ISSN 1995-4255, Contemporary Problems of Ecology, 2012, Vol. 5, No. 1, pp. 46–49. © Pleiades Publishing, Ltd., 2012.
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Ecological Characterization of Calliphoridae (Calliphoridae, Diptera: Insecta) of the Russian Far East

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Abstract—Features of preimaginal and imaginal feeding of calliphoridae of the Far Eastern region of Russia are considered, ecological complexes and trophic groupings are distinguished, and their species composition is indicated. Aspects of calliphoridae' synantropism are discussed.

DOI: 10.1134/S1995425512010067

Keywords: calliphoridae, trophic groupings, ecological complexes, imaginal feeding, synantropic species

By now in the territory of Russian Far East 49 species of calliphoridae have been registered (world fauna numbers about 1400 species). Despite comparatively small species composition this family may be considered as one of the significant ecosystem components. Calliphoridae specimens inhabit all types of ground associations, at that their population density is quite high everywhere. Most of the family species are included in the ecological complex of destructors of organic forms of animal origin (corpses, excrements). Significant part of species belongs to synantropic dipterofauna; at that calliphoridae dominate in anthropocenoses if not qualitatively but quantitatively, and are rather important in medicine and veterinary since further circulation of disease agents. Some specimens of the family parasitize on various species of vertebrates and invertebrates and provoke trauma miasms in humans and animals.

Species composition of the family in the Russian Far East has been well investigated [1–5]. Trophic and topical relations of individual species have been studied [6, 7] as well as the opportunity of calliphoridae use as an indicating group at the analysis of ecosystem state [8]. However the generalized ecological characteristic of calliphoridae of the region is yet unavailable.

In this review main attention is paid to trophic component of ecological niches of calliphoridae species. First of all peculiarities of their preimaginal feeding have been considered.

In the previous works devoted to Sarcophagidae that are ecologically and taxonomically close to calliphoridae we have already indicated at different interpretations in ecological terms used in dipterological literature [9]. They mostly relate to the trophism of the larval stage of development.

Imaginal feeding is much lesser diverse and its description is to a large extent unified. In our opinion difficulties in the development of unified classification of trophic groupings of higher dipterous are bound firstly with unclear terminology, and secondly with frequent confusion of such notions as habitat and feeding environment. For instance necrophagy and necrobionic forms sometimes are understood as synonyms whereas in the first case there is trophic and in the second case topical relation to the habitat objects. Besides it is known that some species of dipterous developing in the animal corpse use for food other species rather than the corpse contents, i.e., at their trophic level they are not macrophages but typical predators (we offer to call these species "necrobionic predators". An example of inaccurate use of a term may be such notions as "saprophagy" and "necrophagy". Saprophagy includes feeding with dead organic substances of plant origin exclusively (decomposing fruits, leaves, stems, etc.). At necrophagy dead protein of plant origin (animal corpses) is used. Confusion of these notions results in the errors of investigations of energy flows in ecosystems. Besides if larvae of some calliphoridae species develop both in animals' corpses and their excrements some authors rather freely use the notions of "copronecrophagy" and "necrocoprophagy" not explaining their functional differences. According to the biological tradition the last part of such terms is basic therefore it should reflect trophic preferendum of the species whereas the first part of the term indicates at optional "addition" to the main food resource. Besides, some difficulties are caused by the notion "parasitism" as applied to dipterous larvae including calliphoridae. For instance species which larvae obligatory develop in live tissues of vertebrates (amphibian, reptiles, birds and mammals) usually are denoted in dipterologoical literature with a special term "myiasis" fly at that avoiding concrete definition of the type of biotic interrelations. However myiosis formation is not ecological but medical and veterinary term (myiosis) specific for certain type of damages caused by the larvae of various families of dipterous insects to

an organism of a vertebrate animal or human. From ecological point of view this is typical parasitism which may take both forms of ecto- and endoparasitism. In this sense in our opinion the most correct is the view of the known dipterologist A. Draber-Monko [10] who in her fundamental monograph provides rather accurate descriptions of this life activity of calliphoridae.

First of all we suggest considering peculiarities of preimaginal trophic groups of calliphoridae species living at the conditions of the studied region. As a criterion for attributing of one or another specimen of the family to one or another group we use the data on trophic preferendum of species exclusively not considering the entire range of their feeding. The later notion is much wider since it includes a number of other trophic media not always typical for the species which use is explained by the factor of fortuity (that may become an evolutionary stimulus to the development of new econiches). For example some calliphoridae—necrophages are sometimes found not only in the feeding media but in vertebrates' wounds as well. Optional character of this phenomenon is obvious therefore to attribute such species to zoophages is inexpedient. Besides we propose to reject from using the notion of "larva polyophagy" (at least in relation to calliphoridae and sarcophagidae) since it is neither informative nor determinative for the place of the species in the ecosystem. However application of such notion is appropriate at the description of dipterous imagoes ecology that will be clarified below.

Tropic groups of larvae are combined in two ecological complexes.

I. Complex of destructors:

1. Necrophages.

2. Copronecrophages.

II. Complex of zoophages:

1. Predators.

2. Parasites:

(1) earthworms;

(2) ground mollusks;

(3) vertebrates.

Ecological role of the species of destructive complex is physical and chemical processing of the corpses and excrements. Due to the vital functions of dipterous—necro- and coprophages, as it is known, dead organic forms are faster involved in ecosystemic cycles. It is known that calliphoridae larvae of this ecological complex have behavioral and biochemical adaptations allowing passing through the development cycle in the shortest period. They excrete proteolitic enzymes (in particular collagenase) so decomposing collagen and elastine [10]. Food substrate acquires semiliquid consistence that furthers active replacement of larvae inside it and efficient assimilation of organics. Some researchers believe that such feeding method was a great step in the evolution of both calliphoridae and other groups of higher dipterous [11]. It should be noted that larvae photophobia makes them replace deep in the substrate that to a great extent prevents from predator's action and extreme weather conditions. According to our observations calliphoridae (similar to their main competitors—sarcophagidae) during feeding usually do not disturb the surface of the feeding substrate developing relatively autonomous habitat that is a peculiar microecosystem of succession type. Only at the completion stage of larvae development full destruction of trophic medium occurs and after that their main objective is maximal fast replacement into the soil for puparium formation. This is the period of ontogenesis when larvae are the most vulnerable to numerous predators (mostly from Formicidae, Vespidae, and Carabidae families). According to our data far from all larvae that completed feeding succeed in migration; synergism of a whole number of factors (increased soil density, unfavorable weather conditions, large number of predators and parasites) results in the death of 20–30% of their total number.

On trophic preferendum in the complex of destructors the groups of necro- and coprophages are distinguished. It should be noted that specialized coprophages among calliphoridae of Far-Eastern fauna have not been found.

Necrophages. Larvae of calliphoridae-necrophages develop in vertebrates' corpses and in the wastes of meat and fish processing plants, animal-breeding farms and in food wastes of a human being. Specimens of this trophic group prefer inhabiting larger feeding media. According to classification proposed by Ozerov [7] these objects vary from the middle (0.5–10 kg) to very large (over 150 kg). Calliphoridae larvae are found in corpses at I–III stages of decomposition, rarely, at stage IV. At simultaneous feeding of larvae of different age and high density of their habitat we noted cases of cannibalism. In synantropic coenosis (including the urban ones) necrophages often inhabit meat and fish including in the living quarters. Females in a number of cases oviposit eggs on the wool of new-born domestic animals (cats and dogs) however according to our observations larvae are not capable for further development and die. An exception in this case is miyosis formation that is of an optional character. The necessary condition for such miyosis is presence of open wounds on the animals' body.

The group of necrophages includes 11 species: *Calliphora genarum* Ztt., *C. subalpina* Rindahl, *C. terraenovae* Mcq., *Cynomya mortuorum* L., *C. cadaverina* R.-D., *Lucilia magnicornis* Siebke, *L. caesar* L., *L. ampullacea* Vill., *L. silvarum* Mg., *Boreelus atriceps* Wd., *Protophormia terraenovae* R.-D.

Copronecrophages. As specimens of the previous trophic group they develop in the corpses of vertebrates, meat and fish waste but equally inhabit mammals' excrements, zoo- and polyphages (less often, phytophages and human's excrements). Larvae are found in feeding habitats of different volume. The

group includes 13 species: *Aldrichina grahami* Aldrich, *Calliphora vicina* R.-D., *C. nigribarbis* Vollenhoven, *C. vomitoria* L., *C. uralensis* Vill., *C. loewi* Enderlein, *Triceratopiga calliphoroides* Rohd., *Lucilia cuprina* Wd., *L. sericata* Mg., *L. illustris* Mg., *Chrysomya albiceps* Wd., *C. megacephala* F., *Phorina regina* Mg.

The zoophages complex includes 18 below listed species.

Endoparasites of earthworms. Progeny is placed by a female either directly on the worm's skin or at the edge of its hole. Infection usually occurs during the period of rains when hosts as a whole appear on the soil surface. As a result of invasion worms die. Parasitism is reliably known for seven species of the Far-Eastern fauna of calliphoridae: *Bellardia stricta* Vill., *B. chosenensis* Chen, *B. bayeri* Jacentkovsky, *B. nartshukae* Grunin, *Onesia subalpina* Kurahashi, *Pollenia pectinata* Grunin, *P. rudis* F. The mentioned species develop in the specimens of *Allobophora* and *Eisenia* (Lumbricidae) genera. Influence of calliphoridae parasitism on the density of earthworm populations has not been studied sufficiently.

Endoparasites of ground mollusks. Eggs and oviposited in the mantle cavity of the host. Larvae develop inside the mollusk shell gradually eating away vitally important organs. Invasion results in the host death. In the region parasitism of three species was registered: *Melinda gentiles* R.-D., *M. io* Kurahashi, *Pollenomiya sinensis* Seguy. The hosts are Pulmonata: *Bradibaena maackii* (Gerstf.), *B. middendorffii* (Gerstf.) (Bradibaenidae), species of *Succinea* genus (Succeneidae).

Ecto- and endoparasites of vertebrates. Progeny is placed by the female on the open wounds and sometimes on the intact skin of amphibian, reptiles, birds and mammals. The group includes 9 species: widespread obligate parasite of toads and frogs *Lucilia bufonivora* Moniez, hypodermic parasite of ungulate animal *Boonopus inexpectacus* Grunin, cutaneous parasites of nestlings *Protocalliphora ambliogma* Peus, *P. azurea* Fll., *P. maruyamensis* Kano et Shinonaga, *P. sabroskyi* Grunin, *P. rognesi* Thompson et Pont, *P. proxima* Grunin, hypodermic parasite of nestlings of several tens of bird species *Trypocalliphora braueri* Hendel.

For a number of the family specimens trophic binds of larvae remain unknown; they may be specified only hypothetically considering ecological data on the close species taxonomy. In particular *Polleniopsis mongolica* Seguy and *Pollenomyia okazakii* Kano are probable parasites of the earthworms or mollusks; necrophage rather probable for *Lucilia chini* Fan, *L. regalis* Mg., *L. shenyangensis* Fan; larvae of *Stomorhina obsoleta* Wd., probably prey upon preimaginal stages of ants. Assumptions are absent only for *Gymnadichosia pusilla* Vill., although the above mentioned predictions may be inaccurate since within the genus calliphoridae are characterized by significant species differences on larva trophism.

Imaginal feeding of calliphoridae is much more diverse compared with the larva ones, and specialization in selection of food substrate is not observed in them. All species of the Far-Eastern fauna should be attributed to the category of polyphages. According to the data of N. A. Kulikova [12] their mouth apparatus belongs to loosening-filtering-sucking morphotype. Hence calliphoridae imagoes may use organic forms of an animal and plants in liquid or semiliquid state. Preferences in feeding may be easily verified at fly catching with baits with the use of standard traps as well as with catching from one or another trophic media. The preferred feeding media are vertebrates' corpses, their excrements, meat and fish products of human's feeding, plants nectar and dead aphids. Besides calliphoridae were registered during feeding human's sudoriferous excretions, mucinous secretions of cloven-hoofed animals, blood and lymph in the open wounds of vertebrates, cell fluid in the damaged areas of the plants, detritus on reservoir shores, Hemolymph of ill or dead pupae and lepidopterans' caterpillars. In the territory of fish processing plants calliphoridae were registered during feeding organics which saturates the ground.

Speaking of calliphoridae it is impossible not to comment on their place in the complex of synantropic dipterous. History of this family investigation started from the description of species included in human's environment. Synantropy in our opinion should be understood as species attribute to anthropocenosis where continuous presence of a human being is determinant for characteristics of ecological niches and is a dominating factor "permitting" or "prohibiting" colonization of the natural fauna specimens in anthropogenic conditions. Usually in the specified complex dipterologists distinguish two groups of species: eusynantrops (endo- and exophillic) and hemisynantrops (communicative and acommunicative). Fauna specimens avoiding ecological contacts with humans and therefore not included in synantropic complex are conventionally called asynantrops. As it was already mentioned in [13] eusynantropic calliphoridae are presented in the ecosystems of the Russian Far East. Specialized ecological relation with human as an only "supplier" of feeding media for larvae and imagoes is specific only for the regions with rather high population density (for instance Southern and Eastern provinces of China, Korea and Japan). In the studied region no calliphoridae species inhabiting exclusively built-up areas has been found. Hemisynantrop grouping includes species with much higher ecological plasticity compared with eusynantrops. Their populations can inhabit both improved and natural cenoses although in the first ones density of their population is much higher than in the second ones. Correlation of "wild" and synantropic populations of particular species may be completely different depending on the habitat. For example at the conditions of the northern and northeastern territories of the Russian Far East (Chukotka, Kamchatka) hemisynantropic populations are "indrawn" almost exclusively in the settle-

ments of all types and in the south of the region (Primorie) they are evenly distributed both in natural and anthropogenic cenoses. Communicative hemisynantrops during adaptogenesis formed (and go on forming) relations with human on a trophic basis—condition of their populations directly depends on the presence of food waste, human and domestic animals excrements, remains of synantropic mammals and birds. On feeding specialization of larvae these are copro- and necrophages developing in the specified trophic media. In this subgroup of hemisynantrops we include 22 species of the Far-Eastern fauna. These are all eight specimens of *Calliphora* genus (*C. genarum* Ztt., *C. subalpina* Ringdahl, *C. vicina* R.-D., *C. vomitoria* L., *C. nigribarbis* Vollenhoven, *C. uralensis* Vill., *C. terraenovae* Mcq., *C. loewi* Enderlein), six specimens of *Lucilia* genus (*L. cuprina*, *L. illustris*, *L. caesar*, *L. sericata*, *L. ampullacea*, *L. shenyangensis* Fan) and *Aldrichina grahami* Aldrich, *Triceratopyga calliphoroides* Rohd., *Chrysomya albyceps* Wd., *Ch. megacephala* F., *Phormia regina* Mg., *Protophormia terraenovae* R.-D., *Cynamya mortuorum* L., and *C. cadaverina* R.-D.

Acommunicative hemisynantrops are bound with human exclusively in a topical aspect. Density of their populations is much higher (compared with natural cenoses) in the territories of settlements, in forests parks and dacha areas, agricultural lands, forest exploitation areas, etc. The reason for this phenomenon is that such biotops often serve as places of rather dense concentration of the hosts of parasitic calliphoridae. In the specified subgroup all endoparasites of earth worms (7 species) should be included. As an example steadily high number of *Pollenia* genus species in urban and rural settlements may be mentioned.

Asynantrops are first of all trophically specialized species for which transition to synantropy in the evolutionary aspect is closed by the absence of respective preadaptations. In this group we include all parasites of ground mollusks and vertebrates (12 species). Besides among synantrops we reckon some necro- and zoophages which due to unclear reasons (probably because of biotopical specialization) have not formed contacts with humans and environment. In particular these are *Lucilia magnicornis* Siebke which in the western parts of its habitat was registered as asynantrop [14], necrophage and optional parasite of amphibian *L. silvarum* Mg. It should be noted that some asynantropic species are sporadically registered in captures in the settlement territories however rise of their populations at such conditions is impossible because of the absence of the necessary complex for ecological niche formation.

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