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Cone flies, *Strobilomyia* spp. (Diptera: Anthomyiidae), attacking larch cones in China, with description of a new species

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A survey of larch cone flies, *Strobilomyia* spp., was carried out in Yunnan and Heilongjiang provinces of China during 1993, using cone collections and visual trappings. A new species of cone fly, *S. lijiangensis* sp.n., is described from the Lijiang area, Yunnan, where it severely damaged cones of Himalayan larch, *Larix potaninii* BATALIN var. *mastersiana* LAW. Unidentified female specimens of a cone fly were obtained from both trappings and cone collections of Siberian larch, *L. gmelini* RUPR. (KUSEN.), in the Da Khinggan mountains of Heilongjiang. Additionnal trappings carried out in 1996 lead to consider that these insects probably correspond to the female of *S. luteoforceps* FAN & FANG that has not yet been described. In addition, *S. svensonni* MICHELSEN is recorded for the first time in China, where it attacks cones of Siberian larch in the northeast. Finally, we present an updated list of 7 larch cone flies in China, including distribution, host, and description of the genital apparatus of females and males.

Keywords: Diptera, cone, insect damage, *Strobilomyia, Larix,* China.

INTRODUCTION

Cone flies of the genus *Strobilomyia* MICHELSEN (= *Lasiomma* STEIN *auct. partim* = *Chorthophila* MACQUART = *Hylemia* ROBINEAU-DESVOIDY) (Diptera: Anthomyiidae) are undoubtely among the most serious insect pests that damage cones and seeds of conifers (ROQUES, 1988). Species of this apparently monophyletic genus occur mainly in the boreal and montane parts of the Holartic, where larval instars develop exclusively in the cones of various groups of Pinaceae except the pine species (MICHELSEN, 1988). A total of 18 *Strobilomyia* species were identified (TURGEON *et al.,* 1994), most of them being related to larch, *Larix* MILLER.

In Eurasia, the species diversity of larch cone flies seems to increase from west to east. The larch cone resource is shared among 3 *Strobilomyia* species in both western Europe (ROQUES *et al.,* 1984) and Finland (PULKINNEN, 1989). However, a total of 7 species, *S. baicalensis* (ELBERG), *S. infrequens* (ACKLAND), *S. laricicola* (KARL), *S. luteoforceps* (FAN & FANG), *S. melaniola* (FAN), *S. sibirica* MICHELSEN, and *S.viaria* (HUCKETT), has been recorded from larch cones in the Far East (POPOVA & ELBERG, 1970; SUWA, 1971; STADNISTSKII *et al.*, 1978; FANG *et al.,* 1980, 1989; FAN *et al.*, 1982, 1990; FANG, 1987; FAN, 1988; MICHELSEN, 1988; KAMIJO, 1993). In most areas of Siberia, Kamtchatka, and northern China, up to 4-5 species were observed to coexist, and larvae of the different species were often found developing within the same larch cone (YAO *et al.*, 1991; ROQUES, unpublished data). Because insects have to cope both

with spatial and temporal heterogeneity of seed cones and to reduce competition for a limited cone resource, the coexistence of such a high number of congeneric species likely relies on specific adaptations developed through the evolution of insect-seed cone relationships. However, the precise knowledge of specific distribution and biology of cone flies is still hindered by taxonomic uncertainties because much of larch cone damage was attributed for a long time to a single species, *Strobilomyia laricicola* in Russia (e.g., EFREMOVA, 1971) and China (e.g., ANONYMOUS, 1960, 1963, 1964, 1977; XU, 1981). The use of male genitalia to identify adults was effective since the 1980's in China (FANG *et al.*, 1980; FAN *et al.,* 1982) but the female genitalia were almost not used although MICHELSEN (1988) detailed most of them.

The large species diversification observed in China also suggested to survey the presence of cone flies in the whole range of larch in the country, especially in the southwestern (pre-Himalayan) range that had never been studied.

In this study, we will present (1) the description of new species found during a survey of larch cone damage in Yunnan province, southwestern China, and during field trappings with visual traps in Heilongjiang province, northeastern China; (2) an update synthesis, mostly based on Chinese literature, of the occurrence and distribution of cone flies in China, including a description of the genitalia of females and males.

MATERIAL AND METHODS

Survey of insect damage to cones of Himalayan larch in the Lijiang area of southwestern China

A stand of Himalayan larch, *Larix potaninii* BATALIN var. *mastersiana* LAW was surveyed on the lower slopes of Yulongxueshan (27°01'N, 100°09'E, 3000-3300 m elevation), Lijiang County, Yunnan province. A total of 50 cones was collected at random from 5 different trees on June 12, 1993. Cones were immediately dissected, and the position of insect larvae recorded. Half of the cone fly larvae was kept in alcohol for further examination and the other half was put on wet sand in order to allow pupation. Then, the pupae were placed into individual rearing boxes. Half of the pupae was stored in an outdoor insectary located at INRA, Orléans, France (107 m elevation), the other half kept at Northeast Forestry University, Harbin, China. Adult emergence was surveyed during 1994 and 1995. However, the emergence dates were only indicative because of differences in altitude and climatic conditions between native and rearing sites.

Survey of cone flies in stands of Siberian larch in northeastern China.

Visual trappings of cone flies were carried out at two sites near Jagedaqi (51°28'N, 124°29'E), Da Khinggan Mountains, Heilongjiang Province, during April-June 1993. The experiments were realized in a seed orchard and in natural stands of Siberian larch, *Larix gmelini* RUPR. (KUSEN.). The trapping procedure has been described in another paper (ROQUES *et al.,* 1995). All of the trapped flies were identified to species using the keys supplied by FAN *et al.* (1982, 1990) and MICHELSEN (1988). We systematically dissected the genital apparatus of both females and males, following an exposure to 10% KOH for 4 hours, because the flies were glued and sometimes crushed. Following larch cone maggot rearings performed during the 1981-1993 period, we also dissected the genitalia of the fly specimens that

were conserved in the collection boxes of the Jagedaqi Forestry Bureau, to obtain additional information on the species composition of the cone fly complex in the area. To confirm the results, an additionnal trapping experiment was realized during May-June 1996 at the same locations, and using the same procedure.

RESULTS AND DISCUSSION

Survey of insect damage to cones of Himalayan larch in the Lijiang area of south-western China

Of the 50 cones of *L. potaninii* collected at Yulongxueshan in June 1993, 76% (i.e., 38) were attacked by cone flies, a few (14%) being additionally attacked by a seed midge *(Resseliella* sp.). Different types of larval damage were observed. Most of the fly larvae (60%) did not enter the axis of the big-size (about 6-8 cm long) cone of Himalayan larch, but tunneled around the axis. Larval course was limited either to the base (20% of the total larvae), to the middle (25%), or to the apex (15%) of the cone. A fewer number of larvae (40%) entered the axis at the apex (15%), the middle (12.5%) or the base (12.5%) of the cone. The different types of larval course were observed in the same cone. The number of larvae per cone varied between 1 (31.8% of the attacked cones) and 3 (26.2%), a maximum of cones containing 2 larvae (42%). The cone fly larvae exited the cones from June 12 to June 21, 1993, and they immediately pupated. A total of 37 pupae were obtained.

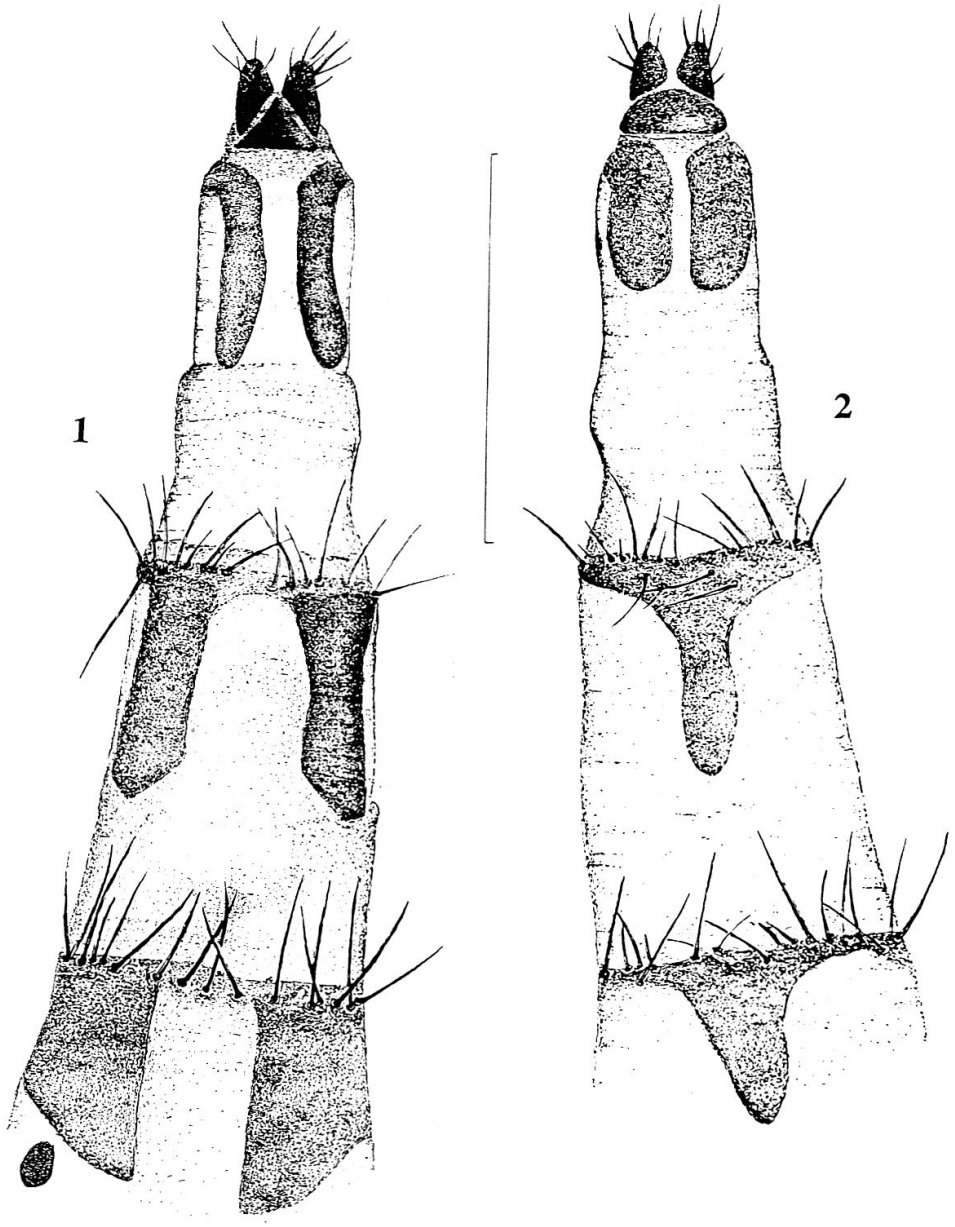
Only 16 adult flies (4♂♂ and 12♀♀) emerged in 1994 from the pupae stored under outdoor conditions at Orléans and Harbin. Adult emergence began on March 21, 1994, and lasted until April 17, 1994. Four parasites, preliminary identified as *Sarothrus* (= *Seitneria*) sp.n., (Hymenoptera: Cynipidae) (M. SÖDERLUND, personnal communication), also emerged from pupae in early May (1-5 May). Related cynipid species were observed to parasitize second-instar larvae, and emerge from pupae of *Strobilomyia laricicola* and *S. melania* ACKLAND in Europe (*Seitneria austriacus* TAVARES; ROQUES, 1988), and *S. melaniola* in northern China *(Seitneria* sp.; ZHANG *et al.,* 1991b). Thus, 54% of the cone fly pupae remained in prolonged diapause in 1994. In 1995, 5 more flies (2♂♂ and 3♀♀) emerged from April 1 to April 8. At this time, the remaining pupae were either in prolonged diapause for 4 of them, or dead for 8 of them.

Although we observed several patterns of larval damage, all of the adults which emerged in 1994 and 1995 were similar, and corresponded to a new species of cone fly. However, we cannot exclude that dead pupae or pupae remaining into prolonged diapause corresponded to other species because the European species of larch cone flies clearly differentiate by their specific damage pattern (ROQUES *et al.,* 1984). Because of the structure of Sternite V in male terminalia and that of female cerci, the new species was clearly linked to the *melania* group defined by MICHELSEN (1988). The description is the following:

Strobilomyia lijiangensis ROQUES & SUN sp.n.

Female

Medium-sized. Wing length 5 mm, i.e. a size approximating that of *S. melania,* the largest species in the *melania* group. Pupa length: 4.9-5.2 mm. Terminalia (Figs 1-2): Ovipositor 2.67 mm long on average. Cerci rounded at apex and not pro-



Figs 1-2: Female ovipositor of *S. lijiangensis* sp.n.: 1- Dorsal view (Tergites VII, VIII and IX); 2- Ventral view (Sternite VII, VIII and IX).

jecting, with 2 long setae at apex and 1 at base. Tergite (T) IX triangular; Sternite (St) IX broader than long. Segment VIII elongate and provided only with setulae. T VIII with elongate pieces, pieces of St VIII large. Segment VII elongate, with long marginal setae; T VII with two large elongate pieces; St VII with a large elongate piece along midline. Segment VI shorter than segments VII and VIII, with marginal setae stronger than those on Segment VII; T VI with two rectangular pieces at sides, St VI with an elongate piece along midline. Spermathecae oval elongate. The ovipositor resembles that of *S. sibirica* (MICHELSEN, 1988) but this species notably differs by the projecting cerci, the shape of the pieces of Sternite VI and the fewer number of marginal bristles on Tergites VI and VII. Cerci of the other species

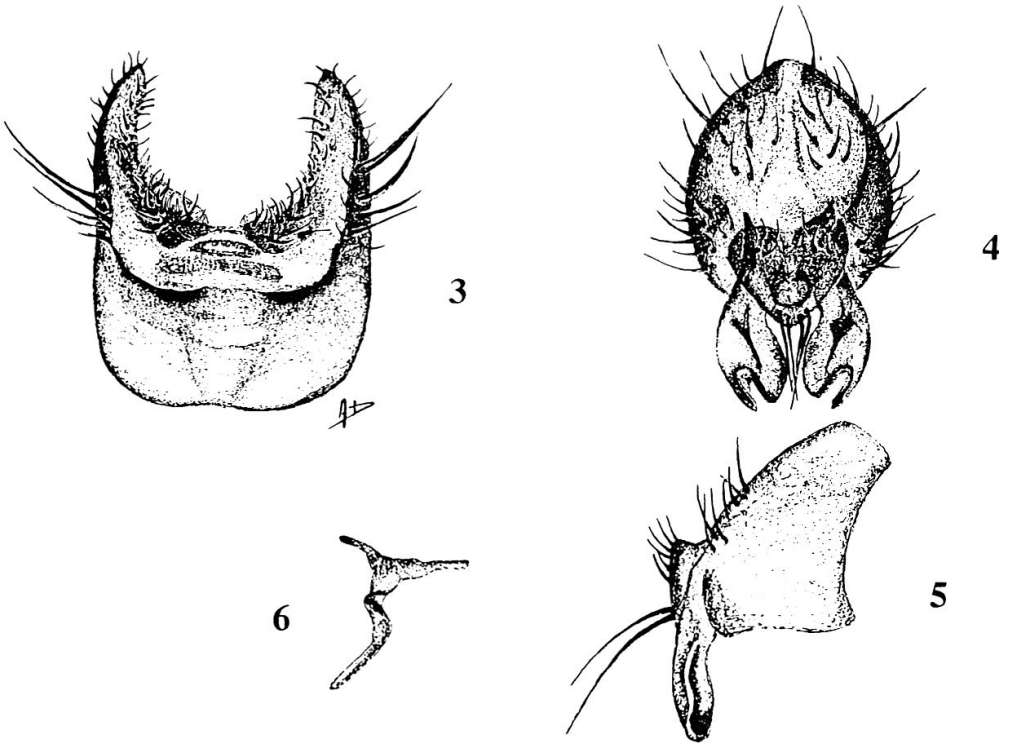
in the *melania* group are either projecting (*S. melania*- ROQUES *et al.*, 1984; *S. melaniola*- Fig. 13, *S. viaria*- MICHELSEN, 1988) or more slender (*S. infrequens*- Fig. 10; *S. baicalensis*- Fig. 12).

Male

Small to medium-sized. Wing length 4-4.6 mm, i.e. an intermediate size in the *melania* group. Pupae length 4.4-4.7 mm. Genitalia (Figs 3-6): Sternite V closely resembling that of *S. melania* (ACKLAND, 1965; ROQUES *et al.*, 1984; MICHELSEN, 1988). Lobes apically convergent, with a distinct group of 10-12 strong medial bristles in a brush-like arrangement at base. Cercal plate heart-shaped, supplied with two pairs of long bristles, the one closer to apex being longer than surstyli. Surstyli very enlarged in the middle. Apical incision not enlarging at bottom. Phallus slender at extremities. The enlargement of the surstyli at its middle is much less important in the other species of the *melania* group (*S. melania*- ROQUES *et al.*, 1984; *S. melaniola*- Fig. 18; *S. sibirica* and *S. viaria*, MICHELSEN, 1988).

Type material

1♂ holotype and 3♂♂, 12♀♀ paratypes, Yulongxueshan (27°01'N, 100°09'E, 3000 m altitude), Lijiang, Yunnan, China, emerged from cones of *Larix potaninii* var. *macrocarpa* (Leg. A. ROQUES, 12.VI.1993). Holotype: ♂, ex. 21.III.1994 (kept at INRA Orléans, France). Paratypes: 1♂, 2♀♀ ex. 23.III.1994 (NFU, Harbin, China); 1♂ ex. 25.III.1994 (SWFC, Kunming, China); 1♂ ex.



Figs 3-6: Male genitalia of *S. lijiangensis* sp.n.: 3- Sternite V; 4- Epandrium, cercal plate, and surstyli (dorsal view); 5- Epandrium, cercal plate, and surstily (lateral view); 6- Phallus.

26.III.1994, (INRA Orléans, France); 4♀♀ ex. 28.III.1994 (INRA Orléans, France); 3♀♀ ex. 4.IV.1994 (INRA Orléans, France), 2♀♀ ex. 8.IV.1994 (SWFC, Kunming, China), 1♀ ex. 17.IV.1994 (INRA Orléans, France).

Survey of cone flies in stands of Siberian larch in northeastern China

The trappings resulted in a total of 339 cone flies from 6 different species (ROQUES *et al.,* 1996). Among the trapped specimens, we identified 150 specimens (62♂♂, 88♀♀) of *Strobilomyia melaniola*, 73 (13♂♂, 60♀♀) of *S. baicalensis*, 63 (27♂♂, 36♀♀) of *S. infrequens,* and 1♂ of *S. laricicola*. These 4 species have already been observed in the Da Khinggan Mountains of northeastern China (FANG *et al.,* 1989; YAO *et al.,* 1991). In addition, we identified 41 specimens (4♂♂, 37♀♀) of *S. svenssoni* MICHELSEN, and 11♀♀ of *Strobilomyia* that could not be referred to any of the described species.

S. svenssoni had previously been recorded from Sweden and Mongolia (MICHELSEN, 1988), but not from China. The host was unknown but supposed to be spruce in Sweden. Five specimens of *S. svenssoni* were also identified within the adult flies reared from cones of Siberian larch, which were kept in the collection of the Jagedaqi Forestry Bureau. Thus, it confirmed that this cone fly attacks Siberian larch, *Larix gmelini.* The life cycle and biology of the species has been described by SUN *et al.* (1995).

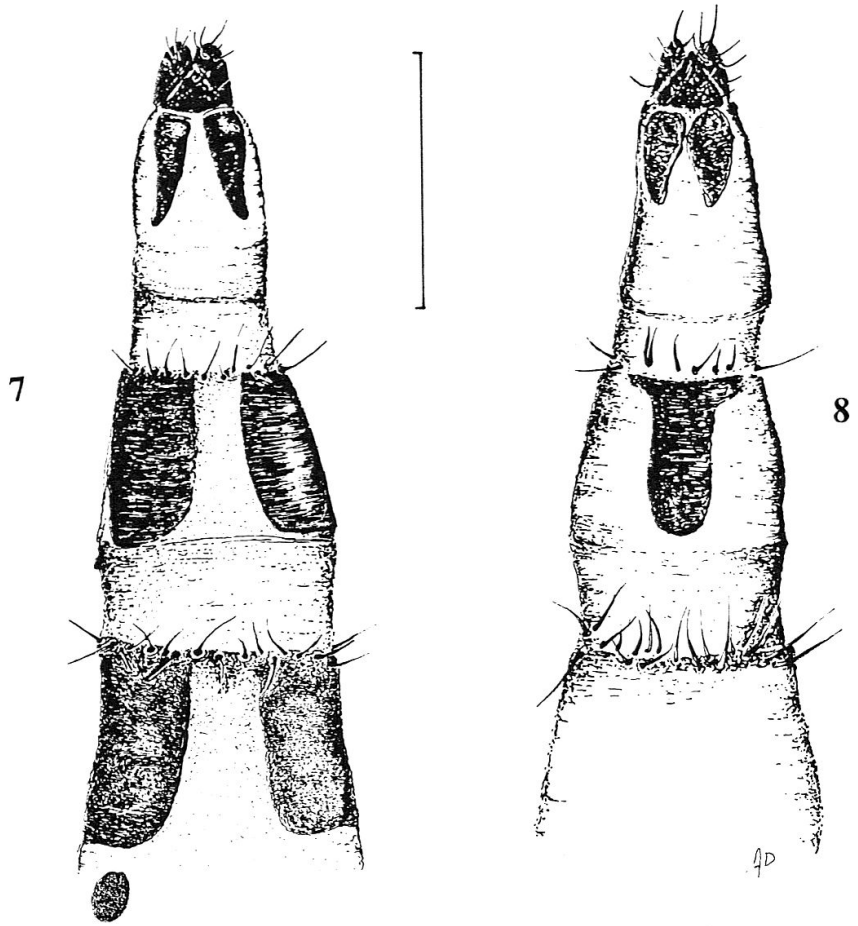
Four female specimens similar to the unidentified individuals caught during the 1993 visual trappings were found in the collection of flies reared from cones of Siberian larch at Jagedaqi Forestry Bureau. We supposed these specimens to be *S. luteoforceps* FAN & FANG because the female of this species was still not described. However, *S. luteoforceps* had only been observed in the Xiao Khinggan Mountains (YAO *et al.,* 1991), and no male of *S. luteoforceps* was neither observed in the collection of Jagedaqi Forestry Bureau nor trapped during the 1993 experiment. By contrast, first results of the 1996 trappings revealed the presence of males of *S. luteoforceps* as well as of females similar to the unidentified 1993 specimens. Although the trapping is not completed yet, 6 males and 3 females were trapped on May 16, 1996, after all. This result ascertained the presence of *S. luteoforceps* in the Da Khinggan Mountains. Therefore, we considered that the female specimens probably correspond to females of *S. luteoforceps*, whose description is the following:

Strobilomyia luteoforceps FAN & FANG

Female

Terminalia (Figs 7-8): Ovipositor rather long, 2.8 mm long on the average. Cerci rounded at apex and not projecting, with 2 long setae at apex and 1 at base. T IX and St IX pieces transversally elongate with two long setae in the middle. Segment VIII provided only with setulae; T VIII pieces clava-shaped; St VIII pieces large. Segment VII with long marginal setae; T VII with two broad rectangular pieces at sides; St VII with a broad rectangular piece along midline. Segment VI with marginal setae stronger than these on Segment VII; T VI with two rectangular pieces at sides. Spermathecae oval-shaped.

The species largely differs from *S. baicalensis* and *S. laricicola* by a much longer ovipositor. The ovipositor of these two species only measured 1.9 mm and

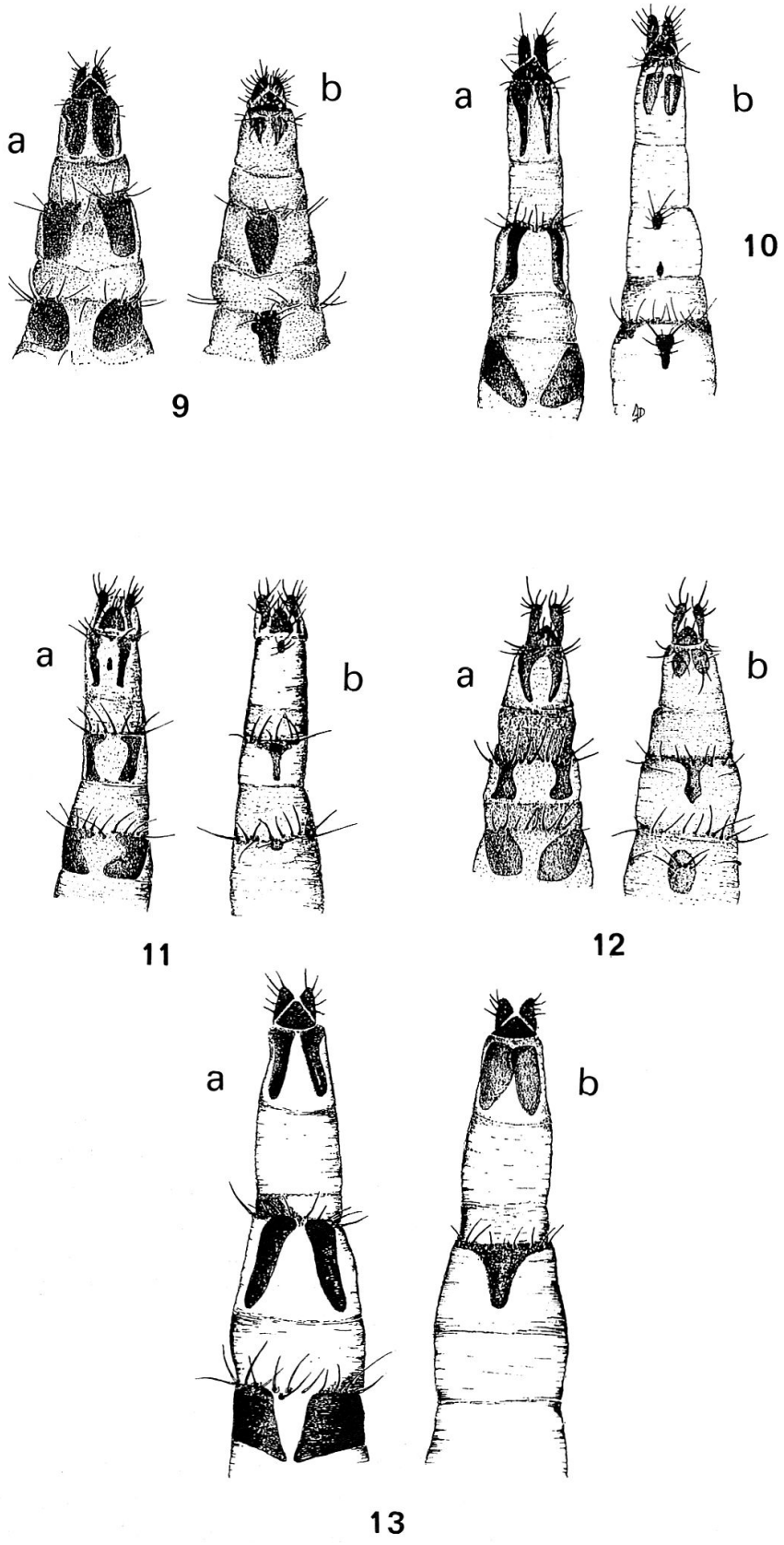


Figs 7-8: Female genitalia of *Strobilomyia luteoforceps* FAN & FANG: 1- Dorsal view (Tergites VII, VIII and IX); 2- Ventral view (Sternite VII, VIII and IX).

2 mm, respectively, in the specimens we observed at the same locations. In addition, St VIII pieces were much smaller in *S. baicalensis* (Fig. 12) whereas cerci were more flattened in *S. laricicola* (Fig. 9). Although the ovipositor size is similar to that of *S. luteoforceps,* the cerci of *S. melaniola* (Fig. 13; FAN *et al.,* 1990) and *S. sibirica* (MICHELSEN, 1988) are notably projecting at apex, whereas *S. svenssoni* (Fig. 11) and *S. infrequens* (Fig. 10) differ by the shape of the sclerotized pieces of Segment VII (ROQUES *at al.* 1984; MICHELSEN, 1988).

Material

15♀♀, Jagedaqi (51°28'N, 124°29'E), Da Khinggan Mountains, Heilongjiang Province, China. 1♀ ex. 16.IV.1988; emerged from cones of *Larix gmelini* collected at Hu Zhong, Jagedaqi region, in late spring 1987 (genitalia kept at INRA Orléans, France); 3♀♀ ex. 17.IV.1988 (genitalia kept at NFU, Harbin, China); 11♀♀ trapped, using blue traps from May 3 to June 13 1993 at Jagedaqi larch seed orchard and in a larch stand located about 3 km west of Jagedaqi City (genitalia kept at INRA Orléans, France).



Figs 9-13: Female ovipositor (a: tergites VII-IX; b: sternites VII-IX) of *Strobilomyia* species observed in larch cones in China: 9- *S. laricicola*; 10- *S. infrequens*; 11- *S. svenssoni;* 12- *S. baicalensis*; 13- *S. melaniola*.

Distribution and host plants of larch cone flies occurring in China

A total of seven species of cone flies has been identified so far in cones of *Larix* spp. in China, including *S. lijiangensis*. Figs 9-13 and 14-19 show the female and male terminalia, respectively. Three of the species present a wide distribution range:

1- *S. laricicola* (Figs 9 and 14) is a widespread Palearctic species continuously observed from Western Europe (ROQUES *et al.*, 1984) to Kamtchatka (ROQUES, unpublished data), and Japan (SUWA, 1971; KAMIJO, 1993), including central Siberia and eastern Siberia (POPOVA & ELBERG, 1970; STADNISTKII *et al.*, 1978). In China, the species was observed in northern China (Inner Mongolia, Heilongjiang, Liaoning, Jilin; FANG *et al.*, 1980, 1989; FAN *et al.*, 1982, 1990; FAN, 1988; YAO *et al.*, 1991, 1993; ZHANG *et al.*, 1991a, 1996; LIU, 1994b; SUN *et al.*, 1994; ROQUES *et al.*, 1995) but also in Hebei and Shanxi (ZHANG & LI, 1991, 1994). Besides *Larix gmelini*, it attacks *L. olgensis* HENRY (SUN & ROQUES, unpublished observations), and *L. principis-rupprechti* MAYR. (ZHANG & LI, 1991, 1994). Damage was also observed on all the other larch species growing in northern Asia, e.g., *L. sibirica* LEDEB., *L. czekanowskii* SZAF., *L. leptolepis* (SIEB. & ZUCC.) GORD., and *L. cajanderi* MAYR. (KAMIJO, 1993; POPOVA & ELBERG, 1970; STADNISTKII *et al.*, 1978; YAMADA *et al.*, 1972).

2- *S. infrequens* (Figs 10 and 15) shows a similar distribution except it has not yet been recorded from Japan. In China, the species has been observed in Inner Mongolia, Heilongjiang, Liaoning, Jilin, Shanxi and Hebei (FANG *et al.*, 1980, 1989; FAN *et al.*, 1982, 1990; FAN, 1988; YAO *et al.*, 1991, 1993; ZHANG *et al.*, 1991a, 1996; ZHANG & LI, 1991, 1994; LIU, 1994b; SUN *et al.*, 1994; ROQUES *et al.*, 1995). It attacks *L. gmelini, L. olgensis,* and *L. principis-rupprechti* in China.

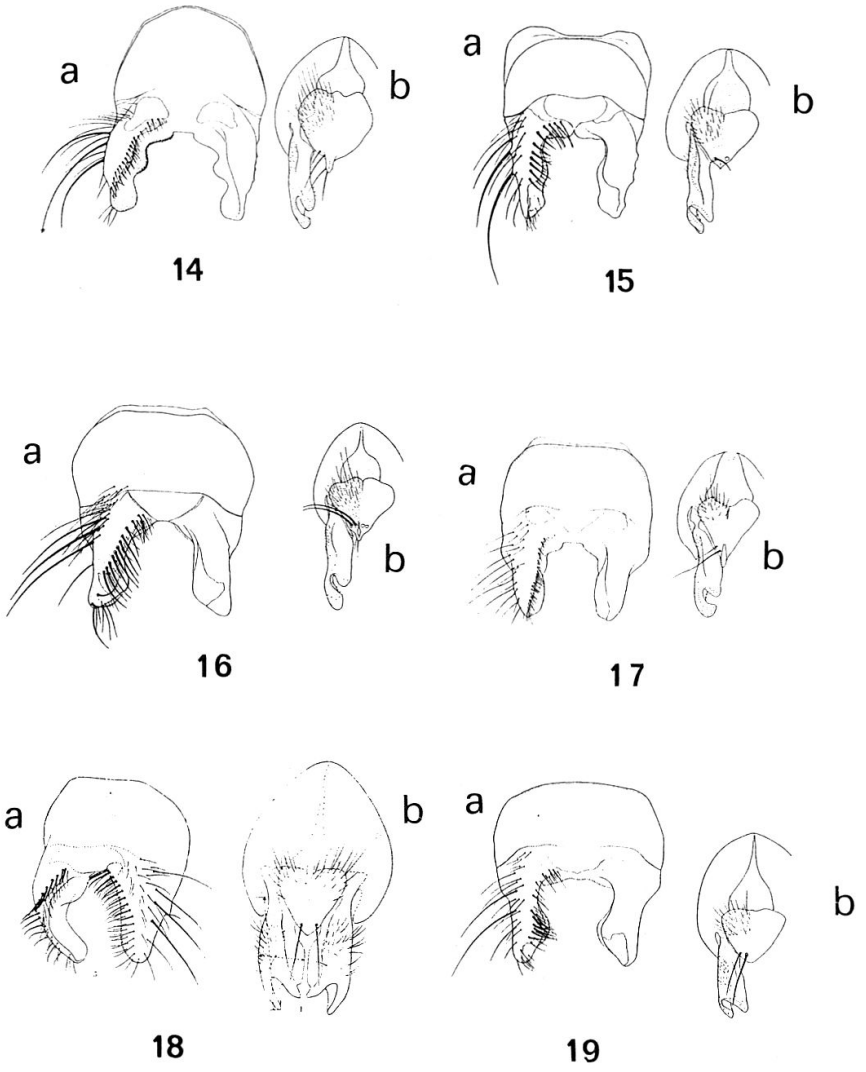
3- *S. svenssoni* (Figs 11 and 16) has been observed in Sweden, Mongolia (MICHELSEN, 1988) and Heilongjiang (SUN *et al.*, 1995; ROQUES *et al.*, 1995), and the only known host is *L. gmelini.*

The 4 other species of larch cone flies seem endemic to Eastern Asia.

4- *S. baicalensis* (Figs 12 and 17) is a northasian species observed from central Siberia to eastern Siberia and Kamtchtka, including the Lake Baikal area and Yakutia (POPOVA & ELBERG, 1970; STADNISTKII *et al.*, 1978; MICHELSEN, 1988; ROQUES, unpublished observations). In China, the species is recorded from Inner Mongolia and Heilongjiang (FANG *et al.*, 1980, 1989; FAN *et al.*, 1982, 1990; FAN, 1988; YAO *et al.*, 1991, 1993; ZHANG *et al.*, 1991a, 1996; SUN *et al.*, 1994; ROQUES *et al.*, 1995). Known hosts are *L. gmelini* and *L. olgensis* in China, and *L. sibirica, L. czekanowskii,* and *L. cajanderi* in other parts of northern Asia.

5- *S. melaniola* (Figs 13 and 18) seems limited to northeastern China (Inner Mongolia, Heilongjiang, Liaoning, Jilin) and central China (Shanxi, Hebei) (FANG *et al.*, 1980, 1989; FAN *et al.*, 1982, 1990; FAN, 1988; YAO *et al.*, 1991, 1992, 1993; ZHANG *et al.*, 1991a, 1996; ZHANG & LI, 1991, 1994; LIU, 1994a; SUN *et al.*, 1994; ROQUES *et al.*, 1995). Attacks concern *L. gmelini, L. olgensis,* and *L. principis-rupprechti*. MICHELSEN (1988) considered the species as *S. viaria,* but FAN *et al.* (1990) showed the two species to differ by the terminalia.

6- *S. luteoforceps* (= *Lasiomma jurtschenkoi* ELBERG) (Fig. 19) is apparently limited to the Far-East, having only been recorded from the northeastern part of China (Xiao and Da Khinggan mountains, Heilongjiang; FANG *et al.*, 1980, 1988; FAN & FANG, 1981; FAN *et al.*, 1982, 1990; FAN, 1988; YAO *et al.*, 1991, 1993; LIU, 1994; SUN *et al.*, 1994), from the Primorié and Amur region of Russia, and from



Figs 14-19: Male genitalia (a: sternite V; b: epandrium, surstylus and cercal plate) of *Strobilomyia* species observed in larch cones in China: 14- *S. laricicola*; 15- *S. infrequens*; 16- *S. svenssoni*; 17- S. *baicalensis*; 18- *S. melaniola*; 19- *S. luteoforceps* (from MICHELSEN, 1988, modified, except 14 from FAN *et al.*, 1990, modified).

Sakhalin (STADNITSKII *et al.*, 1978). In China, it attacks *L. gmelini* and *L. olgensis*, but also *L. cajanderi* in Russia.

7- *S. lijiangensis* ROQUES & SUN.

Two other species may be present in northern China, but were not yet recorded:

- *S. viaria* (HUCKETT), a trans-beryngian species, that has been observed from the northwest of America (Canada, USA) to the Baikal area and northeastern Siberia (Yakutia; MICHELSEN, 1988), including Kamtchatka (ROQUES, unpublished observations). In these areas, it attacks *L. gmelini, L. sibirica,* and *L. cajanderi.*

- *S. sibirica* MICHELSEN, an Eurosiberian species observed in the range of the Siberian larch, *L. sibirica,* from eastern Scandinavia (PULKINNEN, 1989) to central Siberia (Krasnoyask area, Khakassia; POPOVA & ELBERG, 1970; MICHELSEN, 1988).

Only few literature exists about the relationships between cone development and species life cycles (YAO *et al.*, 1991; ROQUES *et al.*, 1995). The specific patterns of oviposition and egg shape are still unclear for some species (SUN *et al.*, 1996) as well as specific larval damage (YAO *et al.*, 1991), and the pupae of only 4 species are described (SUN *et al.*, 1993; FAN & HE, 1995). Because larch cone flies constitute a complex of species whose dominant species may change with year and prolonged diapause, the definition of specific methods of control is needed. It thus requires further studies to precise the specific stages of development and specific damage to cones.

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RÉSUMÉ

Les mouches des cônes de mélèze, *Strobilomyia* spp., ont été inventoriées dans les provinces chinoises du Yunnan et du Heilongjiang durant le printemps 1993, à partir de récoltes de cônes et de piégeages visuels. Une nouvelle espèce, *S. lijiangensis* sp.n. est décrite de Lijiang, Yunnan, où elle présente de fortes attaques sur le mélèze de l'Hymalaya, *Larix potaninii*. var. *mastersiana.* Des femelles d'une espèce inconnue de mouches des cônes ont été obtenues à la fois à partir des pièges et des récoltes de cônes de mélèze de Sibérie dans les Monts Da Khinggan du Heilongjiang. Des piégeages complémentaires réalisés en 1996 amènent à considérer que ces insectes correspondent probablement à l'espèce *S. luteoforceps*, dont la femelle n'était pas décrite. De plus, *S. svenssoni* est décrite pour la première fois de Chine, où elle attaque les cônes de mélèze de Sibérie dans le nord-est. Enfin, l'article présente une liste de 7 mouches des cônes de mélèze identifiées en Chine, incluant leur distribution, les arbres-hôtes et la description des appareils génitaux femelles et mâles.

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