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Diversity of Trichoptera emergence and their longitudinal distribution along streams in central Palawan, the Philippines

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Abstract

Trichoptera emergences were cumulatively collected from two rivers in central Palawan over 11 months by use of specially modified emergence traps. The quantitative samples were identified at species level. Fifty morphospecies, of which fifteen have been recently newly described, are recognized. The highest species diversity was found in pristine headwater streams. Leptoceridae were most speciose with eleven *Oecetis* spp., four *Leptocerus* spp., two *Adicella* spp., and one species each of *Tagalopsyche*, *Triaenodes*, and *Triplectides*. Highest abundances were observed for *Ecnomus cabayugani* (Ecnomidae), *Dipseudopsis digitata*, and *Hyalopsyche winkleri* (Dipseudopsidae) which contributed alone 34% of the annual emergence. A mid-stream site where mayflies were mainly absent had the highest Trichoptera emergence, brackish water sites the lowest. Many species in Palawan (44% of the taxa) were recorded at a single locality, suggesting that they are stenoecious and that the real number of species on the island might be distinctly higher. This is the first study ever covering quantitative and species-level Trichoptera emergence data for a longitudinal river course.

Introduction

The diversity of insects in tropical ecosystems is known to be enormous, but rarely assessed quantitatively at the species level. Since alarming data on the decline of insects during the past decades have been published from Europe (Hallmann *et al.* 2017), the importance of quantifiable data retrieved by systematic, replicable sampling methods has become evident. They are the basis for long-term comparison. Nevertheless, biodiversity is predominantly publicized and exemplified using vertebrates and even those diversity data of insects that are available are largely neglected.

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) pointed out the vast data gaps for aquatic insects in the most recent regional assessment report on biodiversity and ecosystem services for Asia and the Pacific (Faridah-Hanum *et al.* 2018), but also highlighted some regional achievements, such as the comprehensive work of Malicky (2010).

More than 5,800 species of Trichoptera in at least 169 genera, of which 33% are endemic to the region, are known from the Oriental Realm (de Moor & Ivanov 2008, Morse *et al.* 2019), making it the most diverse biogeographic region of the world. On a global scale, *Rhyacophila* Pictet 1834 (Rhyacophilidae), *Hydroptila* Dalman 1819 (Hydroptilidae), *Chimarra* Stephens 1829 (Philopotamidae), *Hydropsyche* Pictet 1834, and *Cheumatopsyche* Wallengren 1891 (Hydropsychidae) are among the most speciose genera. The latter two are also represented by three species each in our samples.

The Philippine Trichopteran fauna is still insufficiently known, despite several works with numerous descriptions of new species published since 1990 (Malicky 2009, 2010, 2017; Mey 1990, 1995, 1998, 2000, 2002; Mey & Freitag 2013, 2019; Uy & Bae 2017; Wells & Mey 2002). To date, 398 species of caddisflies have been identified as occurring in the Philippines (Mey, unpublished data). Palawan and some adjacent islands are referred to as the intra-Philippine biogeographic region of Greater Palawan. The sub-region is commonly expected to have higher faunal similarity with Borneo (Huxley 1868), to which it was presumably connected during the last glacial maxima (Sathiamurthy & Voris 2006).

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All material treated here was collected by emergence traps. This method is probably the only way to gather site-specific and quantitative data of aquatic insect diversity on species level. Compared to light traps and other approaches, emergence collection allows selective macro-habitat choice for sampling. Furthermore, samples usually include rare species overlooked by other methods (Brehm & Meijering 1996).

Unfortunately, the method is rarely applied in tropical environments. Preliminary papers on Palawan emergence data (Freitag 2004a, 2005) cited potential and limitations of the method when applied in the tropics. In particular, fluctuations in water level affect sampling success, especially at streams of higher order and at estuaries. Freitag (2004b) provided the baseline data for this study and compared general emergence patterns of aquatic insects from other biogeographic regions.

We use the opportunity arising from the current cooperation between our institutions, in the scope of the BIO-PHIL and SEABIO projects, to analyze the Trichoptera emergence from Palawan which was collected by the second author almost two decades ago. Fifteen new species were discovered in the samples and were described in a separate paper (Mey & Freitag, 2019). Herein, we present the first data of quantitative species-level emergence of an entire order of aquatic insects along a stream from its headwaters to its mouth in an estuary (Fig. 1).

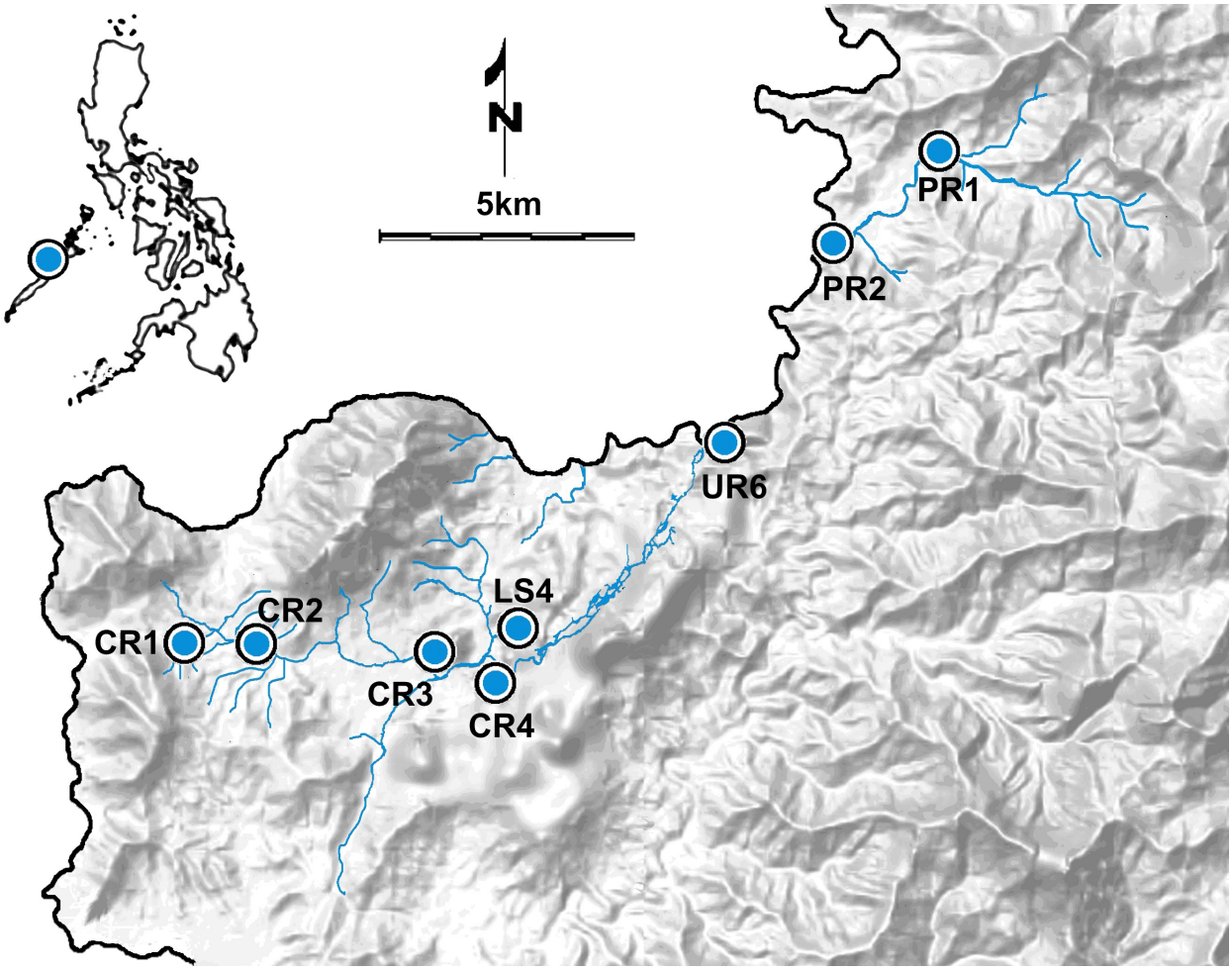

FIGURE 1. Map showing the localities of the emergence traps at the two rivers on the west coast of central Palawan.

Material and Methods

Six emergence traps (Figs 3–4) as described previously in detail (Freitag 2004a) were arranged along the Cabayugan River (often referred to as 'Underground River', especially at its lower subterranean reach which passes Mt. Saint Paul) and two emergence traps were placed at one rhithral and one hypopotamal site of the Panaguman River (Fig. 1). The sampling sites are situated within or in the vicinity of the Puerto Princesa Subterranean River National Park, Palawan, the Philippines (Fig. 2).

FIGURE 2. Local guides of the indigenous group of the Tagbanwa, for whom *Ecnomus tagbanwae* is named, overlooking the upper Cabayugan River basin with sampling sites CR1 and CR2 from Mt. Bloomfield.

Both rivers are of relatively small size, reaching the coast as 4th order streams. Their discharge is estimated with 2,500−18,000 l/s and 841−3,402 l/s, respectively, but they vary in water chemistry. While water of the Panaguman River is slightly acidic, that of the Cabayugan River is neutral to slightly alkaline. Since detailed information with measurements of various environmental variables during the time of sampling were given already by Freitag (2004b), we provide only a brief description of the sampling sites herein:

Cabayagan River
CR 1: 2nd order headwater creek, hilly terrain, 80 m asl., secondary forest
CR2: 3rd order creek, almost flat lowland, 37 m asl., secondary forest
CR3: 4th order stream, flood plain, 28 m asl., paddy fields
CR4: 4th order stream, flood plain, 28 m asl., primary forest
LS4: 1st order spring creek (from karst mountain), flood plain, 28 m asl., primary forest
UR6: 4th order river estuary, 0 m asl., karst forest/ beach forest

Pananguman River
PR 1: 4th order stream, hilly terrain, 8 m asl., secondary forest
PR2: 4th order river estuary, 0 m asl., *Nipa*-dominated riparian swamp forest.

The emergence traps were attached onto trees and other stable objects along riverbanks by a wooden supporting frame carrying the collection assembly made of UV-light-permeable acrylic glass. The opening of the collection assembly connected to the removable screens made of 'organza' nylon (80 mesh/cm). These tent-like screens covered a sampling area of approximately 1 m² including a wide littoral strip. Only at the smallest water body sampled, site LS4, the trap spanned the crenal stream entirely and consequently covered a larger supralittoral portion.

FIGURE 3. The emergence trap installed at the uppermost Cabayugan River sampling site 'CR1' from where the most diverse samples were taken.

The collection assembly housed a removable collection bowl filled with 4% formalin solution with a few drops of detergent. After sampling, material was transferred into 80% ethanol.

The general sampling period was from 04 September 2000 until 02 August 2001 and accumulated samples were taken approximately every two weeks. However, site CR1 was not accessible at the proposed initial sampling period due to refused access by local indigenous groups. Sampling was then commenced by 21 October 2000 after negotiations. Furthermore, traps at sites PR1 and PR2 were just installed at their final position on 16 September 2000. Earlier samples are not considered for this study. Several samples were additionally lost, mainly due to flooding by spates. Therefore, the actual cumulative sampling days vary among the sites. For better comparability, extrapolated numbers of Trichoptera emergence per year and square meter of water surface ($n/(m^2y)$) are additionally provided in Table 1. These extrapolated values have been calculated by multiplying the actual abundance (N) by 365 days divided by the actual days of sampling at the respective site. Values for site LS4 were additionally divided by 0.55, which is the portion of the trap-covered area that actually spanned the water body and excluding the large portion of supralittoral fringe. It should be noted that this analysis is different in the paper of Freitag (2004b), where extrapolated yields per trap were given, not simply yields per covered water surface.

The material is deposited at the Philippine National Museum of Natural History, Manila (PNM), the Ateneo de Manila University (AdMU), the Collection of the Palawan Council for Sustainable Development (PCSD), and the Museum für Naturkunde, Berlin (MfN).

TABLE 1. Abundance of morphospecies (N males/females), days of cumulative sampling per site, actual (N) and extrapolated (N/(m²y)) numbers of Trichoptera emergence and species number (s) per site. The respective percent share of the taxa of the total extrapolated emergence numbers is given in the last column.

Collection site	CR1	CR2	CR3	CR4	LS4	UR6	PR1	PR2	%
Actual sampling period (days)	141	165	120	115	84	133	78	126	n/(m²y)
Glossosomatidae									**0.1**
Agapetus spec.	0/1								0.1
Hydroptilidae									**3.1**
Chrysotrichia barbalis Mey 2003	1/0								0.1
Chrysotrichia minutula Mey & Freitag 2019	2/6								0.8
Hellyethira babuyana Wells & Mey 2002							2/0		0.4
Hydroptila spirulatella Mey 2003						1/0			0.1
Orthotrichia ligula Mey & Freitag 2019	2/8	0/1							1.1
Stactobia spec.	0/5								0.5
Philopotamidae									**3.3**
Chimarra ligula Mey & Freitag 2019				2/1					0.4
Chimarra spec. A	0/1	0/2	0/3		0/3				1.6
Chimarra spec. B					0/4				1.3
Polycentropodidae									**0.4**
Pahamunaya panagumani Mey & Freitag 2019							2/0		0.4
Dipseudopsidae									**28.1**
Dipseudopsis digitata Ulmer 1907	9/7	28/21			0/1		0/1		6.6
Hyalopsyche palawanensis Mey & Freitag 2019		6/5			1/0		20/1		5.3
Hyalopsyche winkleri (Ulmer 1930)		12/2	22/21	10/7	2/1		27/6		16.0
Pseudoneureclipsidae									**3.2**
Pseudoneureclipsis extensata Mey & Freitag 2019	2/6	1/0					9/3		3.2
Ecnomidae									**12.1**
Ecnomus cabayugani Mey & Freitag 2019	41/58	1/6							11.1
Ecnomus monostylis Mey 1998				0/2			2/0		0.6
Ecnomus tagbanwae Mey & Freitag 2019		3/1							0.4
Psychomyiidae									**4.6**
Paduniella bidentosa Mey 1998	0/5	0/21					1/0		2.6
Tinodes sanctipauli Mey & Freitag 2019	11/3	0/1					1/1		2.0
Xiphocentronidae									**0.3**
Abaria heliantha Mey 1998							1/0		0.2
Drepanocentron spec.	0/1								0.1
Hydropsychidae									**5.4**
Cheumatopsyche calawagana Mey 1995			0/6	2/18					3.3
Cheumatopsyche cf. *costalis* Banks 1913	0/9								1.0
Cheumatopsyche spec.			0/6						0.7
Macrostemum fenestrata (Albarda 1881)		0/1	0/2						0.3
Calamoceratidae									**1.9**
Anisocentropus bellus Banks 1931	0/1	1/5			1/0				1.0
Anisocentropus magnificus Ulmer 1907	0/1	1/1			0/1				0.6
Anisocentropus palawanensis Mey & Freitag 2019		2/1							0.3

...Continued on the next page

TABLE 1. (Continued)

Collection site	CR1	CR2	CR3	CR4	LS4	UR6	PR1	PR2	%
Helicopsychidae									**0.5**
Helicopsyche forcipula Mey & Freitag 2019	2/1								0.5
Leptoceridae									**37.2**
Adicella linearia Mey 1998			1/5		2/5		1/4		4.0
Adicella spec.	0/1			0/1	1/0			0/1	0.7
Leptocerus circumflexus Mey 1998		1/1	9/3	5/1			2/2		3.2
Leptocerus palaservius Mey & Freitag 2019	1/3	1/0	2/5	2/2	2/1		8/5		5.4
Leptocerus membranellus Mey & Freitag 2019	1/0	7/6	0/1						1.4
Leptocerus ultimus Mey 1998	0/1	2/6			1/3		0/1		2.3
Oecetis alticolaria Mey 1998	5/5	2/4					13/9		5.8
Oecetis ausani Mey & Freitag 2019	1/0				1/0				0.4
Oecetis. cf. *catenulata* Nebois 1989							1/0		0.2
Oecetis cf. *panayensis* Mey 1998	1/0			3/8					1.5
Oecetis cf. *scutata* Ulmer 1930		1/1							0.2
Oecetis flavicoma Mey 1990							2/3		1.0
Oecetis oecetinellae Mey 1990	2/4	1/2		1/1	0/1		0/1		1.7
Oecetis panayensis Mey 1998	3/1								0.4
Oecetis quezonensis Mey 2003				1/0					0.1
Oecetis spec. A	0/5			0/1			0/3		1.2
Oecetis spec. B			0/2						0.2
Tagalopsyche brunneoides Mey & Freitag 2019	2/2	1/2	1/1	1/1	0/1		13/5		5.0
Triaenodes spec.							0/9		1.7
Triplectides cf. *variipennis* Navás 1927	1/1	2/0			1/0				0.7
Total N	**223**	**163**	**90**	**70**	**33**	**1**	**159**	**1**	**740**
Extrapolated annual emergence N/(m²y)	**577**	**361**	**274**	**222**	**260**	**3**	**744**	**3**	**2444**
Total s (species)	**28**	**23**	**11**	**12**	**15**	**1**	**21**	**1**	**50**

Discussion

Overall, Trichoptera was the second largest fraction of an aquatic insect order that emerged from the Palawan streams, although < 3% as abundant as Diptera (Freitag 2004b). However, they were slightly outnumbered by Ephemeroptera in some rather pristine headwater sites (CR1, CR2). In estuarine sites with brackish water (UR6, PR2), caddisflies were a negligibly small fraction of the emergence. Only one specimen each of an unidentified, obviously euryoecious *Adicella* sp. with marginal abundance in various sites and *Hydroptila spirulatella*, which was not collected in any other site, were recorded there.

Species richness as reported here dropped slightly to 50 morphospecies from the preliminary estimates (Freitag 2004b: 56 morphospecies) due to more rigorous examination of the material and associations of males and females. It is still remarkable, however, that 22 taxa (44%) were collected from only a single locality (Table 1), which might reflect their stenoecious adaptation to certain environmental conditions and microhabitats. In conclusion, the number of still-undiscovered species in Palawan might be high, especially considering that streams in higher altitude were not sampled at all (highest collection site CR1 is just 80 m asl.). We expect the total number of Palawan Trichoptera species to exceed 200 when more habitats have been sampled, including localities of high altitude.

Species richness per site is similar to those of emergence studies in Central Africa (Statzner 1976), Colombia (Flint 1991), and Japan (Tanida & Takemon 1993). A study involving emergence trap and light trap samples from Mindoro Island, the Philippines (Mey & Freitag 2013) yielded 34 species in total and up to 12 species

per site (both numbers without several unidentified female specimens), suggesting that Trichoptera diversity is lower in Mindoro, since the examined material was retrieved from a larger number of streams with a higher gradient in altitude (from 100 m asl. to 530 m asl.).

FIGURE 4. The emergence trap model used in this study installed at the estuarine site 'PR2' of Panaguman River.

Family Leptoceridae dominated the species diversity, especially *Leptocerus* (4 spp.) and *Oecetis* (11 spp.). This trend was less pronounced in Mindoro, where *Cheumatopsyche* and *Chimarra* were reported as being most speciose (Mey & Freitag 2013).

Dipseudopsis digitata, *Hyalopsyche winkleri* (Dipseudopsidae) and *Ecnomus cabayugani* (Ecnomidae) were the most abundant species, those species alone contributing 34% of the extrapolated annual emergence (N/ (m^2y)). Among them, *Ecnomus cabayugani* appears to be stenoecious in rather undisturbed headwaters in forested hilly terrain (CR1).

Extrapolated annual emergence per m^2 was noticeably highest at the rhithral site PR1 (Table 1; comp. Freitag 2004b: fig. 8), where the Trichoptera assemblage is dominated by six species, namely *Hyalopsyche winkleri*, *Hyalopsyche palawanensis*, *Oecetis alticolaria*, *Tagalopsyche brunneoides*, *Pseudoneureclipsis extensata*, and *Leptocerus palaservius*. It was suggested that the scarce Ephemeroptera in Panaguman River were ecologically replaced by Trichoptera (Freitag 2004b).

Beck *et al.* (2006), Freitag *et al.* (2016), and Mey (2001) questioned the proposed faunal similarity of Greater Palawan and Borneo for several insect taxa. However, the taxonomic composition of the Palawan Trichoptera emergence data does not notably differ on family and generic levels from light trap samples taken in Sabah, East Malaysia (Mey, unpublished data). The discovery of the first species of *Pahamunaya* in Palawan, a markedly Oriental genus, is additional clear evidence for the Oriental or Sundaland origin of parts of the Trichoptera fauna of Palawan. At the species level, however, the situation is different. There are many species-pairs bridging the Balabac Strait between northern Borneo and southern Palawan (e.g., in *Ecnomus, Helicopsyche, Leptocerus, Tagalopsyche, Setodes*), which suggests an enduring time period of isolation of Palawan from Borneo in the distant past resulting in divergent evolution on both islands. A more detailed analysis of the

historical biogeographic relationships of Trichoptera between Borneo and Palawan would be a very interesting venture, but drawing any final conclusion is premature at this time because we do not yet have enough data sets available from both islands.

Since molecular-genetic analysis of biodiversity data became more essential during the last decades, it is recommended to use ethanol or isopropanol instead of formalin for the operation of emergence traps. If samples are not taken in short intervals, it might be required to add glycerine to reduce the quick evaporation of the alcohol. Adding a few drops of detergent is still important, even with this modified method of preservation. At least the short-term preservation in such mixture does not inhibit successful amplification and sequencing of mtDNA barcodes as recently tested by the second author during the Taxon Expeditions initiative in Borneo (Maestri *et al.* 2019).

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References

Beck, J., Kitching, I.J. & Linsenmair, K.E. (2006) Wallace's Line revisited: Has vicariance or dispersal shaped the distribution of Malesian hawkmoths (Lepidoptera: Sphingidae)? *Biological Journal of the Linnean Society*, 89, 455–468. https://doi.org/10.1111/j.1095-8312.2006.00686.x

Brehm, J. & Meijering, M.P.M. (1996) *Fließgewässerkunde. 2nd ed*. Quelle & Meyer, Wiesbaden, 302 pp.

Dalman, J.W. (1819) Några nya insecta-genera beskrifna. *Kongliga Vetenskaps-Akademiens Handlingar*, 40, 117–127.

de Moor, F.C. & Ivanov, V.D. (2008) Global diversity of caddisflies (Trichoptera: Insecta) in freshwater. *Hydrobiologia*, 595, 393–407. https://doi.org/10.1007/s10750-007-9113-2

Faridah-Hanum, I., Rawat, G.S., Yahara, T., Abi-Said, M., Corlett, R.T., Courchamp, F., Dai, R., Freitag, H., Haryoko, T., Hewitt, C.L., Hussain, T., Kadoya, T., Maheswaran, G., Miyashita, T., Mohan Kumar, B., Mohapatra, A., Nakashizuka, T., Piggott, J.J., Raghunathan, C., Rawal, R., Sheppard, A., Shirayama, Y., Son, Y., Takamura, N., Thwin, S., Yamakita, T., Febria, C.M. & Niamir, A. (2018) Chapter 3: Status, trends and future dynamics of biodiversity and ecosystems underpinning nature's contributions to people. *In:* Karki, M., Senaratna Sellamuttu, S., Okayasu, S. & Suzuki, W. (Eds.), *The IPBES Regional Assessment Report on Biodiversity and Ecosystem Services for Asia and the Pacific*. IPBES Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem services, Bonn, pp. 220–336.

Flint, O.S. Jr. (1991) Studies of Neotropical caddisflies, XLV: The taxonomy, phenology, and faunistics of the Trichopterta of Antioquia, Columbia. *Smithsonian Contributions to Zoology*, 520, 1–113. https://doi.org/10.5479/si.00810282.520

Flint, O.S. Jr. & Masteller, E.C. (1993) Emergence composition and phenology of Trichoptera from a tropical rainforest stream at El Verde, Puerto Rico. *Journal of the Kansas Entomological Society*, 66, 140–150.

Freitag, H. (2004a) Adaptations of an emergence trap for use in tropical streams. *International Revue of Hydrobiology*, 89, 363–374.

https://doi.org/10.1002/iroh.200310709
Freitag, H. (2004b) Composition and longitudinal patterns of aquatic insect emergence in small rivers of Palawan Island, the Philippines. *International Revue of Hydrobiology*, 89, 375–391.
https://doi.org/10.1002/iroh.200310710
Freitag, H. (2005) Aquatic insect emergence collections of rivers in the St. Paul National Park, Palawan, Philippines and methodological implications for ecological and biodiversity studies. *Journal of Aquatic Sciences*, 2 (2), 66–78.
Freitag, H., Jäch, M.A. & Wewalka, G. (2016) Diversity of aquatic and riparian Coleoptera of the Philippines: Checklist, state of knowledge, priorities for future research and conservation. *Aquatic Insects*, 37, 177–213.
https://doi.org/10.1080/01650424.2016.1210814
Hallmann, C.A., Sorg, M., Jongejans, E., Siepel, H., Hofland, N., Schwan, H., Stenmans, W., Müller, A., Sumser, H., Hörren, T., Goulson, D. & de Kroon, H. (2017) More than 75 percent decline over 27 years in total flying insect biomass in protected areas. *PLoS ONE*, 12 (10), e0185809.
https://doi.org/10.1371/journal.pone.0185809
Huxley, T.H. (1868) On the classification and distribution of the Alectoromorphae and Heteromorphae. *Proceedings of the Zoological Society London*, 1868, 296–319.
Maestri, S., Cosentino, E., Paterno, M., Freitag, H., Garces, J., Marcolungo, L., Alfano, M., Njunjić, I., Schilthuizen, M., Slik, F., Menegon, M., Rossato, M. & Delledonne, M. (2019) A rapid and accurate MinION-based workflow for tracking species biodiversity in the field. *Genes*, 10, 468.
https://doi.org/10.3390/genes10060468
Malicky, H. (2009) Köcherfliegen (Trichoptera) von der Insel Sibuyan (Philippinen). *Entomologica Austriaca*, 16, 9–18.
Malicky, H. (2010) *Atlas of Southeast Asian Trichoptera*. Biology Department, Faculty of Science, Chiang Mai University, XXX+346 pp.
Malicky, H. (2017) A new *Cheumatopsyche* species (Hydropsychidae) from Luzon (Philippines). *Braueria* (Lunz am See), 44, 4.
Mey, W. (1990) Neue und wenig bekannte Arten der Gattung *Hydropsyche* Pictet von den Philippinen (Trichoptera). *Deutsche Entomologische Zeitschrift*, *N. F*., 37, 413–424.
https://doi.org/10.1002/mmnd.4810370418
Mey, W. (1995) Beitrag zur Kenntnis der Köcherfliegenfauna der Philippinen, I (Trichoptera). *Deutsche Entomologische Zeitschrift*, *N. F*., 42, 191–209.
https://doi.org/10.1002/mmnd.4810420116
Mey, W. (1998) Contribution to the knowledge of the caddisfly fauna of the Philippines, III (Insecta: Trichoptera) *Entomofauna*, 19, 1–31.
Mey, W. (2001) Australasian distributions in Trichoptera (Insecta)─a frequent pattern or a rare case? *In*: Metcalve, I., Smith, J.M.B., Morwood, M. & Davidson, I. (Eds.), *Faunal and Floral Migrations and Evolution in SE Asia-Australasia*. Balkema Publishers, Lisse, pp. 255–268.
Mey, W. (2002) Contribution to the caddisfly fauna of the Philippines, IV: Further new species of the genus *Hydropsyche* Pictet. *In*: Mey, W. (Ed.), Proceedings of the 10th International Symposium on Trichoptera, Potsdam, Germany 2000, *Nova Supplementa Entomologica*, 15, 167–172.
Mey, W. & Freitag, H. (2013) Trichoptera of Mindoro, the Philippines I. New species and records from the Baroc River Catchment, Roxas, Oriental Mindoro (Insecta, Trichoptera). *Esperiana*, 18, 259–269.
Mey, W. & Freitag, H. (2019) New caddisflies (Insecta: Trichoptera) from emergence traps at streams in central Palawan, Philippines. *Aquatic Insects*, 40, 1–29.
https://doi.org/10.1080/01650424.2019.1617423
Morse, J.C., Frandsen, P.B., Graf, W. & Thomas, J.A. (2019) Diversity and ecosystem services of Trichoptera. *In*: Morse, J.C. & Adler, P.H. (Eds.), Diversity and Ecosystem Services of Aquatic Insects. *Insects*, 10, 125.
https://doi.org/10.3390/insects10050125
Pictet, F.J. (1834) *Recherches pour servir à l'histoire et l'anatomie des Phryganides*. A. Cherbuliez, Geneva.
https://doi.org/10.5962/bhl.title.8547
Sathiamurthy, E. & Voris, H.K. (2006) Maps of Holocene sea level transgression and submerged lakes on the Sunda Shelf. *The Natural History Journal of Chulalongkorn University Supplement*, 2, 1–43.
Statzner, B. (1976) Die Köcherfliegen-Emergenz (Trichoptera, Insecta) aus dem zentralafrikanischen Bergbach Kalengo. *Archiv für Hydrobiologie.*, 78, 102–137.
Stephens, J.F. (1829) *A Systematic Catalogue of British Insects*: *Being an Attempt to Arrange all the Hitherto Discovered Indigenous Insects in Accordance with their Natural Affinities*. *Containing also the References to every English Writer on Entomology*, *and to the Principal Foreign Authors*. *With all the Published British Genera to the Present Time*. *Part 1*. *Insecta Mandibulata*. Baldwin and Cradock, London.
https://doi.org/10.5962/bhl.title.8987
Tanida, K. & Takemon, Y. (1993) Trichoptera emergence from streams in Kyoto, central Japan. *In:* Otto, C. (Ed.), *Proceedings of the 7th International Symposium on Trichoptera*. Backhuys Publishers. Leiden, pp. 239–249.
Uy, C.J. & Bae, Y.J. (2017) Two new species of Hydropsychidae (Insecta: Trichoptera) from the Philippines. *Animal Systemat-*

ics, Evolution and Diversity, 33, 33–36.
https://doi.org/10.5635/ASED.2017.33.1.051
Wallengren, H.D.J. (1891) Skandinaviens Neuroptera. Andra afdelningen. *Kongliga Svenska Vetenskaps-Akademien Handlingar*, 24, 1–173.
Wells, A. & Mey, W. (2002) Microcaddisflies of the Philippines (Trichoptera, Hydroptilidae). *Deutsche Entomologische Zeitschrift*, 49, 113–136.
https://doi.org/10.1002/mmnd.20020490109