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Original papers

The occurrence and diversity of flies (Diptera) related to ruminant farming in southern Poland

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ABSTRACT. The aim of the study was to determine the biodiversity of flies (Diptera) occurring in livestock buildings and in their direct proximity, in various systems of ruminants rearing. Flies were collected by net sweeping during the summer, in two cowsheds (one large-scale, and one traditional farm), and one specialist sheepfold, located in the Lesser Poland region of Poland. The insects were captured – both inside and outside the premises – three times (at 10:00, 12:00 and 14:00) on selected warm and sunny days of June, July and September, when animals were assumed to be the most harassed. A total of 18365 flies belonging to 13 families were obtained. The largest relative abundance of Diptera were from the Drosophilidae family (61.4%), and dominating Muscidae species – *Musca domestica* L., 1758 (19.2%) and *Stomoxys calcitrans* (L., 1758) (5.7%). More than half (55.5%) of all flies were captured in the morning, and their vast majority not inside a livestock building (28.2%), but in its close proximity (71.8%). This was particularly true of the large-scale cattle farm. The smallest number of insects, although with the highest biodiversity, were collected at the sheepfold. Regardless of their particular animal preferences, the insect species found were commonly occurring in different livestock sectors.

Keywords: dipterans, cattle, sheep

Introduction

Raising livestock is associated with the accumulation of large amounts of manure, which plays an important role in the development and spreading of two-winged (Diptera). Such flies, strongly associated with the environment created by humans and with domesticated animals, are considered to be synanthropic, or even endophilic [1]. Of these, most of them feed, and breed, on animal feces. The coprophages include the black scavenger flies Sepsidae (larvae of all species), hoverflies Syrphidae, Fanniidae, as well as many species (larval and imaginal stages) from the Muscidae family, i.e. the housefly *Musca domestica* Linnaeus, 1758, face fly *M. autumnalis* De Geer, 1776, false stable fly *Muscina stabulans* (Fallén, 1817), or dump flies of the genus *Ophyra* (=*Hydrotaea*) Robineau-Desvoidy, 1830 [2]. Similarly, animal feces are eaten by dark-winged fungus gnats Sciaridae, drain flies Psychodidae, and small dung flies Sphaeroceridae [3]. The remaining insects that are saprophages feed on animal and plant remains (Drosophilidae, some species of Muscidae), or are highly polyphagous (blow flies Calliphoridae, flesh flies Sarcophagidae). Not many hematophagous species occur in the vicinity of farm buildings, such as those from the family Tabanidae, Culicidae or the stable fly *Stomoxys calcitrans* (Linnaeus, 1758) of the Muscidae family, which feed on blood.

The direct negative impact of dipterans on livestock includes causing anxiety and stress in the animals, which results in reduced feeding, as well as skin lesions, facultative and accidental myiasis – initiated by many species of the family Calliphoridae, Sarcophagidae, Muscidae, Fannidae, Syrphidae, Drosophilidae, and Piophilidae – or blood loss leading to immunosuppression. Indirectly, the

presence of flies contributes to the spread of many pathogenic microorganisms and parasites in herds – regardless of whether these insects feed on animal blood, wound leakage, or the secretions of mucous membranes and skin glands. One of the synanthrophic species is the biting and sucking stable fly, *S. calcitrans*, which mechanically carries many pathogens, but the non-biting housefly *M. domestica*, with its licking mouthpiece, is equally dangerous as a disease vector, and is the main threat to humans as a sanitary pest. The stable fly carries viral pathogens, including those causing African swine fever and bovine herpes, anthrax bacteria, rickettsiae anaplasmosis, or parasitic protozoa and helminths causing besnoitiosis, habronemosis, onchocercosis and dirofilariosis in animals [4]. The housefly is responsible for spreading, among others, the polio virus, the bacterial diseases of salmonellosis and cholera, and is a vector for such parasites as lamblia, roundworms, hookworms, or tapeworms [1].

The population dynamics of the most common in human and farm animal habitation housefly, and stable fly, have already been described in details by other authors [5,6]. The aim of this research was to determine the species diversity of dipterans co-occurring with *M. domestica* and *S. calcitrans* on farms differing in size and practiced ruminant management located in similar environmental conditions, as well as to draw attention to diurnal and seasonal differences in the flies activity inside the cowsheds and sheepfolds, or outside – in their surroundings.

Materials and Methods

The material for the study were flies captured at selected farms located in southern Poland (48°43′N,16°55′E; 276-305 m a.s.l.) – two raising cattle (one large, and one traditional farm), and one farm specialized in holding sheep. The distances between the individual surveyed farms ranged from 20 to 35 km. The large-scale farm raised its livestock in a closed cycle. It had 180 Holstein-Friesian black and white milk cows as its basic herd. The animals were kept indoor, on shallow litter that was removed daily. The animals were fed with farm feed, with the addition of feed concentrates. The traditional farm used the indoor-pasture system, raising a Holstein-Friesian red and white milk cow with its offspring on a shallow litter indoors, together with poultry in the same barn. The herd of sheep numbered 50 Olkuska breed ewes in the basic herd, kept on deep litter, in the indoor-pasture system. In the period of the study, as well as in previous years, no pest control was applied at any of the farms.

Observations were made in the summer months, during the period when the appearance of insects intensified. An insect aerial net on a short handle was used to catch dipterans. For comparative purposes, captures were made at all the facilities – both in the buildings holding livestock as well as directly outside of them, in accordance with the same methodology, by sweeping the net. The insects were collected three times a day: in the morning, at noon and in the afternoon (at 10:00, 12:00 and 14:00, respectively). The field collections were conducted three times – in June, July and September. Warm, sunny days were selected for capturing the insects, when the farm animals were present in the buildings.

The collected insects were identified on the basis of morphological characteristics to families, genus and species [7–11]. The activity of flies in the studied facilities were developed for the two most abundant species, i.e. for the housefly *M. domestica* and the stable fly *S. calcitrans*.

The Simpson's index of diversity (1-D), as well as Jaccard index of similarity, were calculated using PAST [12,13] in order to describe and compare the diversity of fly assemblages observed in the studied farms. The dominance structure of assemblages was prepared using the method proposed by Durska [14], in which four classes of species were distinguished, i.e. eudominants (more than 15%), dominants (5.1–15%), subdominants (1.1–5%), and accessory species (up to 1%).

Results

A total of 18365 dipterans belonging to 13 families were collected (Table 1) – the largest number of specimens (82.9%) was caught at the large-scale dairy farm, and the least (3.8%) at the sheep farm. At the large-scale farm, a total of 15233 insects from 12 two-winged families were captured. Most of them were collected in June (62.4%, compared to 21.3% in July and 16.4% in September), although Muscidae were captured mostly in September (64.2%, while only 3.7% in June). In total, the largest number of dipterans were obtained in the morning hours (59.1%) and the least at noon (11.6%). Most insects were caught outside the livestock buildings (81.9%). The most frequently

Table 1. Total number and proportion (%) of individual Diptera taxa captured in the surveyed farms. Sampling inside and outside the premises took place three times (at 10:00, 12:00, and 14:00) on the same selected day of June, July and September, on three farms examined (54 samples were taken; 18 from each farm).

		Farm 1		Farm 2		Farm 3		Total	
Family	Genus/species	Number	%	Number	%	Number	%	Number	%
Muscidae	*Musca domestica* Linnaeus	3194	20.97	308	12.63	15	2.16	3517	19.15
	Musca autumnalis De Geer	188	1.23	0	0.00	2	0.29	190	1.03
	Muscina stabulans (Fallén)	3	0.02	341	13.98	45	6.49	389	2.12
	Muscina assimilis (Fallén)	0	0.00	3	0.12	1	0.14	4	0.02
	Morellia simplex (Loew)	3	0.02	0	0.00	32	4.62	35	0.19
	Graphomyia maculata (Scopoli)	1	0.01	0	0.00	0	0.00	1	0.01
	Ophyra Robineau-Desvoidy	42	0.28	39	1.60	22	3.17	103	0.56
	Stomoxys calcitrans (Linnaeus)	230	1.51	802	32.88	8	1.15	1040	5.66
	Haematobosca stimulans (Meigen)	0	0.00	0	0.00	1	0.14	1	0.01
Fannidae	*Fannia* Robineau-Desvoidy	140	0.92	687	28.17	16	2.31	843	4.59
Calliphoridae	*Lucilia illustris* (Meigen)	3	0.02	1	0.04	1	0.14	5	0.03
	Lucilia sericata (Meigen)	4	0.03	0	0.00	4	0.58	8	0.04
	Calliphora vicina Robineau-Desvoidy	2	0.01	1	0.04	0	0.00	3	0.02
	Calliphora vomitoria (Linnaeus)	0	0.00	1	0.04	0	0.00	1	0.01
	Calliphora uralensis Villeneuve	3	0.02	0	0.00	0	0.00	3	0.02
	Protophormia terraenovae (R. Desvoidy)	2	0.01	0	0.00	0	0.00	2	0.01
Sarcophagidae	*Sarcophaga carnaria* (Linnaeus)	1	0.01	0	0.00	2	0.29	3	0.02
Tabanidae	*Hematopota pluvialis* (Linnaeus)	4	0.03	4	0.16	2	0.29	10	0.05
	Tabanus miki Brauer	1	0.01	0	0.00	1	0.14	2	0.01
Culicidae	*Anopheles* Meigen	22	0.14	24	0.98	47	6.78	93	0.51
	Culex Linnaeus	7	0.05	0	0.00	1	0.14	8	0.04
	Aedes Meigen	1	0.01	6	0.25	0	0.00	7	0.04
Scatophagidae	*Scatophaga stercoraria* (Linnaeus)	1	0.01	0	0.00	1	0.14	2	0.01
Syrphidae	*Eristalis tenax* (Linnaeus)	2	0.01	5	0.21	2	0.29	9	0.05
	Syritta pipens (Linnaeus)	2	0.01	0	0.00	1	0.14	3	0.02
Scatopsidae		0	0.00	0	0.00	19	2.74	19	0.10
Sepsidae		407	2.67	129	5.29	115	16.59	651	3.54
Drosophilidae		10845	71.19	88	3.61	342	49.35	11275	61.39
Cecidomyiidae		1	0.01	0	0.00	0	0.00	1	0.01
Anthomyiidae		124	0.81	0	0.00	13	1.88	137	0.75

Farm 1: large-scale dairy farm; Farm 2: traditional, small-scale farm raising cattle and poultry; Farm 3: specialist sheep farm

confirmed were representatives of the Drosophilidae (71.2%) and the housefly *M. domestica* (21.0%); the stable fly *S. calcitrans* and face fly *M. autumnalis* were observed much less frequently (1.5% and 1.2% of captured insects, respectively). In addition, Sepsidae (2.7%) were relatively frequently listed. Other flies did not exceed 1% of all the insects collected, constituting accessory species. In June, the captures of *M. domestica* and *S. calcitrans* were small both outside and inside the livestock buildings. In July, the number of *M. domestica* increased, and the largest number of insects were collected outside in the afternoon hours. The housefly was most numerous in September, however, especially in the morning inside the buildings (as many as 19.0% of all collected specimens). Stable fly captures were insignificant throughout the study period, with the highest number occurring in September in the morning – in this case, outside the livestock buildings (33.9% of the total number of this fly specimens were collected at that time).

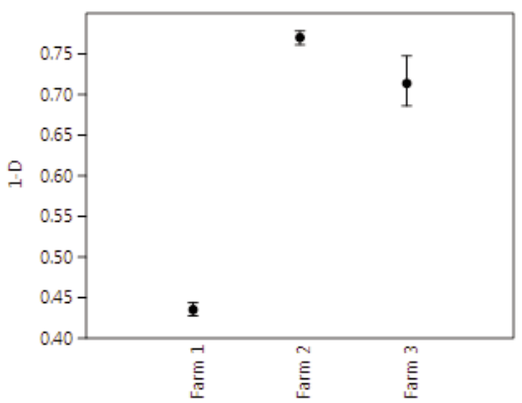

Fig. 1. Simpson's index of diversity (1-D) observed in the farms examined (Farm 1: large-scale dairy farm; Farm 2: traditional, small-scale farm raising cattle and poultry; Farm 3: specialist sheep farm).

At the traditional farm, a total of 2439 Diptera specimens belonging to 8 families were captured (Table 1). Most insects were collected in July (45.1%) and September (31.7%), and the least in June (23.2%). Unlike at the large farm, the majority of flies were captured from the cowshed (85.7%), whereas only 14.3% of the dipterans were captured directly outside the building. The most frequently captured were the stable fly (32.9%) and Fanniidae (28.2%). A relatively large percentage of the insect assemblage was also represented by the false stable fly *Muscina stabulans* (14.0%) and housefly (12.6%), followed by the black scavenger flies Sepsidae (5.3%), Drosophilidae (3.6%) and *Ophyra* sp. (1.6%). In the case of the most numerous families: Muscidae, Sepsidae and Fanniidae, the largest number of them were captured in July (47.4%, 41.1% and 43.7% respectively); while the most specimens of Drosophilidae were collected in September (70.5%). The housefly and stable fly were found mainly inside the livestock building (in 74.4% and 95.4% respectively), and in a similar number regardless of the time of day.

At the sheep farm, a total of 693 flies from 13 families were collected (Table 1) – the highest number in June (59.2%), and then successively in July (26.2%) and September (14.6%). More insects were captured in the morning (56.4%) than at noon (17.2%) or in the afternoon (26.4%). The location of the capture (inside or outside) did not affect the number of specimens obtained at this site (50.4% were caught outside). The most common dipterans were Drosophilidae (49.4%) and Sepsidae (16.6%), followed by mosquitoes of the genus *Anopheles* Meigen, 1818 (6.8%), false stable fly *Muscina stabulans* (6.5%), *Morellia simplex* (Loew, 1857) (4.6%) and *Ophyra* sp. (3.2%). There were relatively few houseflies (2.2%), and even fewer stable flies (1.2%), with one capture of *Haematobosca stimulans* (Meigen, 1824). Most Muscidae were collected in July (49.2%).

At all of the studied farms, the highest percentage of insects from the Diptera order posed the Drosophilidae – 61.4%, and the second largest family in terms of abundance – the Muscidae at 28.8%. Drosophilidae dominated at the larger farms (71.2% of captured insects in the large-scale cowshed and 49.4% in the sheepfold), while at the traditional farm they accounted for only 3.6% of the collected insects. Over half of the collected dipterans (55.5%) were flies captured in the morning; 29.9% of the insects were obtained in the afternoon, and 14.6% at noon. The vast majority of insects were captured outside the livestock buildings (71.8%); the Muscidae, Fanniidae and Culicidae families were captured more often inside the livestock buildings, while the Sepsidae, Drosophilidae and Anthomyiidae were captured more often in their proximity. The most frequently captured species was *Musca domestica* – 19.2% (eudominant) and *Stomoxys calcitrans* – 5.7% (dominant species). Among other dipterans causing problems in animals, *Musca autumnalis* and *Morellia simplex* were common. Of the hematophagous Culicidae mosquitoes, representatives of the *Aedes* Meigen, 1818, *Culex* Linnaeus, 1758, and *Anopheles* genera were found in this study, and of the Tabanidae – *Haematopota pluvialis* (Linnaeus, 1758) and *Tabanus miki* Brauer, 1880.

The Simpson's index of diversity (Fig. 1) reached the lowest value on the large-scale dairy farm (0.44), in contrast to the traditional small-scale and sheep farms, where the values were higher and almost similar (0.77 and 0.71, respectively). On the other hand, the estimated similarities (Jaccard index) of studied fly assemblages were the highest between the large-scale dairy farm and sheep farm (69.2%), whereas significantly lower between the large-scale and traditional small-scale farms (42.3%), or the traditional one and sheep farm (48.0%).

Discussion

The dipteran assemblages collected in the present work differed in numbers among the farms examined, depending on the site of collection,

month, or the time of day. Nevertheless, the fly species observed were more or less prevalent everywhere, despite the type of farming.

In addition to the species found at the currently studied farms – especially the blood-sucking ones – Piątkowski [15,16] mentions flies of the genus *Hydrotaea* (*H. irritans*, *H. armipes*, *H. dentipes*, *H. albipuncta* and *H. pellucens*); the horn fly *Haematobia irritans* (Linnaeus, 1758); *Chrysops relictus* Meigen, 1820; the black flies Simuliidae – *Simulium ornatum* (=*Odagmia ornata*) (Meigen, 1818) and *Simulium argyreatum* Meigen, 1838; biting midges Ceratopogonidae of the genus *Culicoides* Latreille, 1809 (*C. chiopterus*, *C. fascypennis*, *C. grisescens*, *C. impunctatus*, *C. obsoletus*, *C. pulicaris*, *C. punctatus*) and *Forcipomyia bipunctata* (Linnaeus, 1767). However, these two-winged insects are more likely to threaten animals grazing on pastures, and this is probably the reason they were not collected in the proximity of the farm buildings monitored in the present work. The quoted author [17] mentions that the hematophagic Culicidae, Ceratopogonidae, Simuliidae and Tabanidae were inside a cowshed presumably by accident, seeking shelter, as he did not observe them collecting blood during that time.

Among the flies gathered in cowsheds reported in a study by Bielenin et al. [18], 50–75% of the total captures were *S. calcitrans* and *M. domestica*, and the maximum occurrence of muscids was found from July to September. In the individual farms studied by the authors, *S. calcitrans* dominated rather than *M. domestica* – especially in typical livestock barns, compared to pigsties, and the largest number of stable flies were recorded in farms with traditional buildings.

Stomoxys calcitrans is a species considered to be one of the most harmful in livestock breeding and raising around the world. Taylor et al. [19] estimated the relationship between its numbers in cowsheds and the decline in animal performance (milk and meat). In herds constantly harassed by stable flies, the average annual production losses per animal were estimated at 139 kg of milk and from 6 to 26 kg of animal body weight gain. The total losses attributed to these flies in all sectors of cattle production in the US were estimated at USD 2.211 billion per year.

The occurrence of two-winged is correlated with atmospheric conditions, mainly with ambient temperature. Tangtrakulwanich et al. [20] found that *S. calcitrans* usually bites in the late morning or early afternoon. Gilles et al. [21] analyzed the relationship between temperature and altitude, and the number of *Stomoxys* flies and the length of the parasitic season. Despite the lack of a dependence between the intensity of insect occurrence at farms and height a.s.l., population increases began earlier after the winter at lower altitudes, and the decline in the population occurred earlier in the summer, which shifted the season during which animals were being parasitized.

In the case of the housefly, Schou et al. [22] analyzed its physical activity depending on temperature, time of day and density in a given area. It was observed that regardless of insect density, the activity of *M. domestica* increased during the day as the temperature increased until it reached 30°C, and then decreased. Increasing the density of the flies, on the other hand, decreased their physical activity.

In turn, studies by Khan et al. [23] pointed to significant differences in the speed of development and lifespan of the housefly on chicken droppings, as well as on calf and dog feces, compared to the feces of other animals (i.e. horse, buffalo, cow, sheep, goat). The total development time was the shortest in poultry manure and the longest in horse dung. In another experiment, Abu-Rayyan et al. [24] showed that houseflies most preferred chicken manure, and the least number of flies developed in sheep manure, which could be related to the ammonia content, most abundant in poultry droppings.

Similarly, Piątkowski [17] identified the dipterans occurring at an industrial pig farm. Based on his studies and the present work, it can be stated that – regardless of their particular animal preferences – many species are common to different livestock sectors. Such species include: *M. domestica*, *S. calcitrans*, *M. stabulans*, *Lucilia sericata* (Meigen, 1826), *Calliphora uralensis* Villeneuve, 1922 and *Protophormia terraenovae* (Robineau-Desvoidy, 1830). Likewise, Jacquiet et al. [25] noticed the stable fly was only slightly more attracted to horses than to cattle.

This study confirmed *M. autumnalis* in the sheepfold, even though the fly prefers cattle manure, whereas sheep manure, as well as horse manure, is not suitable for its development [1]. *H. stimulans*, also considered a typical bovine species, was found in the sheepfold, as well.

Currently, public opinion in Poland has given particular importance to the flies present at fur farms, due to their inconvenience and potential

epidemiological threat to human settlements. Based on our own observations, we can conclude that the species composition of insects occurring there is the same (in this case, mainly the lesser housefly *Fannia canicularis* (Linnaeus, 1761) and their presence can be minimized using adequate preventive measures.

In the present study, the vast majority of dipterans were captured outside the livestock buildings (71.8%), compared to inside (28.2%), which may indicate that efforts to reduce fly populations should be undertaken not only in the buildings themselves, but especially through preventive activities and improvement of sanitation in their surroundings. The issue of the frequent removal and proper storage of manure is particularly important here, which can disrupt the breeding and development of filth flies, significantly limiting their number. An equally important issue is to ensure that the buildings are "insect-proof", not only can proper ventilation and clean and dry bedding protect against the entrance of insects into the interior, so does securing wall openings, including doors and windows.

In the light of presented results it can be concluded that fly species composition – as indicated by the Simpson's index of diversity – was the most diverse in traditional farm, with some dominant species (*S. calcitrans*, *Fannia* sp., *M. stabulans*, *M. domestica*), which would suggest the greatest sustainability of dipteran community there. Clement et al. [26] demonstrated that the intensive sheep grazing on Mongolian steps had negative impact on the local dipteran diversity, although the Muscidae themselves had positive quantitative response to this factor. If the fly diversity was used as an indicator of farming impact on the environment, then the lowest diversity detected currently in the large-scale dairy farm (Fig. 1) would prove that the intensive farming has a high influence on the environment. Then again, the strongest similarity of dipteran assemblages observed between the large-scale dairy and sheep farms, but without flies diversity decrease on the sheep farm, might suggest a low level of environment disturbances related to sheep farming. Therefore, whether or not the diversity of fly species – and which group of flies – might be treated as a good indicator of adverse impact of farm management on the environment, this requires further research.

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References

[1] Thomas G., Jespersen J. B. 1994. Non-biting muscidae and control methods. *Scientific and Technical Review of the Office International des Epizooties* 13: 1159-1173. https://doi.org/10.20506/rst.13.4.820

[2] Draber-Mońko A. 2003. Flies related to man. *Dipteron* 19: 4-7.

[3] Kunderak K., Łupicki, D., Gocha R. 2004. Preliminary studies on flies Diptera in selected stock-farm in Lower Silesia. *Zeszyty Naukowe Akademii Rolniczej we Wrocławiu. Zootechnika* 488: 253-267.

[4] Baldacchino F., Muenworn V., Desquesnes M., Desoli F., Charoenviriyaphap T., Duvallet G. 2013. Transmission of pathogens by *Stomoxys* flies (Diptera, Muscidae): a review. *Parasite* 20: 1-13. https://doi.org/10.1051/parasite/2013026

[5] Kristiansen K., Skovmand O. 1985. A method for the study of population size and survival rate of house flies. *Entomologia Experimentalis et Applicata* 38: 145-150. https://doi.org/10.1111/j.1570-7458.1985.tb03511.x

[6] Skovgård H., Nachman G. 2012. Population dynamics of stable flies *Stomoxys calcitrans* (Diptera: Muscidae) at an organic dairy farm in Denmark based on mark-recapture with destructive sub-sampling. *Environmental Entomology* 41: 20-29. https://doi.org/10.1603/EN11155

[7] Trojan P. 1957. Keys for the identification of Polish insects 28 (1): Flies – Diptera, Preliminary issue. PWN, Warsaw, Poland.

[8] Trojan P. 1959. Keys for the identification of Polish insects 28 (21): Horse-flies – Tabanidae. PWN, Warsaw, Poland.

[9] Pławilszczikow N. 1968. Keys for the identification of insects. PWRiL, Warsaw, Poland.

[10] Skierska B. 1977. Keys for the identification of Polish insects 28 (9b): Mosquitoes – Culicidae. Imago stages. PWN, Warsaw, Poland.

[11] Draber-Mońko A. 2004. Fauna Poloniae 23: Calliphoridae – Blowflies (Insecta: Diptera). Natura Optima Dux Foundation, Warsaw, Poland.

[12] Hammer Ø., Harper D.A.T., Ryan P.D. 2001. PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica* 4: 9. http://palaeo-electronica.org/2001_1/past/issue1_01.htm

[13] Magurran A.E. 2004. Measuring Biological

Diversity. Blackwell Science, Oxford, UK.
[14] Durska E. 2001. Secondary succession of scuttle fly communities (Diptera: Phoridae) in moist pine forest in Białowieża Forest. *Fragmenta Faunistica* 44: 79-128.
[15] Piątkowski S. 1982. Diptera occurring in a large-head cattle breeding farm. *Wiadomości Parazytologiczne* 28: 125-128.
[16] Piątkowski S. 1986. Preliminary studies of Diptera of genus *Hydrotaea* occurring in cattle breeding quarters. *Wiadomości Parazytologiczne* 32: 419-420.
[17] Piątkowski S. 1982. Diptera occurring in an industrial pig breeding farm. *Wiadomości Parazytologiczne* 28: 129-131.
[18] Bielenin I., Rościszewska M., Petryszak A. 1982. Studies of the seasonal dynamics of Diptera in cow sheds. *Wiadomości Parazytologiczne* 28: 95-96.
[19] Taylor D.B., Moon R.D., Mark D.R. 2012. Economic impact of stable flies (Diptera: Muscidae) on dairy and beef cattle production. *Journal of Medical Entomology* 49: 198-209. https://doi.org/10.1603/me10050
[20] Tangtrakulwanich K., Albuquerque T.A, Brewer G.J., Baxendale F.P., Zurek L., Miller D.N., Taylor D.B., Friesen K. A., Zhu J.J. 2015. Behavioural responses of stable flies to cattle manure slurry associated odourants. *Medical and Veterinary Entomology* 29: 82-87. https://doi.org/10.1111/mve.12103
[21] Gilles J., David J.F., Duvallet G., Tillard E. 2008. Potential impacts of climate change on stable flies, investigated along an altitudinal gradient. *Medical and Veterinary Entomology* 22: 74-81. https://doi.org/10.1111/j.1365-2915.2008.00717.x
[22] Schou T.M., Faurby S., Kjćrsgaard A., Pertoldi C., Loeschcke V., Hald B., Bahrndorff S. 2013. Temperature and population density effects on locomotor activity of *Musca domestica* (Diptera: Muscidae). *Environmental Entomology* 42: 1322-1328. https://doi.org/10.1603/EN13039
[23] Khan H.A., Shad S.A., Akram W. 2012. Effect of livestock manures on the fitness of house fly, *Musca domestica* L. (Diptera: Muscidae). *Parasitology Research* 111: 1165-1171. https://doi.org/10.1007/s00436-012-2947-1
[24] Abu-Rayyan A.M., Abu-Irmaileh B.E., Akkawi M.M. 2010. Manure composting reduces house fly population. *Journal of Agricultural Safety and Health* 16: 99-110.
[25] Jacquiet P., Rouet D., Bouhsira E., Salem A., Liénard E., Franc M. 2014. Population dynamics of *Stomoxys calcitrans* (L.) (Diptera: Muscidae) in southwestern France. *Revue de Médecine Vétérinaire* 165: 267-271.
[26] Clement R.A., Frandsen P.B., McKnight T. 2018. Fly family diversity shows evidence of livestock grazing pressure in Mongolia (Insecta: Diptera). *Journal of Insect Conservation* 22: 231-243. https://doi.org/10.1007/s10841-018-0056-x

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