

## Liver fluke disease in sheep and cattle

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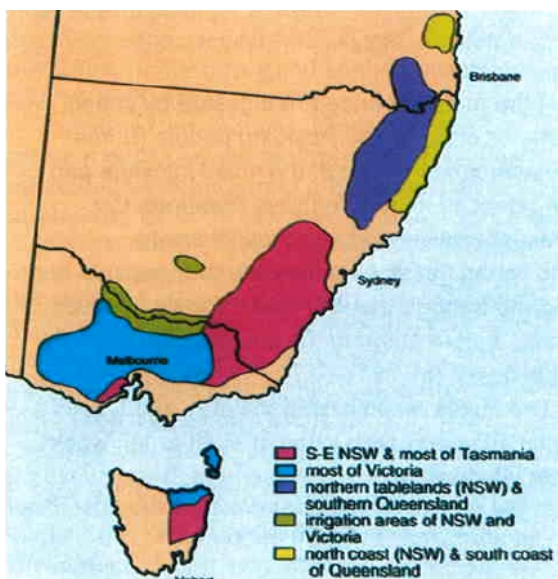
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Up to 40 million sheep and 6 million cattle in Australia graze pastures where liver fluke is endemic. In 1999, it was estimated that graziers spent approximately \$10 million a year on fluke drenches alone; with lost production costing a further \$50–80 million a year. More recently, Lane and others (2015) estimated that the annual cost of fluke to the Australian sheep industry alone was about 25 million dollars.

Deaths account for only a part of this loss. Other significant losses in livestock include:

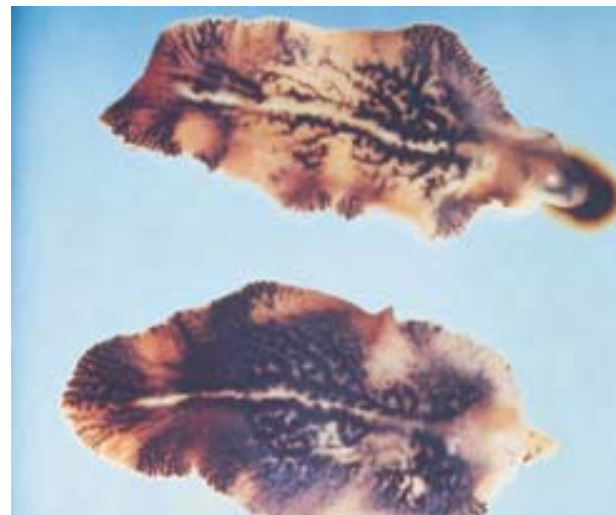
- reduced production and quality of wool  
reduced lambing percentages
- poor growth rate of lambs
- increased costs for replacement stock
- reduced production and quality of milk in dairy cattle
- lower growth rates and lower feed conversion rates in fattening cattle.

Figure 1. Distribution of liver fluke disease in different climatic regions



Liver fluke can develop to sexual maturity in sheep, cattle, horses, pigs, goats, alpacas and deer. Other hosts include kangaroos, wombats and rabbits, which may maintain the contamination of pastures as reservoirs. People can be infected by eating watercress from naturally contaminated creeks.

Figure 2. Liver fluke (*Fasciola hepatica*) from sheep



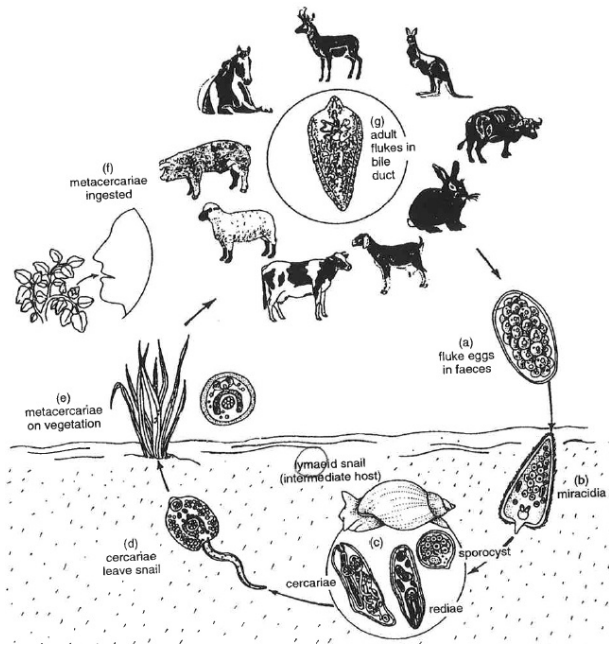
*Fasciola hepatica* infection is widespread across those areas of eastern New South Wales where the annual mean rainfall is about 600 mm or more. Infected areas include the Tablelands and nearby slopes.

Infection is also found in irrigation areas, where the annual rainfall of around 400 mm is supplemented by regular irrigation.

Infection is endemic on the south-eastern coastal areas of Australia, often in combination with stomach flukes (paramphistomes).

Adult flukes in the bile ducts produce eggs which are passed in the faeces (see Figure 3).

Figure 3. Liver fluke lifecycle



Under optimal conditions, the eggs hatch when separated from faecal material in wet areas. The first larvae or miracidia released (b) invade the lymnaeid snails in which they develop and multiply as sporocysts, rediae and cercariae (c).

The tadpole-like cercariae leave the snails (d) and swim until they encyst on vegetation, forming metacercariae (e), which are the infective stage of the fluke. The entire cycle of the liver flukes in the snails takes two to three months under favourable conditions in the field.

If the metacercariae are ingested by sheep, cattle or other hosts, including people (f), the metacercariae excyst in the small intestine and the released immature flukes penetrate the intestinal wall into the abdominal cavity.

The young flukes penetrate the liver capsule and migrate through the liver tissue for six to seven weeks before entering the bile ducts to become adult flukes (g).

The flukes reach sexual maturity and commence egg production at eight to ten weeks after infection.

## Epidemiology

The two primary requirements for the establishment of liver fluke are a suitable snail (the intermediate host) and an environment that suits the fluke eggs, the snails and the larval fluke – such as springs, slow-moving streams with marshy banks, irrigation channels and seepages.

Figure 4. The introduced *Pseudosuccinea (Lymnaea) columella* snail (shell 16 mm long) and its egg mass with embryos

In Australia, the most important intermediate host is the indigenous freshwater snail, *Austropeplea (Lymnaea) tomentosa*. An introduced North American snail (*Pseudosuccinea (Lymnaea) columella*), and an introduced snail from the Pacific area (*Austropeplea (Lymnaea) viridis*, also known as *Radix viridis*), found in defined locations of the NSW coast, have also been identified as additional intermediate hosts.

Figure 5. *Austropeplea (Lymnaea) tomentosa*, the common intermediate host in Australia and New Zealand (shell 12 mm long)

(According to Ponder and others (2016), the *Austropeplea* and other snail genera need to be revised. Further changes in names/taxonomy are possible. Also see Lloyd and others, 2017).

The fluke eggs are passed in the faeces into wet areas. Here they hatch, when mean temperatures increase to above 10°C (mostly from mid- September to May). In summer, the eggs take approximately 21 days to develop into

miracidia. In spring and autumn, hatching can take up to 90 days.

**Figure 6.** The body cavity of *Austropeplea (Lymnaea) tomentosa* showing cercariae just before emission



The larva (miracidium) invades the snail, where it develops and multiplies. One single miracidium hatching from a fluke egg can produce up to 4000 infective cysts (metacercariae).

Actively swimming cercariae released from the snail attach to substrates, especially vegetation. The tail is shed and the cercaria forms a resistant cyst stage (metacercaria). In the presence of sufficient moisture the metacercariae will remain alive for many weeks, depending on the temperature. They survive longer below 20°C; higher temperatures and desiccation will destroy the metacercariae in a short time.

**Figure 7.** Cercariae leave an infected snail, *Austropeplea (Lymnaea) tomentosa*.



The snails, acting as intermediate hosts, produce eggs throughout the year. These eggs hatch when the temperature is right. There is a marked increase in reproduction from spring to late autumn. Snails may produce 3000 eggs a month and one generation of snails from egg to egg takes only about one month under optimum conditions. *Austropeplea (Lymnaea) tomentosa*

survives in dry mud for at least one year, and tolerates low temperatures. The snail can move with and against the water current for long distances.

**Figure 8.** Metacercariae encysted on grass blades.



The larval stages of fluke (sporocysts, rediae) also survive in those snails for long periods, and resume development when climatic conditions improve.

The egg production of adult flukes is responsible for the degree of pasture contamination. Fluke survive for many years in the liver of infected sheep; the adult fluke lays between 20,000 and 50,000 eggs a day, and over a long period. In cattle, the egg production declines as the animal develops a natural resistance to chronic infections.

The epidemiology of the disease is influenced by the grazing habits of animals. Cattle often graze in the wet marshy areas favoured by the fluke snail, so the eggs are deposited in a suitable environment. If food is available elsewhere, sheep and goats prefer to graze away from marshy pastures. Long wet seasons are usually associated with a higher infection rate but sheep are more likely to ingest large numbers of cysts during dry periods after a wet season, when the animals are forced to graze in swampy areas, resulting in heavy infection.

Figure 9. Tablelands cattle grazing in a typical snail habitat - a slowly running stream fed by springs.



## Liver fluke disease

### Acute fasciolosis

There may be an outbreak of the disease following a massive but relatively short-term intake of metacercariae. The high intake is the result of certain seasonal and climatic conditions combined with a lack of fluke control measures; typically, stock forced to graze in heavily contaminated wet areas as a result of overstocking and/or drought.

Animals suffering from acute fasciolosis may not show any obvious symptoms. Some animals may show abdominal pain and may become jaundiced.

Death is usually due to blood loss resulting from haemorrhage in the liver. The liver haemorrhage is the result of the immature fluke burrowing through the liver.

### Subacute fasciolosis

Subacute fasciolosis is characterised by jaundice, some ill thrift and anaemia. The burrowing fluke causes extensive tissue damage, leading to haemorrhaging and liver damage. The outcome is severe anaemia, liver failure and death in 8–10 weeks.

### Chronic fasciolosis

Chronic fasciolosis is the most common form of liver fluke infection in sheep, goats and cattle – and particularly in more resistant hosts, such as horses and pigs. It occurs when the parasites reach the bile ducts in the liver. The fluke ingests blood, which produces severe anaemia and chronic inflammation and enlargement of the bile ducts.

The clinical signs develop slowly. The animals become increasingly anaemic, appetite is lowered, the mucous membranes of the mouth

and eyes become pale and some animals develop oedema under the jaw ('bottle jaw'). Affected animals are reluctant to travel.

Figure 10. Sheep with pale conjunctivae due to anaemia.



Figure 11. Sheep with bottle jaw (oedema) due to chronic fasciolosis.



Figure 12. Calf with bottle jaw.



## Black disease

Black disease is an acute and fatal liver disease which can affect sheep and cattle. It is usually associated with the liver damage caused by the migrating young fluke. This damage provides a suitable environment for the germination of spores of *Clostridium novyi* type B bacteria in the liver.

Figure 13. Sheep liver with migration tracks from early immature fluke (acute fasciolosis).



(blood test; antibody ELISA) is also available for fasciolosis. It is more sensitive (better at detecting true positives) than a fluke egg count and detects infection with both immature and adult fluke.

Additionally a faecal fluke antigen test (copro-antigen test), based on a diagnostic test kit from Belgium (Bio-X), is available at some labs in Australia.

Each test has strengths and weaknesses: discuss with your advisor.

Figure 14. Fatal acute fasciolosis-numerous migrating immature fluke causing fatty degeneration, haemorrhage and fibrosis.



## Parasite–host relationship

In sheep, there is no evidence of acquired resistance to *Fasciola hepatica*. Acute and chronic fasciolosis can occur at any age.

Cattle have a natural resistance and under normal conditions the clinical disease is only likely in young cattle.

Chronically infected cattle can spontaneously recover, and previously infected animals can partially resist reinfection. However, this resistance is only possible because of chronic fibrotic changes in the liver, so with even a small number of fluke present, there may be production losses.

## Diagnosis

Fasciolosis should be considered when there are deaths, anaemia or ill thrift in sheep or cattle grazing on fluke-prone country.

In live animals, chronic fasciolosis is indicated by fluke eggs in faecal samples. The test (at least the sampling method) is generally reliable in sheep but less so in cattle.

Diagnosis in dead animals relies on seeing mature or immature fluke in the liver. Necropsy will also identify other conditions that may be contributing to the problem. A serological test

Figure 15. Sheep liver with haemorrhages due to migration of late immature fluke (subacute fasciolosis).



Figure 16. Fibrinous perihepatitis due to migrating immature fluke.



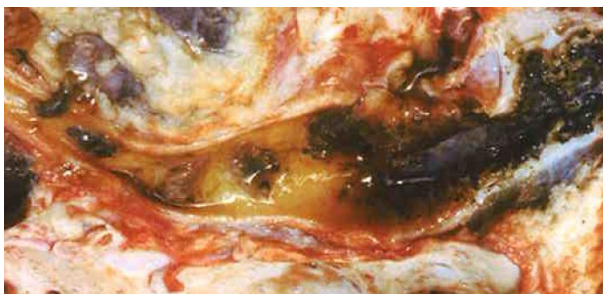
Figure 17. Cross section of calf liver with severe fibrosis. Fluke visible in some bile ducts.



Figure 18. Cross section of fibrotic sheep liver with heavy chronic fluke infection.



Figure 19. Calcified bile duct, adult fluke (cattle).



## Treatment

The treatment recommended will depend on the nature of the disease. Some of the available anthelmintics are not effective against immature fluke and so are not recommended in acute fluke outbreaks. Also, they are less efficient for the strategic control of fasciolosis. The best prevention and control can be achieved with drugs such as triclabendazole, which are effective against early immature and adult fluke, unless resistance is present.

Table 1 (below) summarises the efficacy of various flukicides for treatment of fasciolosis in sheep and cattle.

## Strategic control

Due to the great biotic potential of *Fasciola hepatica* and their intermediate host snails, only a continuous and coordinated strategic application of all available measures can provide economic control of the disease.

Control should be on a preventive rather than a curative basis. For effective control:

- use strategic anthelmintic treatment, to reduce the number of fluke in the host and the number of fluke eggs in pasture;
- reduce the number of intermediate host snails;
- manage fluke-prone areas, to reduce exposure to infection.

These three strategies are detailed below.

## Using anthelmintics

The first of these strategies is the use of anthelmintics, based on the epidemiology of the disease. This makes it possible to determine the time of the year when the maximum effect can be achieved with the fewest possible treatments.

The correct time for anthelmintic treatment depends mainly on climatic conditions and weather data. Timing is basically similar across districts, with only small adjustments required in south – eastern Australia.

## Timing of treatments

Figures 21–23 below outline strategic treatments for the Central Tablelands, the Northern Tablelands and the North Coast of NSW. Fewer treatments than indicated may be required. The weather pattern of the Central Tablelands (Figure 2) is similar to that of the Southern Tablelands. The North Coast pattern (Figure 4), apart from higher rainfall, is similar to conditions on the South Coast.

**Table 1. Comparative anthelmintic efficiency and safety of drenches suitable for the treatment of fasciolosis in sheep and cattle.**

Active ingredient	Safety index <sup>1</sup> at recommended dose	Over 90% efficiency at recommended dose						
		Age of fluke (weeks)						
		2	4	6	8	10	12	14
Triclabendazole (oral; pour-on formulations also available)	20	+	+	+	+	+	+	+
Closantel <sup>2</sup>	5.3				+	+	+	+
Closantel <sup>2</sup> + oxfendazole <sup>3</sup>	5.3			+	+	+	+	+
Closantel <sup>2</sup> + albendazole <sup>3</sup>	5.3				+	+	+	+
Nitroxynil <sup>4</sup>	4.0					+	+	+
Nitroxynil <sup>4</sup> + clorsulon		+	+	+	+	+	+	+
Albendazole	6.0						+/-	+
Oxyclozanide + levamisole	4.0						+/-	+
Clorsulon + ivermectin <sup>5</sup>	20						+	+

Notes: <sup>1</sup>Safety index = maximum tolerated dose divided by the recommended dose rate. <sup>2</sup>Closantel is not registered for use in cattle in Australia. <sup>3</sup>Closantel + oxfendazole compared with closantel + albendazole shows that combining closantel with a benzimidazole (BZ) results in synergism in some but not all cases. It does with oxfendazole, but not with albendazole. Similarly with triclabendazole combined with oxfendazole versus albendazole. <sup>4</sup>Nitroxynil (as Trodax®) is still registered for subcutaneous use in cattle in Australia, but is not currently available. However nitroxynil is available as a component of two injectable cattle products in combination with clorsulon in one of these products, and in combination with ivermectin + clorsulon, in the other. Both products are effective against fluke 2 weeks old and older. Nitroxynil is not effective if given orally (it is degraded by ruminal microorganisms). <sup>5</sup>Various products containing clorsulon + ivermectin are registered for use in lactating cows. '+/-' means that, at 12 weeks, these are less effective in cattle than in sheep. More information on flukicides: Love S, 2017. "Liver fluke – a review", NSW DPI Primefact 813.

### Timing of treatments – irrigation areas

In the irrigation areas a similar program is recommended where the epidemiology of fasciolosis depends mainly on temperature.

### Treating and preventing clinical disease

Treatments are essential when clinical disease is apparent, even though it may be too late to prevent economic losses. Treat according to the charts (Figures 21-23, below) in order to prevent the disease and reduce the problem of liver fluke disease to a manageable level.

### Drugs and resistance

Flukicides (anthelmintics or 'drenches' effective against liver fluke) play an important role in the control of fasciolosis. An efficient strategic control program relying on a minimum number of treatments per year and aimed at long-term elimination of pasture contamination requires drugs that are effective against both mature and early immature flukes.

More frequent treatments are necessary if you use drugs that are only effective against advanced mature fluke aged 12–16 weeks or older.

Resistance of liver fluke to triclabendazole and closantel has been reported and is becoming more common, in Australia and worldwide (Love, 2017). When found it is usually first seen as reduced effectiveness against immature flukes.

A number of drench mixtures effective against fluke and roundworms have been registered for use. Care should be taken not to use them too frequently for roundworms as this may encourage the development of resistance in *F. hepatica*.

Note that, although triclabendazole is regarded as being effective (>90%) against all stages of susceptible fluke, not all products containing triclabendazole are effective against early immature stages. Check product labels.

## Sheep (using closantel-based flukicides)

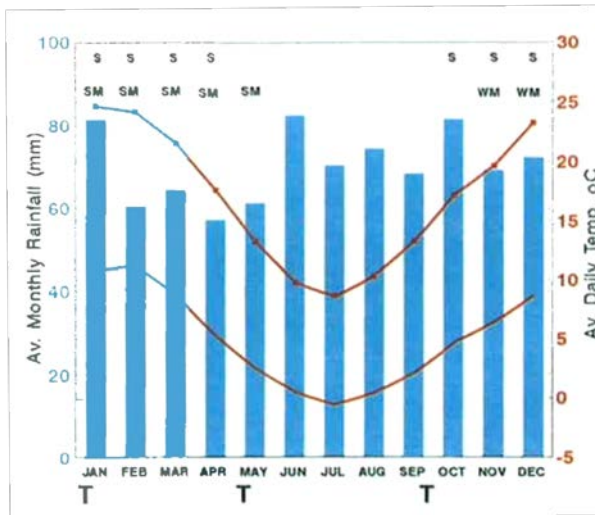
Some of the flukicide treatments for sheep may coincide with drenching for roundworms in the WormKill and DrenchPlan programs and corresponding programs in WormBoss.com.au.

Figure 20. Key to figures (liver fluke control programs) below.

T	treatment	■	rain
T*	optional	—●—	maximum temperature
S	snails active	—	minimum temperature
WM	winter metacercariae		
SM	summer metacercariae		

The optional drench (T\*) in June/July is needed if the flukicide used in April/May was not effective against immature fluke.

Figure 21. Oberon (Central Tablelands, NSW) liver fluke control program.



Closantel is effective against susceptible *Haemonchus* as well as liver fluke, and was a key element of the original WormKill program (1984) before widespread resistance of *Haemonchus* appeared in northern NSW in the 1990s. The drug is effective against young mature fluke aged about six to eight weeks, but has less effect on early immature fluke populations. This lower efficacy against early immature fluke is more pronounced where closantel resistance in immature *F. hepatica* has emerged. The closantel plus oxfendazole mixture (Closicomb®; no longer registered/available) had good synergistic efficacy against susceptible fluke aged four weeks and was used successfully against triclabendazole-resistant fluke.

Figure 22. Armidale (Northern Tablelands, NSW) liver fluke control program.

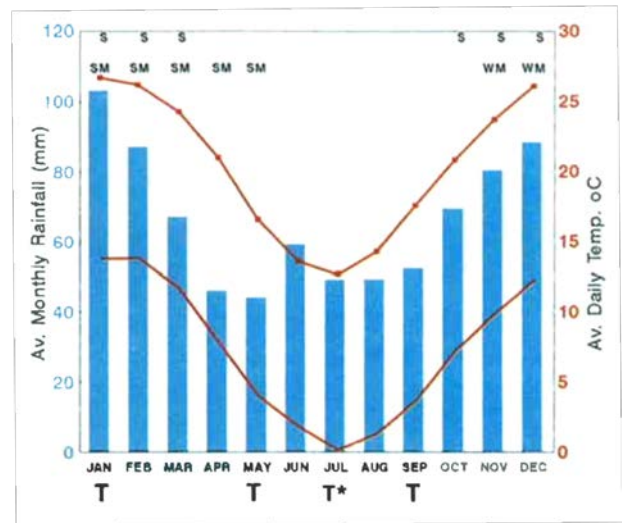
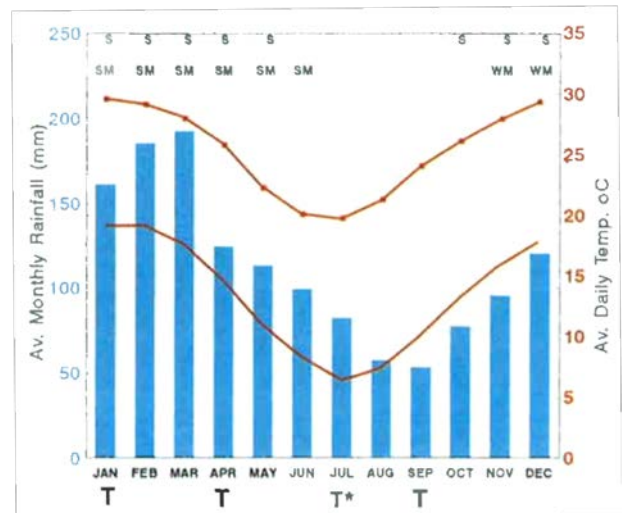


Figure 23. Lismore (North Coast, NSW) liver fluke control program.



Closantel is suitable for the late winter/early spring treatment. If used for the autumn/early winter treatment, an extra fluke drench in mid-winter will be required.

The recommended treatments are:

### Late winter/early spring

Preventive treatment of all sheep at this time reduces pasture contamination before the snails and fluke become active. Otherwise, the contamination of pastures with fluke eggs will result in high fluke burdens in late spring and summer.

### Summer

The larvae that infected snails in the previous autumn resume their development as temperatures increase (over-wintering infection). A fluke drench in January is



necessary to eliminate the fluke picked up in the late spring and early summer.

This treatment can be delayed until February if more convenient. If so, use a drench that is effective against early immature fluke – triclabendazole – because of the additional build-up of fluke during the summer months.

### Autumn (April/May)

The peak production of infective cysts is during late summer/early autumn (summer infection). The aim of this treatment – best given in April/May – is to eliminate fluke picked up during summer and early autumn. Use a drench that is effective against early immature fluke – triclabendazole. In cattle there is the added option of products containing the flukicides nitroxylnil and clorsulon in combination. The efficacy of this combination against all stages of fluke is similar to that of triclabendazole.

This treatment controls clinical disease and reduces pasture contamination.

### Winter

Additional treatments may be required in winter:

- In addition to the autumn treatment, summer rainfall areas in the Northern Tablelands and North Coast may need another treatment in July after a wet summer.
- If flukicides that are not effective against immature fluke were used in April/May, another fluke drench is necessary in June/July. This removes the fluke that survived the April/May drench when they were still at the immature stage. (As noted earlier, drench resistance can reduce the efficacy against flukes.)

**Figure 24. Dam sites that can be snail habitats: snails may be in the edge of this dam near the outflow (foreground).**



## Sheep (using triclabendazole-based flukicides)

Triclabendazole is very effective against both early immature and adult fluke. If this drug is used then good control may be achieved with only three treatments a year.

These treatments are given as follows:

### August/September

To remove fluke carrying over from late autumn and winter, and to prevent pasture contamination.

### January/February

To eliminate fluke picked up during late spring and early summer.

### April/May

To eliminate fluke picked up during summer and early autumn.

## More frequent use, and drug resistance

Using triclabendazole more frequently (for example, every three months from September) reduces fluke disease to a negligible level. However such a program has to be ongoing if new fluke-infected stock are introduced or if there is likely to be reinfection from streams coming from neighbouring paddocks. Also, more frequent drenching may lead to development of drug resistance.

Drug resistance in liver fluke to triclabendazole has been reported and is becoming more widespread in Australia and elsewhere (Love S, 2017). When the closantel plus oxfendazole combination was available, it was suggested that alternating (rotating) this with triclabendazole may delay the development of resistance. The closantel plus oxfendazole combination was considered a good option because of its synergistic effect against liver fluke.

**Figure 25. Snails in the dam overflow during a rainy period.**



## Beef cattle

Cattle are more resistant to fluke infection than sheep. Adult cattle require fewer treatments to control fasciolosis. The recommended treatments are as follows:

### August/September

To eliminate fluke before spring, when conditions become favourable for fluke eggs and host snails. This is an essential treatment for all cattle. It is advisable to treat cattle and sheep at the same time.

### February

An additional treatment for all young cattle.

### April/May

Another important treatment for all cattle, to eliminate any fluke picked up during summer.

### Extra flukicide options for beef cattle

In addition to triclabendazole-based drenches, there are now two extra products for cattle that are effective (>90%) against all stages of liver fluke. Both these products contain a combination of two unrelated flukicides, nitroxylin and clorsulon. One of the products also contains a third active, ivermectin. Because nitroxylin is not effective if given orally, both these products are given by subcutaneous injection. Neither is registered for use in animals that produce or may produce milk or milk products for human consumption.

As always, read and follow the label, taking note of with-holding periods and other constraints.

## Dairy cattle

Treat young heifers and dry cows with a suitable anthelmintic effective against immature fluke, i.e., triclabendazole, and follow the above plan for beef cattle.

Products registered for use in lactating cows (oxyclozanide plus levamisole, clorsulon plus ivermectin, and clorsulon) are only effective against adult fluke aged 12-14 weeks or older. (The registered product that contains clorsulon alone is not currently available).

If paddocks on your property are heavily contaminated and are being grazed, you may need to treat lactating cows monthly during summer and autumn. Products to use are oxyclozanide plus levamisole, or ivermectin plus clorsulon, both these being registered for use in lactating dairy cattle. Either of these drenches also control susceptible gastrointestinal nematodes, as well as

lungworm infections on the occasions they are a problem.

On heavily contaminated pastures, good control of fasciolosis may require a triclabendazole treatment immediately after drying off, as well as a month before calving. The two treatments may especially be warranted if a less effective flukicide is used. If the pre-calving treatment is considered necessary (check with your advisor), consider the possibility that the estimate of calving date may be incorrect, or the cow may calve early, either of which could result in the treatment being too close to calving, with consequent residue issues.

Note also that some products containing triclabendazole can be used in dairy cattle, but with restrictions, whereas some (but not all) triclabendazole-based products which also contain a broad-spectrum active may be precluded from use in animals that are producing or may produce milk products for human consumption. Assume nothing; check the label.

Figure 26. Snail habitat on the NSW South Coast (Jamberoo).



## Mixed grazing

Be careful if sheep and cattle are grazing on the same pasture, whether together or alternately. You may need to treat your cattle every time you treat your sheep, to reduce or eliminate contamination of pastures and thus infection. For best results use a drug highly effective against early immature fluke, i.e. triclabendazole, or against advanced immature fluke, i.e. nitroxylin (registered, but not currently available in a single active drench).

## Resistance to flukicides

In 1999, Fairweather and Boray said resistance was not a major issue, but proposed

various ways of managing it, including grazing management, **use of combinations (of unrelated flukicides) in particular**, and other strategies. Now, however, according to Kelley and others (2016), the situation worldwide is serious, largely due to TCBZ resistance becoming common in many countries. One way to monitor the efficacy of flukicides (against adult fluke at least) is to do a test on the day of drenching and again 3 weeks later, using either a fluke egg count or the coproantigen ELISA. Check with your advisor. (More information: Love S, 2017).

## Intermediate host snail control

This is the second available strategy for control of *Fasciola hepatica*.

### Chemical control

It is unlikely that chemical or biological control will eradicate the snail population, because it reproduces so readily. Rapid repopulation from adjoining areas can occur.

Apart from garden-type situations, there is no product registered in Australia that would be suitable for controlling snails in 'flukey areas' on farm.

Figure 27. Irrigation channel and shallow drainage area.



### Improved drainage

Irrigation projects can provide the snails with ideal habitats. Regular clearing of vegetation from drainage channels may reduce silting and blockages that normally support snail – contaminated herbage.

Seepages from irrigation channels often harbour large snail colonies. In low-lying areas, adequate drainage would prevent accumulation of water. Snails multiply for extended periods in wet, low-lying areas.

Draining marshy pastures and building dams may reduce snail habitats and increase grazing areas.

## Disease control by farm management

This is the third available strategy for control of *Fasciola hepatica*.

### Fencing

On many properties, the snail-infested pastures occupy only a small part of the animals' grazing area. Fencing off these contaminated areas is a most economic and efficient method of controlling fasciolosis. Spending a few hundred dollars on fencing may prevent a serious outbreak of liver fluke disease.

Figure 28. Snail habitat in an irrigation area near Griffith NSW (ineffective drainage).



### Grazing management

The number of animals needing fluke drench could be reduced by more attention to grazing management. Identify the snail-infested pastures on the property. Only those animals that are grazing or have grazed these areas need treatment.

A rotational grazing program was once recommended in Australia to eliminate infection, but unfortunately the system was never widely adopted.

The theory was to first use an effective drench before moving stock to potentially contaminated areas. The second step was to alternate the grazing between the potentially fluke-infected areas and the fluke-free areas.

Grazing in infected areas would be for less time than it takes the fluke to reach maturity and produce eggs (six weeks).

Grazing in fluke-free areas would be for longer periods. Here, any fluke picked up on the fluke-infested paddocks would reach the adult stage but would be removed by drenching about two weeks before stock moved back to contaminated pastures.

The major objection was the difficulty in organising pasture rotation and the problems of moving fences or erecting new fences.

However, the system could be easily applied to many properties where only a small number of paddocks have suitable snail habitats. In mixed grazing properties the more resistant cattle could be grazed on the known fluke-prone areas. These animals are less likely to be affected and would require less treatment.

## Dr Joseph C Boray

Excerpts from an article by Dr Bruce Watt:

*“Joe graduated in veterinary science from the University of Budapest in 1950. Soon afterwards, he commenced his research career and completed a PhD on hydatids. However, he also commenced work on the treatment of liver fluke.”*

*“..(in the 1950s)... over 200,000 Hungarians fled (Hungary). These refugees included some of Hungary’s best and brightest and many have made prominent contributions to Australia”.*

*“ .. (Joe) arrived in 1957 and commenced a twelve-year stint with the CSIRO. He sought to understand the biology of the fluke and snail. He also sought improved treatments for fascioliasis (fluke infestation)”.*

*“Joe interrupted his work with CSIRO to accept an invitation from the University of Hanover. Here he studied the survival of fluke larvae under different climatic conditions. From 1969 to 1972, he taught parasitology to medical and veterinary students and studied the chemical treatment of fluke in Switzerland”.*

*“In 1972, Joe started ten year’s work with the pharmaceutical company Ciba-Geigy. His team worked on the development of new chemical treatments for parasites. These included treatments for ticks in cattle and parasites in dogs. However, Joe was also responsible for the development of cyromazine (Vetrazin®) which remains highly effective against blowflies and triclabendazole (Fasinex®) which has become the cornerstone of fluke control”.*

*“In 1983, Joe moved to the NSW Department of Agriculture at Glenfield then Camden (EMAI)*

*where he looked at chemical resistance in sheep lice and liver fluke. Joe however also looked at chemical combinations to improve the treatment of fluke. He found that triclabendazole acted in synergy with oxfendazole improving the kill of immature fluke”.*

*“In 1999, aged 73, Joe ‘retired’ from NSW Agriculture (or was it DPI) to set up an independent consulting company. I know that Joe was involved in developing a new combination of chemicals to treat fluke to decrease our dependence on triclabendazole”.*

*Dr Bruce Watt, 2010.*

Figure 29. Dr JC Boray, EMAI 1999.



Source of image / photographer unknown

## References and further information

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For further information visit NSW Department of Primary Industries web site [www.dpi.nsw.gov.au](http://www.dpi.nsw.gov.au)

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