

Descriptions of polar gynandromorphic specimens of *Culicoides oxystoma* Kieffer and *Obsoletus* group (Diptera, Ceratopogonidae) from West Bengal, India

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ABSTRACT: Five rare polar gynandromorphic specimens of *Culicoides* (Diptera, Ceratopogonidae), four of *Culicoides oxystoma* Kieffer, and one specimen of *Obsoletus* group were studied. These individuals were collected during pre-monsoon, monsoon and post-monsoon seasons using UV LED light traps from cattle shed and poultry farm located in Purulia, West Bengal, India. The gynandromorphic individuals of *C. oxystoma* revealed a typical one with male genitalia with a slender abdomen. It had the head, antenna, mouthparts, and the associated accessory structures together with the wings were similar to that of a female. On the other hand, three specimens had female genitalia and head, antenna, mouthparts like male. Very interestingly, the gynander specimen of *Obsoletus* group possesses antennal flagellomeres, mouthparts, and wings of females but enlarged pedicel-like male and the presence of basistyle, dististyle but devoid of aedeagus and parameres. © 2025 Association for Advancement of Entomology

KEY WORDS: *Culicoides oxystoma*, *Obsoletus* group, gynandromorph, morphology, India

INTRODUCTION

Gynandromorph individuals are genetically and phenotypically chimeric and can be easily distinguished from others (Goldschmidt, 1934; Laugé, 1985). Gynandromorphism is usually categorized as polar, bilateral, spiral, and oblique (Oke *et al.*, 2020). A polar gynander individual possesses the head of one sex while the abdomen of the other sex. However, a bilateral gynander has the boundary line between the sexes following the longitudinal axis. In contrast, an oblique gynander has the head and one side of the thorax of one sex while the other side of the thorax and the abdomen are of the other. The probable reasons behind gynander formation include loss or damage of a

sex chromosome, polyspermy, binucleate eggs, post-cleavage fertilization, and also due to some symbionts or parasitism (Narita *et al.*, 2010). Mermithid nematodes may produce stunning morphological alterations in their hosts and form an intermediate morph between the sexes (Wülker, 1975).

The occurrence of gynandromorphs has been documented recurrently in various families of the order Diptera (Narita *et al.*, 2010). Gynandromorphs of the nematoceran family Chironomidae, aberrant females copulated with males (Rempel, 1940); in Baltic amber fossils, that deviant female was seen mating with normal females (Boucot and Poinar, 2010). Therefore, a

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gynander can provide essential information about their behavioural and sexual biology (Crosskey, 1990). Mullens *et al.* (2008) state that mermithid parasitism may trigger abnormal host development or morphological features and behaviour.

Beck (1958) recorded the first gynandromorph ceratopogonids parasitized with mermithids. Of the Ceratopogonidae, gynandromorphism was reported in several *Culicoides* spp. (Diptera, Ceratopogonidae). They are incriminated as biological vectors as they transmit various arboviruses, protozoa, and nematodes to livestock and humans (Mellor *et al.*, 2000; Sick *et al.*, 2019). Callot and Kremer (1963) documented mermithids causing intersexes of *Culicoides* spp. Most *Culicoides* intersexes were parasitized by mermithid nematodes with male genitalia and secondary sexual traits of females (McKeever *et al.*, 1997). Intersex male *Culicoides circumscriptus* Kieffer parasitised by *Heleidormis cataloniensis* also documented by Poiner and Monteys (2008).

Although the frequency of this phenomenon is very low in insects, earlier records of gynandromorphism were documented in several biting midges such as *Culicoides varipennis* (Coquillett) (Curtis, 1962), *Culicoides furens* (Poey), *Culicoides leopoldi* Ortiz (Hawkins, 1962), *Culicoides hollensis* (Melandar and Brues) (Khalaf, 1965), *Culicoides crepuscularis* Malloch, *Culicoides haematopotus* Malloch, *Culicoides stellifer* (Coquillett) (Smith and Perry, 1967) and *Culicoides lailae* Khalaf (Navai, 1969). A polar gynandromorph was reported by Oke *et al.* (2020) in *Culicoides subschultzei* Cornet and Brunhes belonging to the subgenus *Remmia* Glukhova (Borkent and Dominiak, 2020) along with observed bi-abdomens in another member of *Schultzei* group, *Culicoides oxystoma* Kieffer in which a distinct abdomen attached to the meta-thorax and interestingly both abdomen of that individual possesses three spermatheca.

The species *C. oxystoma* vectors the following viruses: i) *Orbivirus*: bluetongue virus (BTV),

African horse sickness virus (AHSV), epizootic hemorrhagic disease virus (EHDV), Chuzan virus (CHUV), D'Aguilar virus (DAGV), Ibaraki virus (IBAV); ii) *Orthobunyavirus*: Akabane virus (AKAV), Aino virus (AINOV) (Kurogi *et al.*, 1987; Yanase *et al.*, 2005; Dadawala *et al.*, 2012); nematode: *Onchocerca gibsoni*, the causative agent of filaria of cattle (Buckley, 1938); protozoa: *Leucocytozoon* sp., an intracellular haemosporidian blood parasite and *Leishmania (Mundinia) martiniquensis*, *L. (M.) orientalis*, and *Crithidia* spp. (Sunantaraporn *et al.*, 2022; Songumpai *et al.*, 2022). It is a significant vector species with a wide geographic distribution (Wirth and Hubert 1989). It is one of the seven BTV vectors reported from India (Harrup *et al.*, 2016). It is the predominant species in cattle sheds in the eastern state of India, West Bengal, and in Bluetongue disease (BTD) prone areas of southern India (Chanda *et al.*, 2019; Harsha *et al.*, 2020).

Biting midge species such as *Culicoides obsoletus* Meigen, *Culicoides scoticus* Downes and Kettle, *Culicoides dewulfi* Goetghebuer, and *Culicoides chiopterus* Meigen are members of the subgenus *Avaritia* and belonging to *Obsoletus* group (Campbell and Pelham-Clinton, 1960; Borkent and Dominiak, 2020) and they gained particular importance as they have been implicated as vectors of BTV and SBV in northern Europe (Hoffman *et al.*, 2009; Elbers *et al.*, 2013). Biting midges of the *Obsoletus* species group are increasingly suspected as vectors of the recent emergence of the bluetongue virus in Europe (Augot *et al.*, 2010). In India, bluetongue disease is endemic, and outbreaks have been reported in several states in native and exotic breeds of sheep (Prasad *et al.*, 2009). Morphological anomalies were found in females of *C. obsoletus*. It was concluded that probable causes of these anatomical alterations occur due to some genetic or morphogenetic malformation (Ramilo *et al.*, 2021). This present investigation reports *C. oxystoma* and *Obsoletus* group possessing three types of polar gynandromorphism (anterior-posterior) along with morphometrics firstly from India.

MATERIALS AND METHODS

Study area and collection of wild midges

Adult midges were collected using UV LED light traps from a backyard cattle shed and a poultry farm. The trap was operated overnight from 5.30 pm to 7.00 am. The sampling sites were located in Rajabandh para (23°19' N; 86°22' E) and Kapur Bagan (23°20' N; 86°22' E), respectively, in the district of Purulia, West Bengal, India. Biting midges were collected for three consecutive seasons (pre-monsoon, monsoon, and post-monsoon) from March 2022 to April 2023 from the cattle shed, while sampling was performed for three months (May 2023-July 2023) from a poultry farm.

Mounting and identification of midges

Adult *Culicoides* spp. was sorted out from the rest of the trapped insects and some of them were slide mounted onto glass slides following Wirth and Marston (1968). After that, these specimens were subjected to morphometric measurements and identified based on the key of Wirth and Hubert (1989). Morphometric measurements were noted by following Wirth and Hubert (1989). The characters described by Campbell and Pelham-Clinton (1960), Kluiters *et al.* (2016) and Pagès and Monteys (2005) were applied to morphologically distinguish specimens of the *Obsoletus* group. Morphometric data of the gynanders were recorded in millimeters (mm). Slide-mounted specimens are presently retained with the Entomological collections of Diptera in the Department of Zoology, The University of Burdwan.

RESULTS AND DISCUSSION

Following *Culicoides* spp. were trapped in a backyard cattle shed, including *C. oxystoma*, *C. peregrinus* Kieffer, *C. fulvus* Sen and Das Gupta, *C. actoni* Smith, *C. imicola* Kieffer, *C. orientalis* Macfie, *C. homotomus* Kieffer, *C. palpifer* Das Gupta and Ghosh, *C. anophelis* Edwards and *C. shortti* Smith and Swaminath. *C. oxystoma*, *C. huffi* Causey, *C. arakawae* (Arakawa), and specimens of *Obsoletus* group were identified from the catch of the poultry farm. It was noted that *C.*

oxystoma was the most predominant species in cattle shed and poultry farm.

Four polar gynandromorph individuals of *C. oxystoma* were reported: one with male genitalia and female mouthparts (Fig. 1) and three other specimens with female genitalia and male mouthparts (Fig. 2). Morphometric data of these specimens showed that the head, associated accessory structures, and wings were typical of a female biting midge (Table 1). In contrast, the posterior part was characteristic of a male biting midge with a slender abdomen and conspicuous terminal male genitalia. The labrum-epipharynx bears well-developed terminal teeth; the lacinia was armed with minute teeth; the well-developed mandibles contain a series of minute, broad teeth, and the maxillary palps include a well-developed palpal sensory pit. The other three specimens had head and accessory parts of males and were devoid of basistyle, dististyle, aedeagus, and parameres. However, two of them had punctured and swollen female-like abdomen, although any formations of spermatheca were not found clearly.

Gynander of *Obsoletus* group exhibited polar sexual dimorphism, mixing male and female phenotypic characteristics in the head and genitalia (Table 2). The specimen contained flagellomeres, mouthparts like females (Fig. 3a) but enlarged pedicel-like a male (Fig. 3b), wings of females (Fig. 3c), and a swollen female-like abdomen (Fig. 3d) with the presence of basistyle, dististyle but devoid of aedeagus, and parameres (Fig. 3e). The sensilla coeloconica pattern in the antenna was 3, 13-15. Therefore, this individual did not demonstrate discrete male and female characters in the head and abdomen.

Occurrences of gynandromorphs are infrequent (Hall, 1988). Ratios of events of gynandromorphs within Simuliid range from 1 in 2,300 to 1 in 50,000 as given by Crosskey (1990). Several researchers proposed reasons behind the generation of gynanders. It was also recorded by Mori and Perondini (1980) that the origin of gynandromorphs in *Sciara ocellaris* (Diptera, Sciaridae) was due to the loss of a chromosome. This type of aberration forms in *Drosophila melanogaster* (Diptera,

Table 1. Morphometrics of polar gynandromorph specimens of *Culicoides oxystoma*

Specimens	Antennal ratio	Palpal ratio	Proboscis/ Head ratio	Hind tibial spines	Wing length (mm)	Costal ratio
Female head/ male abdomen (n=1)	1.01,1.09	2	0.65	4	0.96, 0.86	0.52, 0.54
Male head/female abdomen (n=3)	0.96-0.98	1.4-1.6	-	4	0.66	0.50

Drosophilidae) due to chromosomal elimination (Morgan and Bridges, 1919). The number of X chromosomes relative to the number of autosomes is the initial prime factor for sex determination. According to Narita *et al.* (2010), they were losing one of the X chromosomes during the first mitotic division, resulting in individuals with XX and XO cells possessing 50 per cent male and 50 per cent female tissues. This kind of gynander formation arises as a result of double fertilization, where a polar body is fertilized by one spermatozoon and the female pronucleus by another in the case of *Culex molestus* and *Aedes aegypti* (Diptera, Culicidae) (Gilchrist and Haldane, 1947; Rai and Craig, 1963). The gynandromorph individuals of *Culex molestus* and *Aedes cinereus* possess palpus of a male and female antennae on one side, and the other side harbours palpus of a female and antennae of different sex. It would result from somatic crossing-over, as proposed by Gilchrist and Haldane (1947).

Following general observations, gynandromorphic specimens of *Culicoides* have not shown any sign of parasitism (Curtis, 1962; Navai, 1969). *Mermis* Dujardin, a nematode belonging to the family Mermithidae was recorded in *Culicoides alatus* Das Gupta and Ghosh (synonymised as *C. oxystoma*) by Sen and Das Gupta (1958). Mermithidae or other parasites were not found during microscopic observation, which might cause such abnormalities. However, two of three individuals of *C. oxystoma* with male head and female abdomen had punctured abdomen or holes so the nematodes might have escaped through this. Also, external boundaries between female and male

body parts were obvious. The appearance of the punctured abdomen of this morph could not be ascertained as no mermithids were discernible.

Morphological identification of species belonging to the *Obsoletus* group is often difficult or impossible as the species are quite similar. For example, only males can be discriminated between species based on genitalia characteristics. For females, the measurement of the size of the spermathecae is not sufficient for precise identification (Pages and Monteys, 2005). During the present study, only four females of this group were collected of which one was gynandromorphic whose male genitalia was quite abnormal. But based on morphology it was noted that the female specimens along with gynandromorphic individual possess morphometric characters of this group. However, identification up to the species level leads to further extension of works by studying more specimens or applying DNA-based approaches.

Mechanisms causing the development or production of gynanders are of interest due to the implications for vector control strategies. However, there is no procedure for readily producing many gynanders (Hall, 1987). Gynandromorphs could be helpful in genetic, embryological, physiological, neurological, and parasite interaction studies (Hall, 1987, 1990; Sethuraman and O'Brochta, 2005). A gynander with the abdomen engorged with fully developed eggs was noticed by Craig and Crosby (2008). During this study, despite the gynanders possessing typical female mouthparts, there was no evidence of engorgement with blood. It is unknown whether it

Table 2. Morphometric measurements of polar gynandromorph specimen of *Obsoletus* group

Antennal ratio	Length of pedicel (mm)	Palpal ratio	Proboscis/ Head ratio	Hind tibial spines	Wing length (mm)	Costal ratio
1.03, 1.04	0.088	3, 4	0.90	5	1.16	0.60



Fig. 1 Anterior female and posterior male polar gynandromorph specimen of *Culicoides oxystoma*. a) whole specimen, b) head with antenna and c) male genitalia



Fig 2. Anterior male and posterior female polar gynandromorph specimen of *Culicoides oxystoma*. a) whole specimen and b) head with antenna

would have been possible for this individual to have taken a blood meal due to these modifications or not. However, there could be the possibility of alterations in the feeding habits, but this could not be established since the gynander died after trapping. The insect antennae are the principal sensory organs involved in foraging, mate detection,

and various environmental stimuli so that gynander individuals may possess divergent behavioural aspects of mating, breeding, feeding, or habitat selection due to morphological alteration in their antennae (Lane, 1984; Yuval, 2006; Muñoz-Muñoz *et al.*, 2016). As the number and localization of the different types of sensilla are also influences in their behaviour, this leads to the need for further extension of works to observe their alteration of biological and behavioural aspects. The occurrence of such abnormalities in *C. oxystoma* samples, especially during pre-monsoon (March-April), suggests environmental input on morphogenetic dynamics in this embryo of this species, although this requires further explorations. The probable reason behind such a mosaic gynander formation of the specimen belonging to *Obsoletus* group also cannot be stated.

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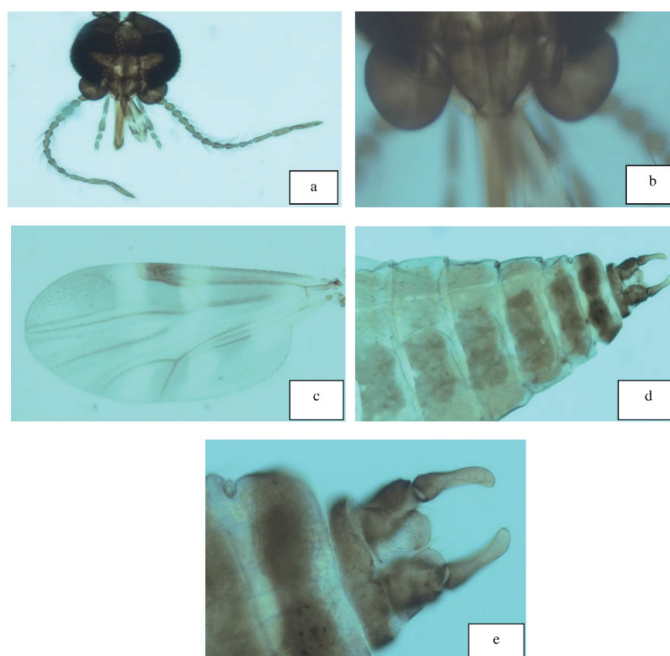


Fig. 3. Dissected parts of polar gynandromorph specimen of *Obsoletus* group. a) head, b) enlarged pedicel-like male, c) wing, d) tapered abdomen, e) male genitalia devoid of aedeagus and parameres

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