SOME BIOLOGICAL PUZZLES REGARDING AKA-TOMBO, *SYMPETRUM FREQUENS*, (ANISOPTERA: LIBELLULIDAE) OF JAPAN

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Sympetrum frequens is a very popular dragonfly in Japan. However, its biology is not well known. During its adult life from June to November a considerable migration from lowlands to highlands and back is observed, but whether they return to the original breeding site is not known. The vicariant species in Eurasia is *S. depressiusculum* which, however, has not been recorded from the greater part of China. No remarkable migratory flight is known for this species. On the Japanese islands, even as far south as the South Ryukyus, *S. depressiusculum* has sporadically been encountered, usually in October; the seasonal Mongolian high pressure is probably responsible for this overseas translocation. *S. depressiusculum* is found throughout the Korean Peninsula, but in the southern part of the Peninsula the body-size becomes almost as large as that of the Japanese *S. frequens*. Progeny reared from eggs of a female *S. depressiusculum* captured in Japan possessed bodily characters that suggested that they were hybrids between the two species. On some high mountains of Honshu (mainland of Japan) a number of small-sized, dark-coloured *S. frequens* were found late in the season when the majority of *S. frequens* had descended to the lower plain area. This might represent an isolated highland colony of this species. An hypothesis for the distribution and evolution of the two *Sympetrum* species is given.

INTRODUCTION

Aka-tombo (*Sympetrum frequens* Selys) is a very common Japanese dragonfly species appearing abundantly all over the Japanese islands from Hokkaido to Kyushu. SELYS LONGCHAMPS named this species one hundred years ago in 1883. However, despite its popularity, this insect presents a number of puzzling biological peculiarities which merit further serious attention.

RESULTS

Life-history of Sympetrum frequens *in the Japanese islands and adult migration*

Sympetrum frequens is a univoltine insect and, in Honshu, the adults emerge fairly synchronously during the last week of June or in the first week of July. They generally start their maiden flight one by one, but occasionally in a small swarm. However, their destination at this stage has never been definitely confirmed.

Throughout midsummer, beginning early or mid-July they are seen in large numbers at high elevation in many districts of Japan. They remain in the highlands, sometimes up to 3000 metres, probably until the approach of the frost season. The seasonal distribution in the Maruike area at Shiga-Kogen (*ca.* 1600 m), Nagano Prefecture in 1955, is shown in Fig. 1 (FUJISAWA, 1957).

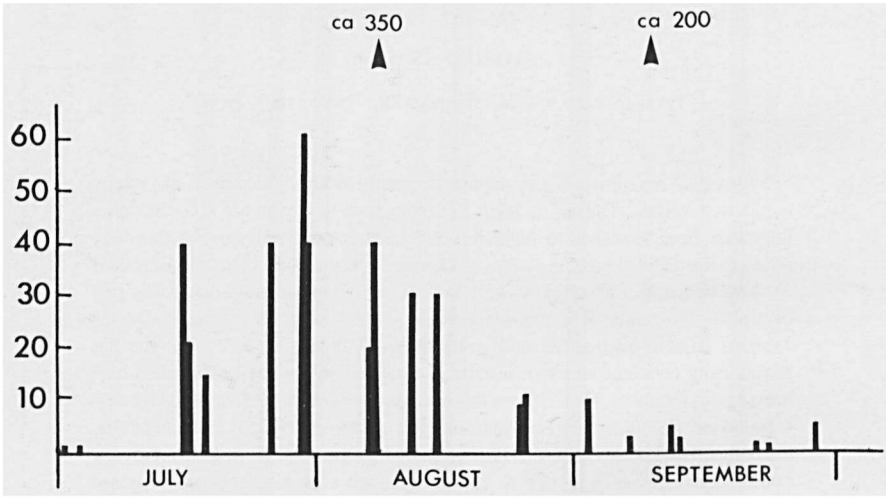

Fig. 1. Prevalence of individuals of *S. frequens* on Shiga-Highland, Nagano Prefecture, during 1955. The numbers above the figure are estimates of the sizes of two observed swarms. (After FUJISAWA, 1957).

BABA (1953) observed a large swarm of mature and reddish-coloured Aka-tombo descending from the mountains to a foothill and to cultivated fields where no adults had been observed on the previous day. They reach all lowland areas of Japan, usually around rice-fields and extending to the sea-coast. On a fine autumn morning they are seen flying in swarms, often in tandem, or alighting on twigs or wire-cords, and laying eggs even into temporary pools.

Thus, *S. frequens* makes a return flight over a large distance. But it has not yet been confirmed how far they fly, nor where they stay in mid-summer. Neither is it known whether they return along the same routes to the original breeding sites.

The eggs are laid by striking the abdomen on the surface of shallow waters over muddy substrates. The eggs have a gelatinous covering over the chorion and

adhere to mud particles. Embryonic development apparently proceeds to a certain stage, but it is believed that the eggs hibernate in a diapause until spring.

The continental vicariant*, Sympetrum depressiusculum *(Selys)

I agree with RIS (1911) who stated that Japanese *S. frequens* is the "direkte Fortsetzung" of Eurasian *S. depressiusculum*. *S. frequens* must be the insular vicariant of *S. depressiusculum* which is strictly confined to continental Europe and northern Asia (BARTENEF, 1915). The latter does not appear to make a regular long-distance flight, and this may be conjectured from the small-sized pterothorax. It is curious that *S. depressiusculum* has never been definitely recorded from the vast area of the Chinese mainland (Fig. 2). The only records so far found for China may be: 1♀, Pekin (BARTENEF, 1915, p. 195); 1♀, Tien-shan: Kuldja (SJÖSTEDT, 1932, p. 9, Sven Hedin Expedition); 3♂ 2♀, "Wei hai wei, T.B. Fletcher, 17.IX.1898, Shan-hai-kwan, Le Chili" (*In coll.* B.M.N.H., confirmed by S. Asahina); 2♂ 5♀, Chefoo, Shantung, 1906, J.C. THOMPSON *leg.* (ASAHINA, 1978).

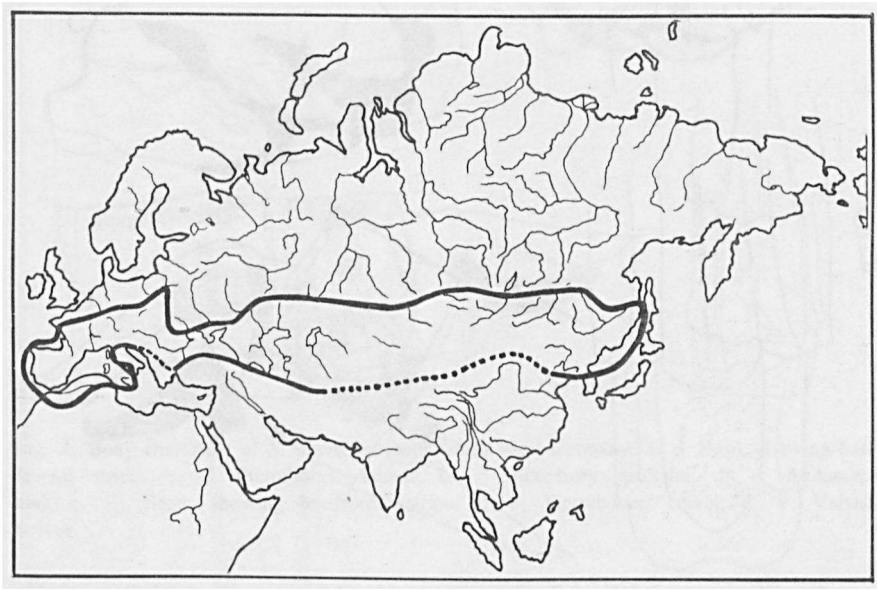

Fig. 2. The distribution of *S. depressiusculum*. (After BARTENEF, 1915).

Distinguishing characteristics of the two species are as follows:

S. frequens: (Fig. 3): 1. Size larger, body length (from head to end of abdomen) *ca.* 40 mm, hindwing *ca.* 30 mm. 2. Basifrontal dark stripe broad, without deep invaginations on the sides. 3. Pterothoracic dark stripe broader, the first lateral stripe extending upwards well beyond the level of the mesostigma, often provided with a thick connecting branch to the second lateral stripe. 4. In mature insects all coxae and trochanters entirely black; in immature insects (excepting very teneral ones), coxae and trochanters largely black.

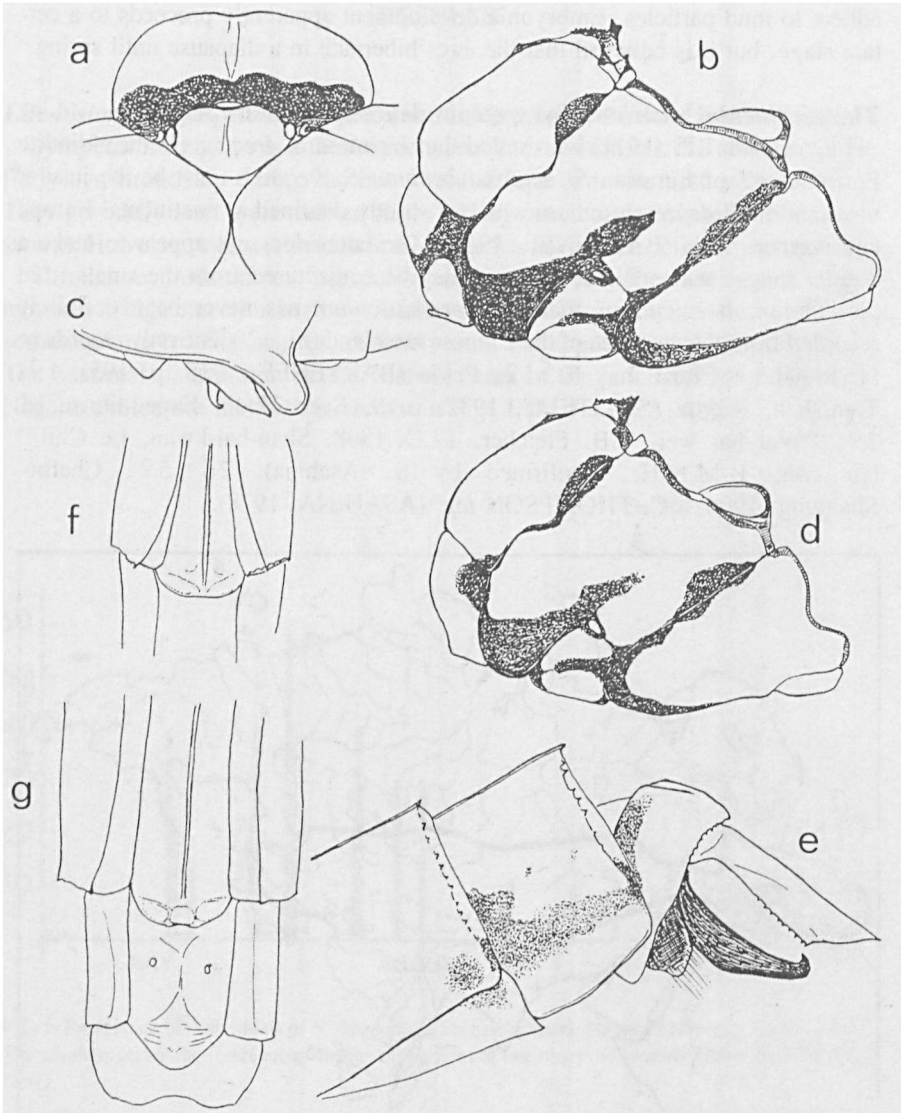

Fig. 3. Body characters of *S. frequens* from Japan. a. ♂ Head, showing basifrontal stripe; b. ♂ Pterothorax, lateral; c. ♂ Accessory genitalia; d. ♀, Pterothorax, lateral; e. ♂ Abdominal end; f, g. ♀, Valvula vulvae.

S. depressiusculum (Fig. 4): 1. Size smaller, body length *ca.* 30 mm, hindwing *ca.* 23 mm. 2. Basifrontal dark stripe strongly undulated on front border with deep or distinct invagination on the sides. 3. Pterothoracic black stripe narrower, the first lateral stripe extending only a short distance above mesostigma, without branchings to connect with the second lateral stripe. 4. In immature insects all coxae and trochanters pale yellowish, inside of profemur more or less pale striped; in immature insects there are small black spots on the coxae and trochanters, but the ground color is largely pale.

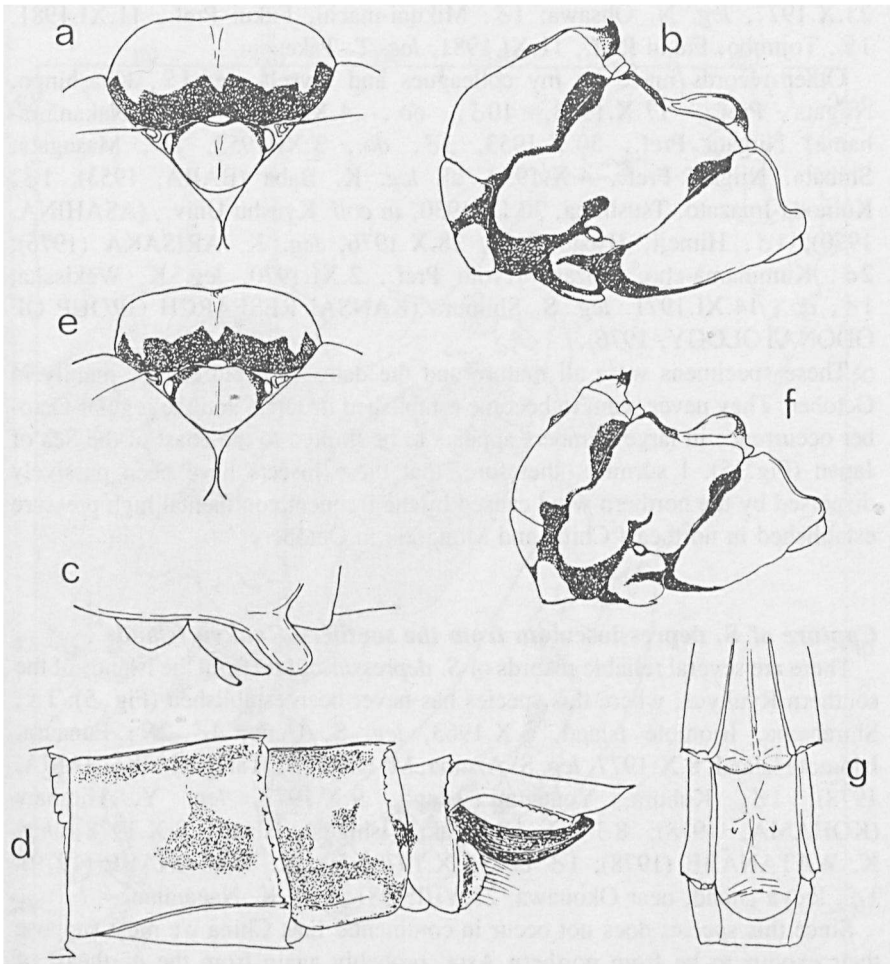

Fig. 4. Body characters of *S. depressiusculum* from West Germany. a. ♂ Head, showing basifrontal stripe; b. ♂ Pterothorax, lateral; c. ♂ Accessory genitalia; d. ♂ Abdominal end; e. ♀, Head, showing basifrontal stripe; f. ♀, Pterothorax, lateral; g. ♀, Valvula vulvae.

Unexpected occurrence of S. depressiusculum *in the Japanese islands*

Among a large series of Japanese *Sympetrum* that I have examined, I found a number of small-sized specimens which I have identified as *S. depressiusculum*. These were: 2♂ 2♀, Okonoshima, near Fukuoka, North Kyushu, 16.X.1932, *ex coll.* Kyushu Univ.; 1♀, Yamashina, Kyoto, 11.IX.1933, *leg.* S. Asahina; 1♀, Kawaji-mura, Ina, Nagano Pref., 27.X.1953, *leg.* F. Ito; 1♂ 1♀, Sakata, Yamagata Pref., 6.X.1952, 4♂ 1♀, *do.*, 15.VIII.-19.X.1953, 1♀, *do.*, 16.VIII.1955, 4♀, Oyama-machi, Yamagata, 22.IX.1957, 1♂, Sakata, Yamagata, 17.X.1967, all *leg.* K. Shirahata; 1♂, Tamatsukuri Spa, Shimane Pref., 18.X.1965, *leg.* M. Nakauchi; 1♂ 1♀, Tottori, 5.X.1969, T. Omori *leg.*; 1♀, Takamatsu, Shikoku,

23.X.1977, *leg.* N. Ohsawa; 1♂, Mikuni-machi, Fukui Pref., 11.XI.1981, 1♀, Tojimbo, Fukui Pref., 11.XI.1981, *leg.* T. Takeuchi.

Other records made by my colleagues and myself are: 1♀, Kitashinpo, Niigata Pref., 17.X.1953, 10♂, *do.*, 4.XI.1953, 2♂, Nakamura-hama, Niigata Pref., 30.X.1953, 3♂, *do.*, 3.XI.1953, 1♀, Masugata, Shibata, Niigata Pref., 4.X.1953, all *leg.* K. Baba (BABA, 1953); 1♂, Komoda-Imazato, Tsushima, 30.IX.1930, *in coll.* Kyushu Univ., (ASAHINA, 1970); 1♂, Himeji, Hyōgo Pref., 28.X.1976, *leg.* K. ARISAKA (1976); 2♂, Kumihama-cho, Kozan, Kyoto Pref., 2.XI.1970, *leg.* K. Wakisaka; 1♂, *do.*, 14.XI.1971, *leg.* S. Shimura (KANSAI RESEARCH GROUP OF ODONATOLOGY, 1976).

These specimens were all mature and the dates of capture were mainly in October. They never seem to become established in Japan and the regular October occurrence in large numbers appears to be limited to the coast of the Sea of Japan (Fig. 5). I surmise, therefore, that these insects have been passively dispersed by the northern wind caused by the frequent continental high pressure established in northeast China and Mongolia in October.

Capture of S. depressiusculum *from the southern Ryukyu Islands*

There are several reliable records of *S. depressiusculum* from the islands of the southern Ryukyus, where this species has never been established (Fig. 5): 1♂, Shirahama, Iriomote Island, 6.X.1963, *leg.* S. Ueno; 4♂ 2♀, Funaura, Iriomote Island, 8.X.1977, *leg.* S. Azuma, M. Kinjo, M. Taniguchi (KOHAMA, 1978); 1♂, Kubura, Yonaguni Island, 9.X.1977, *leg.* Y. Hirahara (KOHAMA, 1978); 8♂ 1♀, Ishigaki, Ishigaki Island, 8.X.1978, *leg.* K. WATANABE (1978); 1♂ *do.*, 5.X.1979, *leg.* K. WATANABE (1979); 1♂, Iheya Island, near Okonawa, 23.VIII.1981, *leg.*, K. Nagamine.

Since this species does not occur in continental East China we must suppose their exodus to be from northern Asia, probably again from the northeast of North China. WATANABE (1978) supposed that the seasonal wind of October would bring the dragonflies from East Siberia and Korea to the Japanese Islands; then the insects are brought along the Ryukyu Island arc to the south. On the same route a hawk species, *Butaster indicus*, is known to migrate southwards in October.

Representative Sympetrum *species in the Korean Peninsula*

I have at hand considerable material of *Sympetrum* from the Korean Peninsula. The northern part, north of about 40^0N, is a high plateau and the material therefrom is almost all typical *S. depressiusculum*. However, the specimens from the median portion of the Peninsula become larger in size, and those from the extreme south of the Peninsula are nearly of the same size as the Japanese *S. frequens*. Do they change gradually from *S. depressiusculum* into *S. frequens*?

I am of the opinion that the large-sized specimens of middle and southern Korea should be treated as large-sized *S. depressiusculum*, mainly based on the

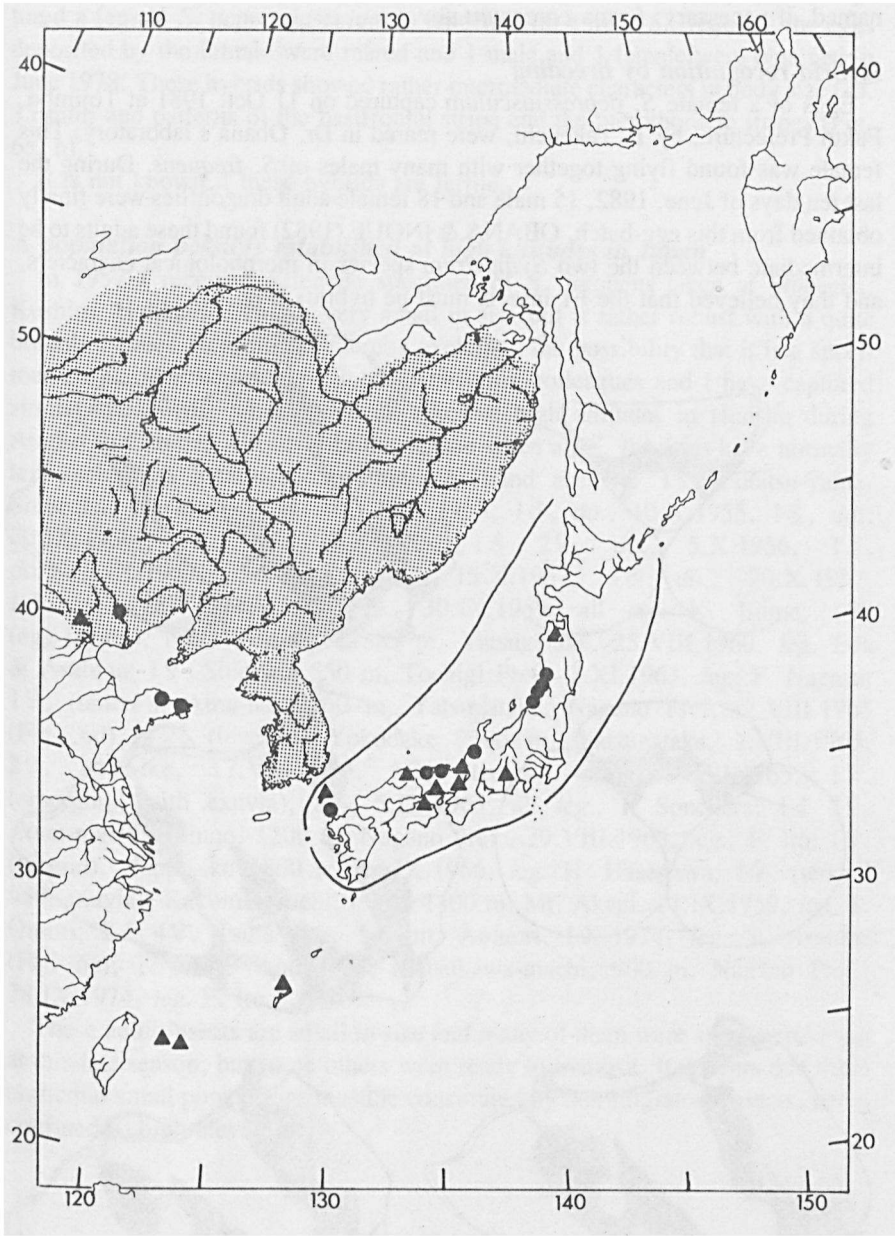

Fig. 5. Distribution of *S. frequens* and *S. depressiusculum*. Stippled: *S. depressiusculum*; Thick black line: Range of *S. frequens*; Black circle: *S. depressiusculum* captured in numbers; Black triangle: *S. depressiusculum* captured singularly.

bodily patterns. These South Korean large-sized *S. depressiusculum* may be named, if necessary, forma *coreanum* nov.

Hybrid recognition by breeding

Eggs of a female *S. depressiusculum* captured on 11 Oct. 1981 at Tojimbo, Fukui Prefecture, by T. Takeuchi, were reared in Dr. Obana's laboratory. This female was found flying together with many males of *S. frequens*. During the last ten days of June, 1982, 15 male and 18 female adult dragonflies were finally obtained from this egg-batch. OBANA & INOUE (1982) found these adults to be intermediate between the two *Sympetrum* species in morphological characters, and they believed that the F1 insects must be hybrids (Fig. 6).

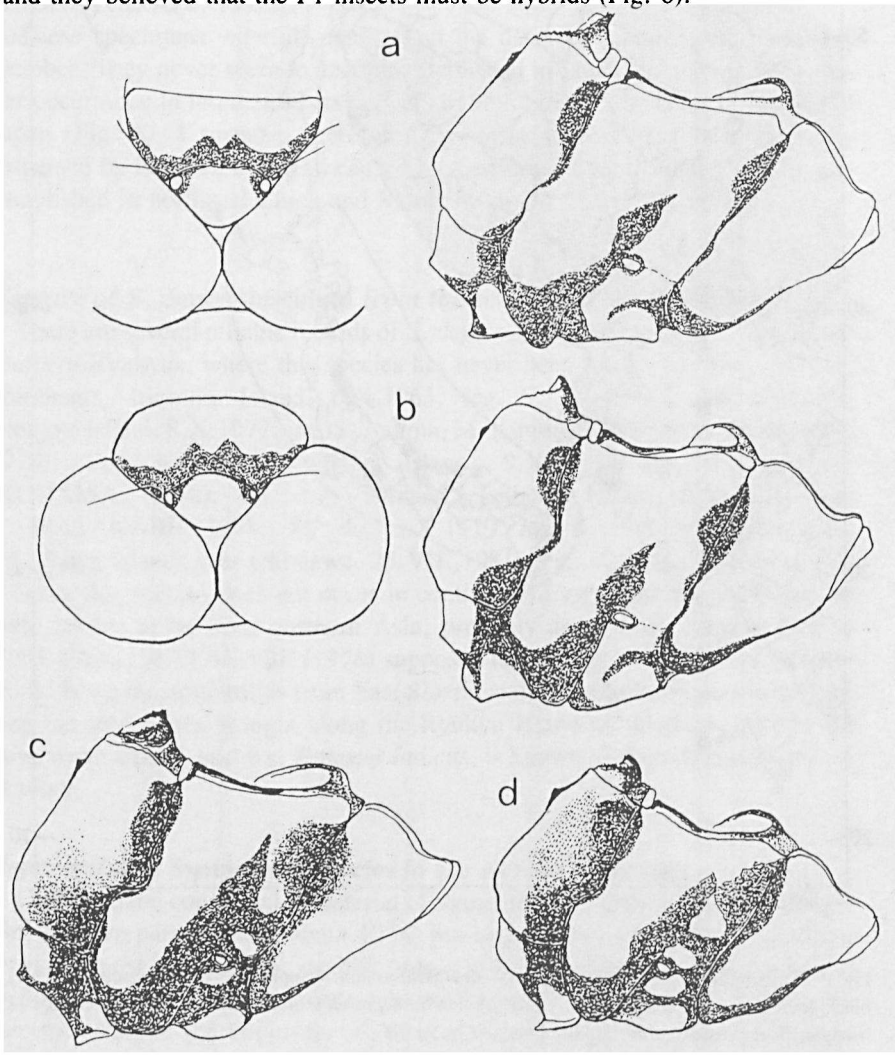

Fig. 6. a. Hybrid ♂, head stripe and pterothoracic stripes; b. Hybrid ♀, head and stripe and pterothoracic stripes; c. Highland ♂, Tsuta 500 m, Aomori Pref.; d. Highland teneral ♀, Yatsugatake 2060 m, Nagano Pref.

A similar breeding experiment was conducted by OHSAWA (1977). He captured a female *S. depressiusculum* in tandem with a male *S. frequens*; the eggs deposited by the female were reared and 1 male and 1 female were obtained in June 1978. These hybrids showed rather intermediate characters in body size (*ca.* 35 mm) and patterns of the basifrontal stripe and the pterothoracic stripes (Fig. 6a, b).

It is not known if these hybrids are fertile.

A population possibly established at high altitudes in Japan

In 1957 I received a female specimen of *S. frequens* taken at Shibecha, Kushiro, Hokkaido. This is very small in size but is rather robust with a quite broadly banded pterothorax, thereby excluding the possibility that it is a specimen of *S. depressiusculum.* Subsequently my colleagues and I have captured similar specimens, which were all taken at high altitudes in Honshu during August to October, very late in the season when all *S. frequens* have normally left such high localities. Specimens at hand are: 1♂ 1♀, Futatsu-yama, Shibecha, Kushiro, Hokkaido, 20.X.1953, 1♂, *do.*, 10.X.1955, 1♂, *do.*, 30.IX.1956, 1♂, do., 2.X.1956, 1♂ 2♀, *do.*, 5.X.1956, 1♂, *do.*, 3.IX.1957, 3♂ 1♀, *do.*, 15.X.1957, 1♂ *do.*, 20.X.1957, 1♂, *do.*, 28.X.1958, 2♀, *do.*, 30.IX.1959, all *leg.* K. Iijima; 1♀, (egg-laying), Nakayama-toge 1885 m, Yatsugatake, 25.VIII.1960, *leg.* Eda & Asahina; 1♀, Shiobara 550 m, Tochigi Pref., 2.XI.1963, *leg.* F. Nagasu; 1♀, (teneral), Ama-ike 2060 m, Yatsugatake, Nagano Pref., 2.VIII.1963 (Fig. 6d), 1♀, (teneral), Yokodake 2300 m, Yatsugatake, 2.VIII.1963, 2♀, Ama-ike, 17.VIII.1963, 1♀, (teneral) *do.*, 18.VIII.1965, 1♀, (emerging; with exuvia), *do.*, 5.IX.1965, all *leg.*, I. Sonehara; 1♂ 2♀, Anan-machi, Shinno, 1200 m, Nagano Pref., 29.VIII.1965, *leg.*, F. Ito; 1♀, (teneral), Happo-ike 1800 m, 14.IX.1966, *leg.* H. Hasegawa; 1♀, (teneral with exuvia), Kakuman-fuchi, Pond, 1400 m, Mt. Akagi, 14.IX.1959, *leg.* T. Omori; 2♂ 4♀, Tsuta Spa, 500 m, Aomori, I.X.1974, *leg.* S. Asahina (Fig. 6c); 1♂ 2♀, (emerging), Matsukawa-machi, 900 m, Nagano Pref., 28.IX.1974, *leg.* F. Ito.

These adult insects are small in size and many of them were still teneral even at this late season, but some others were ready to oviposit. It appears that these particular small populations must be constituted by non-migratory insects, being confined to high elevation.

CONCLUSION

One may suppose that the ancestor of *Sympetrum depressiusculum*, which might have originated from the Angara-Baical fauna, had extended its range far into the Japanese Archipelago during the early Quaternary. In the later Quaternary period, after the third Glacial period, the Japanese islands were almost

detached from the continent (Fig. 7). Then, a particular race of *S. depressiusculum* which remained on the Japanese islands perhaps became bigger in size in the warmer climate and acquired a strong flight ability enabling it to move to a cooler environment in the summer. This established *S. frequens*. Aka-tombo, of Japan.

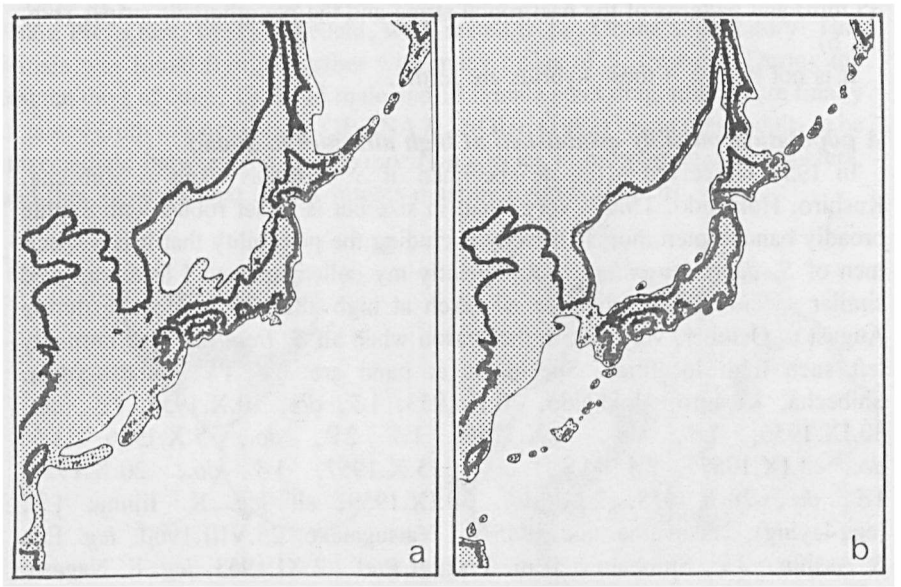

Fig. 7. a. Japanese Islands during Early Quaternary; b. Japanese Islands during Middle Quaternary (Third Glacial Period). (After MINATO & IZIRI 1958).

The continental *S. depressiusculum* has persisted in the cooler continental region; it may perform small-scale migrations, but the return flight and the mass-swarm appear to be absent. However, in northern Asia, due to the weather break in the autumn season, individuals of *S. depressiusculum* are brought from northern China to the Japanese islands by the strong northern wind, and some of them even reach far south to the Ryukyu Islands.

These wind-borne *S. depressiusculum* have never become established in Japan, but appear often to give rise to F1 hybrids, which appear to be sterile.

On the other hand, a population of Japanese *S. frequens* has apparently been isolated at high altitudes in the interior of Japan and these individuals have become smaller and darker. This might eventually change into a particular ecological race of *S. frequens*.

REFERENCES

AISAKA, K. 1976. *Sympetrum depressiusculum* first found from the Inland-Sea side of Hyogo Pref. *Tombo 19*:20. (In Japanese).

ASAHINA, S. 1970. The Odonata of Tsushima. *Mem. nat. sci. Mus. Tokyo 3*:211-223.

ASAHINA, S. 1978. Enigmas about *Sympetrum depressiusculum* in the Far East. *Tombo 21*:14. (In Japanese with English summary).

BABA, K. 1953. Odonata in the northern part of Niigata Prefecture, 3. Notes on the biology of *Sympetrum frequens* and the other species. *Trans. Etsusa ent. Soc. 7*:128-139. (In Japanese).

BARTENEF, A.N. 1915. *The fauna of Russia and bordering countries. Insecta Pseudoneuroptera. Vol. 1. Libellulidae.* Petrograd. (In Russian).

FUJISAWA, S. 1957. *Odonata of Shiga-Kogen, a biological study of the dragonflies on Shiga High Plateau in Nagano Prefecture.* Shimo-minochi Kyoiku Kai, Iiyama. (In Japanese).

KANSAI RESEARCH GROUP OF ODONATOLOGY. 1976. Dragonfly fauna of the Kinki District, Central Japan. Part 3, Libellulidae. *Spec. Publ. Osaka Mus. nat. Hist.* Vol. 8. (In Japanese).

KOHAMA, T. 1978. Three interesting *Sympetrum* species from the Sakishima Islands, the Ryukyus, Japan (Anisoptera, Libellulidae). *Notul. Odonatol. 1*:23-24.

MINATO, M., & S. IZIRI. 1958. *Japanese Islands.* Iwanami, Tokyo. (In Japanese).

OBANA, S., & K. INOUE. 1982. Larval breeding of *Sympetrum depressiusculum* and *S. cordulegaster* with some notes on the second generations. *Tombo 25*:37-41. (In Japanese with English summary).

OHSAWA, N. 1977. Two new additions to the dragonflies of Kagawa Prefecture. *Tombo 20*:29-30. (In Japanese).

OMORI, T. 1970. *Sympetrum frequens* and *Indolestes peregrina* emerging at high altitude on Mt. Akagi. *Nature & Insects 5*:9. (In Japanese).

RIS, F. 1911. Libellulinen monographisch bearbeiteit. 3. *Collns zool. Sélys Longchamps 11*:245-384.

SÉLYS LONGCHAMPS, E. de. 1883. Les Odonates du Japon. *Annls Soc. ent. Belg. 27*:82-143.

SJÖSTEDT, Y. 1932. Swedisch-Chinesische wissenschaftliche Expedition nach den nordwestlichen Provinzen Chinas. Insekten, 3. Odonata. *Arch. zool. 25*: 1-22.

WATANABE, K. 1978. Notes on *Sympetrum depressiusculum* and *S. cordulegaster* taken in Ishigaki Island, the Ryukyus. *Tombo 21*:43-44. (In Japanese with English summary).

WATANABE, K. 1979. Further observations on three interesting dragonfly species in the Yayeyama Islands. *Tombo 22*:31-34. (In Japanese with English summary).