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Preliminary survey of *Pachyrhynchus* weevils (Coleoptera) of the Babuyan and Batanes Islands, Philippines

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Abstract

The Philippine Archipelago is one of Earth's biodiversity hotspots and hosts numerous of endemic and threatened species. The Babuyan and Batanes Islands are located between Taiwan and Luzon (Philippines) and, in part, due to their remoteness, are less explored. In this report, we present a preliminary survey of *Pachyrhynchus* weevils on the Batanes and Babuyan Islands. Species richness of *Pachyrhynchus* weevil was highest on Calayan (6 species, *P. orbifer*, *P. perpulcher*, *P. chlorites*, *P. nobilis*, *P. semperi*, and *P. sarcitis*), followed by Babuyan (4 species, *P. orbifer*, *P. semperi*, *P. nobilis*, and *P. sarcitis*), Camiguin Norte (3 species, *P. orbifer*, *P. semperi*, and *P. sarcitis*), Batan (3 species, *P. perpulcher*, *P. semperi*, and *P. sarcitis*), Fuga (3 species, *P. orbifer*, *P. chlorites*, and *P. sarcitis*), Itbayat (2 species, *P. orbifer* and *P. sarcitis*). The two most species-poor islands were Dalupiri (1 species, *P. orbifer*) and Sabtang (1 species, *P. sarcitis*). Across the different islands, several species exhibited high level of morphological variation in color and color pattern, including *P. orbifer*, *P. chlorites*, *P. sarcitis* and *P. semperi*. Whether these populations on different islets reflect intra- or interspecific variation still needs to be clarified using morphological and genetic evidence, and possibly integrating ecological information in the form of host plant associations.

Keywords: flightless, host plant, polyphagous, Taiwan-Luzon Archipelago, volcanic islands

Introduction

Pachyrhynchus weevils (Coleoptera: Curculionidae) are a group of beetles characterized by remarkably variable dorsal body color patterns. As such, these insects have always attracted the attention of scientists and amateurs. Most *Pachyrhynchus* species are endemic to the Philippines, especially Luzon Island, which has the highest species richness (Schultze 1923). Although more than 100 species of *Pachyrhynchus* have been described (Schultze 1923; Yoshitake 2012), species richness is still likely underestimated, particularly in the remote Batanes and Babuyan Islands situated between Luzon and Taiwan (Fig. 1), as well as other unexplored areas, such as Mindoro Island, the majority of the islands of the West Visayas, central Mindanao, and the mountains of northeastern Luzon (Schultze 1923). *Pachyrhynchus* weevils are flightless; as such, deep ocean channels surrounding major Philippine island banks may have served as barriers to dispersal (i.e., may have impeded gene flow and promoted divergence among populations), and consequently, facilitated speciation and diversification (Claramunt *et al*. 2012; Vogler & Timmermans 2012).

The islands between Taiwan and the Philippines form a double island chain (Fig. 1). In the south of this island chain (just north of Luzon), the double-chain configuration of these island arcs initiates with Camiguin Norte and Fuga islands, which are separated by 50 km. The two linear chains of landmasses continue to the far north, where they converge, near Batan Island (20˚N). The double island chain arrangements consists of an older, western volcanic chain (from south to north: Fuga, Dalupiri, Calayan, central and southern Batan, Sabtang, Itbayat and Orchid Island; Fig. 1), and a younger, eastern volcanic chain (Camiguin Norte, Babuyan Claro, northeastern Batan, Green Island; Yang et al. 1996). Most islands of the western chain originated in the Miocene to Pliocene (>3.5 Myr), whereas the eastern chain originated in the Quaternary (<2.8 Myr; Yang et al. 1996). The landmasses of the Babuyanes and Batanes have never been connected to each other, to other Philippine islands, or to Taiwan—as indicated by deep intervening channels and surrounding ocean (Voris 2000).

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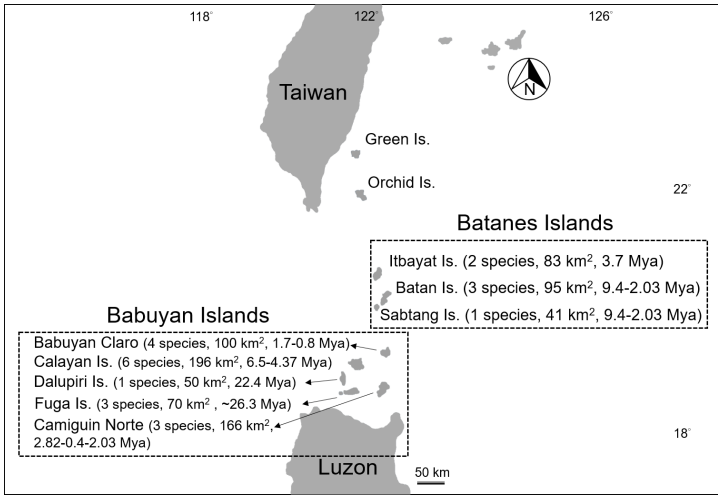

Figure 1. Location of islets of Batanes and Babuyan Islands between Taiwan and the Philippines. Number of *Pachyrhynchus* species, island size and island age are presented in parentheses.

Very few faunistic surveys have been conducted in the islands that lie between Taiwan and the Philippines (Allen *et al*. 2006; Broad & Oliveros 2004; Oliveros *et al*. 2008). The most comprehensive surveys in this area have focused on land vertebrates such as amphibians and reptiles (Oliveros *et al*. 2011), birds (Allen *et al*., 2006; Oliveros *et al*., 2008), and mammals (Broad & Oliveros 2004). As a result, the Babuyan Islands were evaluated as a priority area for biodiversity conservation, based on the presence of numerous threatened and endemic species (Broad & Oliveros 2004). In contrast, the diversity of invertebrates on these same islands is poorly understood. Only a few entomological studies have focused on Odonata (Villanueva 2009) and *Pachyrhynchus* weevils (Tseng *et al*. 2018) have been conducted in these two island groups. In the case of *Pachyrhynchus*, only three species (*P. chlorites* Chevrolat, 1881; *P. viridans* Heller, 1912 and *P. orbifer* Waterhouse, 1841) have been recorded previously in the Babuyan Islands (Kano 1936; Schultze 1923), and only two species (*P. sarcitis* Behrens, 1887 and *P. orbifer*) in the Batanes Islands (Schultze 1923). On Orchid and Green Islands, five species (*P. insularis* Kano, 1929; *P. sonani* Kano, 1930, *P. sarcitis*, *P. tobafolius* Kano, 1929 and *P. yamianus* Kano, 1929) and four species (*P. jitanasaius* Chen & Lin, 2017; *P. sarcitis*, *P. tobafolius* and *P. yamianus*), respectively, have been recorded (Chen *et al*. 2017; Starr & Wang 1992).

According to the dynamic equilibrium theory of island biogeography, species diversity of a given island may be predicted by island size and its distance to a continent or other source of colonists (MacArthur & Wilson 1967). Thus, one testable prediction would relate to the expectation of greater species richness on larger islands of the Babuyanes, which are closer to Luzon. Specifically, we assumed that Camiguin Norte (166 km^2), Babuyan Claro (100 km^2), and Calayan (196 km^2) in the south might have more species than the smaller, more distant landmasses such as Batan (95 km^2) and Itbayat (83 km^2) (Fig. 1). In part, to test this prediction, we conducted a preliminary survey of *Pachyrhynchus* species of the Batanes and Babuyan Islands, with the aim of clarifying species richness and documenting their distributions.

Materials and Methods

Field surveys were conducted during the months of April, 2012 and 2013. We quantify our effort using survey days multiplied by the number of researchers. *Pachyrhynchus* weevils were recorded on Batan, Sabtang and Itbayat of the Batanes Islands Group, and on Calayan, Camiguin Norte, Fuga, Dalupiri, and Babuyan Claro of the Babuyan Islands Group (Fig. 1). We did not have prior knowledge of weevil host plants on these islands, so we searched any potential microhabitats (trees, vines, grasses, herbs, shrubs, etc.) to find weevils. All surveys were implemented by generalized transect sampling situated along established trails. Most forested areas on these islands consist of naturally dense vegetation, and therefore, can be difficult to penetrate. Thus, for our initial surveys and to maximize standardization among sites/islands, searching was limited to established trails. To minimize incidental (or erroneous) inference of host-weevil associations, plant species were recorded as hosts, only after finding weevils on a particular plant species, on three or more occasions. Host plant species were photographed and subsequently identified by Dr. Tsung-Yu Aleck Yang (National Museum of Natural Science, Taiwan).

Pachyrhynchus species were diagnosed according to the morphological keys of Schultze (1923). We acknowledge that recent molecular work suggests that some of Schultze's species may in fact represent species complexes (e.g., *P. orbifer*, Tseng *et al*. 2018) and accept that the genus should likely be revised, integrating both morphological and molecular data. However, we believe that for the purpose of our preliminary survey, Schultze's concepts provide a sound estimate of species richness on the different islands.

Results and Discussion

Species richness, distribution and host plants

Babuyan Islands

In the Babuyan Islands, three *Pachyrhynchus* weevils (*P. orbifer*, *P. sarcitis*, and *P. semperi* Heller, 1912) were recorded on Camiguin Norte Island. All three species were recorded in the vicinity of Panan mountain. *Pachyrhynchus orbifer* was also

Figure 2. Species of *Pachyrhynchus* weevils on Babuyan and Batanes Islands. (a) *P. orbifer* from Camiguin; (b) *P. orbifer* from Fuga; (c) *P. chlorites* from Fuga; (d) *P. orbifer* from Dalupiri; (e) *P. sarcitis* from Calayan; (f) *P. perpulcher* from Calayan; (g) *P. orbifer* from Calayan; (h) *P. nobilis* from Calayan; (i) *P. chlorites* form Calayan; (j) *P. sarcitis* from Babuyan; (k) *P. semperi* form Babuyan; (l) *P. nobilis* from Babuyan; (m) *P. orbifer* from Babuyan; (n) *P. perpulcher* from Batan; (o) *P. semperi* form Batan; (p) *P. orbifer* from Itbayat. *Pachyrhynchus orbifer* has variable color pattern (a, b, d, g, m, p). *P. nobilis* (h, l) and *P. semperi* (k, o) shared similar pattern, but slightly different in body shape. *Pachyrhynchus chlorites* (c, i), have similar pattern within species, but color may different among populations. *Pachyrhynchus sarcitis* (e, j) and *P. perpulcher* (f, n) have almost identical color and pattern within species of the Batanes and Babuyan Islands.

Table 1. The effort value, species, number of individuals, distributions, and host plants of *Pachyrhynchus* weevils in the Batanes and Babuyan Islands.

Island (Effort value)	Location	Species	Host plant	Number of individuals
Camiguin Norte (35)	Panan	*P. sarcitis*	Manila Leea (*Leea guineensis*, Leeaceae) Philippine Leea (*Leea philippinensis*, Leeaceae)	7
	Panan	*P. semperi*	?	2
	Panan Masalawat Mapulapula	*P. orbifer*	Fish Poison Tree (*Barringtonia asiatica*, Lecythidaceae)	9
Fuga (20)		*P. orbifer*	*Aglaia* sp., Meliaceae	14
		P. chlorites	Fish Poison Tree (B*arringtonia asiatica*, Lecythidaceae)	9
		P. sacitis		2
Dalupiri (5)		*P. orbifer*	Elephant's Ear (*Macaranga tanarius*, Euphorbiaceae)	10
Calayan (18)	SE	*P. sarcitis*	Manila Leea (*Leea guineensis*, Leeaceae)	19
	Central mountain		Philippine Leea (*Leea philippinensis*, Leeaceae)	15
		P. orbifer	?	3
		P. perpulcher	Urticaceae	10
	SE	*P. nobilis*	?	9
	Central mountain			16
	SE	*P. semperi*	?	2
		P. chlorites	?	11
Babuyan Claro (24)		*P. orbifer*	?	5
	Brgy. Babuyan Claro	*P. sarcitis*	?	16
	Brgy. Babuyan Claro	*P. nobilis*	?	6
	Brgy. Babuyan Claro	*P. semperi*	?	3
Batan (12)	Mt. Iraja Mt. Matarem	*P. perpulcher*	Urticaceae	12
	Mt. Matarem	*P. sarcitis*	Manila Leea (*Leea guineensis*, Leeaceae) Philippine Leea (*Leea philippinensis*, Leeaceae)	9
	Mt. Matarem Mt. Iraja	*P. semperi*	Bishop Wood Tree (*Bischofia javanica*, Euphorbiaceae)	6 8
Sabtang (12)	Nakanmuan	*P. sarcitis*	?	2
Itbayat (15)	Mt. Karoboboan	*P. sarcitis*	Manila Leea (*Leea guineensis*, Leeaceae) Philippine Leea (*Leea philippinensis*, Leeaceae)	10
	Sta. Lucia	*P. orbifer*	Ceylon Ardisia (*Ardisia elliptica*, Myrsinaceae)	9

found on Masalawat and Mapulapula mountains, and inhabited fish poison trees (*Barringtonia asiatica* (L.) Kurtz, Lecythidaceae) in coastal areas (Fig. 2a). *Pachyrhynchus sarcitis* fed on Manila Leea (*Leea guineensis* G. Don, Leeaceae) or Philippine Leea (*L. philippinensis* Merr.). This species has dark purple-red coloration on dorsal body surfaces, with yellow spots on its elytra. *Pachyrhynchus semperi* was relatively rare compared to other Camiguin Norte species, and no host plant was recorded.

On Fuga Island, *P. orbifer* was recorded associated with *Aglaia* sp. (Meliaceae) on the seashore; the majority of individuals of this species were observed on this tree's trunk (Fig. 2b). Although their markings appear quite colorful, observers noted difficulty of distinguishing *P. orbifer* from a distance, possibly indicating camouflage (not metallic or reflective, this species coloration may result in disruptive patterns, minimizing body outlines, against the background of this tree species' trunk). On the other side of Fuga Island, *P. chlorites* can be found on fish poison trees at the seashore (Fig. 2c). At this locality, *P. chlorites* differs from other populations by the presence of black dorsal surfaces with pink spots (Fig. 2c). We also documented two individuals of *P. sarcitis* on Fuga; this second species is also black with pink spots. Only one *Pachyrhynchus* species, *P. orbifer*, was found on Dalupiri, where it was associated with the host plant Elephant's Ear (*Macaranga tanarius* (L.) Muell. Arg., Euphorbiaceae) in sparse coastal forests (Fig. 2d).

Calayan Island is the largest landmass in the Batanes and Babuyanes groups. As anticipated, more *Pachyrhynchus* species were recorded on Calayan than any other landmass in the Babuyan Islands Group. *Pachyrhynchus sarcitis* was abundant on Calayan, and fed on Manila Leea or Philippine Leea (Fig. 2e). *Pachyrhynchus perpulcher* G.R. Waterhouse, 1841 fed on Urticaceae, and the coloration is similar to *P. sarcitis*, with yellow spots a purple-red background (Fig. 2f). This species is closely-related to *P. tobafolius* (from Orchid and Green islands) and, notably, have near identical markings (Tseng *et al*. 2014). *Pachyrhynchus orbifer* (Fig. 2g) and *P. nobilis* Heller, 1912 (Fig. 2h) are similar to species on Camiguin Norte Island, with pink stripes on the prothorax and elytra. *Pachyrhynchus chlorites* (Fig. 2i) was also found on Calayan Island; this species is related to *P. chlorites* from Fuga Island, and *P. insularis* from Orchid Island (Tseng *et al*. 2014). Although *P. chlorites* and *P. insularis* have similar spot patterns, their background colorations differ (black in *P. chlorites* from Fuga and *P. insularis* from Orchid, versus purple in *P. chlorites* from Calayan Island). On Babuyan Claro Island, four species of *Pachyrhynchus* weevils were recorded: *P. sarcitis* (Fig. 2j), *P. semperi* (Fig. 2k), *P. nobilis* (Fig. 2l), and *P. orbifer* (Fig. 2m). However, the host plants of these four weevils could not be determined because all specimens were presented to researchers by local peoples.

Batanes Islands

We found three species of *Pachyrhynchus* weevils on Batan Island during our fieldwork in 2013. *Pachyrhynchus perpulcher* was discovered on Mt. Iraja and Mt. Matarem, and fed on Urticaceae (Fig. 2n). *Pachyrhynchus sarcitis* fed on *Leea* sp. on Mt. Matarem. *Pachyrhynchus semperi* was discovered on Bishop wood trees (*Bischofia javanica* Blume, Euphorbiaceae) at the edge of the forest on Mt. Matarem and Mt. Iraja (Fig. 2o). Sabtang is a small island, separated from Batan (Fig. 1) by approximately 5 km; on this island we discovered two individuals of *P. sarcitis*. Itbayat Island has two *Pachyrhynchus* weevils, *P. orbifer* (Fig. 2p) and *P. sarcitis*, which we documented feeding on Ceylon ardisia (*Ardisia elliptica* Thunberg, Myrsinaceae) and Philippine Leea, respectively.

Although the Babuyan Islands are close to Luzon, they have heterogeneous species compositions. *Pachyrhynchus* species richness was highest on Calayan (6 species), followed by Babuyan Claro (4 species), Camiguin Norte (3 species), Fuga (3 species), and finally Dalupiri (1 species). This pattern of variable species richness is generally congruent with island size, with the exceptions represented by Camiguin Norte and Babuyan Claro (e.g., Camiguin Norte is larger and closer to Luzon, but has one fewer species). Also, although similarly-sized, Babuyan Claro Island and Batan Island support markedly different species richness. Batan has relatively few *Pachyrhynchus* species, which may be a consequence of its being more distant from Luzon.

Among the *Pachyrhynchus* species found in the Babuyanes and Batanes, *P. orbifer* exhibits greater among-island color variation than other species (Tseng *et al*. 2018). Notably, *Pachyrhynchus chlorites* from Fuga and Calayan shares the same marking pattern, but differs in the component colors. *Pachyrhynchus semperi* on Camiguin Norte also exhibits different color from that recorded for this species on Babuyan Claro and Batan islands, and *P. sarcitis* from Fuga possesses different coloration from populations of the same species on other islands. Finally, other species, such as *P. nobilis* and *P. perpulcher* appear to have identical color and pattern among their different island populations. Variation in spot, versus background, coloration, in the highly variable *Pachyrhynchus* island populations documented here, provides interesting questions and opportunities for future studies in conjunction with phylogenetic and biogeographic analyses.

Deep-water channels and open oceans are strong barriers to dispersal and colonization of islands for flightless organisms

such as the species-rich *Pachyrhynchus* weevils of the Babuyan and Batanes island groups. Limited dispersal ability may contribute to overall reduction in gene flow, and accumulation of phenotypic variation among insular populations, such as the weevil populations documented here. However, whether these populations constitute fully isolated, or reproductively-incompatible different species still needs to be clarified in future studies focusing on phenotypic and genetic variation, possibly integrated with species-specific ecological traits, such as host plant association of the kind documented in this study.

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