LIFE HISTORY OF *SYMPETRUM STRIOLATUM IMITOIDES* BARTENEF AT AN OUTDOOR SWIMMING POOL IN AN URBAN AREA (ANISOPTERA: LIBELLULIDAE)

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Although natural odonate habitats have decreased recently due to disappearance of ponds from urban areas, it is shown that outdoor swimming pools during the off season become available as a habitat for some spp. Out of 24 swimming pools at primary schools in Kyoto city (Japan) examined during the period from late May to early June, late instar larvae of *S. s. imitoides*, *S. frequens* and *S. darwinianum* were found in 22 (92%), 9(42%) and 2(8%), resp. The life history of *S. s. imitoides*, the most common of these, was investigated at the swimming pool of one primary school. Larvae were distributed contagiously in detritus settling towards the periphery of the pool, and we estimated the number of last instar larvae in late May as ca 2000. There were numerous chironomid larvae in the pool which the larvae of *S. s. imitoides* consumed preferentially. Adult emergence was observed from the end of May but was interrupted due to poolcleaning. Mature dragonflies sought out the pool in Oct. and males established territories for 1-18 days. It is concluded, the reason why *imitoides* larvae are found so commonly at swimming pools is that, their life history pattern of laying eggs in Oct. with adult eclosion the next June coincides with the non-use period of the pools, and females lay eggs directly into the water.

INTRODUCTION

Many natural ponds have disappeared from urban areas and their outskirts during the last few decades in Japan (MATSURA, 1994). It can be inferred that the number of species and individuals of dragonflies living in ponds have also decreased. On the other hand, there are several species of odonate larvae that can live in artificial water-bodies such as reservoirs in urban areas. These species include *Pantala flavescens* (Fabr.), *Orthetrum albistylum speciosum* (Uhler) and *Pseudothemis zonata* (Burm.) (ISHIDA, 1969; T. Matsura, unpublished). Among artificial ponds within cities, the outdoor swimming pools of primary schools have comparatively large water surfaces (25 m × ca. 15 m) and are large in number. For example, there are 23 swimming pools at primary schools within a 3 × 4 km area in the center of Kyoto (T. Matsura, unpublished).

ROKUYAMA (1964) first noted that larval odonates, such as *O. a. speciosum* and *Anax parthenope julius* Br., inhabited the swimming pool of his junior high school during the non-swimming season, but this study has been largely overlooked. Odonate larvae have recently attracted people's attention as a vehicle for environmental education (OGAWA, 1992; C. Imai et al., unpublished; UMEDA, 1993). OGAWA (1992) and C. Imai et al. (unpublished) showed that the larvae of *Sympetrum striolatum imitoides* Bart. are most common in the swimming pools of primary schools in the cities of Nishinomiya and Osaka, respectively. However, no ecological studies on *S. s. imitoides* in such swimming pools have been reported to date.

In the present study, we first investigated the distribution of the larvae of *S. s. imitoides* in Kyoto city. Then, to clarify why the larvae of *S. s. imitoides* are so dominant in swimming pools, we examined, in one swimming pool, (i) the seasonality of reproduction and reproductive behaviour, (ii) growth of the larvae and (iii) the season of the adult eclosion.

MATERIAL AND METHODS

SPECIES COMPOSITION OF DRAGONFLY LARVAE IN SWIMMING POOLS. – To examine the distribution of *S. striolatum imitoides* larvae in the outdoor swimming pools of primary schools in Kyoto city, we took 18 samples in 1992 and 6 in 1993 during the period, late May - early June. Sampling was conducted by sweeping detritus on the bottom of the pool with a semicircular aquatic net whose diameter and mesh size were 35 cm and 2 mm, respectively. We twice swept the bottom of each pool along its longer side (25 m). Late instar larvae of dragonflies were found among the detritus, which was rich in phytoplankton such as desmids (T. Bando, pers. comm.), and fallen leaves.

LIFE HISTORY OF *S. STRIOLATUM IMITOIDES*. – Our investigation was carried out in the outdoor swimming pool of Momoyama Primary School, where the highest density of larvae had been noted in 1992. The size of this pool was 25 m × 13 m and the water was filled to a height of ca. 110 cm.

Growth of larvae. – Early instar larvae were collected by vacuuming detritus with a hand-operated pump once a month from December 1992 to March 1993. Sampling was conducted at four points (quadrat size, 1 m^2) in the pool, two of which were located at corners. We stored all the animals collected in alcohol. Late instar larvae were collected by net once about every 10 days from mid April to the end of May 1993. We measured the head width of these larvae with a micrometer inserted in a binocular microscope then released them again into the pool.

Spatial distribution pattern of the larvae in the swimming pool. – We took samples at random from 50 points within the swimming pool on 17 May 1993 to investigate the spatial distribution pattern of the larvae. Sampling was conducted by sweeping detritus on the bottom with a net from a rubber boat. The sampling area at each point was 0.16 m^2 (32 cm × 50 cm).

Adult emergence. – Since there were few places suitable for adult eclosion around the pool, we hung nets (0.9 m in height and 23 m long) along the two longer sides of the pool to facilitate eclosion. We collected the exuviae left on the nets every morning from 29 May to 10 July 1993.

Reproductive behaviour. – Reproductive behaviour of mature dragonflies was observed at the poolside during the day (1000 a.m. - 0400 p.m.) from 22 September to 16 November 1992. We captured them once and wrote individual numbers on their forewings with a paint marker (Mitsubishi PX--20), then released them. Subsequently we were able to record the resting positions of marked males around the poolside. Numbers were read using binoculars.

SPECIES COMPOSITION OF DRAGONFLY LARVAE IN SWIMMING POOLS

Late instar larvae of *S. striolatum imitoides* were found at most swimming pools (92%) at primary schools in Kyoto (Tab. I). The maximum number of larvae of *S. s. imitoides* per sample was 107. Every school was surrounded by houses and buildings and there were only sparse trees around the swimming pools. Odonate larvae, however, were found at all the swimming pools except one.

The second most common species was *S. frequens* but their densities were very low in swimming pools. The average number of larvae per sample for a third species, *S. darwinianum,* was large (Tab. I), but this is because their larvae occurred at a very high density at one primary school. Overall they occurred in only two pools.

Table I

Species and number of dragonfly larvae collected at swimming pools at primary schools in Kyoto city. Numbers in parentheses show the percentage of the total number (24) of swimming pools examined

Species	No. of pools*	No. of larvae collected per pool (± S.E.)**
Sympetrum striolatum imitoides	22 (92%)	28.2±5.5
S. frequens	9 (42%)	1.9±0.5
S. darwinianum	2 (8%)	20.5±12.5
S. baccha matutinum	1 (4%)	1
Orthetrum albistylum speciosum	1 (4%)	1
None	1 (4%)	0

* No. of swimming pools where the existence of the larvae was confirmed.

** These were obtained based only on the pools in which each species was found.

LIFE HISTORY OF *SYMPETRUM STRIOLATUM IMITOIDES* IN THE SWIMMING POOL

GROWTH OF THE LARVAE

Figure 1 shows the histogram of head widths of the larvae based on pooled data. There are four marked peaks, indicating modes for Nth to (N-3)th instars at 5.7, 4.5, 3.4 and 2.6 mm, respectively. First instar larvae were first collected on 9 December. Their stadium was determined by comparing the head width (0.43±0.02

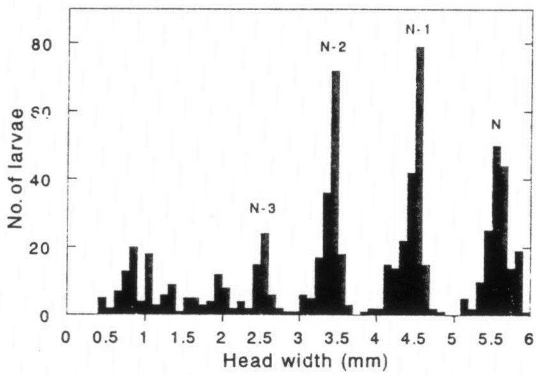

Fig. 1. Histograms of head widths of larval *S. striolatum imitoides* based on the pooled data. Probable instars are indicated.

mm) with those of larvae hatched from eggs in the laboratory.

The larvae grew rapidly from April, though their growth rate had been low before March (Fig. 2). Extremely high densities of chironomid larvae occurred in the pool through the winter and the spring (Fig. 3); there seemed to be several species but we did not identify them further. Many larvae of the mayfly, *Clöeon dipterum*, were also found. It is clear that the late instar larvae of *S. s. imitoides* mainly consumed the larvae of chironomids and mayflies because their undi-gested remains, such as mouth parts or compound eyes, were found in most faecal pellets of the *imitoides* larvae collected at the pool.

SPATIAL DISTRIBUTION PATTERN OF THE LARVAE IN THE SWIMMING POOL

The larvae usually stayed upon or within detritus. The detritus was distributed mainly on the bottom and around the periphery of the pool. The density of the larvae per quadrat was also higher at the periphery than in the central area (Fig. 4; average no. of larvae per quadrat, 2.19±2.01 [n=16] for periphery; 0.85±1.35 [n=34] for centre; $t=2.776$, $P<0.01$). In order to analyze the spatial distribution pattern, MORISITA's (1959) I_δ index was calculated. The value of this index characterizes the spatial distribution as uniform ($I_\delta<1$), random ($I_\delta=1$) or aggregated ($I_\delta>1$). The value obtained (1.96) for *imitoides* indicated that their distribution pattern is aggregated. This is possibly caused by the aggregated distribution of the detritus. We roughly estimated the tótal

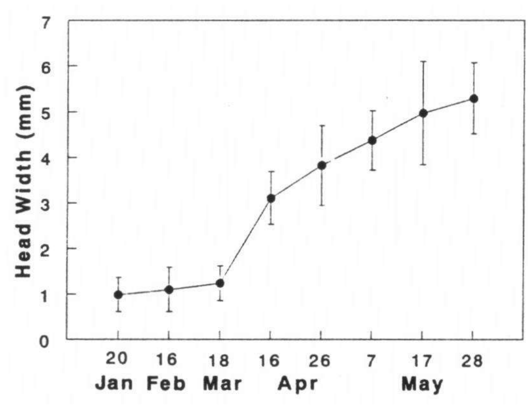

Fig. 2. Seasonal change in the average head width (±s.d.) of larval *S. striolatum imitoides*.

number of late instar *imitoides* larvae in the pool, based on the average numbers of larvae per sample. When the detritus band around the periphery of the pool was 50 cm wide, we estimated a total of 2041 larvae: for a band 30 cm wide, the total would be 1920.

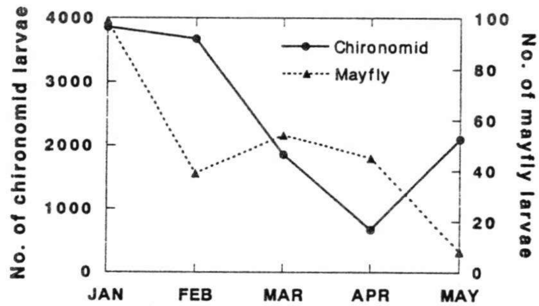

Fig. 3. Seasonal changes in the numbers of chironomids and mayflies per quadrat (1×1 m) during the developmental period of larval *S. striolatum imitoides*.

ADULT EMERGENCE

Adult eclosion was observed to occur only at night. Adults eclosed even on rainy nights and there was no significant difference in the average number of adults eclosing between rainy nights and non-rainy nights (rainy, 17.3±15.0; non-rainy, 13.7±13.3; t=0.357, P>0.7). Adult emergence began from the end of May and increased rapidly from 7 June. The survey was interrupted on 10 June because of pool-cleaning (Fig. 5).

REPRODUCTIVE BEHAVIOUR

Mature *imitoides* adults sought out the swimming pool over a period of about

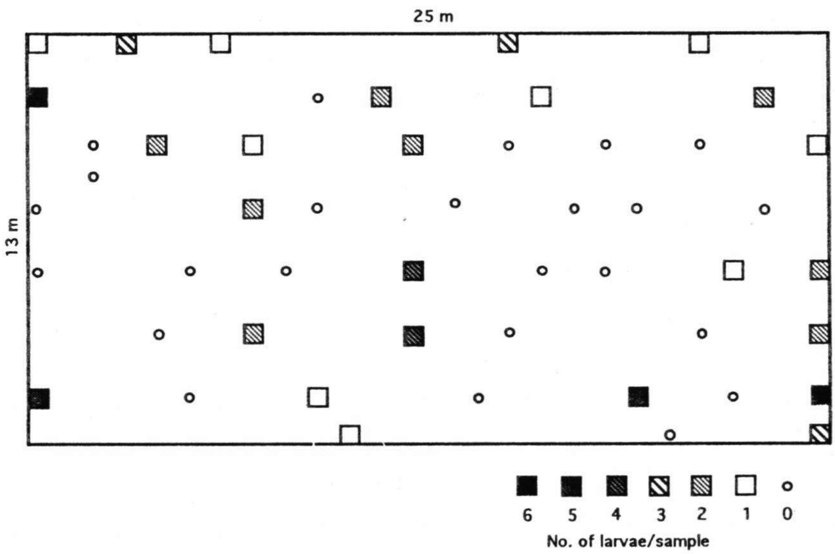

Fig. 4. The spatial distribution of larval *S. striolatum imitoides* in the swimming pool. The numbers of the larvae per random sample (32×50 cm) are shown.

one month from the beginning of October to the beginning of November (Fig. 6). They mainly appeared during the late morning (Fig. 7).

Males often perched on the poolside, and flew out to mate with females coming to the swimming pool or to attack males invading their territories. They sometimes patrolled over the water and even pursued another species of *Sympetrum*. Locations where males perched seemed to be fixed for each individual. The maximum number of males at the swimming pool at any one time was three. Three out of ten males which we had marked never returned but seven males appeared at the pool twice or more (Fig. 8). The longest period over which a male maintained a territory was 18 days. He perched habitually at or very close to the same place.

In contrast, the duration of stay at the pool by females was very short. Although females laid eggs while in tan-

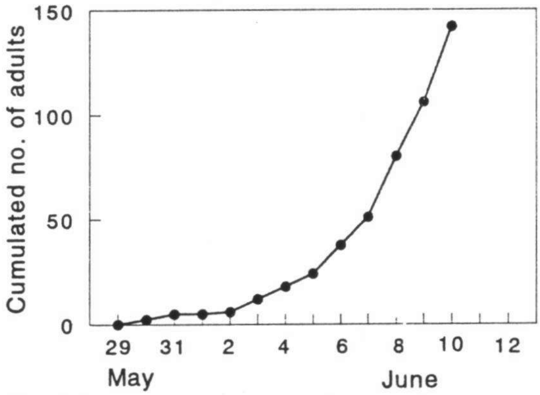

Fig. 5. Seasonal change in the cumulative numbers of adults of *S. striolatum imitoides* emerging from the pool.

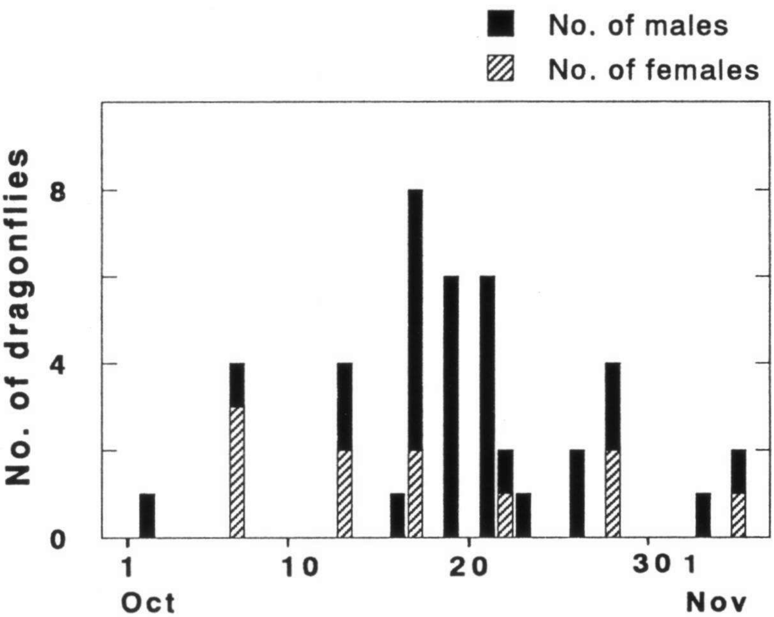

Fig. 6. Seasonal change in the number of *S. striolatum imitoides* observed at the swimming pool.

dem with males, many females appeared singly and laid eggs by beating their abdomens against the water surface. Females flew away immediately after oviposition. Two dissected females contained, respectively, 1211 and 2097 mature eggs in their ovaries.

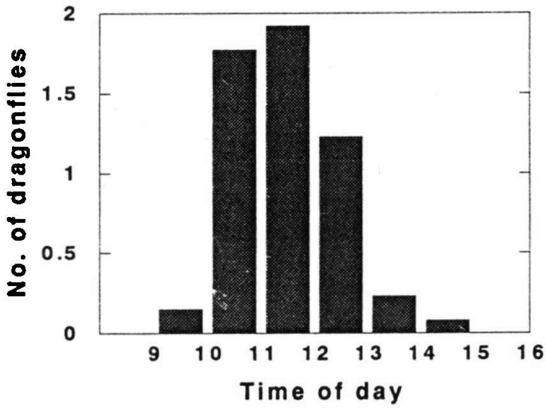

Fig. 7. Time of day when the adults of *S. striolatum imitoides* were observed at the swimming pool. Average numbers of dragonflies per hour were calculated from pooled data on residence time of individual dragonflies.

DISCUSSION

In the present study we confirmed that larvae of *S. striolatum imitoides* occurred in the outdoor swimming pools of most primary schools surveyed in Kyoto city. Previous reports note that it spends its larval period in ponds near the coast, and returns there to lay eggs after spending a feeding period in the mountains (OBANA, 1969). There has been no previous report of either larvae or adults of *imitoides* in Kyoto prefecture (HAMADA & INOUE, 1985), probably because Kyoto city is distant (about 50 km) from the coast. Kyoto city is surrounded by mountains. Adults of *imitoides* coming from the coastal area by Osaka Bay may spend their feeding period in the mountains located to the southwest of Kyoto city, and some of these may not return to the coast but colonize swimming pools in Kyoto. It is unclear whether they have adopted this habitat in recent years or have been overlooked previously.

MOORE (1991) studied colonization of dragonflies in newly constructed small ponds in England for 27 years. There were 20 species breeding around the ponds,

Individual	October														November	
	2	7	12	13	14	16	17	19	21	22	23	26	28	30	2	4
1	+	-	-	+												
2		+														
3				+	-	-	-	-	+							
4						+	+	-	+							
5							+	+	+	-	+	+	+	-	-	+
6							+									
7							+	+	+							
8							+	+								
9								+								
10												+	+	-	+	

+, visiting was obserbed. -, no visiting was observed.

Fig. 8. Days on which territories were maintained by male *S. striolatum imitoides*.

originally. But two species, *S. s. striolatum* (Charp.) and *Ischnura elegans* (Vander L.) appeared first in the ponds and maintained populations there for 27 years. Most swimming pools in primary schools in Kyoto city were constructed after the Second World War. These pools may be regarded as similar to Moore's ponds except that water is drawn off every year before summer. *S. s. imitoides* also might visit swimming pools each year as a pioneer species like *S. s. striolatum* does in England (MOORE, 1991).

Unlike natural ponds, no fish live in the swimming pools. Since fish are major natural enemies of larval odonates in general, swimming pools may be very suitable habitats for *imitoides* larvae. Another reason why so many larvae may occur in the swimming pools is the high density of prey, especially chironomid larvae (Fig. 3). Every swimming pool in the primary schools is filled with tap water in mid September every year after pool-cleaning. The macroinvertebrates which first appeared in swimming pools filled with fresh water were chironomid larvae. DANELL & SJÖBERG (1982), who investigated the secondary succession in an artificial lake, also reported that Chironomidae were early colonizers and were always dominant among the macroinvertebrates in the lake. Our analysis of faecal pellets concluded that the late-instar *imitoides* larvae fed mainly on chironomid larvae. We did not examine, however, the prey composition of the diet for early-instar larvae. No Branchiopoda were observed in the swimming pools, although, in general, early instar odonates consume these preferentially. Further work is needed on the community of microinvertebrates in the pools to establish the diet of early instar odonate larvae.

OTTOLENGHI (1987) reported reproductive behaviour of *S. s. striolatum* at a small artificial pond (surface ca 25 m^2) in Italy. Reproductive behaviour of the males was similar to that of *imitoides* in Japan. However, the maximum male density of *striolatum* studied by Ottolenghi was one male per 5 m^2 (0.2/m^2) whereas that of *imitoides* in the present study was one male per 108 m^2 (0.009/m^2). There were long roofs over both the western and southern edge of the pool in Momoyama Primary School and the males never perched under the roof. Their preference for open and sunny areas restricted them to about half the pool's edge. Even considering this factor, however, there is a large difference in the male density of *s. striolatum* and that of *s. imitoides*. It may be due to a difference in male aggressiveness in the two subspecies.

Why are only *S. s. imitoides* larvae found so commonly at outdoor swimming pools? The most obvious reason is that their life cycle fits in with the swimming pool off-season (Fig. 9). The available period for dragonflies is from mid September to next June. Since water is drawn off to clean the pool at the beginning and the end of the swimming season, it is necessary for dragonflies to oviposit in the autumn and to complete their larval growth and reach eclosion by the next mid June. This is achieved by *imitoides*. A second reason is that females of this species lay eggs by touching the water surface and do not require a mud bank or plant material

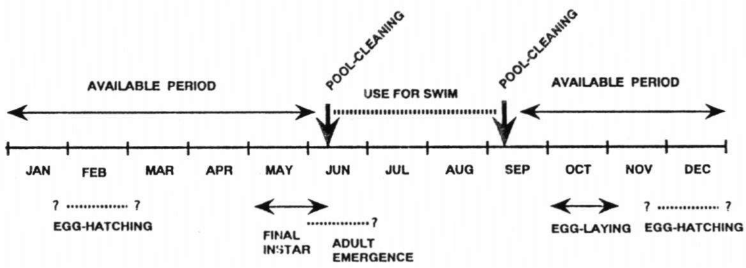

Fig. 9. Annual schedule for use of a swimming pool, and the life cycle of *S. striolatum imitoides*.

for oviposition (EDA, 1975; OTTOLENGHI, 1987). Though numerous *S. frequens* were frequently observed around the swimming pool of the Momoyama Primary School, they seldom came to the pool to oviposit because they usually lay eggs in mud (EDA, 1975). Since no aquatic plants grow in swimming pools, some groups of dragonflies and most species of damselflies, which rely on these for oviposition, would be unable to use a swimming pool as an oviposition site.

In the present study we show that outdoor swimming pools of primary schools in urban areas are substitute habitats for some *Sympetrum* species that live normally in natural ponds, and that the life-cycle pattern and the oviposition mode particularly favour *S. s. imitoides*. From the viewpoint of dragonfly conservation, it is desirable not to use algicide in these pools because algae are food for phytophagous insects such as chironomid and mayfly larvae which become the prey of dragonfly larvae. A short delay of pool-cleaning procedures in June would also allow more adults of *S. striolatum imitoides* to emerge.

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