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The most important lacewing species in Indian agricultural crops, *Chrysoperla sillemi* (Esben-Petersen), is a subspecies of *Chrysoperla zastrowi* (Esben-Petersen) (Neuroptera: Chrysopidae)

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Across the Indian subcontinent, the agriculturally important *Chrysoperla carnea* species-group of Chrysopidae is represented by a single common species, *Chrysoperla sillemi* (Esben-Petersen, 1935). However, the cryptic species within the *carnea* group can be reliably distinguished from one another only by their substrate-borne vibrational duetting songs. Therefore we analyse mating signals recorded from *C. sillemi* collected at several Indian sites between latitudes 11°N and 31°N. Feature by feature comparison of courtship songs indicates that all the *C. sillemi* tested conform acoustically to the subspecies *C. zastrowi arabica* Henry et al. 2006 from the Middle Eastern region. Adult and larval morphology confirm that diagnosis. Here, we revise the nomenclature of the *carnea* group of *Chrysoperla* Steinmann 1964 to reflect our findings, and erect *Chrysoperla zastrowi sillemi* stat. rev. to include both the Indian and Middle Eastern populations. *Chrysoperla zastrowi arabica* Henry et al. 2006 becomes a junior synonym of the new subspecies.

Keywords: *Chrysoperla zastrowi arabica*; systematics; song; cryptic species; Asia; Africa; morphology; biogeography; larvae

Introduction

In a recent paper (Henry et al. 2006), we determined that the southern hemisphere green lacewing *Chrysoperla zastrowi* (Esben-Petersen, 1928) is not confined to southern Africa but instead ranges northward from the African Cape Region to the Middle East. A new subspecies, *Chrysoperla zastrowi arabica* Henry et al., 2006, was erected for those Middle Eastern populations. Support for this action was based largely on analysis of vibrational courtship songs, which have been shown to provide the best characters for reliably distinguishing among the morphologically cryptic species of the *Chrysoperla carnea* group (Henry 2006). In addition, a detailed morphological analysis of both adults and larvae supported placement of "*arabica*" within *C. zastrowi*.

More recently, we have had the opportunity to observe courtship behaviour in living specimens of the *Chrysoperla carnea* group from the Indian subcontinent,

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kindly provided to us from several localities (under permit) by Dr T. Venkatesan. These insects conform morphologically to the published description of *Chrysoperla sillemi* (Esben-Petersen, 1935), later augmented by Brooks (1994). In India, *C. sillemi* is a widespread nomadic species that is used as an important biological control agent against soft-bodied arthropod pests in croplands (Duelli 2001; Henry 2006; Venkatesan *et al.* 2008).

Here, we present the results of analyses of mating songs and morphology in *C. sillemi* collected from five sites on a north–south transect of India spanning > 3000 km. These data are compared qualitatively and statistically with those previously recorded for *C. zastrowi arabica* from the Middle East (western Asia). We evaluate the status of *C. sillemi* and *C. z. arabica* in the light of the new analyses.

Materials and methods

Collecting, rearing and identification of living lacewings

Living adults identified as *C. sillemi* were collected at nine agricultural sites in India between 2006 and 2008 (Table 1 and Figure 1; Acknowledgments). Field-collected and laboratory-reared individuals were shipped to Storrs, CT, USA for maintenance and song analysis. Protocols are described fully in other papers (summarized in Henry et al. 1996, 1999). Larval studies were limited to the progeny of individual adults. Several living adult and larval specimens of verified song phenotype from each locality were placed in 95% ethanol or frozen at – 70 to – 100°C, whereas others were deposited as vouchers in the collection of C.S. Henry, Storrs; the Connecticut State Museum of Natural History, Storrs (CSMNH); The Natural History Museum, London, UK (BMNH); the collection of Peter Duelli, Zürich, Switzerland (PD); and the W.F. Barr Museum, Moscow, ID, USA (WFBM).

Table 1. Collection sites in central and southwest Asia of *Chrysoperla zastrowi sillemi* used in song analyses and morphological studies, 1993–2009.

Local site (and state)	Country	Altitude	Latitude	Date(s)
Ludhiana (Punjab) [1]	Northern India	243 m	30°54′ N	2006–2008
Sirsa (Haryana) [2]	Northern India	205 m	29°32′ N	2006–2008
Anand (Gujarat) [3]	Central India	39 m	22°34′ N	2006–2008
Bangalore (Karnataka) [4]	Southern India	921 m	12°59′ N	2006–2008
Coimbatore (Tamil Nadu) [5]	Southern India	411 m	11°00′ N	2006–2008
Sri Ganganagar (Rajasthan) [a]	Northwestern India	164 m	29°55′ N	June 2009
Udaipur (Rajasthan) [b]	Central-western India	600 m	24°35′ N	June 2009
Dharwad (Karnataka) [c]	Southern India	680 m	15°28′ N	June 2009
Guntur (Andhra Pradesh) [d]	Southeastern India	30 m	16°18′ N	June 2009
Dãmghãn	Northern Iran	1250 m	36°44′ N	June 2002
Eilat	Israel	13 m	29°34′ N	October 1993
Dubai	United Arab Emirates	9 m	25°18′ N	October 1994
Al Buraymi	Oman	536 m	24°15′ N	October 1994

The numbers and letters in brackets correspond to the symbols on the map in Figure 1. In India, detailed song data were taken only from individuals collected at the numbered sites (not the lettered sites).

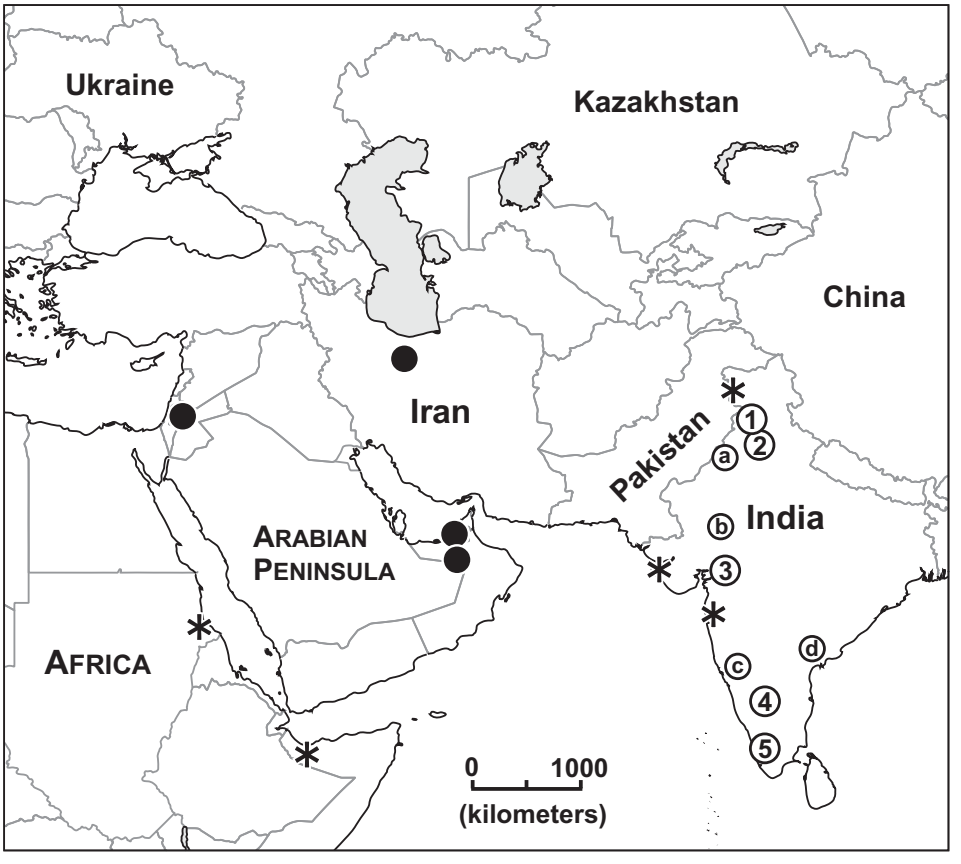

Figure 1. Map of central and southwest Asia showing collecting localities of *Chrysoperla sillemi* (circled numbers or letters) in India and *Chrysoperla zastrowi arabica* (black circles) in the Middle East, identified by song analysis. Both taxa are now assigned to *Chrysoperla zastrowi sillemi* stat. rev. Locality 1 = Ludhiana (Punjab); 2 = Sirsa (Haryana); 3 = Anand (Gujarat); 4 = Bangalore (Karnataka); 5 = Coimbatore (Tamil Nadu); a = Sri Ganganagar (Rajasthan); b = Udaipur (Rajasthan); c = Dharwad (Karnataka) and d = Guntur (Andhra Pradesh). Songs were analysed in detail only for specimens from the numbered (not lettered) sites on the map. Collecting localities of additional specimens exhibiting the *C. z. sillemi* morphotype but not verified by song are shown as black asterisks.

Analysis of songs

Five to 25 complete courtship songs (i.e. the shortest repeated units or SRUs, the phrase exchanged between partners during a heterosexual duet) of each individual of *C. sillemi* were recorded directly to computer disk at a sampling rate of 500 Hz and analysed using a computer (see Henry et al. 1996; Henry and Wells 2006). All songs were recorded at 25 ± 1°C. Males and females in the laboratory were induced to sing by playing back to them pre-recorded songs of *C. z. arabica*, using methods described previously (Wells and Henry 1992, 1994). Measurements were taken on six song features (Table 2; Figure 2): carrier frequency at the start, middle and end

Table 2. Overall mean values at 25 ± 1°C of the features of duetting songs for *Chrysoperla zastrowi sillemi* collected from India (central Asia) and from the Arabian Peninsula (western Asia).

	Frequency measures of volleys (Hz)			Time measures of volleys (ms)		Volleys/SRU
	Start	Middle	End	Duration	Period	
Central Asia (n = 53)	63.46*** ± 2.63	44.25*** ± 1.91	23.93 ± 2.56	2022.25*** ± 245.54	4891.52*** ± 460.88	1
Western Asia (n = 50)	60.30*** ± 2.38	42.71*** ± 2.09	23.04 ± 2.47	2260.05*** ± 300.86	4514.92*** ± 302.42	1

Each value is the mean of the means of n individuals in the geographical region, ± 1 standard deviation. Pairwise comparisons of central Asian to western Asian individuals were assessed for significant differences using t-tests for independent samples. Levels of significance are shown by asterisks: *** $P \leq 0.001$.

SRU = shortest repeated unit exchanged between individuals while duetting, equivalent to the single volley in this species.

Note that the mean for "Start" frequency in western Asia differs from the mean given in Table II of Henry et al. (2006) (55.46 Hz), due to re-measuring using a more sensitive method.

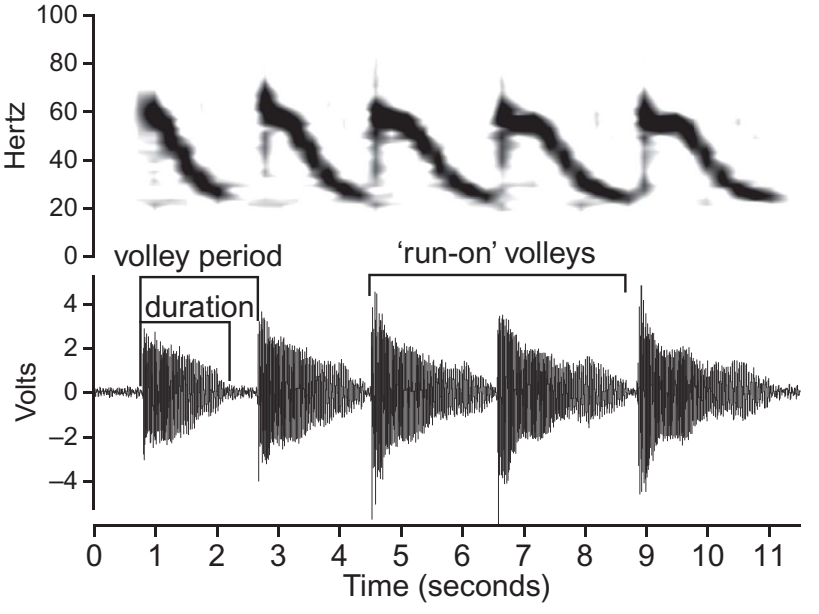

Figure 2. Oscillogram (volts on *y*-axis) and sonogram (Hertz on *y*-axis) of five volleys of a solo (non-duetting) vibrational song of *Chrysoperla sillemi* (now *C. z. sillemi*) from Bangalore, India. During heterosexual duets, each volley is the unit of exchange between partners (i.e. the shortest repeated unit or SRU). Song features discussed in the text are labelled.

of each volley (= SRU); the duration of each volley; the volley period (from the start of one volley to the start of the next); and the number of volleys per SRU (invariant at unity in this taxon – see Henry et al. 2006). The mean of each song feature was calculated from all songs (volleys or SRUs) recorded per individual, and this mean served as the representative value of the feature for each individual in other analyses.

Complete acoustical analyses were performed on the songs of 53 individuals of *C. sillemi* from five of the nine Indian localities (Table 1 and Figure 1): three males and five females from Ludhiana (Punjab), four males and three females from Sirsa (Haryana), three males and four females from Anand (Gujarat), 14 males and nine females from Bangalore (Karnataka), and four males and four females from Coimbatore (Tamil Nadu). Songs of several individuals from each of the other four sites – Sri Ganganagar (Rajasthan), Udaipur (Rajasthan), Dharwad (Karnataka), and Guntur (Andhra Pradesh) – were recorded but not analysed in detail. For a regional comparison of means for each song feature, we pooled individual data from male and female *C. sillemi* at the five primary Indian sites above ("central Asia") and compared them with previously published song data pooled from 50 individuals of *C. z. arabica* at four Middle Eastern sites ("western Asia"; data from Henry et al. 2006). Comparisons were by two-tailed *t*-tests for independent samples, using STATISTICA Version 6.1 (Statistica, 2003).

A principal components analysis (PCA) was used to summarize and visualize the song differences between the central and western Asian regions (Figure 3). The PCA was calculated by STATISTICA from the five song features that showed non-zero variance among individuals (Table 2).

Adult morphology

Thirty-five Indian specimens (22 males, 13 females) identified acoustically as *C. z. arabica* and morphologically as *C. sillemi* were examined for external morphological features that might distinguish them from previously described specimens of *C. z. arabica* (Henry et al. 2006). All insects examined were from Bangalore (Karnataka) in southern India (site 4 on the map in Figure 1).

Adults were examined for the states of 20 characters. These included ground colour of body; presence, extent and colour of markings on stipes, palps, gena, clypeus, frons and postoccipital region; relative abundance and distribution of black and blond setae on pronotum; relative size of basal dilation of tarsal claw expressed as a ratio (see Henry et al. 2002, and explanation below); extent to which forewing is rounded or tapered at apex; relative width of forewing expressed as the ratio of length to breadth at widest point; presence or absence of black markings on wing veins;

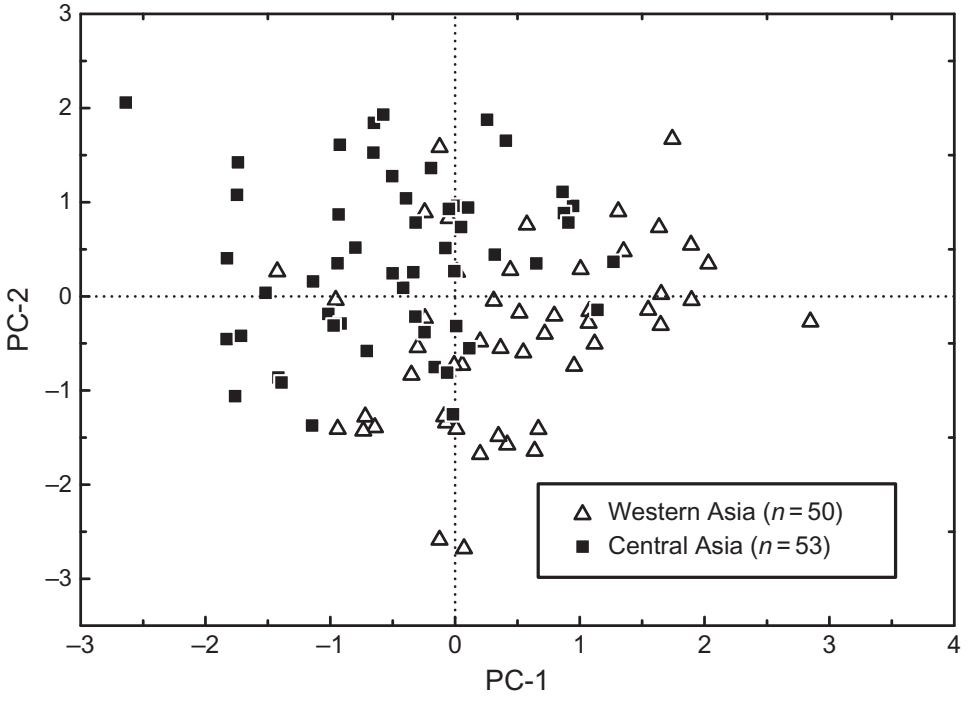

Figure 3. Scatterplot of the first two factors of a principal components analysis of five song features (see text) of *Chrysoperla sillemi* in India (black squares) and *Chrysoperla zastrowi arabica* in the Middle East (open triangles). Both taxa are now assigned to *Chrysoperla zastrowi sillemi* stat. rev. Each data point represents a single individual.

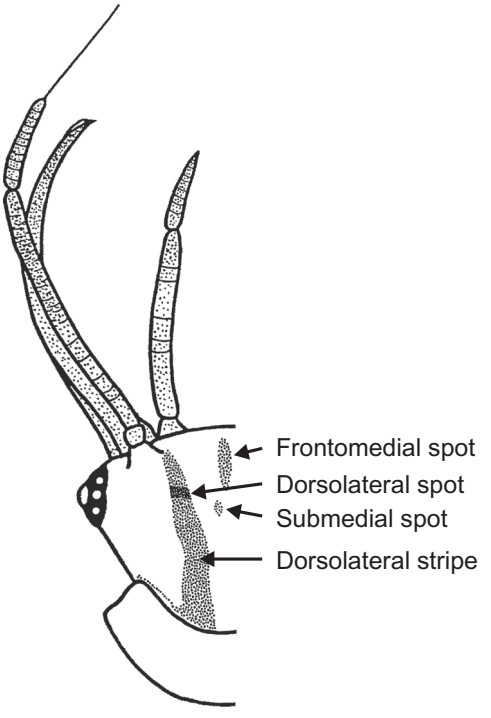

Figure 4. Dorsal view of left half of third-instar larval head capsule of a typical specimen of *Chrysoperla sillemi* (now *Chrysoperla zastrowi sillemi*) from Bangalore, India. Head markings discussed in the text are labelled.

orientation of the Rs cross-vein with respect to the Rs vein (perpendicular or oblique, refer to fig. 4A in Henry et al. 2006); length and colour of costal setae; length of abdominal setae; relative abundance and distribution of black and blond setae on the three distal abdominal sternites; shape and relative proportions of male genital "lip" and "chin" at apex of sternite 8+9 (refer to fig. 4B in Henry et al. 2006); length and colour of setae clothing male genital lip; shape of tignum of male genitalia; and presence or absence of dark brown stripe on pleural membrane of second abdominal segment.

The shape of the pretarsal claw was assessed by removing one metathoracic leg, mounting it in Euparal on a microscope slide, splaying the claws by flattening the pretarsus beneath the cover slip, and viewing and drawing one or both claws using a camera lucida. A ratio was then calculated (AB/BD, see fig. 4 in Henry et al. 2002), representing the extent of dilation of the claw base (see also Brooks 1994; Thierry et al. 1998). Larger numerical ratios correspond to narrower basal dilations.

To determine the shape of the external genital area of the male abdomen, the tip of the abdomen was removed and placed in glycerol, then viewed laterally and drawn (using camera lucida) through a binocular microscope at 100 × magnification. Measurements of lip and chin dimensions were taken from the drawings (refer to fig. 4B in Henry et al. 2006, line segments defined by points A–G). The ratio AB/BC reflects the relative prominence of the chin, whereas DE/FG characterizes the shape of the lip.

Setal colour was judged to be black or blond by examination with reflected light under a dissecting microscope. Internal genitalia of selected males were dissected, stained, mounted and measured using established techniques (Bram and Bickley 1963; Brooks 1994).

Larval morphology

We examined 20 third-instar larvae from four sites (numbers 2–5 in Table 1). Larvae were boiled in distilled water with a drop of liquid detergent and transferred to 70% ethanol with 5% glycerine. Specimens were viewed at 50 ×. Head markings of selected, representative individuals were illustrated and compared with markings in specimens from the Middle East previously assigned to *C. z. arabica* (see fig. 7 in Henry et al. 2006).

Results

Song analyses and geographical comparisons

An oscillogram (lower trace) and spectrogram (upper trace) of a typical solo song produced by a male of *C. sillemi* collected in Bangalore is shown in Figure 2. This figure can be compared directly with fig. 2A in Henry et al. (2006: 2177), which illustrates the solo song phenotype diagnostic of *C. z. arabica*. The grand means of means of all individuals of *C. sillemi* from central Asia (= India), for the six duetting-song features measured, are included in Table 2. Pooling of data from the five principal localities within India seemed justified because of the small sample sizes at four of the localities and close similarity of mean values among all localities (data not shown). Specimens from the other four Indian sites were characterized by songs judged to be indistinguishable from the songs of individuals collected at the five primary sites.

As in *C. z. arabica*, the duetting song of *C. sillemi* consisted of a single-volley SRU repeated several to many times in alternation with a partner; each volley was characterized by a downwardly modulated, pure-tone carrier frequency. Also like *C. z. arabica*, the volleys of duetting participants overlapped slightly or not at all – that is, they were generally "polite" – and were sometimes punctuated by transient volley breaks or run-on phrases (see fig. 2A,B in Henry et al. 2006).

Table 2 also includes pooled song data for *C. z. arabica* from western Asia (= the Arabian Peninsula and Iran), allowing comparison of the grand means of features between taxa/regions. The *t*-tests for independent samples revealed statistically significant differences between *C. sillemi* and *C. z. arabica* for four of the five variable song features, including volley duration ($t = 4.41$, $df = 101$, $P < 0.0001$), volley period ($t = -4.87$, $df = 101$, $P < 0.0001$), initial volley frequency ($t = -6.39$, $df = 101$, $P < 0.0001$), and mid-volley frequency ($t = -3.92$, $df = 101$, $P < 0.001$). These differences, although significant, were nevertheless small: on average, the two taxa differed from one another by only 10.5% in volley duration, 7.7% in volley period, 5% in initial volley frequency, and 3.5% in mid-volley frequency (Table 2). In contrast, *C. sillemi* differed from *C. z. zastrowi* by approximately 50% in volley duration, 31% in volley period, 5% in initial volley frequency, 15% in mid-volley frequency, and 25% in end-of-volley frequency (see Table II in Henry et al. 2006).

A scatterplot of PC1 and PC2 of a PCA of all (variable) song features for *C. sillemi* (western Asia) and *C. z. arabica* (central Asia) is shown in Figure 3. These

two principal components accounted for 67% of variance in song phenotype among individuals. Individuals of the two geographical populations overlapped extensively on this plot of acoustical space, although their respective centroids did not coincide (by inspection; not calculated). In contrast, an earlier, similar PCA that included both *C. z. arabica* (central Asia) and *C. z. zastrowi* (South Africa) showed clear acoustical separation of those two subspecies (fig. 5 in Henry et al. 2006).

Adult morphology

In all 35 specimens examined from the Indian subcontinent the morphology fell within the range of character states previously described for *C. z. arabica* (Henry et al. 2006). In two character states, specimens from the Indian subcontinent fell toward the extreme end of the total range. Specimens from India have the lateral margins of the frons either unmarked or marked with a red stripe. Only in one Indian specimen was the lateral frons marked brown. The majority of specimens from the Middle East and South Africa had the lateral margin of the frons marked brown. In 50% of specimens from India the apical abdominal sternites exhibited up to 70% blond setae, whereas over 90% of specimens from the Middle East and South Africa had 100% black setae on the apical abdominal sternites.

Larval morphology

Larvae of *C. sillemi* varied in the pattern of their head markings, as has been reported in other species of the *carnea* group (Henry et al. 2002). Markings were similar to, but tended to be darker than, those in *C. z. arabica* or *C. z. zastrowi*, and the prominence of the dorsolateral spot varied as in *C. z. arabica*. Five (of 20) larvae fell within the range of variation seen in *C. z. arabica*. Referring to fig. 7 in Henry et al. (2006), two larvae resembled A, one larva resembled B, one larva resembled C, and one larva resembled D. The remaining 15 larvae resembled B or C, but had an additional pair of small spots behind the frontomedial spot (Figure 4). Overall, 85% of the Indian larvae had the dorsolateral spot, 85% had the frontomedial spot, and 75% had the pair of submedial spots. This pair of submedial spots has not been reported in any population of *C. zastrowi*.

Discussion

The exact taxonomic identification of the most important Indian green lacewing species in agricultural crops is not just an academic exercise (Henry and Wells 2007). Green lacewings are efficient predators of a number of important agricultural pests (McEwen et al. 2001). They are mass-reared in many countries, shipped around the world, and released in greenhouses or even into the field. In India, publications on the common green lacewings in agricultural croplands have used a variety of different names, including *Chrysopa carnea* (later *Chrysoperla carnea*), *Chrysopa scelestes* and *Brinckochrysa scelestes* (Duelli 2001). In 1992, the National Centre for Integrated Pest Management at Bangalore, India, issued a list of all chrysopid species known from India (Singh and Narasimham 1992). The authors of that brochure suspected that all the above-mentioned species might be synonyms of a single species, *Chrysoperla sillemi*. Moreover, Brooks (1994) synonymized three additional Indian *Chrysoperla*

species with *C. sillemi*: *Chrysoperla gujaratensis* (Ghosh), *Chrysoperla punensis* (Ghosh) and *Chrysoperla sanandensis* (Ghosh). Consequently, there is at present no other *Chrysoperla* species than *C. sillemi* known from India. We are convinced that many more species of the genus *Chrysoperla* occur in India, and it was a surprise to see that all tested specimens in our study displayed the same song pattern, that of the recently described subspecies *C. z. arabica* (Henry et al. 2006).

Our analyses of morphology and mating signals demonstrate that *C. sillemi* from the Indian subcontinent is the most easterly population yet discovered of *C. zastrowi*. As such, it is nearly indistinguishable in all respects from the subspecies *C. z. arabica* from the Arabian Peninsula and Iran. Consequently, here we combine the western and central Asian representatives of *C. zastrowi* into a single subspecies, *C. z. sillemi* stat. rev., in accordance with when each name first entered the literature. The South African population of *C. zastrowi* retains its subspecific designation as *C. z. zastrowi* Henry et al. 2006.

The discovery of *C. zastrowi* in central Asia makes this nomadic species the most widely distributed member of the *carnea* group, with a total range (over land) of nearly 12,000 km. It is also the only species of the group to be found south of the equator: all other members, although typically wide-ranging, are confined to the Holarctic realm (Brooks 1994). Hence, from South Africa to the Indian subcontinent, *C. zastrowi* is – and has been, under various other names – the best choice for use in programmes of biological control against soft-bodied arthropod pests.

Large gaps in the known range of *C. zastrowi* exist between Iran and India and between the Arabian Peninsula and South Africa, representing areas where collecting of *Chrysoperla* has been poor or lacking. The gap in Asia is not a major problem, because the song phenotype of *C. zastrowi* is essentially the same on each side of the discontinuity. However, the song of *C. zastrowi* from South Africa has a much longer volley duration and volley period than Asian representatives of the species. We predict that future specimens collected from northern and central Africa will show clinal variation of these features, from shorter to gradually longer songs as one moves south. If this prediction receives support, we should consider abandoning current subspecific divisions within *C. zastrowi*. If instead song variation is found to be geographically abrupt, or the African gap is shown to be real, then we may have to recognize *C. sillemi* as a separate species again.

Taxonomy

Order **NEUROPTERA**
Family **CHRYSOPIDAE**
Subfamily **CHRYSOPINAE**

Genus ***Chrysoperla*** Steinmann, 1964

Type species: *Chrysoperla carnea* (Stephens, 1836)

Chrysoperla zastrowi sillemi (Esben-Petersen) stat. rev.

Chrysoperla sillemi Esben-Petersen, 1935: 234.

Holotype. Female, India: Kashmir, Karakorum, Maralbashi, 110 m, 20 March 1930 coll. Sillem. ITZ [examined]. Stat. rev.

Chrysoperla sillemi (Esben-Petersen); Brooks, 1994: 149.

Chrysoperla zastrowi arabica Henry et al., 2006. New synonym.

Adult. Ground colour uniform pale green. Head marked with broad dark brown band, sometimes outlined in red on gena and clypeus. Maxillary palp marked dark brown dorsally on each segment, occasionally unmarked. Stipes marked with mid-dorsal brown line along its entire length; occasionally, marking restricted to the apical third of the stipes. Clypeus with lateral edge marked with narrow brown or red stripe. Frons marked with brown lateral stripe, or red stripe when the clypeal markings are red. Postoccipital region unmarked. Antennae shorter than forewing. Pronotum marked with median pale yellow stripe; lateral setae mostly short, black. Tarsal claw basal dilation ratio 3.5–5.1. Forewing length 11.3–14.0 mm, length : breadth ratio 2.6–3.4; venation entirely green; costal setae relatively short; basal Rs-M cross-vein leaves Rs at right angles or sometimes obliquely. Abdomen predominantly bearing black setae, although Indian specimens often have a mixture of blond and black setae, on three apical sternites, more basal sternites bearing blond setae; lip of sternite 8+9 in male relatively short and narrow with sparse long black setae.

Courtship song (25°C) (updated from 2006). Song consisting of a single-volley SRU 1.1 s (minimum within solos) to 3.4 s (maximum within duets) in duration, usually repeated several to many times with a period of 1.8 s (minimum within solos) to 6.4 s (maximum within duets); carrier frequency is a pure (single-frequency) tone, falling from a range of 55–73 Hz to 17–30 Hz during the course of the volley. Amplitude peaks sharply as the volley begins, then declines smoothly but usually rises again to a broad maximum toward the end of the volley. Volleys of the participants overlap slightly or not at all during heterosexual duets.

Larva, third instar. Head pale tan with a pair of relatively narrow, moderately dark, longitudinal dorsolateral brown stripes with narrow basolateral expansions extending towards the eyes; sometimes (26%) with variably prominent darker spot in dorsolateral stripe mesad of eyes; elongate frontomedial spot usually (85%) present; pair of variably prominent submedial spots behind frontomedial spot uncommonly (16%) present; lateral stripe present behind eye. Thorax pale cream coloured; pronotum with tan, longitudinal, dorsolateral stripes; mesonota and metanota with small brown spots near mid-length. Abdomen pale cream coloured, unmarked, except tubercles sometimes tan.

Second instar. Similar to third-instar except as follows. Head with dorsolateral stripes broader relative to width of head, especially anteriad; stripes narrowing more abruptly on medial margin of antennae; frontal spot rarely developed; lateral stripe behind eye darker. Thorax with pronotal dorsolateral stripes usually more prominent, mesonotal and metanotal spots smaller. Abdomen with tubercles sometimes darker.

First instar. Similar to second-instar larva except as follows. Head with dorsolateral stripes broader relative to width of head; basolateral expansions sometimes absent;

frontal spot absent; lateral stripe behind eye sometimes darker. Thorax with pronotal dorsolateral stripes variably prominent; mesonotal and metanotal spots very small, paler. Abdomen with tubercles frequently pigmented.

Remarks. Chrysoperla zastrowi sillemi can be separated with certainty from the nominate subspecies only by courtship song analysis. However, in most cases adult *C. z. sillemi* can be distinguished from *C. z. zastrowi* by the angle of the basal Rs-M cross-vein, which in *C. z. zastrowi* always leaves Rs at an oblique angle; in most specimens of *C. z. sillemi*, this vein is at right angles to Rs. Both subspecies of *C. zastrowi* can be distinguished from other members of the *C. carnea* group by the relatively small basal dilation of the tarsal claw (large claw ratio). The tarsal claw ratio is larger in *C. zastrowi* than in any other western European member of the species group except for western populations of *C. mediterranea*, but in the latter taxon the claw is hardly dilated at all. Other characters which help to distinguish *C. zastrowi* from other *carnea*-group species, but which are not diagnostic (i.e. black setae on pronotum, genital lip characteristics and green venation), are described further in the main Discussion.

The song of *C. z. sillemi* is best distinguished from that of *C. z. zastrowi* by its shorter volley duration and shorter volley period: each of these features is at least 1.6 times longer in the nominate subspecies than in *C. z. sillemi*. The song of *C. z. sillemi* is also markedly different from that of any other known song species in the *carnea* group. The only other lacewing sometimes showing single-volley SRUs of equivalent length is *C. agilis*, but the carrier frequency in *C. agilis* has a more complex harmonic structure and rises rather than falls during the course of each volley.

Larvae of *C. z. sillemi* and *C. z. zastrowi* are similar, but can usually be distinguished from each other by the frequent presence in *C. z. sillemi* of a frontomedial spot, which is absent in all *C. z. zastrowi*. Another distinguishing feature is the absence in most *C. z. sillemi* of a darker spot in the dorsolateral stripe mesad of the eyes, which is always present in the nominate subspecies. A third feature that is useful for *C. z. sillemi* larvae from India is the common occurrence of the pair of submedial spots. None of the *C. z. sillemi* larvae examined from any region simultaneously lacked the frontomedial spot yet possessed the darker spot in the dorsolateral stripe, which is the universal condition in *C. z. zastrowi*. The larva of *C. z. sillemi* has no features that distinguish it absolutely from that of *C. carnea*, *C. pallida*, *C. mediterranea*, *C. agilis* or *C. lucasina*. Its head markings particularly resemble those of *C. mediterranea* from Carcès, France (Henry et al. 1999) while those of *C. z. zastrowi* most closely resemble markings of some *C. carnea* from Belgorod, Russia (Henry et al. 2002). Even the two submedial spots that distinguish the Indian larvae of *C. z. sillemi* are shared with some *C. carnea* larvae from Berchtesgaden, Germany; Zürich and Brissago, Switzerland; and Tammela, Finland (Henry et al. 2002), as well as with *C. lucasina* from Berchtesgaden, Germany (Henry et al. 1996).

Distribution. Oman, United Arab Emirates, Israel, Iran, India, Pakistan.

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