part of an epithelial cell. The clumps were about 10-13 µm across, the cells being 15-20 µm in diameter. Under high-power magnification the clumps could be seen to be composed of granules about 1 µm in diameter. Most of the granules were clumped centrally but a few lay dispersed towards the cell margins. The inside of a tergite in the dark phase, viewed with reflected light, showed a yellow-pink surface with few black granular clumps, whereas an external view through the transparent cuticle showed that most cells appeared black with the granules usually more dispersed.

In a dark-phase tergite it is possible to peel off the basement membrane to which the proximal ends of the cells adhere and thus to reveal more clearly the distribution of granules in the distal, more peripheral, regions of the cells. In such tergites the distal migration and dispersal of the granules appear to displace and obscure the red pigment. In some cells the granules were seen to be clumped mainly in the central region, but in others they were evenly dispersed throughout the cytoplasm. In the former case each clump of granules could be seen to be surrounded by a thin red zone, giving an over-all chestnut-brown colour to the segment.

In those parts which are unaffected by temperature and remain red in an otherwise darkened abdomen, such as the mid-line regions of the 10th tergite, the granules remain proximally positioned. Thus when they were viewed from within by reflected light, patches of dark granules could be seen in these regions.

When cells were squashed and then viewed under high power the granules were found to remain clustered apparently held together by a cytoskeletal network, perhaps of microtubules as described by FILSHIE et al. (1975).

Discussion

Conclusions about cellular mechanisms based on the examination of poorly fixed material can at best be tentative. However the detection of granules situated proximally in red-phase and distally in dark-phase abdomens strongly suggests that the mechanism of colour change is similar to that described in some blue odonates (VERON et al., 1974) and in the blue grasshopper *Kosciuscola* (FILSHIE et al., 1975). This is made all the more likely by the observation that blue as well as red chlorocyphids show similar temperature-dependent colour changes. Colour changes have not previously been described in red odonate species, or in the Chlorocyphidae. Moreover in other species they occur at lower temperatures than in chlorocyphids.

One implication of the darkening at temperatures below 25°C is that bright red males perched on territorial sites in the sun maintain abdominal temperatures above this level. Such a temperature in the thorax would facilitate instant take off in pursuit of rivals or females (cf. MAY, 1991). No colour change was noted in the thorax or head, nor was any colour change seen in the dark coloured females whose epithelia lack black granules. The likely function of colour change is to reduce the visibility of inactive males perched in the shade, rather than to enhance the rate of warm-up when exposed to the sun. By this means inactive males may be able to avoid detection both by other males and by predators.

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FIRST RECORD OF COMMENSAL FLIES, *DESMOMETOPA* SP., ON A DRAGONFLY, *CORDULEGASTER BOLTONII* (DONOVAN) (DIPTERA: MILICHIIDAE; – ANISOPTERA: CORDULEGASTRIDAE)

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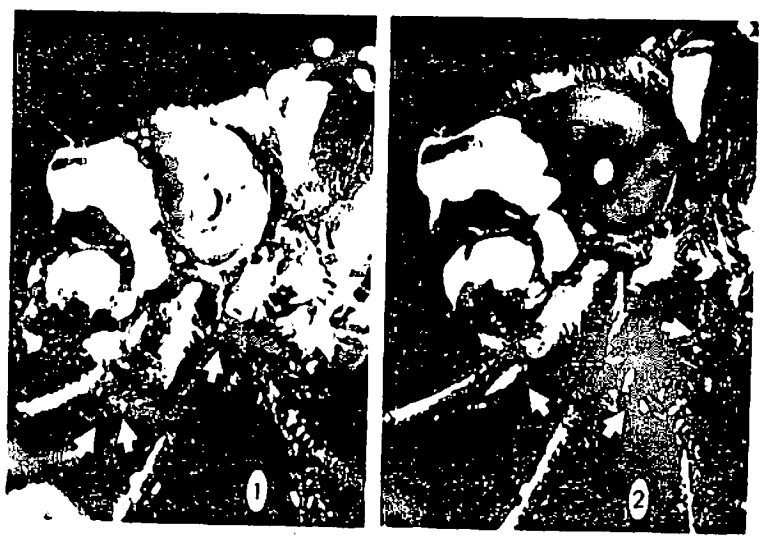
Abstract – The flies were seen near the mouthparts of a perching and feeding ♂ *C. boltonii*. They sucked from the prey being consumed by the dragonfly and dabbed its mouthparts after its meal, possibly cleaning them. During the dragonfly's flight the flies probably rested on the lateral thorax. It seems likely, *Cordulegaster* was accompanied by *Desmometopa* at least for 20 min.

Commensalism of adult Diptera on large predaceous arthropods has been so far reported in spiders, bugs and robber flies only.

Introduction and observations

Commensalism in dragonflies is hitherto known from larvae only (e.g. DREYER, 1986; HAWKIN & WATSON, 1990) but not previously from adult dragonflies. On August 27, 1990, I observed a male of *Cordulegaster boltonii* patrolling along a small ditch in the Kinzig-valley near Haslach (Baden-Württemberg, FRG). From time to time it rested on herbaceous vegetation at several localities along the ditch where it perched or fed on large prey. The ditch was accompanied by a small path close to the margin, so I could easily approach the resting dragonfly and observe it from a very close distance without disturbance. On one of these occasions I was very surprised to notice some minute flies sitting and running nimbly about the front parts of the head or sucking and probing the fluid-covered prey (Figs 1-2) which had already been chewed by the dragonfly and formed to an uniform mass. During the next 20 minutes I had several opportunities to watch closely this *Cordulegaster* individual (which



Figs 1-2. *Desmometopa* sp. (see arrows) are sucking the pieces of the prey of *C. boltonii* male on sitting near their food source.

Sternberg, 1993

easily could be individually identified by certain wing damage) while feeding and perching on its sites. I always noticed some flies on its face or near its mouthparts. Due to their characteristic M shaped mark between their eyes the flies easily could be identified as *Desmometopa* spp. (possibly *D. m-nigrum* Zetterstedt or *D. sordidum* Fallen). In order to identify the flies more precisely I netted the dragonfly after 20 min, but unfortunately the meshs of my net were too wide and the flies escaped before they could be collected.

Adult milichiid flies especially of the genus *Desmometopa* are known to be commensalists on larger predaceous arthropods, such as spiders (e.g. BIRO, 1885, *in* HENNIG, 1937; BIRO, 1899; LUNDSTÖM, 1906; FROST, 1913; RICHARDS, 1953; McMILLIAN, 1965; ROBINSON & ROBINSON, 1977; SIVINSKI & STOWE, 1980; LANDAU & GAYLOR, 1987), reduviid bugs (Reduviidae, Hemiptera) (BIRO, 1885, *in* HENNIG, 1937; BIRO *in* KERTÉSZ, 1899; RICHARDS, 1953; ROBINSON & ROBINSON, 1977) and robber-flies (Asilidae, Diptera) (BIRO, 1897, 1899; PEYERIMHOFF, 1917). Flies associated with spiders and bugs are seen either coming to their host after prey has been caught (BIRO, 1885, *in* HENNIG, 1937), or they remain in the vicinity (e.g. on non-sticky supportive lines of the spider web, or on the cephalothorax of a non-feeding spider itself), waiting for subsequent meals (ROBINSON & ROBINSON, 1977; SIVINSKI & STOWE, 1980). But *Desmometopa* flies, which accompany the very mobile asilids, were always found riding on the predator's back during its flight and obviously often seem to be associated with high fidelity with a certain individual host (*Ommatius minor* Del.; see BIRO, 1897) at least for some time so that they are always present before the asilid preyed on an insect (BIRO 1897, 1899; PEYERIMHOFF, 1917).

The flies obviously locate their food by tracking volatile products of the external digestion or the haemolymph of the prey (SIVINSKY & STOWE, 1980) and BIRO (1899) stated that the *Desmometopa* flies were simply attracted by the scents of freshly killed insects. There is also some evidence that in the case observed here the milichiid flies were associated continuously with the dragonfly for some time and settle on the predator's face or, more probably, on its lateral thorax even while in flight: (1) The flies observed here doubtless were associated with the *Cordulegaster* male at least during the 20 min I observed the dragonfly and I suppose that they would have spent some more time on their host if they had not been expelled by me (see above). I always could recognize the flies immediately after the *Cordulegaster* perched in the immediate vicinity of my own watching point and flies never could be seen flying to the dragonfly after its landing. (2) The dragonfly was always accompanied by the flies even if it was only perching and not feeding. (3) The occurrence of the constant number of five flies during the 20 minutes I observed

Fig. 3. For some moments one *Desmometopa* fly sat on one of the *Cordulegaster*'s wing where it fled to after it was expelled from the dragonfly's head while the *Cordulegaster* was cleaning its head with the fore-legs. From there (presumably) it returned to the head or thorax of the *Cordulegaster* during the takeoff phase of the latter.

the dragonfly does not seem to be accidental considering the fact that, if the dragonfly would be 'resettled' repeatedly by the flies, it would be very unlikely that the number of flies remained constant on every perch site even at different localities along the habitat. Five flies were seen also on the *Cordulegaster*'s head even after one fly sat on one of the dragonfly's wing (Fig. 3) to where it fled when the dragonfly vigorously cleaned its face with its forelegs brushing the fly off, and then the dragonfly started to fly. In this situation I expected that the fly on the wing would be lost after takeoff of the dragonfly, but surprisingly there were still five flies when the dragonfly perched again. Obviously the fly from the wing was able to return to the dragonfly's body (head or thorax) during the takeoff phase of the dragonfly when the flight velocity of the latter was still low. This observation seems to prove the high fidelity of these fly specimens to the 'hospitable' predator as already stated by BIRO (1897). (4) With respect to the speed of the large flying *Cordulegaster* male, the flight velocity of the minute *Desmometopa* presumably is much lower, so it seems to be impossible for the flies to 'settle' onto the dragonfly during its flight.

With respect to the flight manoeuvres of the dragonfly, particularly when catching prey, it is very astonishing that the flies were able to settle on the dragonfly for such a long time, presumably the pubescent hairs of the *Cordulegaster*'s face and especially on its thorax may facilitate the phoretic habit of the flies or even make it possible. Immediately after the dragonfly has landed and for some seconds afterwards the *Desmometopa* flies were found more often on the lateral thorax or on the coxae than on the head before they changed to their food source at the dragonfly's mouth. If the dragonfly had caught a prey the flies probed the prey and after a prey had been consumed they dabbed the dragonfly's mouthparts probably cleaning them. But if the dragonfly was not feeding they rested on the lateral thorax, the coxae and legs. Thus, the thorax normally seems to be the place where they stay during the flight of the dragonfly. Because neither the dragonfly's legs nor the struggling movements of a larger restrained prey could reach the lateral thorax and brush off the flies, the thoracic pleurites may represent the safest place for the flies near their food source around the mouth of their host, while the dragonfly is flying and not feeding.

Corresponding to most other observations of commensal flies on predaceous arthropods (l.c.) all five flies observed on the dragonfly were females. While the dragonfly fed on the prey the flies sat on the labrum, labium, sometimes on the basal parts of the mandibles (see Figs 1-2) and even on the prey itself. The flies did not show any fear and seemed to have no respect for the jaws. The flies skilfully avoided being grasped by the heavy moving jaws of the predator or being stripped off by cleaning movements of its legs by running away quickly or - if disturbances were too strong - by short flights, e.g. to the wings (Fig. 3), the thorax or the substrate on which the *Cordulegaster* was sitting. But there they remained only for some moments before they returned back to the dragonfly's face and/or its prey again. The dragonfly itself obviously did not take any notice from the sponging flies, and the brushing off of one fly mentioned above seemed to be accidental. After these observations I tried to find other dragonflies associated with commensal flies. But in the subsequent years (1990-1992) neither in the described habitat nor anywhere else I was able to discover another one. I also did not recognize any dragonflies associated with flies before and it has not been recorded previously.

Conclusions

The behaviour of the *Desmometopa* flies on the *Cordulegaster* is similar to Biró's observations on the asilid *Ommatius minor*, where the flies accompany an individual asilid with high fidelity and ride on its thorax during its flight. They rest on the asilid's thorax while their host is not feeding and only change to its head and mouthparts when the asilid is consuming an insect. This behaviour seems to be the only possibility for the little flies to participate in food from very mobile predaceous large insects, which external digestion products (or the haemolymph of its prey) may be necessary in some *Desmometopa* species for maturation (e.g. of the gonads) of the females. The occurrance of commensal flies on dragonflies (and also on other predaceous arthropods) seems to be very rare and the observation described here is unique yet within odonates. But probably this paper inspirit other odonatologists to search after phoretic flies on dragonflies.

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DRAGONFLY DISTRIBUTION ALONG NEW CALABAR RIVER, NEAR PORT HARCOURT, NIGERIA (ANISOPTERA)

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Abstract – During 13 months larvae were collected bimonthly at 6 sample sites and then reared to the adults. Chloride and Biochemical Oxygen Demand (BOD) were measured monthly at each sample site during 12 months in order to assess the influence of these factors on odon. distribution along the river. A total of 11 spp. were collected (1-8 spp. per site). Regression analysis indicated that odon. distribution was significantly affected by Chloride and BOD, accounting for 32.4 and 48.3%, resp. of the variation in distribution. As each variable increased, the number of spp. per site decreased.

Introduction

In the Afrotropical region, dragonfly studies fall into two major areas: those restricted to one or two species (e.g. GAMBLES, 1966, 1970, 1971, 1972; LINDLEY, 1970; PARR & PARR, 1972, 1974; PARR, 1974) and those restricted to taxonomy, collection and identification of adults (PINHEY, 1961a, 1961b, 1962, 1971; DUMONT, 1977, 1978). Such studies contribute immensely to the understanding of regional fauna, but some other aspects of interest are neglected. For example, studies concerned with the collection and identification of adults do not provide information on larvae, breeding sites and breeding periods of adults. Studies restricted to one or two species are of limited application because the diversity of dragonflies in Africa is enormous.

Within the Afrotropical region, published information on dragonflies is unevenly distributed. For example, there is no information on the lower Niger delta. Yet this delta is a complex ecological area, located in the tropical rainforest and provides a gradual transition from fresh to salt water. It has a high diversity of aquatic insects. This study was therefore undertaken to determine the odonate larvae distribution along the New Calabar River, near Port Harcourt. The study is also intended to provide some baseline information on dragonfly species found in the area.

Material and methods

Dragonfly distribution along the New Calabar River, near Port Harcourt was investigated for 13 months (November 1989-November 1990) by bimonthly collecting larvae from 6 sample sites along the river (Fig. 1), and rearing them to adults. Also, two variables, Chloride and Biochemical Oxygen Demand (BOD) (an index of pollution), were measured monthly at each sample site for a period of 12 months (December 1989-November 1990) and related to dragonfly distribution along the river. These two factors were chosen because transition from fresh to salt water is gradual in the area, and water pollution, especially from petroleum products, is fairly common.

The collection of larvae was restricted to the lotic margin and was done from a canoe using a dip net. During collection, the net was submerged in water under aquatic weeds, and, while holding the handle of the net with one hand, the weeds were held and shaken with the other hand in order to dislodge larvae clinging to the roots of weeds into the net. This process was repeated 50 times per sample site per sample period. The larvae were taken to the University of Port Harcourt campus for rearing.

For each sample site, only representative larvae were reared after each sample period for the more common species; all the less common larvae were reared. Rearing was done in a small open-air house. Larvae from each sample site were reared separately using water collected from the sample sites. The purpose of the rearing was for easier identification of the species, most of which are only known in the adult or final larval stage. Rearing involved placing 3-5 larvae in a clear plastic container (11 cm long, 6 cm wide, 16 cm deep) half-filled with water. A 17 cm long by 2 cm wide flat stick was placed diagonally within each container for the insects to crawl out and emerge. The open end of the container was covered with nylon-screen, held in place with a rubber band. Water in the container was changed daily. The larvae were fed chironomid larvae collected from gutters within the University Campus. Upon emergence, the adults were killed with ethyl acetate and dried in a desiccator containing anhydrous calcium chloride pellets. These adults were later identified by S.J. Brooks (British Museum, Natural History) and R.W. Garrison (Asuza, California, USA).

Water samples for the determination of Chloride and BOD were collected from each sample site during high tides. These are the periods when salt water flows into coastal inlet waters. The Argentometric Method was used to measure Chloride (APHA, 1985). The Azide Modification Method was used to determine the initial and final Dissolved Oxygen (DO) (APHA, 1985). The final DO was determined after 5 days of incubation. BOD was computed from the difference between initial and final DO. Regression analysis was used to test whether Chloride and BOD significantly affected dragonfly distribution along the river. Both variables were treated as independent variables, while the number of dragonfly species per sample site was the dependent variable.

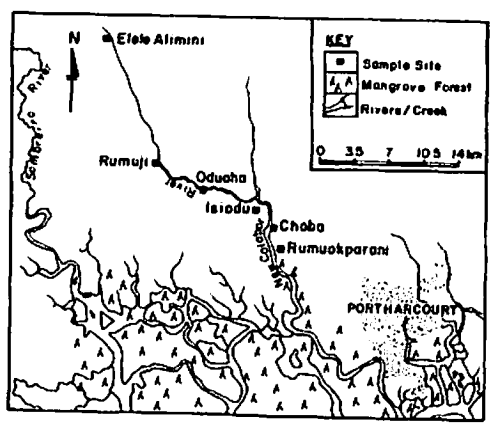

Fig. 1. Map of a section of the lower Niger delta, showing New Calabar River and the six sample sites.

Results and discussion

A total of 11 species was collected. The number of species per sample site ranged from 1 to 8 (Tab. I). Regression analysis indicated that dragonfly distribution along the river was significantly affected by Chloride and BOD. Based on Rsquare (Tab. I), Chloride and BOD accounted for 32.4 and 48.3 percent of the variation in distribution, respectively. The slope of the regression equation (β) (Tab. I) indicated that there was a negative relationship between each variable and the number of species per sample site. In other words, as each variable increased, the number of species per sample site decreased.

Species collected per sample site are listed in Table II. The highest number of species was collected from Elele Alimini, followed by Rumuji and then Oduoha, while only one species was collected from Rumuoparani (Tab. II, Fig. 1).

Rumuoparani is the transition zone between fresh and mixohaline (brackish) water as indicated by the mangrove forest; mangrove thrives in mixohaline and salt water environments (Fig. 1). Three species, *Chalcostephia flavifrons*, *Gomphus* sp., and *Urothemis edwardsi*, are limited in distribution from Elele Alimini to Oduoha (Tab. II, Fig. 1). *Trithemis stictica* was collected throughout the year from Elele Alimini to Oduoha and from Isiodu and Choba only in January 1990 (Tab. II, Fig. 1). This indicates that the