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Distribution of bovine *Fasciola gigantica* (Cobbold, 1885) in the district des Savanes, northern Côte d'Ivoire

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Abstract

Fascioliasis, caused by an infection with liver flukes of the genus *Fasciola*, is an important disease of livestock in most parts of the world. However, little is known about the distribution of fascioliasis in sub-Saharan Africa. We report results of a cross-sectional study conducted in 2014 in the district des Savanes in the northern part of Côte d'Ivoire. We obtained 275 livers from bovine suspected with fascioliasis and 51 unsuspected livers from 24 slaughterhouses. Livers were dissected using a standard operating procedure and all *Fasciola gigantica* flukes were removed from the tissues of the liver and the biliary ducts. We found *F. gigantica* in 125 livers from bovines suspected with fascioliasis (45.5%) in 10 departments of the district des Savanes. Among the unsuspected livers, five were positive for *F. gigantica* (9.8%). The distribution of fascioliasis showed considerable spatial heterogeneity, both at regional (ranging from 18.0% to 52.3%) and departmental level (ranging from 14.3% to 64.0%). Poro region was the most affected (52.3%) with a relatively homogeneous distribution. The departments most affected by fascioliasis were M'Bengué (64.0%), Sinématiali (62.1%) and Ferkessédougou (52.9%). Our study confirms that fascioliasis is an important veterinary disease in the northern part of Côte d'Ivoire, and hence, high-risk areas need to be targeted for prevention and control measures.

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Introduction

Fascioliasis, also known as large liver fluke disease or hepatic distomatosis, is a neglected tropical disease, caused by helminths of the genus *Fasciola* (Fürst *et al.*, 2012; Harrington *et al.*, 2017; Mas-Coma *et al.*, 2019). While fascioliasis is an important veterinary disease, it can also affect humans (Mas-Coma *et al.*, 2019). The species *Fasciola gigantica* has been described in numerous sub-Saharan African countries (Schillhorn Van Veen, 1980). Typical manifestations of infected animals include general weakness, pronounced emaciation, diarrhoea, dehydration with enlarged eyeballs and an increased susceptibility to secondary infections (Kaboré *et al.*, 1993). Lesions in the liver, which is the main target organ for adult *Fasciola*, lead to a parenchymatous hepatitis, which progresses to a cholangitis and then to a cirrhosis (Kaboré *et al.*, 1993; Kassaye, 2011). The consequences of this parasitic infection are manifold, including increased animal mortality, weight loss, drop in milk production and confiscating of parasitized livers at abattoirs (Wamae and Ihiga, 1991; Mage *et al.*, 2002; Colin, 2009). There are considerable economic repercussions, as it is estimated that an infection with *F. gigantica* can result in up to 25% loss in meat production (Vissoh, 1980).

In Côte d'Ivoire, the first case of bovine fascioliasis was reported by Morel in the mid-1950s in livestock bred in the northern parts of the country (Morel, 1959). A study conducted in 1996 and 1997 in municipal abattoirs of Korhogo in the district des Savanes estimated the prevalence of bovine fascioliasis to be 4% (Achi *et al.*, 2003). A coprological survey by Soffo performed in 2010 in the departments of Boundiali, Ferkessédougou, Korhogo and Tengrela in northern Côte d'Ivoire, revealed a prevalence of 28.6% (Soffo, 2010). These previous investigations in the northern part of Côte d'Ivoire demonstrate the importance of veterinary fascioliasis.

The objective of this study was to deepen the understanding of the distribution of fascioliasis in the entire district des Savanes, which is the main region for cattle husbandry in Côte d'Ivoire. Our data complement recent findings (Kouadio *et al.*, 2020) and will inform decision-makers for spatial targeting of prevention and control measures.

Materials and methods

Ethical considerations

This study was performed in accordance with ethical standards and regulations and was approved by the ethics committee of Côte d'Ivoire (authorisation no.: 32-MSLS/CNERdkn) and Basel, Switzerland (authorization no.: EKBB 64/13). Animal health authorities in the district des Savanes, veterinary agents and participating butchers were informed about the objectives, procedures, potential risks and benefits of the study and were asked for written informed consent.

Cattle livers with suspected *Fasciola* infection were confiscated according to national regulations for vigorous inspection. A random selection of livers from seemingly healthy animals were purchased from the butchers at abattoirs for a negotiated price to complement the sample of confiscated livers with a less biased sample of livers from seemingly healthy cattle.

Study area

The district des Savanes is situated in the northern part of Côte d'Ivoire between 8° and 11° N latitude and between 4° and 7° E longitude. The district des Savanes comprises three regions and 10 departments: Poro region (including the districts of Dikodougou, Korhogo, M'Bengué and Sinématiali), Tchologo region (including the districts of Ferkessédougou, Kong and Ouangolodougou) and Bagoué region (including the districts Boundiali, Kouto and Tengrela) (Figure 1).

It is important to note that the district des Savanes is the principal livestock breeding zone of Côte d'Ivoire, harbouring an estimating 40% of all Ivorian livestock that consisted of approximately 1.59 million cattle, 1.73 million sheep, 1.38 million goats, 360,000 pigs and 58.4 million chickens in the late 1990s (RNA, 2001; RGPH, 2002). Cattle breeds, mostly consisting of the longhorn humped zebus of *Bos indicus* type, of N'dama and Baoulé (which are part of the West African humpless shorthorn breeds (*B. taurus* type) and their crossbred (*B. taurus x B. indicus*) are mainly raised in traditional sedentary or transhumant systems (Yoboué, 2010). According to statistics from the regional office of the Ministry of Animal and Aquatic Resources (MIRAH), approximately 59,000 livestock animals are slaughtered every year in the district des Savanes (MIRAH, 2013).

The tropical to semi-arid climate in the study area is characterised by a dry season from November to May, and a rainy season from June to October. The vegetation consists of islands of dense forests, clear forests and a whole range of savannahs (wooded, grassy). There is a dense network of rivers, mainly governed by the Bandaman River and its tributaries (Badenou, Bou, Lokopho and Solomougou), two tributaries of the Niger River (Bagoué and Kankélaba) and a tributary of the Comoé River (Léraba Occidental) (Figure 1). To these permanent watercourses, an estimated 250 water retention sites of different sizes are connected that were mainly constructed in the 1980s by the '*Société pour le Développement des Productions Animales*' (SODEPRA) to help the development of agro-pastoralism in the northern parts of Côte d'Ivoire (Aka *et al.*, 2000).

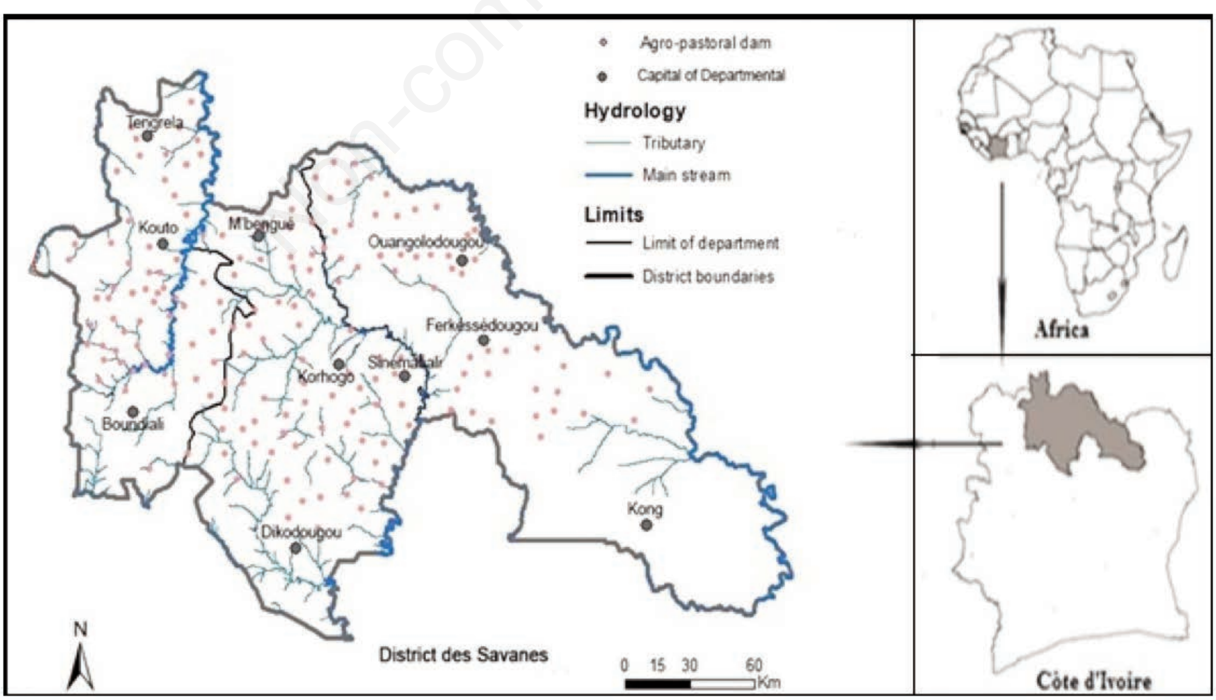

Figure 1. District des Savanes in the northern part of Côte d'Ivoire, including hydrological network and regional and departmental boundaries.

Sample collection

Cattle, sheep and goat livers were collected during the rainy season from June to September 2014 from abattoirs and slaughter sites in each of the 10 departments of the district des Savanes. Sample collection involved at least 20 livers per department. Livers were confiscated by hygiene inspection agents, whenever *Fasciola* infection was suspected (*i.e*. showing signs of parenchymatic hepatitis, telangiectasias, hyperplastic cholangitis and fibrosis). Additionally, 5 livers from animals with a healthy appearance were purchased in each department to complement the samples.

Livers were placed into a cooling box with ice and, within a maximum of 48 hours, transferred to the regional laboratory in Korhogo. For each liver, a standard sample collection form was issued, indicating the race of the animal, age, sex, native country and the reason for slaughtering.

During this study, a total of 326 livers were collected from 102 slaughtering sites in the district des Savanes. All livers collected were taken from animals bred in Côte d'Ivoire. There were 275 livers confiscated from animals with suspected *Fasciola* infection, while the remaining 51 livers were obtained from animals appearing healthy. Of the collected livers, 296 were from cattle, 20 from sheep and 10 from goats.

The analysis of animal livers allowed determining the proportion of livers (confiscated and healthy) that were infested by the fluke according to breed, sex and age. Moreover, the analysis showed the distribution of fascioliasis in the district des Savanes in this cross-sectional survey

The proportion of animal livers (confiscated and healthy) infected with *F. gigantica* was estimated by the number of animals infected with *Fasciola* spp., divided by the number of animals analysed.

Laboratory procedures

In the laboratory, the different macroscopic lesions indicative of fascioliasis or other potential liver pathologies were identified and recorded. The big bile ducts were opened with a pair of scissors and flukes that were found inside were placed into a glass containing physiological solution. The livers were subsequently dissected into thin slices (3-5 mm thickness) and pressure was exerted on the parenchyma to retrieve flukes located in the smaller capillaries. The obtained liver slices were put into containers and immersed in physiological solution. The containers were stored at room temperature for at least 2 hours.

The resulting maceration solution was poured through three sieves superimposed upon each other with reducing mesh-widths from top to bottom of 5 mm, 3 mm and 125 µm, respectively. Liver pieces were subsequently douched with a pressurised water jet to wash out remaining flukes. Complete flukes, as well as flukes severed during the slicing of the livers, were recuperated from the 3 mm sieve and added to the flukes collected in the first step. All collected flukes were subsequently identified at species level and counted. In case of severed flukes, only the pieces with heads were counted.

Statistical analysis

Data were entered into a Microsoft Excel spreadsheet and analysed with SAS version 9.0 (SAS Institute Inc.; Cary, NC, USA). In addition to descriptive analysis, logistic and negative binomial regressions were employed to compare and evaluate the association between different parameters of interest. A P-value of 0.05 was considered as statistically significant. Analyses were limited to cattle, because the number of sheep and goat livers was too small for any meaningful statistical analysis.

Results

Of the 275 confiscated livers collected from the district des Savanes, 125 (45.5%) were found to be infected with *F. gigantica.* Among the 51 apparently healthy livers purchased, 5 (9.8%) were infected with *F. gigantica*. No flukes were found in goat livers. Confiscated cattle livers (47.2%) and confiscated sheep livers (45.0%) showed comparable infection rates (Table 1). In addition to *F. gigantica* infections, cases of dicrocoeliasis were observed in 271 (83.1%) of the livestock livers. Of all analysed livers, 115 (35.3%) were coinfected with *F. gigantica* and *Dicrocoelium dendriticum*.

Fasciola flukes were found in multiple cattle livers in each of the 10 departments in the district des Savanes. Fascioliasis was found at 41 of the 49 study sites in Poro, 23 of 30 sites in Tchologo and 9 of 23 sites in Bagoué (Figure 2). Infections with *F. gigantica* were most frequent in Poro (52.3%), least frequent in Bagoué (18.0%), while an intermediate level was seen in Tchologo (36.6%) (P=0.001).

The proportion of infected cattle livers in the 10 departments of the district des Savanes ranged from 14.3% to 64.0% with significantly higher infection rates in the departments of M'Bengué (64.0%; P=0.004), Sinématiali (62.1%; P=0.050), Ferkessédougou (52.9%; P=0.002), Korhogo (48.7%; P=0.005) and Dikodougou (43.5%; P=0.031), compared to Tengrela. The departments with the lowest infection rates were Kong, Tengrela, Kouto Boundiali and Ouangolodougou, ranging between 14.3% and 40.0% (Figure 3). An analysis of infection rates in cattle by race, sex and age group revealed non-significant differences (Tables 2 and 3).

Table 1. Number of cattle, sheep and goat examined, and number of livers infected with *Fasciola* spp. in the district des Savanes in the northern part of Côte d'Ivoire.

Animal type	Confiscated livers (suspected of fascioliasis)			Purchased livers (from seemingly healthy animals)		
	No. of animals analysed	No. of animals infected with *Fasciola* spp. (%)	95% CI	No. of animals analysed	No. of animals infected with *Fasciola* spp. (%)	95% CI
Cattle	246	116 (47.2)	41.0-53.4	50	5 (10.0)	1.7-18.3
Sheep	20	9 (45.0)	23.2-66.8	0	0 (0.0)	-
Goat	9	0 (0.0)	-	1	0 (0.0)	-
Total	275	125 (45.5)	39.6-51.4	51	5 (9.8)	1.6-18.0

*Statistically significant difference; CI, confidence interval.

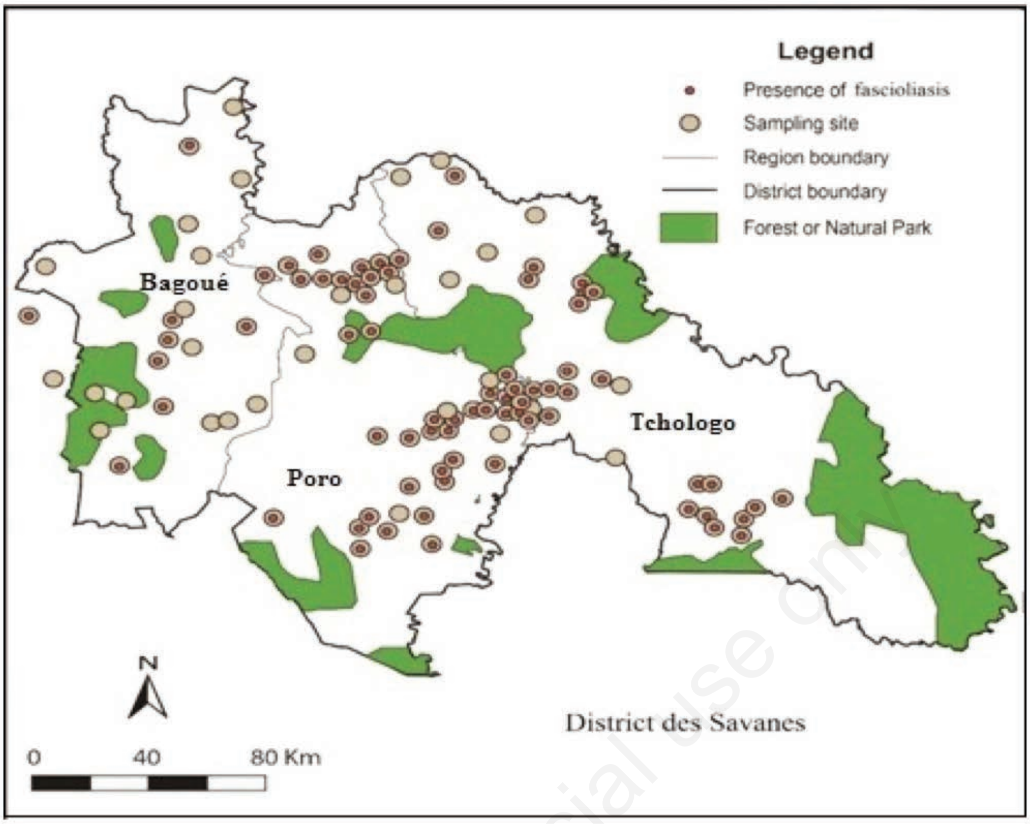

Figure 2. Liver collection sites in the district des Savanes in 2014, Côte d'Ivoire.

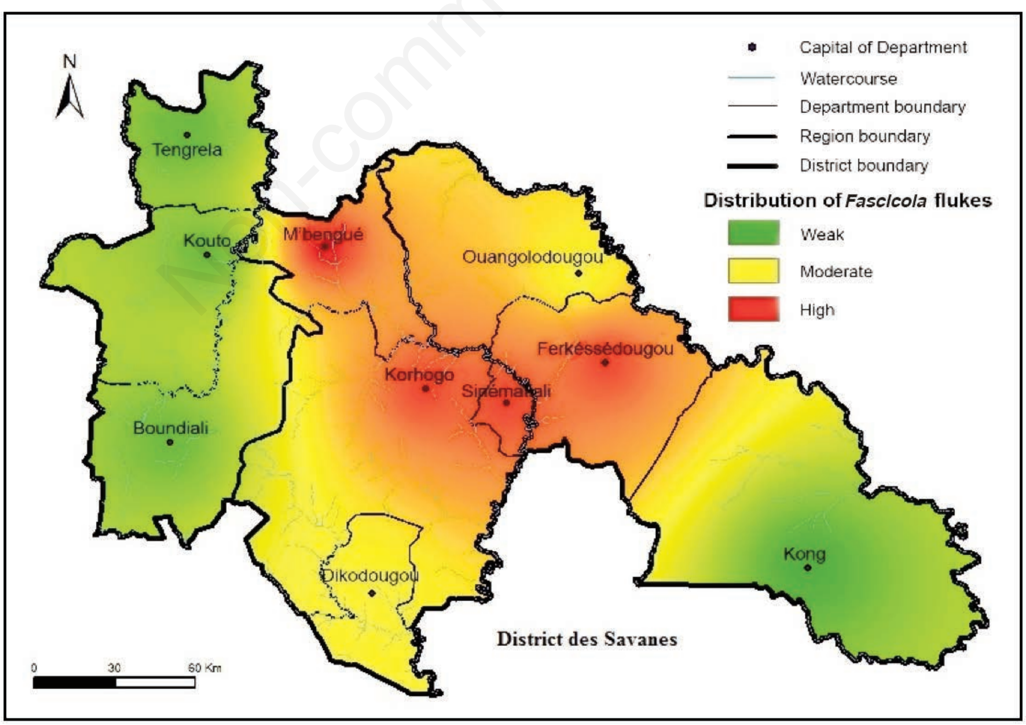

Figure 3. Distribution of fascioliasis infected cattle livers between June and September 2014 in the district des Savanes, Côte d'Ivoire. This figure shows how many infected cattle livers were found in the respective areas, irrespective of the number of parasites per infected liver.

Female cattle were slightly more infected than male cattle. Cattle of the N'dama race were less frequently infected than cattle of Métis, Zébu or Baoulé races. Animals older than 6 years tended to be more often infected with *F. gigantica*, compared to cattle aged 4-6 years or cattle equal or younger than 3 years.

Parasite load in the infected cattle livers varied from 1 to 1216 *Fasciola* spp. with a mean count of 145 *Fasciola* spp. (Table 4). At the unit of the department, the mean parasite load varied between 7 and 476 flukes. Analysis of confiscated cattle livers showed a statistically higher risk of exposure in the departments Boundiali (P=0.046), M'Bengué (P<0.001) and Ouangolodougou (P<0.001), compared to the departments Dikodougou (P=0.008) and Tengrela (P=0.010) (Figure 4).

The risk of exposure to fascioliasis was statistically lower for cattle of the N'dama race (P=0.016; mean *Fasciola* fluke count: 22) and higher in animals aged above 6 years (P=0.001; mean *Fasciola* fluke count: 259) as well as animals with a compromised health status at the time of slaughtering (P<0.001; mean *Fasciola* fluke count: 283). No differences were found as a function of sex or the co-infection with *D. dendriticum*.

Discussion

This cross-section study, conducted in the second half of 2014 in livestock in the district des Savanes in the northern part of Côte d'Ivoire, confirmed that fascioliasis is endemic, thus corroborating historic accounts (Morel, 1959; Achi, 1990) and recent investigations (Kouadio *et al.*, 2020). The proportions of *Fasciola*-infected livers not only among confiscated livers (45.5%), but also livers from seemingly healthy animals (9.8%), demonstrate the impor-

Table 2. Proportion of infected cattle, sheep and goat livers by *Dicrocœlium dendriticum*.

Animal type	No of livers analysed	No. of animals with of *Dicrocœlium*-infected livers (%)	No of livers with co-infection (*Dicrocœlium* and *Fasciola*)
Cattle	296	257 (86.8)	109 (36.8%)
Sheep	20	12 (60.0)	6 (30.0%)
Goat	10	2 (20.0)	0 (0.0%)
Total	326	271 (83.1)	115 (35.3%)

Table 3. Proportion of infected cattle livers by different parameters, collected from June to September 2014 in the district des Savanes, Côte d'Ivoire.

	No. of animals analysed	No. of animals infected with *Fasciola* spp.	% infected	P-value
Region				
Poro	153	80	52.3	
Tchologo (r)	82	30	36.6	
Bagoué	61	11	18.0*	0.001
Department				
Korhogo	76	37	48.7*	0.005
Dikodougou	23	10	43.5*	0.031
Sinématiali	29	18	62.1*	0.050
M'Bengué	25	16	64.0*	0.004
Ferkessédougou	34	18	52.9*	0.002
Kong	28	4	14.3	
Ouangolodougou	20	8	40.0	
Boundiali	22	4	18.2	
Kouto	22	4	18.2	
Tengrela (r)	17	3	17.7	
Race				
Zébu (r)	216	85	39.4	
Baoulé	28	12	42.9	
N'dama	12	3	25.0	
Métis	40	21	52.5	
Sex				
Male (r)	119	45	37.8	
Female	177	76	42.9	
Age group				
Group 1 (<3 years)	115	43	37.4	
Group 2 (4-6 years)	128	49	38.3	
Group 3 (>6 years) (r)	53	29	54.7	

*Statistically significant difference; (r) reference.

Table 4. Mean parasite load in confiscated, whole cattle livers, collected in the district des Savanes, Côte d'Ivoire.

	No. of livers confiscated and analysed	No. (%) of confiscated livers infected with *Fasciola*	Mean parasite load per infected liver	Incidence rate ratio	95% CI
Department					
Korhogo	70	37 (52.9)	72	r	–
Boundiali	19	4 (21.1)	265	3.7*	1.0-13.2
Dikodougou	20	9 (45.0)	21	0.3*	0.1-0.7
Ferkessédougou	24	17 (70.8)	116	1.6	0.8-3.3
Kong	23	4 (17.4)	169	2.3	0.7-8.4
Kouto	20	4 (20.0)	73	1.0	0.3-3.6
M'Bengue	19	15 (78.9)	342	4.7*	2.3-10.0
Sinématiali	23	16 (69.6)	65	0.9	0.4-1.9
Tengrela	15	2 (13.3)	7	0.1*	0.0-0.6
Ouangolodougou	13	8 (61.5)	467	6.5*	2.5-16.7
Total	246	116 (47.2)	145	–	–
Cattle race					
Zébu	180	80 (44.4)	167	r	–
Baoulé	24	12 (50.0)	114	0.7	0.3-1.6
Métisse	33	21 (63.6)	94	0.6	0.3-1.1
N'dama	9	3 (33.3)	22	0.1*	0.0-0.7
Age group					
Group 1 (<3 years)	88	40 (45.5)	83	r	–
Group 2 (4-6 years)	114	48 (42.1)	129	1.6	0.9-2.8
Group 3 (>6 years)	44	28 (63.6)	259	3.1*	1.6-6.1
Sex					
Female	146	76 (52.1)	140	r	–
Male	100	40 (40.0)	153	1.1	0.6-1.9
Dicrocoeliasis					
Liver without dicrocœliasis	36	12 (33.3)	139	r	–
Liver with dicrocœliasis	210	104 (49.5)	145	1.0	0.4-2.5
General health status					
Good	170	80 (47.1)	82	r	–
Bad	76	36 (47.4)	283	3.4*	2.0-5.9

*Statistically significant difference; (r) reference. CI, confidence interval.

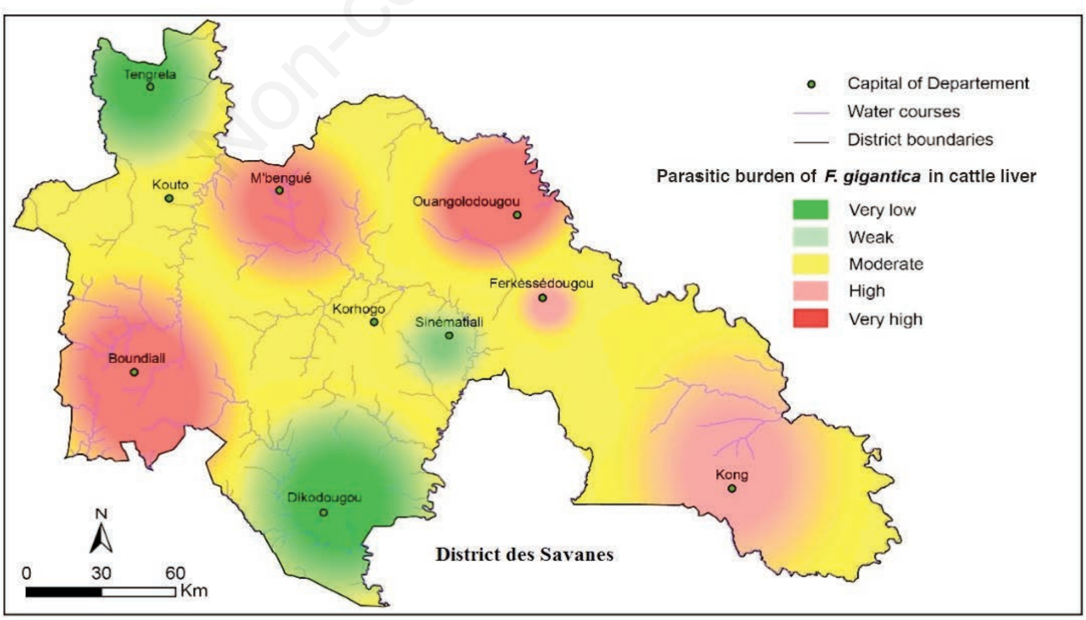

Figure 4. Distribution of *Fasciola gigantica* burden found in cattle livers between June and September 2014 in the district des Savanes, Côte d'Ivoire. This figure shows the distribution of *F. gigantica* in the different regions.

tance of *Fasciola* parasitizing livestock in the district des Savanes. We found fascioliasis in 73 of 102 investigated sites. Indeed, the disease is widely distributed. Particularly high rates of infection were observed in the regions of Poro and Tchologo, where 83% and 76% of the examined livers were infected with *Fasciola* spp., respectively. In the region Bagoué, on the other hand, fascioliasis showed a less pronounced infection rate, as 39% of investigated field sites were found with positive livers. In prior studies conducted in Côte d'Ivoire, fascioliasis prevalence in municipal abattoirs in Odienné, Korhogo and Ferkessédougou, as well as the prevalence of fascioliasis in municipal abattoirs in Abidjan varied between 4% and 11% (Achi, 1990; Achi *et al.*, 2003). An inspection of livers in abattoirs showed comparable infection rates in sub-regions of Benin (6.4-24.8%) and Nigeria (2.3-23.4%) (Assogba and Youssao, 2001a, 2001b; Oladele-Bukola and Odetokun, 2014).

The high rate of infection with *Fasciola* spp. in confiscated livers also revealed that the proportion of infected livers reported by visual inspection might be overestimated, since a higher number of false-positive *Fasciola* diagnosis may occur when using the confiscation criteria of parenchymatic hepatitis, telangiectasias, hyperplastic cholangitis and fibrosis. The latter two of these criteria are not pathognomonic for bovine fascioliasis (Meissonnier and Mage, 2007). The complete dissection of livers during the course of this study allowed for the collection of a comprehensive data set. In fact, the advantages of performing complete liver dissection to detect liver flukes are well documented in the literature. For example, Meissonnier and Mage (2007) confirmed that visual inspection of liver cannot reliably detect liver flukes for low-intensity infections of less than 10 flukes per liver. Other authors, who performed complete dissection of livers, also observed numerous false-negative livers (Gimard, 2001; Mekroud *et al.*, 2006; Rapsch *et al.*, 2006). Fascioliasis is an important veterinary problem in the district des Savanes. Areas at highest risk are concentrated in the Poro and Tchologo regions, while the Bagoué region is less affected. Considerable spatial variation of fascioliasis at the unit of the department was observed. Fascioliasis is transmitted through intermediate host snails proliferating in freshwater bodies. The presence of a dense river network in the district des Savanes, as well as several water retentions sites (N'Goran, 1998) might explain the wide distribution. In fact, pastures around the numerous permanent water bodies attract a considerable number of local and transhumant animals, especially during the dry season. Animal movements in an environment potentially infected by intermediate host snails (Krauth *et al.*, 2016) without surveillance might enhance fascioliasis transmission. Our observations confirm previous results from Yildirim and colleagues (2007) and Yohannes and Abebaw (2012), who showed that the importance of fascioliasis in a given region is related to climatic conditions, the presence of permanent water bodies and the predominant livestock breeding system. Additionally, in the departments of Boundiali, M'Bengué and Ouangolodougou, the close proximity of numerous transhumance routes with livestock originating from Mali and Burkina Faso, where fascioliasis is considered enzootic (Schillhorn Van Veen, 1980), can explain the particularly high infection probability of animals from these departments (Tager-Kagan *et al.*, 1978; Urquhart *et al.*, 1996; Radfar *et al.*, 2015). However, the non-random sampling of the livers analysed in this study might explain the large distribution of fascioliasis in the district des Savanes. In fact, for economic reasons, the study focused mainly on confiscated livers suspected of fascioliasis.

The tendency of fascioliasis distribution to be highly variable within a given region has already been observed in Senegal (Vassiliades, 1978; Diaw *et al.*, 1990), Niger (Tager-Kagan, 1977) and in the Democratic Republic of the Congo (Chartier *et al.*, 1991). The considerably lower prevalence of fascioliasis in the departments of Kong, Tengrela, Kouto and Boundiali may be related to a lower exposure of animals during the dry season, as water sites in this area tend to dry out early. According to Tager-Kagan *et al.* (1978), in the Sudanese Sahel zone, the infection of animals susceptible to fascioliasis occurs mostly during the dry season at permanent water sites. The absence of veterinary examination for a large number of cattle slaughtered outside of abattoirs in certain areas and the livestock supply of the large cities of Côte d'Ivoire from these departments (Yao and Kallo, 2015) also needs to be considered.

In this study, we could also show that confiscated cattle livers were infected at comparable rates to confiscated livers of smaller ruminants, mainly sheep (47% vs. 45%). This finding is in contrast to observations from other countries such as Iraq (Kadir and Rasheed, 2008) and Tanzania (Mellau *et al.*, 2010), where fascioliasis was more of a concern in cattle compared to sheep. Some authors postulated that small ruminants are equally susceptible to fascioliasis as cattle, but that their feeding behaviour exposes them less to the parasite (Oguneinade, 1984; Haroun and Hillyer, 1986; Boray, 2007). Sheep, and even more so goats, rarely move to lower and more humid sections of the pastures if sufficient food is available elsewhere (Traoré, 1989). The similar infection rates between cattle and sheep in this study could be due to similar exposure to *F. gigantica* by frequenting the same pastures or by mixed livestock breeding.

Compared to a study conducted in 1990, our cross-sectional survey shows a net increase of parasite load in infected livers in some abattoirs in the northern part of Côte d'Ivoire (Achi, 1990). Differences in the mean parasite load in infected livers [145 flukes per liver in this study compared to 36.5 flukes per liver in a previous study by Achi (1990)], indicate an increase in parasite numbers in the pastures of the district des Savanes. The parasite load observed here is much higher than in other countries such as Iran (~14 flukes per liver), Nigeria (~30 flukes per liver), Haïti (~49.5 flukes per liver) and Ethiopia (~52 flukes per liver) (Ogunrinade, 1984; Blaise, 2001; Alemu and Belay, 2015; Radfar *et al.*, 2015). The high parasite load of infected livers observed in the district des Savanes in 2014 is a result of favourable environmental conditions for the development of *F. gigantica* and the intermediate host snails as well as the absence of effective prevention and treatment programmes against fascioliasis in the mostly sedentary livestock breeding sites. In fact, Ogunrinade (1984) showed that the number of flukes found in the liver of infected animals is directly correlated to the dose of metacercariae ingested by them. The author could show that a single dose of 5000, 1000 and 500 metacercariae from *F. gigantica*, led to a parasite load of 1444, 325 and 77, respectively. The discontinuation of the '*Société de Développement de la Production Animale*' (SODEPRA) after the 1990s by the government of Côte d'Ivoire and its replacement by other livestock management organisations have not improved control and prophylaxis against livestock diseases (Coulibaly, 2013). The absence of formal structures in charge of animal health in the northern regions of Côte d'Ivoire during a decade of political crisis (2002-2011), generally contributed the progression of certain livestock pathologies such as trypanosomiasis (Acapovi-Yao *et al.*, 2013).

We found that the parasite load in livers of animals was significantly higher for animals with a generally poor health state prior to slaughtering. Poor general health of animals is a risk factor for fascioliasis. Our results confirm the results of Hagos (2007), Mihreteab *et al.* (2010) and Alemu and Belay (2015), who also noted an association between general health status and fascioliasis. According to these authors, reduced liver function caused by immature flukes and the diversion of essential nutrients in the liver by adult flukes renders the infected animal less resistant and more susceptible to various pathologies. Dicrocoeliasis, on the other hand, was not found to be a risk factor for fascioliasis in our study and did not have an influence on the *F. gigantica* parasite load in the liver of infected animals. Co-occurrence of both *Dicrocoelia* and *Fasciola* parasites in the same animal is believed to be essentially due to the sometimes heterogeneous character of the frequented pastures (Euzeby, 1971).

Despite the hypothesis that the immunity of animals varies as a function of age (Doyle, 1972; Ogunrinade and Adegoke, 1982; Mungube *et al.*, 2012) and the physiological makeup of females (Ogunrinade, 1978), non-significant difference in infection with fascioliasis between animals of different age and sex was observed, confirming findings from Ethiopia (Yildirim *et al.*, 2007; Bekele *et al.*, 2014), Kenya (Nganga *et al.*, 2004) and Algeria (Mekroud, 2004). However, cattle aged 6 years and above had a parasite load that was 2- to 3-fold higher than the load of younger cattle. Animal age is therefore an important risk factor for exposure to *F. gigantica*. Similar results have been reported from Ethiopia (Ayalew *et al*., 2013). A higher parasite load in older animals could be explained by their greater feeding capacity leading them to graze larger portions of the pastures compared to younger animals, which, in turn could translate to a higher exposure to metacercariae (Molalegne *et al.*, 2010). Another theory is that older animals have accumulated several generations of *Fasciola* flukes in their livers (Kassaye, 2011). Doyle (1972) also mentioned that the acquired immunity against the parasites during repeated infections diminishes with progressing age, leaving older animals more susceptible. According to Ahmed *et al.* (2007), higher infection risk in older animals could likewise be due to other physiological factors, such as stress, gestation, inadequate alimentation and other infectious diseases.

Another interesting observation concerns the different parasite loads observed between cattle species with the lowest mean number of flukes per liver in cattle of the race N'dama (~22 flukes) followed by the Métisse (~94 flukes), Baoulé (~114 flukes) and the Zebu (~1167 flukes). The N'dama cattle race, which is well adapted for tropical, humid conditions and extensive traditional livestock rearing systems (Soffo, 2010) seems less sensitive to *Fasciola* infections and fascioliasis accounts for a comparatively low percentage of all mortality among this trypanotolerant race (Mourad and Magassouba, 1996).

Conclusions

The practice of dissecting entire livers as performed during the course of this study, confirmed a higher sensitivity as diagnostic method compared to visual liver inspections at the slaughtering site, which is based on searching for lesions that are not always pathognomonic for fascioliasis. Fascioliasis was observed in the entire district des Savanes in northern Côte d'Ivoire with considerable spatial heterogeneity between different departments. The prevalence of *Fasciola* in animals slaughtered at official abattoirs and slaughter sites is higher in the regions of Poro and Tchologo, with particularly high infection rates in the departments M'Bengué, Sinématiali, Ferkessédougou, Ouangolodougou, Dikodougou and Korhogo. This study confirmed a high abundance of individual *F. gigantica* flukes in cattle livers in the departments of Boundiali, M'Bengué and Ouangolodougou. These departments should be prioritised in the fight against fascioliasis to reduce the negative impact this fluke infection has on animal health and improve economic benefits of animal husbandry in the district des Savanes, which constitutes the main cattle rearing area of Côte d'Ivoire.

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