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A Mega-Diverse Water Beetle Genus (Coleoptera: Hydraenidae: *Hydraena* Kugelann) Commonly Overlooked in Southeast Asia and its Potential Use for Environmental Biomonitoring

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Abstract

This study summarizes the current knowledge of the water beetle genus *Hydraena* Kugelann in Southeast Asia. The surprising species diversity and endemism rates in *Hydraenopsis* Janssens, the only subgenus present in Southeast Asia, are discussed. Data of five published *Hydraena* surveys from the Philippines and Singapore are used to evaluate species richness and the occurrence of species assemblages that are subject to the presence and quality of forests. Species richness was found to be generally higher in old grown forests. Some species appeared to be confined to near-natural forests. The denomination of indicator species is impeded by adequate sampling data, so it is suggested to intensify efforts in taxonomic and ecological research on these water beetles. It is concluded that the species richness and the common occurrence of the genus in the region might make *Hydraena* useful as biomonitoring organisms.

Keywords: *Hydraena*; Water beetles; Species richness; Endemism; Philippines; Singapore; Southeast Asia; Biomonitoring; Indicator species

Introduction

The Polyphaga family Hydraenidae (Minute Moss Beetles) is one of the most diverse, but least studied groups of predominantly aquatic and semi-aquatic beetles. Its largest genus, *Hydraena* Kugelann (Long-palped Water Beetles), is circumglobally distributed and comprises about 900 described species. A revised phylogenetic concept [1] recognizes five subgenera, namely *Hydraena* s.str. (mainly "Laurasian" distribution), *Hydraenopsis* Janssens (mainly "Gondwanan" distribution), *Phothydraena* Kuwert (Mediteranean distribution), *Spanglerina* Perkins (Central American distribution), and *Holcohydraena* Kuwert (Holarctic distribution). The overwhelming part of the genus' species diversity is confined to the more widely-distributed subgenera *Hydraena* s.str. and *Hydraenopsis*.

Jäch and Balke [2] estimated a total number of 500 species of aquatic Hydraenidae occurring in the Oriental Region. Only 120 of them had been named and described until 2007. While the Palaearctic and the Australian regions are quite well studied in regard to their hydraenid fauna, most islands and the continental areas of Southeast Asia have received little attention. Results of recent taxonomic studies of *Hydraena* in the Philippines by the AQUA Palawana Program [3,4] and surveys on the islands of Luzon [5] and Mindoro [6,7] have revealed a high number of new species, most of them endemic to one or a few islands.

Some *Hydraena* are used as indicator organisms for water quality, e.g. by DIN 38410-2 [8]. However, as of now, no representative of the subgenus *Hydraenopsis* is officially recognized as an indicator species, due to insufficient taxonomic and ecological knowledge.

Aquatic macroinvertebrate taxa in general are suitable as monitoring organisms as their occurrence depends on both aquatic and terrestrial environmental conditions. They have developed fast reproduction cycles and efficient re-colonization strategies as they are commonly exposed to small-scale, natural "catastrophic events" such as flash floods or drying-up of their habitat. Therefore, collection in the wild for biomonitoring and other scientific purposes does not generally affect the population's survival, as long as the habitats are not destroyed or polluted.

This study uses species richness, distributional, and land-cover data of published taxonomic papers to evaluate the potential use of *Hydraena* species for biomonitoring and as indicator organisms.

Materials and Methods

Published taxonomic studies of the *Hydraena* fauna in clearly defined and well-sampled areas of the Philippines and Singapore are analyzed in regard to species richness, regional species distribution and habitat conditions. The original data, sampling methods, and detailed area descriptions are published by Freitag and Jäch [3], Freitag and Zettel [4], Freitag [5], Freitag and Pangantihon [6], and Jäch et al. [9]. All sampling sites are located in lowlands. Various microhabitats (submerged leaf litter, littoral sediments, submerged wood) where *Hydraena* species usually occur were sampled. Species lists of all sampled microhabitats of each site were combined for this paper. Data of the following regional surveys were used:

PAL1: Philippines, Palawan; Puerto Princesa City; Puerto Princesa Subterranean River National Park, Brgys. Cabayugan and Marufinas; 10°15'22"N 118°49'37"E and 10°09'05"N 118°58'45"E, 8m – 150m asl.

PAL2: Philippines, Palawan; Taytay; Lake Manguao Catchment, Brgys. Bato and Poblacion; inbetween 10°49'02"N 119°29'47"E and 10°44'29"N 119°34'00"E; 15m-100m asl.

MIN: Philippines, Oriental Mindoro; Socorro and Victoria; Lake Naujan Catchment, Brgys. Leido, Lapug, Malayas, Subaan; inbetween 13°09'26"N 121°18'29"E and 13°06'46"N 121°21'45"E, 3m – 20m asl.

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LUZ: Philippines, Luzon; National Capital Region; Quezon City; Ateneo de Manila University Campus, Loyola **Heights;** inbetween 14°38'30"N 121°04'30"E and 14°38'04"N 121°04'56"E; 37m – 63m asl.

SIN: Singapore, various sites between 1°26'43"N 103°43'27"E and 1°18'25"N 103°50'13"E; 8m-70m asl.

Google earth satellite images were enhanced by the use of Corel Photopaint software tools to obtain high contrast images that allows discrimination of old grown forests, secondary vegetation, and other land-use types. These images were used as an underlay for (Figures 1-3), illustrating the *Hydraena* species richness at the selected sampling areas.

This preliminary analysis is based solely on a descriptive comparison of the species habitats and species occurrence data. A comprehensive, statistically supported analysis was not carried out due to the varying and inconsistent quality of the habitat variables that are available from the original publications. Some of these studies are purely taxonomic.

Results and Discussion

All species recorded from Southeast Asia up to date belonged to the subgenus *Hydraenopsis*.

Representatives occurred in various freshwater habitats and were quite common, although they might be easily overlooked due to their small size, or by unconscious exclusion of their typical microhabitats from sampling. *Hydraena* species were usually found to be unevenly distributed within a suitable habitat. They commonly occurred in a clumped distribution pattern. Therefore, in order to obtain an accurate representation of *Hydraena* diversity in a sampling area, many microhabitat patches should be assessed.

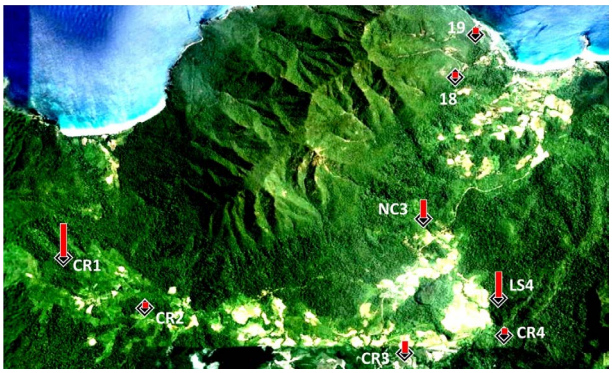


Figure 1: Enhanced satellite image of the Puerto Princesa Subterranean River National Park, Palawan, Philippines, with Hydraena species richness at the sampling sites indicated by red columns. Old grown forests visible as dark green coarsely granular patterns.

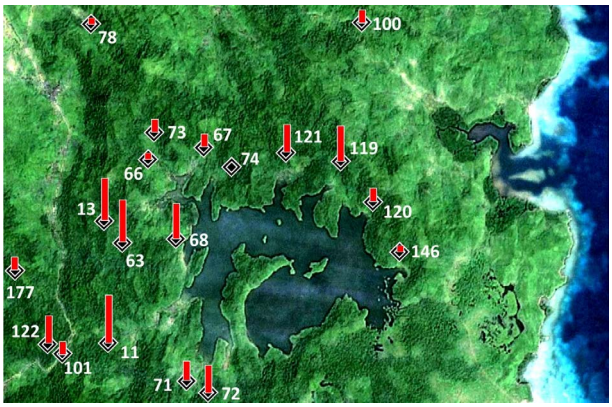


Figure 2: Enhanced satellite image of the Lake Manguao Catchment, Taytay, Palawan, Philippines, with Hydraena species richness at the sampling sites indicated by red columns. Old grown forests visible as dark green coarsely granular patterns.

The taxonomic knowledge of the genus varies greatly among countries and islands. The Republic of China (Taiwan: 13 species) and the Republic of Singapore (7 species) appear comparably well-explored in regard to their hydraenid fauna [9,10], while in contrast, lists of described species for Indonesia (12 species predominantly from Sumatra and Java) and Malaysia (3 species) are rudimentary [9,11].

In the Philippines, the knowledge of the *Hydraena* fauna in some islands has substantially improved during the last decade. Only two species, *Hydraena scabra* d'Orchymont and *H. boettcheri* d'Orchymont, were known from the country until 2007. Twelve additional endemic species were recently described (see checklist in [5]), and further species descriptions from the Philippines are in preparation. The distribution of most species was restricted to one or a few islands (Table 1).

The number of recorded species differed considerably, from none to seven species per site (Table 2).

Habitats in primary forest usually accommodated more *Hydraena* species than farmlands, secondary forests and other secondary vegetation. This trend was particularly evident for sites in comparably large patches of old grown forest (Figures 1-3), while sites in altered habitats or those close to altered habitats usually displayed low species-richness. However, the available data do not allow clear conclusions regarding whether the age and extent of the forest cover alone, or in combination with other environmental variables, affect the *Hydraena* species richness. Furthermore, it is not surprising that non-replicated sampling might not be sufficient to detect the majority of species at a certain site. Seasonal aspects are likely to affect species occurrence and species richness.

Some island endemic species (e.g. *H. jojoorculloi, H. nielshaggei* (Figure 4a), *H.* sp.D, *H. yangae* (Figure 4b), *H. hendrichi*, *H. michaelbalkei*) seemed to be either rare or confined to certain habitat conditions., Although they belong to different species groups, all of these species, except for *H. hendrichi,* are characterized by comparably small size and shallowly to moderately deeply impressed elytral and pronotal punctures (Figures 4-5).

Another assemblage of more widely distributed species (*H. paulmoritz*, *H. jacobsoni, H. scabra* (Figure 4c), *H. palawanensis*) appeared to be quite common in various habitats, including disturbed and undisturbed sites. The same applied for *H. hosiwergi,* though it is

Island	No. of species recorded	No. of island-endemic species	References
Palawan	15	12	[3, 4]
Luzon*	4	2	[5]
Mindoro*	9	6	[6, 7]
Singapore	7	3	[9]
Taiwan	13	12 (13)	[10, 14]

Table 1: Island endemism of Hydraena species in several Southeast Asian islands and Taiwan: total number of species including published records of still undescribed species, number of island endemic species and taxonomic references. * = more undescribed material available at NMW, ADMU and other scientific collections that was not treated in any publication yet and which is not included herein.

probably endemic to Palawan. Among these, *Hydraena paulmoritz*, *H. jacobsoni,* and *H. scabra* belong to the same species group [9] that can be recognized externally by color patterns and the deeply impressed, large elytral and pronotal punctures. In contrast, *H. palawanensis* is a small species, with shallow and inconspicuous punctures that rather resembles the previously mentioned group of rare and island-endemic species.

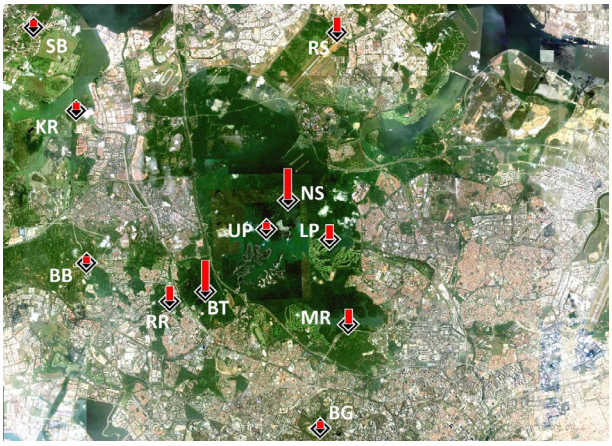
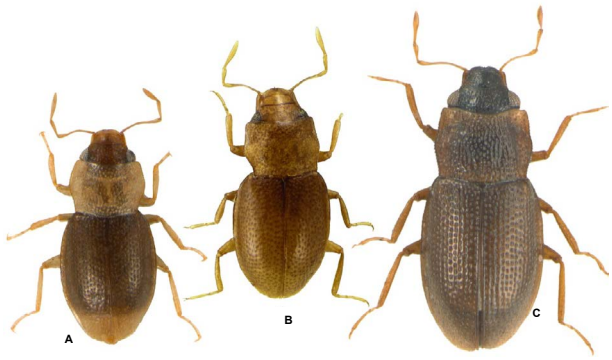


Figure 3: Enhanced satellite image of the central portion of Singapore Island with Hydraena species richness at the sampling sites indicated by red columns. Forests visible as dark green patterns.



Figures 4: Examples of two rare species that are confined to near-natural forests: A) Hydraena nielshaggei Freitag & Jäch from Palawan, B) H. yangae Jäch, Díaz, & Skale from Singapore; and one typical representative of an undemanding species group: C) H. scabra d'Orchymont, a widely distributed species in the Philippines.

The respective members of the *Hydraena porcula* group [10] displayed partly contrary characteristics: the large, Palawan-endemic *H. hosiwergi* is common and undemanding, while the Singapore-endemic *H. yangae* is small and so far only recorded from natural forests; the medium-sized *H. hendrichi* is more widely distributed in the Sundaic Region, but might be confined to forested and less disturbed habitats.

All previously known Singaporean *Hydraena* species are considered as "target species" for conservation efforts as they are found to be threatened due to anthropogenic alterations of their specific habitats and their low ecological amplitude [12]. Balke et al. [12] generally regard "water beetles" (in the sense of True Water Beetles [13,14]) as a useful biomonitoring group because the following factors are fulfilled:

1) the group is species-rich; 2) they are present in all types of freshwater and brackish water habitats; 3) several species are confined to particular microhabitats; 4) there is rapidly increasing taxonomic data; 5) the general biological knowledge on most groups is increasing; and 6) some large, colorful, and enigmatic species may attract public interest.

Moreover, some water beetle species might be useful as specific bioindicators for the evaluation of habitat conditions and water quality when particularly No. 3) and further criteria are fulfilled, such as: 7) the species are somewhat common and easily collectable in their typical habitats; 8) they are widely distributed (not regionally endemic); and 9) somewhat easily identifiable. These conditions are usually presupposed for bioindicator species.

While 1), 3), and 7) are true for Southeast Asian *Hydraena*, some other criteria are not fulfilled for most representatives by critical evaluation: their non-ambiguous determination requires dissection of the male genitalia; the rate of island endemism is very high (Table 1) and would require different indicator species for various islands of the same archipelago; the taxonomic and ecological knowledge is still very insufficient for many islands, regions and entire countries in the Oriental Region, as pointed out above.

Island	Site Code	Vegetation/ land use	*Hydraena* species recorded
PAL1	CR1	Disturbed primary forest	*H. hosiwergi, H. kodadai, H. nielshaggei, H. pseudopalawanensis, H. zetteli*
PAL1	CR2	Secondary forest	*H. nielshaggei,*
PAL1	CR3	Paddy fields/ farmland	*H. palawanensis*, *H. pseudopalawanensis*
PAL1	CR4	Disturbed Primary forest*	*H. zetteli*
PAL1	LS4	Primary forest	*H. claudia, H. palawanensis*, *H. pseudopalawanensis*, *H. zetteli*
PAL1	NC3	Secondary forest	*H. hosiwergi, H. palawanensis*, *H. pseudopalawanensis*
PAL1	PR1	Secondary vegetation	*H. jojoorculloi, H. kodadai, H. sp.2*
PAL1	18	Secondary forest	*H. castanescens*
PAL1	19	Secondary forest	*H. kodadai*
PAL2	11	Disturbed primary forest / secondary vegetation	H. claudia, H. castanescens, H. hosiwergi, H. jojoorculloi, H. kodadai, H. palawanensis, H. scabra
PAL2	13	Disturbed primary forest /	*H. claudia, H. hosiwergi*, *H. jojoorculloi, H. kodadai*, *H. manguao, H.scabra*
PAL2	63	Disturbed primary forest /	*H. claudia, H. jojoorculloi, H. kodadai, H. palawanensis, H.* sp.2, *H.* sp.E
PAL2	64	Secondary forest/ reforestation	*H. claudia, H. hosiwergi*, *H. manguao, H. palawanensis*, *H. scabra*
PAL2	65	Secondary vegetation/ farmland	*H. hosiwergi*, *H. palawanensis*,
PAL2	66	Secondary vegetation/ paddy fields	*H. manguao*

PAL2	67	Secondary forest	*H. kodadai, H. palawanensis*
PAL2	68	Secondary forest	*H. hosiwergi*, *H. manguao, H. palawanensis*, *H.* sp.2, *H.* sp.E
PAL2	71	Secondary forest	*H. claudia, H. hosiwergi*, *H. palawanensis*
PAL2	72	Secondary forest	*H. claudia, H. hosiwergi*, *H. manguao, H. palawanensis*
PAL2	73	Secondary vegetation/ secondary forest	*H. hosiwergi*, *H. jojoorculloi,*
PAL2	74	Secondary forest/ reforestation	*H. hosiwergi*, *H. kodadai*
PAL2	78	Secondary vegetation	*H.* sp.D
PAL2	100	Degraded forest secondary forest	*H. hosiwergi*, *H. kodadai*
PAL2	101	Secondary forest	*H. claudia, H. hosiwergi*
PAL2	119	Disturbed primary forest	*H. claudia, H. hosiwergi*, *H. kodadai*, *H. manguao, H. palawanensis*
PAL2	120	Disturbed primary forest	*H. hosiwergi*, *H. kodadai*
PAL2	121	Disturbed primary forest	H. claudia, H. castanescens, H. hosiwergi, H. palawanensis
PAL2	122	Disturbed primary forest	*H. claudia, H. castanescens, H. hosiwergi*, *H. kodadai*
PAL2	146**	Disturbed primary forest	*H. hosiwergi*
PAL2	177**	Disturbed primary forest	*H. claudia, H. hosiwergi*
MIN	1**	Secondary vegetation	NONE
MIN	2**	Farmland & secondary vegetation	*H. palawanensis, H. scabra, H. sp.A, H. sp.B*
MIN	3**	Farmland & secondary vegetation	*H. scabra, H. sp.A, H. sp.B, , H. sp.C*
LUZ	ADM1	Secondary vegetation/ polluted	NONE
LUZ	ADM2	Secondary vegetation/ unpolluted	*H. ateneo, H. palawanensis*, *H. scabra*
LUZ	ADM3	Secondary vegetation / unpolluted	*H. ateneo, H. palawanensis, H. scabra*
LUZ	ADM4	Secondary vegetation/ eutrophic	NONE
LUZ	ADM5	Secondary vegetation/ eutrophic	NONE
SIN	BB	Secondary vegetation/ secondary forest	*H. paulmoritz*
SIN	BG	Secondary vegetation/ park	*H. jacobsoni*
SIN	BT	Primary Forest	*H. formula, H. hendrichi, H. jacobsoni, H. paulmoritz*
SIN	KR	Secondary vegetation/ secondary forest	*H. paulmoritz*
SIN	LP	Secondary forest	*H. jacobsoni, H. paulmoritz*
SIN	MR	Secondary forest/ disturbed primary forest	*H. michaelbalkei, H. singaporensis*
SIN	NS	Primary forest	*H. formula, H. jacobsoni, H. paulmoritz, H. singaporensis*
SIN	RR	Secondary forest/ disturbed primary forest	*H. formula, H. yangae*
SIN	RS	Secondary vegetation	*H. jacobsoni, H. paulmoritz*
SIN	SB	Secondary (?) swamp/ mangrove forest	*H. paulmoritz*
SIN	UP	Secondary forest	*H. singaporensis*

Table 2: List of sampling sites of Hydraena surveys (see Material and Methods) with land-use and forest classification and list of recorded species.
* this river section is situated in disturbed primary forest, but very close to upstream farmlands; **single, non-replicated sampling; label codes as in the original publication except for: BB=Bukit Batok Nature Park; BG=Botanical Gardens; BT=Bukit Timah Nature Reserve; KR=Kranji Reservoir; LP=Lower Peirce Reservoir; MR=MacRitchie Reservoir; NC3 =Nagdayan Creek; NS=Nee Soon Swamp Forest; RR=Stream near Rifle Range Road (east Bukit Timah); RS=River Sembawang/Senoko (habitat destroyed); SB=Sungai Buloh Wetland Reserve; UP=Upper Peirce Forest.

Furthermore, it must be assumed that the public appreciation of such small and non-spectacular taxa might be rather low, and there might be little public acceptance for *Hydraena* species as an argument for conservation endeavors. Nevertheless, at least one recently discovered species, namely *Hydraena ateneo*, received international media attention due to its unusual type locality in the middle of a megacity.

Our recent knowledge on Southeast Asian *Hydraena* does not yet allow us to denominate some species as bioindicators. Ecological studies on the micro- and macro-habitat requirements of various species are needed from many countries in the region. Regional ecological surveys in the taxonomically explored islands might be a first step towards the identification of indicator species that are common enough, but also confined to certain environmental conditions.

Widely distributed species (in particular the closely related group of species including *Hydraena scabra, H. paulmoritz*, *H. jacobsoni*) are probably not suitable as indicators for disturbance since they occur in various habitats: waters in disturbed areas with secondary vegetation and in primary forests. On the other hand, endemic species that are more or less confined to pristine forest may be too rare, and they are not always detectable in such habitats.

For several reasons, it would be a great advantage to establish measures beyond the intricate species identification level to make use of *Hydraena* species for biomonitoring by non-specialists. Unfortunately, the use of externally identifiable species groups, body size classes, or similar measures do not appear to be suitable tools as of now. The most promising approach might be the use of the species richness in an area subjected to the number of microhabitats sampled and the number of sampling replicates. Mostly, but not in all cases, it should be possible to discriminate morpho-species of *Hydraena* collections by comparing external characters like size, shape, color, and punctures. This would easily allow assessment of species richness. Such attempts should be based on replicated sampling during different seasons and should take into account varying microhabitats and the patchy micro-distribution of *Hydraena* species.

Based on this preliminary assessment, it is suggested (1) to increase

efforts in the taxonomic study of the genus, especially in previously unexplored islands and areas; (2) to study micro- and macro-habitat requirements and preferences of hydraenids; (3) to investigate the occurrence patterns of *Hydraena* species in time and space subject to water parameters, substrate quality, hydraulic conditions, land-use and surrounding vegetation.

A better knowledge of the hydraenid fauna of Borneo, as well as Malaysia and Indonesia in general, would particularly contribute to a better understanding of the ecological adaptations and distribution patterns of several species groups of the subgenus *Hydraenopsis* in Southeast Asia.

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