J. Hyg., Camb. (1978), **81**, 399
Printed in Great Britain

Myxomatosis: changes in the epidemiology of myxomatosis coincident with the establishment of the European rabbit flea *Spilopsyllus cuniculi* (Dale) in the Mallee Region of Victoria

By ROSAMOND C. H. SHEPHERD and J. W. EDMONDS

Keith Turnbull Research Institute, Vermin and Noxious Weeds Destruction Board, Department of Crown Lands and Survey, Frankston 3199, *Victoria, Australia*

(*Received* 21 *February* 1978)

SUMMARY

Outbreaks of myxomatosis during the winter or spring have coincided with the establishment of the European rabbit flea in the Mallee region. The severity of these outbreaks has varied from causing complete suppression of the normal spring increase in rabbit numbers to being completely ineffective in a year in which late spring rains allowed rabbit breeding to extend into the early summer.

In 1973 and 1974 effective spring myxomatosis caused heavy mortality in kittens before they emerged from the warrens. The age of the population increased as the result of few young rabbits coming into the population and of the lessened stress on old rabbits in a low summer–autumn population. This effect was reversed in the late-breeding year, 1976, when flea numbers were apparently too low to maintain a spring outbreak and rabbit numbers increased rapidly.

INTRODUCTION

Wild rabbit populations in the Mallee region of Victoria have been subjected to summer epizootics of myxomatosis in most years since 1951. These epizootics varied in severity and timing depending on the occurrence of vectors and the number of rabbits surviving from the preceding breeding season but the end result was generally a population reduction of about 80% (Shepherd *et al.* 1978).

The European rabbit flea *Spilopsyllus cuniculi* (Dale) was released in the region in 1970 (Shepherd & Edmonds, 1976). Establishment of the flea was accompanied by a shift in myxomatosis occurrence from summer to spring (R. C. H. Shepherd & J. W. Edmonds, unpublished data). Spring outbreaks occurred in 1973, 1974, 1975 and 1976.

This paper reports in detail changes in the epidemiology of myxomatosis at Pine Plains in the Mallee region following the change in epizootic timing, and the changes in population structure.

MATERIALS AND METHODS

The methods of population estimation and rabbit collection have been described previously (Shepherd, Edmonds & Nolan, 1978).

The occurrence of antibodies to myxoma virus was tested by the methods of Mansi (1957) or Sobey, Conolly & Adams (1966). The ages of the rabbits were estimated by the method of Myers & Gilbert (1968).

RESULTS AND DISCUSSION

The first significant spring outbreak of myxomatosis recorded from Pine Plains occurred in September–October 1973 during the last months of a successful breeding season which had begun in late March. It was accompanied by a decrease of about 60% in the population, an increase in mean age, and an increase in the occurrence of antibodies from about 20 to 70% of rabbits tested (Fig. 1).

The population did not recover and remained constant at the low level into the late summer. The normal 75–80% increase in numbers with spring breeding did not occur, nor did the previously regular population reduction in the late summer–autumn (Shepherd *et al.* 1978).

1974 was a year of very high rainfall in the Mallee region, the highest on record at several recording stations, and there was some rabbit breeding during the late summer and early autumn in response to unusual green pastures. However, the main breeding season began in late autumn as in the previous year. Although no cases of myxomatosis were observed the increase in antibody occurrence in June suggests that myxomatosis did occur. Although breeding had been observed for 2 months no sub-adults were collected in June whereas 4% of the May collection were sub-adults. The percentage of sub-adults rose to 11% in July but dropped to 2% in August and 5% in September. The failure of more than a small number of sub-adults to appear in the population suggests that mortality was most severe in kittens before they appeared above ground.

Following this early winter myxomatosis the population increased steadily until a second outbreak of myxomatosis, in this case accompanied by diseased rabbits above ground, began in mid-September. The population drop over the next 3 months (by about 80%) despite the breeding season which continued into November, indicates the severe mortality which occurred. No sub-adult rabbits were observed to enter the population in November 1974, although the rabbits were still breeding in October.

Again in 1975 there was no indication of late summer–autumn mortality under nutritional stress. Breeding began at a very low level in the late autumn but there is no evidence of a recurrence of late autumn myxomatosis. The main breeding season did not begin until winter and sub-adult rabbits were not observed to enter the population until September.

The spring outbreak of 1975 was less severe than previous spring outbreaks. The population numbers were highest in December but did not approach the peak numbers which were recorded before the establishment of the rabbit flea. However there was a similar pattern of antibody occurrence (12%).

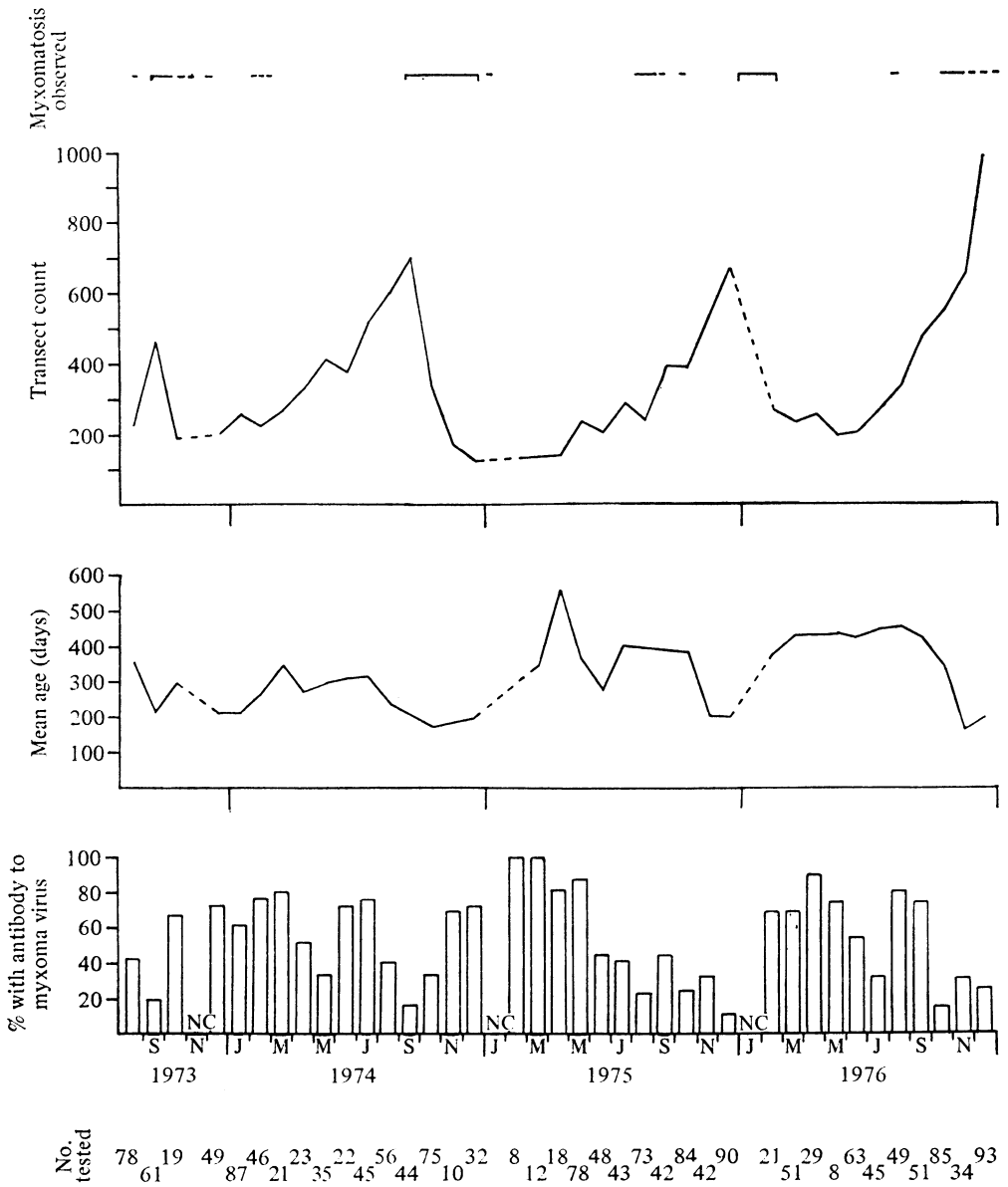

Fig. 1. The percentage of rabbits carrying antibodies to myxoma virus, the mean age of rabbits and the number of rabbits counted over a 30 km transect, and the periods over which myxomatosis was observed at 'Pine Plains' in the Mallee region of Victoria. Observations were made at monthly intervals from August 1973 to December 1976. NC, No collection made that month.

An epizootic, probably mosquito borne, broke out in mid-summer and reduced the population by about 60%. The population then remained comparatively stable until breeding began in early winter 1976. Myxomatosis occurred in August in the breeding population. It appeared to slow the population increase but no myxomatosis was observed above ground in September. The population increased

Table 1. *The numbers of fleas on rabbits more than* 109 *days old, shown as mean number on male and female rabbits and the number of rabbits examined, during the period August–December* 1976

	Male rabbits	Female rabbits
August	15·7 (26)	50·0 (24)
September	29·0 (53)	84·7 (57)
October	40·8 (33)	110·5 (35)
November	39·0 (19)	19·6 (18)
December	18·7 (43)	17·1 (59)

steadily. Few sub-adults were seen to enter the population in July and August but 17% of the September population were sub-adults and the proportion of sub-adults continued to increase until the end of the year. Unusually heavy late spring rains allowed breeding to continue into early December and the population reached the highest numbers counted since 1970 (1539 compared with 1322 in December 1970) (Shepherd *et al.* 1978).

The increase in population from October to December was accompanied by a small increase in the percentage of rabbits with antibody and a few cases of myxomatosis were observed on each visit. The myxomatosis which occurred had little or no effect on the population increase.

The inability of the rabbit flea to spread myxomatosis through the high and largely susceptible population at this time may have been due to the comparatively low numbers of fleas present. The flea counts made during the August–December period of 1976 (Table 1) show that although flea breeding accompanied the late winter rabbit breeding, the fleas did not respond to the November–December rabbit breeding and the numbers per rabbit probably dropped below the threshold numbers required to initiate and maintain an effective outbreak of myxomatosis.

In January 1977 the combination of 'trickle' myxomatosis and nutritional stress killed many young rabbits. This effect continued through February and the mean age rose steadily to peak at about 700 days in May. This pattern of age increase during the summer–autumn months of the year was similar to that of the pre-flea patterns although the peaks were usually considerably lower (Shepherd *et al.* 1978).

The reasons for the failure of the fleas to maintain high numbers during the late spring and early summer of 1976 are not known. Numbers were higher during the late spring in previous years, e.g. 69·8 and 121·7 mean numbers on males and females respectively in November 1974, although the breeding conditions were apparently less favourable. Possibly the effects of the decrease in the number of pregnancies towards the end of each breeding season were accentuated by the comparatively higher ambient temperatures of early summer. It would be interesting to know whether the rabbit flea can breed successfully during the early summer in the similar climate of the Iberian Peninsula.

Field strains of myxoma virus were collected during each outbreak. There was no evidence of any change in the virulence of the field strains from the virulence

of the strains present in the field before the introduction of the rabbit flea (Edmonds *et al.* 1975). However, the highly virulent Lausanne strain has been used experimentally in the area (Shepherd & Edmonds, 1977).

The extent to which pressures other than myxomatosis contributed to heavy spring mortality in young rabbits is not known. However, the data presented here suggest that in the presence of the usual winter–spring rabbit breeding season the rabbit flea was able to spread myxomatosis sufficiently to prevent a major rabbit population increase but that the flea was quite ineffective when the rabbit breeding season extended into late spring and early summer.

This work was supported by the Wool Research Trust Fund. We are grateful to Mrs J. Dam and Mr A. Gocs for technical assistance. The O'Sullivan family of 'Pine Plains' were most co-operative as always. We are most appreciative of Dr W. R. Sobey's comments on the draft.

REFERENCES

Edmonds, J. W., Nolan, I. F., Shepherd, Rosamond, C. H. & Gocs, A. (1975). Myxomatosis: the virulence of field strains of myxoma virus in a population of wild rabbits (*Oryctolagus cuniculus* (L.)) with high resistance to myxoma. *Journal of Hygiene* **74**, 417.

Mansi, W. (1957). The study of some viruses by the plate gel diffusion precipitin test. *Journal of Comparative Pathology* **67**, 297.

Myers, K. & Gilbert, N. (1968). Determination of age of wild rabbits in Australia. *Journal of Wildlife Management* **32**, 841.

Shepherd, Rosamond C. H. & Edmonds, J. W. (1976). The establishment and spread of *Spilopsyllus cuniculi* (Dale) and its location on the host, *Oryctolagus cuniculus* (L.), in the Mallee region of Victoria. *Australian Wildlife Research* **3**, 29.

Shepherd, Rosamond C. H. & Edmonds, J. W. (1977). Myxomatosis: the transmission of a highly virulent strain of myxoma virus by the European rabbit flea *Spilopsyllus cuniculi* (Dale) in the Mallee region of Victoria. *Journal of Hygiene* **79**, 405.

Shepherd, Rosamond C. H., Edmonds, J. W. & Nolan, I. F. (1978). A review of methods used to capture live wild rabbits in Victoria. *Journal of Wildlife Management* (in the Press).

Shepherd, Rosamond C. H., Edmonds, J. W., Nolan, I. F. & Gocs, A. (1978). Myxomatosis in the Mallee Region of Victoria, Australia. *Journal of Hygiene* **81**, 239.

Sobey, W. R., Conolly, D. & Adams, K. M. (1966). Myxomatosis: a simple method of sampling blood and testing for circulating soluble antigens or antibodies to them. *Australian Journal of Science* **28**, 354.