Odonatologica 23(2): 125-132 *June 1, 1994*

AUTUMNAL MIGRATION OF MATURE *SYMPETRUM FREQUENS* (SELYS) IN WESTERN KANTO PLAIN, JAPAN (ANISOPTERA: LIBELLULIDAE)

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Received September 3, 1993 / Revised and Accepted January 28, 1994

This is an endemic sp. of Japan and has a migratory nature. Autumnal migration is a return movement of mature individuals from the highlands to the lowlands for breeding. In the study areas of the Kanto region, they take naturally the course of the foot of Kanto Mountain – Sayama Hills or Kawagoe in the Kanto Plain. This paper treats migration, and other related behaviours in the Kawagoe area.

INTRODUCTION

In Honshu, the mainland of Japan, *Sympetrum frequens* is regarded as a migratory species. Most individuals breed in the lowlands in autumn, the eggs overwinter and hatch the next spring and the larvae grow up in early summer. Tenerals migrate to the highlands, spending time there to maturate; when mature, they return to the lowlands (KINOSHITA & OBI, 1931; BABA, 1953; FUJISAWA, 1957; ASAHINA, 1984; TANAKA, 1983, 1985a, 1985b). Other recent evidence shows that, in the highlands, precocious adults breed in the summer, and larvae and emergence have also been observed (ASAHINA & EDA, 1960; SONEHARA, 1966, 1992; MIYAKAWA et al., 1972). Recently UÉDA (1988) suggested that the species has a wider range of plasticity in its life-history than previously estimated. MIYAKAWA (1989, 1991, 1992) pointed to the possibility that tenerals which emerge in the lowlands do not always migrate to the highlands, and some of them spend the summer in the lowland hills where deciduous forests are present, such as the Sayama Hills.

This paper describes characteristics of the autumnal migration and related behaviours of mature *S. frequens*, mainly on the basis of my own observations in the study areas from 1973 onwards.

STUDY AREAS

Study areas are located in the middle in a NS-span, and on the W side in an EW-span of Kanto Plain, including Sayama Hills and Kawagoe. The Kawagoe investigation area is located 15 km E from the foot of Kanto Mountain and 15 km NE from Sayama Hills (Fig. 1).

OBSERVATIONS AND DISCUSSION

MATURE INDIVIDUALS FOUND AT THE FOOT OF KANTO MOUNTAIN IN AUGUST

Short time observations were carried out in late August 1992 at 4 points along the foot of Kanto Mountains.

22 August, at Kuroyama (150 m a.s.l.). The head stream of Oppe R., 10 ♂, 5 ♀, on twigs or electric wires, 5-10 m above ground in the valley, and 26 individuals on the wires (20 m long, 10 m above ground).

25 August, at Ogose (100 m a.s.l.), mature 6 ♂, 7 ♀ perching on twigs of cherry trees or lower plants under trees (0.3-5 m above ground) along a stream at the foot of the mountain. Furthermore, many individuals were found on the tree tops up-stream.

The same day, at Kamakitako (artificial lake, 150 m a.s.l.), mature 23 individuals perching on twigs, 1.5-10.0 m high, of trees along the shore and 17 individuals on the electric wires, 10 m above the water surface. A total of 40 individuals was counted during 5 minutes.

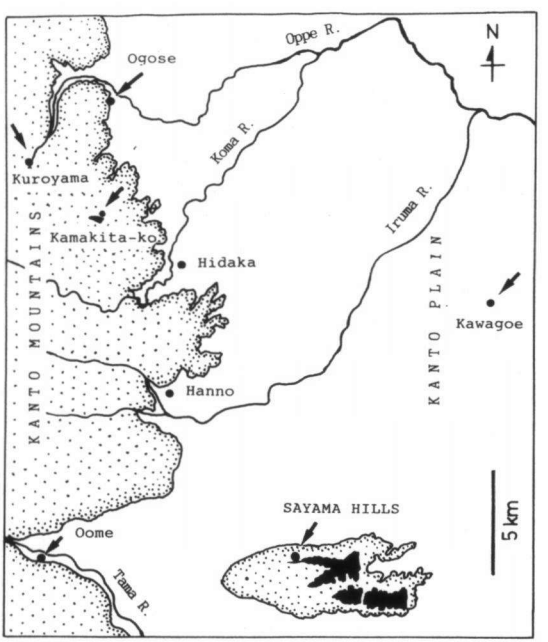

Fig. 1. Map of the observation areas. Contour lines of mountains and hills indicate 100 m above sea level. Surveyed areas are indicated by arrows. (From MIYAKAWA, 1992).

27 August, at Oome (165 m a.s.l.) and adjacent road 4.5 km along Tama R. At Oome, 25 individuals perching on trees and electric wires (5-10 m above ground) were counted during 3 min. A further 114 individuals were counted from our car running at 50 km/h along the road for 4.5 km.

From these brief observations along the foot of Kanto Mountain, I became aware of the following points: In late August, (1) mature *S. frequens* populated the border of the mountain foot; – (2) their daytime microhabitats were seen only at the place where there was dense cover of forest along the edge of a steep slope; – (3) electric wires (5-10 m high) at or near the forest were used as a preferred perch, equivalent to tree twigs of the same height. – The above (1) and (2) are the same as observed in Sayama Hills. The mountain foot populations were regarded as in the phase waiting to migrate towards the lowland plains.

What kind of external factors release the migration of *S. frequens* inhabiting the foot of Kanto Mountain? In the hot late summer, possible one factor is the decrease in temperature. Observations in Sayama and Kawagoe revealed that the mass immigration to Sayama (25-VIII-1991 and 7-IX-1992) and the first immigration to Kawagoe occurred almost concurrently, just after the sharp decrease in the temperature (4-8°C within one or two days).

INCREASE IN MATURE INDIVIDUALS IN THE SAYAMA HILLS IN AUGUST

Sayama Hills, less than 200 m a.s.l., are covered with well grown deciduous forests, mainly composed of *Quercus* trees, and the temperature is ca 3°C lower than the neighbouring town areas of the plain. Tenerals migrated to the Hills at the end of June or early July, and their number increased till mid-July and then decreased to a minimum in early August. Entering mid-August, premature and mature individuals appeared and the number of mature dragonflies increased further. In late August or early September, sharp increases of immigrants, probably from the foot of Kanto Mountain were observed several times each year (MIYAKAWA, 1989, 1991, 1992).

FLUCTUATION OF NUMBERS AT KAWAGOE IN EARLY AUTUMN

In the autumn of 1991, the first immigrants were recorded on 26 August. The number was 82. Thereafter the number was counted every day until 1 September. In this period, the number decreased gradually until 30

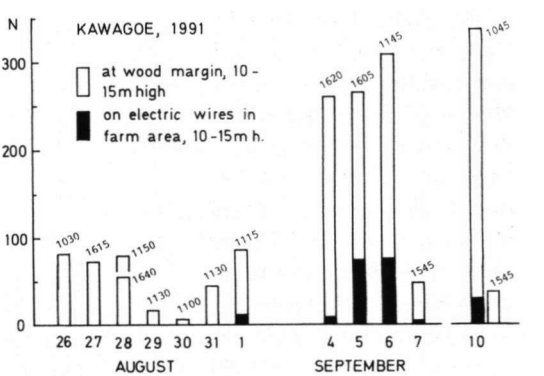

Fig. 2. Number of matures present at Kawagoe from the first arrival on 26 August to two weeks later, in 1991. On 10 September the number of individuals was 337 at 1045 h, whereas it was reduced to 68 at 1545 h. This reduction seems to be due to emigration which probably occurred in the afternoon.

August and then increased. On 4 September the number increased to three times as high as that of the first week of immigration (Fig. 2).

On 28 August and 10 September, observations were made twice a day (in the morning and in the afternoon). These revealed that on both days the number was higher in the morning than in the afternoon. The decrease in number in the afternoon suggested that a number of individuals had emigrated from the observation area, probably in the afternoon, as is also described later.

TANDEM MIGRATION AND SINGLE MIGRATION

Mature individuals of *S. frequens* behave sexually in the mornings and are solitary in the afternoons. Consequently, the morning migration is performed in tandem and the afternoon migration in the single state (MIYAKAWA, 1976; ARAI, 1978).

Direct observations of the tandem and single migrations during one day at Kawagoe: On 24 September 1984, I had an opportunity to observe both migrations near or at my house. The weather was sunny and warm throughout the day.

In the morning (0800-0915 h), a great number of tandems appeared from the South. Some pairs stayed on the wing 1 m above the raddish farm to search the oviposition sites. There was no water body, but a plastic sheet was being used to protect the plants from drying up. Most of the pairs oviposited faultily on the dry surface of the sheet.

In the afternoon (1500 h) I found some single individuals migrating towards ESE for the first time. Then I began to count them from a West side window of my room on the second floor of my house. The range of vision from there is restricted horizontally 50°, vertically 30° and 45 m in depth where electric wires (15 m high) are crossing. As the dragonflies flew at a low speed (ca 7 km/h), approaching me in the range of vision, they were easily counted. The counting was made at 5 min intervals, and the temperature and light intensity were recorded (Fig. 3).

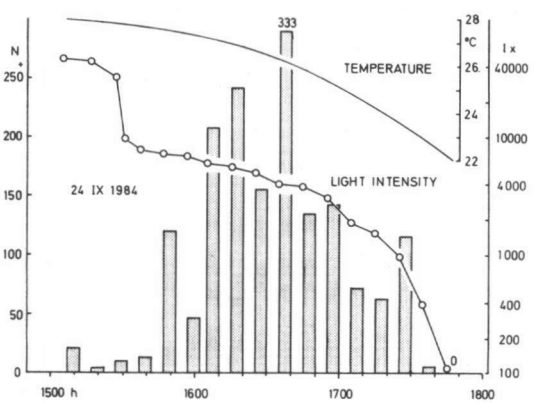

Fig. 3. Temporal change in the number of migrating matures at Kawagoe and in temperature and light intensity. Migration ceased when the light intensity fell to about 100 lux.

The migration continued from 1500 h to 1740 h, with a peak frequency of 333/5

min at 1640 h. The light intensity and temperature at the end of the migration were 100-200 lux and 22°C, respectively. 1694 individuals passed through the observation space within the counting period (mean 21.1/min; max. 66.6/min).

Two previous dates in the same observation area are added here, viz. 27 September 1982; 1640-1730 h, orientation ESE, total N=956, max. N=307 at 1702 h, end 1721 h, 70 lux; – 4 October 1982: 1600-1630 h, orientation ESE, total N=11, max. N=6 at 1610 h, end 1630 h, light intensity unknown.

These three sets of data reveal that the density of migrating individuals varied according to day and time of day.

Where had the single migrants passing or arriving at Kawagoe started from, and when did they start?

If the orientation (ESE) and the migrating speed (7 km/h) were constant, the foot of Kanto Mountain is a highly possible supplying area, because Kawagoe is located about 15 km from there and hence the migrants would be able to reach Kawagoe in about 2 hours. If so, the first and last groups on 24 September 1984 would have started from the foot of Kanto Mountain at about 1300 h and 1500 h, respectively.

ORIENTATION OF MIGRATION OBSERVED AT KAWAGOE

From 1973 onwards, I have recorded 39 single mass migrations in the afternoons at Kawagoe (MIYAKAWA, 1976, and unpublished). The orientation ranged from ESE to NNE (about E on average) (Fig. 4). This range of orientation would allow for dispersal all over the Kanto Plain. However, compared to the orientation of tandem migrations (nearly N or NE), the average orientation of single migrations differs.

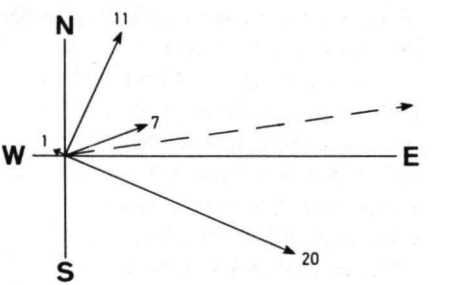

Fig. 4. Orientation of a single migration observed at Kawagoe. It ranged from ESE to NNE.

SEASONAL CHANGE IN BEHAVIOUR OF THE KAWAGOE POPULATION THROUGHOUT AUTUMN

The first immigrants in early autumn inhabited exclusively the wood canopy, ca 15 m above ground in the day time (Stage I). As the season proceeded, some of the individuals began to perch on the electric wire along the wood margin, 11.5 m above ground (Stage II), and later some individuals perched on the top of low rods (1-3 m high) along or near the wood margin (Stage III), and finally some perched on vegetables (carrots, 0.3 m) in cultivated field (Stage IV). Figure

5 shows the observations in September and October 1988.

The perch height in Stage I (15 m) corresponds approximately to that of the summer habitat, observed in the Sayama Hills and other places, and also to that of the flying height in the autumnal migrations. Stage II is a slight downward modification of Stage I. It is Stage III that people become aware of the presence of "Akatombo" in the lowlands. Stage IV is represented by sexually motivated individuals in the morning. Males perform mating behaviour in two ways, viz. (1) patrolling around the carrot field to detect perching females, and/or (2) waiting on the perch for approaching females in flight (5-15 m high). If males succeeded to mate, the tandems flew away towards N or NE.

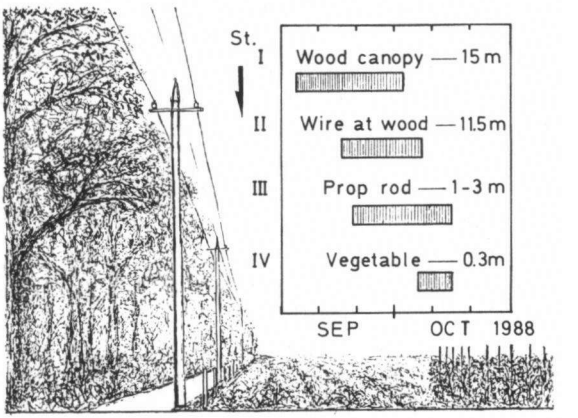

Fig. 5. Scenery of the most frequently used observation point and seasonal change of perching height of matures in the Kawagoe area. As season and age of matures advanced, the perch height gradually lowered to near the ground.

In the afternoon of mid- or late September, individuals staying in the area (Fig. 5) spent time on the perch (10-15 m high) for feeding or on the wing, flying to and fro in the vegetable farm, for a long time. As dusk approached, all of them ceased the daytime activity when the light intensity fell to about 100 lux, and entered the adjacent wood margin, 2-3 m above ground, for roosting (Fig. 6). A light intensity of 100 lux is suggested to be the lower limit of light sensitivity in mature *S. frequens* (cf. Fig. 3).

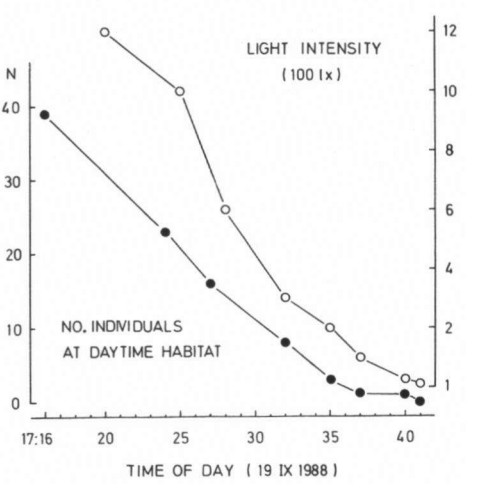

Fig. 6. Cessation of daytime activity of matures in relation to decrease in light intensity at the point shown in Figure 5.

A POSSIBLE INITIAL STAGE OF EMIGRATION FROM KAWAGOE

On 21 September 1984, at 1200-1330 h, a considerable number of individuals stayed in the air, 10-20 m above ground. The weather was slightly cloudy, with almost no wind, and the temperature was 25°C. Some of them began to move exclusively eastwards (1330 h). This behaviour was regarded as an initial stage in the emigration. The flying speed was about 7 km/h. The orientation and the flying speed were the same as shown by migrants passing through the Kawagoe study area, as stated previously.

CONCLUDING REMARKS

ASAHINA (1984) stated that *S. frequens* derived from the continental species, *S. depressiusculum*, in the Quarternary period. Although flight activity greatly differs between the two, the former being the stronger, the circadian time-table of behaviours of *S. frequens* is quite similar to that of *S. depressiusculum* observed in southern France by MILLER et al. (1984).

S. frequens is found in the four main islands of Japan. In Obihiro and Kushiro, Hokkaido (both 43°N), the seasonal migration of the species is not observed (SATO, 1990). In the Yokote basin of Akita Prefecture (ca 39°N, 26-56 m a.s.l.), juvenile individuals of the species were found in late August 1971, 1978 and 1986. They perched on the top of higher rods or twigs, as compared to other sympatric *S. infuscatum*, *S. darwinianum* and *S. pedemontanum elatum* (K. Miyakawa, unpublished). These observations suggest a possibility that, in northern Honshu, *S. frequens* does not always migrate to the highlands in summer, as was previously stated in the case of the Sayama Hills. Conversely, the presence of *S. frequens* in the lowlands in August is not recorded from south-western Japan.

On 18 September 1984, 1130-1600 h, a large flying swarm of mature (red) *S. frequens* was observed from the uppermost floors of three different high buildings (100-226 m high) in Tokyo city. The swarm in each case was seen just near the building and some individuals perched on the windows of the building. *S. frequens* may have recognized the high buildings as projections from the ground, because migrating matures are still in the 'forest canopy' phase, as previously mentioned. Immatures and matures of *S. frequens* usually fly well in a swarm. Immatures' swarm flights in the highlands have been observed twice a day, in the morning and just before twilight (TSUBUKI, 1987), and matures' swarm flights in the lowlands have been observed before twilight. However, *S. frequens* is a 'percher' for feeding, and the purpose of these flights is unknown. At least it cannot be regarded as feeding. If so, the purpose of the swarm flight may be 'flight' itself to preserve the flight activity for a coming long distance migration.

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