The species of Chalcidoidea (Hymenoptera) introduced to North America for biological control of the cabbage seedpod weevil, and the first recovery of *Stenomalina gracilis* (Chalcidoidea: Pteromalidae)

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Abstract—The species of Pteromalidae (Chalcidoidea) introduced to British Columbia, Canada, from Europe in 1949 as *Trichomalus fasciatus* (Thomson, 1878), *Xenocrepis pura* Mayr, 1904, and *Habrocytus* sp. for classical biological control of *Ceutorhynchus obstrictus* (Marsham, 1802) (Coleoptera: Curculionidae) are shown to be misidentifications of *Trichomalus perfectus* (Walker, 1835), *Mesopolobus morys* (Walker, 1848), and *Stenomalina gracilis* (Walker, 1834), respectively. Species reared subsequently from seedpods of *Brassica* spp. (Brassicaceae) in British Columbia and reported in the literature under the first three names are shown to be misidentifications of, respectively, *Trichomalus lucidus* (Walker, 1835), *Mesopolobus moryoides* Gibson, 2005, and one or both of *Pteromalus puparum* (L., 1758) and *T. lucidus*. There is no evidence that either *T. perfectus* or *M. morys* established in North America, but *S. gracilis* is newly recorded from southern British Columbia based on specimens reared from Brassicaceae seedpods in 2004 and 2005.

Résumé—Les espèces de Pteromalidae (Chalcidoidea) introduites d'Europe en Colombie-Britannique, Canada, en 1949 sous les noms de *Trichomalus fasciatus* (Thompson, 1878), de *Xenocrepis pura* Mayr, 1904 et d'*Habrocytus* sp. pour faire une lutte biologique classique à *Ceutorhynchus obstrictus* (Marsham, 1802) (Coleoptera : Curculionidae) ont été mal identifiées et appartiennent en fait respectivement aux taxons *Trichomalus perfectus* (Walker, 1835), *Mesopolobus morys* (Walker, 1848) et *Stenomalina gracilis* (Walker, 1834). Des espèces élevées subséquemment à partir de capsules de graines de *Brassica* spp. (Brassicaceae) en Colombie-Britannique et citées dans la littérature sous les trois premiers noms ci-haut ont aussi été mal identifiées et appartiennent respectivement à *Trichomalus lucidus* (Walker, 1835), à *Mesopolobus moryoides* Gibson, 2005 et à l'une ou les deux des espèces *Pteromalus puparum* (L., 1758) et *T. lucidus*. Il n'y a pas d'indication que *T. perfectus* ou que *M. morys* se soient établies en Amérique du Nord; cependant, la présence de *S. gracilis* est signalée pour la première fois dans le sud de la Colombie-Britannique, à l'étude de spécimens élevés sur des capsules de graines de Brassicaceae en 2004 et 2005.

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Introduction

The cabbage seedpod weevil, *Ceutorhynchus obstrictus* (Marsham, 1802) (Coleoptera: Curculionidae), was introduced accidentally from Europe to western North America about 70 years ago. Since then it has become an invasive pest throughout much of America north of Mexico and a major economic pest of canola (*Brassica napus* L. and *B. rapa* L.) and other Brassicaceae (Kuhlmann *et al.* 2002; Gibson *et al.* 2005). The only attempt at classical biological control of this pest in North America was the introduction of three species of Pteromalidae (Chalcidoidea) from Europe to British Columbia, Canada, in 1949. McLeod (1951) stated that 183 individuals of *Habrocytus* sp. (= *Pteromalus* sp.) had been released at Sardis and 1271 individuals of *Xenocrepis pura* Mayr, 1904 (= *Mesopolobus morys* (Walker, 1848)) and 198 individuals of *Trichomalus fasciatus* (Thomson, 1878) (= *Trichomalus lucidus* (Walker, 1835)) had been released at Sardis and Dewdney. These sites are in the lower Fraser Valley near Vancouver (Fig. 1), where *C. obstrictus* was first found in North America in 1931. McLeod (1953) subsequently reported *Habrocytus* sp., *T. fasciatus*, and *X. pura* as being reared in British Columbia during two surveys to monitor the spread of *C. obstrictus* from 1939 to 1951.

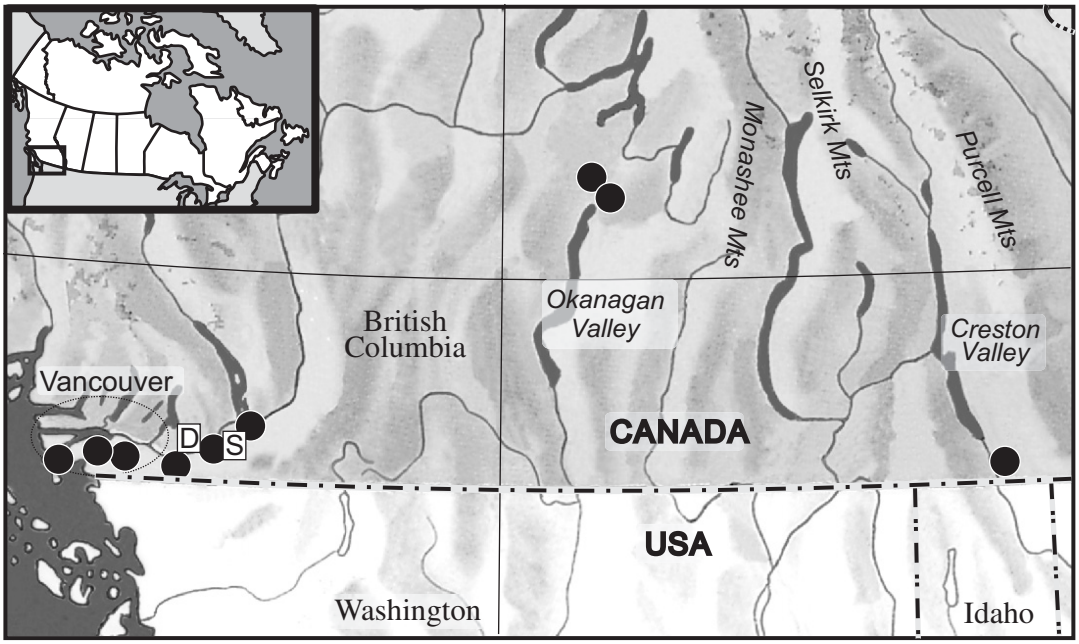
As part of a study of the introduced and native chalcid parasitoids of *C. obstrictus* in North America, G. Gibson examined voucher specimens of the chalcid species that McLeod (1951) reported as being introduced from Europe, cultured in Ontario, and released in British Columbia in 1949. Voucher specimens of species reported in the literature as being reared subsequently from *C. obstrictus* in British Columbia were also examined to confirm their identities. Finally, new surveys for cabbage seedpod weevil parasitoids were conducted in 2004 and 2005 in southwestern British Columbia near the original 1949 release sites and further east at sites in the Okanagan Valley and Creston Valley (Fig. 1). These surveys were made to determine whether any of the introduced species had established. Here we report the corrected identifications of the introduced and previously reported parasitoids and confirm the presence of one of the three introduced species in British Columbia.

Materials and methods

This study is based on voucher specimens of the three species that McLeod (1951) listed as imported from Europe and released in British Columbia (BC) in 1949 against *C. obstrictus*, voucher specimens of the species reported in McLeod (1953) as reared from *C. obstrictus* in BC from 1939 to 1951, specimens that were either collected or reared from Brassicaceae seedpods in BC in 2004 and 2005 and in Alberta and Saskatchewan from 2002 to 2005, and specimens from other collections and localities listed in Gibson *et al.* (2005). Unless stated otherwise, all voucher specimens are in the Canadian National Collection of Insects and Arachnids (CNC), Ottawa, Ontario, including those reported in McLeod (1951, 1953). The latter material was transferred to the CNC from the Belleville Research Station after that station closed in 1972. Voucher material of the introduced species includes originally identified European specimens of two of the three species from which the colonies were established and all three of the species colonies. Cultured specimens are labelled as either "Belleville coll." or "Union, Ontario", and these and the European specimens are associated by a common experiment number, 18310H9–1. McLeod (1953) did not give exact localities of specimens examined but stated that two surveys had been conducted, one from 1939 to 1945, by R. Glendenning of Agassiz, that included Vancouver Island and one from 1949 to 1951, by the Vancouver laboratory, of important seed-growing areas in BC. McLeod (1953) stated that for the latter survey, *C. obstrictus* had been reared from cabbage, cauliflower, Brussels sprouts, Swede turnip, and wild turnip (*Brassica* spp.), and he provided parasitism rates for seedpods of cabbage on Vancouver Island and turnip from Fraser Valley. These data were used to identify possible voucher material of the species listed in Table II of McLeod (1953).

In our 2005 survey, parasitoids were reared from the seedpods of *B. napus*, *B. rapa*, *Raphanus raphanistrum* L. (wild radish), and *Sinapis arvensis* L. (wild mustard) (Brassicaceae), which were collected from 17 sites near Abbotsford, Agassiz, Chilliwack, Delta, Ladner, Langley, and Surrey in the lower Fraser Valley in southwestern BC, 2 sites near Armstrong and Enderby in the Okanagan Valley, and 9 sites near Creston in the Creston Valley in southeastern BC (Fig. 1). Collected seedpods were

Fig. 1. Map of southern British Columbia showing 1949 introduction sites (squares: D, Dewdney; S, Sardis) of *Mesopolobus morys*, *Stenomalina gracilis*, and *Trichomalus perfectus*, and 2005 survey sites (dots) for parasitoids of the cabbage seedpod weevil.



brought to the laboratory and placed in cardboard boxes (18 cm × 18 cm and 16 cm tall), and the boxes were sealed with tape. Each box had a small cylindrical plastic vial attached over an opening in the side of the box to collect parasitoids as they emerged. After all parasitoids had emerged, the boxes were opened and any additional parasitoid adults that had not moved to the plastic collecting vials were collected. Parasitoids were preserved in 70% ethanol and subsequently identified by G. Gibson.

Results

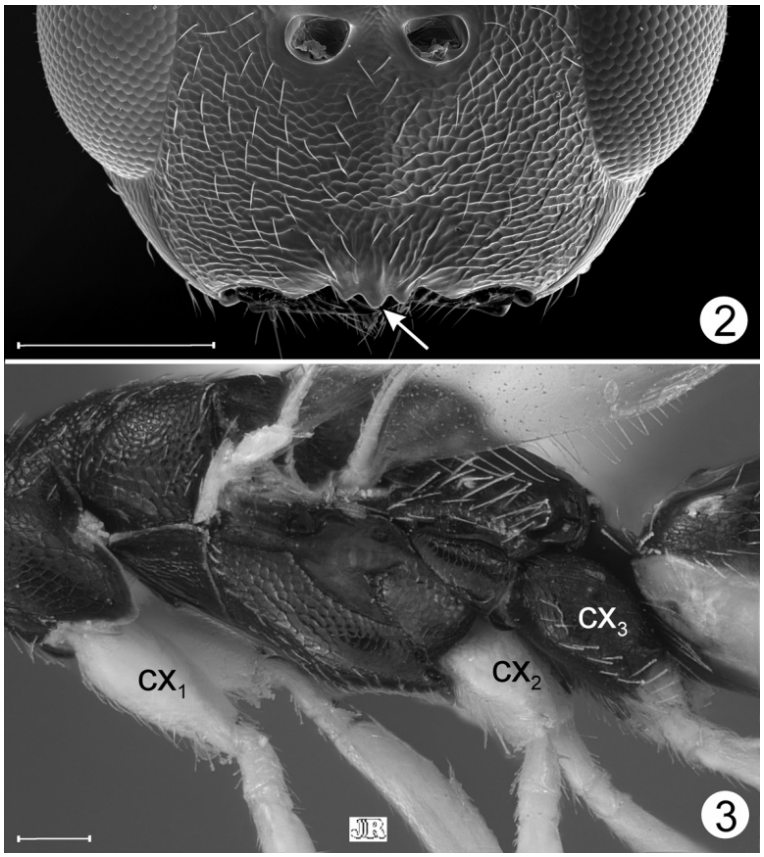
European specimens were found in the CNC for two of the three species reported as cultured in Ontario and subsequently released in BC. These had been identified as *Habrocytus* sp. and *X. pura*. No European voucher material of the species originally identified as *T. fasciatus* was located. Based on label data of the specimens, at least the first two taxa were obtained from Dallikon, Switzerland, contrary to the statement of "England" in McLeod (1951, 1962). Originally identified voucher specimens of all three species cultures established from the European specimens were also located. All specimens that were identified as *X. pura* (6 ♀, 5 ♂ from Dallikon; 5 ♀, 7 ♂ from culture) are *M. morys*. Eight female and one male culture specimen that had been identified as *T. fasciatus* are all *Trichomalus perfectus* (Walker, 1835). One other male identified as "pteromalid" and another as "*Habrocytus* or *Trichomalus* sp." are also *T. perfectus*. The species imported and cultured as *Habrocytus* sp. was also misidentified and comprised a mixed culture. Of 14 specimens from Dallikon identified as *Habrocytus* sp., 4 females and 4 males are *Stenomalina gracilis* (Walker, 1834), 1 female and 1 male are *M. morys*, 1 female and 1 male are *T. lucidus*, 1 male is *T. perfectus*, and 1 female is *Pteromalus semotus* (Walker, 1834) (Pteromalidae). Of 47 culture voucher specimens that were identified as *Habrocytus* sp., 29 females and 15 males are *S. gracilis* and 3 females are *M. morys*. Consequently, most of the material released in BC as *Habrocytus* sp. was undoubtedly *S. gracilis*, but *M. morys* and possibly also *T. lucidus* and *P. semotus* may have been released.

The exact specimens that represent voucher material for McLeod (1953) are uncertain, but the CNC has 24 females and 5 males labelled as reared from *C. obstrictus* on turnip or wild mustard/turnip from localities in the Fraser Valley (Abbotsford, Aldergrove, Matsqui, Newton

Station, Nicomen Island, Sardis, Vancouver) from 1949 to 1951. These specimens were identified as either *M. morys* or *Zatropis* sp. Another 17 females and 5 males from Ladner that were reared in 1953 and 1954 were identified as *Zatropis* sp. *Zatropis* Crawford, 1908 is a junior synonym of *Lyrcus* Walker, 1842 (Bouček 1993), but all 51 specimens are *Mesopolobus moryoides* Gibson, 2005. Another 85 females and 44 males labelled as reared from *C. obstrictus* from Vancouver Island and localities in the Fraser Valley (Agassiz, Chilliwack, Dewdney, Ladner, Nicomen Island, Sardis, Vancouver) from 1939 to 1951 were identified as *T. fasciatus* or were not identified to species in the CNC miscellaneous collection of *Trichomalus* Thomson, 1878. Of these, all are *T. lucidus* except for 1 female from Vancouver Island collected 2 August 1949, 1 female from Vancouver collected 23 August 1951, and 1 male from Marine Drive, Vancouver, collected 23 August 1951. These three specimens had been identified as *T. fasciatus*, but the first female represents an unidentified species of *Chlorocytus* Graham, 1956 and the second female and the male represent at least one unidentified species of *Pteromalus* Swederus, 1795 (Pteromalidae). No specimen bearing a *Habrocytus* sp. identification label that could represent voucher material from McLeod (1953) was found in the CNC, but 4 females and 1 male found in the miscellaneous *Pteromalus* collection were labelled as reared from *C. obstrictus* in turnip seed, collected 12 July and emerged 25–28 July 1950, from Matsqui. All five specimens are *Pteromalus puparum* (L., 1758). These undoubtedly represent at least some of the specimens listed as *Habrocytus* sp. in McLeod (1953) but likely represent an incorrect host association because of unrealized contamination of mass-reared seedpods by the diamondback moth, *Plutella xylostella* (L., 1758) (Lepidoptera: Plutellidae). Numerous individuals of this other pest of canola emerged from the rearing boxes containing mass-collected *Brassica* spp. seedpods in our 2005 survey. There are also 2 females in the National Museum of Natural History (USNM), Washington, D.C., labelled as reared from *C. obstrictus* and collected from Dewdney, 27 June 1934, by R. Glendenning. The specimens were identified as "*Habrocytus* sp." but are *T. lucidus*. It is possible that the record of *Habrocytus* sp. in McLeod (1953) results partly from these two females even though they were collected prior to the listed surveys. Voucher specimens of the other three chalcid species listed in McLeod (1953), *Eupelmus vesicularis* (Retzius, 1783) (as *Eupelmella vesicularis*) (Eupelmidae) (see Gibson 1990, 1995), *Eurytoma* sp. (Eurytomidae), and *Necremnus tidius* Walker, 1839 (as *Necremnus duplicatus* Gahan, 1941) (Eulophidae) (see Gibson *et al.* 2005), were also found and the identifications verified.

There have been no published records of parasitoids reared from *C. obstrictus* in BC since those of McLeod (1953), but in 2004 we reared 63 parasitoids from the seedpods of either *B. napus* or *B. rapa* collected near Creston. The parasitoids included 39 females and 19 males of *T. lucidus*, 2 females of *M. moryoides*, 2 females of *S. gracilis*, and 1 male of *Euderus* sp. (Eulophidae). One female *N. tidius* was also reared from near Armstrong ("Hwy 97 N. Armstrong, 49°27.755′N 199°08.707′W, 7.VII.2004, *ex.* volunteer mustard pod, H. Philip & B. Costello") and 1 female *S. gracilis* was reared from near Abbotsford ("49°03.146′N 122°11.321′W, 5.VII.2004, *ex.* volunteer canola pod, H. Philip & B. Costello"). These records represent the first known presence of *S. gracilis* in North America. Because *S. gracilis* was found among only 65 parasitoids reared, we initiated a more intensive survey in 2005 to investigate whether the presence of either *M. morys* or *T. perfectus* could also be proven. A comprehensive analysis of the results of this survey will be presented elsewhere, but a total of 1125 chalcid parasitoids were reared from *B. napus*, *B. rapa*, and *R. raphanistrum* seedpods collected from localities in the lower Fraser Valley near the original (1949) sites of release of *M. morys*, *S. gracilis*, and *T. perfectus* (Fig. 1). Of these, 548 individuals (49%) were *T. lucidus*, 327 (29%) were *S. gracilis*, 122 (11%) were *M. moryoides*, and 81 (7%) were *N. tidius*. The remaining 47 parasitoids (4%) consisted of several other species, all of which were uncommon and at least some of which likely were parasitoids not of *C. obstrictus* but of other insect contaminants of the mass-reared seedpods. From the two sites sampled in the Okanagan Valley, 1 female *M. moryoides* and 1 female and 1 male *Lyrcus maculatus* (Gahan, 1914) (Pteromalidae) were reared from the seedpods of *B. rapa* collected near Enderby, whereas 18 *M. moryoides*, 2 female *T. lucidus*, and 1 female *Pteromalus* sp. were reared from the seedpods of *S. arvensis* collected near Armstrong. A total of 281

Figs. 2 and 3. *Stenomalina gracilis*: 2, female lower face (arrow points to median tooth of clypeus); 3, male lateral mesosoma (cx_n: pro-, meso-, and meta-coxa). Scale bars = 200 μm.



parasitoids were reared from the seedpods of either *B. napus* or *B. rapa* from sites near Creston in southeastern BC. Of these, 246 individuals (88%) were *T. lucidus*, 12 (4%) were *S. gracilis*, and 7 (2%) were *M. moryoides*. The remaining 16 parasitoids (6%) consisted of other species.

Discussion

Voucher specimens deposited in the CNC prove that *M. morys*, *T. perfectus*, and *S. gracilis* were introduced to BC in 1949. Several surveys of parasitoids of *C. obstrictus* in western Canada as well as western and southeastern United States of America failed to recover any of the species (see Gibson *et al.* 2005) except for the rearings of *S. gracilis* reported here. Our 2004 and 2005 surveys of chalcid parasitoids associated with Brassicaceae seedpods recovered *S. gracilis* from localities near the original 1949 introduction release sites as well as from the Okanagan and Creston valleys in southeastern BC, but not *M. morys* or *T. perfectus*. Parasitism rates of *C. obstrictus* by *S. gracilis* appear to be much higher near the original introduction release sites than in Creston (29% versus 4%), which is separated from the release sites by several mountain ranges (Fig. 1). Furthermore, extensive surveys of chalcid parasitoids associated with canola seedpods in Alberta and Saskatchewan from 2002 to 2005 did not recover any *S. gracilis* (unpublished data). These results suggest that the presence of *S. gracilis* in southern BC, the only part of North America from which the species is known, is the result of the 1949 introduction, followed by establishment and dispersal as far east as Creston. In Europe, both *T. perfectus* and *M. morys* are much more common parasitoids of *C. obstrictus* than is *S. gracilis* (Murchie and Williams 1998; Klander 2001). The absence of *T. perfectus* and *M. morys* from our surveys indicates these two species did not establish after their 1949

introductions and could be considered for reintroduction for classical biological control of *C. obstrictus*.

Gibson *et al.* (2005) described and illustrated morphological features to differentiate *M. morys* from *M. moryoides* and *T. lucidus* from *T. perfectus*. Although no described species of *Stenomalina* Ghesquière, 1946 were recorded in North America by Noyes (2002), Bouček and Heydon (1997) included the genus in their key to the genera of Pteromalidae from the Nearctic region and estimated that more than 10 species are present. Individuals of *Stenomalina* are morphologically similar to those of *Chlorocytus* except that the clypeus has a distinct median tooth (Fig. 2) rather than being truncate, which is unique among known parasitoids of *C. obstrictus*. Graham and Claridge (1965) and Graham (1969) keyed *S. gracilis* (as *Stenomalina muscarum* (L., 1758) of authors) as one of 12 valid species of *Stenomalina* in the Palearctic region. Females of *S. gracilis* are very similar to two other European species, *Stenomalina iera* (Walker, 1844) and *Stenomalina micans* (Olivier, 1813), except that, as the name implies, they are somewhat more elongate-slender with slightly more slender legs and a longer marginal vein, as described by Graham and Claridge (1965) and Graham (1969). In addition, the head in dorsal view has the anterior surface comparatively flat instead of convex in the other two species (*cf.* Figs. 21, 22 in Graham and Claridge 1965; Figs. 473, 474 in Graham 1969). Males of *S. gracilis* are more readily identified to species than females are because they uniquely have the pro- and meso-coxae yellow, similar to the rest of the legs but contrasting distinctly with the dark metacoxae and mesosoma (Fig. 3). Males of other known species of *Stenomalina* and other known parasitoids of *C. obstrictus* in North America have all the coxae dark.

Noyes (2002) listed seven known host species for *S. gracilis*, including *C. obstrictus* and six species in four families of Diptera (Agromyzidae, Calliphoridae, Cecidomyiidae, and Tephritidae). *Stenomalina gracilis* was reared from *C. obstrictus* in England by Nasredlin (1973), in northern Germany by Klander (2001), and in Switzerland by Muller *et al.* (2004). Klander (2001) also reared *S. gracilis* from *Ceutorhynchus alliariae* Brisout, 1860, *Ceutorhynchus pallidactylus* (Marsham, 1802), *Ceutorhynchus roberti* Gyllenhal, 1837, *Microplontus edentulus* (Schultze, 1897), and *Microplontus rugulosus* (Herbst, 1795) (Curculionidae). Although parasitism rates of *S. gracilis* vary among localities and host species surveyed in Europe, this species is usually the third most common chalcid parasitoid of *C. obstrictus* after *T. perfectus* and *M. morys*.

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