

UDC 576.895.771

SYNANTHROPY OF BLOODSUCKING MOSQUITOES (DIPTERA, CULICIDAE) UNDER CONDITIONS OF KYIV

N. P. Kilochytska

*Taras Shevchenko National University of Kyiv
Volodymyrska str., 64, Kyiv, 01601 Ukraine
E-mail: kילוchytska@ukr.net*

Received 5 March 2012

Accepted 14 September 2012

Synanthropy of Bloodsucking Mosquitoes (Diptera, Culicidae) under Conditions of Kyiv. Kילוchitskaya N. P. — The 35 anthropophilic species are analyzed. The main tendencies of adaptations tending the transition of bloodsucking mosquito to synanthropic existence are considered. It is shown, that certain part of blood-sucking mosquitoes species inhabiting natural biocoenoses have been already adapted before the assimilation into the anthropogenic landscapes.

Key words: bloodsucking mosquitoes, Culicidae, synanthropy, Kyiv.

Синантропия кровососущих комаров (Diptera, Culicidae) в условиях Киева. Кילוичцкая Н. П. — Проанализировано 35 антропофильных видов комаров. Рассмотрены основные направления адаптаций, способствующих переходу кровососущих комаров к синантропному существованию. Показано, что определённая часть видов комаров, населяющих природные ценозы, уже преадаптирована к освоению антропогенных ландшафтов.

Ключевые слова: кровососущие комары, Culicidae, синантропия, Киев.

Introduction

The global warming accompanied by radical changes in temperature and humidity could lead to significant implications for species composition and increase the quantity and rate of reproduction of bloodsucking mosquitoes, the carrier agents of vector-borne diseases and, as a consequence, to rise the circulation intensity of such causative agents. At that, the expansion of tropical disease distribution to more moderate latitudes accompanied by change of their distribution features is probable.

Under conditions of urbanization of landscapes, the tendency to replacement of bloodsucking mosquitoes coherent evolution by phases of incoherent evolution associated with deep disturbance of cenotical structure is observed. One of the responses to the increase of the urbanization rate is a transition of some part of “wild” species to the facultative or obligatory existence in agrocoenoses. The problem of the distinct factors hierarchy is especially topical during the evaluation of mosquitoes adaptation in anthropogenous landscapes where a significant rise of part of endophilic and polycyclic species is observed. In this situation, the most significant target is to identify the main tendencies of species diversity changes and mosquitoes ecology in urbanized landscapes.

Kyiv is located in the flood plains of numerous rivers and creeks. The majority of them (Hlybochytsya, Lybid', Yurkovitsya, Kiyanka, Setoml', Syrets', Nyvka, Pochayna, Syrets' Creek) are currently either completely or partly embedded in sewage system pipes. The floods of Dnieper and Lybid' rivers only are 17.6% of the city territory. At the same time by 2001 the Kyiv built-up area (landscape and architecture systems) was approximately 30% (Stetsyuk et al., 2001).

Abundance of waterways along with the hilly terrain is adequate for the formation of different kinds of circulating and inflowing water reservoirs (bays of Dnieper and Desenka rivers, reclamation canals, lakes, ponds, departmental water reservoirs). Only the scheduled bonification by the City Sanitary and Epidemiological Services within the city area exceeds 176 water reservoirs which total water table area is equal to 1735 ha (from 0.9 to 175 ha). It is easy to estimate the hatching of malarial mosquito larvae if their density in different water reservoirs varies from 0.8 to 3.0 agents/m² (according to City Sanitary and Epidemiological Services data).

According to monitoring studies 35 anthropophilous species and subspecies of bloodsucking mosquitoes were recorded in Kyiv (Kילוchytska, 2008; Kילוchytska, Kילוchytskiy, 2009). The certain changes in species

composition and quantity of mosquitoes over 30 years have been recorded, since the latest consolidated report on mosquitoes (inhabiting Kyiv area) was published (Sheremet, 1978).

This paper is based on the results of analysis of bloodsucking mosquito collection for 2003–2010, collection materials of the Laboratory of ecology and toxicology of Taras Shevchenko National University of Kyiv and collection of adult female mosquitoes during the same period of time submitted for analysis by City Sanitary and Epidemiological Services (by the “collecting from oneself” method).

The terms used in this work (coherent evolution, incoherent evolution, anthropophilous species, acommunicative species, communicative species, eurygamy, stenogamy, eusynanthropic, hemisynanthropic, asynanthropic, endophilic, exophilic, communicative, non-communicative, polyphagous, polystationality) are adopted from Artamonov (2003).

Results

Synanthropic species are trophically and topically associated with the human and the human biological environment and are the components of anthropocoenosis. In order to evaluate potential possibilities of bloodsucking mosquitoes transition to synanthropic existence in city we first of all paid attention to requirements for the habitat necessary for imago and preimaginal phases of development (egg, larva, pupa) of different mosquitoes species.

One of the limiting factors is the absence of water reservoirs suitable for development of mosquito preimaginal phases in the city. Female mosquitos of the genera *Culex*, *Culiseta* and *Coquillettidia* oviposit boat-like clutches of eggs glued together on the water surface. *Anopheles* females oviposit separately eggs supplied by floats on the water surface as well. Females of *Aedes* and *Ochlerotatus* oviposit eggs in moist soil separately. Their eggs, in the state of diapause, can survive from several months to several years in moist soil. Consequently, the essential condition for mosquito development from the first four genera is the presence of long-term permanent or semi-permanent water reservoirs, whereas representatives of the two other genera can occur in temporary water reservoirs. In urban areas, the lack of natural water reservoirs (overgrown with higher water plants coastal zone of the lakes, ponds, tanks, ditches and underfloodings) is compensated by artificial ones (pools devoid of vegetation, fire water ponds, barrels, containers, etc.).

Larvae of most mosquito genera (with the exception of *Coquillettidia*) develop in different kinds of water reservoirs and quite often they are the significant part of the neuston fauna. The main factors limiting larval lifetime are the duration of water reservoirs existence and the presence of predators. The limiting factor for the *Coquillettidia* genus larvae which belong to periphyton is the absence of the higher vascular plants in the permanent water reservoirs.

Comparing the participation degree of different stages in the Diptera adaptive evolution, we agree with opinion of most dipterists that mosquito adults are more conservative than larvae and thus the “driven” phase. The role of imago stipulates the expansion and reproduction (nectarophagous, hematophagous, search for substrate and water reservoir, its evaluation and oviposition).

Biological markers, which directly or indirectly lead to the success in adapting to an urbanocoenosis, and are found in different species of mosquitoes separately are as follows: the ability to autogenous oviposition; the imago’s need for carbohydrates nutrition (nectarophagous); anthropophyly; the presence of diapause (larval — in representatives of the genera *Anopheles*, *Orthopodomyia*, *Coquillettidia*, and *Culiseta*, and imaginal — in *Anopheles*, *Culex*, and *Culiseta*); swarming and copulation in a large space — eurygamy, and inability for swarming and copulation in a small space — stenogamy.

Based on the assessment of the representation degree of different species in the collection (based on Sauhword, 1978) among 35 mosquitoes species attacking human, one super-dominant (*An. maculipennis*); two dominants (*Cx. pipiens* and *Ae. vexans*) and 6 recedent species with index of dominance less than 5 % but higher than 1 % were detected (see the table 1).

Table 1. Species of mosquito, which dominate in attacking on human in Kyiv

Таблица 1. Виды комаров, доминирующие при нападении на человека в г. Киев

Species	Index of dominance, %	
	range values, 1992–2008	average
<i>Anopheles maculipennis</i> Meigen (complex)	2.3–66.0	35.6
<i>Culex pipiens</i> Linnaeus (complex)	2.5–50.9	18.8
<i>Aedes vexans</i> (Meigen) (complex)	1.8–41.6	14.6
<i>Ochlerotatus sticticus</i> Meigen	1.8–21.6	9.0
<i>Aedes cinereus</i> Meigen	1.4–6.4	3.6
<i>Culiseta annulata</i> (Schrank)	0.7–5.9	2.7
<i>Ochlerotatus cataphylla</i> Dyar	0.1–6.9	2.7
<i>Coquillettidia richiardii</i> (Ficalbi)	0.1–4.6	2.4
<i>Anopheles claviger</i> (Meigen)	0.1–2.8	1.3
<i>Ochlerotatus caspius</i> (Pallas) (complex)	0.1–3.8	1.1

For the classification, of the synanthropic representation degree we apply the system suggested by Gregor, Povolony (1958) applicable to the higher dipterans, as modified by Mihalyi (1967). According to this system, three groups of synanthropic species are recognized: a) eusynanthropic: endophilic (attributed to residential and utility building) and exophilic (living outside); b) hemisynanthropic: communicative (directly contacting with human), non-communicative (incontacting) and c) asynanthropic. Since the authors applied as a fundamental criterion, an ability of some species of dipterans to infect food and human skin and animals fell without taking into account the changes in species variety of such dipterans under conditions of anthropogenic influence on ecosystems we found useful to amend in the systems following Artamonov's suggestions (2003).

The mosquitoes which lose connection with natural coenosis and are characterized by strong ecological relations with human as a source of food for imago and for larvae indirectly should be referred to the first group (eusynanthropus). Among 35 anthropophilic species only *Culex pipiens* Linnaeus (f. *molestus*), which populations distinctly timed to urbanocoenosis could be referred to eusynanthropus with some approximations. This species is characterized by the following: the ability to autogenous oviposition, the absence of diapauses and the need for nectarophagy, stenogamia and (especially in the cold season) is the distinctly expressed endophily. Such biological features allow *Cx. pipiens* f. *molestus* to develop year-round in the flooded basement and to attack a human for the bloodsucking, inside the premises.

Formation of *Cx. pipiens* f. *molestus* synanthropy was originally recorded in 1775 in Cairo and Alexandria (Egypt). The original description of this taxon indicated that it was characterized by the high aggression to human and reached particularly high numbers in urban areas. For the first time *Cx. pipiens* f. *molestus* was observed in Europe in 1921 (London) and then it spread throughout Western Europe by 1950. In Ukraine, the mosquito was recorded in 1926 (Dnipropetrovsk), and by 1990 it became ubiquitous in more than 300 cities of the former USSR in all landscape and climatic zones (Vinogradova, 2004).

During this period changes of biotopes inhabited by the immature stages of *Cx. pipiens* f. *molestus* occurred. In temperate climatic regions, the breeding sites of its larvae in urban areas were the coastal shallows, pits, ditches, bogs, fire barrels. Then they were almost entirely replaced by the filtration fields. However, in 1940–50s *Cx. pipiens* f. *molestus* hatching in the basements of Leningrad and Moscow was reported for the first time, followed by accelerated growth of its population and the range expansion (Bogdanova et al., 1992).

In 1964 the WHO International Workshop established that the biological progress and the spreading of *Cx. pipiens* f. *molestus* were closely linked with the urbanization processes (in particular, with the construction of buildings with district heat supply), which is a general trend in the world (Seminar..., 1965). Currently, the process of progressive urbanization of the other anthropophilous species such as *Culiseta longiareolata* Macquart,

overwintering as the egg stage, the larvae and fertilized females are also observed. This species occurred initially in a spring lake and then in artificial ponds, barrels of water, pools, etc.; they were recorded by E. the flooded basements in Javan (Tajikistan).

The second group (hemisynanthropes) consists of mosquitoes of greater ecological flexibility: their population is equally capable of occupying both urbanized and natural habitats. By food specialization along with *Cx. pipiens* f. *molestus* "pure" anthropophilic mosquito is *Coq. richiardii*. In Kyiv environment its larvae live in a few reservoirs overgrown with higher vascular vegetation, where they overwinter as a diapausing larval stage. A similar pattern have been recorded earlier in Moscow and Leningrad (Sheremet, 1978). *Coq. richiardii* with good reason could be categorized as communication exophilic hemisynanthrope, which forms a connection with human primary on the trophic basis (hematophagous), and the status of their populations directly depends on the availability of breeding sites for the larvae.

An. maculipennis is a casually anthropophilic bloodsucker, which prefers to attack the cattle out of city (Gutsevich et al., 1970), while by the intensity of attacking humans in Kyiv it takes the superdominant position. In the city, its larvae can develop in a various permanent ponds. The tendency of adults is to hide for the day and survive the winter (imaginal diapause) in various outbuildings (unheated rooms, barns, cellars, basements, tunnels and even subways) and lack of alternative feed source in urbanocoenoses contributes to more aggressive attack the human. In fact, *An. maculipennis* is a typical communicative endophilic hemisynanthrope in Kyiv.

In natural coenoses, polycyclic *Ae. vexans* as well as *An. maculipennis* is an optional anthropophilous bloodsucker. Its larvae are produced in a variety of open preferably floodplain ponds. Perhaps it is the clue for explaining the reasons of high numbers of this species in Kyiv. *Ae. vexans* of Kyiv population should be attributed to the communicative exophilic hemisynanthrope.

Long-term population dynamics (and the attack activity) of phenological summer polyseasonal species (*O. sticticus*, *O. caspius*, *Ae. cinereus*, *Cs. annulata* and *An. claviger*) correlates directly with the presence and seasonal heavy rains. Larvae produced by early spring species *O. cataphylla* are among the first to appear in the melt water, mostly in open temporary ponds, and thus they have time (as opposed to other spring species) to complete preimaginal development before breeding sites dry up. Significant anthropophily of hematophagous adults and the ability of immature stages to develop in urbanized landscape attribute *O. sticticus*, *O. caspius*, *O. cataphylla*, *Ae. cinereus*, *Cs. annulata* and *An. claviger* to the category of communicative exophilic hemisynanthropes.

The last 25 species of mosquitoes which intensity of which to attack a human does not exceed 1.0% in the whole complex of bloodsuckers were referred to a group of optional communicative exophilic hemisynanthropes. Optional anthropophily of these species is explained by the fact that in the environment *Ochlerotatus excrucians* Walker and *Aedes cinereus* Meigen mainly attack domestic animals; *Cs. annulata*, *Cx. pipiens* f. *pipiens* Linnaeus and *O. caspius* are ornitophilous species; *Culex territans* Walker attacks more frequently reptiles and amphibians (Gutsevich et al., 1970).

Synanthropic fauna is formed by means of the penetration and retention of a part of populations occupying adjacent natural ecosystems in the anthropocoenosis. Direction and speed of this process are poorly predictable especially when it is associated with mosquitoes of high flight activity and rapid adaptation. Initially, 50–60 years ago the number of species, which inhabited urban habitats was less than the number of species living in their neighborhoods. Currently, a clear tendency towards increasing the species diversity of mosquitoes in urban areas is observed regardless of the climatic zone, the size and age of the city. Thus, 32 species of mosquitoes were registered in the vicinity of Moscow in 1962–1969, while 21 species were recorded within its boundaries. In 1983–1985 the number of mosquitoes species reached 26 in the city. 30 species of mosquitoes were record-

ed in Leningrad and its environs in 1928–1958 while only five of them in the city. Observations of 1983–1987 showed the presence of 22 mosquito species in Leningrad (Bogdanova et al., 1992).

In the city of Kyiv considering the minor quantitative changes, one should note certain qualitative changes in mosquito species diversity in 1978–2008. Two species of mosquitoes of the genus *Culiseta* (*Cs. glaphyroptera* Schiner and *Cs. morsitans* Theobald) and four representatives of the genus *Ochlerotatus* were added to the list of species. The elimination of *Ochlerotatus pulchritarsis* Rondani bred in hollows and six other species of this genus (*O. annulipes* Meigen, *O. behningi* Martelli, *O. intrudens* Dyar, *O. cataphylla* Dyar and *O. leucomelas* Meigen), whose larvae are propagated in grass-covered and enriched with leaf litter temporary forest ponds and their edges under natural conditions could be explained by the progressive urbanization (ordering/regulation) of the urban area accompanied by the disappearance of corresponding types of reservoirs (Kilochytska, Kilochytskiy, 2009). V. M. Beklemishev (1952) observed earlier this tendency, which is the human development of the territory directly worsens the environment for the existence of mosquitoes of the genera *Aedes* and *Ochlerotatus* deteriorate.

Observation of *Ochlerotatus euedes* Howard, Dyar et Knab, *O. cyprius* Ludlow, *O. diantaeus* Howard, Dyar et Knab and *O. pullatus* Coquillett in Kyiv is obviously related to the presence of such artificial ponds without vegetation such as pits, trenches, potholes or ruts, etc. in the areas of capital construction during the spring season.

Understanding the process of synanthropic fauna formation is facilitated by the use of the “preadaptation” concept (the process of rising the character in species, which originally does not have any adaptive value and becomes adaptive only after changing the living conditions of animals and, if the need arises, it is used afterwards in future generations). In particular, E. Mayr (1974) considered the species were preadapted if it was able to occupy a new habitat.

The analysis of larval habitats in Kyiv shows that most of the mosquito species domesticate the ponds, which are not different in their characteristics from those natural conditions. Eight species develop only in ponds and lakes (in the coastal heavily overgrown area), the most numerous of them, *An. maculipennis*, *Cx. pipiens* f. *pipiens* and *Ae. cinereus*, are propagated. Fourteen species are the most abundant in floodplains, flooding of rivers and streams such as *Ae. vexans*, *An. maculipennis*, *O. cantans*, *O. excrucians*, *O. caspius*, *O. flavescens* and *O. behningi* *O. cataphylla*, *O. diantaeus* and *Cx. thailary* are propagated in roadside ditches. *Cx. pipiens* f. *pipiens* and *An. maculipennis* predominate in pools, tanks and barrels while *Cx. pipiens* f. *molestus* predominate in basements. Larvae of *Anopheles plumbeus* Stephens, *Aedes geniculatus* Olivier and *O. pulchritarsis* are propagated in the hollows.

A regular appearance of saline ponds (as a result of melting snow sprinkled with mixture of sand and NaCl or KCl) in the city leads there to the primary development of a number of such historically preadapted to the existence in water of different salinity such species as *An. maculipennis*, *An. claviger*, *O. caspius caspius*, *O. detritus*, *O. caspius dorsalis*, *O. excrucians*, *O. leucomelas*, *Ae. vexans*, *Ae. cinereus* and *Cx. theileri*. Perhaps the mineral pollution of water results in preferential conditions for the development of some acommunicative species of mosquitoes in the city.

Summarizing the results, it can be stated that the main complex of preadaptations of bloodsucking mosquitoes enabling their inflow of species into the synanthropic fauna from adjacent ecosystems includes the following factors.

— **Polyphagous adults.** Such species could most likely shift for feeding on humans and commensal animals since there are no vitally important imaginal trophic differences for these hematophagous.

— **Polystationality.** It is common for almost all representatives of all genera (except *Coquillettidia*), which manifested in the absence of strict determinism in the choice of habitats (reservoirs) for preimaginal development.

— **Tolerance to the fluctuations of climatic factors.** Increasing the number of species, which are tropically and topically related to the human, does not depend on the climatic zone, the size and age of the city.

— **There are neither predators or parasites** of anthropogenic origin in ponds.

— **Significant expansion of the distributional radius of adults.** Such a benefit especially effectively appears in Kyiv during the migration of mosquitoes in the valleys of numerous rivers (especially the Dnieper), along the railways and roads.

The author thanks O. M. Pogorelova (chief entomologist of Kyiv Sanitary Epidemiological Service) for the granted materials.

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