Validation of an interactive map assessing the potential spread of *Galba truncatula* as intermediate host of *Fasciola hepatica* in Switzerland

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Abstract

Bovine fasciolosis, caused by *Fasciola hepatica*, is widespread in Switzerland. The risk regions were modelled in 2008 by an interactive map, showing the monthly potential risk of transmission of *F. hepatica* in Switzerland. As this map is based on a mathematical model, the aim of the present study was to evaluate the interactive map by means of a field survey taking different data sources into account. It was found that the interactive map has a sensitivity of 40.7-88.9%, a specificity of 11.4-18.8%, a positive predictive value of 26.7-51.4%, and a negative predictive value of 13.1-83.6%, depending on the source of the data. In conclusion, the grid of the interactive map (100 x 100 m) does not reflect enough detail and the underlying model of the interactive map is lacking transmission data.

Introduction

Bovine fasciolosis, caused by *Fasciola hepatica*, is widespread in Switzerland. A study by Rapsch *et al*. (2006) estimated a true prevalence of 18.0% in slaughtered cattle of all age groups. Median financial losses, mainly due to reduced milk production and reduced fertility, are estimated at € 299 per infected animal per year (Schweizer *et al*., 2005a). Nevertheless, farmers often are unaware of the disease (Schweizer *et al*., 2005b). In order to enhance awareness among owners and give farmers and veterinarians a decision-making tool for investigating a herd for fasciolosis, an interactive map was designed, showing the monthly potential risk of transmission of *F. hepatica* in Switzerland (Rapsch *et al*., 2008). The interactive map is based on risk density distribution derived from environmental factors. Geographical (soil condition, forest cover) and meteorological (temperature, rainfall) data from Switzerland and biological data of the intermediate host *Galba truncatula* and the free-living stages of *F. hepatica* were accounted for. The model's output is an environmental relative risk measurement for the development of *G. truncatula* and the free-living stages of *F. hepatica* all over Switzerland. In order to visualise the density distribution, a grid of 100 x 100 m cells was created for the whole country and the risk density for each cell of the grid was visualised by a colour scale ranging from highest (red) to no (white) risk, representing five risk classes. The elements of the map (canton boundaries, water bodies, landform configuration, cities, forest, monthly risk, risk during the year) are grouped in layers, which can be activated or deactivated. Maps produced by means of geographical information systems (GIS) are often used in human or veterinary medicine in order to identify epidemiological patterns of disease outbreaks for example. GIS is especially helpful when trying to answer epidemiological questions concerning vector borne diseases or diseases transmitted by intermediate hosts (Rinaldi *et al*., 2006) and with increasing technical possibilities, the number of studies using GIS has also increased (Hendrickx *et al*., 2004; Simoonga *et al*., 2009). Risk maps for the transmission of *F. hepatica* have been designed for parts of Europe (Ollerenshaw, 1966; Rapsch *et al*., 2008), parts of the United States (Malone *et al*., 1987, 1992), Ethiopia (Yilma and Malone, 1998) or Cambodia (Tum *et al*., 2004). Some of the models were validated mainly by means of definite host prevalence surveys (Malone *et al*., 1992; Malone and Gommes, 1998; Tum *et al*., 2007).

The aim of the present study was to evaluate the interactive map by means of a field survey based on the presence or absence of suitable snail habitats and presence of snails.

Materials and Methods

In order to evaluate the risk model, findings of potential *G. truncatula* habitats and snail findings from three data sources were used and then compared to the risk map.

Data sources

Snail findings emanating from a field survey in 2010

The basis of the interactive map designed by Rapsch *et al.* (2008), covering the whole of Switzerland, is a 100 x 100 m grid (containing a total of 4'152'874 grid fields). During a field survey in 2010, 361 grid fields were searched for the presence of potential *G. truncatula* habitats deriving from 80 coordinate points in the Northeast of Switzerland chosen by a random generator (Java Random). Water bodies, forests and settlements were excluded. The region was chosen due to ease of surveillance (location of the Vetsuisse Faculty, Zurich) on the one hand and due to the overlapping with the study region surveyed by Schweizer *et al.* (2007) on the other. The field survey was conducted from July to October 2010. The 80 randomly chosen points were visited and the minimal area of 100 x 100 m was investigated including the randomly chosen point. Due to the topography and the landscape, it was not possible to set up identical investigation areas, so the randomly chosen coordinate points did not always lie in the middle of the investigation area but were always included. If the 100 x 100 m area around the randomly chosen coordinate points was dry and no evidence for potential *G. truncatula* habitats could be seen nearby, the investigation was stopped recording this area as *negative*. If the area around the randomly chosen point included potential habitats, *e.g.* drainage ditches, swampy areas or small streams as described by Schweizer *et al.* (2007), the coordinates of the potential habitats were recorded using a global positioning system (GPS) device (Garmin eTrex H) and the potential habitats were searched for snails for 30 minutes. This was usually an area of more than 100 x 100 m (Figure 1). Snails found were collected and frozen at –20°C until further identification by binocular loupe.

Earlier snail findings

From a regional survey in northeastern Switzerland investigating the prevalence of *F. hepatica* in the intermediate host, the coordinates of naturally occurring habitats were taken. Wells were excluded, as these are man-made habitats. The field surveys were conducted from 1999 to 2002 in the months of May to October. A total of 54 habitat findings in the Northeast of Switzerland were taken from the study of Schweizer *et al.* (2007).

Snail findings emanating from the *Centre Suisse de Cartographie de la Faune*

From 1990 to 2010 a total of 749 *G. truncatula* findings from all over Switzerland was registered by the *Centre Suisse de Cartographie de la Faune* (CSCF). The snails were found in all months of the year. Of these, 66 findings had to be excluded due to incomplete recording of the coordinates and 236 findings were excluded because they were derived from forest or settlement areas. In such areas, cattle are not usually grazed and therefore the model gives no risk for transmission (Rapsch *et al.*, 2008). Repeated findings in one month were utilised once. From the CSCF data a total of 428 findings were taken.

Comparison of the risk map with the field survey data

For the study at hand, the risk class 0 of the map created by Rapsch *et al.* (2008) was defined as *no risk* and the risk classes 1 to 5 were summarised as *risk*. In order to calculate the sensitivity, specificity,
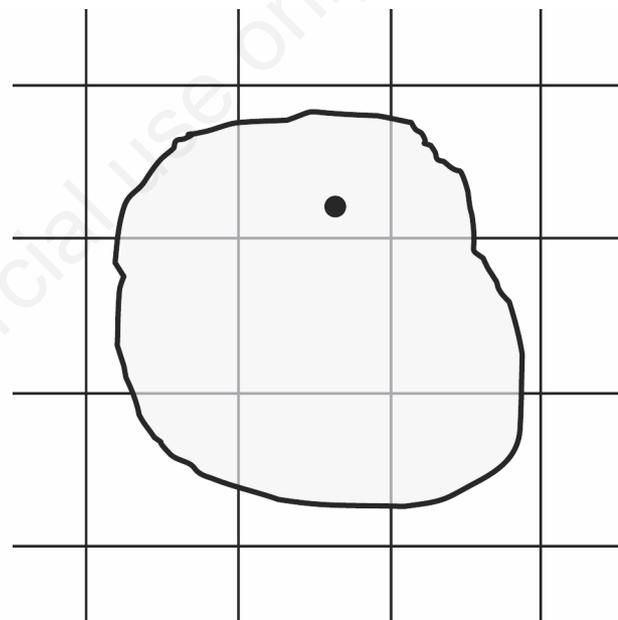
Figure 1. A diagram of the investigated area (grey) around a randomly chosen starting point (•). Underlying is the 100 m x 100 m grid from the interactive map. In this example a total of 9 grid cells were investigated.

Table 1. Data sources for the evaluation of the original interactive map.

Data source	Subject	Information
Field survey 2010	Randomly chosen fields from Northeast Switzerland (n=361)	1. Fields without risk of transmission (no potential habitats) 2. Fields with potential risk of transmission 2.1. without *G. truncatula* 2.2. with *G. truncatula*
Schweizer *et al.* (2007)	*G. truncatula* findings from Northeast Switzerland (n=54)	Potential risk of transmission
CSCF	*G. truncatula* findings from all over Switzerland (n=428)	Potential risk of transmission

G. truncatula, Galba truncatula; CSCF, *Centre Suisse de Cartographie de la Faune.*

positive and negative predictive value of the map, the snail searches from three different surveys from Switzerland (Table 1) were then compared to the map predicted risk (*no risk vs risk*). As the interactive map models potential habitats of *G. truncatula* on a monthly basis, the evaluation of the map also takes the month of finding into account. The investigated fields from the field surveys were either classified *negative*, when no potential habitats were found or *positive* when either potential habitats (without snails) or habitats with snails were found (Table 2). All coordinates were rounded to the next 100 m interval, in order to match the 100 x 100 m grid of the interactive map. Subsequently, the monthly risk groups of the investigated areas were taken from the model. Multiple coordinates lying in one grid area were utilised once.

The sensitivity, *i.e.* the true positives divided by the true positives + the false negatives; specificity, *i.e.* the true negatives divided by the true negatives + the false positives; the positive predictive value, *i.e.* the true positives divided by the true positives + false positives; and the negative predictive value, *i.e.* the true negative divided by the true negatives + false negatives were calculated for the map.

Two different calculations were made in order to achieve the sensitivity, specificity and the predictive values of the interactive map. First, from all data sources the true monthly findings were compared to the modelled monthly risk group, *e.g.* the findings in January were compared to the January risk model. Second, from all data sources only the findings from July, August, September, and October were taken. During these months the field survey in 2010 took place. The data from July and August were then compared to the corresponding monthly risk model, whereas the data from September and October were compared to the August risk model as this model predicts the largest risk areas. As the overall model is lacking an underlying transmission model, we assumed, that the areas with the best environmental conditions for the survival and reproduction of *G. truncatula,* and the survival of the free-living stages of *F. hepatica,* in August would also have a higher risk for transmission in the following months (taking the lag of time for reproduction of the snail into account).

Results

Classification of the grid fields

From the field survey in 2010, 271 grid fields did not contain potential habitats and were therefore *negative* areas. Potential habitats (*positive*) were found in 90 grid fields. Out of these, 14 harboured a total of 133 *G. truncatula* specimens. A total of 89 snails were found in risk class 1 (66.9%), two in risk class 2 (1.5%), four in risk class 3 (3.0%), 28 in risk class 4 (21.1%) and 10 in risk class 5 (7.5%). The potential habitats in risk class 0 did not contain any *G. truncatula* specimens. Together with the findings from Schweizer *et al*. (2007) and the CSCF, a total of 496 grid fields with *G. truncatula* specimens was found.

Validity of the interactive map

Validity based on the findings from the field survey 2010 compared per month

In 76 grid fields, consisting of swampy areas, ditches and other humid biotopes, no *G. truncatula* specimens were found. Nevertheless, these grid fields were classified *positive*, as they serve as potential habitats. When comparing the monthly-modelled risk class to the actual findings in the field (Table 3), the sensitivity of the interactive map was 88.9%, the specificity 18.8%, the positive predictive value 26.7% and the negative predictive value 83.6%.

Validity based on the findings of all data compared per month

When comparing the monthly-modelled risk groups with the actual findings in the field (Table 4), the sensitivity of the interactive map was 40.7%, the specificity 18.8%, the positive predictive value 51.4% and the negative predictive value 13.0%.

Validity based on the findings of all data from July to October

When comparing the findings from all sources from July to October

Table 2. Classification of results of the field surveys compared to the risk model.

Interactive map	Field survey	
	Positive (presence of potential habitats)	Negative (absence of potential habitats)
Risk (risk class 1 to 5)	True positive	False positive
No risk (risk class 0)	False negative	True negative

Table 3. Comparison of results of the field survey 2010 with the risk classes in the model (interactive map) per month.

Interactive map	Findings from the field survey 2010	
	Number of negative grid fields* (%)	Number of positive grid fields* (%)
Risk class 0	51 (18.8)	10 (11.1)
Risk class 1	34 (12.6)	28 (31.1)
Risk class 2	33 (12.2)	12 (13.3)
Risk class 3	31 (11.4)	11 (12.2)
Risk class 4	38 (14.0)	5 (5.6)
Risk class 5	84 (31.0)	24 (26.7)
Risk class 1-5	220 (81.2)	80 (88.9)
Total	271 (100)	90 (100)

Negative grid fields, grid fields without potential habitats; positive grid fields, grid fields with potential habitats either with snails or without (but with typical vegetation).

(Table 5) compared to the modelled risk maps July to October, the sensitivity was 53.7%, the specificity 18.8%, the positive predictive value 46.5% and the negative predictive value 23.6%. When comparing the findings from all sources from July and August (Table 6) compared to the corresponding risk model and the findings from September and October compared to the August risk model (Figure 2) the sensitivity was 65.2%, the specificity is 11.4%, the positive predictive value is 49.2% and the negative predictive value 20.0%.

Discussion

The interactive map of Rapsch *et al*. (2008) models areas with suitable environmental conditions for the survival and reproduction of *G. truncatula*, including survival of the free-living stages of *F. hepatica*. The risk areas modelled are corroborated by a study by Ducheyne *et al*. (2015) modelling the spatial distribution of *F. hepatica* in dairy cattle in Europe, including Switzerland.

The aim of the present study was to evaluate the risk map from Rapsch *et al*. (2008) by comparing the modelled risk areas with find-

ings from different field surveys with respect to the main intermediate host snail *G. truncatula* of *F. hepatica*. This approach was chosen because the risk map models the potential spread of *G. truncatula* and not the spread of *F. hepatica* itself (except its free-living stages). In comparable studies, risk maps are evaluated by cattle prevalence data (Malone *et al*., 1992; Malone and Gommes, 1998; Tum *et al*., 2007). In Switzerland there is excessive movement of animals, especially of young stock going to alpine pastures during the summer months. If these first and second summer grazing animals become infected with *F. hepatica*, they will shed eggs and secrete antibodies into their first and second lactation (Knubben-Schweizer and Torgerson, 2015). Positive results of bulk milk antibody tests are therefore not necessarily indicative for a new infection on the premise in question but it can be derived from very different geographical regions. It would therefore be more appropriate to search for potential snail habitats and snails than to compare the risk map to prevalence data in cattle.

The search for potential snail habitats and snails poses several challenges. Even though typical habitats, as described by Schweizer *et al*. (2007), with putative suitable environmental conditions may be present, *G. truncatula* can still be absent. To the authors' experience, this is especially true, when habitats are visited once only as the size of the

Table 4. Comparison of results of the monthly risk models (interactive map) with the results of the field surveys from January to December.

Interactive map	Classification of the grid fields based on the field surveys° from January to December		Total
	Positive	**Negative**	
Risk (risk class 1-5)	233	220	453
No risk (risk class 0)	339	51	390
Total	572	271	843

Positive, presence of potential habitats either with snails or without (but with typical vegetation); negative, absence of potential habitats. °Field survey 2010, data from Schweizer *et al.* (2007) and findings from *Centre Suisse de Cartographie de la Faune.*

Table 5. Comparison of results of the monthly risk models (interactive map) with the results of the field surveys from July to October.

Interactive map	Classification of the grid fields based on the field surveys° from July to October		Total
	Positive	**Negative**	
Risk (risk class 1-5)	191	220	411
No risk (risk class 0)	165	51	216
Total	356	271	627

Positive, presence of potential habitats either with snails or without (but with typical vegetation); negative, absence of potential habitats. °Field survey 2010, data from Schweizer *et al.* (2007) and findings from *Centre Suisse de Cartographie de la Faune.*

Table 6. Comparison of the findings from all sources in July and August compared to the corresponding risk model and the findings from all sources from September and October compared to the August risk model.

Interactive map	Classification of the grid fields based on the field surveys° from July to October		Total
	Positive	**Negative**	
Risk (risk class 1-5)	232	240	472
No risk (risk class 0)	124	31	155
Total	356	271	627

Positive, presence of potential habitats either with snails or without (but with typical vegetation); negative, absence of potential habitats. Findings from September and October are compared to the August model. °Field survey 2010, data from Schweizer *et al.* (2007) and findings from *Centre Suisse de Cartographie de la Faune.*

snail population depends on the cumulative environmental conditions of the previous months. For this reason, not only snail findings were assessed as positive but also potential habitats as can be seen in Figures 3 to 5.

Another challenge is the identification of the snails. Those from the present study and from Schweizer *et al*. (2007) were identified by an experienced person by macroscopic inspection. In questionable cases (*e.g.* very small snails) the identification took place under a binocular loupe. For the data from CSCF, the way the snails were identified is unknown. Misidentification cannot be ruled out, especially for very small snails.

In the current study, the infection status of the snails was not investigated as it was not of primary interest. In the study of Schweizer *et al*. (2007), the snails were examined using PCR to detect *F. hepatica* infection finding 7.0% of 4733 snails positive. The risk of infection of *G. truncatula* with *F. hepatica* depended on the source of the snails (type of habitat and type of pastured cattle, respectively).

Another challenge in this field survey was that it was not always possible to survey the grid fields due to limitations, such as slope, water

course, street, building, land use etc. In such areas, it was therefore decided to choose a coordinate point and search the area around it. In the model, the surveyed area was then mapped and the number of grid fields covered by this area were analysed.

Several approaches were used to calculate the sensitivity, specificity

Figure 3. Drainage ditch in a swampy area making a potentially suitable habitat for *Galba truncatula*.
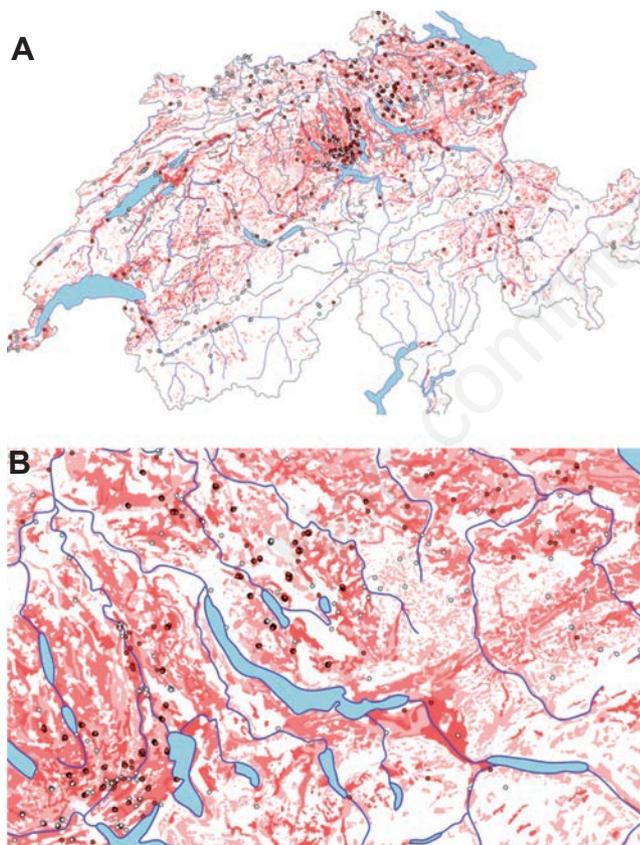
Figure 2. A) Risk map for the transmission of *Fasciola hepatica* in Switzerland. B) Detail of figure 2A: Northeast of Switzerland, where the survey at hand has been conducted. The risk for the month of August is shown. White areas are no risk (risk class 0), red shaded areas are risk (risk class 1 to 5). Additionally, the findings of *Galba truncatula* searches from 3 sources can be seen, where the red dots are positive findings (either potential habitats or snails) and the white dots are areas, with no potential snail habitats.

Figure 4. A swampy area making a potentially suitable habitat for *Galba truncatula*; notice the rush as an indicator plant described by Rondelaud *et al*. (2011).

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