Importance and potential impact of liver fluke in cattle and buffalo

D.B. Copeman and R.S. Copland
Introduction

In this study the potential importance of liver fluke was estimated by considering the impacts of infection at the level of individual animals, farms or smallholdings, regions, countries and globally. Economic costs have been estimated for different reasons including the justification and creation of research or control programs, to design control programs to ensure that they are targeted correctly, and to assess the impact of control programs. The total global economic loss attributed to fasciolosis has been estimated earlier to be more than US$3 billion per year (FAO 1994).

This chapter reviews studies that may be used to estimate the losses caused by fasciolosis, with a focus on large ruminants in Asia. It is estimated that 300 million bovines are exposed to fasciolosis worldwide. The review builds on an earlier comprehensive review (Spithill et al. 1999) in which impacts on weight gain, draught performance, fertility and lactation were summarised and used to develop dollar estimates of lost productivity. These authors highlight the difficulty of such estimation, citing:

- incomplete information on all the elements of offtake (including milk, draught power, meat and asset accumulation) from cattle and buffalo production systems
- the risks of extrapolation from experiments on Fasciola hepatica (in cattle and sheep)
- the high variability within and between tropical production systems in breed, sex and cropping systems
- presence of other parasite and infectious diseases.

In the face of such incomplete and diverse information it is worthwhile to question the value of making broad estimates of loss. However, there is no doubt that control programs need to be justified and supported by accurate economic data as there is increasing competition for public and private investment. Also, even broad estimates will help to direct research towards new approaches to control and projects most likely to be beneficial.

The practical questions that stimulate these studies include the following.

- How does liver fluke infection caused by Fasciola gigantica reduce the productive outputs of cattle and buffalo in tropical Asia?
- What are the best ways to measure production losses at the local level?
- What are the benefits and costs of suppressive drenching trials as a way of measuring local impact and demonstrating production losses to extension agents and farmers?
- Can GIS methods be used to predict areas where prevalence is sufficiently high to cause significant production loss?
- Can recommendations be made on the best ways to assess impact to justify, plan, implement and monitor liver fluke control programs?

The following sections review studies that estimate the existing and potential losses from F. gigantica in tropical cattle and buffalo systems. The main lessons to be drawn from these studies and the gaps that need to be filled by further research are discussed.
**National and global impacts**

Liver fluke infection (fasciolosis) of cattle and buffalo is one of the most important parasitic diseases in Indonesia (Partoutomo et al. 1985) and its impact has been estimated in several studies. Thorbecke and van der Pluijm (1993) estimated that, of the overall losses from livestock diseases in Indonesia, losses from fasciolosis are second only to Newcastle disease. Prevalence of liver fluke in parts of Indonesia has been estimated at 25–90% in cattle and buffalo (Edney and Muchlis 1962; Soesetya 1975; Beriajaya 1979; Edney and Muchlis 1962; Soesetya 1975; Beriajaya and Soetedjo 1979), and in sheep and goats (Beriajaya and Copeman 1997). Estimates of the annual economic losses have been made by several authors (Table 2.1). The figure of A$96 million (US$65 million) (Winrock 1986) accounted only for the cost of lost meat production. The total annual cost of lost meat production, lost draught power and reduced fertility in infected cattle/buffalo has subsequently been assessed at A$176 million (US$107 million).

The losses in some other countries in Asia, including Cambodia, Vietnam and the Philippines, can be estimated where the farming practices in countries are similar to Indonesia and prevalence rates for fasciolosis are comparable. In 1997 the size of the cattle and buffalo herd in Asia was estimated at 589 million (FAO 1997) with the Indonesian herd (15 million) representing 2.5% of the Asian total. Using a conservative scenario of 10% prevalence and annual loss per infected animal of US$42, economic losses in cattle and buffalo alone exceeded US$2.4 billion in Asia. Similar calculations for the African cattle herd of 201 million (FAO 1997), where prevalence rates are similar to Asia, predict losses at US$0.84 billion, bringing total world losses to at least US$3.2 billion. The worldwide annual loss from fasciolosis is a substantial figure by any valuation and possibly greater than the earlier estimate of US$2 billion by Boray (1985).

Recent studies in Cambodia (Sothoeun 2007) have confirmed the impact of fasciolosis in areas of high prevalence. Where prevalence exceeds 30%, for example, annual weight gains are reduced by 20–40 kg, pregnancy rate is lowered by 10% and there is 2.5 kg less liver available for consumption. Taking into account these losses and the costs of implementing a practical control program the net benefit per head of cattle and buffalo in these high risk zones of Cambodia is 274–326 thousand riel (A$76–91).

**Sources of production losses**

**Weight gain**

Monitoring weight gain of young animals is a useful way to assess the impacts of infection and interventions to prevent or control infection, improved nutrition or treatment with an anthelmintic. Younger growing animals are more susceptible to infection, less costly to maintain under experimental conditions and any results can be applied to production systems that are producing young growing animals for sale. A linear relationship between burden of adult *F. gigantica* and weight gain has been described in yearling zebu cattle. It was found that each fluke...

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1 Reproduced as an appendix to this monograph

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South-East Asian countries rely heavily on the draught power of livestock but liver fluke infection can markedly weaken cattle and buffaloes.
Table 2.1 Prevalence of fasciolosis caused by *Fasciola gigantica* in several Asian countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>Range (%)</th>
<th>Mean (%)</th>
<th>Number of animals sampled</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambodia</td>
<td>7–50</td>
<td>38</td>
<td>273</td>
<td>Sothoeun (unpublished)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>245</td>
<td>575</td>
<td>Sothoeun et al. (2006)</td>
</tr>
<tr>
<td></td>
<td>0–57</td>
<td>12</td>
<td>1,406</td>
<td>Tum et al. (2004)</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td>18</td>
<td></td>
<td>(409 animals infected out of 2,254 sampled)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cattle 61</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Buffaloes 31</td>
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<td></td>
<td></td>
<td></td>
<td>25 Soetedjo (unpublished)</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td>38</td>
<td></td>
<td>(Average of prevalence data)</td>
</tr>
<tr>
<td>Philippines</td>
<td>35–100</td>
<td></td>
<td></td>
<td>Tongson (1978)</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td>Molina et al. (2005)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cattle Female</td>
<td>49</td>
<td>133</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Male</td>
<td>27</td>
<td>119</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Buffaloes Female</td>
<td>50</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Male</td>
<td>37</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cattle</td>
<td>33</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Buffaloes</td>
<td>47</td>
<td>32</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td>45</td>
<td></td>
<td>(318 animals infected out of 711 sampled)</td>
</tr>
<tr>
<td>Vietnam</td>
<td>23–90</td>
<td></td>
<td></td>
<td>Luong (unpublished), 21–30% in goats</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cattle</td>
<td>76%</td>
<td>140</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Buffaloes</td>
<td>76</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coastal</td>
<td>5.3–27.9</td>
<td>11,252</td>
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<td></td>
<td></td>
<td>Delta</td>
<td>13–59.2</td>
<td>Luong (unpublished) (2,650 infected)</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td></td>
<td></td>
<td>(3,119 infected out of 11,455 sampled)</td>
</tr>
<tr>
<td>Thailand</td>
<td></td>
<td>Beef</td>
<td>212</td>
<td>Pholpark (unpublished)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dairy</td>
<td>7</td>
<td>Srihakim and Pholpark (1991)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Buffaloes</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0–85</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Laos</td>
<td></td>
<td>Cattle</td>
<td>9</td>
<td>Vongthilath (unpublished)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Buffaloes</td>
<td>21</td>
<td>274</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cattle</td>
<td>0–81</td>
<td>107</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Buffaloes</td>
<td>38</td>
<td>243</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td></td>
<td></td>
<td>(182 animals infected out of 700 sampled)</td>
</tr>
<tr>
<td>India</td>
<td></td>
<td>Cattle</td>
<td>24.4</td>
<td>Sanyal and Singh (1995)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>39</td>
<td>977</td>
<td>Gupta et al. (1986)</td>
</tr>
<tr>
<td>China</td>
<td></td>
<td>27</td>
<td>120,000</td>
<td>Jiangang (unpublished)</td>
</tr>
</tbody>
</table>
reduced the potential annual gain by about 200 g, with infected animals achieving only about half the annual weight gain of that shown by control animals (Sewell 1966). Weight change in infected animals is also a useful parameter to monitor because most cases of fasciolosis are subclinical.

One deficiency of these types of studies is that many animals can compensate for reduced growth when the cause (e.g. liver fluke) is removed and so the total impact has not been measured accurately. Further, comparisons across studies are difficult because of differences in levels of infection, the age and sex of animals, the interaction between level of nutrition and pathogenic effect, and the difference between breeds and within breeds in resistance to infection. It is sufficient to conclude at this point that reports of weight-gain reduction need to be accompanied by descriptions of all the factors known to contribute to the effect of fasciolosis, including sex, age, breed and previous exposure.

**Draught performance**

Anaemia resulting from fasciolosis has been shown to reduce work output by 7–15% (Roberts et al. 1991). Combined with a further indirect reduction of 20% in potential work capacity in animals whose growth has been restricted by fluke infection, it can be concluded that liver fluke can seriously lower the work potential of both cattle and buffalo. The economic significance of this may, however, be changing rapidly in production systems where hand tractors are replacing animals as sources of draught power. In many systems, however, even if there is a gradual reduction in their use, draught power from large ruminants remains important and should not be ignored. Indeed, as the prices for fossil fuel increase, draught animal power may remain viable in more isolated areas, particularly with poorer farmers.

The cost of the reduced draught capacity caused by *F. gigantica* may be measured as the opportunity cost to a farmer caused by the longer time taken by infected animals to perform a specific task; this amounts to about 27–35% more time with buffaloes according to the conclusions of J.A. Roberts and D.B. Copeman (unpublished). As the average draught animal in Indonesia is used in land preparation for growing rice only about 23 days per year, the opportunity cost for a farmer with infected buffalo in this situation is thus the value of his labour for about seven days per year.

Further evidence that infection with *F. gigantica* adversely affects draught capacity was collected by Suhardono (2001) in Indonesia. Farmers were surveyed during the second year of a trial to measure the effects in Ongole cattle of a single treatment with triclabendazole administered in July, about six weeks after harvest of the second seasonal rice crop in the area. The survey revealed that animals treated for fasciolosis (with triclabendazole) were used twice as many days as untreated animals for preparing land for planting rice. This result suggests that farmers recognised that the treated cattle performed better than those that were untreated. Furthermore, those with untreated animals avoided the opportunity cost associated with increased time to prepare their land by hiring animals that had received treatment. Thus, where this hiring option is available, the economic cost associated with reduced work capacity in animals infected with *F. gigantica* may be the cost of hiring replacement animals for land preparation rather than the opportunity cost of a farmer’s labour.

**Fertility**

A link has also been observed between infection with *F. gigantica*, anaemia and fertility (Suhardono 2001). There were significantly longer intercalving intervals and a lower packed cell volume in Ongole cows in Indonesia infected with *F. gigantica* than in those treated with triclabendazole each July for two years. In his study, Suhardono (2001) found that treated cows had a mean intercalving interval of 18.5 months whereas in untreated cows the interval was 31.5 months. It is thus reasonable to conclude that infection with *F. gigantica* is likely to adversely affect reproduction. Furthermore, the extent may be proportional to the degree of anaemia induced, an outcome that varies according to the level of nutrition, level of infection and breed.

**Lactation**

Needham (1977) found no measurable difference in weaning weight of calves (an indicator of milk output of their dams) from cows infected with
*F. gigantica* and those treated each 8–12 weeks with an adulticide. Such contradictory reports are to be expected due to differences between studies in factors likely to affect milk output. These include level of nutrition, size of infection and differences in resilience to infection between individuals and breeds. However, at present, too few studies have been undertaken to enable meaningful prediction of the extent to which any of these determinants affects lactation in animals infected with *F. gigantica*.

**Sources of prevalence data**

The first step in establishing the importance and cost of fasciolosis is to determine the prevalence of infestation. A simple approach to estimating the national impact of fasciolosis is to estimate prevalence in different systems, determine the loss caused by infestation per animal per year in each of these systems, and then multiply these to provide an overall estimate of impact.

No comprehensive, countrywide surveys of prevalence have been conducted in South or South-East Asia. Prevalence is difficult to establish because of the dependence on local physical and climatic conditions for the survival of the intermediate host snail (see Chapter 3). Prevalence may vary from 0% to 100% over a comparatively short distance (Srihakim and Pholpark 1991; Tum et al. 2004). Therefore, figures given for the national prevalence may conceal certain areas of high risk and high prevalence and hence loss. Nevertheless, national figures are presented in Table 2.1 to provide an overview. To establish prevalence, faeces need to be collected for faecal egg counts or livers examined for parasites in abattoirs. Both of these techniques are subject to inaccuracies. The faecal egg count method has a low sensitivity with many false negatives. Sothoeun et al. (2006) reported that 27% of animals with *F. gigantica* in their livers yielded negative faecal egg counts. Therefore, prevalence estimates based on faecal egg counts may underestimate true prevalence. On the other hand, prevalence data based on abattoir surveys may be inaccurate because older and sometimes sick animals are generally slaughtered (Sothoeun et al. 2006; Luong, unpublished).

The epidemiology of fasciolosis suggests that the prevalence would be higher in wetter, more fertile areas (see Chapter 3). These high-risk intensive agricultural areas are often associated with high numbers of cattle and buffaloes.

A further source of bias is that districts selected for study have often been chosen because preliminary data indicated these were areas of high risk. This is illustrated by the data from Cambodia. Sothoeun et al. (2006) found prevalence levels of 24.7%. However, a preliminary whole country study by Tum et al. (2004) found a national average prevalence of 11.6% (163 infected animals out of 1406 tested). Multiple methods were used to estimate prevalence and the level of infection at which each animal was categorised as ‘infected’ varied widely. Nonetheless, assuming that each infected animal lost production by an average amount determined by experimentation some national figures for the economic impact of the fasciolosis can be generated (Table 2.2).

**Regional observations of production losses**

**Giangxi province, China**

Fasciolosis is found in cattle, buffaloes and goats in all provinces of China with *Fasciola gigantica* found in 10 southern provinces. Most research has been on *Fasciola hepatica* and sometimes *F. hepatica* and *F. gigantica* were not distinguished. From 1949 to 1989 several national surveys were conducted in which major mortalities in goats, cattle and buffalo were identified. *Fasciola gigantica* is found only in south China, south of the Changjiang River. *Fasciola hepatica* and *F. gigantica* are found in varying proportions, often together in the same animals. In Guangxi *F. gigantica* was more common than *F. hepatica* and in some counties the infection rates are above 90%.

There are about 10 million cattle and buffaloes in Guangxi. They are owned by smallholder farmers who represent about 80% of the 40 million people in the province. Most of the area is mountainous and cattle and buffaloes are allowed to graze freely in hilly areas. Fasciolosis is more serious in rice-producing areas.
Table 2.2 Estimated number of cattle and buffaloes infected with *Fasciola gigantica* in various countries of Asia in areas of high or low prevalence. As an approximate indication of the total costs in each area the number of infected animals has been multiplied by the cost per infected animal derived from Sothoeun (2007, see also appendix) of between A$82 and A$98. Livestock numbers are derived from FAO (2004) and the prevalence data from Table 2.1.

<table>
<thead>
<tr>
<th>Country</th>
<th>Total number of large ruminants (thousands)</th>
<th>Prevalence scenario</th>
<th>Total number of infected animals (thousands)</th>
<th>Range of total losses (millions of Australian dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambodia</td>
<td>3,625</td>
<td>High (18.1%)</td>
<td>656</td>
<td>54–64</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low (11.0%)</td>
<td>399</td>
<td>33–39</td>
</tr>
<tr>
<td>Indonesia</td>
<td>14,000</td>
<td>High (38.2%)</td>
<td>5,355</td>
<td>439–525</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low (20.0%)</td>
<td>2,800</td>
<td>230–274</td>
</tr>
<tr>
<td>Philippines</td>
<td>5,799</td>
<td>High (44.8%)</td>
<td>2,598</td>
<td>213–255</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low (34.0%)</td>
<td>1,972</td>
<td>162–193</td>
</tr>
<tr>
<td>Vietnam</td>
<td>7,050</td>
<td>High (27.0%)</td>
<td>1,903</td>
<td>156–186</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low (15.0%)</td>
<td>1,057</td>
<td>87–104</td>
</tr>
<tr>
<td>Thailand</td>
<td>7,000</td>
<td>High (11.8%)</td>
<td>826</td>
<td>68–81</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low (11.8%)</td>
<td>826</td>
<td>68–81</td>
</tr>
<tr>
<td>Laos</td>
<td>2,350</td>
<td>High (26.0%)</td>
<td>611</td>
<td>50–60</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low (15.0%)</td>
<td>352</td>
<td>29–34</td>
</tr>
<tr>
<td>China</td>
<td>129,348</td>
<td>High (27.2%)</td>
<td>35,182</td>
<td>2,885–3,448</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low (12.0%)</td>
<td>15,521</td>
<td>1,273–1,521</td>
</tr>
<tr>
<td>India</td>
<td>283,200</td>
<td>High (25.0%)</td>
<td>70,800</td>
<td>5,806–6,938</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low (10.0%)</td>
<td>28,320</td>
<td>2,322–2,775</td>
</tr>
<tr>
<td>Total</td>
<td>452,372</td>
<td>High (26%)</td>
<td>117,932</td>
<td>9,670–11,557</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low (11%)</td>
<td>51,248</td>
<td>4,202–5,022</td>
</tr>
</tbody>
</table>
India

In India fasciolosis is widespread and is primarily caused by *F. gigantica* although *F. hepatica* is reported in the temperate Himalayan region. Building of dams and the establishment of new irrigation systems have further widened the distribution of *Fasciola* by creating more water-covered areas suitable for propagation of its intermediate hosts, the lymnaeid snails. Thus, fasciolosis has started to appear in the semi-arid and arid regions of western India where it was hitherto non-existing.

The onset and advancement of monsoon rains have a profound effect on the incidence and seasonality of fasciolosis in India. Most of the available information on the prevalence of *F. gigantica* comes from abattoir surveys and coprological studies on animals visiting clinics, and is thus biased. It is, however, apparent that the prevalence of fasciolosis in a tropical country like India is largely determined by rainfall and production systems. A review of some of the recently conducted surveys indicate a high level of incidence in the endemic areas throughout India but in the endemic areas of the northern plains, a high 10–39% infection was recorded in cattle and buffalo. A nationwide survey in dairy animals organised by the National Dairy Development Board (NDDB) indicated two critical periods in the year: July–September and February–March (Sanyal and Singh 1995).

Lao PDR

A survey of 76 cattle and 274 buffaloes killed at the slaughterhouse of the Vientiane municipality revealed infection with *F. gigantica* in the livers of 9% of cattle and 21% of buffaloes. At the slaughterhouse of Luang Prabang only 1 of 2 cattle and 17 buffaloes examined were infected.

*Fasciola gigantica*, *Toxocara vitulorum* and strongyles are regarded as the most important parasites of ruminants in the Lao PDR. Fasciolosis has a substantial negative effect on production but is not a significant cause of mortality. It is recommended that valuable animals are treated but preventive programs that rely on chemotherapy are unlikely to be sustainable (Vongthilath, unpublished; Douangngeun, unpublished.)

Philippines

Fasciolosis is still the leading cause of morbidity and mortality in ruminants in the Philippines. Fasciolosis research has always played second fiddle to research on the more dramatic and explosive diseases with international implications, which would account for the meagre research output. The low research priority given by the national government to fasciolosis and other economically important parasitic diseases and the lack of trained manpower for research have all contributed to a lack of qualitative and quantitative information.

Of the 252 cattle examined in Cotabato (Mindanao) in 1997, 173 (69%) were found infected with *F. gigantica* based on the presence of *Fasciola* eggs in the faeces. Cattle older than four years had the highest prevalence (82%), for those two to four years old the prevalence was 78% and for those five months to two years, prevalence was 53%. The prevalence was 72% in females and 62% in males. Barangay Bannawag had the highest prevalence proportion (92%), followed by Katidtuan (89%). Proportions of animals infected among eight villages ranged from 36% to 73%.

A study in two slaughterhouses (Mlang and Kabacan) in 1999 determined the prevalence of fasciolosis in cattle and carabaos. All animals from Mlang were negative for fasciolosis. Of 282 animals examined from Kabacan, 83 (33%) cattle and 15
(47%) carabaos were positive. There was a higher prevalence of fasciolosis in cattle and carabaos older than six years (69% and 59%, respectively). Carabaos three to six years old had a prevalence of 25% and those younger than one to three years 17% (Molina et al. 2005).

**Thailand**

The economic loss from fasciolosis in cattle and buffalo throughout Thailand has been assessed at not less than 100 million Baht (about US$3 million). Recent investigations have shown that the average prevalence of *F. gigantica* in cattle and buffalo in Thailand was 12%. However, the prevalence varies considerably between villages, ranging from 0% to 85%. Prevalence is high in areas surrounding dams or large ponds in which *Lymnaea auricularia rubiginosa*, the intermediate host of *F. gigantica* is found. The disease has a seasonal pattern on which control of the disease is based. All cattle and buffalo older than eight months should be treated for liver flukes each September. In addition, animals in poor condition should be treated in April to prevent severe losses, especially in high-prevalence areas or where strategic treatment was missed.

Diagnostic results of the Northeast Regional Veterinary Research and Diagnostic Center in 1998 revealed that the average prevalence proportions of infection with *F. gigantica* in beef cattle, dairy cattle and buffaloes in north-east Thailand were 22%, 7% and 7% respectively. However, the prevalence varied considerably between villages.

Humans are also infected with *F. gigantica*. From 1967 to 1990, 25 cases of human fasciolosis were reported in Thailand, of which 19 occurred in the north-east. Since then at least 10–20 new cases of human fasciolosis have been confirmed in the Khon Kaen University Hospital each year. Fasciolosis should therefore be regarded as a newly emerged zoonosis and an important public health problem (Pholpark, unpublished).

**Cambodia**

A national survey was conducted in Cambodia to identify zones of high prevalence for further studies into the epidemiology of this infection. Faecal samples were collected from 273 cattle and buffaloes in October and November 1998 and examined for *F. gigantica* eggs. The 14 villages in this study were in Saang district of Kandal province and in Cheung Prey district of Kompong Cham province. The proportion of animals with *Fasciola* eggs in their faeces varied greatly from village to village. All villages in Cheung Prey district had < 20% prevalence and the mean of samples from these villages was 7%. In Saang district, one of the six villages had a low prevalence, two had a medium level (20–50%), and two had a high prevalence (> 50%). The average prevalence in Saang district was 38% (Suon et al. 2006).

**Vietnam**

Between 1996 and 1998 faeces of 11,252 cattle or buffaloes from different regions of Vietnam were examined for eggs of *F. gigantica*. Prevalence varied from 5–28% in the coastal areas to 13–59% in the delta areas. In earlier studies age was shown to be an important determinant of infection. Prevalence increased from 16% in animals younger than three years to 37% in animals older than five years. An abattoir survey of 495 cattle and buffaloes also revealed increasing prevalence with increasing age. At three months of age, 6.8% of animals examined were infected. Prevalence in animals from four to six months old was 11%, from 7–12 months 36.4% and from 12–24 months 45.5% (Luong, unpublished).

**Nepal**

Among the diseases of ruminants, fasciolosis is probably the most common and perhaps one of the most important causes of livestock deterioration in Nepal. It is widespread throughout the country, affecting all species of ruminant livestock, including yaks and yakows of the Himalayas. The different local names of this disease, such as namle, mate and lew, in different regions are proof of its continued existence for many years in Nepalese animals.

Singh et al. (1973) reported an infection rate of 50–90% in animals in areas below 1800 m and estimated it caused an annual economic loss of NRs 200 million (US$20 million). Recent studies have indicated a similar prevalence of the disease but a higher estimate of economic loss (US$37 million) calculated only on decreased buffalo milk and buffalo meat production (Mahato 1993; Mahato et al. 1997).
Although infections with *F. hepatica* have been reported, infection with *F. gigantica* is the most common and widespread cause of fasciolosis throughout the country. Among the species of lymnaeid snails found in Nepal, *Lymnaea auricularia* race *rufescens*, *L. auricularia* sensu stricto and *L. viridis* have been identified as the important intermediate hosts.

The pre-monsoon rains together with rice cultivation practices promote habitat creation for *Lymnaea* spp. over a wide area. After the monsoon when rice is harvested, animals acquire infection during grazing from heavily contaminated rice fields. Rice straw, the principal food of large ruminants during the dry season (December–April), is another important source of infection with *Fasciola*, especially in stall-fed animals. Thus, it appears that there is a good case for introducing appropriate management practices to prevent animals becoming infected.

In Nepal, attempting to control the intermediate hosts using molluscicides, even during the dry season, is of limited value because of the numerous permanent habitats and the great biotic potential and aestivating ability of the lymnaeid snails. Epidemiological studies have revealed that most snails are infected by fluke eggs deposited on pasture during March–May and again in October–November. This pattern suggests that administration of anthelmintic in February and again in late August to control pasture contamination is an appropriate strategy for the control of fasciolosis in Nepal.

**Suppression trials with anthelmintics**

Applying anthelmintics to kill off existing infections and prevent new ones has made it possible in a few cases to measure production loss in situ. That is, infected and uninfected animals have been compared in their normal production environment. The value of such studies is that an upper limit of acceptable benefits for deworming or other control measures can be estimated without having to rely on extrapolation from experimental results. The disadvantage remains, however, that to estimate the total effect, treatment needs to be continued for at least a complete season. Even then the impacts on reproductive rate are not included. The results of the three studies described below have been important in increasing the accuracy of production loss estimates and raising awareness among scientists, policymakers and farmers, of the magnitude and extent of the liver fluke problem. These, in themselves, are important outcomes.

**Philippines**

A two-year suppressive treatment study begun in February 2000 compared irrigated and rainfed cropping systems. Selection of the study areas was based on the recommendation of livestock technicians. The number of animals, willingness of the animal owners and barangay officials to cooperate, accessibility of the area and whether they were from a Christian or Muslim area were all taken into account.

Takepan was chosen for the irrigated cropping system, and Colambog for the rainfed area. Both areas are in Pikit, Cotabato province and inhabited by both Muslim and Christians. Buffaloes and cattle were weighed, drenched with triclabendazole (*Fasinex*-Novartis) at a dose rate of 24 mg/kg body weight and 12 mg/kg body weight respectively. Two other areas, Dagupan in Kabacan and Datu Paglas in Maguindanao, serve as controls for the rainfed and irrigated areas, respectively. Data such as age, sex, body weight, reproductive performance, feeding system, draught power and function of the animals were gathered from both the treated and the control groups every four months for two years. All animals used in the study were marked with ear tags. The buffaloes are used for draught power for land preparation in lowland and in upland areas and for hauling farm products such as coconuts, rice, corn and other farm products from the field to the market. Cattle, however, were used for meat and breeding and not for draught power. Cattle and carabaos (buffaloes) graze communal areas near the dikes or river banks and canals and, from the rice planting to harvesting period, are fed with grasses by a cut and carry system or allowed to graze.

Information programs and consultations with barangay (district) officials and animal owners were conducted before the study began. Information about the project and its activities, about fasciolosis and about possible benefits from the study were
explained. Faecal egg counts were done to determine the prevalence of fasciolosis in the respective areas.

The average age at first calving was 4.0 years old in carabaos and 2.6 in cattle. The age group of one day old to three years old was more common than the older age groups in all study areas. There were more cattle (643) than carabaos (501) and more female animals (772) than male (340) and castrated animals (32). The mean live-weight gain per day was higher in treated animals in the irrigated area (0.32 kg) than in the control group (0.24 kg). However, in the rainfed area it was higher in the control group (0.35 kg) than in the treated group (0.29 kg). Generally, cattle had higher weight gain than in buffaloes in all study areas except in the control irrigated area with few cattle. The intercalving interval in buffaloes in control treated and rainfed areas was the same (19 months) but was higher in the treated irrigated areas (13 months) than in the control irrigated area.

In cattle, the intercalving interval was 16 months and 14 months in treated rainfed and irrigated areas and 15 months in control rainfed. However, data on the intercalving interval for controls in irrigated areas are not yet available. The prevalence rate for fasciolosis infection during the preliminary sampling in the study areas ranged from 33% to 95%.

Indonesia

A study by Suhardono (2001) demonstrated that the treatment of cattle reared in West Java in association with intensive production of irrigated rice with triclabendazole in July significantly reduces their level of exposure to infection with *F. gigantica* over the following 12 months. In comparison with untreated animals treated animals had improved reproductive and draught performance and higher packed cell volume (PCV) values, and yearlings had a higher weight gain. It was concluded that the timing of such
annual treatment should be about six weeks after harvest of the second seasonal rice crop in an area. Furthermore, to achieve the best effect, all animals sharing common grazing should receive treatment.

Treatment in July may be regarded as strategic as it is about six weeks after the end of the period when rice is harvested, which is when most infection with *F. gigantica* occurs in this area.

**Cambodia**

The impact of fasciolosis on weight gain, reproductive performance, draught capacity and PCV of cattle was studied in the upper delta of the Mekong River in Cambodia where the risk of infection with *F. gigantica* is high (Tum et al. 2004). Farmers in two villages in Saang province, Preak Samrong and Preak Trang, participated in the study. Cattle in Preak Samrong were maintained free from infection with *F. gigantica* by treating them every three months for nine months with triclabendazole at 12 mg/kg body weight. No control of *F. gigantica* was practised in Preak Trang but cattle received the placebo Zanisef every three months. At the start of the study, there were 224 cattle in Preak Samrong village made up of 60 castrated males, 113 females, 49 male calves and 2 bulls. In Preak Trang village, there were 202 cattle comprising 13 castrated males, 144 females, 41 male calves and 4 bulls. Every three months all animals were weighed, faeces were collected for examination for *Fasciola* eggs, blood was collected for estimation of PCV, and condition score, skin coat, and draught strength were recorded. Weights of pregnant females were adjusted to remove the effects of pregnancy.

In Preak Samrong 52 animals were sold: 13, 26 and 13 during first, second and third periods of three months respectively. In Preak Trang, 69 cattle were sold during the same periods comprising 32, 14 and 23 animals respectively.

Mean weight gains of males and females were similar for the age group 0–0.5 years and for 0.6–1.5 years so were combined in analyses of differences between control and treated groups. Nine months after observations began treated males plus females in both the 0.5–1.5 years and 1.6–2.5 years age groups had gained significantly more weight than comparable animals in the control village (Table 2.3). During the same period weight gains of treated and control castrated males three years of age and over were similar, as were weight gains of females in this age group (Sothoeun et al. 2006).

### Table 2.3 Comparison of mean weight gains ± SE of treated and control groups over the nine months of observations in Cambodia.

<table>
<thead>
<tr>
<th>Groups compared</th>
<th>Treated (kg, mean ± SE)</th>
<th>Control (kg, mean ± SE)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male + female 0.5–1.5 years</td>
<td>99.0 ± 10.3</td>
<td>74.2 ± 4.9</td>
<td>0.02</td>
</tr>
<tr>
<td>Male + female 1.6–2.5 years</td>
<td>86.4 ± 4.4</td>
<td>73.9 ± 4.3</td>
<td>0.05</td>
</tr>
<tr>
<td>Castrated male 3 years and over</td>
<td>45.1 ± 4.9</td>
<td>43.1 ± 4.7</td>
<td>0.77</td>
</tr>
<tr>
<td>Females 3 years and over</td>
<td>39.3 ± 6.7</td>
<td>28.3 ± 4.8</td>
<td>0.19</td>
</tr>
</tbody>
</table>

### Predicting impacts using geographical information systems

A geographic information systems (GIS) model for mapping the risk of fasciolosis in cattle and bufaloes was developed for the Kingdom of Cambodia using determinants of inundation, proximity to rivers, land use, slope, elevation, and the density of cattle and buffaloes. Determinants were subjectively weighted according to their perceived relative importance before combining them to produce a risk map of fasciolosis. The model estimates that 28% of Cambodia is potentially at risk of fasciolosis with...
areas of high and moderate risk concentrated in southern and central Cambodia. The estimates of risk reflect the actual prevalence of fasciolosis in most districts surveyed, suggesting that the epidemiological determinants and weightings used to produce the model were appropriate. These results will be progressively refined as more detailed field surveys are completed to fully validate the model. A comparison between levels of risk predicted by the maps and field measurements of prevalence in 11 provinces (n = 1406) showed general agreement, which suggested that the epidemiological determinants and weightings used to produce the maps are appropriate (Tum et al. 2004). One constraint on the validity of this conclusion was that prevalence was measured at the provincial level, a very large unit, and animals were not sampled at random. An additional study sought to correct this deficiency by measuring prevalence at a more detailed scale, at district level. Faecal samples were collected from a randomly selected set of animals in four districts in one province for areas at high, moderate and no risk. This result supported the earlier conclusion that there is a good relationship between prevalence and risk predicted by the GIS model (Figure 2.1).

In Thailand (Pholpark, unpublished observations) fasciolosis is one of the most important parasitic diseases in adult cattle and buffaloes in north-east Thailand. Prevalence varies considerably between villages. It is higher in areas surrounding dams or large ponds in which Lymnaea (Radix) auricularia rubiginosa, the snail intermediate host of F. gigantica, is found. Strategic treatment with an effective drug is considered to be the most effective control measure. In this study, instead of performing an epidemiology survey, a GIS is being applied to define the fasciolosis risk areas and the
appropriate time for strategic treatment of animals. In a pilot GIS study in Khonkaen province during 1999 the parameters used for analysis of the data were surface water, rainfall, temperature, and the boundary of the province, district or subdistrict. From results of the pilot study the high *Fasciola* risk areas and the time for strategic treatment were defined quite accurately when compared with the results of the epidemiological study that had been conducted from 1982 to 1984 (Srikitjakarn et al. 1988). However, the parameters used were considered too imprecise. To improve their predictive precision, seven parameters are now being used for analysis of data in the current GIS field trial in Kalasin province. They are:

- temperature
- rainfall
- surface water
- boundary of river, brook or irrigation canal
- slope class
- boundary between wet lands and grazing areas
- the boundary of the province, district, or sub-district.

**Conclusions**

It is evident from these studies that comprehensive data on the impact of fasciolosis over several years are difficult and expensive to obtain. This is due mostly to the long-term and chronic nature of the disease, its multiple effects on productivity and the difficulty of making an accurate diagnosis. There is also a natural bias in many studies, including those reported here, to focus on areas where the problems are known and not undertake a systematic survey with a wider statistical base. Nonetheless there is no doubt that the disease is widespread throughout most of tropical Asia with hotspots in areas susceptible to seasonal flooding and irrigated rice production. The exact figures will always be open to discussion but a consensus view would be that the impacts are relatively high and often unrecognised.

The challenge is how to use the information. Two pathways are suggested by the data reported here. One is to make use of increasingly accessible technologies based on GIS mapping to make predictions about places and systems that can be targeted for control programs. As more data are

![Animals infected by liver fluke produce fewer offspring and the interval between litters is longer.](img)
collected the predictive models for such programs will become more accurate and useful to planners and extension services. The second pathway is to develop relatively simple ways to demonstrate to farmers and extension workers the impacts of fasciolosis and the benefits of control. Computer models and reports are not sufficient to convince them that their time and resources should be used for fluke control when there are so many other competing demands. The use of suppressive drenching with monitoring of the impacts by farmers and extension workers themselves may provide the required stimulus.

References


Epidemiology of *Fasciola gigantica* in cattle and buffalo

Suhardono and D.B. Copeman
Epidemiology of *Fasciola gigantica* in cattle and buffalo

Suhardono and D.B. Copeman

### Introduction

The patterns of infection of liver fluke are determined by the interaction of environmental factors, the biology of the parasite and the production system in which cattle and buffalo are expected to perform. Given the essential relationship between the parasite *Fasciola* and the water-dwelling snails of the genus *Lymnaea* that act as intermediate hosts, it is no surprise that liver fluke disease is most common in rice production systems (or areas providing a suitable habitat for the intermediate host), which may be contaminated with parasite-containing cattle faeces. These systems are not static, with gradual transition from single to double, to sometimes triple rice crops per year, and increasing reliance on machinery to replace large ruminants as a source of draught power. Nonetheless it is still common for cattle and buffalo to be allowed to graze on recently harvested rice paddies, and straw to be cut and carried to stall-fed animals. Cattle faeces, possibly containing parasite eggs, are also used as fertiliser in many rice production systems.

A series of experiments and surveys from ACIAR projects are described which, when taken with other published work from other parts of Asia, identify opportunities for intervention and control. The results underscore the paradigm that has dominated modern integrated control of parasites: that control can only occur when the life cycle, environmental interactions and production systems are well understood.

The practical questions that stimulated these studies include the following.

- What is the seasonal pattern of liver fluke infection and how best can it be assessed in smallholder farming systems?
- What is the role of snails in the transmission of *Fasciola gigantica* in each of the production systems studied?
- What are the sources of infection for snails, and for large ruminants by metacercariae, and can these sources be eliminated?
- What opportunities are available for biological control through competition with the intermediate stages of *F. gigantica*?
- How do sources and patterns of infection differ between rice-based systems and more extensive grazing systems?

### The parasite

*Fasciola gigantica* is one of the most important parasites of cattle and buffalo in the humid tropical areas of the world. In some regions it may also be important in sheep, goats and other domestic animals. Wild herbivores are susceptible, but laboratory animals are not readily infected. Human infection may be more common in endemic areas than the occasional case reports suggest. Hammond and Sewell (1975) proposed that *F. gigantica* is better adapted to cattle than sheep in that it is more infective and lives longer in cattle.

The intermediate hosts of *F. gigantica* are tropical aquatic snails which thrive in clear, stagnant or slow-moving water with high oxygen content and abundant aquatic vegetation (Kendall 1954). Such ecological situations are typically found at the fringes of rivers or lakes where the water levels are stable, and in irrigated rice fields throughout the humid tropics. *Fasciola gigantica* is transmitted worldwide by snails not readily distinguishable on morphological grounds or on grounds of their ecological requirements from the single superspecies *Lymnaea auricularia sensu lat.* (Kendall 1965). The life cycle...
Once the water level drops too fast during the dry season for the fringing aquatic vegetation to persist or the oxygen level drops too low, the habitat will be rendered unsuitable for these snails (Kendall 1954). In irrigated rice fields the population of snails is influenced by the availability of water for irrigation and the stage of growth of the crop. Snails and their eggs surviving from the previous crop may colonise recently planted rice fields or they may enter with water introduced to flood the field after planting. Their numbers then increase over the next few months before declining again a few weeks before harvest (Widjajanti 1989). Despite being aquatic, the snail hosts of *F. gigantica* are able to survive desiccation in the shade on the surface of the soil for some weeks. After one month, Widjajanti (1989) observed that mean survival time was reduced by about one-third, and egg masses by about one-half relative to hydrated controls. However, she found no adverse effect of desiccation for one month on subsequent hatchability of eggs. The eggs did not hatch until rehydrated, prompting her to propose this as a possible mechanism for survival of the population in habitats subject to periodic desiccation.

**Figure 3.1** The life cycle of *Fasciola gigantica* (w.p.i. = weeks post infection).

![Life cycle diagram of Fasciola gigantica](image-url)
The time taken for miracidia to develop in eggs of *F. gigantica* and for sporocysts, rediae, and cercariae to develop in snails varies with temperature. Grigoryan (1958) considered 24°C to 26°C optimal for development of miracidia, found that eggs did not survive temperatures more than 43°C and desiccation was rapidly fatal. At 27°C cercariae may develop as early as 26 days after snails are infected (al Kubaisee and Altaif 1989). Development of larvae in the snail becomes slower as the temperature drops and it eventually stops. Below 16°C only a succession of daughter redial generations are produced, but they switch to production of cercariae when the mean temperature is raised to 20°C (Dinnick and Dinnick 1964). Cercariae are shed in up to 15 waves (usually three or fewer) one to eight days apart over a period of up to 50 days (Grigoryan 1958; Da Costa et al. 1994; Dreyfuss and Rondelaud 1994). Maximum shedding at the optimum temperature range of 25°C to 27°C occurs 46–50 days after infection (Dinnick and Dinnick 1963; Asanji 1988). The number of cercariae produced per snail is usually a few hundred, but varies from fewer than one hundred to over a thousand.

After release from the snail, cercariae exist as metacercariae. About two-thirds attach to various objects near the surface to the water (Ueno and Yoshihara 1974). The remainder become floating cysts (Dreyfuss and Rondelaud 1994). Floating cysts may move with the flow of water to become a source of infection where the habitat is unsuitable for snails and therefore presumed safe from infection. The duration of survival of metacercariae is inversely related to temperature and directly to the degree of hydration. In water at 26°C, a high proportion of metacercariae remained viable for six weeks, but few were viable after 10 weeks. At 30°C and 35°C, however, few metacercariae remained viable after five and two weeks respectively. When metacercariae are stored out of water, the duration of their viability is directly related to relative humidity, and inversely to temperature and exposure to sunlight. All metacercariae stored at 21–31°C and 30–50% relative humidity were dead by day 35 (Grigoryan 1959). Desiccated metacercariae exposed to direct sunlight were all dead within eight hours. In lowland equatorial regions, therefore, aquatic habitats should be safe to graze about two months after death of snails but this period will be extended in cooler habitats for up to six months. Similarly, metacercariae which become dry on aquatic vegetation as a result of receding water levels or on hay are likely to be no longer infectious after about six weeks in lowland tropical areas but may survive up to about four months in cooler climates.

Exposure of animals to infection with *F. gigantica* from rivers and lakes may be restricted to only a few weeks each year. Infection usually occurs about two months after the habitat becomes stable (and thus favourable for snails) towards the end of the wet season and persists during the dry season for a few weeks after the habitat is no longer suitable for snails. Exposure of animals to infection from irrigated rice fields occurs when stock graze stubble, eat rice stalks after harvest, or drink water flowing from the fields. Exposure will occur throughout the year in regions where rice cropping is continuous, but only for a few weeks after harvest when rice cropping is seasonal. Infection is highest from fields fertilised with animal manure.

Newly encysted metacercariae require at least 24 hours to become infective (Boray 1969). Larval flukes develop in the hepatic parenchyma and, in cattle, enter the bile ducts about 89 days after infection (Guralp et al. 1964). The prepatent period is about 14 weeks (Grigoryan 1958; Guralp et al. 1964; Sewell 1966). The output of eggs rises for the first 12–14 weeks after eggs appear in the faeces then falls to low levels (Sewell 1966; Prasitirat et al. 1996). With the same infecting dose, faecal egg counts are up to 80% lower in buffaloes than in cattle (Prasitirat et al. 1996). Hammond and Sewell (1975) found the number of *F. gigantica* in cattle begins to fall about 28 weeks after infection. Most survived less than a year but some survive up to four years (Alicata and Swanson 1941; Hammond and Sewell 1975).

A sound understanding of relationships between the life cycle of *F. gigantica* and the system of seasonal flooding of rice paddies in South-East Asian countries (Figure 3.2) is essential for developing control strategies for fasciolosis.
Figure 3.2 (a) The annual cycle of rice production on irrigated or rainfed rice paddy showing the development of the snail population and infective liver fluke metacercaiae.

Figure 3.2 (b) The annual cycle of rice production and grazing on the banks of seasonal lakes and rivers showing the development of the snail population and infective liver fluke metacercaiae.
Eggs in faeces

The transmission cycle of *F. gigantica* is dependent on the expulsion and survival of eggs in faeces until the eggs hatch and the resulting miracidia are released into water. Management of dung has the potential to reduce transmission, especially when cattle and buffalo dung are used to fertilise rice paddies; a common practice throughout Asia.

The projects studying eggs per se have focused on:

- reducing the numbers of eggs that survive and hatch through an examination of environmental factors that enhance and reduce survival
- improving methods to detect eggs in faeces—which had the dual purpose of improving field diagnosis of infection and evaluation of control strategies under field conditions.

Survival of eggs in dung heaps

An experiment was conducted to evaluate the impact of exposure to sun on the eggs of *F. gigantica*. Eggs were placed in dung heaps located in the shade or exposed to the sun, and examined at intervals for up to 14 weeks. Fewer viable eggs were recovered from Petri dishes than dung heaps and the rate and extent of decline in viability of eggs was greater in dung exposed to the sun than in shaded dung. This difference was attributed to the higher temperature in dung in the sun than the shade, due to the effect of direct sunlight on exposed dung and a higher rate of fermentation in exposed than shaded dung.

It was concluded that strategies for storing dung which would reduce the risk it poses for infecting *L. rubiginosa* with *F. gigantica* when used as fertiliser in rice fields include:

- storing dung in the sun rather than the shade, preferably in a thin layer to heat and desiccate it
- mixing a carbohydrate with the stored dung to increase heat through fermentation (Suhardono et al. 2006a).

To further test the hypothesis that increasing the heat generation during a composting process would reduce egg development, a trial was conducted (Suhardono and G. Adiwina, unpublished) using a microbial additive that has been adopted by some farmers in Indonesia as a means of improving the quality of manure as organic fertiliser. It is expected that the technology will also be useful for controlling fasciolosis through generation of heat, interfering with the development of eggs of *F. gigantica*.

Three types of marketed micro-organism (Stardec®, Gama 96®, and Em-4®) were used in this study. There were five heaps of faeces, each 150 cm long, 60 cm wide and 30–40 cm high, four of which were treated with microbes and one used as a non-treated control, all located in the shade. Group I was mixed with Stardec®, Group II with Gama 96®, Group III with Em-4® (remixed if the temperature was more than 50°C), and Group IV was faeces mixed with Em-4® (remixed every 24 hours). Five samples of faeces from groups I and II were collected every week for three weeks. They were then incubated in the dark at room temperature for three weeks, with a change of water every week, to promote development of *Fasciola* eggs. A similar procedure was applied to faeces in groups III and IV but samples were taken every day for four days. The temperature in the pile of faeces in Group I was 41–43°C from days 1 to 7 then decreased rapidly. In Group II, the temperature was 37–40°C. In Groups III and IV from 12 hours post incubation the temperature was 42–60°C. The hatchability of eggs in the non-treated control group was 71%. Almost no eggs developed in Groups I, III and IV from faeces collected any time after deposition. From Group II, however, a few eggs developed from the sample collected in week 1 but none in weeks two and three. From this study it can be concluded that addition of micro-organism in the process of
decomposition of faeces can kill eggs of *F. gigantica* and could be promoted as a way to reduce infection of snails with *F. gigantica* in rice fields where faeces is used as fertiliser.

**Improved detection methods**

One of several methods used to confirm liver fluke infection is by finding fluke eggs in the faeces. This is most effectively done using concentration techniques (e.g. Taira et al. 1983). Concentration can be achieved by both flotation and sedimentation of fluke eggs. The flotation method, which is generally used for concentrating nematode eggs, can also be used to float eggs of *Fasciola* spp.. However, the eggs become distorted, making it difficult to differentiate between eggs of *Fasciola* spp. and those of *Paramphistomum* spp. Methods based on sedimentation of eggs do not have this drawback. They are also easy to perform, require little equipment and not only allow detection but also enable quantification of fluke eggs in faeces. As a consequence, techniques based on sedimentation are widely used for this purpose. Most are based on the method described by Boray and Pearson (1960). However, the sensitivity and repeatability of a technique based on this method was found to be low when used for detecting eggs of *F. gigantica* in bovine faeces. A series of experiments was conducted to find a more sensitive and reliable method consistent with the capacity of diagnostic laboratories in Asia (Suhardono et al. 2006b).

In summary, the method uses 3 g of faeces suspended in 0.05% Tween-20. The suspension is passed through three 6-cm diameter sieves in tandem to remove fibrous debris, with respective apertures of 1 mm, 450 μm, and either 266 or 200 μm. The filtrate is allowed to sediment for three minutes in a conical flask, is recovered, and then resuspended in 200 mL of 0.05% Tween-20 and once more allowed to sediment for three minutes. The sediment is washed in a sieve with an aperture of 53 μm, which retains the eggs but allows fine debris to pass through. Residue on the sieve is recovered in about 15 mL of water to which one or two drops of 1% methylene blue are added. The eggs are counted using a dissecting microscope. Use of Tween-20 instead of water as the suspending agent for faeces increased the proportion of eggs recovered threefold and reduced variability between repeated counts. This method can detect about one-third of the eggs present. It was concluded that the high proportion of *F. gigantica* eggs lost may be due to the presence of hydrophobic and covalent bonds on the eggs which bind them to debris with which they are discarded. The method is fully described in a published paper (Suhardono et al. 2006b).
**Snail ecology**

**West Java**

Fasciolidae need one intermediate host, a freshwater gastropod from the superfamily of pulmonate snail, family Lymnaeidae. In tropical regions *L. auricularia sensu lat.* serves as intermediate host of *F. gigantica* (Hubendick 1951; Kendall 1954). Besides *Fasciola* the snail also serves as an intermediate host of other trematodes (Basch and Lie 1965; Boray 1985; Estuningsih 1991). *Lymnaea rubiginosa* is a fully freshwater snail (Van Benthem Jutting 1954) and serves as intermediate host of *F. gigantica* in Indonesia (Boray 1980; Muchlis 1985). Other species of *Lymnaea* have been found in Indonesia (Boray 1980) but have proven to be totally resistant to *F. gigantica* infection. The distribution of *L. rubiginosa* in Indonesia is widely spread and the biology of the snail is well described by Widjajanti (1990). Little is known of the population dynamic of this snail in the area where agricultural activities are conducted intensively. Since it is known that the life cycle of the liver fluke is heavily dependent on *L. rubiginosa* then it is clear that the distribution of the disease will be determined by that of the snail. The aim of this study is to determine the population dynamics of the snail *L. rubiginosa* in the rice paddy environment and its infection with fluke trematodes.

A field study was conducted in five villages in the subdistrict of Surade in West Java. In summary the findings were that the population dynamics of *L. rubiginosa* in the paddy fields vary with the cropping practices of wet paddy and that the population was very high during the wet season. More snails were found close to human habitation and more of these were infected with trematode larvae. Passive migration in streams formed by heavy rain is the most important way that snails are disseminated into new habitats such as paddy fields. In the dry season most snails die from lack of water, with the surviving snails being mainly in streams, rivers or water springs. There is no sign of snail aestivation during droughts. Infection with *F. gigantica* in snails occurred throughout the year with the peak in May, October and February. Infection with non-*Fasciola*, mainly echinostome, tended to occur more in the dry season than in the wet.

A more detailed study was conducted in West Java to catalogue all the trematodes that use *L. rubiginosa* as a first intermediate host and to identify their definitive hosts (Estuningsih and Copeman 1996). Trematode larvae in 3,253 *L. rubiginosa* were collected from irrigated rice fields at five sites around Bogor, and another 2,875 from Surade. Four types of cercariae were found in snails from the Bogor area: echinostome, strigeid, *Trichobilharzia* sp. and xiphidiocercariae; whereas in snails from Surade there were xiphidiocercariae and cercariae of *F. gigantica*, *Schistosoma* sp. and echinostomes.

The larval echinostomes found in *L. rubiginosa* from the Bogor area, and adult echinostomes in domestic ducks and chickens which grazed harvested rice fields in this area were both identified as *Echinostoma revolutum*. Since no echinostome was found in 24 rats, 11 lizards or 35 frogs caught in the vicinity of the Bogor rice fields, it was concluded that domestic ducks and chickens were the main definitive hosts for *E. revolutum* in the area. The implication here is that the prevalence of cercaria of *F. gigantica* in the snail population is a very poor indicator of the prevalence in the definitive hosts of interest.

Manure used as fertiliser contains liver fluke eggs, and flooding of rice paddies before planting allows snail populations to build up.
Cambodia

The snail ecology study in Cambodia was conducted from April 1999 to March 2001 in two communes of Saang district, Kandal province: Knong Preak village of Preak Koy commune and Preak Kseow village of Rokar Kpos commune.

The snail density in the two collection sites varied markedly throughout the year. In Preak Kseow village snail density rose from 0.29 snails/m² in November 1999 to 14 snails/m² in May 2000, then peaked at 19 snails/m² in June but rapidly decreased after this. Again, in November 2000, snail density increased from 0.34 snails/m² to 3.46 snails/m² in February 2001. Preak Kseow village had a six-month period of snail density at a level of greater than 5/m². Snail density was greater than 5/m² from February to July inclusive. Knong Preak had a snail density of greater than 5/m² for only two months, December and January. Density peaked at a higher level of 27/m² in January but tailed off to a long period when no snails were found from March to October. Snail density again increased from few in November–December 2000 to a peak of 12.26 snails/m² in January 2001, then dropped immediately to zero in February.

In most of the year in Preak Kseow there was a low but constant rate of infection, below 5%, of snails with *Fasciola* larvae except for a peak in September 2000 (17.2%). The percentages of snails infected with larvae of *Fasciola* were as follows.

<table>
<thead>
<tr>
<th>Month</th>
<th>1999 %</th>
<th>2000 %</th>
<th>2001 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>4.7</td>
<td>2.7</td>
<td></td>
</tr>
<tr>
<td>February</td>
<td>0.7</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>March</td>
<td>0.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>0.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>June</td>
<td>2.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>July</td>
<td>0.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>August</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>September</td>
<td>17.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>October</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>November</td>
<td>0.0</td>
<td>4.8</td>
<td></td>
</tr>
<tr>
<td>December</td>
<td>2.3</td>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>

Only the months of August, October, December 2000 and January 2001 showed no infection of snails with *Fasciola* larvae.

In Knong Preak village of Preak Koy commune snail infection with larvae of *Fasciola* occurred only in December 1999 and January 2000 with infection rates 0.4% and 3.6% respectively. Infection occurred again in November–December 2000 and January 2001 with infection rates of 0.6%, 1.1% and 0.9% respectively. No infection occurred in the remaining months (Southeun, unpublished observations).

**Infection of snails by the intermediate stages of *Fasciola gigantica***

The results of the study indicated that the prevalence of the larval stage of fluke infections related to the proximity to human settlement (and the accompanying animal pens). Both the size of the snail population and its infection with trematodes are inversely related to the distance from kampongs (villages). Infection with *F. gigantica* was not detected in small snails 10 mm long and most infections are in the size classes 2 and 3 (10–20 mm). The infection of snails is dominated by the disposal of ruminant faeces containing the eggs of the parasite into fresh water. This occurs particularly where faeces are applied to the paddy fields as a fertiliser, and where the drainage from cattle pens goes directly to the paddy fields. The highest prevalence of infection in snails is in paddy fields directly adjacent to cattle pens. There is also infection at the drainage level of the next lower paddy field but the level of infection was extremely low. Infection with non-*F. gigantica* trematodes was higher than that with *F. gigantica* and the highest was in the fields directly adjacent to cattle pens. Based on the result of this preliminary study, further work was therefore designed in two selected snail habitats in rice field areas, one close to a kampong (< 100 m) and the other remote (500 m) and was started in the following month in May 1993 (Suhardono 2001).
Competition with *Echinostoma*

**Echinostoma** in other hosts

In a series of experiments to investigate further the host range of *Echinostoma*, 50 mallard ducks as well as native chickens, rats and edible frogs were examined for the presence of *E. revolutum* (Gonzaga and colleagues, unpublished observations). The study aimed to show the percentage of ducks, chickens, field rats and edible frogs with echinostomosis and which organs were commonly inhabited by the trematodes, and compared the carcass weight of infected and non-infected ducks.

*Echinostoma revolutum* were found in the caecum and large intestine of 24 (48%) mallard ducks, 27 (54%) native chickens and 23 (46%) rats examined. There were no *E. revolutum* found in the alimentary tract of edible frogs.

It was concluded that infection of *E. revolutum* is sufficiently common in mallard ducks, native chickens, and rats in the Kabacan region that they would be a suitable resource for biological control of infection with *F. gigantica*.

**Location and infectivity of metacercariae**

**Distribution on rice straw**

The distribution of metacercariae of *F. gigantica* on fresh rice stalks was determined by cutting the lower 40 cm of stalks into lengths of 10 cm and feeding 10 kg from each level to groups of two previously uninfected merino sheep (Table 3.1). Two additional sheep were each infected with 250 metacercariae as positive controls and one uninfected sheep acted as a negative control. Seven to ten weeks later all sheep were killed and immature flukes harvested. It was found that sheep fed with the lower 10 cm of the stalks harboured 98% of the flukes recovered from animals fed rice stalks. Thirty-three and 41% respectively of the dose of metacercariae given to the two positive control sheep were recovered as

**Table 3.1** Number and size of *Fasciola gigantica* recovered from *Fasciola*-naïve merino sheep infected with metacercariae of *F. gigantica* or fed portions of rice stems cut 0–10, 10–20, 20–30 or 30–40 cm from the ground.

<table>
<thead>
<tr>
<th>Sheep no.</th>
<th>Source of infection/ distance of cut stalk from the ground</th>
<th>Week sheep killed</th>
<th>Number of <em>F. gigantica</em> recovered</th>
<th>Length ± SD (mm)</th>
<th>Width ± SD (mm)</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>603</td>
<td>Nil</td>
<td>6.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>611</td>
<td>250 mc</td>
<td>8</td>
<td>83</td>
<td>8.8 ± 1.5</td>
<td>1.9 ± 0.4</td>
<td>37</td>
</tr>
<tr>
<td>612</td>
<td>250 mc</td>
<td>7.5</td>
<td>103</td>
<td>6.5 ± 1.0</td>
<td>1.3 ± 0.3</td>
<td>78</td>
</tr>
<tr>
<td>628</td>
<td>0–10</td>
<td>10.5</td>
<td>137</td>
<td>10.1 ± 2.1</td>
<td>2.2 ± 0.4</td>
<td>49</td>
</tr>
<tr>
<td>629</td>
<td>0–10</td>
<td>10.5</td>
<td>113</td>
<td>12.2 ± 2.0</td>
<td>2.4 ± 0.5</td>
<td>53</td>
</tr>
<tr>
<td>623</td>
<td>10–20</td>
<td>10.5</td>
<td>4</td>
<td>13.2 ± 1.8</td>
<td>2.7 ± 0.3</td>
<td>2</td>
</tr>
<tr>
<td>A60</td>
<td>10–20</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>500</td>
<td>20–30</td>
<td>10.5</td>
<td>1</td>
<td>12.5 ± 0.0</td>
<td>2.5 ± 0.0</td>
<td>1</td>
</tr>
<tr>
<td>98</td>
<td>20–30</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>102</td>
<td>30–40</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>708</td>
<td>30–40</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

* = distance in centimetres of the pieces of rice stem from ground level

mc = metacercariae of *F. gigantica*

n = number of flukes measured
larval flukes. It was concluded that rejection of the lower portion of rice stalks previously immersed in water would help control infection with *F. gigantica* in animals fed on fresh rice straw (Suhardono et al. 2006d).

**Effect of temperature and humidity**

The viability of the metacercariae of *F. gigantica* when stored in water at 13°C for up to 23 weeks, exposed to the sun for up to eight hours or stored at a range of temperatures and humidities for up to 10 weeks was studied (Table 3.2). Excysted metacercariae were categorised microscopically as viable (motile and undamaged), dubious (not motile and undamaged) or dead (visible necrosis). Infectivity of viable and dubious metacercariae and unselected reference metacercariae held in water at 7°C for 20 or more days was assessed by comparing numbers of flukes recovered from infected merino sheep. Mean recovery rates were respectively 54.6%, 7.2% and 37.2% for viable, dubious and unselected metacercariae. Metacercariae immersed in water remained viable longer than those allowed to desiccate. Viability was promoted by decreasing temperature and increasing humidity. Exposure to direct sun killed metacercariae within eight hours. Results indicated that in lowland Indonesian irrigated rice paddies, metacercariae immersed in water are likely to survive for less than five weeks while those that become desiccated will survive less than two weeks. This information, together with the option of exposing fresh rice stalks to direct sunlight before feeding them to livestock, can help farmers reduce infection with *F. gigantica* (Suhardono et al. 2006c).

**Sources of metacercariae for infection**

Rice straw is believed to be the main source of infection of cattle and buffaloes with *F. gigantica* in areas where irrigated rice is grown extensively (Jeno et al. 1975; Harrison et al. 1996). However, this conclusion has been based on largely circumstantial evidence on the ecology of the snail intermediate host and observations that prevalence of fasciolosis in draught animals is high in lowland rice irrigation areas (Edney and Muchlis 1962; Soesetya 1978; Morel and Mahato 1987; Suhardono and Estuningsih 1989). Furthermore, the possibility that water from rice fields may also be a source of metacercariae for animals and that there may be other sources has not been investigated.

The objective of this study was to identify the sources of metacercariae of *F. gigantica* infecting cattle in a lowland area of West Java where two tandem irrigated crops of rice are grown most years followed by either a period of fallow or a dryland crop.

### Table 3.2 Percentage viability of metacercariae of *Fasciola gigantica* exposed to the sun or shaded while being maintained damp or dry at ambient temperature of about 30°C.

<table>
<thead>
<tr>
<th>Hours exposed</th>
<th>Percentage viable</th>
<th>Under sunshine</th>
<th>Under shade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Damp</td>
<td>Dry</td>
<td>Damp</td>
</tr>
<tr>
<td></td>
<td>Live</td>
<td>Dubious</td>
<td>Live</td>
</tr>
<tr>
<td>0</td>
<td>88</td>
<td>6</td>
<td>88</td>
</tr>
<tr>
<td>2</td>
<td>94</td>
<td>5</td>
<td>29</td>
</tr>
<tr>
<td>4</td>
<td>33</td>
<td>37</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>19</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>11</td>
<td>0</td>
</tr>
</tbody>
</table>
Water and rice stubble from recently harvested rice fields containing *L. rubiginosa* infected with *F. gigantica*, and water and forage from other habitats of *L. rubiginosa* where free-grazing cattle were observed to eat or drink were fed to merino sheep. They were then monitored, either by counting fluke numbers in the liver at necropsy or by observing *Fasciola* eggs in faeces, to determine sources of viable metacercariae. Infection with *F. gigantica* was acquired from the clear effluent water and water containing sediment from rice fields, and from rice stalks, but not from irrigation channels, the only other habitat of *L. rubiginosa* in the study area. It was concluded that the most important risk factor for cattle to become infected with *F. gigantica* was to allow them to graze in recently harvested rice fields. Fields most heavily contaminated were those flooded again after harvest and risk of infection was greatly increased by feeding fresh herbage to cattle from such fields or by allowing animals to drink from rice fields (Suhardono 2001).

**Influence of production systems**

**Seasonal variation in Cambodia**

A study was conducted in Cambodia to generate baseline data on the incidence and level of infection of *Fasciola* in cattle and buffalo. The study was conducted in six villages in four communes of Saang district of Kandal province and eight villages in four communes in Chem Prey district of Kampong Cham province. The 373 families directly involved in the project either brought their animals for study or were interviewed. The project examined 1,790 cattle, 5,126 faecal samples, 596 cattle livers and 8,008 snails.

To understand the epidemiology of fasciolosis, the research included an abattoir study, a tracer study, an agricultural cycle study and a snail ecology study. In addition, impacts of fasciolosis on production were monitored in a suppressive treatment trial.

For the abattoir study, a total of 645 cattle were examined at the district abattoirs (Chem Prey district of Kompong Cham province and Saang district of Kandal province) and of these 502 head (77.82%) were identified as originating from within Saang district.

Nearly all the cattle examined were described as the crossbred type, which is a cross between the imported large tall-bodied white-coated Haryana breed and the smaller local breed. A total of 644 cattle had their sex recorded. Of these, 82.9% were castrated males, 15.2% females and 1.9% bulls. The average age of cattle brought for slaughter was seven years old, with a range from two to 12 years old. Females were on average younger (5.6 years) than castrated males (7.4 years).

A total of 575 faeces samples were examined for *Fasciola* eggs, of which 142 (24.7%) were positive. Of the 596 cattle examined at the slaughterhouse, 176 (30%) had liver damage. Female cattle with both liver damage and eggs in their faeces had lower body condition than other females. There were no differences in bodyweight or condition between male cattle that had eggs in their faeces, liver damage, both, or neither of these.

There is some evidence of a seasonal infection with *Fasciola*. Positive faecal samples rose from a low of 11% in December 1998 to 34% in April 1999, 28% in May and 55% in June, then declined progressively for the remainder of 1999. These results indicate that infection was highest over the months from about November to April. Liver damage by *Fasciola* infection was high in December, January, February and March (39%, 36%, 43% and 37% respectively) and then decreased, thus providing additional evidence that infection with *Fasciola* is seasonally highest at the end and start of the year.

The average cattle liver weight was 6.2 kg (range 5.3–10.4 kg). In the 32 damaged livers examined there were means of 30.5 adult and 40.3 immature flukes per liver. The average weight of damaged liver tissue was 2.3 kg (range 0.3–10.4 kg).

A tracer study was conducted in four villages in three communes of Saang district, Kandal province: Preak Kseow village of Rokar Kpos commune, Slay Tany and Preak Run villages of Preak Koy commune and Ang village of Krang Yov commune. The study began in April 1999 and was completed at the end of March 2001. A total of 446 cattle in the target area were used (Preak Kseow village 130 head, Slay Tany 99 head, Preak Run 129 head and Ang 88 head). All were treated with triclabendazole (Fasinex) at 12 mg/kg body weight (0.1 ml/kg) to free them from any pre-existing *Fasciola* infection.
Using a prepatent period for *Fasciola* of four months, it was calculated that cattle were infected in all villages from September 1999 to March or April 2000. In Svay Tany village infection began in September (6%) and reached a peak in April (50%). Between May and July no cattle were infected, then some were infected from August of the following year. In Preak Kseow village incidence rose from 9% in September to the peak of 87% in April. No infection occurred from May to July, however, it began again in August. In Preak Run village incidence rose from 3% in September to 37% in December, dropped to 12% in February, rose again in March and reached a peak in April (57.2%). Once again the infection began from the following August. In Ang village, only small percentages of cattle were infected with *Fasciola* (1.6–4.0%). Infection occurred from September to March intermittently.

Tracer studies thus confirmed the pattern of infection with *Fasciola* suggested by the abattoir study, that incidence of infection is highest from October to April. It also indicated that April was a peak month for infection and that little infection occurred from May to August (Southeun et al., unpublished).

### Seasonal variation in Indonesia

There are reports on prevalence proportions from most countries where infection with *F. gigantica* is endemic. Few studies, however, have attempted to define monthly or seasonal incidence rates even though this information provides a logical basis for rational decisions on control. Fasciolosis in Indonesia mainly occurs in cattle and buffaloes and is widespread in the main islands (Adiwinata 1955; Kraneveld 1924; Soesetya 1975; Nurdin and Salsabila 1979; Rivai 1979; Soemardi and Rubino 1979; Tarmudji and Ginting 1983; Tarmudji et al. 1983). In Indonesia old reports recognised the presence of more than one species of *Fasciola* (Krijgsman 1933). However, Mukhlis (1985) concluded only one species of liver fluke occurred in indigenous cattle and it was *F. gigantica*. The recent work of Kurniasih et al. (1996) supported this conclusion, but from molecular studies introduced the possibility of their being more than one subspecies of *F. gigantica*.

To complete their life cycle liver flukes use lymnaeid snails as their intermediate host. On the island of Java, there is only one species of snail from the seasonal water sources are focal points for grazing and the continual cycling of liver fluke infection through snails.
family Lymnaeidae, *L. javanica*, which is synonymous with *L. rubiginosa* (van Benthem Jutting 1956). *Lymnaea rubiginosa* is an aquatic snail which spends most of its time floating at the surface of water (Widjajanti 1989). It thrives in the clear, slowly moving shallow water of irrigated rice fields.

In most countries of South-East Asia the main reason for raising cattle in rice-cropping communities is to provide a source of power during the processing of land before it’s cultivated (Jarrige 1980). They also provide manure which is used as fertiliser in rice fields and an alternative source of income if the crop fails. The management of these animals is closely integrated with cropping practices. Farmers mostly feed their cattle with crop residues as most do not have enough land to grow special fodder for their animals.

**Two seasonal studies**—Monthly fluctuations of faecal *Fasciola* egg counts were monitored in 60 Ongole cattle each four weeks for 13 months in five villages in the subdistrict of Surade, West Java. Faecal egg counts of *F. gigantica* were also estimated for additional groups of 30 cattle selected each month from the same villages. It was concluded that estimates of prevalence of infection with *F. gigantica* are likely to be conservative when based on faecal egg counts. It was proposed that the sudden drop in apparent prevalence during December followed by gradual recovery during the following few months was a consequence of immune stimulation (induced by an influx of metacercariae acquired by animals from rice stubble at the beginning of the harvest season in January) which either causes loss of adult worms or suppression of their egg output (Figures 3.3 and 3.4).

The incidence and time of infection with *F. gigantica* in Ongole cattle in a rice-cropping environment in West Java was undertaken using 30 Ongole tracer cattle each four weeks for 16 months in 1993–94. It was found that over 80% of infection was acquired from January to June which coincided with the period of harvest of irrigated rice. It is also concluded that the main source of infection with *F. gigantica* in cattle is fresh rice straw, especially that from fields within about 200 m of a cattle pen.

In parallel with the green revolution of Indonesia, rice stubble has become abundant. This has been due mainly to high-yield varieties of rice being introduced, a relatively short time from planting to harvest and an increase in irrigation (Heytens 1991). Because more rice stubble is available, it has become a major dietary component for cattle. Irrigated rice is increasingly producing two crops per year and this also serves to maintain a high population of *L. rubiginosa*. The close relationship between rice cultivation and cattle management and the suitability of irrigated rice fields as a habitat for *L. rubiginosa* causes the pattern of liver

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**Figure 3.3.** Prevalence of *Fasciola gigantica* eggs and mean egg counts per gram of faeces (EPG) ± SD of each batch of 30 Ongole cattle chosen each four weeks to become tracers, before they were treated with triclabendazole.

**Figure 3.4.** Incidence of *Fasciola gigantica* infection as detected by eggs in faeces in relation to monthly rainfall and the seasonal activities for rice production.
### Table 3.3 Key research finding and their implications for control.

<table>
<thead>
<tr>
<th>Key finding</th>
<th>Implication for control programs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluke eggs are susceptible to heat and exposure to the sun.</td>
<td>Dung could be composted or exposed to sun before being spread as fertiliser. This can supplement the containment of dung to prevent contamination of waterways and rice paddies.</td>
</tr>
<tr>
<td>Laboratory methods for counting fluke eggs can be improved.</td>
<td>Diagnosis of suspected cases and in field survey can be improved. Evaluation of interventions in the field can be made more accurate.</td>
</tr>
<tr>
<td>Composting and heat induced by additives can reduce infectivity of eggs.</td>
<td>Different methods of composting need to be evaluated for their impact on fluke egg survival.</td>
</tr>
<tr>
<td>The role of <em>Lymnea rubiginosa</em> is confirmed in areas of high fluke prevalence in Indonesia.</td>
<td>Knowing which species and their distribution is an important aspect of identifying areas of potential problems.</td>
</tr>
<tr>
<td>Many parasite species found in <em>Lymnea</em>, including <em>Echinostoma</em> in Java.</td>
<td>Many species use <em>Lymnea</em> as an intermediate host, therefore accurate identification of cercariae is essential.</td>
</tr>
<tr>
<td><em>Echinostoma</em> found in a range of warm-blooded vertebrates in the Philippines.</td>
<td><em>Echinostoma</em> may be very widespread and has the potential to interfere with transmission of <em>Fasciola</em>.</td>
</tr>
<tr>
<td>Distribution of metacercaria is limited to the bottom 10 cm of rice straw.</td>
<td>Cutting rice straw higher than 10 cm would prevent infection being carried with fodder to stalled animals.</td>
</tr>
<tr>
<td>Exposure of metacercariae on rice straw to sun reduces their viability.</td>
<td>Leaving contaminate rice straw in the sun before feeding could reduce exposure to infection.</td>
</tr>
<tr>
<td>Prepatent periods in Ongole cattle confirmed to be 18 weeks (4 months).</td>
<td>This conforms to expectations but needs to be confirmed if local experimental studies are to be conducted.</td>
</tr>
<tr>
<td>Pattern of infection in Cambodia consistent with 4-month prepatent period for infection.</td>
<td>Once established that <em>Lymnea</em> is the intermediate host and <em>Fasciola</em> the cause of disease similar control principles can be applied across the region.</td>
</tr>
<tr>
<td>In Cambodia the highest level of infection occurs between October and April, with no new infections between May and August.</td>
<td>Timing of chemical treatments and interventions to prevent infection can be focused on periods of non-transmission and transmission, as appropriate.</td>
</tr>
<tr>
<td>Similar patterns in Indonesia with tracer studies provide a clearer picture.</td>
<td></td>
</tr>
<tr>
<td>Infection is intimately associated with the cycle of rice planting and harvesting in Indonesia.</td>
<td>Changes in rice production system need to take account of implications for liver fluke infection and control programs.</td>
</tr>
</tbody>
</table>
fluke disease in cattle to vary directly with the intensity of cropping of irrigated rice (Edney and Muchlis 1962).

No information is documented on the time of acquisition of and source of infection with *F. gigantica* by cattle in Indonesia. As prevalence is highest in rice-growing areas, this study was undertaken to determine the time of acquisition of *F. gigantica* in Ongole cattle raised in a farming area dominated by the cultivation of irrigated rice.

**Implications for control programs**

The main findings present in this chapter have been tabulated (Table 3.3) and their implications for potential control programs listed.

**References**


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