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Ecology of the Lacewing *Chrysoperla nigrocapitata* Henry et al., 2015 (Neuroptera, Chrysopidae) in the South of the Russian Far East

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Abstract—The lacewing *Chrysoperla nigrocapitata* Henry, Brooks, Johnson, Haruyama, Duelli et Mochizuki, 2015 (Neuroptera, Chrysopidae) was first recorded in Russia in 2021. This paper provides information on the biology, trophic associations, phenology, and habitats of the species in the south of Primorskii Territory. Late-instar larvae of *Ch. nigrocapitata* were observed feeding on young nymphs of the leaf-footed bugs *Coreus marginatus orientalis* (Kiritshenko, 1916) and *Molipteryx fuliginosa* (Uhler, 1860) (Heteroptera, Coreidae) with weakly sclerotized cuticle, as well as on fruit sap of the red raspberry *Rubus idaeus* L. (Rosaceae). The development of the species from egg to adult was observed under laboratory conditions. The developmental time of the pupae ranged from 11 to 7 days ($m = 9.5 \pm 0.56$ days) at the mean daily air temperature varying from 18.7 to 27.8°C ($m = 23.2 \pm 1.21$°C; $n = 6$).

Keywords: *Chrysoperla nigrocapitata*, ecology, trophic associations, phenology, Russia, Primorskii Territory, Neuroptera, Chrysopidae

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The currently known fauna of the Russian Far East includes 23 species from 7 genera of the family Chrysopidae (Makarkin, 1985a, 1985b, 1985c, 1995, 2000; Tsukaguchi, 1995; Tsukaguchi and Tago, 2018; Dobosz et al., 2019). The genus *Chrysoperla* Steinmann, 1964 belongs to the tribe *Chrysopini* and the subfamily Chrysopinae Schneider, 1851 and is represented in the region by 3 species: *Ch. carnea* (Stephens, 1836), *Ch. nipponensis* (Okamoto, 1914), and *Ch. nigrocapitata* Henry et al., 2015. *Chrysoperla nigrocapitata* was described from Japan (Honshu Island) and South Korea (Henry et al., 2015). In 2016, individuals of this species were discovered by us for the first time in the south of the Russian Far East, where its late-instar larvae fed on young nymphs of the bug *Molipteryx fuliginosa* (Uhler) (Heteroptera, Coreidae) with weakly sclerotized integuments (Makarkin et al., 2021).

Adults of the closely related sympatric species *Chrysoperla nigrocapitata* and *Ch. nipponensis* have black staggered series of transverse veins on the forewings, whereas these veins are green in other eastern Palaearctic lacewings of the *Ch. carnea* group. At the same time, *Ch. nigrocapitata* cannot be reliably distinguished from *Ch. nipponensis* by external characters of the adults, which have only minor statistical differences, but their larvae are clearly different. The substrate-borne vibrational courtship signals are also different in the two species, and these differences are detected equally by both sexes, confirming the existence of premating reproductive isolation (Henry et al., 2013, 2015).

Larvae of *Ch. nigrocapitata* differ from all the other known larvae of the *Ch. carnea* group in the dark brown or black dorsal surface of the head capsule with very contrasting light lines along the epicranial suture, forming a Y-pattern. The cephalic pattern in *Ch. nipponensis* larvae is usually dominated by a pair of distinct dorsolateral stripes against a pale background, typical of the larvae of the *Ch. carnea* group (Henry et al., 2015). The

larvae of these species also differ in body coloration, with large brown spots on the meso- and metanotum in *Ch. nigrocapitata* and smaller spots in *Ch. nipponensis* (Henry et al., 2015).

This paper reports the first data on the ecology of *Ch. nigrocapitata* in the south of the Russian Far East.

MATERIALS AND METHODS

The work was carried out in agrocenoses and ecotone areas of Ussuriisk Urban District (the villages of Kamenushka and Kaimanovka) from late April and early May to the end of October 2016–2021. The study methods included visual observation, manual collection of adults and larvae, shaking insects off plant branches onto a sheet, sweep-net sampling, and photography. Different potential feeding sites of lacewing larvae were examined: fruiting shrubs of red raspberry *Rubus idaeus* L. (Rosaceae), leaves of vegetable crops infested with aphids, and cages with insects kept for experiments (Markova et al., 2018). Eggs of lacewings were collected for rearing larvae and adults and their subsequent identification. The larvae were kept in the laboratory in individual Petri dishes or cages until the emergence of the adults. They were fed on eggs and young nymphs of leaf-footed bugs and on aphids collected from cucurbit crops. The cocoons and adult lacewings were preserved on cotton pads.

The material was identified by V.N. Makarkin and deposited in the collections of the Zoological Museum of the Federal Scientific Center of the East Asia Terrestrial Biodiversity, Far Eastern Branch of the Russian Academy of Sciences (Vladivostok).

RESULTS AND DISCUSSION

Chrysoperla nigrocapitata Henry et al., 2015

Material. Russia. *Primorskii Territory*, Ussuriisk Urban District: env. of Kamenushka, floodplain forest along Barsukovka River, side of forest road, on *Artemisia* sp., 17.VIII.2021, 2 larvae of III instar; Kaimanovka, household plot, cage on raspberry shrub with nymphs of *Molipteryx fuliginosa*, 11.VII.2016, 2 larvae of III instar; on raspberry shrubs: 19–26.VII.2019, 3 larvae of III instar; 19–26.VII.2020, 4 larvae of III instar; on raspberry fruit, 25.VII.2020, 1 larva of III instar; cage, on fruit clusters of Russian dock *Rumex confertus* Willd.

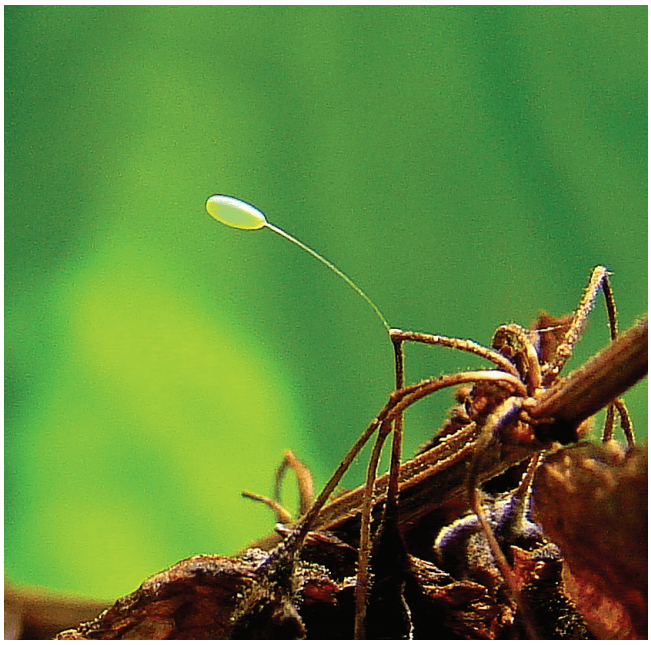

Fig. 1. Egg of *Chrysoperla nigrocapitata* Henry et al. on fruit cluster of *Rumex confertus* Willd.

with egg clutches and nymphs of *Coreus marginatus orientalis*: 8.VII.2021, 1 larva of III instar; 29.VIII.2021, 1 larva of III instar; on raspberry shrubs, 18.VII.2021, 1 larva of III instar; on cucumber leaves with aphid colonies, 29.VII.2021, 1 larva of III instar (T.O. Markova and M.V. Maslov).

In addition, egg clutches of *Ch. nigrocapitata* were found on fruit clusters of Russian dock on 16.VIII.2021. These clutches were monitored in a cage (Fig. 1; Fig. 2); the development of a single larva took place from August 18 to August 30, and the adult male emerged on September 11, 2021.

The developmental time of *Ch. nigrocapitata* pupae ranged from 7 to 11 days ($m = 9.5 \pm 0.56$ days) at the mean daily air temperature varying from 18.7 to 27.8°C ($m = 23.2 \pm 1.21$°C) (n = 6).

Phenology. In South Korea and Japan, the larvae and adults of *Ch. nigrocapitata* and *Ch. nipponensis* were recorded from late May to August, while only adults were encountered in early spring and in autumn (Henry et al., 2015).

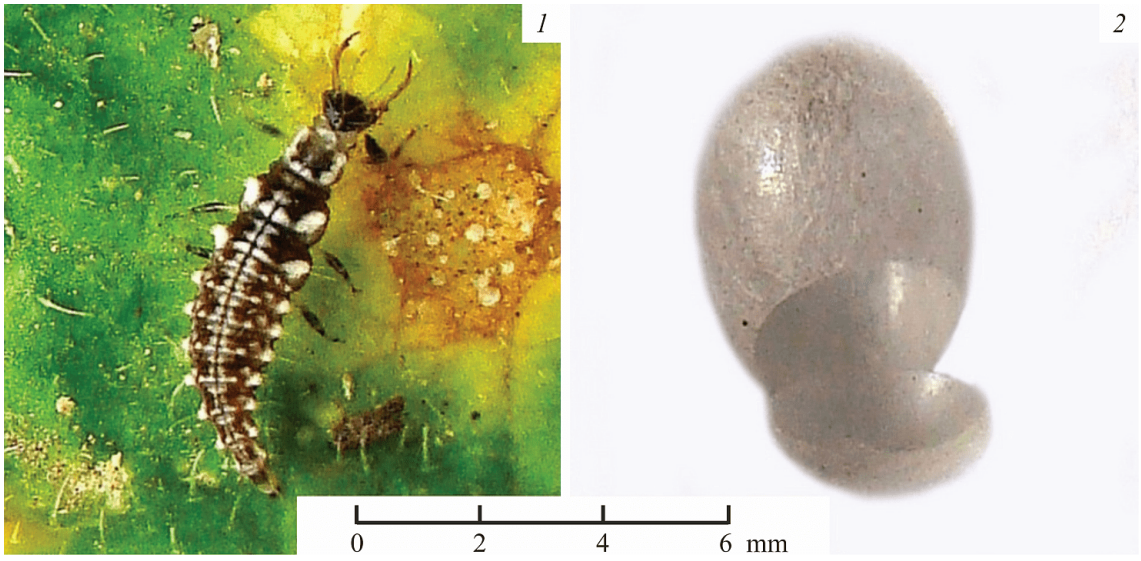

Fig. 2. Immature stages of *Chrysoperla nigrocapitata* Henry et al.: (*1*) III instar larva; (*2*) cocoon after emergence of the adult.

Laboratory observations of adult *Chrysoperla* lacewings revealed changes in their coloration from green to yellowish or reddish brown at the onset of autumn and winter reproductive diapause (MacLeod, 1967; Sheldon and MacLeod, 1974; Duelli et al., 2014). When larvae of *Ch. nigrocapitata* and *Ch. nipponensis* collected in nature were kept from the III instar to adult emergence at a short photoperiod (8L : 16D) and air temperatures of 16–22°C, the adults also entered winter diapause and changed their coloration (Henry et al., 2015).

It was difficult to determine the onset of flight of the overwintered generation of *Ch. nigrocapitata* in Primorskii Territory, because adults of the sympatric species *Ch. nipponensis* and *Ch. nigrocapitata* could not be reliably differentiated. Egg clutches of *Ch. nigrocapitata* were found from early July to the end of the middle third of August, and late-instar larvae, from the middle third of July to the end of August. The larvae pupated from the end of the beginning third of July to the end of the middle third of August, and adults of the new generation emerged from the end of the middle third of July to the beginning of the middle third of September.

Trophic associations. Most Chrysopidae are zoophagous at the larval stage, but larvae of *Chrysoperla* lacewings also consume non-animal food rich in carbohydrates, such as nectar, pollen, and honeydew secreted by aphids (Downes, 1974; Limburg and Rosenheim, 2001; Hogervorst et al., 2008). Under laboratory conditions, one-third of the larvae of *Chrysoperla externa* (Hagen) successfully developed into adults while feeding only on pollen of *Pennisetum purpureum* (Schum.) (Poaceae) (de Oliveira et al., 2010).

In the beginning and middle thirds of July 2016 and 2021 and the last third of August 2021, we observed larvae of *Ch. nigrocapitata* feeding on young nymphs of the bugs *Molipteryx fuliginosa* and *Coreus marginatus orientalis* with weakly sclerotized integuments (Fig. 3). In July 2019–2021, some raspberry shrubs were simultaneously colonized by the predatory larvae of *Ch. nigrocapitata* and the herbivorous nymphs (II and III instars) of *M. fuliginosa* and *Coreus m. orientalis*. The lacewing larvae were probably attracted by the high abundance of bug nymphs on the shrubs. In agrocenoses, the larvae of *Ch. nigrocapitata* also fed on aphids, and this food was used for rearing lacewings in cages (see Fig. 3).

Larvae of *Ch. nigrocapitata* were observed feeding on fruits of *Rubus idaeus* in the middle and last thirds of July 2020 and 2021. One III instar larva collected on a raspberry shrub on 18.VII.2021 was kept in a separate cage and offered both aphids and raspberry fruit; this larva preferred a carbohydrate diet and developed successfully to the adult (Fig. 4). The larvae varied in the intensity of red-brown coloration of their meso- and metanotal spots. The pigmented areas were wider near

Fig. 3. III instar larvae of *Chrysoperla nigrocapitata* Henry et al. consuming different prey: (*1*) a nymph of dock bug *Coreus marginatus orientalis* (Kir.); (*2*) aphids on the leaves of cucurbit crops.

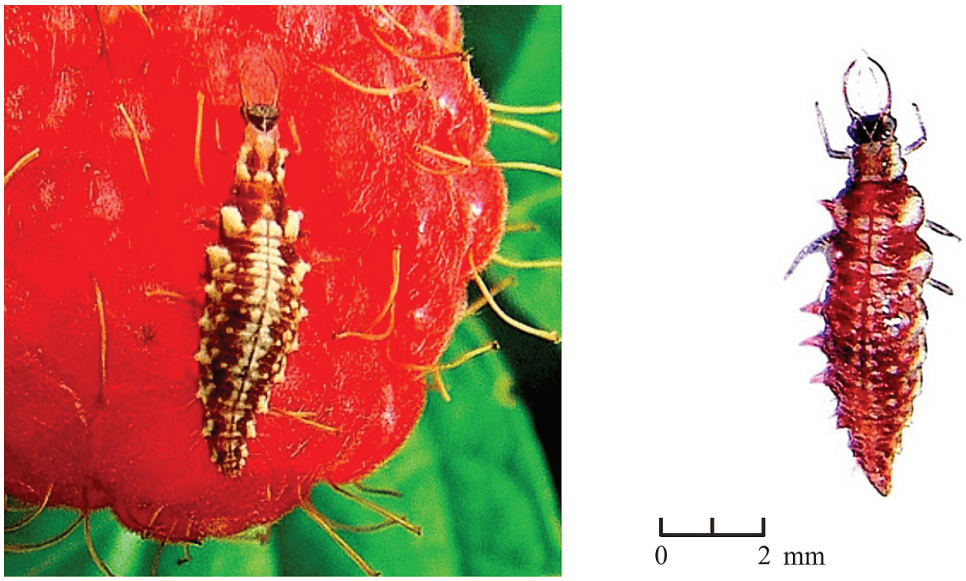

Fig. 4. Changes in coloration of the III instar larva of *Chrysoperla nigrocapitata* Henry et al. after feeding on fruit sap of *Rubus idaeus* L.

the mid-length of the segments. The larval body turned pinkish before pupation (see Fig. 2; Fig. 3; Fig. 4).

Habitats. Late-instar larvae of *Ch. nigrocapitata* were found on herbaceous plants in open areas. They were collected on *Artemisia* sp. on the side of a forest road in floodplain forests near fields, as well as on leaves of cucurbit crops (watermelons, cucumbers) with aphid colonies in agrocenoses. Unlike in South Korea and Japan (Henry et al., 2015), *Ch. nigrocapitata* is not a rare species in Primorskii Territory. It was recorded together with *Chrysopa intima* McLachlan, *Ch. per-*

plexa McLachlan, *Chrysoperla carnea*, and possibly *Ch. nipponensis*. So far, feeding on the nymphs of Coreidae has been observed only in *Ch. nigrocapitata*.

Distribution. Primorskii Territory of Russia; South Korea, Japan (Honshu Island).

The reported data are preliminary and may be supplemented by further monitoring of *Ch. nigrocapitata* as a potential entomophage of insect pests in the south of Primorskii Territory.

CONCLUSIONS

1. *Chrysoperla nigrocapitata* is not a rare species in Primorskii Territory. Its late-instar larvae are found on herbaceous plants in ecotone areas and on the leaves of cucurbit crops with aphid colonies in agrocenoses.

2. Although most Chrysopidae are zoophagous at the larval stage, the larvae of *Ch. nigrocapitata* also consume carbohydrate-rich plant foods and honeydew.

3. *Chrysoperla nigrocapitata* was recorded in agrocenoses together with *Chrysopa intima* McLachlan, *Ch. perplexa* McLachlan, and *Chrysoperla carnea*. Feeding on the nymphs of Coreidae has been confirmed only for *Ch. nigrocapitata*.

4. Egg clutches of *Ch. nigrocapitata* were found from early July to the end of the middle third of August; the III instar larvae were found from the middle third of July to the end of August. The larvae pupated from the beginning third of July to the end of the middle third of August; adults of the new generation emerged from the end of the middle third of July to the beginning of the middle third of September.

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COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest. The authors declare that they have no conflict of interest.

Statement on the welfare of animals. All the applicable international, national, and/or institutional guidelines for the care and use of animals were followed. All the procedures performed in studies involving animals were in accordance with the ethical standards of the institution or practice at which the studies were conducted.

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