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A survey of sheep and/or cattle farmers in the UK shows confusion over the diagnosis and control of rumen fluke and liver fluke

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ABSTRACT

Calicophoron daubneyi (rumen fluke) is an emerging parasitic infection of livestock across Europe. Despite increasing in prevalence, little is known about the level of awareness of rumen fluke or current control practices used by UK farmers. *Fasciola hepatica* (liver fluke) is a common parasitic infection of cattle and sheep in the UK. Co-infections with these parasites can present in sheep and cattle, but the only drug with reported efficacy against rumen fluke is oxyclozanide. Between December 2019 and March 2020, 451 sheep and/or cattle farmers completed an online questionnaire, capturing their awareness and current means of control for liver fluke and rumen fluke. Most respondents (70%) were aware of rumen fluke, with 14% recording its presence on their farms and 18% having previously treated for rumen fluke. Almost all respondents (99%) were aware of liver fluke and higher numbers of respondents reported its presence on farm (67%) with 88% having previously treated for liver fluke. Respondents who were aware of rumen fluke said they were concerned about the parasite (81%), although rumen fluke was less of a concern than liver fluke ($p < 0.05$). Of respondents who reported rumen fluke presence on their farm, 42% cited incorrect diagnostic methods, including those traditionally used to detect liver fluke. Respondents were more likely to treat annually for liver fluke, as opposed to rumen fluke ($p < 0.05$). The most frequently used drug for the treatment of liver fluke infection was triclabendazole (53% sheep treatments, 34% cattle treatments) and only a minority of farmers treated with a product effective against rumen fluke (oxyclozanide; 42% cattle treatments, 35% sheep treatments). A small proportion of farmers stated that they used a non-flukicide drug to treat sheep for liver fluke infection (1.6% sheep treatments). These results demonstrate a broad awareness of liver and rumen fluke in sheep and cattle, but reveal confusion amongst farmers about their diagnosis and treatment, highlighting the need to provide best practice advice to the livestock industry for the control of both parasites.

1. Introduction

Paramphistomes (rumen flukes) are parasitic trematodes with a global distribution, infecting a wide variety of ruminants. Previously little attention has been paid to rumen fluke across Europe as it was considered of limited clinical importance (Malrait et al., 2015). Passive diagnostic surveillance has demonstrated an increase in rumen fluke infection in ruminant livestock across western Europe over the past 20 years, but its economic significance remains unknown (Huson et al., 2017; Mage et al., 2002; Ploeger et al., 2017; Toolan et al., 2015; VIDA 2019). *Calicophoron daubneyi* has been shown to be the primary species of rumen fluke in the UK and heavy infections with the immature stages of the parasite have been identified as a potential cause of fatal disease outbreaks in both sheep and cattle (Gordon et al., 2013; Jones et al., 2017; Malrait et al., 2015; Mason et al., 2012; Sargison et al., 2016). Generally, infection with the adult parasites appears to be well tolerated, but the impact of rumen fluke on production is not fully understood and investigations are difficult due to the lack of diagnostic tests to detect immature parasites (Fenemore et al., 2021; Huson et al., 2017; Sargison et al., 2016).

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Fasciola hepatica (liver fluke) is a parasitic trematode capable of infecting a wide variety of mammalian hosts. Primarily found in temperate regions, it is the causative agent of fasciolosis, an economically important disease of sheep and cattle (Andrews et al., 2021). Acute fasciolosis in sheep can result in significant mortality, caused by the migration of the immature parasites through the liver, whilst chronic fasciolosis is considered a significant cause of morbidity (Sangster et al., 2021). In the UK, liver fluke infection results in substantial economic losses, reductions in productivity and negatively impacts livestock health and welfare (Bennett & Ijpelaar, 2005).

Liver fluke and rumen fluke have similarities in their life cycle, not least the ability to infect the same intermediate snail host in the UK, *Galba truncatula* (Jones et al., 2015). This is thought to contribute to their overlapping distribution and why they are often found as co-infections (Fenemore et al., 2021).

The control of liver fluke in the UK is primarily achieved through use of anthelminthics (flukicides) including; albendazole, closantel, clorsulon, oxyclozanide, nitroxynil and triclabendazole (Alvarez et al., 2021). Triclabendazole has been the flukicide of choice due to its unique ability to target the immature stages of liver fluke in the first few weeks of infection (Boray et al., 1983). The widespread use of triclabendazole has led to the development of resistance, leading to the increased use of alternative flukicides (Kamaludeen et al., 2019; Kelley et al., 2016; Overend and Bowen, 1995).

Oxyclozanide is the only anthelminthic to have consistently shown efficacy against rumen fluke (Arias et al., 2013; Huson et al., 2017; Paraud et al., 2009). Arias et al. (2013), also reported the efficacy of an oral dose of closantel at reducing faecal egg counts in cattle. Oxyclozanide is licensed in the UK as a treatment for liver fluke, but not for rumen fluke. Under prescription and guidance of a veterinarian, oxyclozanide can be used off-license to treat rumen fluke infection, but this reliance on one compound increases the risk of developing resistance, posing a threat to the future control of rumen fluke in livestock in the UK (Huson et al., 2017).

It is important to understand the impact that management factors, particularly methods of parasite control adopted by farmers, have on the transmission of liver fluke and rumen fluke in livestock. This information is crucial in working towards improving the control of both parasites. Studies evaluating current chemotherapeutic control of liver fluke employed by farmers in the UK are limited, and mainly focus on sheep farmers (McMahon et al., 2016; Morgan et al., 2012). There has only been one previous study of farmers in Wales that captured rumen fluke treatments (Jones et al., 2017). More surveys have been carried out in Ireland evaluating the control of liver fluke and/or rumen fluke with both dairy farmers (Bloemhoff et al., 2014; Selemetas et al., 2015) and sheep farmers (Martinez-Ibeas et al., 2016; Munita et al., 2019).

Despite increasing prevalence, little is known about awareness of rumen fluke infection amongst farmers in the UK or about current control practices in sheep and cattle. Hence the aim of this study was to capture rumen fluke awareness and describe current chemotherapeutic control measures for both liver fluke and rumen fluke by sheep and/or cattle farmers in the UK.

2. Methods

2.1. Ethical approval

This study obtained ethical approval from the University of Liverpool's Veterinary Research Ethics Committee (VREC897).

2.2. Questionnaire design

An online questionnaire (Jisc Online Surveys, Bristol, UK) was designed in both English and Welsh to capture awareness of liver and rumen fluke in the UK and evaluate current chemotherapeutic control practices in sheep and cattle. All respondents were asked about their farm characteristics and awareness of liver and/or rumen fluke. If respondents were aware of liver and/or rumen fluke, they were asked if they knew whether they had liver and/or rumen fluke on their farm. Respondents were also asked how concerned they were about liver and/or rumen fluke. Respondents were then asked if they had ever treated for liver and/or rumen fluke, if so, when did they last treat. As treatment regimens can vary year on year, this survey asked farmers about treatments in 2019, for liver and/or rumen fluke, the most recent full calendar year when the questionnaire was released. Those respondents who had treated for liver fluke were asked about their awareness of triclabendazole resistance and if they knew whether it was present on their farm. The questionnaire included both open and closed questions and the online platform facilitated automated skipping of non-applicable questions.

The questionnaire was piloted in winter 2019 with 10 participants including; colleagues, veterinarians and sheep and/or cattle farmers and refined based on feedback. The questionnaire launched in December 2019 and closed in March 2020. The questionnaire was open to any farm in the UK with sheep and/or cattle. Completing the questionnaire was voluntary and informed consent was gained from respondents via the submission of the online questionnaire.

As an incentive to complete the questionnaire respondents were offered the opportunity to enter a prize draw to win a tablet or a luxury hamper. The questionnaire was distributed and advertised via email, social media, magazines, journals, newsletters and meetings through various stakeholders including; funding bodies, sheep and cattle breeding associations, farming groups, young farmers clubs, veterinary practices, farming and agricultural media outlets, journals, levy boards and government agencies.

2.3. Data analysis

Once the questionnaire had closed, Welsh responses were translated into English and all responses were collated in Microsoft Excel (Microsoft, 2016). Responses were checked for eligibility, and any respondents that did not have cattle and/or sheep or were not from the UK were excluded. Responses were checked for duplicate submissions, which were also excluded.

Not all respondents answered all questions; results are presented using the total number of responses for each question as the denominator when calculating percentages. Data analysis was conducted using Microsoft Excel (Microsoft 2016) and SPSS (IBM, SPSS statistics 26). Chi-squared or Fishers exact tests were performed to evaluate associations between categorical variables. Mann Whitney-U or Kruskal-Wallis tests were used to investigate associations between continuous and categorical variables. In the case of multiple comparisons, the Bonferroni correction was applied.

3. Results

3.1. Respondent characteristics

Over the four months from December 2019 to March 2020, a total of 470 responses were recorded. Of these responses 451, were deemed valid and usable. Those excluded included farms with no sheep or cattle, farms not based in the UK, duplicate submissions and responses with no questions completed. Respondents were from every country in the UK, with the highest proportion being from England (63.03%, n = 283/449) and Wales (20.27%, n = 91/449), followed by Scotland (12.92%, n = 58/449) and Northern Ireland (3.79%, n = 17/449) (Fig. 1). In terms of enterprise, most farms bred sheep (85.76% n = 385/449), 46.10% (n = 207/449) had beef sucklers and 25.38% (n = 114/449) reported having beef stores/fattening/or other. A smaller proportion of respondents recorded having a dairy herd (7.79% n = 35/449) (Table 1).

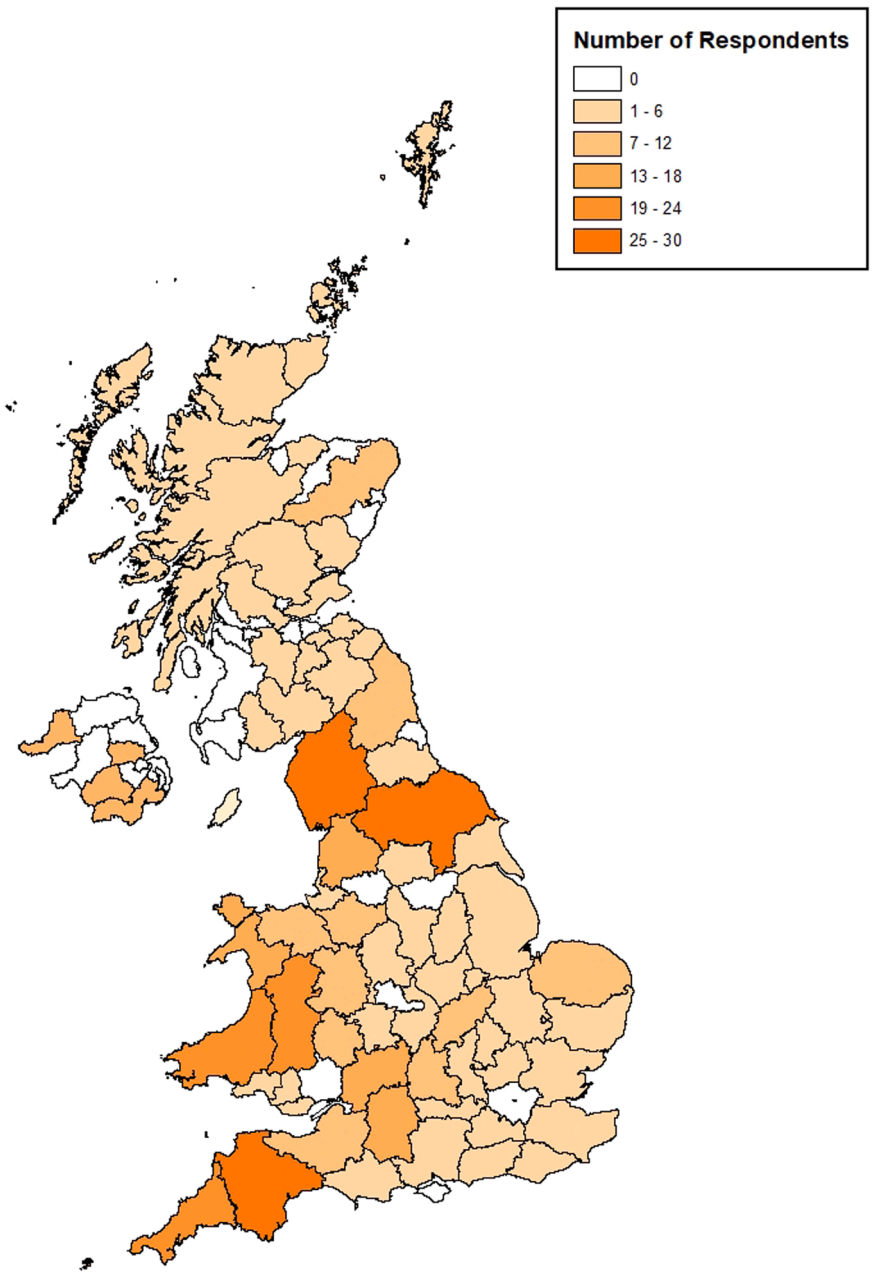

Fig. 1. Location of respondents by UK county (n = 449)(Map created in ArcMap10.7 with ONS county boundaries).

Table 1
Farm enterprise characteristics of respondents (n = 449).

Farm Enterprise	Percentage of respondents	Median flock/herd size	Range
Breeding Sheep	85.76%	275	4–4500
Beef Sucklers	46.10%	40	2–700
Beef Stores/Fattening/ Other	25.38%	11	0–770
Dairy Herd	7.79%	135	20–1000

3.2. Liver fluke and rumen fluke awareness and concern

The majority of respondents were aware of rumen fluke (70.28%, n = 317/451). Farms with higher median numbers of breeding sheep were statistically more likely to be aware of rumen fluke (U= 9896.5, $p < 0.001$). There was a significant association with country and rumen fluke awareness ($\chi^2 = 13.16$, df=3, $p < 0.001$), with all respondents from Northern Ireland having previously heard of rumen fluke. Almost all respondents (98.89%, n = 446/451) were aware of liver fluke. Respondents expressed concerned about rumen fluke (81.07%, n = 257/317), although this was less of a concern than liver fluke ($\chi^2 = 177.15$, df=5, $p < 0.001$) (Fig. 2).

3.3. Presence of liver fluke and rumen fluke on farm

Of those who were aware of rumen fluke, 19.87% (n = 63/317) reported the presence of rumen fluke infection on their farm, 28.71% (n = 91/317) reported the absence of rumen fluke on their farm and 51.42% (n = 163/317) did not know if they had rumen fluke infection on their farm. Currently there are two methods available to detect rumen fluke infection (post-mortems or faecal egg counts (FECs)). Of those who reported rumen fluke presence on their farm, 57.14% (n = 36/63) reported using FECs and 25.40% (n = 16/63) cited post-

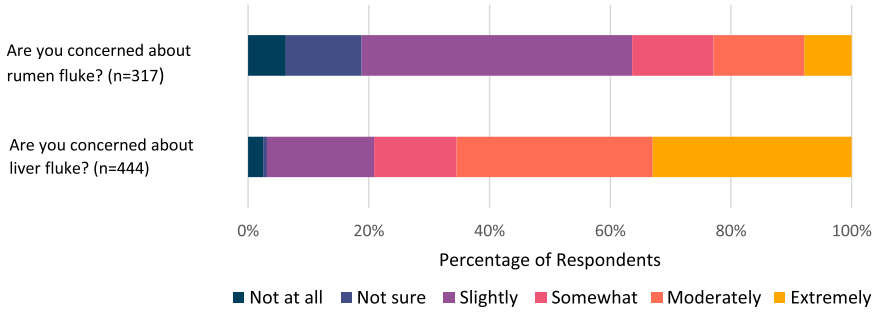

Fig. 2. Graph showing percentage of respondents level of concern regarding liver fluke and rumen fluke on a 5-point Likert scale.

mortems. The remainder, 42.86% (n = 27/63), cited other methods which are commonly used as liver fluke diagnostics (Fig. 3).

Of those who were aware of liver fluke, 67.79% (n = 301/444) of respondents reported the presence of liver fluke infection on their farm, 19.81% (n = 88/444) stated liver fluke infection was absent and 12.38% (n = 55/444) said they did not know if liver fluke infection was present on their farm. Liver fluke presence on farm was associated with higher median numbers of breeding sheep ($\chi^2 = 19.86$, df=2, $p < 0.001$).

Of respondents who reported liver fluke infection in their livestock, 59.46% (n = 179/301) attributed this knowledge to abattoir returns, 40.53% (n = 122/301) cited FECs, 40.53% referenced post-mortems (n = 122/301), 7.97% (n = 24/301) said blood tests, 3.98% (n = 12/301) used bulk tank milk tests and 4.31% (n = 13/301) cited copro-antigen tests. A few respondents said they did not know 0.99% (n = 3/301) and 16.27% (n = 49/301) reported other methods (Fig. 3).

3.4. Previous treatments

3.4.1. Rumen fluke

Just over a quarter of respondents (26.18%, n = 83/317) who were aware of rumen fluke, stated that they had previously treated for rumen fluke. Previous treatment for rumen fluke, was associated with reported presence of rumen fluke infection on farm ($\chi^2 = 83.29$, df=2, $p < 0.001$) and the level of concern regarding rumen fluke ($\chi^2 = 76.71$, df=5, $p < 0.001$). There was a significant association between previous treatments and country of respondent ($\chi^2 = 38.5$, df=8, $p < 0.001$), with respondents from Northern Ireland more likely to have previously treated for rumen fluke.

3.4.2. Liver fluke

Most respondents who were aware of liver fluke, stated that they had previously treated for liver fluke (89.24%, n = 398/446). As with rumen fluke, previous treatment was associated with concern about liver fluke ($\chi^2 = 92.3$, df=5, $p < 0.001$). Farms with higher median numbers of breeding sheep were more likely to have previously treated for liver fluke (U = 8218.5, $p < 0.001$).

3.5. Sheep treatments

3.5.1. Rumen fluke

The majority of respondents who treated their sheep for rumen fluke (74.54%, n = 41/55), stated their last treatment was in 2019/2020. Over half, 53.44% (n = 31/58) of the respondents who recorded treating sheep for rumen fluke, do so on an annual basis. Of those who do not treat annually 63.64% (n = 14/22) said they treated as required, 27.27% (n = 6/22) reported only treating once before, 4.5% (n = 1/22) treated only when advised and 4.5% (n = 1/22) treated every other year.

Most respondents who treated their sheep for rumen fluke infection in 2019 reported treating once (47.72%, n = 21/44), or twice (38.63%, n = 17/44), with 9.09% (n = 4/44) treating three times and 4.5% (n = 2/44) reporting treating four times or more (Fig. 4). In total 41 respondents, recorded 73 treatment events in 2019. Of those who specified most of these treatments were recorded over the autumn and winter period (68.05%, n = 49/72), but only 34.92% (n = 22/63) of these events included oxyclozanide (Fig. 5).

3.5.2. Liver fluke treatments

From respondents who had previously treated their sheep for liver fluke the majority (88.62%, n = 296/334) recorded their last liver fluke treatment in sheep in 2019/2020. Most respondents (78.36%, n = 268/342) stated that they treated their sheep for liver fluke infection on an

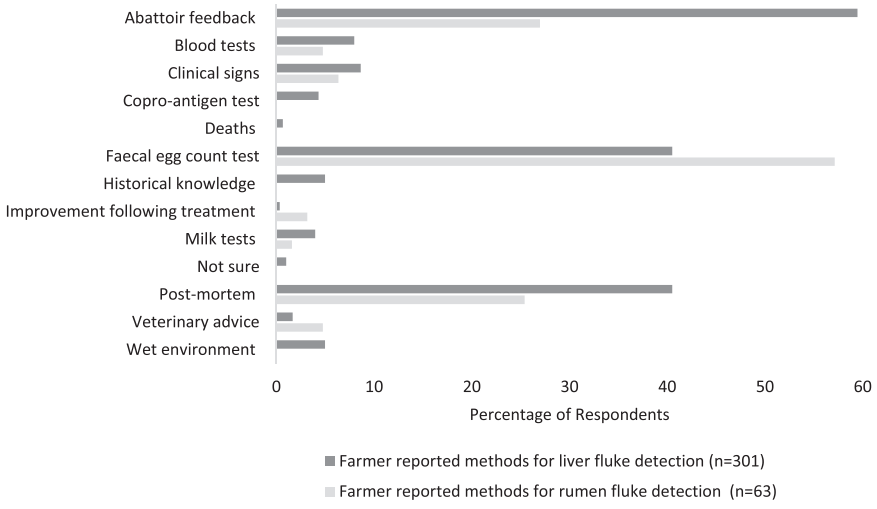

Fig. 3. Farmer reported methods for the detection of rumen fluke (n = 63) and liver fluke (n = 301) on their farm.

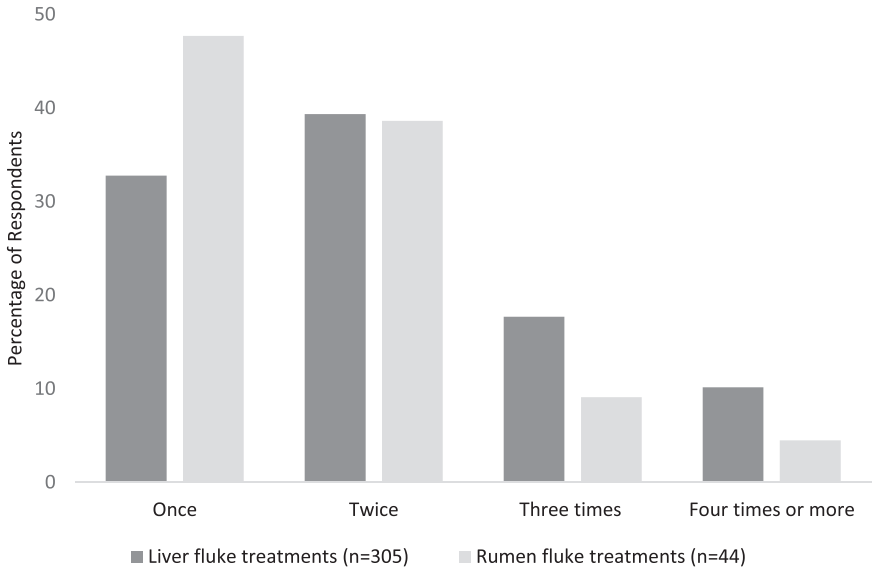

Fig. 4. Number of treatments recorded of sheep for liver fluke (n = 305) and rumen fluke (n = 44) in 2019.

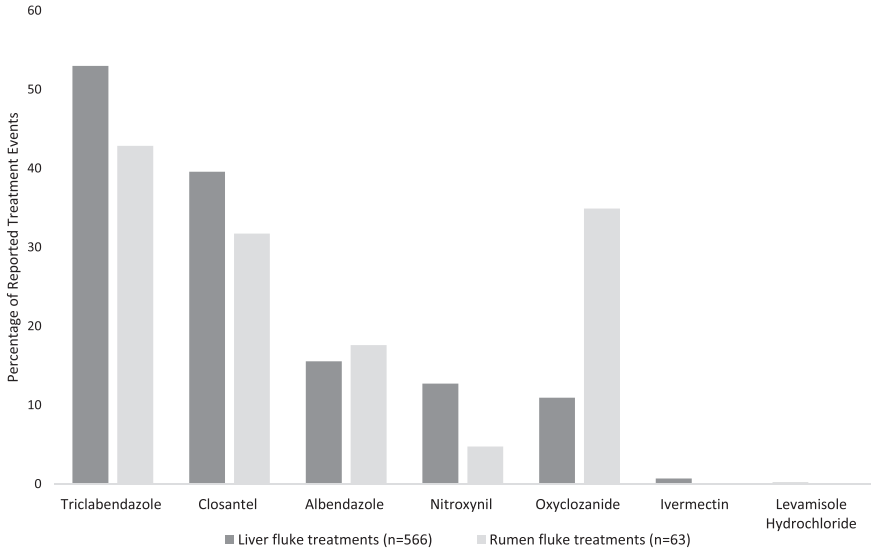

Fig. 5. Farmer reported anthelminthic used in the treatment of sheep for liver fluke (n = 566) and rumen fluke (n = 63) shown as percentage of reported treatment events in 2019.

annual basis, significantly higher than those reporting annual treatments for rumen fluke ($\chi^2 = 17.68$, df=1, $p < 0.0001$). The majority of those who reported not treating on an annual basis only treated when required (65.15%, n = 43/66). Treating annually was associated with higher numbers of median breeding sheep on farm (U= 10762.5, $p < 0.05$). In 2019, 32.78% (n = 100/305) of respondents recorded treating their sheep for liver fluke once, 39.34% (n = 120/305) treated twice, 17.70% (n = 54/305) treated three times and 10.16% (n = 31/305) treated four times or more (Fig. 4). A higher treatment frequency was associated with higher numbers of median breeding sheep on farm ($\chi^2 = 15$, df=4, $p < 0.05$). Overall, in 2019, 297 respondents recorded 619 treatment events. Of respondents who specified the timing of treatments, 70.13% (n = 425/606) occurred across autumn and winter. From those respondents who stated which flukicide they used, the most used was triclabendazole (53%, n = 300/566). Five treatment events were recorded using the non-flukicides ivermectin and levamisole hydrochloride (Fig. 5). With the exclusion of these non-flukicides there was an association between the active compound and the season ($\chi^2 = 803.9$, df=20, $p < 0.001$), with triclabendazole being used more frequently in autumn and winter, compared to spring and summer.

3.6. Cattle treatments

3.6.1. Rumen fluke

Most respondents who had previously treated cattle for rumen fluke, recorded their last treatment for rumen fluke in 2019/2020 (68.18%, n = 30/44). The majority of respondents (59.09%, n = 26/44) reported treating on an annual basis. Those who do not treat every year reported only treating as required (80%, n = 12/15), treating every other year (13.33%, n = 2/15) and treating every 2–3 years (6.66%, n = 1/15). In 2019, most respondents only treated once (38.64%, n = 17/44) or twice (29.55%, n = 13/44), with 4.55% (n = 2/44) stating they treated three times (Fig. 6). In total 32 respondents, recorded 41 treatment events in 2019. From respondents who specified most reported treating in autumn and winter (69.44%, n = 25/36), with only 42.11% of treatment events including oxyclozanide (n = 16/38) (Fig. 7).

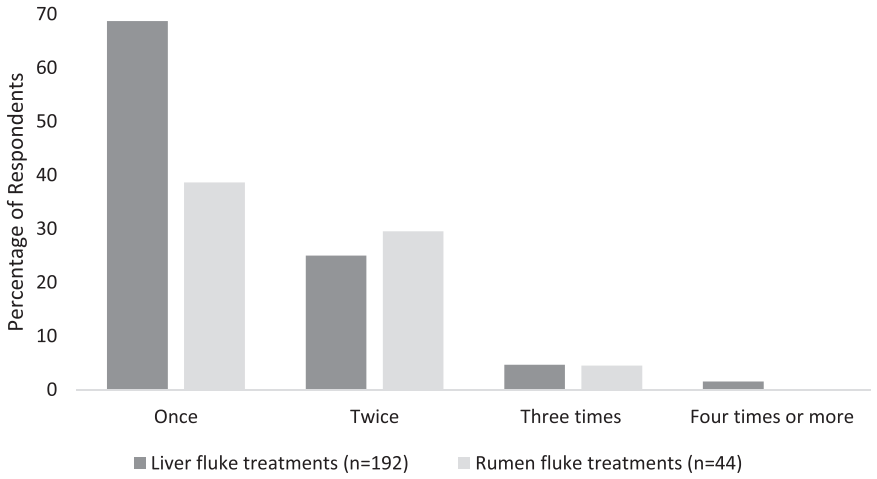

Fig. 6. Number of treatments recorded of cattle for liver fluke (n = 192) and rumen fluke (n = 44) in 2019.

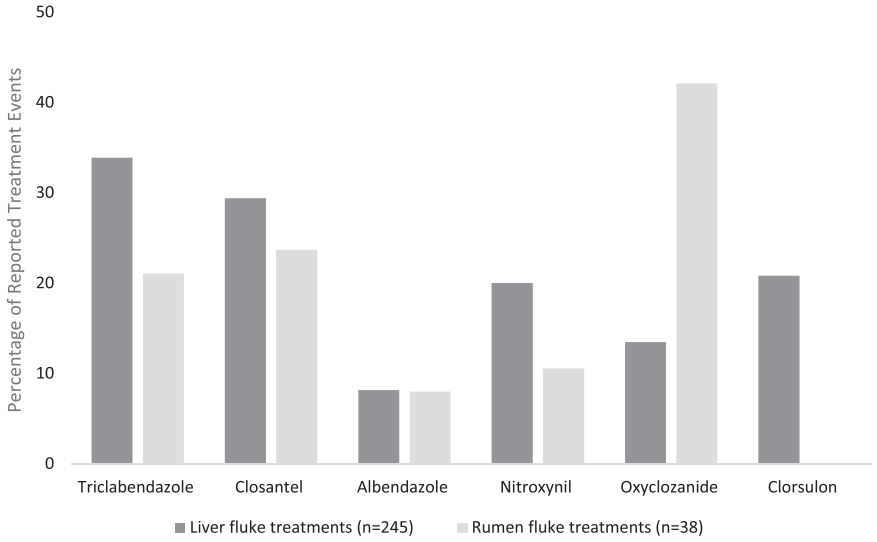

Fig. 7. Farmer reported anthelminthic used in the treatment of cattle for liver fluke (n = 245) and rumen fluke (n = 38) shown as percentage of reported treatment events in 2019.

3.6.2. Liver fluke

Of those who had previously treated their cattle for liver fluke, almost all respondents recorded their last treatment in 2019/2020 (89.21%, n = 182/204). The majority of respondents (83.17%, n = 178/214) recorded treating every year, significantly higher than those reporting annual treatments of cattle for rumen fluke infection (χ^2 = 12.79, df=1, $p < 0.001$). Most who reported not treating every year stated they only treated when required (58.33%, n = 21/36). In 2019, most respondents (68.75%, n = 132/192) only treated their cattle once, 25% (n = 48/192) treated twice, 4.68% (n = 9/192) treated three times and 1.56% (n = 3/192) treated four times or more (Fig. 6). In total 181 respondents, recorded 258 treatment events, in 2019. From respondents who specified, 77.43% (n = 175/226) of these treatment events occurred over autumn and winter. The most frequently used drug was triclabendazole (33.87%, n = 83/245) (Fig. 7).

3.7. Triclabendazole drug resistance in liver fluke

Of respondents who had previously treated for liver fluke infection, 83.75% (n = 335/400) were aware of triclabendazole resistance in liver fluke. Of those aware of resistance, 15.27% (n = 51/334) recorded knowing it was present on their farm, 29.34% (n = 98/334) did not know if it was present on their farm and 55.38% (n = 185/334) reported they did not have resistant parasites on their farm. Farmers with higher median numbers of breeding sheep were more likely to report the presence of triclabendazole resistance on their farm (χ^2 = 21.15, df=2, $p < 0.001$). Of those respondents who reported the presence of resistance 60.78% (n = 31/51) reported detecting resistance through a diagnostic test, 70.58% (n = 36/51) stated they had experienced treatment failure and 11.76% (n = 6/51) reported other reasons they thought they had resistance.

4. Discussion

This study is the first to capture the awareness of rumen fluke and current chemotherapeutic practices used in its control from sheep and/or cattle farmers across the UK.

Farmers reported a lower awareness of rumen fluke compared to liver fluke. Despite reports of increasing rumen fluke prevalence across the UK, this study showed not all farmers have previously heard about rumen fluke. Rumen fluke awareness in this study is higher than that reported in a survey of 100 young Welsh farmers in 2015, where 49% had previously heard of rumen fluke, suggesting an increasing awareness of rumen fluke amongst farmers in the UK over recent years (Jones

et al., 2017). However, this may reflect regional differences and the geographic scope of the two studies. There was a significant association between rumen fluke awareness and region, with all farmers in Northern Ireland being aware of rumen fluke. This could be attributed to the higher levels of rumen fluke across the island of Ireland, leading to an increased awareness (Martinez-Ibeas et al., 2016). Given the low number of respondents from Northern Ireland in this study (n = 17), further work would be needed to confirm this conclusion.

This study was the first to evaluate farmers concern about liver and/or rumen fluke in the UK to gain a better understanding of what is driving farmers to treat. The majority of those who had previously heard about rumen fluke were concerned, but the level of concern was significantly lower than the concern about liver fluke. This is not surprising given the known risk from liver fluke and its clinical importance.

In this study, most farmers did not know if rumen fluke was present on their farm. A study of 104 sheep farmers in Ireland reported similar results, with 40% being unaware of clinical cases of rumen fluke on their farm (Martinez-Ibeas et al., 2016). As the authors suggest, this demonstrates the lack of diagnostic tests available for rumen fluke, especially those with the ability to detect immature parasites (Huson et al., 2017; Martinez-Ibeas et al., 2016). Nearly a fifth of respondents in this study reported the presence of rumen fluke on their farm. There are currently only two methods to detect rumen fluke on farm; faecal egg count tests and post-mortems, but nearly half of respondents cited a method more commonly used to detect liver fluke. This suggests confusion between the two parasites and their diagnosis. It is important to note that the use of farmer reported presence of liver fluke and rumen fluke has its obvious limitations, but parasitological surveys on these farms were beyond the scope of this study.

Current recommendations in the treatment of liver and rumen fluke in livestock advocate for a diagnostic led approach (COWS, 2020; SCOPS, 2022). The results from this study show that is not always the case, which could be leading to unnecessary treatments, which could be driving the development of drug resistant parasites in the population.

Of respondents who had previously heard about rumen fluke, just over a quarter had previously treated for it. This is lower compared to previous studies undertaken in Ireland, where in 2013 a study of Irish dairy farms demonstrated that all 235 respondents had treated for rumen fluke and a study of Irish sheep farms showed 75% of respondents dosed for rumen fluke across the autumn and winter period (Martinez-Ibeas et al., 2016; Selemetas et al., 2015). As previously highlighted, this could be due to the higher levels of rumen fluke recorded across Ireland. Previous treatments were significantly associated with farmer reported presence of rumen fluke on farm and respondents concern about rumen fluke. There was a significant association between region and previous rumen fluke treatment, with farmers in Northern Ireland more likely to have previously treated for rumen fluke. This could be linked to the fact that all respondents from Northern Ireland were aware of rumen fluke, so might have been more likely to have treated in the past, or rumen fluke is more prevalent in Northern Ireland. There are no studies evaluating regional differences in the treatment of rumen fluke in the UK, but it has been shown for liver fluke that respondents from Ireland, Northern England, Scotland or Wales were more likely to treat for fasciolosis compared to farmers from the midlands and Southern England (Morgan et al., 2012). When examining regional differences, it is important to consider the geographic distribution of liver and rumen fluke, as it is likely to be a major factor in driving treatment. Given the small number of respondents from Northern Ireland in this study, further work would be needed to draw conclusions on any regional differences in treatment across the UK.

Farmers were more likely to treat for liver fluke on an annual basis compared to rumen fluke in both sheep and cattle. Most farmers treated for rumen fluke once or twice annually, which agrees with the observations recorded in a survey of Irish sheep and dairy farms (Martinez-Ibeas et al., 2016; Selemetas et al., 2015). In the treatment of rumen fluke, most respondents were only treating once during the autumn and winter period and as others have suggested this is unlikely to reduce the risk from pasture contamination (Martinez-Ibeas et al., 2016).

In this study the majority of reported treatment events for rumen fluke did not include oxyclozanide, the only effective anthelminthic against rumen fluke. The use of unsuitable products in the treatment of rumen fluke has been reported in previous studies (Martinez-Ibeas et al., 2016; Selemetas et al., 2015). A survey of Irish sheep farms showed that nearly 50% of farmers were using products not containing oxyclozanide (Martinez-Ibeas et al., 2016).

The percentage of farms treating sheep and/or cattle for rumen fluke with oxyclozanide is higher than that reported by Jones et al. (2017), this could be due to an increasing awareness of rumen fluke which has led to an increase in treatments in the UK. The use of unsuitable products in the treatment of rumen fluke in both sheep and cattle could be arising in part from confusion between liver and rumen fluke and their control, as highlighted in this study. It may also reflect a lack of accessible information on parasite control (Selemetas et al., 2015). The results from this study could be used to improve information on liver and rumen fluke, by contributing to farmer and veterinary focused knowledge exchange organisations.

This study reported triclabendazole as the most frequently used in the treatment of liver fluke. The dominant anthelminthic in the treatment of liver fluke in sheep has shown to vary across different studies in the UK and Ireland (McMahon et al., 2016; Morgan et al., 2012; Munita et al., 2019). McMahon et al. 2016 reported the decreasing use of triclabendazole in the treatment of liver fluke infection in sheep from Northern Ireland between 2005 and 2011, with an increase in the use of closantel and oxyclozanide. The decreasing use of triclabendazole is most likely attributed to farmers becoming more aware of issues with resistance (Coyne et al., 2020; Kamaludeen et al., 2019; McMahon et al., 2016; Overend and Bowen, 1995). In this study, over 80% of those who had previously treated for liver fluke were aware of resistance to triclabendazole. As McMahon et al. 2016 suggest, the increasing use of oxyclozanide is most likely due to the increasing awareness of rumen fluke.

A small number of liver fluke treatment events in this study recorded using a non-flukicide, which has been observed in previous studies (Bloemhoff et al., 2014; Morgan et al., 2012; Munita et al., 2019). As Morgan et al. (2012) suggest, the use of inappropriate drugs is likely to select for resistance in other parasites such as nematodes.

When interpreting the results from this study it is important to consider its limitations. Due to the nature of the non-probability, voluntary sampling approach utilised there is likely to be some level of sampling bias (Clark et al., 2021). Farmers who have more experience with liver and/or rumen fluke, and are more interested and engaged in their control are more likely to complete the questionnaire. Distributing the questionnaire online may have also induced bias, excluding those without internet access. Self-desirability bias may have occurred where farmers answer questions as they think they should, not actually reporting true beliefs or practices (Bellet et al., 2015; Clark et al., 2021; Coyne et al., 2020; Horne and Weinman, 1999). Recall bias may have also been present, especially when asking farmers about treatment events over the course of a year. In an attempt to reduce recall bias, the survey was released in December 2019, when the autumn and winter treatment timepoints most relevant for fluke control will have been fresher in farmers minds, and the questionnaire contained a product guide, detailing all the available flukicide treatments alongside pictures of the commercially available products. Taking these limitations into account the results of the questionnaire may not represent the entirety of the target population of UK sheep and cattle farmers, but provides invaluable insights into current awareness of rumen fluke and liver fluke, and chemotherapeutics used in their control on farms in the UK.

5. Conclusion

The results from the questionnaire suggest confusion between liver

fluke and rumen fluke amongst farmers. Awareness of rumen fluke was lower than liver fluke, although in reality this is likely to be even lower given the confusion apparent between the parasites. The survey showed that farmers were concerned about rumen fluke, but the concern was less severe compared to liver fluke. Some farmers reported treating for rumen fluke, but most recorded using unsuitable products, and the number treating for rumen fluke on an annual basis was significantly lower compared to liver fluke. The most frequently used drug in the treatment of liver fluke was triclabendazole, in both sheep and cattle; but is important to consider there are multiple factors influencing drug choice.

These results demonstrate confusion amongst farmers about both parasites and their control, highlighting the need to raise awareness of rumen fluke and work to provide best practice advice for the control of these parasites in livestock.

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CRediT authorship contribution statement

Rebecca C. Hoyle: Conceptualization, Methodology, Investigation, Formal analysis, Writing – original draft. **Hannah Rose Vineer:** Resources, Writing – review & editing. **Jennifer S. Duncan:** Methodology, Writing – review & editing, Supervision. **Diana. J.L. Williams:** Methodology, Writing – review & editing, Supervision. **Jane E. Hodgkinson:** Conceptualization, Methodology, Writing – review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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