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Keynote: The Trichoptera fauna of Asia

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Abstract

Many foreign and indigenous scientists have contributed extensively to our knowledge of Asian caddisflies. At the time of the Trichoptera Symposium in 2012, the number (1,090 spp.) and density (43 spp./Gm^2) of Trichoptera species in the East Palearctic Region were the least for any of the Earth's 7 biogeographic regions as defined by the Trichoptera World Checklist; the number (5,313 spp.) and density (405 spp./Gm^2) in the Oriental Region were the greatest. Limnephilidae, Rhyacophilidae, and Leptoceridae are the most speciose families in the East Palearctic Region; Leptoceridae, Hydropsychidae, and Hydroptilidae in the Oriental Region. In the East Palearctic Region, 288 fossil species have been reported, most of which are ichnotaxa, sedimentary impressions of larval cases for which the family is unknown; in the Oriental Region, only two fossil species are known, both from Burmese amber. Based on cosmopolitan species, the distinction between the East Palearctic and Oriental Regions is as great or greater than average; the distinction between the East and West Palearctic Regions is less than average but between the East Palearctic and the Nearctic Region is greater; the fauna of the Oriental Region is conspicuously endemic. Future increases in knowledge of the Asia Trichoptera fauna will result from accelerated collecting in poorly explored regions; increasing the rate of identifying and describing new and poorly known species, especially with use of modern molecular, computational, and networking tools and especially focusing on descriptions of larvae in the Oriental Region; mentoring young Asian Trichoptera scientists for excellence in research quality and productivity; and promoting international collaborations for theoretical and applied science in Asia.

Key words: East Palearctic Region, Oriental Region, species, endemism, future research

Introduction

Asia is the largest continent, consisting of the East Palearctic and Oriental Biogeographic Regions, with all extremes of climate and topography. For purposes of the Trichoptera World Checklist (Morse 2012), the Eastern Palearctic Region (EP) consists of all lands east of the Russian Ural mountains and the Caspian Sea; north of Iran, Afghanistan, Pakistan, oriental China and the island of Kotakara-jima (Watase Line/Tokara Channel, Tokara-gunto); and west of Midway Island, the Aleutian Islands, Saint Lawrence Island, and Alaska. The Oriental Region (OL) consists of all lands east of Heard, Kerguelen, St. Paul, Amsterdam, Rodriguez, and Seychelles Islands and Iran; south of the Russian Federation, Turkmenistan, Uzbekistan, Tajikistan, the East Palearctic Chinese Provinces of Xinjiang and Qinghai (Schmid 1966), Gansu, Shaanxi, Henan, and Shandung, and the island of Akuseki-shima (Watase Line/Tokara Channel, Tokara-gunto); west of Guam, Palau, Halmahera, Obi, Buru, Teun, and Barbar Islands and Australia; and north of Antarctica (Fig. 1).

East Palearctic Trichoptera

Eight of the 17 "*Phryganea*" species described from Sweden by Linnaeus (1758) occur in both the East Palearctic and West Palearctic Regions, including in their modern combinations the polycentropodid *Neureclipsis bimaculata* (L.); the phryganeids *Phryganea grandis* L. and *Semblis phalaenoides* (L.); the limnephilids *Limnephilus griseus* (L.) and *Limnephilus rhombicus* (L.); and the leptocerids *Athripsodes*

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albifrons (L.), *Mystacides longicornis* (L.), and *Mystacides nigra* (L.). Subsequently, *Semblis atrata* Gmelin 1789 became the first caddisfly species described originally from the East Palearctic Region (Siberia), although it was later found also in the West Palearctic Region. *Thamastes dipterus* Hagen 1858 was the first endemic East Palearctic and Asian caddisfly species described. Matsumura (1904) was the first Asian scientist to describe Asian caddisflies [*Limnephilus fuscovittatus* Matsumura, *Hagenella apicalis* (Matsumura), and *Oligotricha fulvipes* (Matsumura)].

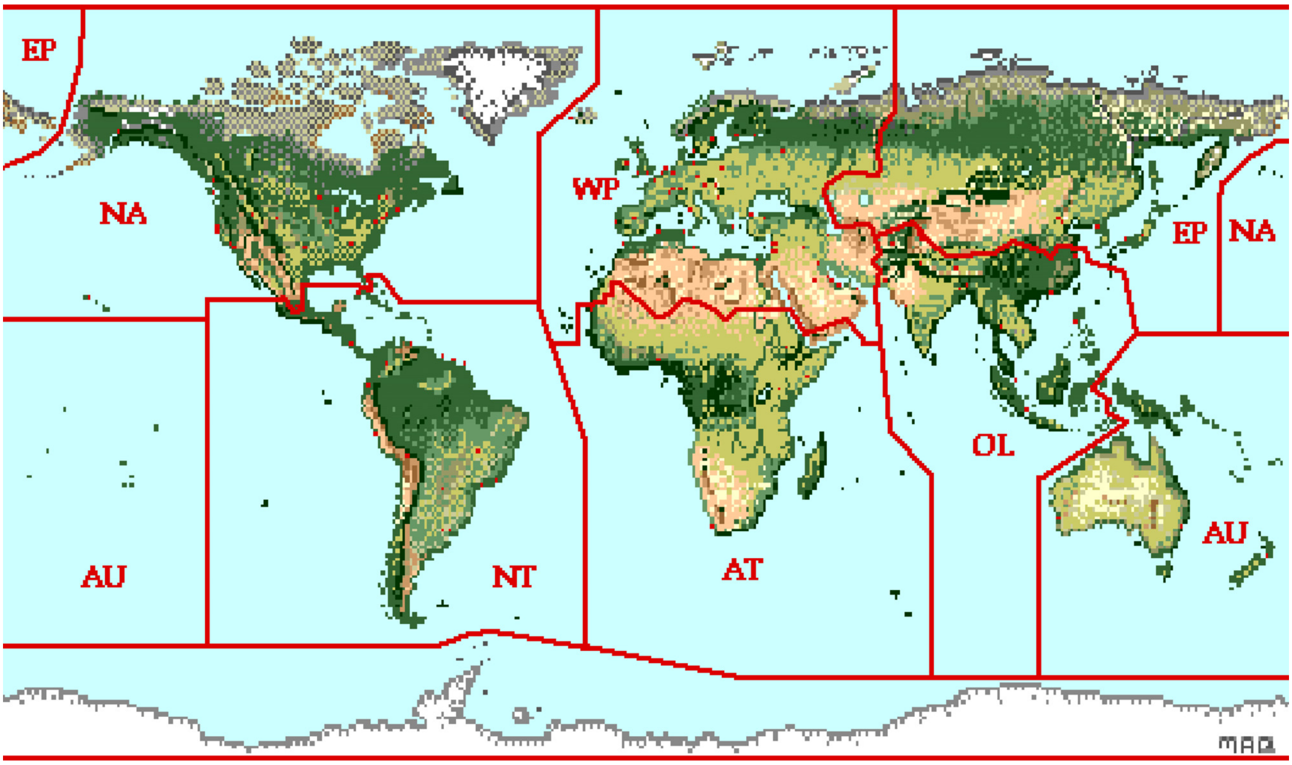

FIGURE 1. World biogeographic regions according to the Trichoptera World Checklist (Morse 2012).

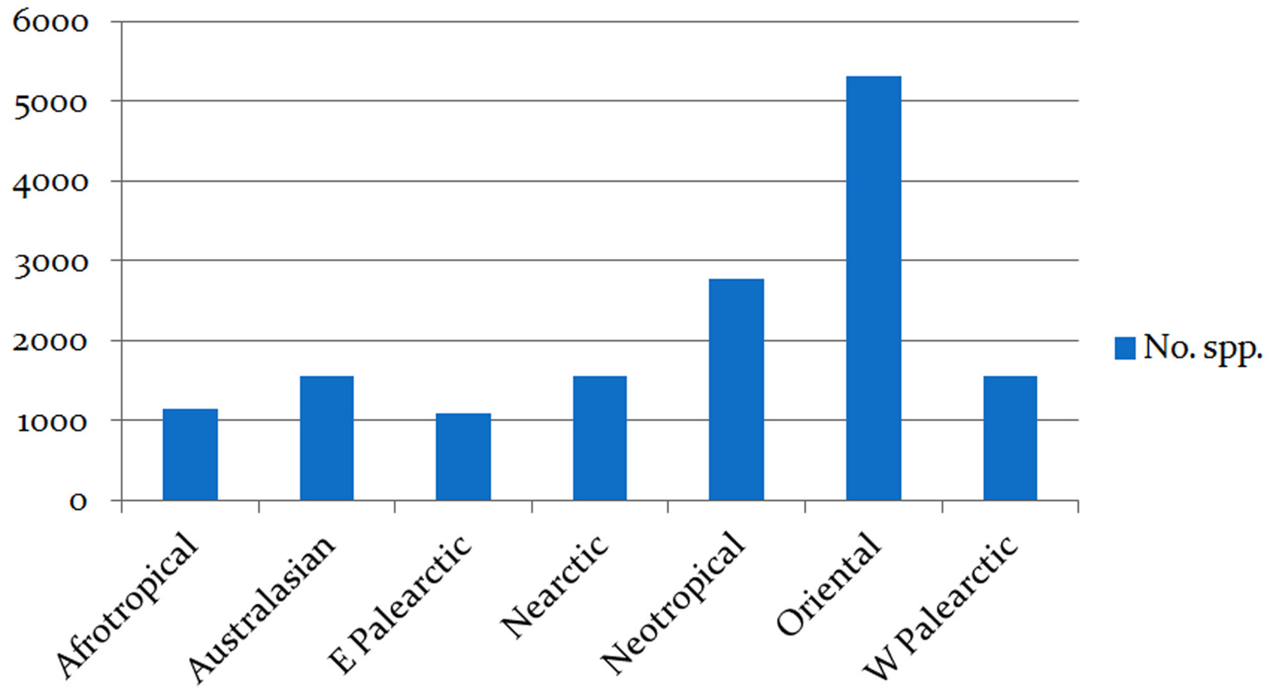

FIGURE 2. Number of extant species of Trichoptera in the world biogeographic regions (Morse 2012).

As of the time of our 2012 Symposium, 1,090 extant East Palearctic caddisfly species had been described, slightly fewer than in the Afrotropical Region (1,130) and the fewest for any biogeographic region (Fig. 2). In conjunction with its large land area, the density of species in the East Palearctic Region (43 spp./Gm^2) also is less than for any of the other biogeographic regions (Fig. 3).

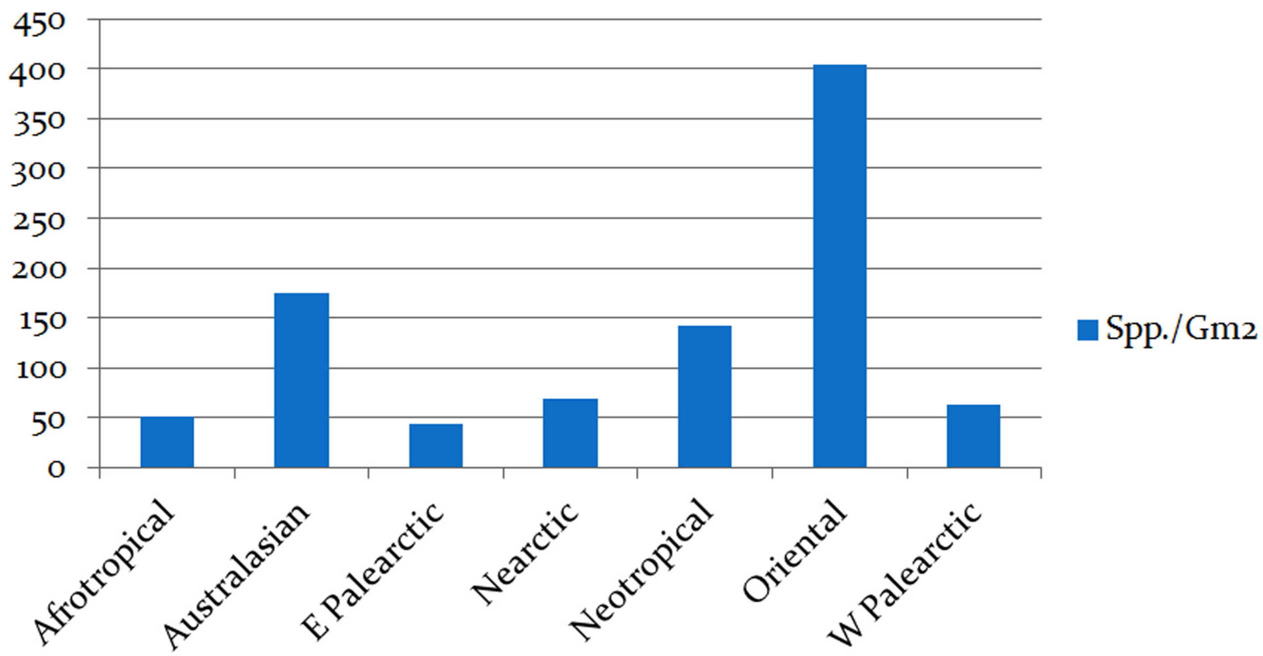

FIGURE 3. Density of extant species of Trichoptera in the world biogeographic regions (spp./Gm^2).

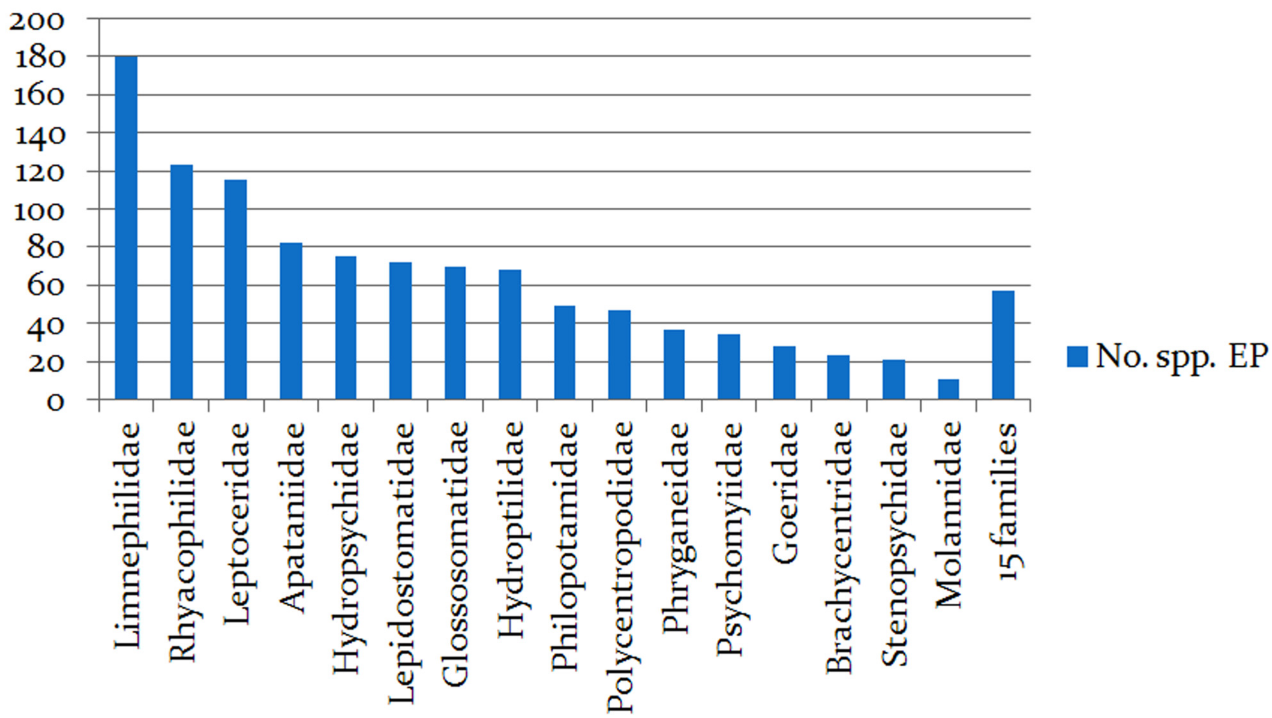

FIGURE 4. Number of extant species of Trichoptera in the East Palearctic families (Morse 2012).

With 180 extant species, the Limnephilidae are the dominant Trichoptera family in the East Palearctic Region, consistent with the high proportion known from the rest of the Holarctic. The high number of limnephilid species is followed by those of Rhyacophilidae (123 spp.) and Leptoceridae (114 spp.) and 28 other families with fewer representatives in the East Palearctic (Fig. 4). Of particular note, 40% of the world's fauna of Apataniidae (82 of 203 spp.) occurs in this region.

The 288 fossil caddisfly species of the East Palearctic Region are mostly from Jurassic and Cretaceous sedimentary deposits. Of these, 222 are species for which the family is uncertain, mostly ichnotaxa known only from fossilized larval cases. The family with the largest number of East Palearctic fossil caddisfly species identifiable to family is the fossil family †Vitimotaluliidae (14 spp.) (Fig. 5).

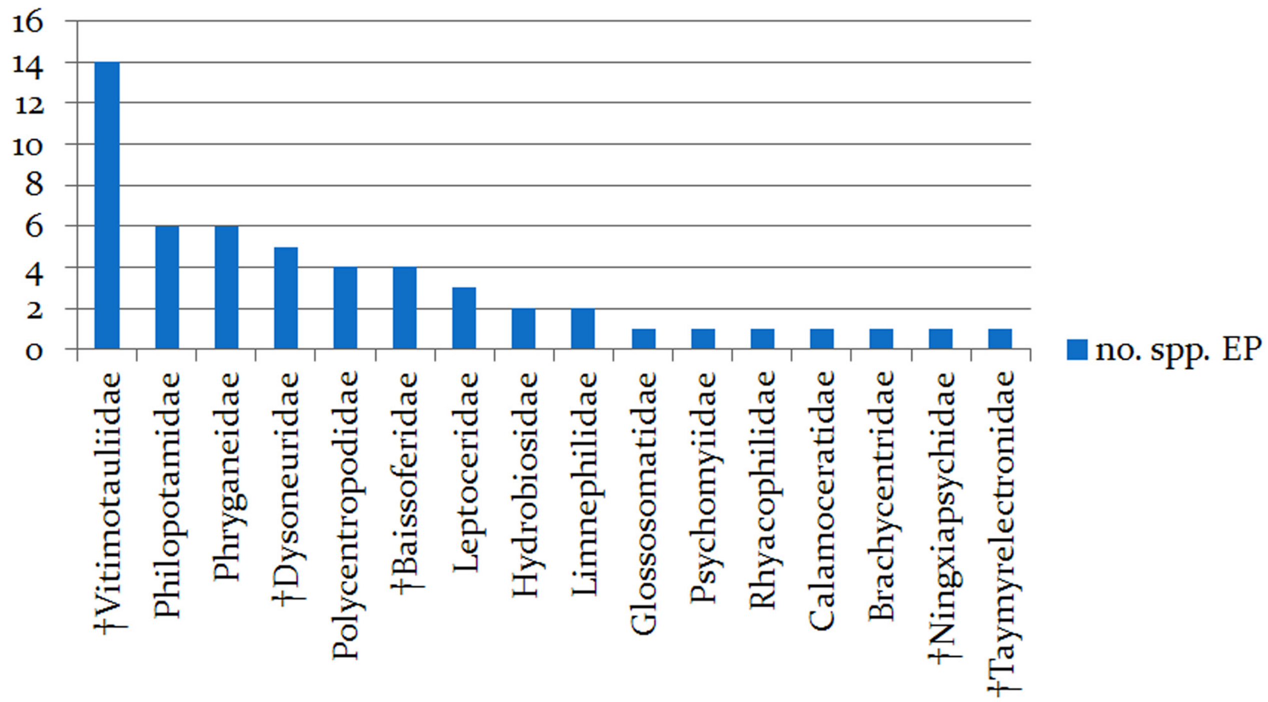

FIGURE 5. Number of fossil species of Trichoptera in the East Palearctic families (Morse 2012).

The Russian scientist A.V. Martynov described more extant East Palearctic species (160 spp.) than any other trichopterologist. Through the years, the leading indigenous East Palearctic authors for extant species have included M. Kobayashi, M. Tsuda, T. Ito, M. Iwata, T. Nozaki, H. Nishimoto, N. Kuhara, S. Matsumura, and K. Tanida (all Japanese) and T.I. Arefina and I.M. Levanidova (Russian) (Fig. 6). Most of the East Palearctic fossil Trichoptera species (90%) were described by I.D. Sukatsheva (268 spp.); eleven other authors collaborated with her or contributed the remaining fossil species from this region on their own.

Oriental Trichoptera

Dipseudopsis notata (Fabricius 1781) was the first probable Oriental species described; it was apparently mislabeled "boreal America," but probably is endemic to India or Sri Lanka (Weaver & Malicky 1994). Masatoshi Iwata (1928) was the first Asian to describe Oriental caddisflies: *Hydropsyche formosae* Iwata, *Tinodes formosae* Iwata, *Ganonema formosae* Iwata, *Catoxyethira formosae* (Iwata), and *Rhyacophila formosae* Iwata. Huang Qi-ling ("Hwang Ch-l." in Ross & Hwang 1953) was the first indigenous Oriental scientist to describe caddisflies (with H.H. Ross): *Glossosoma aveletum* Ross & Hwang, *G. taeniatum* Ross & Hwang, and *G. sellatum* Ross & Hwang.

As of the time of our 2012 Symposium, 5,313 extant Oriental caddisfly species had been described, nearly twice the number for the Neotropical Region (2,780 spp.) and the most for any biogeographic region (Fig. 2). In conjunction with its small land area, the density of species in the Oriental Region (405 spp./Gm^2) also is much more than for any of the other biogeographic regions (Fig. 3).

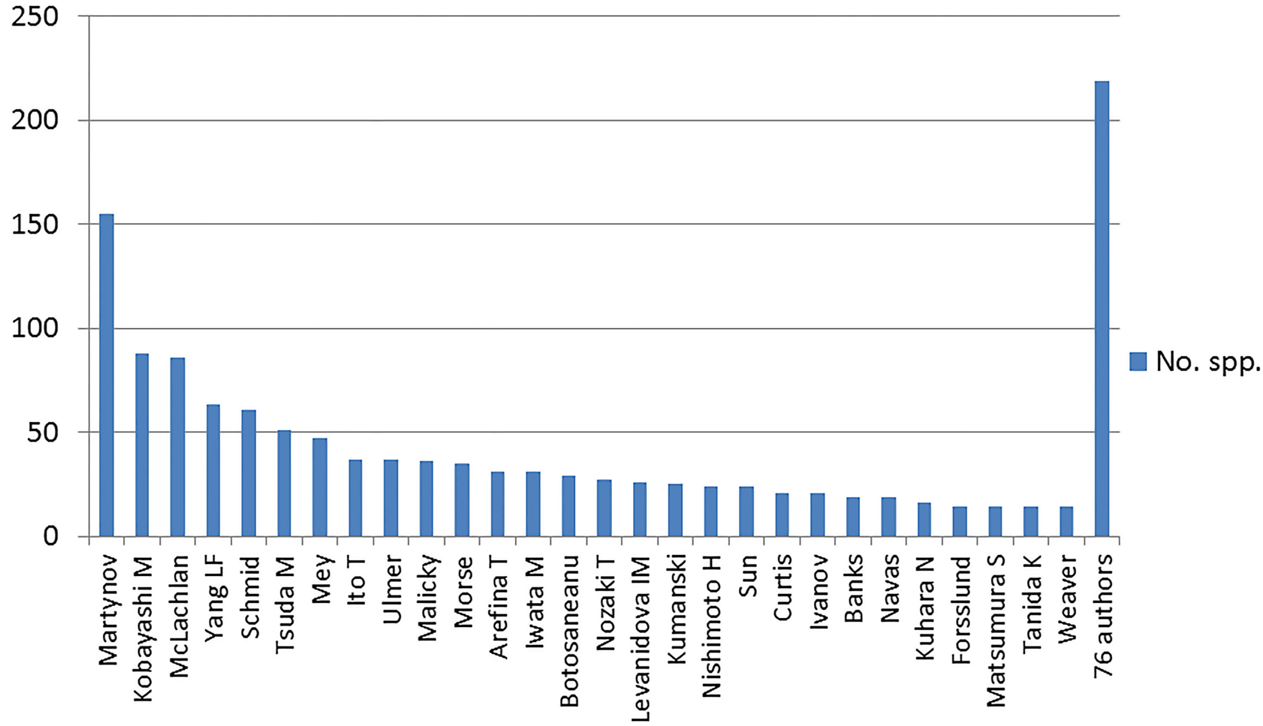

FIGURE 6. Number of extant East Palearctic species described by various authors (Morse 2012).

With 932 known extant Oriental species, the Leptoceridae are the dominant Trichoptera family from among the 31 caddisfly families known in the Oriental Region; the next-most speciose Oriental families are Hydropsychidae (715 spp.), Hydroptilidae (556 spp.) and Philopotamidae (533 spp., Fig. 7). These are the same four dominant families in the Afrotropical and Australasian Regions and four of the five most-speciose families in the Neotropical Region, confirming the general dominance of these families in tropical and subtropical habitats globally. Notably, 46% of the world's fauna of Leptoceridae (2,012 spp.) and 39% of the world's fauna of Hydropsychidae (1,815 spp.) occurs in this Oriental Region.

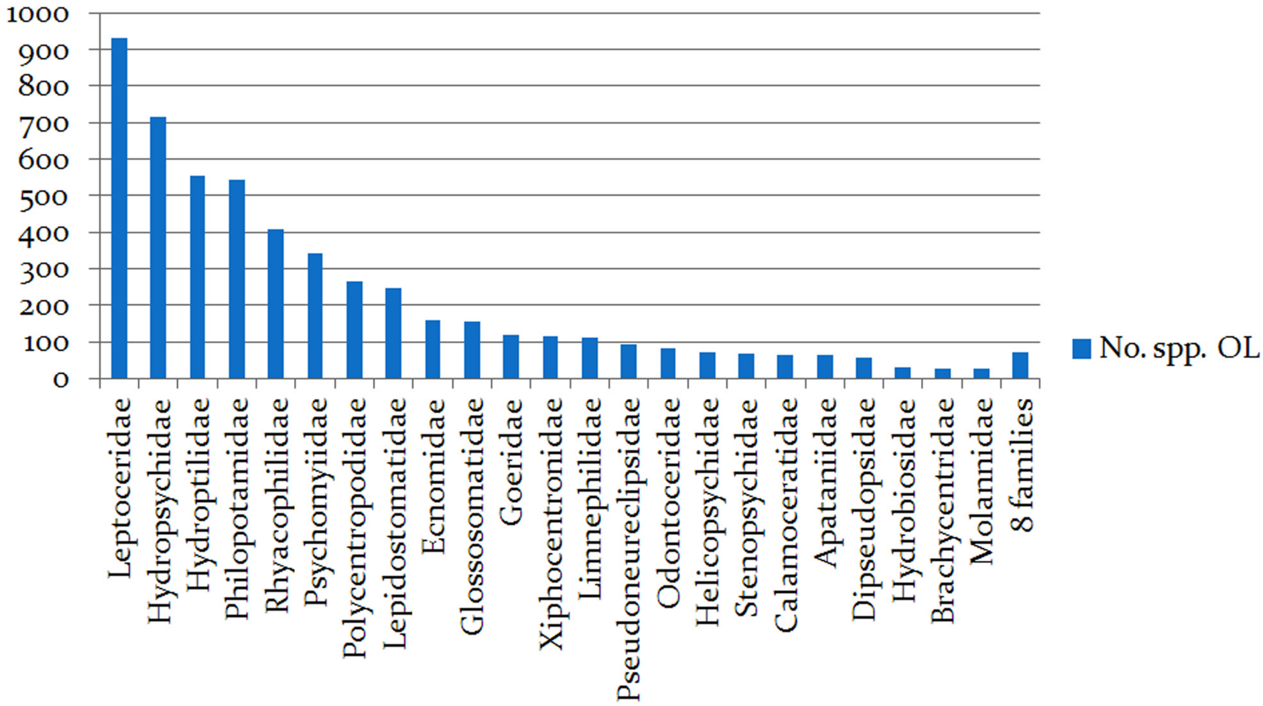

FIGURE 7. Number of extant species of Trichoptera in the Oriental families (Morse 2012).

Only 2 fossil caddisfly species are known from the Oriental Region, both from Cretaceous-late-Albian Burmese amber: †*Palerasnitsynus* †*ohlhoffi* Wichard, Ross, & Ross 2011 (Psychomyiidae) and †*Burminoptila* †*bemeneha* Botosaneanu 1981 (Hydroptilidae).

From 1758 through the 1920s, relatively few caddisfly species were known from Asia. Since then, the rates of increase in the number of known species in the East Palearctic and Oriental Regions have escalated, but at very different rates (Fig. 8). The divergence began especially with the works of L. Navás (66 species in 13 publications during 1930–1936) and A.V. Martynov (120 species in 5 publications during 1930–1932, 1935–1936) and M.E. Mosely (91 species in 14 publications during 1934–1942, 1949), describing species mainly in China and India. During 1959 through 1997, the Swiss-Canadian scientist F. Schmid published extensively on the results from his expeditions in Pakistan (1953), Sri Lanka (1954), India (1958–1962) and neighboring areas. The Austrian scientist H. Malicky began publishing on the Oriental fauna in 1970 (Malicky 1970); his output on the Asian fauna accelerated when he began in 1987 describing species from Thailand (Malicky 1987) and surrounding regions and developed a very productive collaboration with P. Chantaramongkol and her students that has persisted until the present. Similarly, J.C. Morse and Chinese scholar Yang L-f. and their students began collaborating in 1987 (Yang & Morse 1988) and also have continued a productive effort until the present. Together, Malicky (1,811 spp.) and Schmid (1,019 spp.) have described more extant Oriental species than any other trichopterologists. Through the years, the leading indigenous Oriental authors for extant species have included P. Chantaramongkol and T-o. Prommi (Thailand), and Yang L-f., Sun Ch-h., Li Y-w., Tian L-x., and Huang Q-l. (all Chinese). These and other major contributors are noted in Fig. 9.

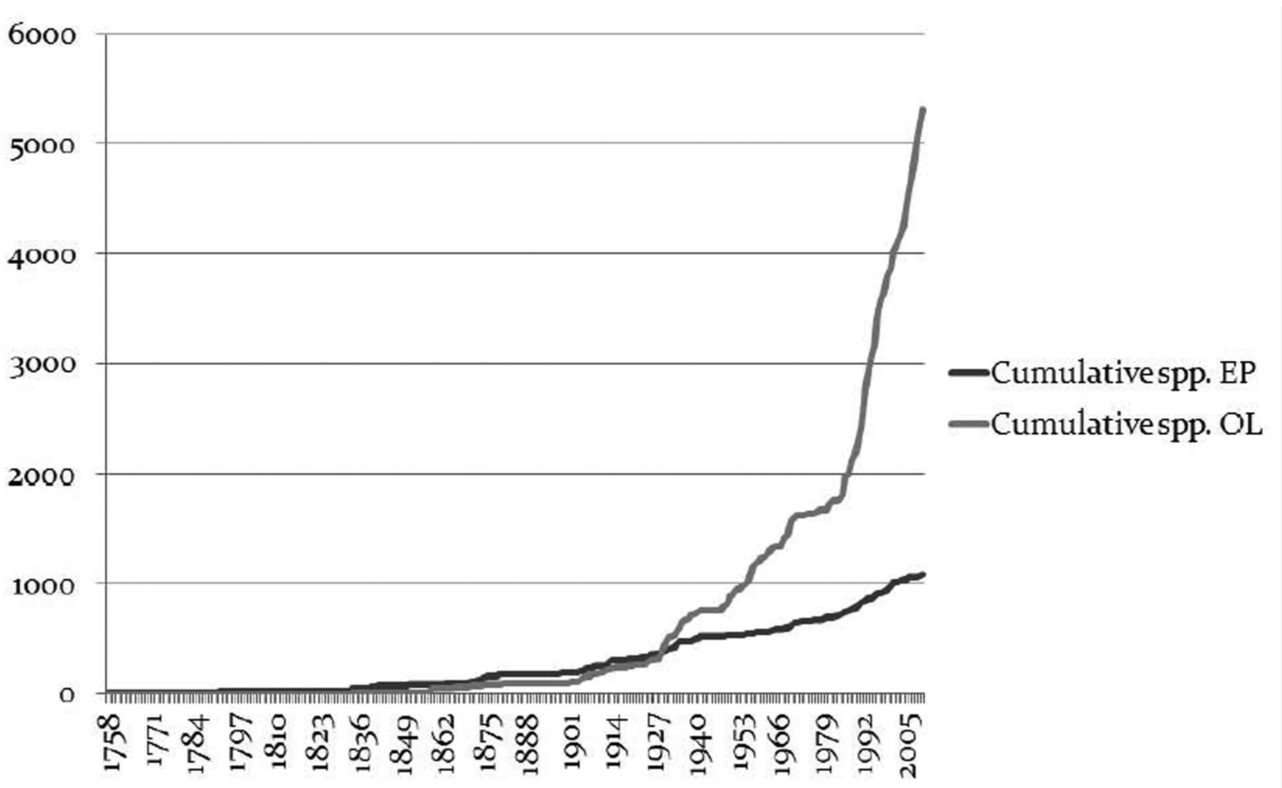

FIGURE 8. Cumulative number of extant East Palearctic and Oriental species of Trichoptera since 1758.

Relationships of Asian Trichoptera Faunas

Globally, about 9% of caddisfly species occur in two or more biogeographic regions. By comparison, the caddisfly faunas of the East Palearctic and Oriental Regions seem relatively distinct: 86 species are common to both regions (9% of EP species occur also in the OL and 2% of OL species occur also in the EP Region) (Table 1). Considering the most speciose families in Asia, 24 species of Leptoceridae (29% of EP spp., 2% of OL spp.), 14 species of Limnephilidae (7% of EP spp., 12.5% of OL spp.), 8 species of Hydropsychidae (11%

of EP spp., 1% of OL spp.), 5 species of Rhyacophilidae (4% of EP spp., 1% of OL spp.), and 3 species of Hydroptilidae (4% of EP spp., 0.5% of OL spp.) occur in both regions.

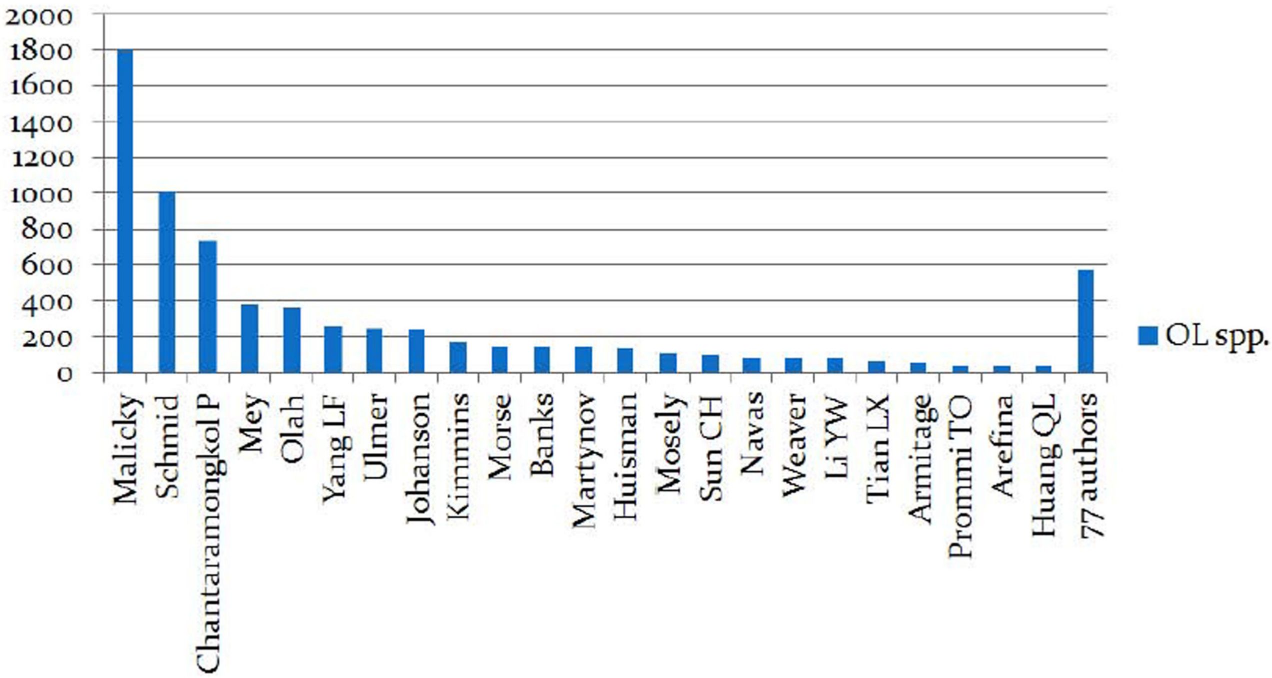

FIGURE 9. Number of extant Oriental species described by various authors (Morse 2012).

TABLE 1. Cosmopolitanism of Asian (East Palearctic and Oriental) Trichoptera species, showing number of species occurring in pairs of biogeographic regions and the percentage of shared species of Asian regions (Morse 2012). No species occur in both the East Palearctic or the Oriental and the Neotropical Biogeographic Regions. AT = Afrotropical, AU = Australasian, EP = East Palearctic, NA = Nearctic, OL = Oriental, WP = West Palearctic.

Regions	Shared spp.	% of shared species, with number of those cosmopolitan spp. having wider distribution
EP+OL	97 spp.	09% of EP spp., 2% of OL spp., with 18 spp. EP+OL+WP
EP+WP	196 spp.	18% of EP spp., with 40 spp. EP+NA+WP, 18 spp. EP+OL+WP
EP+NA	57 spp.	05% of EP spp., with 40 spp. EP+NA+WP
OL+AT	2 spp.	0.04% of OL spp., with 0 spp. having wider distribution
OL+AU	9 spp.	0.2% of OL spp., with 1 sp. OL+AU+EP+WP
OL+WP	23 spp.	0.4% of OL spp., with 18 spp. EP+OL+WP, 1 sp. EP+NA+OL+WP, 1 sp. AU+EP+OL+WP

In contrast, the East and West Palearctic (WP) faunas show a stronger relationship (196 species occur in both regions, *i.e.*, 18% of EP species occur also in the WP) whereas the East Palearctic and Nearctic (NA) faunas have a weak relationship (57 species occur in both regions, *i.e.*, 5% of EP species occur also in the NA) (Table 1). The fauna of the Oriental Region seems generally to be much more predominantly endemic: 23 species (0.4% of OL species) occur also in the West Palearctic Region (mostly distributed throughout Eurasia), 9 (0.2% of OL species) occur also in the Australasian Region, and 2 (0.03% of OL species) occur also in the Afrotropical Region (Table 1).

Future work with the Asian Trichoptera Fauna

An expectation of a keynote discussion such as this is to stimulate thinking about the future. Because the human population of Asia continues its exponential growth, the negative impact on the Trichoptera fauna is most likely accelerating. This trend implies several important tasks for those of us who study these insects. Among these tasks are the following:

(1) We need to accelerate our efforts to document the diversity of Trichoptera before it is extirpated.
(2) We need to make our results understandable for decision-makers.
(3) We need to assist decision-makers in recognizing appropriate means to minimize human impacts.
(4) We need to evaluate the effectiveness of those impact-minimizing efforts.

Here I will focus briefly only on some aspects of the first of these tasks. To accelerate the documentation of Trichoptera diversity in Asia and elsewhere, we must first increase the rate of capture of Trichoptera specimens in poorly explored regions, preserving them appropriately for long-term molecular and morphological study. This will involve investment and commitment for the cost and for the physical and political challenges of field work in remote parts of Asia.

We then need to devote ourselves to the follow-up laboratory work and to the exploration of creative ideas for increasing the rate of identification and description of unknown and poorly known species (at least adults and larvae) encountered in those field expeditions. These creative ideas are likely to involve growing use of molecular tools to help diagnose genetic distinctions in conjunction with morphological distinctions and use of powerful new computing and networking capabilities for capturing, sharing, analyzing, and storing data and for preparing and publishing digital descriptions and illustrations.

In order to increase the rate and effectiveness of ecological research and of biomonitoring efforts, special emphasis is needed for describing and diagnosing larval caddisflies in Asia. Use of caddisflies for monitoring water quality is widespread in many countries of the world, including several Asian countries. In the East Palearctic Region, 37% of the species (406 of 1,090 species) are recognizable as larvae, generally the more common species, allowing their regular use in refined biomonitoring programs. Keys for identifying them are readily available (Kawai & Tanida 2005, Tsalolikhin 2001, Yoon 1995), although they are increasingly in need of updating. By contrast, in the Oriental Region <1% of the species (50 of 5,313 OL species) are recognizable as larvae. The available major resources diagnose Oriental Trichoptera only to the family and sometimes to the generic level (Dudgeon 1999, Morse *et al*. 1994, Yule & Yong 2004). Indeed, larvae of many genera in these guides are known only from Holarctic representatives and many endemic genera simply are unknown. The need for fundamental taxonomic work is especially serious in Oriental Asia to describe the still-mostly-unknown species, to associate and describe their larvae, and to prepare diagnostic identification aids using those descriptions so that the incredibly diverse fauna can be appreciated and protected, studied ecologically, and used for biomonitoring work. The available identification aids for southern Asia were produced in an effort to meet those current needs to the extent possible, with the caveat that they are woefully inadequate, outdated, and often erroneous in their details as we await scientific progress in the region.

Fortunately, recent developments in molecular biology, particularly in DNA sequencing, can now not only help discover cryptic, ecologically different species, but can also accelerate the process of associating unidentifiable larvae with their identifiable adults (*e.g*., Zhou *et al*. 2007). To take advantage of this technology, however, an extensive library of DNA sequences is crucial, so that it is important to link the discovery and description of adults with standard routines for sequencing the DNA, particularly of the mtCOI gene, which seems at least as suitable in Trichoptera for these purposes as it has proven to be for many other animals. With a consensus of collaborating colleagues sequencing DNA of recently captured material at every opportunity, establishment of a useful library and advancement in this line of research are very possible in relatively short periods of time. High throughput sequencing systems can process many samples very quickly. For example, half of the species of caddisflies of Mongolia were sequenced in just 3 years time and a robust world library of caddisfly sequences is growing rapidly in the Barcode of Life Database (BOLDSystems 2013).

Recognizing our personal limits and the size of the task, we must also train, equip, and employ the next generation of young Asian scientists for this work. We can do this by encouraging them into our field from their early age, sharing our excitement for our science and its value for the environment and for meeting human needs, facilitating the formal and informal cooperative and independent field and laboratory learning opportunities for these young scholars, providing them with the field and laboratory tools and skills needed to accomplish their professional tasks, mentoring and modeling for them the highest ethical and technical standards of excellence in quality and productivity for research results, and creating and enabling their eventual employment opportunities in our science.

We need also to promote international (transboundary) collaborations throughout Asia to observe biodiversity impacts and coordinate effective mitigating responses. This will entail both formal and informal international cooperation on joint research and environmental management projects and informing, engaging, and empowering all relevant scientific, public, business, and governmental stake-holders. Hopefully, the increased knowledge among these stake-holders about the distribution and ecological requirements of the freshwater biota and about the value of that biota for all Asians will help slow the extirpation of the Trichoptera fauna.

It is an exciting time to be immersed in biodiversity and faunistic research, especially with such an interesting and important group of animals as the Trichoptera. The challenges are substantial, but the opportunities to make a positive difference for our world are even greater, especially in Asia!

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