 people are supplying Consolidated Traders Ltd or their counterparts with skins. You also have possum trappers, including many school children, who trap and sell just the odd possum. There is a fairly acceptable market for whole carcasses, where the middle man is skinning them and supplying the skins to the traders. We do not recover carcasses in control work, which can cost up to $10 a hectare, though it can cost as little as $2 per hectare - this depends on the control method carried out.

TOPIC 8 : EFFECT OF ANIMAL CONTROL ON NON-TARGET SPECIES

<u>CUMMINS</u>. One of the topics suggested for discussion is the effect of control methods on non-target populations.

<u>FALLA</u>. The Nature Conservation Council of course is known to have recently expressed interest in finding out as much as possible about the effect of our accelerated possum control programme on non-target populations. Having found it difficult to get anything more than a somewhat patronising assurance from control bodies that the matter was being looked after, there has not been what Council would have regarded as a very specific assurance that everything possible was being done. Now I think it could be said that there is a feeling throughout the community that the non-target effects of a massive and fairly indiscriminate application of any toxic agent is a matter of general concern. There may be some inarticulate sections of the human population who cannot do very much about it. This is why the Nature Conservation Council has taken the matter up.

In this symposium there have been only two references to non-target populations; the first was a reference in relation to the Haupiri study of the N.Z. Forest Service, though no details were given as to how checks were to be made of the non-target effects; the other reference was by Dr Cook to the effect that there was a marked increase in bird populations following a control operation. Having been an ornithologist for over some 60 years now, studying bird populations throughout New Zealand, I was immensely interested to hear that there was a place where this has happened. My own experience has been completely the reverse through the whole of that period. Following any sort of extensive poisoning operations there tends to be a depression in the bird populations which is probably due in some cases to a depression in insect populations. Now admittedly my active field work was in the cyanide era and I'm perfectly certain that cyanide was basically responsible for a severe depression in a whole range of insect fauna and therefore indirectly on the insectivorous birds.

As recently as last year this was the experience of Dr Douglas Flack who while working on one of his study species in a mainland province, (as distinct from his work on island populations), found so much frustration that he practically had to give up his study of robins. Every time his work was in an area where there had been pest control his study population of robins had declined. I asked him if before he left New Zealand he would put this in writing and say something about it publicly because it is not any use at second hand; I am therefore quite sure that Dr Flack will have something quite substantial to say about his experience throughout parts of New Zealand in the last 4 or 5 years.

So we would very much appreciate some explanation of how Dr Cook's bird population explosion was monitored, who monitored it, how they did it, and what particular species showed such a very spectacular rise after a heavy dosage of 1080. Now admittedly there are not very much data on which this can be assessed but it would be helpful if you could get some sort of information as to how these checks are done. We know that the Wildlife Service have been called in at Karioi state forest and other areas, and a report is being compiled citing bird deaths that occurred after 1080 air-drops.

CUMMINS. We do seem to have a live grenade thrown into the ring. I wonder who is going to pick it up.

SPURR. As part of our next four years' research, the Forest Research Institute is starting a major programme of investigating deaths in non-target species resulting from poison operations.

COLEMAN. To expand on Dr Spurr's comments, over the next 4 years 1/11 of our scientific effort will go into the effects of 1080 on non-target species. When you consider we have a watching brief over all the noxious animals, our ungulate research officers are looking with a rather jaundiced eye at the number now being pulled into possum research, including the non-target species work. So we are treating this seriously. I would like to take up another two points. In the original Forest Service trials of 1080 detailed surveys were made for bird carcasses; from memory the blackbird *Turdus merula* was a common species that was identified, but very few other dead birds were found. Secondly, my personal view is that we must establish our priorities. If we are going into sheep farming industy and keas *Nestor notabilis* attack our stock then the keas are destroyed. If we are to grow pine trees as long as there are adequate reserves, then pine trees in these areas are key issues and other things must become secondary to this.

HAMILTON. I would like to know if anyone is looking into the problem of where 1080 is going after it passes through the possum, or otherwise. There is an

appalling amount distributed, one lethal dose per square metre. It must be going somewhere - is it retained in the soil or ending up in say insects or birds?

COLEMAN. In terms of leaching of 1080 into the soil-forest humus, this is well documented by Dr Andrew Peters' work. I do not know about the insect-life.

NELSON. The Agricultural Pests Destruction Council is supporting research by Dr Walker of Canterbury University on the breakdown of 1080 by micro-organisms.

CROOK. We have heard two quite contrary views about the question of poisoning non-target bird species, one by Sir Robert Falla, the other by Dr Coleman. I am not aware that Dr Flack had trouble with poison operations and robins, despite my working with him for several years. On the other hand not only blackbirds were affected. The work of the Wildlife Service in this area is still in a formative stage, which is one reason the Service has not taken an active role at this symposium. In Karioi state forest in the winter of 1976 there were 158 dead birds recovered from the poisoned forest area of which 36 were blackbirds and 66 were chaffinches *Fringilla coelebs*; the rest included 14 robins *Petroica australis*, 7 pied tits *Petroica macrocephala* and 18 whiteheads *Mohoua albicilla*. Now the 1080 poisoned carrot was dropped at Karioi at 40 kg/ha. and included some raspberry-flavoured lure. I think even if 1080 does kill birds we must examine whether this is significant or not in terms of the bird fauna - this is still very much an open question.*

PRACY. In relation to the effect of 1080 on birds, I was in charge of the initial Forest Service trials. After intensive searching I think the sum total in 5 trials was 3 blackbirds. Regarding Karioi forest, in 1976 there was an exceptionally severe winter. This was also the problem in the Wairarapa where there was 16,000 acres (6475 ha) of ground and aerial control;

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* further information is to be found in the following reports:

BATCHELER, C.L. 1978. Report to Minister of Forests and Minister of Agriculture and Fisheries on compound 1080, its properties, effectiveness, dangers, and use. N.Z. Forest Service, Wellington.

HARRIS, G. 1977. Report on the use of sodium fluoroacetate (1080). Nature Conservation Council.

for 20 miles (32 km) outside the poison area you had a natural mortality of birds. No one is going to tell me these birds were flying 20 miles (32 km) from the poison zone and then dying. Winter conditions can have an adverse effect on bird populations, especially severe frosts.

Secondly, when you talk about toxic sowing rates of 40 kg per hectare, you must not forget that in some of these areas 20 kg per hectare of pre-feed is put out also. Any good field operator will make careful assessment of the country for sowing rates, such as in a situation like Karioi. It is a completely ludicrous sort of a situation to go and sow 20 kg per hectare of pre-feed and condition birds to a non-toxic bait, then in a week or ten days to put on 40 kg per hectare of toxic material. When you condition birds ahead on a high pre-feed rate and you have a high toxin sowing rate, then you are just asking for trouble. And this is a field problem. You cannot stand on a road, look into the hill country and say "I'll sow that with 40 kg and 20 kg pre-feed" and that's that. It does not work that way. You must do a field assessment.

Let me make our problem quite clear - there are forest and habitat types for which you get down to 12 lb an acre (2.2 kg/ha) of toxin and no pre-feed; likewise there are areas where you can use 15-20 lbs per acre (2.8-3.7 kg/ha) and probably 5 lb (2.8 kg) pre-feed. Again in extremely dense cover you need maybe 30-40 lbs per acre (5.5-7.3 kg/ha) of toxin. Sowing rates depend on habitat type and condition, physical condition of the animal and availability of food.

McLEAN. Regarding the birds, Mr Chairman, I wonder if anyone has ever thought of the damage the possum is doing to bird-life. I have spent 20 years in the Wairarapa and then went away for 4 years. I am amazed at the fall-off in bird-life throughout the Wairarapa in general while I was away. There has been practically no poison or 1080 used there during that time. I personally believe that the possum is a deciding factor in the fall-off of our bird-life.

WODZICKI. Mr Chairman, many of us here agree with what Sir Robert Falla has to say. I wish to point out that figures on bird casualties alone may have little value. We have methods to assess bird populations in New Zealand forests in terms of densities, which are far more meaningful. Also if you know the population dynamics of a species, then if you poison you can determine whether the population will recover, or whether it is doomed.

GREEN. There has been absolutely no criticism of the vast amounts of insecticides and pesticides that the agricultural industries are putting on our pastures throughout the country, and I am sure that *per annum* this is having a far greater impact on insect populations compared with 1080 drops, or with amounts of cyanide. I would sincerely hope that appropriate investigations are carried out to see what effect the massive use of these chemicals is having on our flora and fauna. Regarding the control operation at Karioi where last winter 158 birds were killed, I believe, and I stand open to correction, that the particular poison operation used a raspberry lure which is usually not done, particularly in most Forest Service operations. It seems that this raspberry lure is attracting a lot of birds and is therefore probably one of the major factors responsible for the deaths.

GIBB. Mr McLean mentioned there are fewer birds in the Wairarapa than there used to be. I think we might both be getting a bit deaf you know! Regarding the methods of measuring bird populations mentioned by Dr Wodzicki, one can measure bird density in a pine forest if one devotes enough time to it. It is not easy and it takes much experience. It certainly cannot be done in anything other than a small-scale research operation. In Ecology Division we have tried to develop methods of monitoring bird populations, primarily in beech forests and in conjunction with the Wildlife Service. Even after many trials I would be surprised if these methods would reliably detect changes before and after a poison operation of less than, say, 30 percent. These measures are pretty crude and are not accurate. They may be sufficient for use as repeated measurements on large blocks of country to give an index of bird numbers in different forest types. I do not think they suffice as a measure of bird populations before and after poisoning operations.

YOUNG. I would like to ask Sir Robert Falla that, given there are plans to review 1080 control, who would be responsible for implementing any trials. Would this be done under any moderation, or is it to be left again for the different groups now in the business to make their own estimates?

FALLA. We have not received any indication as to who will accept the responsibility for the very considerable amount of further routine research and assessment. One basic problem is that the funding is very much directed to the agency that is dealing with an economic problem; assessment of such things as the impact on non-target species does not appear initially to matter very much.

There seems little chance of alternative funding, unless from an endowment fund without any tags or commitments. As far as I know the universities through the Universities Grants Committee is the only source of mounting research programmes of this kind.

It is good to hear from the N.Z. Forest Service, the Agricultural Pests Destruction Council and the DSIR, that there could be more research on particular economic aspects, but there is a limitation even there. The most the Nature Conservation Council expects to do, having tapped available expertise and information, is to present to Government (as is its statutory duty) recommendations on 1080 which will include lines of research.

ANONYMOUS. There seems to be a gap between what this symposium is discussing as research, and what might be simply described as good servicing of the management people. I heard from a Pest Destruction Board Supervisor who was surveying the scope of his job and possum eradication. His comments echoed the sentiments "If I had any brains I wouldn't be in this job". Again, Les Pracy commented on the necessary understanding of the field operator in carrying out an air drop as it proceeds across different habitats over hill and down dale. There is a different requirement needed in each section of the air drop zone; because of a lack of study and documentation the thing is put down as 40 kg per hectare full stop. So there is a gap from the research level down to the actual carrying out of the control operation. It would seem people like university departments could assist by putting either students onto the problem, or control agencies could give employment to graduates to try and fill this gap.

FRY. I would like to comment very strongly here - that everyone in the field who is concerned with attempts to control is very disturbed at the lack of control they're getting, and we would like research directed to obtain better control.

TOPIC 9 : POSSUMS ON OFFSHORE ISLANDS

FALLA. In discussion on 1080 control and funding of research in general I made reference to the high costs of some of the research projects. There is also room for encouraging smaller individual projects, which would just need a little sympathetic encouragement rather than heavy financial backing. I am thinking particularly of a point arising from Dr Tyndale-Biscoe's address; he asked whether there was any indication that discrete populations of possums were settling to levels of stability well below the sustaining capacity of the environment. I do have the impression that the very interesting study that is going on at Kapiti Island* is likely to provide quite useful information on this aspect at the end of 5 or 6 years' work. This is being done at the request of the Lands and Survey Department's District Office in Wellington, who are responsible for Kapiti Island's welfare; it is also being done against a very steady pressure to stop the research altogether, and to get on with the job of exterminating the possums on the island. I think there is some room for encouragement of research of this kind, and discouragement of well-meaning but otherwise quite misdirected criticism of the work going on in the Kapiti sanctuary.

On Codfish Island, which I have visited two or three times over a long period of years, there are possums but there has been quite a considerable improvement in the general appearance of the vegetation; you find from the files that John Bamford's reports of the early 1950's indicate that there was no substantial sign of any increase in possums and certainly no significant damage. I suspect that if a follow-up study was now carried out it would be found that there are even fewer possums; I do not think anybody other than the prejudiced could feel that possums were doing any harm at all on Codfish. Now that too would seem to be the sort of place in which a single investigator could go, with little more than a technical assistant, and do quite a useful individual study.

GREEN. I agree with Sir Robert Falla's point regarding long term stabilisation between possums and their various habitats. I think this is the long term sort of work that should certainly be carried out in a variety of habitats. I wonder though whether the results you would get from a place like Codfish Island would be applicable in other habitats in New Zealand.

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* See BELL, B.D. & ATKINSON, I.A.E. 1976. Opossum research on Kapiti Island. *Forest and Bird 199:* 12-17.

Elsewhere there may be far more diverse habitats, with pasture, willow, pole plantings, and so on; it could well be that the results from Codfish may not be terribly useful in other areas of the country, given the plasticity of *Trichosurus vulpecula*.

HARPER. I would like to comment briefly on this. I am planning a trip to Codfish Island to look at the sea birds. I would welcome somebody to join the party to look at possums.

PRACY. Further to Sir Robert Falla's comments, in about 1972 there was a survey party on Codfish Island which included John Bamford and myself. What Sir Robert anticipated was precisely the case. Peak populations there occurred about 1948; there is photographic evidence and reports to substantiate this. There were two types of assessment. Results suggest there has been a generally very light and scattered population from 1948; in the lower kamahi belt and in the damaged rata-kamahi forest there was what you would call a heavy or dense population. You did have forest mortality but you also had a lot of forest recovery.

TOPIC 10 : USE OF VERNACULAR NAME 'POSSUM' OR 'OPOSSUM'

CUMMINS. In general discussion on his Keynote Address Dr Tyndale-Biscoe commented on the uses of the terms 'possum' or 'opossum' for *Trichosurus vulpecula*. Would anyone like to comment further?

SPURR. A quick look through the titles of the papers in the symposium programme shows that 12 papers use the common name 'possum' and 6 use 'opossum', and in the abstract section 2 papers change usage so that 10 use 'possum' and 8 use 'opossum'. While these figures mean very little, the fact remains that both names are of common usage in New Zealand. The editor of the Proceedings of this symposium will thus be faced with the decision (a) to publish a mixture of common names as used by authors; or (b) to standardise the common name. I think it is desirable if the name was standardised, not just in the Proceedings of this symposium but preferably in all future New Zealand publications.

Kean (1964) objected to the term 'possum' because he claimed (1) that it breaks with previous and current Australian usage and he quoted references dating from 1924 to 1942; (2) it conflicts with the standard dictionary definitions which give 'opossum' as American Indian in origin and 'possum' either as colloquial or a figure of speech. Troughton (1965) noted that objection (1) could not be conclusively substantiated since 'possum' had been in common usage in Australia since the time of European settlement. Caughley (1965) further stated that a glance through scientific papers published in the previous 10 years showed that most zoologists and all Australian zoologists have used 'possum'. Troughton also noted that the standard dictionary usage is frequently subject to addition or amendment. Caughley went on to state that the use of 'opossum' for *Trichosurus* confuses it with *Didelphis;* he suggested that we in New Zealand conform with Australian usage to standardise the common name, removing the anomaly of two distinct animals sharing the one name. I agree with Kean (1965) that personal opinions are scarcely relevant. Nevertheless I would support Caughley on two grounds: (1) standardisation of the vernacular or common name is desirable; (2) the name should be standardised to 'possum' to conform with Australian usage and such standardisation could be achieved if New Zealand journals could be persuaded to implement it.

KEBER. This business about standardisation of common names just means conformity. Why don't we use the binomial classification so there is no confusion.

SPURR. I agree on that point, but I was referring to Dr Tyndale-Biscoe's comments in his Keynote Address.

CUMMINS. Personally I use 'possum' but that is just because I am lazy!

PRACY. I remember living in the bush for a year, and somebody presented us with an old gramaphone. With this gramaphone was a record some American used to sing that referred to "a possum on a limb". If my better half wanted to annoy me she would play this record, and I told her "One of these days I'll break it over your b- head" and she really annoyed me, she played this record about 3 times, and the fourth time I went "boom" like that and from that day on I've never called the opossum a 'possum'.

CUMMINS. I am quite happy to see some diversity. I don't think it really matters much. The confusion arises of course for people outside New Zealand, who don't know what we're talking about. They talk about the brush-tailed phalanger and so on.

B.D. BELL. We accept that in popular usage and in general conversation many of us use both 'opossum' and 'possum'. I would support Dr Spurr in his appeal for conformity in scientific literature on the two sides of the Tasman. New Zealand has one species, the Australians have many more species and have already adopted 'possum'. *Didelphis*, the North American species, is generally referred to these days as 'opossum'.

GREEN. Could we have a show of hands to indicate how the audience as a whole feels about the use of the term 'possum' or 'opossum' in New Zealand literature?

CUMMINS. The results are 38 votes for 'possum', 13 votes for 'opossum' and 6 abstentions. The symposium vote is for 'possum' by a clear majority of 25.

ANONYMOUS. Yes there does appear to be a majority who prefer to use 'possum' and I think for articles which are to be read overseas it might be less confusing if we used the Australian nomenclature. I am quite happy for people to stick to what they want to call it - if they want to call it an honorary rabbit they can!

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TROUGHTON, E. 1965. Note from an Australian mammalogist on usage of the common name 'possum'. *Tuatara 13:* 192-193.

TOPIC 11 : COMMUNICATION AMONGST MARSUPIAL WORKERS

CUMMINS. In discussions on the issue of 1080 poison, it seems there is a communication problem, or perhaps it is just a general conflict of interests. There must be people in the audience who have ideas about improving communication, either by symposia such as this one, through a journal, or through other types of meeting.

LEES. My own area of concern regards communicating to children the risks of disease from coming into contact with possums. In the zoo we often meet children who keep possums as pets. It is illegal, but a large number of children do it. So publicity is needed, and it is important the children of New Zealand learn about this.

CUMMINS. Professor Blackmore referred to the schools' publication on this aspect in our Workshop session on diseases and public health. I think it is worthwhile to keep the possum in perspective - most domestic animals can be health hazards if precautions are not taken.

B.D. BELL. Regarding the risk of leptospirosis from possums, I think most children keep young possums as pets. Mr Hathaway pointed out in his paper that its incidence only becomes high in sexually mature animals, so perhaps the risks regarding *Leptospira* are not that great in the majority of pet possums. Nevertheless, I endorse the need to caution children against disease risks in general from pet animals, whether of domestic or wild origin.

GREEN. I personally have found this a most useful and enjoyable two days. I would sincerely hope that it will not be the first and only symposium on marsupials held in New Zealand*. I will certainly be talking with Peter Harper about his electrophoresis techniques. I would suggest there is room for increasing the times that we get together as people with like interests, or even as people with dissimilar but related interests. I for one have been very grateful for the opportunity to be here.

BROCKIE. The possum community is often criticised for lack of communication between themselves and people outside. I am fairly new to the world of possums but I think it's something of a myth. I think there is a great deal of communication; perhaps I am biased through having worked in several government departments, for there is certainly much traffic of documents between them. A blockage seems to occur between government departments and various interested groups, such as Federated Farmers and perhaps the fur or meat traders. On the whole though communication is better than generally thought.

HARPER. As an outsider I have found this conference very interesting. I think we ought to find out if we can have some sort of newsletter or some form of similar communication between the universities, the government departments, and other interested parties. I think it is extremely important to resolve good communications amongst marsupial people. (A newsletter *The Possum Post* is now in circulation in New Zealand - Editor).

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* see footnote over page.

FOOTNOTE:

At the 49th Congress of ANZAAS held at Auckland in January 1979 a further symposium entitled 'Marsupial Biology' was held under the chairmanship of Dr C.H. Tyndale-Biscoe at which the following papers were to be presented:

TYNDALE-BISCOE, C.H. Recent developments in marsupial biology.

BELL, B.D., BROCKIE, R.E., COWAN, P.E., EFFORD, M.G. & WHITE, A.J.* Demography of *Trichosurus vulpecula* in Australia and New Zealand.

COLEMAN, J.D. & GREEN, W.Q.* Dispersion of opossums within a Westland podocarp mixed hardwood forest.

GREEN, W.Q. & COLEMAN, J.D.* Nightly movement patterns of *Trichosurus vulpecula* as derived from radio-telemetry data and their relationship to forest/pasture habitat types.

FITZGERALD, A.E. & WARD, G.D.* Changing diet and activity patterns of the brush-tailed opossum in New Zealand broadleaf podocarp forest.

BATCHELOR, T.A.* A behavioural study of the rock wallaby *(Petrogale penicillata)* on Motutapu Island, New Zealand.

ALLEN, N.T. The function of the cloacal gland in two species of opossums.

BROWN, G.D. Studies of the environmental physiology of marsupials using multichannel telemetry.

BAUDINETTE, R.V.* The physiological correlate of locomotion in marsupials.

MILLER, J.H.* The uptake of p-aminohippurate by renal cortical slices in the possum *Trichosurus vulpecula*.

CATLING, D.C. & SUTHERLAND, R.C. Seasonal variation and effect of gonad ectomy on levels of LH, FSH and testosterone in male tammar wallabies (*Macropus eugenii*).

TYNDALE-BISCOE, C.H. Hormonal control of embryonic diapause and reactivation in the tammar wallaby.

Those papers marked with an asterisk appear in the 49th ANZAAS Congress Abstracts, Volume 1, Section 11 (Zoology), pp. 319-322 (1979).

TOPIC 12 : FUNDING OF MARSUPIAL RESEARCH

CUMMINS. Sir Robert Falla's reference to funding for research on 1080 and non-target species brings up the matter of funding marsupial research in general. Most of us in the universities are wondering whether University Grants Committee funding has gone the way of the black robin.

MORIARTY. Yes, the U.G.C. certainly has got some sort of a pretty torrid recession. One gets up against a financial brick wall which one gets tired of banging one's head against. I think this symposium has highlighted so many areas where the universities could play a role or DSIR could play a role. We are so much restricted by lack of funding that the problem just about becomes insurmountable.

CUMMINS. As the people involved in marsupial research we have not as yet functioned as a unified pressure group.

MORIARTY. Not in the least. I think that a unified front would be desirable. In our case at Massey we tried for U.G.C. money - well it's not there so it doesn't exist. The only other source of supply is the Medical Research Council, for particular projects in which we are involved, and their funding is of course restricted.

CUMMINS. There must be some other ideas on our functioning as a unified pressure group or bringing some pressure to bear on Government to increase funding for basic or applied research.

YOUNG. At Auckland University we have and do entertain hopes of money from government agencies; we have received considerable support from them, and also from Golden Kiwi. The government agencies themselves are under pressure and are obviously not going to pass money off into our accounts, when they require it themselves. I think if we get involved in a big 1080 reassessment this might be because they want an assessment that would be considered independent, unbiased, and more sensitive. We would certainly like to get into that area.

SPRINGETT. As a newcomer I wonder if we could derive a rough order of magnitude for the total expenditure on research on possums since say 1972 in relation to the $6 million income into this country from the fur trade.

CUMMINS. That would be a very useful exercise but I doubt if we have the time to contribute much now. Dr Coleman how do you see this problem of funding to basic or to applied science?

COLEMAN. I certainly do not disbelieve that the research going on in the universities or in Ecology Division, DSIR is not going to support the management people in the future. Because we seem to be in a position of wanting to destroy possums throughout New Zealand, I do not wish to knock pure or less-applied research on the head. There is obviously room for both pure and applied research.

WORKSHOP DISCUSSION : CONCLUDING REMARKS

CUMMINS. Obviously there seems to be a need for more coordination between applied research people. I would like to say I have greatly enjoyed chairing this discussion and meeting so many people that I've been communicating with for a long time. I hope such a meeting can come off again as a symposium in maybe a couple of years and I hope I can be here to participate. Thank you all very much.

MORIARTY. You can't get away so easily. I would like on behalf of this symposium to thank you and the committee very much for the immense amount of time and effort you must have put into organising this symposium. It has been extremely rewarding for all of us I'm sure. We might not always agree with the opinions expressed, but we've heard a lot of interest and I would like to thank you very much indeed for the tremendous amount of effort you've put into it.

(The symposium closed with acclamation).

PRIORITY RATINGS FOR VARIOUS RESEARCH TOPICS

At the end of the Workshop Discussion the symposium delegates were asked to complete a questionnaire that sought opinion on the relative priorities of a range of research topics. 35 delegates submitted returns.

Respondents used a score from 1 (high) to 5 (low) for ranking the priority of each topic. The mean priority score for each topic is given in the list below together with the number of returns for that topic (which varied since some delegates did not rank every topic). The topics are arranged in decreasing order of mean priority score.

	Research topic	Mean priority score (from 1 (high)) to 5 (low))	No. of Returns
(highest priority)			
1	Population assessment techniques	1.52	31
2	Evaluating efficiency of control	1.76	29
3	Control techniques	1.86	29
4	Diseases, parasites & epidemiology	1.87	30
5	Impact of control on non-target species/environment	2.00	29
6	More coordination of 'pure' and 'applied' research	2.03	30
7	More 'applied' research	2.12	26
8	Rationalisation & restructuring of present wildlife research	2.27	26
9	Basic physiology/pharmacology	2.28	28
10	Reproduction and development	2.28	28
11	Behaviour	2.42	31
12	Evaluating importance as pests	2.60	30
13	More 'pure' research	3.08	25
(lowest priority)			

31 of the respondents listed their personal field of interest; 18 fell broadly under the category of 'basic research' and 13 under the category 'applied research and management':

Basic research		Applied research & Management	
Basic & experimental research	2	Diseases & health	4
Behaviour	2	Management of captive animals	1
Ecology	5	Pest Control	7
Reproduction	3	Wildlife Surveys	1
Immunology	3		
Neurophysiology	1		
Histochemistry	1		
Chemo taxonomy	1		
Total	18	Total	13

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