EPIDEMILOGY OF PARAMPHISTOMOSIS IN CATTLE

P. F. Rolfe,*† J. C. Boray,* P. Nichols* and G. H. Collins†

*Elizabeth Macarthur Agricultural Institute, NSW Agriculture, Private Mail Bag 8, Camden,
New South Wales 2570, Australia
†Department of Veterinary Pathology, The University of Sydney, New South Wales 2006, Australia

(Received 18 December 1990; accepted 30 May 1991)

Abstract—Rolfe P. F., Boray J. C., Nichols P. and Collins G. H. 1991. Epidemiology of paramphistomosis in cattle. International Journal for Parasitology 21: 813–819. The epidemiology of paramphistomosis in cattle was studied using tracer calves in a subtropical location in eastern Australia. Two species of paramphistomes were present: Calicophoron calicophorum and Paramphistomum ichikawai. The former species was the most abundant. Gyraulus scottiunus and Helicorbis australiensis acted as intermediate hosts, respectively. Paramphistome burdens varied seasonally and were dependent upon the number of infected host snails. Peak fluke burdens and clinical paramphistomosis occurred in late summer in year 1 and early winter in year 2. The peak fluke burdens coincided with prolonged inundation of the grazing areas resulting in rapid multiplication and infection of host snails, and the period after the inundated areas dried out. The prevalence of infection in snails was high in both years, peaking at 98% in year 1 and 58% in year 2. The main host snail, G. scottiunus, aestivated and retained infection for at least 24 weeks in soil, and in vegetable debris on the surface of the soil, resulting in rapid reappearance of host snails and infective metacercariae after the onset of seasonal rain. Metacercariae survived on herbage for up to 12 weeks, depending on the environmental conditions. Paramphistome burdens in calves could be predicted from the prevalence of infection in the host snail, the water levels and an index of surface water on the grazing site. Control of paramphistomosis during and after flooding may be achieved by removal of susceptible cattle from pasture or regular treatment during these periods. Strategic treatment during the dry season may reduce contamination of snail habitats and infectivity of the pasture in the following wet season.

INDEX KEY WORDS: Paramphistomosis; epidemiology; Calicophoron calicophorum; Paramphistomum ichikawai; Gyraulus scottiunus; Helicorbis australiensis; cattle.

INTRODUCTION

The epidemiology of paramphistomosis in cattle has not been investigated in Australia, and limited information is available from overseas (Mereminski, 1970; Mereminski & Gluzman, 1979). Several epidemiological factors have been identified from natural outbreaks of the disease in sheep and cattle and from limited laboratory studies. These include: the system of management and grazing habits of the cattle (Horak, 1967; Boray, 1969b), the biological potential of the snail hosts (Swart & Reinecke, 1962; Dinnik, 1964; Mereminski, 1967; Horak, 1971) and the potential of the flukes to infect intermediate and definitive host (Durie, 1953, 1956; Dinnik & Dinnik, 1954; Dinnik, 1964; Horak, 1967; S'mnaliev & Vasilev, 1979). The only relevant studies in Australia have been performed. The seasonal pattern of infection with paramphistomes depends on the species of definitive and intermediate host, the topography of the snail habitats and the climate. Studies of the host–parasite interrelationship in Fasciola hepatica have shown that episodes of transmission and levels of infection can be predicted (Ollerenshaw & Rowlands, 1959; Ollerenshaw, 1966; Ross & Woodley, 1968; Boray, 1969c; Ross, 1970; Hope Cawdery, Gettinby & Grainger, 1978; Malone, Loyacano, Hugh Jones & Corkum, 1984). Predictive models of disease are important in the implementation of control measures that are effective and economical.

This study aimed to describe the seasonal variation of paramphistome infection in cattle in subtropical eastern Australia, to correlate infection with climatic and environmental variables and to devise a method for predicting the occurrence of disease.

MATERIALS AND METHODS

Selection of study area. The farm was situated in the Clarence River Basin, in eastern New South Wales. This area has sub-tropical climate and experiences a hot wet summer and autumn, and a mild dry winter and spring. Rainfall can occur throughout the year but is concentrated in summer and autumn. Mean daily minimum air temperatures range from 9°C in winter to 20°C in summer. Mean daily maximum air temperatures range from 19°C in winter to 26°C (Bureau
of Meteorology, Sydney). Inundation is frequent and persists for long periods during the wet season. The farm has a history of outbreaks of acute paramphistomosis. The area selected for the study, of 10.89 ha, was low-lying and contained many shallow depressions. The snails Heloborus australiensis and Gyraulus scottianus (Mollusca: Gastropoda, Planorbidae, Planorbiniae) were present. The main pasture grasses present were Paspalum dilatatum, Aconopus affinis, A. compressus, Pennisetum clandestinum and Trifolium repens, while in the areas more subject to inundation Paspalum paspalodes and Cynodon dactylon predominated.

Experimental design. The study area was continuously grazed by adult cattle that were chronically infected with P. ichikawai and C. callicophorum to maintain contamination of snail habitats. Ten of these cattle were monitored for the presence of paramphistome eggs in faeces at the end of each grazing period (see below). Groups of weaned heifer calves, aged 4–6 months, that had been grazing effectively for at least 4 weeks were selected. The calves were confirmed free of paramphistomes by examination of faeces for eggs using a modified sedimentation technique (Rolfe & Boray, 1987). Groups of 10 calves were placed on the study area for successive periods of 56 days, coinciding with the shortest prepatent period of paramphistomes (Paramphistomum ichikawai) recorded in Australia (Durie, 1953). At the end of each grazing period the calves were removed, starved for 24 h, killed and any flukes recovered and counted (Rolfe & Boray, 1987). The mean logarithmic fluke count \( \log_{10}(X+1) \) was calculated for each group of calves. The calves were clinically examined (temperature, heart rate, body condition and presence of diarrhoea) before and after grazing. Faecal samples were taken at the time of examination to determine the presence of paramphistomes for eggs using a modified sedimentation technique (Rolfe & Boray, 1987). Snails were collected at the beginning of each grazing period. The calves were confirmed free of paramphistomes by examination of faeces for eggs using a modified sedimentation technique (Rolfe & Boray, 1987).

Groups of 10 calves were placed on the study area for successive periods of 56 days, coinciding with the shortest prepatent period of paramphistomes (Paramphistomum ichikawai) recorded in Australia (Durie, 1953). At the end of each grazing period the calves were removed, starved for 24 h, killed and any flukes recovered and counted (Rolfe & Boray, 1987). The mean logarithmic fluke count \( \log_{10}(X+1) \) was calculated for each group of calves. The calves were clinically examined (temperature, heart rate, body condition and presence of diarrhoea) before and after grazing. Faecal samples were taken at the time of examination to determine the numbers of paramphistome eggs in faeces. The study was continued for 2 seasonal years beginning in spring (October) 1983 and ending in summer (December) 1985.

Studies of the intermediate hosts. Six sites, each of 15 m², were selected to represent the range of habitats in the study area. Snails were collected at the beginning of each grazing period. When the site was dry, soil was removed to a depth of 6 cm from an area of 10 cm². The soil was layered 2 cm deep in trays and covered with 5 cm of water. Snails were recovered from the edges of the trays over the next 10 days. When the site was inundated, the water was sampled by a hand sieve 8 cm in diameter and mesh 500 mm, using 10–15 sweeps over 5 min between 8 and 12 am. All parts of the body of water were sampled. Snails recovered by two methods were identified and counted; in year 2, the snails were also identified as adult or immature. Mature G. scottianus were > 1 mm; mature H. australiensis were > 3 mm in diameter. Two hundred mature snails of each species from each site were examined at 12–25 × magnification for infection with cercariae. The mean prevalence of infection for all sites was calculated, and expressed as a percentage and as a ratio of infected to uninfected snails. The total number of G. scottianus recovered at each sampling was log-transformed (base 10). The proportion of infected snails was expressed either as a simple proportion, as an angular transformation (A.T.) or as a logit transformation (L.T.)

Collection of meteorological and environmental data. Climatic information was obtained from the Bureau of Meteorology, Department of Science Weather Station at Coffs Harbour, New South Wales. All measurements were made according to the methods of the Bureau of Meteorology (1986). The total corrected evapotranspiration for each grazing period \((CE)\) was calculated from the pan evaporation rate \((PER)\) allowing for when free water was present \((0.9 \times \) pan evaporation) or when no free water was present on the soil surface \((0.64 \times \) pan evaporation). An index of free water present on the soil surface for each grazing period \((W_I)\) was calculated using the following formula:

\[
W_I = R - (CE + WS + f)
\]

where \( R = \) total rainfall (mm) for grazing period; \( CE = \) total corrected evapotranspiration for grazing period (mm); \( WS = \) estimated capacity of the soil for water storage (mm) (150 mm for this soil type); \( f = \) estimated total water infiltration of soil for grazing period—25 mm per grazing period during high rainfall and 75 mm during low rainfall. The values of \( WS = f = \) were supplied by the Department of Agriculture and Fisheries, New South Wales, based on soil type, the degree of water saturation of the soil and the level of the water table. A positive value for \( W_I \) was an indication of soil water surplus and suitability of the site for multiplication of snails. At the end of the grazing period the sites were assessed visually for pasture type and length, and the water depth was measured if free water was present. Water and soil temperatures were measured at each sampling site. If free water was present the temperature was measured 3 cm below the water surface. Soil temperature was measured 5 cm below the soil surface.

Analysis of data. It was assumed for the purpose of analysis of data that the study area was continuously contaminated with paramphistome eggs. The mean populations of flukes in the tracer animals were correlated with the number of G. scottianus recovered and the proportion of snails infected at each sampling, and with climatic and environmental data. Statistical analysis of the data was by simple and multiple regression (Reg—NSW Agriculture) using mean logarithmic fluke counts, the proportion of infected snails and the total snail numbers for each grazing period as the dependent variables. Relationships were considered significant when individual \( P \) values were < 0.05. Predictive forecasting equations were prepared using snail numbers and proportion infected, climatic and environmental data calculated for the previous 2, 4 or 6 month prior to the times of slaughter.

RESULTS

Observations on experimental animals

A total of 140 tracer calves grazed the study area over 14 grazing periods. A regular pattern of grazing was established within 3–5 days of placement of calves on the site. Grazing occurred throughout the experimental area including the inundated areas. The resident cattle grazed the areas with the most available pasture; in wet periods they preferred higher ground although some animals, particularly calves, grazed the lower inundated areas. Inundated areas were grazed more as the water receded. All groups of tracer calves, except groups 7, 8, 9 and 14 lost weight during the grazing period. Clinical paramphistomosis was seen in two animals from group 2, six from group 3, and three from group 11. Clinical signs observed were severe weight loss, debility, anorexia, diarrhoea and...
sub-mandibular oedema. Signs varied from mild to severe and were associated with burdens of 4000 to over 20,000 flukes. No clinical paramphistomosis occurred in resident cattle.

Faecal egg counts of individual resident cattle were generally high in late winter and early spring, an indication of large fluke burdens resulting from infection during summer and autumn. The total contamination of the study areas with paramphistome eggs for each grazing period was estimated to range from 0.17 to 12.3 \times 10^7 eggs ha\(^{-1}\) day\(^{-1}\), with peak levels occurring in late summer and early winter in both years.

Other helminths were present in the abomasum and small intestine of the calves. Heavy burdens of *Haemonchus placei*, *Cooperia* sp. and *Trichostrongylus* sp. occurred in calves in groups 4, 5 and 6.

**Environmental observations**

In year 1 heavy rainfall during the first grazing period inundated large parts of the study area; maximum inundation occurred in March 1984 (Fig. 1). The study area progressively dried out and there was no free water by September 1984. Rainfall in October and November produced scattered temporary inundation in the lower depressions. There was abundant pasture until May 1984 after which both the quantity and quality of pasture deteriorated. Concurrently there was an increase in the amount of faecal contamination of the inundated areas.

In year 2 the dry conditions continued until mid-February 1985, although thunderstorms produced temporary inundation. From mid-February until August 1985, frequent rain produced extensive inundation, at a maximum in May, followed by a period of receding water and deteriorating pasture conditions. No free water was present on any site from August until December 1985. The period of general inundation was shorter in year 2 (6.5 months) than in year 1 (10 months).

**Fluke burdens**

Flukes were identified as mostly *C. calicophorum* with low numbers of *P. ichikawai*. The mean number of flukes present at necropsy in each group of tracer calves is shown in Fig. 1. Peak burdens occurred in mid to late summer in the first year (group 3, \(x = 19,322\)) and the late autumn to early winter in the second year (group 11, \(x = 9963\)). The maximum number of flukes found in an individual animal was: in the rumen 20,398 (group 12); abomasum, 1500 (group 6) and small intestine, 50,804 (group 11). Heavy burdens of flukes, i.e. \(x > 1000\) in all organs, were present for 6 months in year 1 and 8 months in year 2. Heavy ruminal burdens indicated infection early in the grazing period.

The mean total fluke burdens were significantly correlated with the prevalence of infection in *G. scottianus* determined at the end of the corresponding grazing period (\(P = 0.33\%, r = 0.85\)). The angular transformation (A.T.) and logit (L.T.) transformation
of the prevalence of infection ratio were also significantly related but at a lower level \((P = 0.51\%, r = 0.84; P = 1.77\%, r = 0.76)\). The relationship between the mean fluke burdens in tracer calves, and the prevalence of infection in snails with *C. calicophorum* was expressed as

\[
\log_{10}(1 + \text{fluke burden}) = 2.7334 + 1.886 \times \text{prevalence of snail infection*}
\]

*expressed as a ratio.

The mean fluke burdens were significantly related to the water level on the sites at the end of the grazing period \((P = 4.38\%, r = 0.55)\) and the index of surface water \((W)\) at the beginning of the grazing period \((P = 4.68\%, r = 0.54)\). These relationships were expressed as

\[
\log_{10}(1 + \text{fluke burden}) = 2.7780 + 0.142 \times W^*
\]

*water level at the end of 8 week grazing period.

\[
\log_{10}(1 + \text{fluke burden}) = 3.2301 + 0.21 \times W^{**}
\]

**index of water level at the beginning of 8 week grazing period.

**Snails**

The most common species of snail acting as intermediate host was *G. scottianus*; *H. australiensis* was less common and less widely distributed. *Gyraulus gilberti*, the other intermediate host in Australia (Durie, 1953, 1956), was not found. *G. scottianus* was abundant in the temporary habitats. *H. australiensis* was initially present in the more permanent sites, but it became widely dispersed. Other species of aquatic snail that were recovered included the *Physa* sp. and *Glyptophysa* sp. They were the only species of snails found in the semi-permanent creek which crossed the study area.

The age structure of the populations of the two species of host snails was examined in year 2. When *G. scottianus* emerged after heavy rain, adult snails predominated. When the habitats remained wet the number and proportion of immature snails gradually increased. It was not possible to make similar observations for *H. australiensis* because of the low numbers recovered.

The number of adult *G. scottianus* increased from the beginning of inundation on all sites in both years of study. Large numbers of *G. scottianus* were present within 24 h after previously dry sampling sites were inundated. If inundation continued (as after grazing period 9) there was a rapid increase in snail numbers which continued as long as suitable habitats were available.

The prevalence of infection in adult *G. scottianus* mostly followed the trend in numbers of *G. scottianus*, but there were important differences. In year 1, the prevalence declined rapidly after the initial rise when the numbers of snails continued to rise. In year 2 the prevalence gradually increased during inundation and peaked just before the habitats dried. The prevalence in adult *G. scottianus* was high in both years (peaking at 91% in year 1 and 58% in year 2), on all sites. The highest prevalence was consistently found on the site that was least frequently inundated.

The number of adult *H. australiensis* recovered at each site varied but was always lower than the numbers of *G. scottianus*. The prevalence of infection was also lower, but followed the same trend over time as the latter species. Few immature snails of either species were found to be infected. The other planorbid species, *Physa* and *Glyptophysa*, were not infected with paramphistomes.

The ability of both species of host snail to survive through dry periods was confirmed by recovering snails from soil and surface vegetable debris in shallow depressions when there was no free water and in water in areas recently inundated after long dry periods. The shallow depressions were the first areas to be inundated after heavy rain and were the focus for extended inundation of larger areas; they were the only sites where snails could be recovered if there was no free water. The bases of the dry depressions were covered with vegetable litter; most snails were recovered from the top 3–5 cm of the soil associated with vegetable debris. In dry soil adult *G. scottianus* survived for at least 8 weeks and on some sites, for 24 weeks. *H. australiensis* was less frequently recovered than *G. scottianus*.

In year 2, some of the adult *G. scottianus* recovered from soil during grazing periods 12 and 14 contained mature cercariae. At the end of grazing period 7, when sampling took place immediately after heavy rainfall and was preceded by an 8-week dry period, an initial prevalence of infection of 3% at one site increased to 20% after the snails were left in an aquarium for 10 days, presumably as a result of the maturation of previously undetected infection.

The prevalence of infection \(\%\) in *G. scottianus* and the A.T. and L.T. transformations were highly significantly related to the water level in the habitats at the time of sampling \((P = 0.15\%, r = 0.89; P = 0.06\%, r = 0.91; P = 0.027\%, r = 0.93, respectively)\). Water level 2 months prior to sampling was significantly related only to the logit transformation of the prevalence of infection in snails \((P = 3.99\%, r = 0.73)\). Other variables considered independently that were significantly related to prevalence of infection included the water index 2 months prior to sampling \((P = 4.44\%, r = 0.68, \text{for snail infection A.T.}, P = 4.47\%, r = 0.68, \text{for snail infection L.T.}), \text{and the terrestrial minimum temperature} (P = 3.14\%, r = 0.71, \text{for snail infection L.T. only})\). The number of *G. scottianus* snails at the sampling sites was significantly related to the water level at the time of sampling \((P = 0.02\%, r = 0.84)\). There were no other significant relationships with environmental or climatic variables.

**Meteorological data**

Monthly data of selected variables collected over
Epidemiology of paramphistomosis in cattle

Fig. 2. Rainfall, water index ○—○ and level □—□ and mean daily temperatures (air maximum ▲—▲ and minimum ▼—▼ soil minimum ●—●), at Yamba pilot station over 2 years.

the period of study are shown in Fig. 2. Air temperatures were similar in both years of the study although in 1984 there was a greater range in terrestrial temperatures between summer and winter compared to other years. Relative humidity was always high but there was a noticeable decrease in late winter and early spring because of the dry conditions at this time. Evaporation rates were higher in summer (high temperature and rainfall) and lower in winter. The Water Surplus Index reflected the seasonally dry conditions in late winter and spring of year 1 and year 2 of the study, and the period immediately before the start of the trial.

**DISCUSSION**

The study confirmed the importance of paramphistomosis as a cause of clinical disease in susceptible cattle in this area. The effects of subclinical infection on production will be reported elsewhere. The absence of clinical disease in the resident cattle supports the observation of Horak (1971) that host resistance develops and limits acquisition of further infection, although adult flukes in these cattle continue to produce eggs.

Calves in this study acquired infection when they grazed inundated areas that were viable snail habitats. Other reports from Australia (Boray, 1969a) and Africa (Horak, 1971) indicate the definitive hosts are infected after the snail habitats have dried out and livestock are attracted to low lying areas for available pasture. The differences in the time of acquisition in this study may be due to the naive grazing habits of tracer calves compared to resident cattle and the lack of areas for grazing away from snail habitats especially when inundation was extensive. Resident cattle in this study were depositing eggs on inundated areas as indicated by the immediate rise in snail numbers and followed by the rise in the prevalence of infection within the snails. The delay between these events is explained by the time needed for development of infection within the snails.

The pattern and prevalence of infection in *G. scottianus* and to a lesser extent *H. australiensis* were similar in both years of the trial, although the peak in number and prevalence of infection occurred at different times in each year. The pattern of infection was strongly associated with the onset and continuation of seasonal rain leading to inundation and the establishment of suitable snail habitats. Temperature had little effect on the rate of increase in snail populations or on the rate of development of the paramphistomes in the snails in this environment. However, it could be a limiting factor if unseasonal rainfall led to inundation extended into late winter. Brotowidjoyo (1981, thesis cited above) found reduced fecundity and delayed hatching of eggs in *G. scottianus* (syn. *Pygmanisus pelorius*) at 15°C compared with 25°C. The development of *F. hepatica* within lymnaeid snails has been found to be affected at soil temperatures below 10°C (Boray, 1969c). The high prevalence of infection with *C. calicophorum* in *G. scottianus* indicates that the snail is highly susceptible to infection and that there were large numbers of eggs deposited on pasture. Compared with
other trematode infections in other snails, the prevalences found in this study are very high (Boray, 1969c; Schillhorn Van Veen, 1980; Malone et al., 1984). The fecundity, longevity and ability of the snails to aestivate are apparently not affected by the presence of the parasites. The ability of both species of host snails to aestivate is an important factor in the epidemiology of the disease. After the onset of seasonal rains, snails that have survived the dry period are able to immediately resume development and reproduction so that infective metacercariae are released within 30 days of the re-establishment of the habitat, or within hours if snails already contain mature cercariae. There are no studies that examine the process of aestivation in planorbid snails but this phenomenon has been well documented in the snail hosts of schistosomes (Oliver & Barbosa, 1955; Barbosa & Olivier, 1958), where it has been found to be both active and passive. Some snails actively penetrate the soil while others are accidentally covered by debris, vegetation and soil. In this study the evidence for either method is not definitive.

*G. scottianus* were found in moderate numbers up to 20 mm below the soil surface. A few of these snails survived for up to 6 months. However, under laboratory conditions, if the water level of a tank was allowed to recede, snails that dried out did not retreat, but usually died.

The close relationship between prevalence of infection in the host snail and the size of fluke burdens in cattle gives an indirect but simple and practical forecasting method for this environment. The experience gained in this study suggests that a mean burden of 2000 flukes per animal accumulated over an 8 week grazing period is detrimental to the health of the animal. This level of infection coincided with a 30% prevalence of infection in adult *G. scottianus* at the end of each grazing period. In this study control measures would then have been indicated from January to March 1984 and March to June 1985. As metacercariae persist on pasture for at least 1 month (Horak, 1962) and probably up to 2–3 months after flooding has receded, especially during the cooler parts of the year, susceptible cattle should be removed from the pasture or treated with anthelmintics for 6–12 weeks after the pasture has dried out.

The occurrence of light to moderate infection in tracer calves at times apart from the periods of extended inundation reflects in part the ability of paramphistomes to survive in aestivating snails. Sporadic heavy rainfall at these times, although not sufficient to maintain inundation for extended periods, was sufficient to temporarily inundate surface depressions. At these times large numbers of snails were recovered, a proportion of which were infected and resulting in light infection of tracer calves with flukes.

The water index was a less useful predictor of prevalence of infection in *G. scottianus*, and of fluke burdens in tracer calves, but has the advantage that it can be calculated by the examination of climatic data. However, a forecasting system based solely on this variable is unlikely to be useful because of the low level of correlation with the size of fluke burdens in tracer calves.

A forecasting system based on epidemiological factors can help to integrate control strategies in a cost effective manner. The control of paramphistomosis should involve both pasture management and dosing with anthelmintics. The prevalence of infection in snails can be used to predict the time when it would be necessary to remove or treat susceptible cattle. In normal seasons in this locality, significant fluke burdens in cattle could be expected in late summer and early autumn, however, removal of livestock at this time may conflict with the need for pasture at a time of declining pasture quality and quantity elsewhere. Drenching should not be necessary in this environment if susceptible animals are removed from pasture early in the period of inundation and before the prevalence of infection in snails reaches 20%. The maturation of the small burden of flukes in the animals should provide a useful level of host resistance without causing disease (Horak, 1971). The alternative is to allow the animals to stay on the pasture and to treat with anthelmintics to remove potentially dangerous burdens of flukes. An alternative strategy for control might involve a single treatment of chronically infected animals in the period between the seasonal peaks in availability of infective metacercariae, in order to reduce the number of eggs deposited on pasture and the opportunity for infection of the snails in the subsequent wet season. The effectiveness of this strategy has not been evaluated. The benefits from this treatment would have to be balanced against a possible increase in susceptibility to re-infection in the treated animals although total elimination of infection is unlikely with most available anthelmintics (Rolfe & Boray, 1987).

This study illustrated the conditions necessary in this environment for the development of infection with paramphistomes in cattle. The intermediate hosts were well adapted for survival. The ability of *G. scottianus*, and to a lesser extent *H. australiensis*, to aestivate in soil during long dry periods, to re-establish populations above ground soon after inundation and to quickly resume reproduction, provided the optimum conditions for the survival and transmission of paramphistomes. The snails were highly efficient intermediate hosts as shown by the high prevalence of infection that developed during the periods of inundation. Up to 14 weeks of inundation of habitats was required for multiplication of *G. scottianus* from residual population foci and spread over the study areas. Large burdens of flukes were found in susceptible cattle within 5 weeks of grazing contaminated pasture. In both years, clinical signs were observed in tracer calves from 16 to 24 weeks after the onset of heavy seasonal rain and inundation of pasture. The time of occurrence of disease may be delayed.
depending on the stocking rate, previously acquired fluke burden susceptibility and the grazing habits of the cattle involved.

Acknowledgements—This study was supported by the George Aitken Pastoral Trust and Pitman Moore (Australia).

REFERENCES


