Epidemiological studies of *Fasciola gigantica* infections in cattle in the highveld and lowveld communal grazing areas of Zimbabwe

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ABSTRACT

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During the period between January 1999 and December 2000, the distribution and seasonal patterns of *Fasciola gigantica* infections in cattle in the highveld and lowveld communal grazing areas of Zimbabwe were determined through monthly coprological examination. Cattle faecal samples were collected from 12 and nine dipping sites in the highveld and lowveld communal grazing areas respectively. Patterns of distribution and seasonal fluctuations of the intermediate host-snail populations and the climatic factors influencing the distribution were also determined by sampling at monthly intervals for a period of 24 months (November 1998 to October 2000) in six dams and six streams in the highveld and in nine dams in the lowveld communal grazing areas. Each site was sampled for relative snail density and the vegetation cover and type, physical and chemical properties of water, and mean monthly rainfall and temperature were recorded. Aquatic vegetation and grass samples 0–1 m from the edges of the snail habitats were collected monthly to determine the presence or absence of *F. gigantica* metacercariae. Snails collected at the same time were individually checked for the emergence of larval stages of *F. gigantica.* A total of 16264 (calves 5418; weaners 5461 and adults 5385) faecal samples were collected during the entire period of the study and 2500 (15.4%) of the samples were positive for *F. gigantica* eggs. Significantly higher prevalences were found in the highveld compared to the lowveld ($P < 0.001$), for adult cattle than calves ($P < 0.01$) and in the wet season over the dry season ($P < 0.01$). Faecal egg output peaked from August/September to March/April for both years of the study.

Lymnaea natalensis, the snail intermediate host of *F. gigantica* was recorded from the study sites with the highveld having a significantly higher abundance of the snail species than the lowveld ($P < 0.01$). The snail population was low between December and March and started to increase in April reaching a peak in September/October. The number of juvenile snails peaked between April and August. The mean number of snails collected was negatively correlated with rainfall and positively correlated with temperature. Mean number of snails collected was also positively correlated with *Potamogeton* plant species and negatively correlated with *Cyperus* plant species. However, none of the *L. natalensis* collected from the habitats were found shedding *Fasciola* cercariae. Metacercariae were found on herbage from the fringes of the snail habitats between February and August for both years, with most of the metacercariae concentrated on herbage 0–1 m from the banks of the habitats.

Based on the findings of this study, anthelmintic treatment should be administered in December/January to control chronic and mature fasciolosis. A second treatment should be given in April/May to reduce pasture contamination and subsequently snail infection, as this is the time the snail population starts to build up. To control acute fasciolosis due to the immature liver flukes a third treatment should be given in August.

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The first application of molluscicides to control the snail intermediate hosts can be done in June the time when the snail is harbouring the parasite and a second application in September in order to kill new generations of infected snails

Keywords: Cattle, communal grazing, epidemiology, *Fasciola gigantica, Lymnaea natalensis*, Zimbabwe

INTRODUCTION

Infection with *Fasciola gigantica* is regarded as one of the most common single helminth infection of ruminants in Asia and Africa (Harrison, Hammond & Sewell 1996; Roberts & Suhardono 1996). Its economic importance is mostly obvious when the disease causes mortality, but even subclinical infections have been shown to cause high losses from reduced feed efficiency, weight gains, milk production, reproductive performance, carcass quality and work output in draught animals, and from condemnation of livers at slaughter (Vassilev & Jooste 1991).

The fluke affects bovines in Zimbabwe and is endemic in most parts of the country (Needham 1977; Vassilev & Jooste 1991; Vassilev 1994, 1999). *Lymnaea natalensis,* an aquatic snail, is the intermediate host of this species in Zimbabwe (Needham 1977). In 1986, 46.3% of livers were condemned due to *F. gigantica* in Zimbabwe (Chambers 1987). The prevalence as determined by coprological examination was 26.3% between February 1988 and March 1990 (Vassilev & Jooste 1991). Based on the results of coprological and slaughterhouse studies, *F. gigantica* is reported to be present throughout the year in bovines in the country (Vassilev & Jooste 1991). The prevalence is much higher in the high rainfall areas than the dry areas (Needham 1977; Chambers 1987; Vassilev 1994, 1999) and is also related to the density of animals and the availability of the snail intermediate host (Vassilev 1999).

Studies on *F. gigantica* infection in cattle in Zimbabwe were concentrated mainly on prevalence and economic importance of the infection. Little information is available on the life cycle and transmission dynamics of the host-parasite systems. The aim of this study was to determine the epidemiology of *F. gigantica* in cattle in the highveld and lowveld communal grazing areas of Zimbabwe, and to use this information to recommend appropriate measures to control the parasite.

MATERIALS AND METHODS

Study location

Based mainly on rainfall and temperature, Zimbabwe is divided into agro-ecological regions I, II, III, IV and V (Fig. 1). On the basis of altitude, the country is also divided into three major relief regions: the highveld (1 200–2 000 m), middleveld (900–1 200 m) and the lowveld (below 900 m).

The rainy season is from November/December to March/April, and the dry season occurs from April/May to October/November. The mean annual rainfall for Regions I–III is over 1 000 mm, 750–1 000 mm and 650–800 mm, respectively. Region IV receives a low rainfall of 450–650 mm that is erratic and subject to periodic droughts. In Region V rainfall is very erratic and is less than 500 mm per annum.

Hills and valleys characterize the topography of the highveld; in which streams and rivers are located. Dams, rivers, streams and marshy areas, which serve as watering places for livestock are common in the area. In the lowveld, the topography is generally flat land, with man-made dams serving as watering points for livestock.

Seven districts were randomly selected within Agro-ecological regions II, III (highveld) and IV (lowveld) (Fig. 1); four from the highveld and three from the lowveld (Table 1).

Selection of study sites

Dip tanks used for the control of cattle ticks in communities were chosen as the study sites owing to the availability of animal handling facilities and access to large populations of cattle. Three dip tanks were randomly selected from each district giving a total of 21 study sites; 12 from the highveld and nine from the lowveld (Table 1). In these areas cattle were dipped weekly during the rainy season and fortnightly during the dry season for the control of ticks.

Animals

Local indigenous cattle used in the study were Sanga type (a stabilised *Bos taurus* x *Bos indicus* cross breed) commonly known as “Mashona”. Cattle from each of the study sites were categorised into calves (less than 12 months old), weaners (1–2 years old) and adults (over 2 years old). Calves and weaners were further divided into males and females. Adults were further categorised into dry, lac-

TABLE 1 Study sites, cattle census and total samples collected in the highveld and lowveld communal grazing areas of Zimbabwe for the period January 1999 to December 2000

Region	District	Distance from nearest meteorological station (km)	Number of dip tanks surveyed	Cattle census	Total faecal sample collected	Number of dams surveyed	Number of streams surveyed
Lowveld	Zvishavane	12	3	20 175	2 116	3	0
Lowveld	Mberengwa	14	3	30 649	3 174	3	0
Lowveld	Plumtree	9	3	24 041	2 504	3	0
Highveld	Wedza	8	3	30 189	3 121	3	0
Highveld	Murewa	10	3	25 801	1 390	2	1
Highveld	Zvimba	13	3	12 339	1 243	1	2
Highveld	Mazowe	10	3	26 165	2 716	0	3

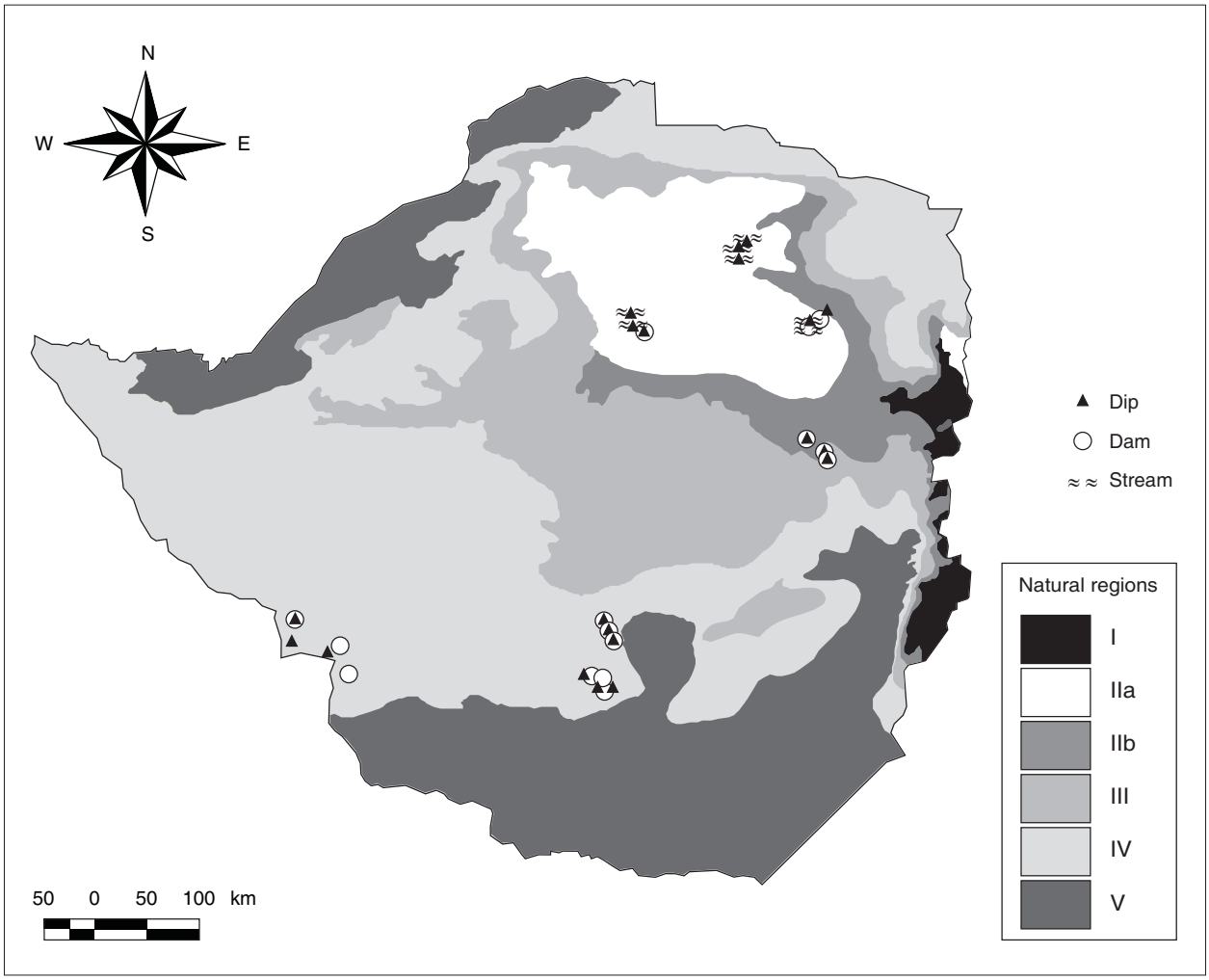

FIG. 1 Location of dips and snail habitats sampled in the different natural regions in the highveld and lowveld communal grazing areas of Zimbabwe

tating and pregnant cows, oxen and bulls. Rectal faecal samples were collected from each category of cattle once every month. The survey covered the period from January 1999 to December 2000.

Snail studies

In each of the study districts, both drinking and grazing sites were identified, representing habitats of the

intermediate host snails (Fig. 1). The sites included dams and streams within the grazing areas. Monthly, from November 1998 to October 2000, each site was sampled for snails, using the scooping method as described by Coulibaly & Madsen (1990). However, due to logistical problems, no snails could be collected from some of the sites in March, April, June and August 2000. Each snail collected was identified according to Brown & Kristensen (1989), and to establish the seasonal breeding trends of the snails, the shell height of each was measured before it was returned to its habitat. The snails were categorised into two groups, namely juveniles (4–5 mm), growing and adults (>5 mm); and the sampling method used precluded collection of snails <4 mm in length.

All snails sampled at each site were screened for patent *F. gigantica* infection by being placed in individual glass tubes and exposed to fluorescent light for 1 h, followed by darkness for another hour. However, shedding of the snails should have been preferably done in the dark and this could not be carried out as the snails were returned to their respective habitats after the identification and shedding process. Emerging cercariae were identified using the key of Frandsen & Christensen (1984) and percentage of snails infected with *F. gigantica* cercariae was calculated monthly for each site.

Aquatic vegetation and grass samples 0–1 m from the edges of the snail habitats, electrical conductivity and pH of the water were recorded monthly for each site. Electrical conductivity and pH of the water were both measured at the study sites, using a portable electronic conductivity meter (Phillips Heriss, 20.1267) and a portable pH meter (Phillips Heriss, 20.1264). Collected vegetation samples were identified and examined for the presence or absence of *F. gigantica* metacercariae.

Parasitological analysis

Faecal samples were quantitatively examined for *F. gigantica* eggs by the sedimentation technique as described by Boray & Pearson (1960). The eggs of *F. gigantica* were distinguished from those of amphistomes on the basis of their colour, *F. gigantica* eggs being bright yellow while those of amphistomes were colourless. The prevalence of *F. gigantica* at each site was defined as described by Margolis, Esch, Holmes, Kuris & Schad (1982).

Meteorological data

Mean monthly temperatures and mean monthly rainfall data from the meteorological station nearest to each study site were obtained from the recordings by Department of Meteorology, Belvedere, Harare.

Statistical analysis

Faecal egg counts were logarithm-transformed [$\log_{10}$ (egg count + 1)] to stabilize the variance before analysis. The effect of age, sex, year, season and location on transformed egg counts was measured by the General Linear Model (GLM) in SPSS (version 8.0). Categories were generated as follows:

- Three for age (calves, < 12 months old; weaners, 1–2 years old; and adults, > 2 years old)
- Two for season (wet, November to April and dry, May to October)
- Nine for sex (female calves, male calves, female weaners, male weaners, dry, lactating and pregnant cows, oxen and bulls)
- Two for locations (highveld and lowveld).

Least Significant Difference (LSD) was used as the post-hoc test to measure variances between different categories. Values of $P < 0.05$ were considered as significant. The correlation between egg counts and climatic factors (rainfall and temperature) was determined by linear regression model.

To stabilize for variances, the snail counts were logarithm-transformed [$\log_{10}$ (snail count + 1)]. The effect of location, season, year and type of habitat on transformed snail counts were measured by GLM, and LSD was used as the post-hoc test to measure variances between different categories. For seasonal analysis of fluctuations in snail populations, the year was divided into four seasons: rainy (December to February), post-rainy (March to May), cold dry (June to August) and hot dry (September to November) as described by Chandiwana, Christensen & Frandsen (1987). The correlation between snail densities and climatic factors (rainfall and temperature) was analysed using a linear regression model.

RESULTS

Faecal egg counts

A total of 16264 (calves 5418, weaners 5461 and adults 5385) faecal samples were collected during the entire period of the study and 2500 (15.4%) of the samples were positive for *F. gigantica* eggs. In the lowveld, the overall number of animals positive for *F. gigantica* eggs differed significantly between the 2 years with the second year having a significantly higher prevalence ($P < 0.01$) than the first

TABLE 2 Mean prevalence (%) of *Fasciola gigantica* in the different categories of cattle by year, region and district in the highveld and lowveld communal grazing areas of Zimbabwe as from January 1999 to December 2000

Year	Region	Agro-ecological zone	District	+N	Animal category									
					Calves		Weaners		Adult cows			Oxen	Bulls	Overall
					Females	Males	Females	Males	Dry	Lactating	Pregnant			
1999	Highveld	II & III	Wedza	1 497	14.6	16.1	18.2	18.6	18.5	32.6	21.8	21.0	25.5	18.8
		II	Murewa	1 390	23.6	16.5	20.5	20.8	39.8	50.5	54.5	26.2	43.2	26.9
		II	Zvimba	842	8.7	11.0	7.2	9.2	21.2	43.4	30.3	23.2	27.0	15.2
		II	Mazowe	1 368	9.4	8.7	17.3	19.3	12.0	32.6	37.7	22.5	21.7	18.3
			Overall	5 097	14.8[a]	13.3[a]	16.7[b]	17.9[b]	25.9[c]	38.6[d]	37.7[d]	23.1[e]	29.5[d]	20.3[aa]
	Lowveld	IV	Zvishavane	1 354	3.8	2.8	3.8	5.0	12.2	11.5	10.5	10.0	14.3	6.2
		IV	Mberengwa	1 554	2.2	2.1	2.5	3.7	5.1	6.1	9.1	6.6	2.3	3.9
		IV	Plumtree	1 109	2.7	2.9	4.3	2.0	5.4	9.7	15.1	6.4	11.4	4.8
			Overall	4 017	2.9[c]	2.5[c]	3.3[c]	3.7[c]	7.4[b]	8.8[b]	10.9[e]	7.7[b]	9.2[e]	4.9[bb]
2000	Highveld	II & III	Wedza	1 624	18.9	16.9	20.6	19.4	27.6	33.3	44.2	28.7	32.8	23.3
		II	Murewa	–	–	–	–	–	–	–	–	–	–	–
		II	Zvimba	401	11.9	10.6	10.8	11.7	10.7	16.0	33.3	15.8	26.3	14.0
		II	Mazowe	1 348	12.6	13.7	15.6	19.3	27.8	35.8	46.4	34.4	50.0	22.9
			Overall	3 373	15.6[a]	14.9[a]	17.2[b]	18.6[b]	24.9[c]	32.8[e]	44.0[f]	29.7[d]	37.6[e]	22.0[aa]
	Lowveld	IV	Zvishavane	762	4.2	2.9	5.7	7.5	19.6	22.9	26.9	21.6	33.3	11.4
		IV	Mberengwa	1 620	7.6	9.7	14.5	13.4	19.7	28.0	26.8	18.6	20.7	15.4
		IV	Plumtree	1 395	7.2	8.1	12.8	10.8	15.5	23.0	31.7	15.9	24.6	13.5
			Overall	3 777	6.8[b]	7.6[b]	12.3[d]	11.1[d]	17.9[e]	25.5[g]	28.4[g]	18.2[f]	25.0[g]	13.9[cc]

Figures with a different superscript in a column or row under overall prevalence are significantly different at $P < 0.05$

+N = Total number of animals sampled

TABLE 3 Seasonal mean prevalence (%) and mean faecal egg counts (FEC) of *Fasciola gigantica* in the different age categories by region and year in the highveld and lowveld communal grazing areas of Zimbabwe as from January 1999 to December 2000

Season	Region	Age group	Year 1 (Jan to Dec 1999)			Year 2 (Jan to Dec 2000)		
			*N	Mean prevalence (%)	Mean ± SD	*N	Mean prevalence (%)	Mean ± SD
Wet	Highveld	Calves	754	18.3	8.9 ± 2.3	581	18.8	10.8 ± 3.1
		Weaners	775	20.1	13.1 ± 3.6	597	20.6	16.4 ± 3.6
		Adults	759	44.4	21.6 ± 4.4	571	37.0	26.1 ± 5.7
		Overall	2 288	27.6[a]	14.5 ± 3.8	1 749	25.3[a]	17.8 ± 4.7
	Lowveld	Calves	656	4.3	2.5 ± 4.0	604	10.6	2.7 ± 3.3
		Weaners	669	4.6	7.9 ± 2.1	594	14.0	8.3 ± 5.6
		Adults	657	11.4	13.1 ± 3.8	599	29.9	14.8 ± 5.7
		Overall	1 982	6.8[b]	7.8 ± 3.5	1 797	18.1[c]	8.6 ± 4.5
Dry	Highveld	Calves	955	10.7	2.4 ± 4.2	536	11.4	3.6 ± 1.8
		Weaners	921	14.9	7.5 ± 4.4	550	14.9	9.6 ± 1.7
		Adults	933	17.7	11.9 ± 5.5	538	29.2	13.6 ± 4.1
		Overall	2 809	14.4[d]	7.3 ± 4.9	1 624	18.5[e]	8.9 ± 4.7
	Lowveld	Calves	671	1.2	1.4 ± 1.1	661	4.1	1.6 ± 1.2
		Weaners	695	2.3	2.5 ± 2.5	659	9.7	4.1 ± 2.8
		Adults	669	5.8	4.3 ± 3.0	660	16.4	7.2 ± 3.9
		Overall	2 035	3.1[e]	2.7 ± 3.1	1 980	10.1[d]	4.3 ± 3.7

Figures with a different superscript within a column or row under overall prevalence are significantly different at $P < 0.05$
SD = Standard deviation
*N = Total number of animals sampled

TABLE 4 Parasite burdens of *Fasciola gigantica* infection in various categories of cattle in the communal grazing areas of the highveld and lowveld for the period January 1999 to December 2000

Animal category	Low (EPG* < 10) Infected cattle (%)	Moderate (EPG* 10–25) Infected cattle (%)	Heavy (EPG* > 25) Infected cattle (%)
Female calves	95.4	3.3	1.4
Male calves	96.8	2.4	0.8
Female weaners	95.6	3.4	1.0
Male weaners	96.9	2.4	0.7
Dry cows	88.4	10.4	1.2
Lactating cows	90.7	6.4	2.9
Pregnant cows	87.1	10.6	2.3
Oxen	92.1	5.8	2.1
Bulls	92.9	5.4	1.7

* EPG = eggs per gram

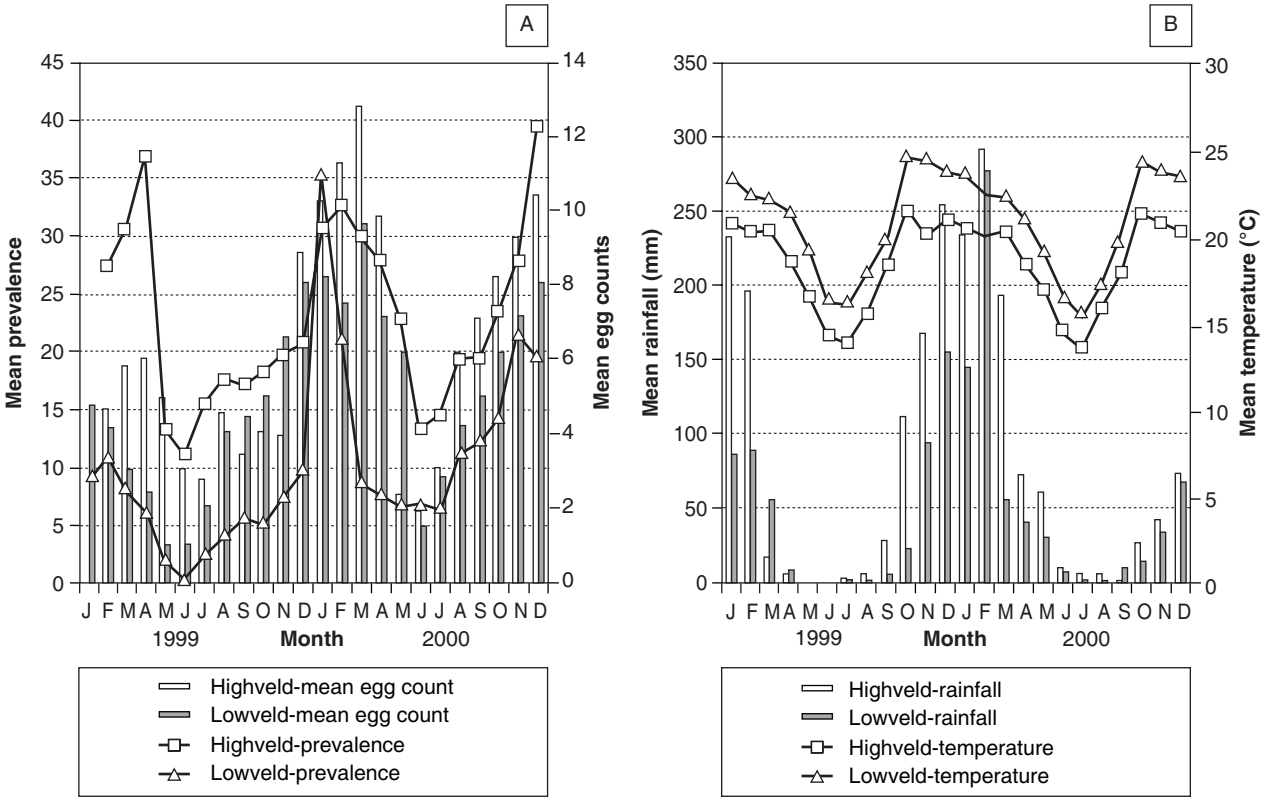

FIG. 2 Mean monthly prevalence (%) and mean monthly faecal egg counts of *Fasciola gigantica* in cattle (A) and mean monthly rainfall and temperature (B) in the highveld and lowveld communal grazing areas of Zimbabwe sampled for the period January 1999 to December 2000

year while no significant difference was observed between the 2 years for the highveld (Table 2). For both years the highveld had a significantly higher prevalence ($P < 0.001$) than the lowveld (Table 2).

For both regions, there were significant differences in prevalence of *F. gigantica* among the age categories ($P < 0.001$) with adults having a higher prevalence than the younger animals (Table 2). Except for lactating cows on lowveld in Year 1, pregnant and lactating cows, and bulls had significantly higher prevalences compared to oxen and dry cows ($P < 0.01$). However, there were no significant differences between female calves and male calves and between female weaners and male weaners (Table 2).

The highest recorded monthly egg count during the study period was 102 eggs per gram of faeces in a weaner during April 2000. The mean faecal egg count for positive animals combined was 12.1 and 5.9 for the highveld and lowveld, respectively. Calves, weaners and adults had respective mean faecal egg count

TABLE 5 Recovery of *Lymnaea natalensis* from seven districts in the highveld and lowveld communal grazing areas of Zimbabwe for the period November 1998 to October 2000

Region	Agro-ecological zone	District	No. of sites	Year 1 (Nov 98 to Oct 1999)		Year 2 (Nov 99 to Oct 2000)	
				Total collected	Mean ± SD	Total collected	Mean ± SD
Highveld	II	Mazowe	3	472	13.1[a] ± 24.3	328	9.9[a] ± 15.2
	II & III	Wedza	3	336	9.3[a] ± 102	201	6.1[b] ± 6.0
	II	Murewa	3	376	10.4[a] ± 16.9	507	14.1[a] ± 22.2
	II	Zvimba	3	155	4.3[b] ± 13.1	162	5.4[b] ± 11.0
		Overall	12	1 339	9.3[a] ± 17.1	1 198	9.1[a] ± 15.4
Lowveld	IV	Zvishavane	3	71	2.0[b] ± 5.3	191	6.4[b] ± 19.6
	IV	Mberengwa	3	444	12.3[a] ± 28.8	92	3.1[b] ± 7.9
	IV	Plumtree	3	67	1.9[b] ± 4.1	27	0.9[b] ± 4.2
		Overall	9	582	5.4[a] ± 17.6	310	3.6[b] ± 12.5

Figures with a different superscript within a column or row are significantly different at $P < 0.05$
SD = Standard deviation

of 4.2, 8.7 and 14. Adult cattle had a significantly higher mean egg count ($P < 0.01$) than the young cattle.

The wet season had a significantly higher prevalence and mean egg counts than the dry season ($P < 0.001$) (Table 3).

Faecal egg output was persistent during all the months of the 2-year study period. All age groups showed a similar seasonal trend with respect to both prevalence and mean faecal egg counts. Random calving occurs in communal grazing areas, and therefore the age groups were combined as shown in Fig. 2. Mean monthly faecal egg output and monthly prevalences of *F. gigantica* were significantly higher for the highveld than the lowveld ($P < 0.001$) (Fig. 2). Both mean monthly faecal egg outputs and prevalences peaked from August/September to March/April for both regions (Fig. 2).

Overall, respectively 93.2%, 5.8% and 1% of the faecal samples had low (<10), moderate (10–25) and high (> 25) numbers of *F. gigantica* eggs per gram of faeces. A higher percentage (over 5%) of adults had a moderate output of eggs compared to other categories of cattle. Over 1% of adult cattle had a high output of eggs than other categories of cattle (Table 4).

Snail abundance and distribution

The relative abundances and distribution of snails according to region and district are shown in Table 5. A total of 3429 *L. natalensis* was collected, 2537 from the highveld (74%) and 892 from the lowveld (26%). The highveld had a significantly higher mean number of snails collected in the second year ($P < 0.01$) than the lowveld while there was no significant difference between the regions in the first year. The mean numbers of *L. natalensis* collected in Wedza (highveld) and Mberengwa (lowveld) districts showed an annual variation with higher numbers collected in the first year ($P < 0.01$) than in the second. Overall, mean numbers of *L. natalensis* collected in the lowveld showed annual variations with significantly higher numbers collected in the first year ($P < 0.01$) than the second while there were no significant annual variations in the highveld.

Distribution of the snails according to habitat is shown in Table 6. Significantly higher numbers ($P < 0.001$) of *L. natalensis* were collected from highveld dams

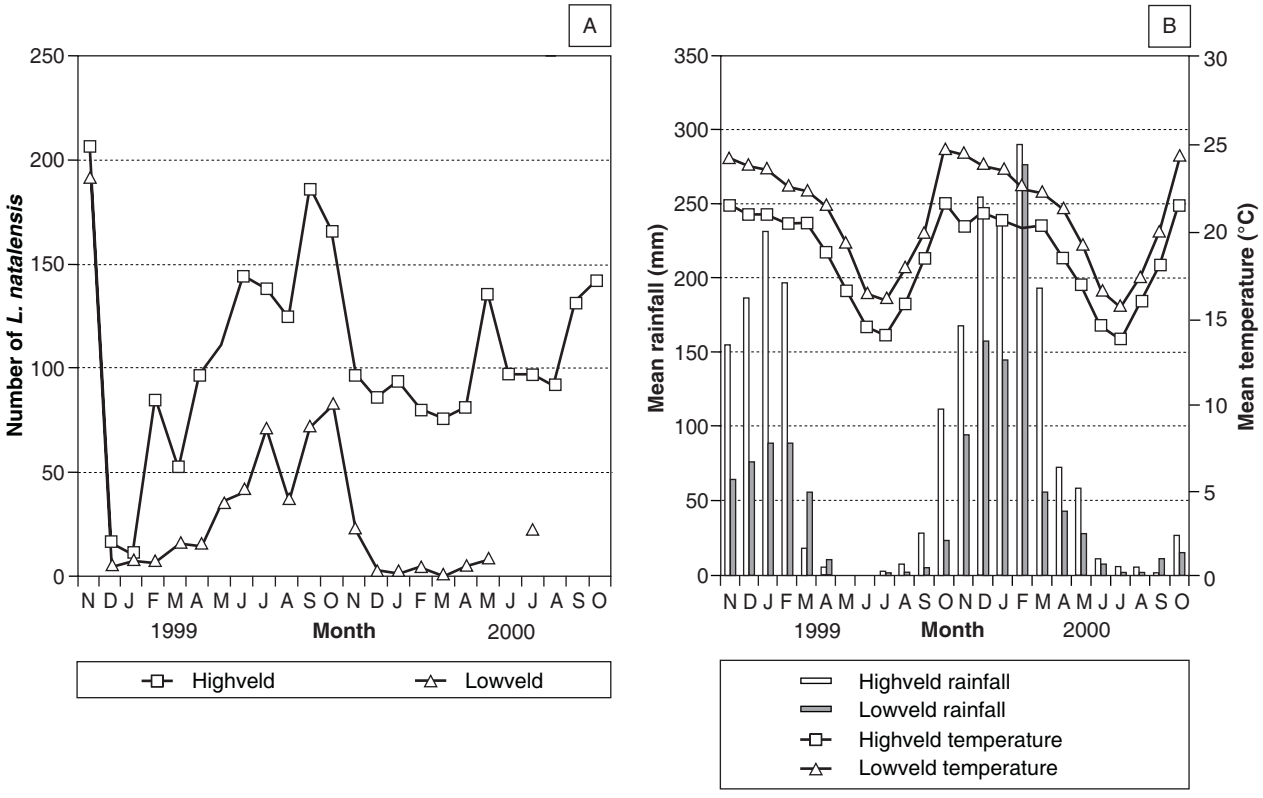

FIG. 3 Monthly variation of *Lymnaea natalensis* in the highveld and lowveld (A), and mean monthly rainfall and temperature in the highveld and lowveld (B) communal grazing areas of Zimbabwe sampled for the period November 1998 to October 2000

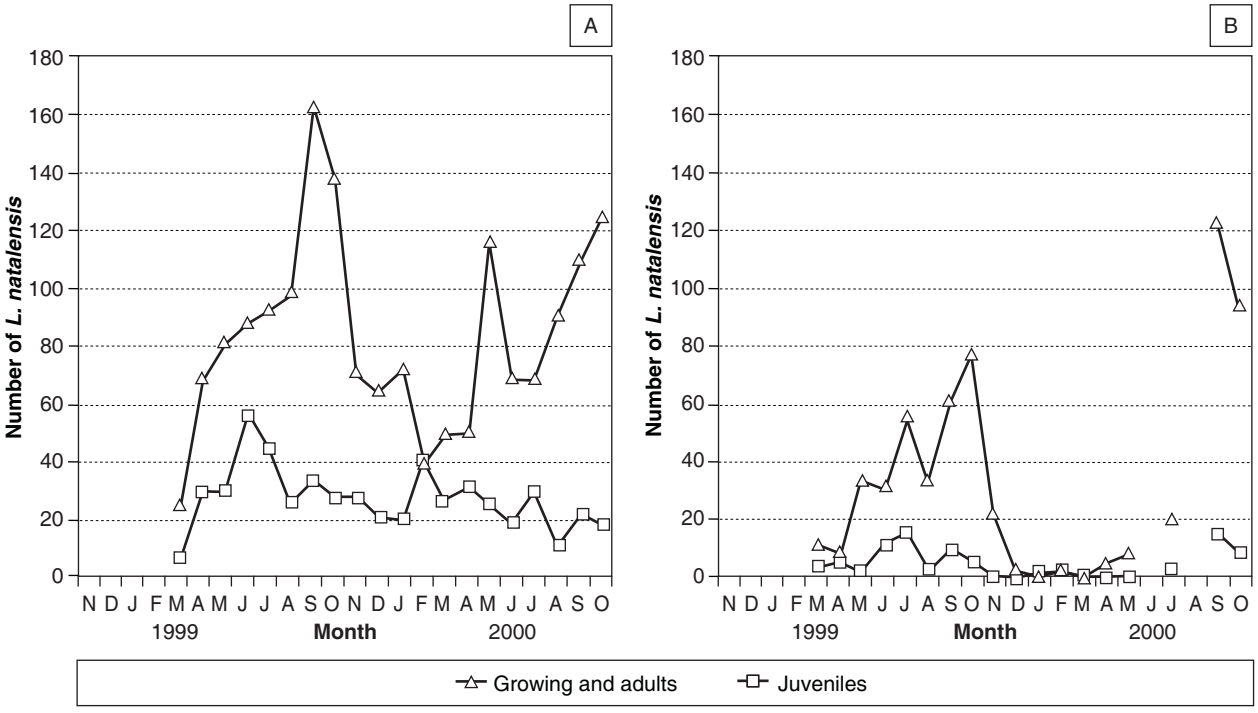

FIG. 4 Monthly variations of juvenile (4–5 mm shell height) and growing/adult (> 5 mm) *Lymnaea natalensis* snails in the highveld (A) and lowveld (B) communal grazing areas of Zimbabwe sampled for the period November 1998 to October 2000

TABLE 6 Recovery of *Lymnaea natalensis* according to habitat from seven districts in the highveld and lowveld communal grazing areas of Zimbabwe for the period November 1998 – October 2000

Region	District	No. of sites	Year 1 (Nov 98 to Oct 1999)		Year 2 (Nov 99 to Oct 2000)	
			Total collected	Mean ± SD	Total collected	Mean ± SD
Highveld	Stream	6	567	$7.9^{a} \pm 18.5$	420	$6.6^{a} \pm 12.3$
Highveld	Dam	6	772	$10.7^{a} \pm 15.6$	778	$11.4^{a} \pm 17.5$
Lowveld	Dam	9	582	$5.4^{b} \pm 17.6$	310	$3.5^{c} \pm 12.5$

Figures with a different superscript within a column or row are significantly different at $P < 0.05$
SD = Standard deviation

TABLE 7 Seasonal distribution of *Lymnaea natalensis* in the highveld and lowveld communal grazing areas of Zimbabwe for the period November 1998 to October 2000

Region	Season	Year 1 (Nov 1998 to Oct 1999)		Year 2 (Nov 1999 to Oct 2000)	
		Total collected	Mean ± SD	Total collected	Mean ± SD
Highveld	Post-rainy (Mar to May)	259	$7.2^{a} \pm 9.5$	294	$9.8^{a} \pm 18.4$
	Cold-dry (Jun to Aug)	407	$11.3^{b} \pm 16.2$	275	$9.2^{b} \pm 14.0$
	Hot-dry (Sep to Nov)	560	$15.6^{b} \pm 26.7$	371	$10.3^{b} \pm 16.8$
	Rainy (Dec to Feb)	113	$3.1^{a} \pm 6.3$	258	$7.2^{d} \pm 12.4$
Lowveld	Post-rainy (Mar to May)	67	$2.5^{c} \pm 4.4$	14	$0.5^{e} \pm 1.8$
	Cold-dry (Jun to Aug)	149	$5.5^{d} \pm 11.0$	23	$2.6^{d} \pm 5.2$
	Hot-dry (Sep to Nov)	346	$12.8^{d} \pm 32.3$	264	$9.8^{d} \pm 21.4$
	Rainy (Dec to Feb)	20	$0.7^{e} \pm 1.7$	9	$0.3^{e} \pm 0.7$

Figures with a different superscript within a column or row are significantly different at $P < 0.05$
SD = Standard deviation

than lowveld dams. However, there was no significant difference in mean number of snails collected between streams and dams in the highveld.

Seasonal distribution of *L. natalensis* is shown in Table 7. For both regions and years, the cold-dry and hot-dry seasons had significantly higher mean numbers ($P < 0.01$) of snails collected than the post-rainy and rainy seasons. Seasonal variations between the years were not significantly different except for the rainy season in the highveld and the post-rainy season in the lowveld. The snail population was low between December and March and started to increase in April reaching a peak in September/October (Fig. 3).

The number of juvenile snails peaked between April and August (Fig. 4). The mean number of snails recorded was negatively correlated with rainfall ($r = -0.66$) and positively correlated with temperature ($r = 0.69$). The mean number of *L. natalensis* collected were correlated with aquatic vegetation positively with *Potamogeton* spp. ($r = 0.64$) and negatively with *Cyperus* spp. ($r = -0.59$).

However, none of the *L. natalensis* collected from the studied habitats were found shedding *F. gigantica* cercariae.

Metacercariae were found on herbage growing in water and 0–1 m from the edges of the snail habitats between February and August for both years, with most of the metacercariae concentrated on herbage 0–1 m from the banks of the habitats. No grass samples could be obtained from the snail habitats between September and November due to overgrazing.

DISCUSSION

Evidently, from this study and other earlier studies in Zimbabwe (Needham 1977; Davies 1982; Chambers 1987; Vassilev 1999; Pfukenyi & Mukaratirwa 2003) infection with *F. gigantica* is more common in the high-rainfall districts of the highveld than in the relatively dry districts of the lowveld. In Kenya, the pattern of distribution of fasciolosis followed zones of high rainfall, snail-infested areas and areas of high animal density (Cheruiyot 1983). Wet and humid areas of Bahr el Ghazal Province of Sudan were also reported to have a high prevalence of fasciolosis than the more open and dry savannah Dafur Province (Majok, Zessin, Baumann & Farver 1993).

In West Africa, the prevalence of fasciolosis in cattle has been reported to vary widely according to the availability and distribution of the host snail (Schillhorn van Veen 1980a). The greatest risk of fasciolosis in East Africa has been reported to occur in areas of extended annual rainfall associated with high soil moisture and surplus water, with risk diminishing in areas of shorter wet season and/or lower temperatures (Malone, Gommes, Hansen, Yilma, Slingenberg, Snijders, Nachtergaele & Ataman 1998; Yilma & Malone 1998). Metacercariae survival is reduced in hot conditions (Torgerson & Claxton 1999) and the duration of their viability is directly related to relative humidity and inversely to temperature and exposure to sunlight (Spithill, Smooker & Copeman 1999). High-rainfall areas favour development and survival of both the intermediate host snail and the developmental stages of the parasite (Torgerson & Claxton 1999) and hence arid areas were found to be generally unsuitable for the occurrence of fasciolosis due to soil moisture deficit (Malone *et al.* 1998). The high-rainfall districts of the highveld, with a wider distribution of seasonal streams, permanent rivers and seasonal pools had a significantly higher abundance of the snail intermediate hosts than the relatively low-rainfall districts of the lowveld. Hence, as supported by the results of this study, the chance of cattle becoming infected can be expected to be higher in the highveld, characterized by wet/swampy grazing areas where distribution of snail habitats is widespread, than in the lowveld, with dry-land grazing and focal distribution of snail habitats.

The prevalence of *F. gigantica* infection recorded as a result of coprological examination of cattle in this study was lower than that reported by most of the previous authors who used slaughterhouse data (Chambers 1987; Vassilev & Jooste 1991; Pfukenyi & Mukaratirwa 2003). This variation could probably be due to the fact that reports in the abattoir study included livers damaged by immature fluke infection, which cannot be detected through coprological examination. In addition, liver flukes, like most parasites, are overdispersed in the cattle population, therefore, a small percentage of animals carry the greatest fluke burdens and thus shed the most eggs (Kaplan 1994). This factor causes large variation in the number of eggs shed by different animals grazing the same pasture. In addition, most cattle that are infected with flukes shed relatively few eggs, i.e. less than 5 eggs per gram of faeces even in heavily infected herds (Malone & Craig 1990). Other factors that must be considered are the long prepatent period of liver flukes, where in recently infected animals eggs are found only from 8 weeks after infection (De León, Quiñones & Hillyer 1981) and the variation in seasonal production of eggs, which de-

pends on transmission and duration of infection (Kaplan 1994). Hence, the low prevalence noted in this study could also be attributed to the low sensitivity of the egg count technique used to determine the proportion of animals infected.

In accordance with earlier reports (Schillhorn van Veen, Folaranmi, Usman & Ishaya 1980; Baldock & Arthur 1985; Vassilev 1994, 1999; Waruiru, Kyvsgaard, Thamsborg, Nansen, Bøgh, Munyua & Gathuma 2000) the prevalence of *F. gigantica* was higher in adult cattle than in either the weaners or the calves. The higher infection rate in older animals is reported to be probably associated with age and consequently longer exposure time (Schillhorn van Veen *et al.* 1980; Vassilev 1999; Waruiru *et al.* 2000).

From this and also other studies (Schillhorn van Veen 1980a; Mzembe & Chaudhry 1981; Jithendran & Bhat 1999), the prevalence of *F. gigantica* was found to be significantly higher during the wet season than the dry season. Reports on the duration of the period during which animals are exposed to infection with *F. gigantica* vary between habitats and the rate of infection is not constant throughout the year but concentrated over a relatively few months (Spithill *et al.* 1999). The pattern of infection in any area is a reflection of the timing and duration of ecological circumstances favourable for the population of snails and survival of metacercariae, as well as the management of livestock which permits dung from infected stock to contaminate snail habitats and allows stock to feed on fringing vegetation from sites where metacercariae are present (Spithill *et al.* 1999).

The snail population was low during the period December to March, and high between April (end of wet season) and October (end of dry season). This agrees with earlier observations from other parts of the world (Mzembe & Chaudhry 1979; Schillhorn van Veen 1980b; Morel & Mahato 1987; Chowdhury, Mondal, Huq & Rahman 1994; Tembely, Coulibaly, Dembele, Kayentao & Kouyate 1995). Therefore, towards the end of the wet season eggs of *F. gigantica* dropped on pasture survive to infect the new generation of snails. Investigations on the life cycle of *F. gigantica* indicated that the cercariae are released from mid- to end of the dry season and cattle are thus exposed to a high level of infection during these periods (Mzembe & Chaudhry 1979). However, in this study, none of the snails was found shedding *Fasciola* cercariae. Shedding was done during the day and all collected snails were returned to their respective habitats after the shedding process. Time and method of shedding could probably have contributed to the negative results since about 80 % of *F. gigantica* cercariae are shed at night (Guralp, Ozcan & Simms 1964; Da Costa, Dreyfuss, Rakotondravao & Rondelaud 1994).

From this study, *F. gigantica* metacercariae are available on vegetation surrounding snail habitats from February to October. The observed peak snail population and cercarial release during mid to end of dry season coincide with a reduction of the available grazing areas and sources of drinking water for cattle. This therefore increases the need for cattle to graze near, and drink from permanent water sources. From April to September/October, cattle are therefore ingesting metacercariae leading to a build-up of immature liver flukes and this new infection matures progressively as more metacercariae are ingested with receding water levels. Therefore, the incidence of the immature liver flukes is more likely to be high during the dry season. Egg production by *Fasciola* spp. in cattle is less persistent than in sheep and goats due to limited patent periods of infections (7–9 weeks in moderate infections and 13–15 weeks in heavy infections), lower fecundity and more rapid elimination of the flukes (Dickson 1964; Boray 1969). Hammond & Sewell (1975) found the number of *F. gigantica* in cattle beginning to fall about 28 weeks after infection and most adult parasites surviving less than a year but some surviving 3–4 years. The presence of high burdens of immature flukes and aging of previously acquired mature flukes would probably account for the low faecal egg production observed in this study during the dry season.

The findings in this study of faecal egg counts in cattle peaking from August to March suggest that the first infective stages were picked up around June/July and transmission occurred throughout October. Studies have shown that the prepatent period for *F. gigantica* varies between 8 and 12 weeks in susceptible young animals but may be longer in older or previously exposed animals (De León *et al.* 1981; Elsheikh, Ali, Homeida, Lutfi & Hapke 1992; Kaplan 1994). The patent period varies between 12 and 28 weeks (Hammond & Sewell 1975). In 8–12 weeks postinfection, the flukes mature and this probably explains the high faecal egg count seen in this study during the rainy season. Peak liver condemnations due to chronic fasciolosis in the country have been reported to be during the rainy season between December and April (Pfukenyi & Mukaratirwa 2003). Similar observations have been reported in Sierra Leone (Asanji & Williams 1984) and Zambia (Pandey & Ahmadu 1998) where peak liver condemnations

due to chronic fasciolosis were recorded during the rainy season. Both total fluke counts and the faecal egg counts were reported to be highest during the wet season in West Africa (Schillhorn van Veen, 1980a). In Malawi, the mature flukes have also been reported to be high from December to April (Mzembe & Chaudhry 1981). Hence, the mature parasites contaminate the environment during the rainy season between December and April.

Based on findings from this study, anthelmintic treatment should be administered in December/January to control chronic and mature fasciolosis. A second treatment should be given in April/May to reduce pasture contamination and subsequently snail infection, as this is the time the snail population starts to build up. To control acute fasciolosis due to the immature liver flukes, a third treatment should be given in August. Triclabendazole has been found to be effective against both immature and mature flukes (Suhardono, Widjajanti, Stevenson & Carmichael 1991; Waruiru, Weda & Munyua 1994) and may be used.

Molluscicides have been used successfully as a short-term control method (Crossland 1976) and can be cost effective (Urquhart, Armour, Doyle & Jennings 1970) but have gained little acceptance. The main problems are environmental pollution and killing of non-targeted aquatic organisms (Roberts & Suhardono 1996) and also high biotic potential of lymnaeid snails ensures rapid repopulation. However, in Malawi, Mzembe & Chaudhry (1981) recommended the application of molluscicides in June, the time when the snail is harbouring the parasite and a second application in September in order to kill new generations of infected snails. This proposed intermediate host snail control method could also probably be applicable to Zimbabwe, as the population dynamics of the snail hosts are similar. However, this method of control would prove to be difficult in the highveld where distribution of snail habitats is widespread.

Drainage or fencing-off of wet areas (Osborne 1967) prevents infection of pastures, but is rarely cost effective on grazing land in developed countries and neither is it feasible in developing countries (Roberts & Suhardono 1996). Due to widespread distribution of the snail habitats, this method is difficult or perhaps almost impossible in the communal grazing areas of the highveld.

Whatever control strategy is employed in the regions studied, it is imperative that it should be village-based as cattle in communal areas are grazed together and there is no benefit for only a few farmers to carry out the recommended control measures. The anthelmintic treatment should be organized and preferably done at the same time within a village. In communal areas cattle are dipped weekly during the rainy season and fortnightly during the dry season for the control of ticks, and diptank facilities where all animals are gathered during dipping sessions could, therefore, be used for organized worm control. However, simple user-friendly extension material to make cattle owners aware of this parasite and its control should be produced and disseminated to them and the extension staff.

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