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Egg Release and Egg Load in the Japanese Skimmer *Orthetrum japonicum* (Odonata, Libellulidae) with Special Reference to Artificial Oviposition

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Abstract Egg release rates were examined for the Japanese skimmer *Orthetrum japonicum* by dipping the abdomen of females in vials of water. The duration of egg release was about 100 sec. The number of eggs released was about 200 to 300 in both paddy fields (oviposition sites) and forests (roosting and feeding sites). Some eggs were unfertilized. The number of eggs released correlated with the number of mature eggs loaded in the abdomens. The release rate also increased linearly with the number of mature eggs loaded. Egg release was thus primarily determined by the number of mature eggs in ovaries.

Key words: Artificial ovipositition; egg release; egg load; mature eggs; *Orthetrum japonicum*.

Introduction

One important element in the progress of the study of reproductive success is to develop new techniques which estimate the number of eggs actually laid. This is particularly important in studying some dragonflies under natural conditions. WATANABE and TAGUCHI (1990) estimated the reproductive success of a damselfly, *Mnais pruinosa*, by measuring the duration of oviposition posture of a female.

Techniques of investigation have been developed for research on the egg laying habits of libellulid dragonflies (*e. g.*, MCVEY, 1984). Some of them easily released eggs once their abdominal apices were submerged (*e.g.*, IVEY *et al.*, 1988). OBANA (1979) reported that skimmers, *Orthetrum* spp., often released eggs even in a glassine envelope after they were captured.

Following the procedure outlined below, we examined the oviposition duration, the number of eggs laid in relation to the number of eggs loaded and the egg releasing rate of a skimmer, *O. japonicum*. WATANABE and HIGASHI (1989) reported that skimmer females spent much time in forests (=hills) and only visited paddy fields to mate and oviposit. The data were analyzed for the difference between females captured in the hills (roosting area) and those captured in paddy fields (reproductive area).

Materials and Methods

During the flight season of the skimmer *O. japonicum* (between April and June, 1990), sexually mature females were captured in forests and paddy fields in Mie Prefecture, central Japan. We captured the skimmers on sunny and windless days (total 22 days). Most of the skimmer females which we encountered (about 90%) were successfully collected with a total of 87 females captured for the study.

After capturing a skimmer, we gently grasped its wings and folded them over its back. Immediately after the capture, the terminal part of the abdomen (3 or 4 segments) of each female was repeatedly submerged vertically in a vial of water, until egg release stopped. This method ensured easy release of eggs by the female skimmer. The temperature of the water in the vial was 28.1±0.4°C (±SD, n=119).

In the field a female flying over water taps its abdomen on the surface of the water. According to preliminary observation on natural oviposition, the female dipped the abdominal apex two times per second. Each female continued such dipping for 3 min. Out of 87 females captured, 15 specimens released no eggs. They were discarded.

After the artificial oviposition, females were placed in 50% ethyl alcohol for dissection under a binocular microscope. The mature eggs in the ovaries were counted. They were oval with a resilient chorion, and difficult to break even with a needle. They matured sufficiently to be laid (HIGASHI & WATANABE, 1993). Eggs artificially laid were reared in a petri dish in the laboratory to examine their hatchability.

Results and Discussion

Females of *O. japonicum* awaiting sexual maturity were located in the hills (WATANABE, 1986). Sexually mature females stay there and visit paddy fields for a short time for oviposition and mating (WATANABE & HIGASHI, 1989). HILTON (1983) reported that female *Cordulia shurtleffi* had never, or seldom, searched the oviposition sites for prey. In most dragonfly species, females that exhausted most of their mature eggs require a lot of prey insects in order to develop their immature eggs (MILLER, 1987). These females tend to spend much time in forests for foraging (WATANABE & HIGASHI, 1989). Accordingly, females appearing in paddy field need to load a certain amount of eggs mature enough to be laid (FINCKE, 1986).

In the experiment of artificial oviposition, sixty-three out of 72 females started to release eggs within one minute after dipping (Table 1). The oviposition duration was about 100 seconds in females captured in the paddy fields as well as those in the forests (U-test, z=0.064, n.s.). Since there was no significant difference between females captured in the paddy fields and the forests (U-test, z=0.988, n.s.), they both released 200 to 300 eggs as a result of this procedure. CORBET (1962)

Table 1. Oviposition duration, the number of eggs released, proportion of abnormal eggs and hatchability in females of *O. japonicum* captured in the paddy fields and the forests, respectively (±SE).

Starting time for egg release from the artificial oviposition (sec)		0–20	20–40	40–60	60–80	80–100	100–120	Total*
Number of females investigated	Paddy fields	17	5	3	2	1	0	28
	Forests	31	5	2	2	3	1	44
Oviposition duration (sec)	Paddy fields	87.6±11.9	109.2±10.8	99.3±29.9	32.0±27.0	68.0	—	88.1±8.7
	Forests	104.9±16.8	101.2±43.5	111.0±30.0	28.5±27.5	69.3±39.3	236	101.8±13.5
Number of eggs released	Paddy fields	204.5±57.8	300.8±120.4	204.7±91.7	117.5±110.5	45.0	—	209.8±42.4
	Forests	365.8±48.8	358.8±184.0	245.5±203.5	36.0±35 0	154.0±131.2	201	326.4±42.5
Proportion of abnomal eggs (%)	Paddy fields	0.78±0.44	0.48±0.24	1.94±1.81	0.00±0.00	0.0	—	0.76±0.32
	Forests	0.69±0.58	0.03±0.03	0.00±0.00	0.00±0.00	0 00±0.00	0.5	0.50±0.41
Hatchability (%)	Paddy fields	82.2±3.3	87.2±4.8	84.3±8.8	87.0±13.0	89.0	—	83.9±2.4
	Forests	88.7±3.0	81.4±4.1	77.5±22.5	100.0±0.0	60.7±13.3	10.0	84.2±3.2

* Values are for the statistical analysis, see text.

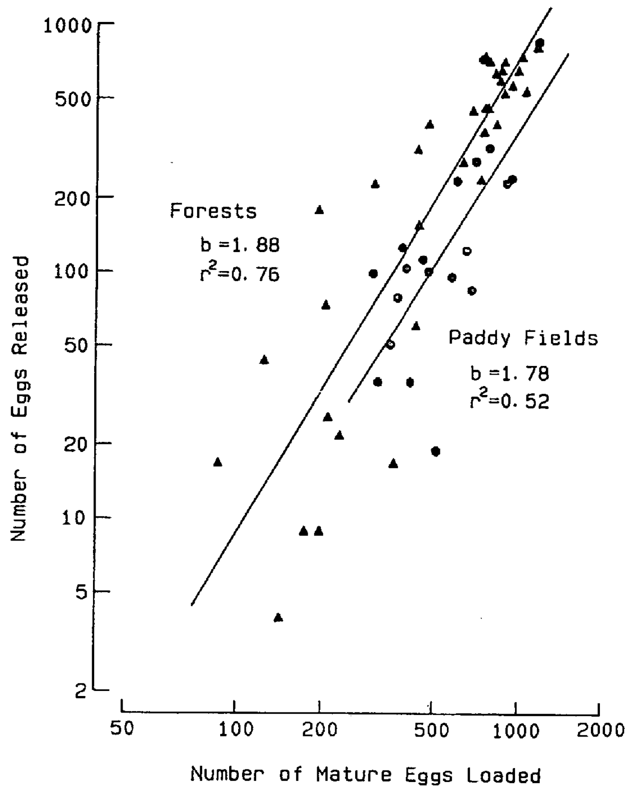

Fig. 1. Relation between the number of mature eggs loaded and the number of eggs released for females captured in paddy fields (circle) and forests (triangle).

pointed out that some libellulids release from a few hundred to a few thousand eggs within 5 min. HIGASHI and WATANABE (1993) estimated that *O. japonicum* laid about 300 eggs daily.

The release rate of female *O. japonicum* was about 2.0 to 3.5 eggs/sec. MCVEY (1984) reported that egg release rate ranged from a low of 1.3 eggs/sec for *Sympetrum rubicundulum* to 28 eggs/sec for *Plathemis lydia*, and concluded that egg flow rate increased with abdomen length among libellulids. In fact, egg release rate for *O. ferruginea* with the abdomen length of 36–39 mm was 18.0 eggs/sec (MCVEY, 1984), while that of *O. japonicum* was less than 30 mm.

MCVEY (1984) found that the egg hatching success of *Erythemis simplicicolis* under artificial conditions was 97%. Hatchability of the Japanese skimmer was about 84% in each oviposition bout despite the difference in habitats (each hatchability was transformed by angular transformation, F=0.644, n.s.) and the time after artificial oviposition. A few eggs were white or abnormal in shape. They were regarded as unfertilized or dead eggs, because none of them hatched. The proportion of unfertilized eggs was less than 1% both in paddy fields and in forests (each proportion was transformed by angular transformation, F=1.323, n.s.).

Egg load here means the total number of mature eggs that have been released

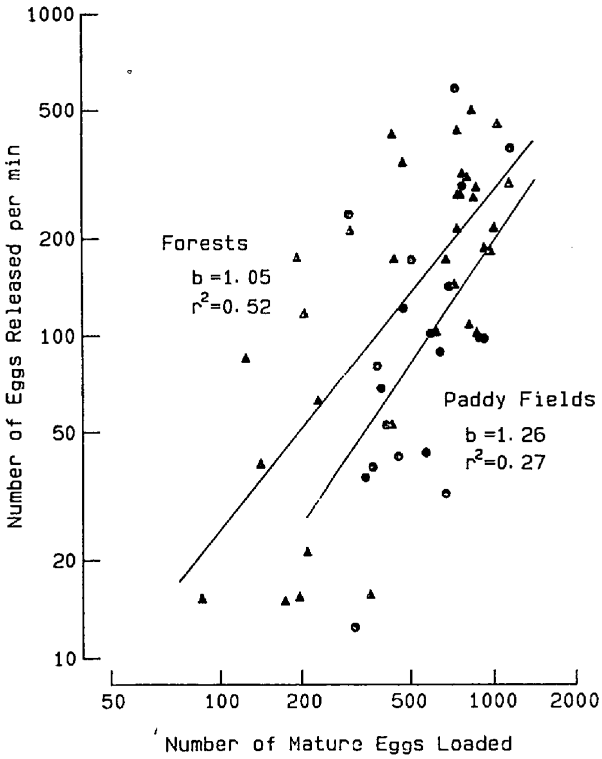

Fig. 2. Relation between the number of mature eggs loaded and egg release rate (No./min) for females captured in paddy fields (circle) and forests (triangle).

and those remaining in the ovaries. There was a positive correlation between the number of the eggs loaded and the number of eggs released. The regression coefficient of the paddy fields and that of the forests was 1.78 ($r^2=0.52$, $P<0.001$) and 1.88 ($r^2=0.76$, $P<0.001$), respectively (Fig. 1). This shows that the number of eggs released may be determined by the number of the eggs loaded wherever the females were captured. No significant difference was observed in the regression coefficients between the paddy fields and the forests ($F=0.048$, n.s.).

There was also a positive correlation between the number of eggs loaded and the number of eggs released per min (Fig. 2). The regression coefficient was 1.26 ($r^2=0.27$, $0.025>P>0.01$) in the paddy fields and 1.05 ($r^2=0.52$, $P<0.001$) in the forests. There was no significant difference between them ($F=0.163$, n.s.). Therefore, the egg release rate was determined by the number of mature eggs developed in ovaries.

The artificial oviposition method thus showed a few effects that caused serious disturbance for releasing eggs in the skimmer. Possible effects of other traits, *e.g.*, age, mating frequency, and the like, need to be investigated. However, with minor modifications we feel that our techniques will be applicable to a broad spectrum of field studies on dragonfly species.

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