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SHORT COMMUNICATIONS

MONILIFORM EGG-STRINGS LAID BY *DAVIDIUS MOIWANUS TARUII* ASAHINA & INOUE, A CASE OF "NON-CONTACT SITTING OVIPOSITION" (ANISOPTERA: *GOMPHIDAE*)

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A case of "non-contact sitting oviposition (sensu EDA, 1960, Insect Ecol. 8: 82-88) and the formation of moniliform egg-strings in *D. moiwanus taruii* is described. This seems to be the second record of this type of oviposition and the first record of moniliform egg-string formation in Odonata. Some considerations are made on the types of oviposition in the Order, especially in relation to the adhesive power of the surface material of eggs.

INTRODUCTION

SCHIEMENZ (1953) classified the oviposition types of German dragonflies according to the nature of laying substrates, the level of oviposition sites and the presence or absence of an accompanying male. EDA (1960) proposed his own classification with an additional category, i.e. whether flying or sitting. He summarized his system into six types as follows: "*a*" sitting-oviposition into plant tissue; – "*b*" sitting-oviposition into mud or moss; – "*c*" sitting-oviposition into water; – "*d*" flying-oviposition into mud or sand; – "*e*" flying-oviposition into water; and "*f*" non-contact flying oviposition.

Furthermore two types, flying-oviposition into plant tissue ("*g*") and non-contact sitting-oviposition ("*h*") were supposed. The latter was actually observed in a gomphid dragonfly, *Davidius moiwanus moiwanus* by NARAOKA (1975).

One of the present authors (N.S.) observed another case referable to "*h*", demonstrated by another subspecies, *D. moiwanus taruii*. In this case the eggs were laid as moniliform egg-strings which we like to name oviposition "*h-2*" against Naraoka's case as "*h-1*".

Figs. 1-2. *Davidius moiwanus taruii* Asahina & Inoue: moniliform egg-string formation. (Photo N. Shimizu).

OBSERVATIC

On June 23, 1975, oviposition by a female of *Davidius moiwanus taruii* was observed at a marsh in Katsuragawa-bomuracho, Ohtsu, Shiga Prefecture. This habitat is a small marsh, 340 m above sea-level, left between a hill and a bus road along the Adogawa river in a widely opened valley west of Mt. Hira.

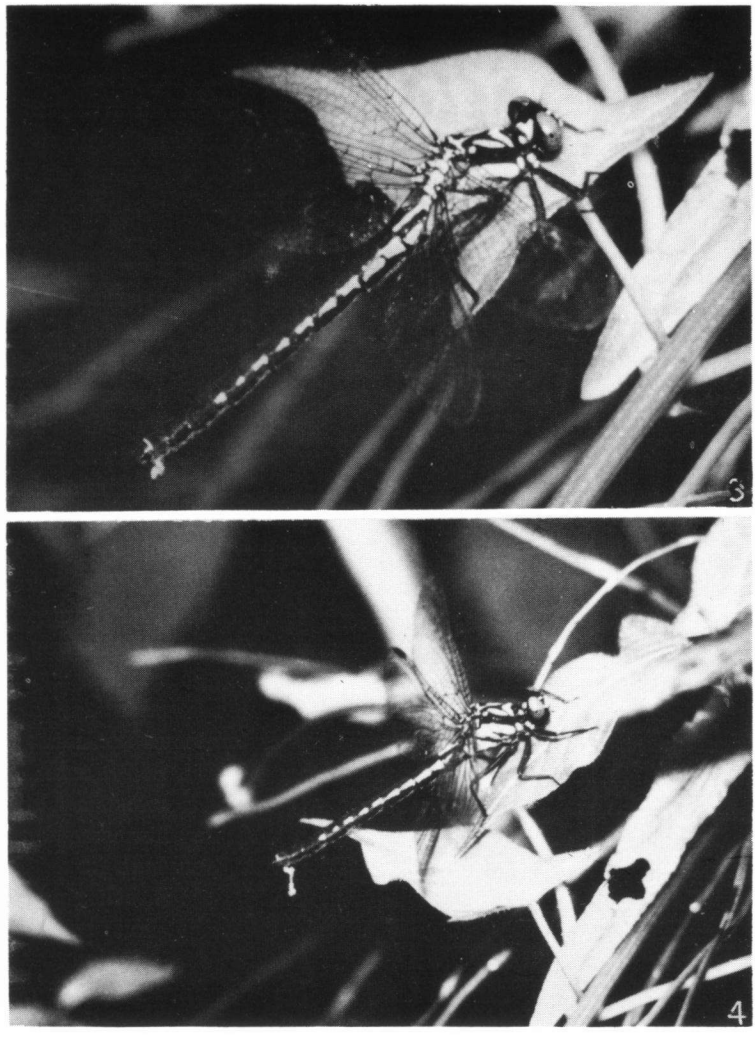
At noon, a female insect sitting on a leaf of *Petasites* started to fly over a small open water surface in the marsh. For a short while she flew to and fro low above the water and alighted on a grass near the water at a height of about 30 cm. Then she extruded eggs one by one, arranged in a row from her erected valvula vulvae. The eggs adhered to each other to form an extruded moniliform egg-string (Fig. 1). It grew to some 8 mm in length and dropped off by its own weight. She was always sitting without flicking of the abdomen. Then she flew, moving only 20 or 30 cm, and perched again. Soon another string was formed (Fig. 2), and she repeated her "perching–egg-string formation–flying" process several times in a few minutes. In some cases the egg-string was deformed to be an egg-mass (Figs. 3-4), in another case she flew with a string which dropped during flight. The eggs fell down on to wet mud or on to mosses but not on to the water surface directly. At last she moved back to a leaf of *Petasites*, and the oviposition was not observed any more.

It was a day almost cloudy with occasional rain, but it was fine and windless at the time of the observation.

PREVIOUS OBSERVATIONS

Sitting-oviposition into substrates (Eda's "*a*" and "*b*") is commonly observed in many odonate families, while sitting-oviposition into water "c" is known only in one gomphine species, *Lanthus fujiacus* (TAKETO, 1960). Taketo's descriptions may be translated as follows: "A single female landed on the bank of a stream and dipped the tip of the abdomen into the water. She was always sitting still, but the eggs were released into the water one by one".

Three other, but similar, types of oviposition are mentioned by PAULSON (1969). Female insects of *Micrathyria hageni* and *M. ocellata* placed eggs on the leaf in water, which we may call "α", while *M. aequalis, M. mengeri* and *M. schumanni* placed eggs underneath the leaf in water "β" and *M. ocellata* placed eggs on mud "γ". These are contact sitting-oviposition though not into substrates but merely on substrates, because their ovipositors are reduced and cannot deposit eggs into substrates. According to the classification recently proposed by SCHMIDT (1975), *Micrathyria's* cases belong to "*3-b*" (ovipositor reduced to vaginal valves or completely reduced, eggs laid single or in egg-mass), while Eda's "*a*" and "*b*" belong to Schmidt's "*1-b*" (deposit single eggs into substrates, ovipositor with supporting ridges). CORBET (1962) mentioned



Figs. 3-4 *Davidius moiwanus taruii* Asahina & Inoue: egg-masses deformed from egg-strings. (Photo N. Shimizu).

another type of sitting-oviposition observed in two species of tropical libellulids: "A species of *Tetrathemis* has been seen by FRASER (1932) to alight on a leaf some feet above the water and exude an egg mass which adhered to it", and "The African libellulid, *Brachythemis lacustris* settles to oviposit, and lays its eggs in a gelatinous mass which adhered to an emergent aquatic plant about 2-5 cm above the water level". This is again a contact sitting-oviposition on

substrates, though the substrates are not in the water but some distance above the water. This type which we would like to name "δ", somewhat resembles non-contact sitting-oviposition "*h*", but in the former the eggs leave the abdomen by adhesion to substrates while in "*h*" eggs or egg-strings leave the abdomen by their own weight.

Egg-mass formation has often been reported in the *Corduliidae* (*Tetragoneuria* [= *Epitheca* after WALKER, 1966] *cynosura*, WALKER, 1953; *E. spinigera*, KORMONDY, 1959; *E. bimaculata bimaculata*, ROBERT, 1958; *E. bimaculata sibirica* and *E. marginata*, SONEHARA, 1967) and in the *Gomphidae* (*Gomphus vulgatissimus*, ROBERT, 1958; *G. postocularis*, EDA, 1973; *Stylurus nagoyanus*, ISHIDA, 1973; *Anisogomphus maackii*, OBANA, 1974). An egg-mass is formed by extrusion from the genital opening during sitting and is released during flight either by touching some solid object in the water (in the form of an egg-strand: *Epitheca*, "*e-2*") or by touching the water surface (*Gomphidae*, "*e-1*"). Non-contact sitting-oviposition "*h*" is different from them, because the eggs are extruded during sitting and are released during sitting without touching any object.

DISCUSSION

It is impressive that the question pending for fifteen years since EDA's supposition (1960) was solved by two successive cases observed by Naraoka and Shimizu within an interval of fifteen days of the same month, by the same species, though different subspecies. This type, non-contact sitting-oviposition "*h*" would be quite suitable for poor hoverers such as the females of the two subspecies of *D. moiwanus* laying eggs on wet mosses, while non-contact flying-oviposition "*f*" for good hoverers such as *Sympetrum* species. In NARAOKA's case (1975), *D. moiwanus moiwanus* laid eggs also in type "*f*", but the eggs were spread on wet mosses. Thus, "*h*" and "*f*" in *D. moiwanus* are confined to wet mosses. What advantages can they expect by not being laid into the water surface directly? We are inclined to think that they survive in a smaller, isolated aquatic environment, lying in mossy marshes during quite helpless earlier stages. They may be pushed out later (e.g. by heavy rain), after they have attained a larger size, into a larger environment, where they can grow avoiding the disadvantages due to over-population.

Moniliform egg-strings in "*h-2*" might be considered to be a substitute for egg-strands in "*e-2*". The egg-strand must be stuck to the abdomen so as not to be released on its way to the oviposition site. Therefore, it is necessary to be released at the oviposition site by touching some solid object in water, but a moniliform egg-string may be released freely during sitting or flying. Thus, the moniliform egg-string may be substantially different from the egg-strand. In fact, the former has eggs lying in a row and not covered with a thick envelope, so each

egg in the string is easily observed (Fig. 2), while the latter has many – at least several – eggs in every cross section (ROBERT, 1958; SONEHARA, 1967) and they are covered with a thick gelatinous envelope causing it to be a broader strand. KORMONDY (1959) called the latter "a gelatinous string or strand", and we like to call it "egg-strand" in contrast to the "egg-string" or "moniliform egg-string" of "*h-2*".

As to the moniliform egg-string formation, we have looked for any special structure in the valvula vulvae of this subspecies. The valvula vulvae of *D. moiwanus taruii* are generally not visible and are hidden by the tergum when viewed laterally, but become visible when erected (Fig. 1). Among many specimens in hand, we found a single one with half erected valvula vulvae as shown in Figure 5. The shape is much the same in the other subspecies of *D. moiwanus* and different species of this genus (ASAHINA, 1950; ASAHINA & INOUE, 1973). Therefore we came to think that the egg-string formation would have a relationship with the adhesive character of the eggs.

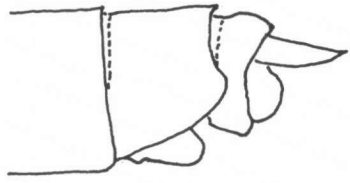


Fig. 5. *Davidius moiwanus taruii* Asahina & Inoue, ♀: half erected valvula vulvae, lateral view (Muraoka-cho, Hyogo Prefecture, Japan, May 25, 1967; K. Tani leg.).

Eggs, if covered with very strong adhesive may not leave the abdomen without the aid of a releasing action of some kind. Immersion in the water will lower the adhesion. Touching the water surface will be aided by the surface tension of the water as well as the wiping and washing action of the water. Touching a substrate will be quite effective. Shock by flicking of the abdomen will also act to release. Those with weak adhesion will leave very easily. The weight of the egg-string when it arrives at its breaking length will be rather light when the adhesion is weak. Thus the releasing mechanism will be classified into several steps with one or a combination of the above mentioned releasing actions, depending on the strength of adhesion as follows:

(1) Sitting-oviposition on substrates in water "α" "β": adhesion of adhesive to substrates surpassing that to abdomen + lowering adhesion by immersion;

(2) Sitting-oviposition on substrates above water "δ": adhesion of adhesive to substrates surpassing that to abdomen;

(3) Flying-oviposition into water as egg-strand "*e-2*": touching substrates + lowering adhesion by immersion;
(4) Flying-oviposition into water as egg-mass "*e-1*": touching water surface + lowering adhesion by immersion:
(5) Flying-oviposition into water as separate eggs "*e*": touching water surface (+ flicking of the abdomen);
(6) Sitting-oviposition into water as separate eggs "*c*": touching water surface;
(7) Non-contact sitting-oviposition in moniliform egg-string "*h-2*": cut by its own weight;
(8) Non-contact flying-oviposition "*f*": egg's own weight (+ flicking of the abdomen);
(9) Non-contact sitting-oviposition in separate eggs "*h-1*": egg's own weight;
(10) Sitting and flying-oviposition into substrates "*a*" "*b*" "*d*": presumably only caught by substrates.

Allied species may have allied adhesive characteristics in their eggs, causing allied types of oviposition. Four species and two subspecies are known in our oriental genus *Davidius*. ASAHINA (1945) made a general description of oviposition of this genus as follows: "Eggs are laid one by one from the horizontally held abdomen of a hovering insect". This indicates a non-contact flying-oviposition "*f*". EDA (1960) reported: "Observation of oviposition of *Davidius fujiama* and *D. nanus* revealed that their eggs fall on some shady wet mosses near the stream rather than into water directly in many cases." This falls also under the same category as above "*f*". Nothing has been brought on record about the Korean species *D. lunatus*. NARAOKA (1975) reported that the oviposition of *D. moiwanus moiwanus* is the combination of non-contact flying-oviposition "*f*" and non-contact sitting-oviposition "*h-1*". In both types the eggs fell on wet mosses or sands near the stream one by one from the abdomen, without flicking. *D. moiwanus taruii* also revealed the same combination though the latter predominates and with the addition of moniliform egg-string "*h-2*" with "*f-2*". In our opinion, "*h-1*" may shift to "*h-2*" under very humid conditions. We have a rainy season in summer from the beginning of June to the middle of July which coincides with the reproductive period of this subspecies and, in fact, "*h-2*" was observed on a cloudy and humid day with occasional rain, except at the time of this observation, while "*h-1*" was on a fine day. Each species or subspecies may have diverse types of oviposition (PAULSON, 1969; EDA, 1975).

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