Distribution, biocological peculiarities of staphylinids (Coleoptera, Staphylinidae) in livestock biocenoses of forest-steppe and steppe Ukraine

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As a result of research in the territory of livestock farms, 103 species of predatory Coleoptera were found, including Staphylinidae accounting for 51.4%, Histeridae – 27.3%, Carabidae – 21.3%. A total of 39 species of the Staphylinidae family were identified, belonging to 5 subfamilies: Oxytelinae, Steninae, Staphylininae, Tachyporinae, Aleocharinae. Species composition of staphylinids varied in relation to the types of animal rearing premises. In cowsheds and calf pens species diversity was higher (35 species). To study the peculiarities of feeding in laboratory conditions, we monitored 9 species of Staphylinidae: Philonthus addendas Sharp, Ph. cruentatus (Gmel.), Ph. rectangulus Sharp, Ph. varians (Piky.), Ph. spinipes Sharp, Ph. nitidus F., Creophilus maxillosus (L.), Ontholestes marinus (L.), Oxytelus sp. Feeding specialization of imagoes and larvae of different ages was studied. We determined that the mass of food consumed per day is higher than the weight of the beetles. Large species of staphylinids prefer feeding on average-aged larva of flies and can eat puparia. Peculiarities of the development of coprophilous staphylinids were studied on the example of Ph. spinipes Sharp. During 24 h a female laid 1–3 eggs (+28°C). Duration of the egg phase depends on the temperature regime (in +20°C – 4–5, +28°C – 3–4 days). Cessation of egg laying was observed with decrease in the temperature to +14°C. The development takes part in three larval stages. Duration of the larva phase at +28°C was 8–10 days, at +20°C – 13–14 days. The first moulting was observed on the 2–3th days (in +28°C) after the larvae emerged from the eggs. At +28°C the pupa phase lasted 8–10 days. Decrease in temperature prolonged the rate of the development. At +24°C it practically did not change (9–10 days), at +18°C – increased to 13–15 days.

Keywords: Philonthus; coprophilous species; zoophilous flies; entomophages; biomethod.

Introduction

A relevant task for the agro-industrial complex is the development of efficient biological scientifically-based and rationally-organized methods of control of numerous ectoparasites of agricultural animals. Elimination of invasive diseases significantly increases the volumes of production of livestock products (meat, milk) of high sanitary-hygienic quality (Zarhanska et al., 2018; Kulyaba et al., 2019; Gutyj et al., 2019).

Zoophilous diptersans (Insecta, Diptera) ecologically related to the grazing animals include a broad spectrum of forms and species (hermaphroidges, hemerophiles, coprophages, representatives of other ecological and ecological-systemic groups) (Jonsson & Mayer, 1999; Campbell et al., 2001; Baranovski et al., 2016). Diptera have inhabited various habitats. Over the course of evolution, they have adapted to development in small amounts of food substrate (Eggleton & Belshaw, 1993; Kriosheina, 2008). Activity of zoophilous flies is observed from May to October with peak of abundance in August and September (Lysyk, 1993). The stable fly (Stomoxys calcitrans (Linnaeus, 1758)) is one of the most dangerous species of flies for cattle around the globe (Cruz-Vizcarra et al., 2004; Muermorn et al., 2010; Pluasik et al., 2013). Zoophilous diptersans are carriers of many infectious and parasitic diseases (Masmeatathip et al., 2006; Boyko et al., 2009; Saegerman et al., 2018). A whole set of preparations and devices are used against harmful flies. For example, traps of different constructions, distracting food substrates (fruits, flowers) as a source of sugar for adult insects. Chemical agents with various active substances are broadly used for disinfection (Gilles et al., 2007; Müller et al., 2012; Hardy, 2014; Solórzano et al., 2015; Boyko & Brygadyrenko, 2017). Negative effects of chemical treatment of livestock complexes stimulates the search of new, more progressive biological methods against ectoparasites (Skovgård & Nachman, 2004; Ovrtusk & Schliserman, 2012; Paliy et al., 2018). The main practical purpose of new methods, at the current stage, is maintaining species diversity of natural enemies of harmful Diptera and their active use in biomethod.

Staphylinidae is the largest family of beetles in the fauna of Ukraine, not taking into account the subfamily Aleocharinae, which is studied insufficiently and subfamilies Pselaphinae and Scaphidiinae, which have been identified to staphylinids relatively recently. In Ukraine 810 species of staphylinids are known, and the total number presumably equals no less than 1,300 species. Species diversity of the family is studied insufficiently, which is indicated by recent descriptions of new species (Gontarenko, 2009, 2013). Genus Philonthus Curtis, 1829 is cosmopolitan and numerous by number of species. Global fauna comprises over 1,000 species, including 300 in the Palearctic, in the European part of the CIS the genus is represented by 69 species. The faunistic list of Philonthus genus for the Middle Prydniprovie includes 52 species (Gontarenko & Petrenko, 2001).

Staphylinidae are a significant part of the entomofauna of livestock agrobiocenoses, and are one of the main factors which prevents mass reproduction of diptersans in natural and artificial ecosystems. Species of the Philonthus genus are the dominant group of entomophages which regulates the number of harmful ectoparasites of agricultural animals. An important biological characteristic of entomophages is the indicator of rapid increase in the number of their population. The value of this
indicator is determined by fertility, rate of the development of generation, ratio of sexes and number of generations per year (Lövei & Sunderland, 1996; Svobodová et al., 2016). Coprophilous *Philonthus* undergo a complete life cycle in fecal substrate. Larvae and imagos of beetles which constantly live in manure eliminate pre-imago stages of synanthropic and zoophilous flies. Concentration of *Philonthus* in flocks of agricultural animals increases in the process of decomposition of excrement (Bruge, 1993; Cabrera & Chani, 2003). Staphylinids identify their prey by contact, using tactile and taste receptors. They are not able to identify prey at a distance, unlike some species of ground beetles which use eye-sight and smell reflexes. Shape and location of the mandibles in *Philonthus* (small and average-sized species) determine specialization in piercing relatively large prey, though with soft coverings (Wheater, 1989). The role of staphylinids as bioregulators of the abundance of synanthropic and zoophilous flies in agroecosystems of Ukraine has not yet been studied. This determines the relevance and purpose of our studies. The objective of the study was faunistic overview of Staphylinidae in livestock biocenoses of forest-steppe and steppe Ukraine; study of peculiarities of biology and ecology (development, feeding) of dominant coprophilous species of staphylinids in laboratory conditions.

**Materials and methods**

Staphylinids were collected from livestock premises, from the territories of farms, manure-depositing sites and pastures located in the forest-steppe and steppe zones of Ukraine (Kharkiv, Poltava, Kievograd, Chernkassy, Kherson, Dnipropetrovsk Oblasts) in the period from 2005 to 2015 (Table 1).

### Table 1

| No | Territory where samples were collected | Date of samples collected | Number of samples |
|----|---------------------------------------|---------------------------|------------------|
|    | date | month | year | premises | number | pasture |
| 1  | Kharkiv Oblast, Zmiiv Raion, Zadonetska village | May | 2009 | August | 15 |
| 2  | Kharkiv Oblast, Derhachi Raion, Malaya Dunyivka village | June | 2014 | August | 18 |
| 3  | Kharkiv Oblast, Valley Raion, Ohulitsi village | June | 2008 | August | 12 |
| 4  | Kharkiv Oblast, Kharkiv Raion, Temrivka village | July | 2013 | July | 21 |
| 5  | Kievograd Oblast, Znamianska Raion, Subbotsi village | August | 2013 | May | 19 |
| 6  | Kievograd Oblast, Petrov Raion, Luhanka village | June | 2015 | August | 10 |
| 7  | Kievograd Oblast, Petrov Raion, Petrovka village | June | 2013 | July | 18 |
| 8  | Kherson Oblast, Beryslav Raion, Lvovo village | July | 2012 | August | 15 |
| 9  | Poltava Oblast, Poltava Raion, Kalashnyake village | August | 2006 | June | 12 |
| 10 | Poltava Oblast, Novi Sanzhary Raion, Novi Sanzhary village | September | 2007 | July | 10 |
| 11 | Chernkassy Oblast, Chornobai Raion, Kovnai village | September | 2010 | November | 15 |
| 12 | Dnipropetrovsk Oblast, Novomorskov Raion, Andritvka village | September | 2010 | November | 15 |

In livestock premises the insects were collected manually using aspirators on windows, walls, floor, and also in places of intense breeding of flies (trenches, manure transporters, rotting substrate, manure, separate fecal pits). Density of beetles (number of individuals per 1 m² of area) was taken into account. For studying the complex of predatory coleopterans on the pastures, fecal pits of cattle of different freshness were surveyed (one to five days). First the pits were examined on the exterior, then the pathways of insects inside them were examined. The soil under the manure substrate was loosened, and the detected insects were extracted, counted and identified. Soil diggings on the pastures were performed according to the existing recommendations (Agrinskiy, 1962; Braga et al., 2013). Some part of the collected material (50%) was fixed in 70% ethanol for further survey of species composition of coleopterans, and the remaining part was incubated in the insectarium for further cultivation in laboratory conditions. For mass collection of insects from the litter, manure, we used a thermo-eclector. Laboratory cultivation and experimental study of the peculiarities of the biology of certain species of staphylinids were performed in boxes of the insectarium. Temperature and moisture regimes which directly affect the number of cultivated insects were maintained (Rodriguez et al., 2019). A constant microclimate was maintained in the boxes: temperature of 25-26 °C, relative moisture – to 95%, weak diffused light. Humid river sand was put on the bottom of the boxes. Every day, eggs were extracted from the densicators, and then put into the incubator. Larvae and imagos of the beetles were fed with different stages of larvae and crushed poparia of laboratory culture of *Musca domestica* Linnæus, 1758. Small species of entomophages were kept in Petri dishes on water-moistered filter paper and fed with housefly eggs. Coprophilous species of *Philonthus* in flocks underwent a complete life cycle. Therefore, as substrate for the rearing of *Philonthus spinipes* Sharp, feces of cattle were used. Beetles were kept in closed boxes (with consideration of high flying activity) with 6–8 individuals in each. Moistened sand and cow manure was put in equal portions on the bottom of the containers.

Assemblages of coleopterans were kept in the collections of the National Scientific Center Institute of Experimental and Clinical Veterinary Medicine of the National Academy of Agrarian Sciences of Ukraine.

**Results**

As a result of entomological studies in the territory of livestock complexes, 103 species of predatory coleopterans were found, including 51.4% Staphylinidae, 27.3% – Histeridae, 21.3% – Carabidae. A total of over 2,000 specimens of beetles of the Staphylinidae family was collected and identified. We identified 39 species of staphylinids, belonging to 5 subfamilies: Oxytelinae, Steninae, Tachyporinae, Aleocharinae, Staphylininae (Table 2).
Ph. quisquiliarius

observations. After 24–48 h, the maximum number of beetles was observed in the surveyed fresh excrements of animals 8–10 h after the start of the excrement formation. Dominant species were Stenus comm. LeCont., Philonthus nitidus (Grav.), Ph. politus Sharp, ph. longicornis Stephens, Ph. politus Sharp, P. rectangulus LeCont. and eating the soft tissues. Larvae of M. domestica (L.) consumed III age larvae. As prey, II age larvae chose II–III age larvae of flies, in dung, and therefore, on the number and species composition of staphylinids. For the study of food specialization in the laboratory conditions, 9 species of coprophilous staphylinids were monitored. Adult beetles of Philonthus addundus Sharp collected in cowsheds were fed with house fly larvae of II and III age. We determined that over 24 h one imago ate 2–3 larvae of flies. Larvae of beetles at 1 age (with partial eating-out of the internal organs) over 24 h consumed 2–4 I age larvae of flies. Beetle larva in III age – 5–8 II–III age larvae of flies. Over cultivation we obtained 4 generations of Ph. addundus Sharp. Larvae of Ph. cruscentus (Grav.) were fed with crushed pupae of M. domestica L. Over 24 h one adult beetle consumed 2–3 puparia of flies. The species was cultivated to 4th generation. Coprophilic Ph. rectangulus Sharp caught on pastures were kept in the culture to 4th generation. Over 24 h imagoes consumed 2–3 I age larvae of flies and crushed puparia. During observations on feeding of Ph. varians (Payk.) we noted elements of necrophagia. The beetles ate remains of the larvae and puparia of flies, which had been torn by other large species of staphylinids. During 24 h one beetle consumed 3–5 housefly eggs. The species was cultivated to 3rd generation. In the experiment Ph. spinipes Sharp imagoes preferred to feed on larvae of flies of the final age (4–5 larva a day). One of the most abundant species in our assemblages was Ph. nitidus F. It is common in the territory of swine and cattle farms of the forest-steppe zone of Ukraine. In the culture it was kept to the 6th generation. Over 24 h, the beetles consumed 3–4 adult houseflies and 3–6 larvae of older age. Imagoes can also feed on puparia of flies, gnawing holes inside them and eating the soft tissues. Larvae of Ph. nitidus of 1 age actively attacked I–II age larvae of flies (5–6 specimans a day), and less eagerly consumed III age larvae. As prey, II age larvae chose II–III age larvae of flies. Ph. nitidus (Payk.) and 5 puparia of M. domestica L. and ate 5–6 individuals a day. Third age larvae of Ph. nitidus F., apart from consuming larvae of flies of older ages, attacked the pupae. Over 24 h they consumed 5–7 larvae of flies and 2–4 pupae. Beetles of Creophilus maxillosus (L.) collected under the litter of pignets were fed with III age larvae, puparia and imagoes of housefly. During the experiment, over 5 days one adult individual consumed 55 III age larvae and 10 puparia of M. domestica L. During the cultivation, 3 generations of C. maxillosus (L.) were obtained. O. similis (Fabricius, 1792) was cultivated to 4th generation. Over 24 h imagoes of this species ate up to 10 III age larvae of flies. Adult Oxytelus sp. were collected in feces of cattle in pastures. The beetles feed on rotting substrate, therefore as fodder crushed pupae of M. domestica L. were used. Two generations were obtained.

peculiarities of the development of coprophilous staphylinids were studied on the example of the abundant species Ph. spinipes Sharp. This cosmopolitan species is new to the fauna of Ukraine. The beetles are closely associated with manure (pre-imago development) in cattle pas-
The upper layers of manure rapidly lose moisture, therefore served on the 2–3rd days (in +28 °C). During observations on separately placed pairs of Ph. spinipes Sharp imagos, freshly laid eggs were observed every day. The duration of the egg phase depends on the temperature conditions: 8–10 days in +28 °C, 13–14 in +20 °C. The larva develops in three stages. The first mouling was observed on the 2–3rd days (in +28 °C) after larvae hatched from the eggs. The upper layers of manure rapidly lose moisture, therefore Philonthus transform into pupae in middle and lower layers of the substrate. Last-age larvae of Ph. spinipes Sharp constructs an air chamber with smooth walls in the excrements a few days before pupation. The larva transforms into pupa in 20–40 seconds. The cuticle is torn in the direction from head to the segments of the abdomen. With wave-like movements the pupa frees itself from the larva coatings and turns to the ventral side. It remains motionless in this position. At +28 °C the pupa phase lasts 8–10 days. Decrease in the temperature prolongs the development. At +24 °C it practically did not change (9–10 days), at +18 °C it was prolonged to 13–15 days. During this phase the pupa was observed to undergo change in colour from yellow to dark-brown.

Discussion

Prolonged anthropogenic activity influences the dynamics and structure of Staphylinidae communities. It has been proved that technogenic pollution causes changes in the linear sizes and morphometric features of staphylinids (Faly, 2010). The number and biomass of short-clytra beetles does not change significantly, species diversity decreases and changes in the composition of the dominants occurs. This group of coleopterans can be an indicator of anthropogenic changes in the environment (Edwards, 1991; Bogach, 1993). A relevant task is maintaining species diversity of Staphylinidae as a potential natural enemy of harmful dipterans.

According to our observations, over recent years the number of coleopterans in the pastures has been seen to decrease. Perhaps, this is related to transition of most livestock farms to maintenance of animals in stalls as well as decrease in the number of livestock on individual farms. For preventing significant losses of production of livestock, caused by attacks of parasitic insects, two technogenic approaches exist in livestock farming. The first approach is based on no-pasture maintenance of cattle along with traditional grazing in summer. The second approach is based on protective treatments of animals using insecticidal and repellent preparations (von Stein & Soderlund, 2012). Rapid decrease in the number of predatory beetles (from 40 to 5–8 individuals per 1 m²) is observed not only in pastures, but also in livestock premises, in which our opinion is related to uncontrolled use of chemical preparations against flies. An important role in the development of larvae of zoophilous flies in the places of feeding the animals belongs to hay. Manure mixed with hay is known to contribute to more stable and rapid reduction and prediction of the number of harmful dipterans (Skoda et al., 1991).

On livestock farms, regardless of the form of ownership, a number of measures are taken for protecting animals against infectious and invasive diseases. Among these measures an important role belongs to protection against zoophilous flies. Despite its disadvantages, the biometal method still remains a poorly developed scientific sphere, which is explained by the difficulties in controlling the relations between useful and harmful organisms in the environment. Mass use of toxic environment-polluting insecticides in livestock causes the necessity to develop ecologically safe methods against dipterans. These methods should be based on modern knowledge of the peculiarities of zoophilous flies and their entomophages.

Conclusions

In livestock complexes of Kharkiv, Poltava, Kirovograd, Chernivtsi, Kherson and Dnipropetrovsk Oblasts of Ukraine, 103 species of predatory Coleoptera were found: Staphylinidae equaled 51.4%, Histeridae – 27.3%, Cantharidae – 21.3% of the total. During the period of 2013–2015 in the studied territories the number of coleopterans was observed to decrease. Perhaps, this is related to increased exploitation of the land, transition of most farms to stall maintenance of animals and decrease in the number of cattle.

We identified the species composition and dominant species of staphylinids – potential bioregulators of the number of zoophilous flies in the territory of livestock complexes. Total of 39 species was found, belonging to 5 subfamilies: Oxytelinae, Steninae, Tachyporinae, Aleocharinae, Staphylininae. The dominant species of staphylinids in the pastures were Anotopus insecatus (Grev.), Oxytelus sculptus Grev., Philonthus nitidus F., Ph. crentusatus (Gmel.), Ph. rectangulus Sharp, Ph. varians (Payk.), Ph. spinipes Sharp, Ontholestes murinus (L.), Creophilus maxillosus (L.), Aleochara bipustulata (L.), A. bilineata Gyll. Species diversity of staphylinids was higher in cowsheds and calf pens.

In laboratory conditions, the peculiarities of feeding of larvae and imagos of 9 species of Staphylinidae were studied: Philonthus adderdae Sharp, Ph. crentusatus (Gmel.), Ph. rectangulus Sharp, Ph. varians (Payk.), Ph. spinipes Sharp, Ph. nitidus F., Creophilus maxillosus (L.), Ontholestes murinus (L.), Oxytelus sp. We determined high feeding activity of beetles: mass of consumed food per day exceeded the weight of the insect. Over the period of their development, staphylinids on average consume and traumatize 70–100 larvae of flies of different ages. We observed a pattern in the relationship between the sizes of predator and victim. Large species of staphylinids attack fly larvae of the last age and are able to eat puparia.

We determined that over 24 h one female Ph. spinipes Sharp lays 1–3 eggs (in +28 °C). Duration of the egg phase at +20 °C was 4–5, at +28 °C – 3–4 days. Egg-laying was observed to stop at +14 °C. Development occurs in three larval stages. Duration of the larva phase in +28 °C was 8–10 days, and at +20 °C – 13–14 days. The first mouling was observed on the 2–3rd days (in +28 °C) after the larva emerged from the egg. Pupa phase in +28 °C lasted 8–10 days. Decrease in the temperature prolonged the development. At +24 °C it practically did not change (9–10 days), at +18 °C it increased to 13–15 days.

On the basis of study of biocological peculiarities of coprophilous staphylinids, promising species can be distinguished – entomophages for use in bioregulation of the number of zoophilous flies. The obtained data form a practical basis for developing ecologically clean biological methods against parasitic dipterans in livestock rearing premises.

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