Predicting the risk of *Alaria alata* infestation in wild boar on the basis of environmental factors

Daniel Klich a, Marek Nowicki b,*, Anna Didkowska b, Zbigniew Belkot c, Bartłomiej Popczyk a, Jan Wiśniewski b, Krzysztof Anusz b

a Department of Animal Genetics and Conservation, Institute of Animal Science, Warsaw University of Life Sciences, Cisowskiego 8, 02-786, Warsaw, Poland
b Department of Food Hygiene and Public Health Protection, Institute of Veterinary Medicine, Warsaw University of Life Sciences, Nowoursynowska 159, 02-776, Warsaw, Poland
c Department of Food Hygiene of Animal Origin, Faculty of Veterinary Medicine, University of Life Sciences in Lublin, Akademicka 12, 20-950, Lublin, Poland

**Abstract**

*Alaria alata* is an emerging parasite that poses a potential risk for those consuming game, pork, snails and frogs. One paratenic host of *A. alata* that is known to play an important role in its spread through its feeding habitats is the wild boar. However, no statistical analysis of the influence of aquatic environments and carnivores on the occurrence of *A. alata* in wild boars has yet been performed. The present study combines a small-scale analysis based on hunting districts in the Mazowieckie province with a large-scale analysis based on data for all provinces in Poland. We applied various modeling approaches, including logistic regression and a generalized linear model in order to determine the presence, intensity and prevalence of *A. alata*. We used the *Alaria* mesocercariae migration technique (AMT) to estimate the risk of *A. alata* infestation of wild boar. However, the effect was weak, probably as a result of the large home range size of these animals. The large-scale analysis found that wetlands influence the prevalence of *A. alata* in wild boar, with the estimated risk increasing in the north of the country; this finding is consistent with other studies. Our findings indicate that the occurrence of *A. alata* in wild boar requires analysis on many levels, and environmental factors play a key role in risk assessment.

1. Introduction

Even though with the possibility is very low, *Alaria alata*, a widespread emerging parasite, may pose a potential risk for human consumers of game, pork, snails and frogs (Möh et al., 2009; Korpystra-Dzirba et al., 2021). The life cycle of this parasite is complex and includes definitive, intermediate and paratenic hosts. The definitive hosts are carnivores such as canids, felids and mustelids (Wójcik et al., 2001; Takeuchi-Storm et al., 2015). In Europe, the definitive hosts are typically red foxes (*Vulpes vulpes*), wolves (*Canis lupus*) and raccoon dogs (*Nyctereutes procyonoides*) (Murphy et al., 2012; Rentería-Solís et al., 2013; Ozolinia et al., 2018).

The *A. alaria* fluke produces its eggs (a dispersive parasite form) in the digestive system of the definitive host, and they are then excreted into the environment with the feces. These are consumed by intermediate hosts such as snails, tadpoles and frogs, where they develop into miracidia (Portier et al., 2012; Patrelle et al., 2015; Voelkel et al., 2019; Ozolinia et al., 2021). In the paratenic host, the parasite does not reach the adult stage, but it can survive for months in the muscle or adipose tissue (Riehn et al., 2013). The parasite can later reinfect the definitive host if the paratenic host is consumed. Several mammal species have been described as paratenic hosts (Shimalov and Shimalov, 2001; Rentería-Solís et al., 2018); of these, the wild boar (*Sus scrofa*) is known to play an important role in spreading *A. alata* due to its feeding habitats (Ozolinia et al., 2020).

In the context of public health, it must be noted that *A. alata* poses a potential risk to consumers of wild boar meat. Alariosis has been described in humans (McDonald et al., 1994; Kramer et al., 1996); however, the etiological agent in this case was *Alaria americana*, and not *A. alata*, which occurs in Europe. Considering the close relationships between these two *Alaria* species and the difficulties in the diagnosis of alariosis in humans (non-specific symptoms), it should be assumed that...

* Corresponding author.
E-mail address: marek_nowicki@sggw.edu.pl (M. Nowicki).
A. alata may also be a potential zoonotic agent in Europe, as classified by organizations such as the Swiss Agency for the Environment, Forests and Landscape. In such cases, humans may act as paratenic hosts.

As eating frogs is a rather local dietary habit, the most likely route of transmission to humans in Europe is the consumption of infected wild boar meat (Dollfus and Chabaud, 1953). In Europe, the prevalence of A. alata in wild boar is thought to range from 0.6% (France, magnetic stirrer method) (Portier et al., 2011) to as much as 44.3% (northeast Poland, mesocercariae migration technique) (Strokowska et al., 2020). A. alata larvae are believed to be capable of effective survival in a refrigerator; therefore, as noted by the French Agency for Food, there is a real risk of human infection as a result of eating meat from A. alata-infected wild boar (Korynska-Dzirba et al., 2021). The most effective method of avoiding infection would appear to be proper heat treatment, as is the case with Trichinella spp. (Gamble et al., 2019).

However, considering the popularity of homemade semi-raw meat products, A. alata should not be neglected as a potential pathogen for humans.

The infection rate among wild boar depends on their exposure to the sources of A. alata. Previous studies have reported it to be correlated with the number of foxes (definitive host) living in the same territory (Mohl et al., 2009) and the presence of amphibians in the area (Ozolin ska et al., 2021). The presence of amphibians can be estimated indirectly based on the occurrence of marshland and water areas in a given region. Previous studies have noted a significant difference in the occurrence of A. alata in snails and frogs between seasons: a prevalence of 30% has been observed among snails and frogs in the autumn, and 100% in the spring (Wojcik et al., 2001).

However, no direct evaluation has been performed of the influence of local aquatic environments and carnivores on the occurrence of A. alata in wild boars in a given area. Such data would be of great importance in identifying areas where monitoring should be increased; it could also be used to outline further research directions and support effective preventive activities. Therefore, the aim of the present manuscript was to determine the influence of environmental factors in predicting the occurrence of A. alata infestation in wild boar.

2. Material and methods

2.1. Sample collection and examination

Samples were collected from 576 hunted wild boar from 14 of the 16 Polish Provinces. Provinces (called also voivodeships) are the highest-level administrative division in Poland. The exact numbers of samples taken from individual provinces are presented in Table 1. The procedure used to collect and transport material is described by Strokowska et al. (2020). Samples of muscles, adipose and connective tissue were tested with the Alaria mesocercariae migration technique (AMT) according to Riehn et al. (2010). The characteristic movement and morphological features of this parasite (the body is clearly divided into two sections, with a wing-like shape at the front) were used to assess its presence in tissues. All samples were tested within a maximum of seven days after material collection.

2.2. Data elaboration and statistics

2.2.1. Small-scale analysis

Samples with known locations, i.e., where these wild boars were hunted, were assigned to hunting districts. To determine the small-scale impact of variables on wild boar infestation with A. alata, only samples from hunting districts in the Mazowieckie province were examined. The numbers of the most common mesopredators, namely the red fox (Vulpes vulpes) and raccoon dog (Nyctereutes procyonoides), were obtained from the Polish Hunting Association for each of the hunting districts. This data was obtained for 2017. The density of predators in each hunting district was then calculated based on its area.

For each hunting district, land cover data was also obtained from the Corine Land Cover database (CLC) for 2018 (https://land.copernicus.eu). The type of land cover was determined using Quantum GIS (version 3.4.5), which is an open source geographic information system (GIS) software. All cover types within the boundaries of each hunting district were calculated with regard to their percentage. Following this, four cover types were selected for further analysis: areas covered by water (referred to with codes 5.1.1 and 5.1.2 in CLC), wetlands (referred to with code 4.1.1 in CLC), arable land (referred to with code 211 in CLC) and forests of various types (referred to with codes 3.1.1, 3.1.2, and 3.1.3 in CLC). Of these, the first two (areas covered by water and wetlands) were expected to have an impact on A. alata infection, while the last two cover types (arable and forests) dominated in the hunting districts.

The impact of environmental characteristics on the occurrence of A. alata mesocercariae in wild boars was determined using a logistic regression model which included all six known explanatory variables for the hunting districts as covariates: density of red foxes as number of individuals per 10,000 km² (FOX); density of raccoon dogs as number of individuals per 10,000 km² (RACOON); percentage of areas covered by water (WATER); percentage of wetlands (WETLANDS); percentage of arable land (ARABLE); percentage of forested areas (FORESTS). All A. alata-infected samples were marked as 1; all negative samples were marked as 0. The explanatory variables were verified based on Pearson’s correlation coefficient: all values were lower than |r| = 0.7. The quality of the model was verified according to the percentage of correctly classified cases and AUC (area under the ROC curve).

The impact of similar environmental characteristics on the intensity of A. alata mesocercariae in wild boar was evaluated using a generalized linear model with gamma distribution and the log link function. In this model, the dependent variables were the number of A. alata mesocercariae in wild boar (only infected cases); the explanatory variables were (FOX), (RACOON), (WATER), (WETLANDS), and (FORESTS). The variable for arable land (ARABLE) was not included because it was closely correlated with FORESTS (Pearson’s r = −0.809, p = 0.000). Model selection was performed according to Burnham and Anderson (2002), where the model presenting the lowest AIC value was chosen as the best one. Akaike weights (w) were calculated for each model, and the sum of Akaike weights (Σw) for each variable included in the models was within ΔAIC = 2.

2.2.2. Large-scale analysis

The prevalence of A. alata was evaluated against land cover types and red fox density for all provinces. Raccoon dog density was not included due to lack of data. The prevalence of A. alata in wild boar in a
of the highest-ranked models, and the ΔAIC equaled 0.51 between the highest-ranked model and the next-highest-ranked model (with FOX and RACOON included). Moreover, the ΔAIC between the highest-ranked model and the null model equaled only 3.14 (Table 4). FOX was present in all models within ΔAIC = 2, thus its sum of Akaike weights was the highest (\(\sum \omega_i = 0.5\)); RACOON and WETLANDS also demonstrated high Akaike weight sums (\(\sum \omega_i = 0.18\) and \(\sum \omega_i = 0.12\)).

### 3.2. Large-scale analysis

The highest-ranked generalized linear model for the prevalence of *A. alata* in wild boar was statistically significant (\(\chi^2 = 10.363, df = 1, p = 0.001\)) and included only WETLANDS (Table 5). The model presented a clearly higher Akaike weight (\(\omega_i = 0.57\)) than the other lower-ranked models (Table 6) and differed from the null model by ΔAIC = 7.29. The estimated prevalence of *A. alata* increased with the percentage of wetland cover in provinces; however, the model predicted a prevalence of over 100% for the Podlaskie province (Fig. 1).

The calculated trends of *A. alata* prevalence in Poland as a whole were similar to the predicted values; however, differences can be observed in particular provinces. On the basis of literature values and data from the present study, our calculations indicated an increase in the prevalence of *A. alata* in wild boar in the north and north-east (Fig. 2A). These values ranged from 0% in Opolskie in the south-west to 54.6% in Warmińsko-Mazurskie in the north-east, but higher values were also observed in the Zachodniopomorskie (the north-west, 42.9%) and Podlaskie (north-east, 41.7%) provinces.

Our model did predict a higher prevalence of *A. alata* in the north (Fig. 2B), with values ranging from 6.8% in Malopolskie, 7.5–7.7% for Śląskie and Opolskie Provinces in the south, to over 100% in Podlaskie in the northeast. Higher values were also observed in the Warmińsko-Mazurskie (43.3%) and Kujawsko-Pomorskie (30.7%) provinces.

### 4. Discussion

As predicted, areas covered with wetlands appear to be of significant importance in determining the occurrence of *A. alata* in wild boar. Our findings also indicate that mesocarnivore density also had an important influence on *A. alata* occurrence and intensity in wild boar. While the land cover types showed an effect in the large-scale analysis, mesocarnivores demonstrated a weak effect in the small-scale analysis, i.e., in hunting districts. Although our findings are generally in line with current knowledge, some effects seem to derive from more complex

Table 3

| Source     | B    | SE   | Wald \(\chi^2\) | P     | OR  |
|------------|------|------|-----------------|-------|-----|
| Intercept  | -0.333 | 1.107 | 4.403          | 0.035 | 0.997 |
| FOX        | -0.023 | 0.020 | 1.133          | 0.249 | 0.997 |
| RACOON     | 0.328 | 0.157 | 4.369          | 0.037 | 1.388 |
| FORESTS    | 1.816 | 1.546 | 1.379          | 0.240 | 6.144 |
| ARABLE     | 1.872 | 1.417 | 1.744          | 0.187 | 5.500 |
| WATER      | -4.855 | 9.722 | 0.249          | 0.617 | 0.008 |
| WETLANDS   | -70.818 | 74.034 | 0.915         | 0.339 | 0.000 |

Table 4

| Model     | ΔAIC | \(\omega_i\) | Rank |
|-----------|------|--------------|------|
| FOX       | 0.00 | 0.15         | 1    |
| FOX + RACOON | 0.51 | 0.11        | 2    |
| FOX + RACOON + WETLANDS | 1.58 | 0.07 | 3    |
| FOX + WATER | 1.83 | 0.06    | 4    |
| FOX + FOREST | 1.83 | 0.06    | 5    |
| FOX + WETLANDS | 1.97 | 0.06   | 6    |
| Null      | 3.14 | 0.03        | 10   |
It is not surprising that wetlands have an effect on the prevalence of *A. alata* in wild boar as the life cycle of *A. alata* requires an aquatic environment: miracidia, an invasive form of *A. alata*, are released from eggs into water, thus the first intermediate hosts are freshwater animals (Mohl et al., 2009). It has previously been proven that an abundance of wetlands is positively correlated with the occurrence of adult forms of this parasite in final hosts (Ramisz and Balicka-Ramisz, 2001). This tendency was also confirmed by Tylkowska et al. (2018) in Poland, where the most foxes that were found to be infected with *A. alaria* were those living near water reservoirs.

Regarding the presence of *A. alata* mesocercariae in wild boar, Sailer et al. (2012) reported a higher prevalence in an area of Austria that is located in the backwaters of two rivers than an area to the north of one of these rivers, i.e. with less wetland, as described previously by Pestal (1989). Therefore, the lack of this water-related effect in the present study is puzzling. Although this may seem of minor importance, some regions of Poland, especially the northern part, are characterized by large numbers of lakes and of water resources in general (Gorniak and Piekarski, 2002). This could partially correlate with WETLANDS and cause a lack of effect by areas covered by water.

Our present findings do not suggest that wetlands or other cover types demonstrated any effects in the small-scale analysis. This may, on the one hand, result from the rough scale of Corine Land Cover, but it might also be caused by the home range size of animals. The mean area of the studied hunting districts was 5,000 ha, which is generally larger than that of the home range of wild boar, which typically cover several hundred hectares (Sodeikat and Pohlmeyer, 2002). However, this home range is dependent on many factors: for example, males and young individuals may have larger home ranges of over 1,000 ha (Mauget, 1980; Keuling et al., 2008). Home range size is also strongly influenced by aspects of landscape structure, such as the number of forest patches or the degree of elevation (Fattebert et al., 2017). In addition, the home range can extend to 3,500 ha under the influence of hunting (Sodeikat and Pohlmeyer, 2002); this effect could also be strengthened by the dispersion of animals as a result of hunting pressure (Keuling et al., 2008). Furthermore, the wild boar has a large dispersive ability, and individuals can migrate up to several hundred kilometers (Keuling et al., 2010; Jerina et al., 2014). This is an important consideration as, during the sampling period, wild boar were under increased hunting pressure.

![Fig. 1. The trend in prevalence of *A. alata* in provinces with WETLANDS.](image1)

![Fig. 2. The prevalence of *A. alata* in wild boar in provinces in Poland calculated from literature values and data from the present study (A) and predicted by percentage of areas covered by WETLANDS (B) (for detailed information, see: Methods). The figure shows prevalence values for a given province and confidence intervals (lower; upper).](image2)
aimed at slowing the spread of African swine fever (Klich et al., 2021). Therefore, it would be reasonable to assume that the home range size of wild boar in Poland was significantly larger during the year of sample collection, and the lack of effect that was observed in the small-scale analysis would not be present in other hunting conditions.

In addition to the land cover effect, mesopredators seem to play a significant role in increasing the intensity of *A. alata* in wild boar. This was noted in the small-scale analysis, in which, despite having somewhat low explanatory power, red fox and raccoon dog numbers were shown to have an effect. These species are present as definitive hosts in the *A. alata* cycle (Takeuchi-Storm et al., 2015; Kórpya-Dzirba et al., 2021), and the red fox is considered to be the main definitive host of *A. alaria* in Europe (Portier et al., 2011). Indeed, a recent study in Poland found a high prevalence of *A. alata* in red foxes (78.7%) based on intestinal examination (Karamon et al., 2020). *A. alata* does not yet appear to have been described in raccoon dogs in Poland; however, it has been confirmed in neighboring Lithuania, and the data suggests that *A. alata* may even be found in greater abundances in raccoon dogs than in red foxes (Bruzinski-Schmidhalter et al., 2012). As such, it might be recommended to test raccoon dogs in Poland for *A. alata*, especially considering the observed positive correlation between its presence in raccoon dogs and wild boars.

Our data also indicate a clear upward trend in the threat posed by *A. alata* in wild boar towards the north of the country. This north-south gradient seems to be in line with the results of a previous study of the adult form of this parasite in foxes in Poland which indicated significant differences in prevalence between the northern regions (93.7% and 96.5%) and the southern regions (15.2% and 24.7%) (Karamon et al., 2018). The predicted prevalence in this study in the southern provinces did not exceed 10%, while all northern provinces showed a prevalence of over 20%, and even over 40% in north-eastern Poland. However, the model predicted a prevalence of over 100% for the Podlaskie province, suggesting the model did not have a good fit (Fig. 1.). Therefore, it should be stated that the large-scale analysis also has limitations resulting from the quality of the data used. The calculated prevalence was characterized in some provinces by a large range of confidence intervals resulting from the small sample size (e.g., for Zachodniopomorskie, the calculated prevalence was 42.9%, but CIs ranged from 6.2 to 79.5; for Podlaskie, the calculated prevalence was 41.7%, but CIs ranged from 13.8 to 69.6). Despite the uncertainty of estimation in our study, a similar north-south trend is also visible in the larger European areas, which is probably the result of the large size of the home range of the studied animals.

5. Conclusions

As our findings show, the occurrence of *A. alata* in wild boar requires multifactorial analysis. Environmental factors play a key role in risk assessment of *A. alata* in wild boar, therefore they should be taken into account when establishing meat inspection strategies and making possible recommendations to hunters in the face of a potential public threat. We recommend that selection of regions for meat inspection should include areas abundant with water and wetlands as well as those with higher local densities of foxes and raccoon dogs. In Poland, such meat inspections should first target northern provinces. A significant limitation occurs when predicting the risk of *A. alata* infection in small areas, which is probably the result of the large size of the home range of the studied animals.

Ethics approval and consent to participate

Not applicable.

Availability of data and material

The data supporting the conclusions of this article are included within the article. Raw data are available from the first author.

Funding

Not applicable.

Authors’ contribution

DK: conceived, designed and coordinated the study; DK also carried out the study, the statistical analysis and drafted the manuscript. MN, JW: sample collection and laboratory work, manuscript review and editing. AD: drafted manuscript. ZB: sampling, manuscript review and editing. BP: data gathering and analysis. KA: coordinating the study, manuscript review and editing.

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.

Acknowledgements

Not applicable.

References

Baker, R.M., Paulsen, P., 2014. Findings of Alaria alata mesocercariae in wild boars (Sus scrofa, Linnaeus, 1758) in west Hungary (Transdanubia regions). Wien Tierarztl. Monatsschr 101, 120–123.

Bikha-Zajee, E., Marucci, G., Pirig-Komorovszka, A., Cichocka, M., Rózycki, M., Karamon, J., Sroka, J., Bełski, A., Mizak, L., Concej, T., 2021. Occurrence of Alaria alata in wild boars (Sus scrofa) in Poland and detection of genetic variability between isolates. Parasitol. Res. Jan;120 (1), 83–91. https://doi.org/10.1007/s00436-020-06914-x. Epub 2020 Oct 26. PMID: 33103216; PMCID: PMC7846538.

Bruzinski-Schmidhalter, R., Sarkinias, M., Malakauskas, A., Mathis, A., Torgerson, P. R., Deplazes, P., 2012. Helminths of red foxes (*Vulpes vulpes*) and raccoon dogs (*Nyctereutes procyonoides*) in Lithuania. Parasitology 139 (1), 120–127. https://doi.org/10.1017/S003118201100171X. Erratum in: Parasitol. 2012, 139(3), 418.

Burnham, K.P., Anderson, D.R., 2002. Model Selection and Inference: A Practical Information-Theoretic Approach, 2nd Edition. Springer-Verlag, New York. https://doi.org/10.1007/978-0-387-68866-2.

Dollfus, R.P., Chabaud, A.G., 1953. Distomum musculorum suis (H.C.J. Duncker 1896, mesocercariae d’Alaria alata (J.A.E. Goetz 1782), (Trematoda, Strigeidae) chez un sanglier (*Sus scrofa L. 1758*, Fera) (*Distomum musculorum suis, mesocercaria of Alaria alata in the wild boar Sus scrofa L*). Ann. Parasitol. Hum. Comp. 28 (5–6), 354–364 (In French).
D. Klich et al.

Ozolina, Z., Mateuska, M., Liptaj, L., Dekne, G., 2020. The wild boar (Sus scrofa, Linnaeus, 1758) as an important reservoir host for Alaria alata in the Baltic region and potential risk of infection in humans. Vet. Parasitol. Reg. Stud. Rep. 22, 100485. https://doi.org/10.1016/j.vetpar.2020.100485.

Patrello, C., Portier, J., Jouet, D., Delorme, D., Ferté, H., 2015. Prevalence and intensity of Alaria alata (Goeze, 1782) in water frogs and brown frogs in natural conditions. Parasitol. Res. 114 (12), 4405–4412. https://doi.org/10.1007/s00436-015-4680-z.

Paulsen, F., Forejtek, P., Hutaraova, Z., Vondansky, M., 2013. Alaria alata mesocercariae in wild boar (Sus scrofa, Linnaeus, 1758) in south regions of the Czech Republic. Vet. Parasitol. 197 (1–2), 384–387. https://doi.org/10.1016/j.vetpar.2013.05.024.

Pestá, K., 1989. První nález Agamodistomum suai (STILES, 1908) v cemerníve v CSSR. [The first finding of Agamodistomum suai (STILES, 1908) in black clover in the CSSR]. Veterinarství 39, 437–439 (in Czech).

Portier, J., Jouet, D., Ferté, H., Gibout, O., Heckmann, A., Boireau, P., Vallée, I., 2011. New data in France on the trematode Alaria alata (Goeze, 1792) obtained during Trichinella inspections. Parasite 18 (3), 271–275. https://doi.org/10.1051/parasite/201118271.

Portier, J., Jouet, D., Vallée, I., Ferté, H., 2012. Detection of Panstrongylus triannulus and Anisus vorax as first intermediate hosts of Alaria alata (Goeze, 1792) in natural conditions in France: molecular evidence. Vet. Parasitol. 190 (1–2), 151–158. https://doi.org/10.1016/j.vetpar.2012.06.020.

Rajković-Janje, R., Marinčul, A., Bisić, S., Benić, M., Vinković, B., Mihaljević, Z. Prevalence and seasonal distribution of helminth parasites in red foxes (Vulpes vulpes) from the Zagreb County (Croatia). Z. Jagdwiss. 48, 151–160.

Ramírez, A., Balilica-Ramírez, A., 2001. The prevalence of Alaria alata in red foxes (Vulpes vulpes L.) in the western part of Poland. Tierärztliche Umsch. 56, 423–425.

Rentería-Solis, Z.M., Hamedy, A., Michel, F.U., Michel, B.A., Lücke, E., Ster, N., Wichelt, G., Riehn, K., 2013. Alaria alata mesocercariae in raccoons (Procyon lotor) in Germany. Parasitol. Res. 112 (10), 3595–3600. https://doi.org/10.1007/s00436-013-3547-4.

Rentería-Solis, Z., Kolodziej-Sobocińska, M., Riehn, K., 2018. Alaria sp. mesocercariae in Eurasian badger (Meles meles) and wild boar (Sus scrofa) from the Białowieża Forest, north-eastern Poland. Parasitol. Res. 117 (4), 1297–1299. https://doi.org/10.1007/s00436-018-5819-5.

Riehn, K., Hamedy, A., Grosse, K., Zeiter, L., Lücke, E., 2010. A novel detection method for Alaria alata mesocercariae in meat. Parasitol. Res. 107 (1), 213–220. https://doi.org/10.1007/s00436-010-1853-7. Epub 2010 Apr 20. PMID: 20405145.

Riehn, K., Hamedy, A., Grosse, K., Wüste, T., Lücke, E. 2012. Alaria alata in wild boars (Sus scrofa, Linnaeus, 1758) in the eastern parts of Germany. Parasitol. Res. 111 (4), 1857–1861. https://doi.org/10.1007/s00436-012-2956-4.

Riehn, K., Hamedy, A., Saffa, J., Lücke, E. 2013. First interlaboratory test for the detection of Alaria alata sp. mesocercariae in meat samples using the Alaria sp. mesocercariae migration technique (AMT). Parasitol. Res. 112 (7), 2653–2660. https://doi.org/10.1007/s00436-013-3452-1.

Sailer, A., Glawisching, W., Ischik, I., Lücke, E., Riehn, K., Paulsen, P. 2012. Findings of Alaria alata mesocercariae in wild boar in Austria: current knowledge, identification of risk factors and discussion of risk management options. Wien. Tierärztlche Mon. 99, 346–352.

Schleupner, C., 2007. Estimation of Spatial Wetland Distribution Potentials in Europe. FNU-135. Centre for Marine and Atmospheric Science. Hamburg University.

Shimalov, V.V., Shimalov, V.T., 2001. Helminth fauna of the American mink (Mustela vison Schreber, 1779) in Belorusian Polesie. Parasitol. Res. 87 (10), 886–887.

Sodeikat, K., Pohlmeyer, K., 2002. Temporary home range modifications of wild boar family groups (Sus scrofa L.) caused by drive hunts in Lower Saxony (Germany). Z. Jagdwiss. 48 (1), 161–166.

Strokowska, N., Belkot, Z., Wiśniewski, J., Nowicki, M., Didkowska, A., Anusz, A., Szukic, K., 2021a. Infestation of wild boar meat from the Eastern Lublin province with Alaria mesocercariae. Med. Veter. 77 (12), 588–593.

Strokowska, N., Nowicki, M., Klich, D., Belkot, Z., Wiśniewski, J., Didkowska, A., Chyła, P., Anusz, K., 2020. The occurrence of Alaria alata mesocercariae in wild boars (Sus scrofa) in north-eastern Poland. Int. J. Parasitol. Parasitic Wildl. 12, 25–28. https://doi.org/10.1016/j.jipaww.2020.04.006.

Sodeikat, K., Nowicki, M., Dzikowska, A., Filip-Hütsch, K., Wiśniewski, J., Belkot, Z., Anusz, K., 2021b. A comparison of detection methods of Alaria alata mesocercariae in wild boar (Sus scrofa) meat. Int. J. Parasitol. Parasitic Wildl. 16, 1-4.

Takachuki-Strom, N., Al-Sahi, M.N., Thamsborg, S.M., Enemark, H.L., 2015. Alaria alata mesocercariae among feral cats and badgers, Denmark. Emerg. Infect. Dis. 21 (10), 1872–1874. https://doi.org/10.3201/eid2110.A14181.

Tyłkowska, A., Pilarczyk, B., Pilarczyk, R., Zysko, M., Tomza-Marciniak, A., 2018. The presence of Alaria alata fluke in the red fox (Vulpes vulpes) in the north-western Poland. Jpn. J. Vet. Res. 66, 203–208.

Voelkel, A.C., Dolle, S., Koethe, M., Haas, J., Makrutzki, G., Birka, S., Lücker, E., 2011. Detection of Panstrongylus triannulus and Anisus vorax as first intermediate hosts of Alaria alata (Goeze, 1792) in the Province of Kuyavia and Pomerania. Wiad. Parazytol. 47 (3), 423–426 (in Polish).