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Original Article

Diversity and distribution of amphibians and reptiles in the Caramoan Island Group, Maqueda Channel, Southern Luzon, Philippines

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A B S T R A C T

We report for the first time the herpetological biodiversity (amphibians and reptiles) of the Caramoan Island Group (CIG), Maqueda Channel, southern Luzon Island, the Philippines. Herpetofaunal biodiversity assessment, using the standard field-based methodology for survey work, was conducted at nine sites in the CIG, off the northeast coast of the Bicol Peninsula of southern Luzon. The overall species richness (*s*) in the CIG is 22 (three amphibians, 12 lizards, and seven snakes) represent new island records for a variety of the native species, ten of which are endemic to the Philippines. Beta diversity (β-diversity) of the CIG is 0.84 reflecting a relatively high degree of local area turnover of species when among-site comparisons were quantified; this finding most likely reflects habitat variability which is consistent with our observation emphasizing how a high proportion of faunal diversity is associated with, or confined, to very specific microhabitats (limestone areas, lower-montane forests, mangroves, beach coastal forests, etc.). The overall community similarity index of the archipelago was 0.545 implying that CIG has moderate overlap of amphibian and reptilian species composition. Our findings provide baseline information on the unique composition of herpetofauna in the CIG, which highlights a general paucity of knowledge about the Peninsula's herpetofaunal diversity.

Introduction

Several islands and islets of the Caramoan Island Group (CIG) are found just off the coast of the Maqueda Channel, bordering southeastern Camarines Sur Province, of the Bicol Peninsula (and faunal subregion), of Luzon Island in the northern Philippine archipelago (NAMRIA, 2020). The Municipality of Caramoan is known for limestone cliffs and caves found in Caramoan National Park, a 34.7 km^2 natural protected area composed of a hilly peninsula, with deep gorges and rough, rocky terrain, lowland forests, and distinct microhabitats such as mangrove forests, sand dunes, and beaches. Prominent features include caves, tall tower-like and isolated limestone karst formations, white sandy beaches, small lakes, and brackish water lagoons, and a subterranean river (Bradesina 2016).

The unique geographic location and biogeography of CIG is significant particularly as it relates to the distribution of terrestrial land vertebrates, which colonize island systems. Dispersal to, colonization of, and establishment of populations on oceanic islands are usually dependent on many factors such as organismal traits, environmental factors, weather and currents, habitat heterogeneity, and other ecological factors (Brown et al 2014). In fact, as suggested by Siler et al (2010), complex geographic settings such as topographic relief, patchily-distributed habitat types, and other insular systems may provide environmental heterogeneity which may promote differentiation and divergence of micro-endemic (i.e. endemic to only a very small region), naturally range-restricted species. In the recent description of the Bicol Peninsula's endemic *Brachymeles lukbani*, a legless fossorial lizard, Siler et al (2010) hypothesized a close evolutionary relationship with

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B. minimus, another legless species restricted to Catanduanes Island, and suggested that restricted geographic distributions of endemic species may result, even at fine scales, due to habitat patchiness and environmental variability tied to variable topography (see also Auffenberg and Auffenberg 1988; Brown et al 2020).

In general, because of limited knowledge about species distributions, ecological requirements, and evolutionary relationships of the amphibian and reptile fauna of Luzon, detailed understanding of the processes involved in the assembly and long-term maintenance of the island's herpetological biodiversity have not been fully ascertained (Brown et al 1996, 2000, 2012, 2013a, b; Siler et al 2011; Devan-song and Brown 2012). Nevertheless, available studies showed underestimation of Luzon's biodiversity (Siler et al 2011) and numerous taxonomic analyses and synthetic revisionary studies are steadily increasing our understanding of the unique and endemic biodiversity of the island (Brown et al 2020; Barley et al 2020; Diesmos et al 2015; Leviton et al 2018). The underestimation of the herpetofaunal diversity in many parts of the Philippines appears to be true also for many small islands, including those associated with the Caramoan Peninsula (the CIG). As such, field-based surveys and resurveys are crucial for characterizing faunal similarity and endemism among islands. If done regularly, these studies will provide a fundamental baseline for conservation and protected area management, to stimulate future research focusing on species distributions and, ultimately, to test biogeographical hypotheses (Siler et al 2012; Brown et al 2013a). This study is a first attempt to ameliorate a conspicuous knowledge gap regarding amphibian and reptile species of small islands associated with the Caramoan Peninsula of southern Luzon (see also Auffenberg and Auffenberg 1998; Diesmos et al 2015; Leviton et al 2018).

From 2008 to the present, a shift in resource-use patterns by local human populations in the coastal areas of Caramoan was observed—from sustenance fishing to recreation fishing. This shift transpired when local and international media attention soared with the international hit series TV reality show "Survivor" was filmed in the area (Bradesina 2016). Although the public's open access to natural, undeveloped Caramoan beaches may have brought economic opportunities and welcomed adventure tourism revenue, it also sparked concerns regarding sustainability of the area's natural resources and unique habitats (Bradesina 2016); these included the same unique microhabitats (beach coastal forests, fragile limestone karst ecosystems, etc.) that biologists had already identified as potentially associated with processes of speciation and fine-scale faunal diversification (Brown et al 2008; Siler et al 2011; Oliveros et al 2011). From recent summaries (e.g. Brown et al 2013a), we may predict that surveys of the many unexplored islands of the CIG might result in possible discoveries of new, endemic taxa (Brown et al 2020). Furthermore, novel information informing us about barriers to dispersal (e.g. ocean channels, low elevation dry, arid habitats, etc.) that may give rise to ecological and evolutionary differentiation among montane forest obligate land vertebrates (Brown and Diesmos 2002, 2009), should also contribute to our understanding of the evolutionary history of Philippine vertebrates in general (Brown et al 2013a).

To date, herpetological diversity of the CIG has remained undocumented despite studies of nearby Bicol Peninsula forests (Auffenberg 1988; Auffenberg and Auffenberg 1988 1989). It is suspected that like other small island groups of the Philippine archipelago (Oliveros et al 2011; Siler et al 2012), the terrestrial fauna of CIG may be surprisingly diverse and, thus, could provide important information needed to fuel conservation, inform management, and also elucidate evolutionary and ecological processes. It is likewise reasonable to consider that the geologically unique and ecologically isolated CIG may have undergone faunal development, diversification—giving rise to microendemism as a result of over water dispersal or range expansion via land bridges exposed by Pleistocene sea level oscillations (review: Inger 1954, Brown and Diesmos 2009). Accordingly, we initiated this study of the assemblages of amphibians and reptiles of CIG to better understand the probable patterns of endemism and regional levels of resident biodiversity in the Caramoan Peninsula and its small, isolated islands. By using the standard field-based methodology for survey work, we provide an initial characterization of the CIG small islands resident amphibians and reptiles, to take a first step toward biogeographical hypothesis testing which we eventually hope may yield insight into the origins and diversification of resident amphibian and reptile lineages of the Caramoan Peninsula.

In addition, because healthy ecological communities are often dependent on high level of biodiversity and ecological services provided by a wide variety of species in complex terrestrial forest communities (Balvanera et al 2017), we seek a baseline source of data to consider the roles of reptiles and amphibians, with their specific taxonomic and functional diversity as indicators of environmental health and stability. Finally, given the Caramoan's rapid development and expanding human population, we identify a need to create conservation programs for amphibians and reptiles, to increase local awareness and protect Caramoan's unique populations. However, such programs are dependent on the information on species distribution, abundance, natural history, and the habitats on which they depend. The present study may take an initial step toward the goal of providing this urgently needed and critically important basic information.

Material and methods

We conducted herpetofaunal surveys, using general methodology (Brown et al 2000, 2012, 2013b; Siler et al 2011, 2012) at the following sites: Sabitang-Laya Island (site 1), Sitio Bogtong in Lahuy Island (site 2), Tanasac Island (site 3), Cotivas Island (site 4), southern Lahuy Island (site 5), Sitio Nipa northern Lahuy Island (site 6), Guinahoan Island (site 7), Lahos Island (site 8), and Catanauan Island near Pitogo Bay (site 9) (Figure 1).

We conducted team-based surveys in the early morning, midday, afternoons, and evenings. Extensive sampling targeted different habitat types (small streams, rivers, forest edges, grassy open areas, forest gaps, interior forests, and forest trails at all elevations), during variable environmental conditions (assuring that surveys were performed, for example, during both dry and rainy nights, on each island) and under different atmospheric conditions (rainy season and dry season).

Identification of species follows taxonomy of Alcala and Brown (1998), Diesmos et al (2015), and consulting Frost (2017), Alcala (1986) and Diesmos et al (2008) for amphibians, Brown and Alcala (1978) as modified by Brown et al (2007, 2008) and Zug et al (2007) for gekkonid lizards, Brown and Alcala (1980) and Mausfeld et al (2002), Linkem et al (2010, 2011) Linkem and Brown (2013), and Barley et al (2013, 2020) for scincid lizards, and Welton et al (2013, 2014) for varanid lizards. In identifying lizards belonging to the genus *Draco*, the monograph of McGuire and Alcala (2000) was used; other lizards of the family Agamidae were identified according to Welton et al (2017) and Siler et al (2014). For the taxonomy of snakes, Leviton (1964, 1967, 1970), Malhotra and Thorpe (2004), Ota and Ross (1994), Utiger et al (2005), and Leviton et al (2014) were utilized; snake distributions and identifications were confirmed with drafts of monographs now available in published form (Leviton et al 2018; Weinell et al 2019). All specimens were photographed extensively in life whenever possible (by JBF and RMB) to document color pattern variation and to allow for subsequent reconsideration of species identification.

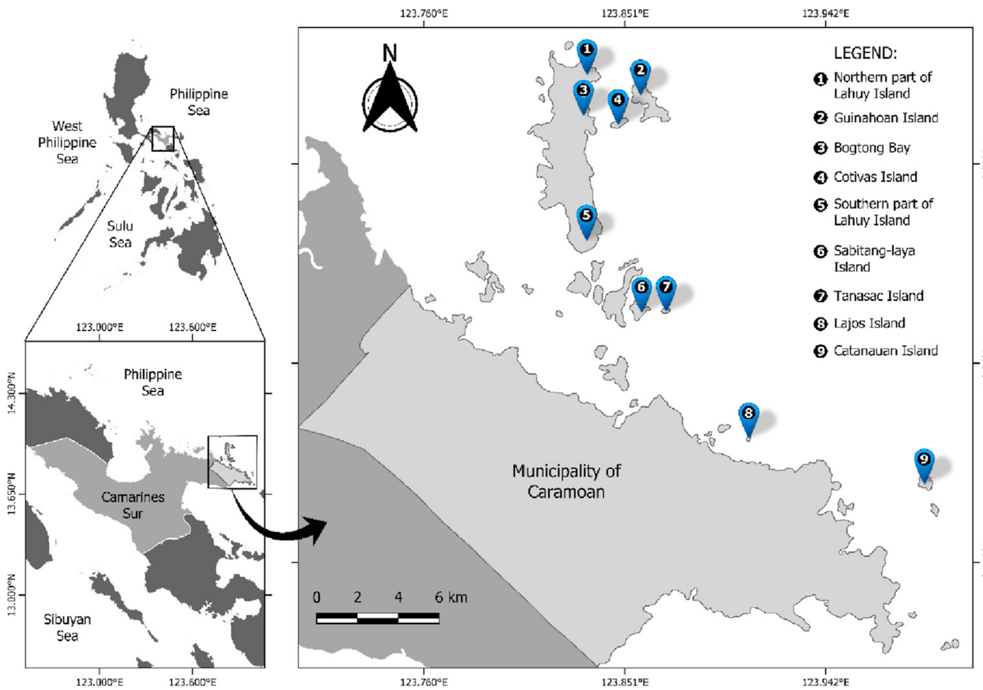

Figure 1. Location of the study sites at the Caramoan Island Group (CIG).

Here we present our results in the form of taxonomic listing and species accounts with photographs taken during the surveys. Each species account includes its formal scientific name, common names, an approximate, admittedly subjective population trend characterization, and its accepted the International Union for Conservation of Nature (IUCN) conservation status, along with notes on habitats and natural history. Population trends and conservation status were based on the current published information of the IUCN Red List of Threatened Species. Version 2019-2. The International Union for Conservation of Nature and Natural Resources. <https://www.iucnredlist.org> ISSN 2307-8235. Status of species with no IUCN Status are summarized to the best of our ability by one coauthor (RMB) who participated extensively in initial IUCN amphibian and reptile status assessments (2000–2019).

To infer the degree of the herpetological species diversity in the CIG, species richness (s = the number of species of reptiles and amphibians, or alpha species diversity) per island is presented below. Beta (β) diversity, or the amount of variation in species composition among sampling units (which in this study is referred to as site or habitat-specific communities) was also computed. To compute this index, the beta diversity reformulated of Ricotta (2008) was used:

$$\beta AN = \sum_i \frac{N - Ni}{S \times N}$$

where N is the total number of sites, Ni is the number of sites that contain species i, and S = is the total number of species in the N sites. The range of beta diversity takes values from 0 to 1; with 0 indicating no differences (or faunal turnover) between sites, and 1 indicating complete faunal disparity, or turnover, with no species shared by two units.

We also characterized a community similarity index, to provide an initial measure of biogeographical affinities of island communities or unique assemblages of islands in the CIG. We used the multiple-site community similarity index, an extended Sørensen similarity index (Diserud and Ødegaard 2007), starting initially with the nine sites inventoried, clustered in four locations based on proximity. The formula for computing community similarity was

$$\frac{ab + ac + ad + bc + bd + da + dc - abcd}{a + b + c + d}$$

where '*a*', '*b*', '*c*', and '*d*' the numbers of species found in sites A, B, C, and D, respectively, and ab the number of species shared by sites A and B, etc., until '*abcd*' which is the number of species found in all four locations: Sabitang-Laya and Tanasac Islands (location 1), Sitio Nipa, Sitio Bogtong and the southern part of Lahuy Island (location 2), Cotivas and Guinahoan (location 3) and Lahos and Catanauan Islands (location 4). The multiple-site similarity measure should therefore be in the range 0–1, with 0 indicating no similarity and 1 indicating complete similarity.

Results

Taxonomic list of the reptilian and amphibian taxa in the CIG

Twenty-two species of amphibians and reptiles in the CIG (three amphibians, 12 lizards, and seven snakes), all representing new island records, were documented in this study. Two gekkonid lizards and one frog species appear to represent undescribed or otherwise taxonomically uncertain identifications; these species cannot be reliably identified; hence, they are included only by identification to the level of genus, with "species" designations temporarily assigned numbers to denote their status as uncertain and flag each as potential subjects of further taxonomic study. One of these has been the focus of a recent taxonomic study describing the Caramoan population of *Pseudogekko* as a new species (Brown et al 2020).

Species accounts for amphibians and reptiles of the CIG

Amphibia

Bufonidae

Rhinella marina **(Linnaeus, 1758)**
(Figure 2)

This anuran species was found in six of the eight islands of the CIG during the field collection and is known to be an invasive, introduced species, widely occurring and abundant throughout the Philippine archipelago (Diesmos et al 2006), particularly in residential areas and agricultural lands in most islands (Inger 1954; Brown and Alcala 1970; Alcala and Brown 1998; Diesmos et al 2006, 2015; Devan-Song and Brown 2012). Introduced originally at central Philippine island of Negros during the boom of sugar cane agricultural production (Brown and Alcala 1970; Alcala and Brown 1998; Diesmos et al 2006), this species is now observed to be in high densities at low-elevation agricultural areas (Alcala 1957; Afuang 1994; Brown et al 2013). Conservation of this highly invasive species is not required, instead measures to protect those species negative affected by its increasing population and range is needed. The species has been put to various uses across its geographic range, such as for educational purposes, skins are used for bags in Mexico and for drum skins in Papua New Guinea, while whole animals are stuffed and sold as souvenirs in Nicaragua (IUCN 2019).

Common name(s): Cane toad
Current Population Trend: Increasing (IUCN, 2019)
Conservation Status: "Least Concern" (LC; IUCN, 2019).

Dicroglossidae

Fejervarya vittigera **(Wiegmann, 1834)**
(Figure 3)

Fejervarya vittigera is a Philippine endemic that is commonly observed in low-elevation habitats, such as rice fields, ponds, lakes, stream banks, and forests. They are often seen in highly disturbed areas, denuded streams, and water-filled roadside ditches (Devan-Song and Brown 2012; Brown et al 2012, 2013b). In some places, their density population has declined due to the introduction of Asian Bullfrog, *Hoplobatrachus rugulosus*, which preys on them and/or outcompetes them (Diesmos et al 2006; Brown et al 2012). A few individuals of this species were seen along the small streams leading to shoreline of Sitio Nipa at Lahuy Island. This species is harvested for food by local communities, but not at levels that constitute a major threat to the species (A. Diesmos pers. comm. March 2018, as cited in IUCN, 2019).

Figure 3. *Fejervarya vittigera* Photo: copyright RMB and JBF

Common name(s): Common pond frog, Luzon wart frog
Current population trend: Decreasing (IUCN 2019)
Conservation status: Decreasing, "Least Concern (LC; IUCN 2019)

Rhacophoridae

Polypedates leucomystax **(Gravenhorst, 1829)**
(Figure 4)

This Philippine non-endemic frog species was found near the village on the dry shore of the coastal area of Sitio Bogtong, Barangay Gogon, Lahuy Island. *Polypedates leucomystax* in the Philippines belongs to a putatively distinct, but only slightly divergent genetic lineages that thrive in Southeast Asia (Brown et al 2010). A variant of this species is genetically identical all over most of its Philippine range and had spread throughout the archipelago due, most likely, to human-mediated transport via trade of agricultural and forest products. This Philippine genetic variant is widespread and commonly found in dry, coastal habitats, near streams, grassy fields, low elevation standing water bodies, and also in high-elevation, pristine forests (Diesmos et al 2005, 2006; Brown et al 2012; Devan-Song and Brown 2012). *Polypedates leucomystax* may represent a complex of poorly known cryptic species—hence, a main conservation issue is cryptic diversity within the species complex, because some of the hidden taxa might be of conservation concern. However, species boundaries need to be

Figure 2. *Rhinella marina* Photo: copyright RMB and JBF

Figure 4. *Polypedates leucomystax* Photo: copyright RMB and JBF

established before conservation strategies can be formulated (IUCN 2019).

Common name(s): Common tree frog, four-lined tree frog, golden tree frog, or striped tree frog
Current population trend: Stable (IUCN 2019)
Conservation status: "Least Concern" (LC; IUCN 2019)

Reptilia (lizards)

Agamidae

***Bronchocela marmorata* (Gray, 1845)**
(Figure 5)

Bronchocela marmorata is widely distributed in the Philippines. An individual of this species was collected at night on a tree in the forest of the Sitio Nipa, northern part of Lahuy Island. Characteristics used for identification of this species overlap with that of *Bronchocela cristatella* (Kuhl 1820), and it has previously been postulated that both species co-occur widely throughout the archipelago (Hallerman 2005); this hypothesis has not been supported with genetic data, and Philippine populations appear referable to *B. marmorata*. Hence, further studies are needed to distinguish between two forms morphologically and genetically (Siler et al 2011; Brown et al 2013). It is not known if the species is present in any protected areas. Further studies are needed to investigate the taxonomy, distribution, abundance, and natural history of this species (IUCN 2019).

Common name(s): Marbled crested lizard, marbled bloodsucker, marbled agamid lizard
Current population trend: Unknown
Conservation status: "Least Concern" (DD; IUCN 2019)

Agamidae

***Hydrosaurus pustulatus* (Eschscholtz, 1829)**
(Figure 6)

An individual of this species was collected at night on a branch of a tree in Catanauan Island, a small island. *Hydrosaurus pustulatus* is commonly observed in many isolated islands in the Philippines, except for Palawan (Siler et al 2010, 2014); it is a semi-aquatic species generally restricted to riparian vegetation present in lowland tropical moist forests (both primary and secondary) to open cultivated areas. Possibly omnivorous, it is associated with food trees and prefers shrubs and trees often overhanging water as resting places. This is an oviparous species that buries eggs in sandy

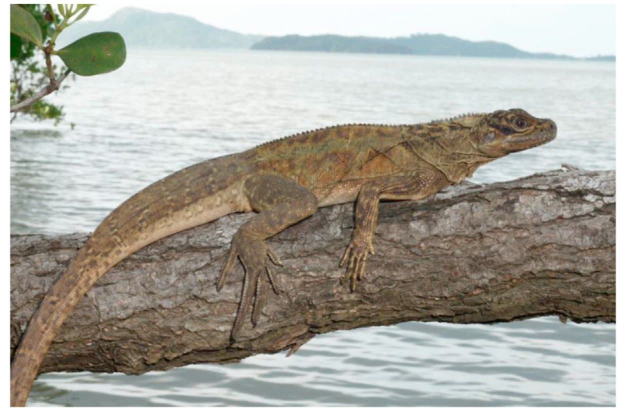

Figure 6. *Hydrosaurus pustulatus* Photo: copyright by RMB and JBF

substrates such as riverbanks. Populations of *H. pustulatus* have been recorded from many protected areas. There is a need to better regulate the collection of this species from the wild, as populations are generally considered to be susceptible to overharvesting. There is also a need for improved regulation to prevent contamination of waterways used by this species with agrochemicals (IUCN 2019)

Common name(s): Philippine sailfin lizard, crested lizard, sailfin lizard, sailfin water lizard, soa-soa water lizard
Current population trend: Decreasing (IUCN, 2019)
Conservation status: "Vulnerable" (VU; IUCN, 2019)

Gekkonidae

***Gekko mindorensis* (Taylor, 1919)**
(Figure 7)

Individuals of this species were collected in a small islet called Tanasac near Sabitang-Laya Island. Widely distributed throughout the Philippine archipelago (Brown and Alcala 1978; Siler et al 2012), *Gekko mindorensis* belongs to a genus with increasing number of species (Rösler et al 2006; Brown et al 2008, 2009; Linkem et al 2010) and is now considered a complex of cryptic species (Siler et al 2011, 2014: Mcleod et al 2011). Occasionally confused with *Gekko monarchus* and *G. kikuchii*, subpopulations of *G. mindorensis* are frequently assigned arbitrarily to one species or the other (IUCN 2019; Siler et al 2014b). Conversion of land to agricultural use, disturbance of caves and limestone areas and logging for timber threaten this species. The species is found in numerous protected

Figure 5. *Bronchocela marmorata* Photo: copyright RMB and JBF

Figure 7. *Gekko mindorensis* Photo: copyright RMB and JBF

areas. Additional studies into the taxonomic relationship between *G. mindorensis*, G. *kikuchii*, and *G. monarchus* are needed, as are further studies into the distribution of these and other related candidate species (IUCN, 2019).

Common name(s): Mindoro narrow-disked gecko
Current population trend: Stable (IUCN, 2019)
Conservation status: "Least Concern" (LC, IUCN, 2019)

Gekkonidae

***Gekko gecko* (Linnaeus 1758)**
(Figure 8)

Individuals of *Gekko gecko* were collected on the southern and northern parts of Lahuy Island. Known to be present throughout the Philippines except in Batanes and Babuyan Island group (Oliveros et al 2011), this common human commensal species (Brown et al 2012) can be found more frequently in human-made structures and less frequently in forests (Brown et al 2013). Recent advertisements in Malaysia, Indonesia, and the Philippines indicating that the consumption of *G. gecko* tongues and internal organs are a cure for human immunodeficiency virus and cancer (Caillabet 2011, 2013) rendered these geckos heavily hunted in Southeast Asia (IUCN 2019). No direct conservation measures are currently needed for this species, but regulation of trade and enforcement of quotas where these exist would be beneficial. International trade monitoring is needed, potentially including CITES monitoring to collect data on trade volumes (IUCN 2019).

Common name(s): Tokay gecko
Current population trend: Unknown (IUCN, 2019)
Conservation status: "Least Concern" (LC) (IUCN, 2019)

Gekkonidae

***Hemidactylus frenatus* (Duméril and Bibron, 1836)**
(Figure 9)

Hemidactylus frenatus is a common "house" gecko, with populations throughout much of the Philippines. It is commonly observed on residential buildings under exterior electric lights and preying on insects (Devan-Song and Brown 2012; Brown et al 2012, 2013; McCleod et al 2011). This species was collected on a branch of a small mangrove tree in Sitio Nipa of Lahuy Island and on the wall of a nipa hut in Catanauan Island. It is unlikely that any major threat is impacting this species; hence, there are no known species-specific conservation measures in place for this species, except however, in places where its distribution coincides with protected areas. In general, no conservation measures are required for this species at present (IUCN 2019).

Figure 8. *Gekko gecko* Photo: copyright RMB and JBF

Figure 9. *Hemidactylus frenatus* Photo: copyright JBB

Common name(s): Common house gecko, bridled house gecko
Current population trend: Stable
Conservation status: "Least Concern" (LC; IUCN 2019)

Gekkonidae

***Lepidodactylus* sp.**
(Figure 10)

An individual of this species was collected at night on leaves of a tree at Cotivas Island. The specimen appears to most closely resemble *Lepidodactylus lugubris*, but uncertainty regarding Philippine *Lepidodactylus* populations render the single individual unidentified to species.

Common name(s):
Current population trend: Unknown
Conservation status: Unknown

Gekkonidae

Pseudogekko hungkag Brown, Meneses, Wood, Fernandez, Cuesta, Clores, Tracy Buehler, and Siler 2020.
(Figure 11)

A specimen of this new species (Brown et al 2020) was observed on the branch of a small coastal beach forest scrub 1.5 m above the ground, on Lahos Island (site 8). The tree is near the huge limestone formations <10 m from the coast. This heavy-bodied lizard species is only the second member of the *Pseudogekko brevipes* Complex described from the Luzon Pleistocene Aggregate Island Complex

Figure 10. *Lepidodactylus* sp. Photo: copyright RMB and JBF

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Figure 11. *Pseudogekko hungkag* Photo: copyright RMB and JBF

(PAIC) (Brown and Diesmos 2009; Voris 2000). Another individual of this species was first observed also in a coastal beach forest scrub and mixed secondary forest at Layak Lagoon, Barangay Pandanan, Caramoan Peninsula, while climbing on a suspended vine about 4 m above the ground (Brown et al 2020).

Common name(s): Bicol hollow-dwelling forest gecko.
IUCN conservation status: Unknown
Population trend: Unknown
Conservation status: Recommended (Brown et al 2020) "Data Deficient" (DD; IUCN 2019)

Scincidae

***Eutropis borealis* (Brown and Alcala 1980)**
(Figure 12)

Specimens of *Eutropis borealis* were caught inside the forest on a small island called Catanauan Island. This species is considered a habitat generalist (Brown et al 2012; Barley et al 2020), and past studies have found it present all over Luzon and nearby smaller island groups (Brown and Alcala 1980; Brown et al 1996, 2000, 2012; Diesmos et al 2005; Siler et al 2011). It is commonly observed in rotting logs on forest floor of mixed primary and secondary growth forest (Brown et al 2013) and along riverbanks (Brown et al 2012). This species is usually observed basking in sunspots at the edges of forests (Brown et al 2012), and southern Luzon populations were recently elevated to the status of full species after having been considered a subspecies of *E. multicarinata* (Brown and Alcala 1980; Barley et al 2020).

Common name(s): Northern two-striped mabuya
IUCN conservation status: Unknown
Population trend: Unknown
Conservation status (Recommended): "Least Concern" (LC; Brown et al 2012)

Scincidae

***Parvoscincus decipiens* (Boulenger, 1895)**
(Figure 13)

Individuals of this small-bodied forest species, *Parvoscincus decipiens*, were collected in the forest of the small Catanauan Island. This species prefers minimally disturbed and intact forests and other mid- to high-elevation pristine habitats (Taylor 1922; Brown and Alcala 1980; Brown et al 2012; Siler et al 2011; McLeod et al 2011; Linkem and Brown 2013). They occur around small streams, leaf litter, fallen tree trunks, and decaying logs, and other habitats that are still covered by vegetation (Brown et al 2012).

Common name(s): Black-sided skink, Philippine black-sided forest skink
IUCN conservation status: Unknown
Current population trend: Unknown
Conservation status (Recommended): "Near Threatened" (NT, Brown et al 2012)

Scincidae

***Brachymeles bonitae* (Duméril & Bibron, 1839)**
(Figure 14)

The Caramoan population of slender-bodied skinks is of uncertain taxonomic status (Siler et al 2011); this species was observed to be abundant in two remote small islands of CIG, Cotivas and Catanauan. Specimens were collected while burrowing within and

Figure 12. *Eutropis borealis* Photo: RMB and JBF

Figure 13. *Parvoscincus decipiens* Photo: copyright RMB and JBF

Figure 14. *Brachymeles* c.f. *bonitae* Photo: copyright RMB and JBF

under decaying logs in loose soils. Specimens examined to date appear to be morphologically identical to *Brachymeles bonitae*, but genetic data and character-based diagnoses will be necessary to confirm its identity (see Siler et al 2016).

Common name(s):
Current population trend: Unknown
Conservation status: Unknown

Scincidae

Emoia atrocostata (Lesson 1830)
(Figure 15)

A specimen of this species was collected near the mangrove swamp area of Bogtong Bay, Sitio Gogon in Lahuy Island. *Emoia atrocostata* inhabits mangroves, back-beach vegetation, and rocky shorelines. They are commonly observed on rocky beaches near or along the intertidal zone, during low tide, while preying on insects and other invertebrates. This lizard is widely distributed in the Pacific region and in many parts of the Philippines (Alcala and Brown 1967).

Common name(s): Mangrove skink, littoral whiptail skink, tidepool or littoral skink
IUCN conservation status: Unknown
Current population trend: Unknown
Conservation status: Unknown

Varanidae
Varanus dalubhasa (Welton, Travers, Siler & Brown, 2014)
(Figure 16)

Figure 15. *Emoia atrocostata* Photo: copyright RMB and JBF

Varanus dalubhasa is Bicol faunal region endemic monitor lizard species discovered and described recently on the basis of genetic data. It is considered a habitat generalist, often thriving in a range of habitats from primary forest to more urbanized areas, and is most likely to be found in mangroves, coastal plains, and riparian habitats. Like most water monitors, they seek out shelter in the form of rock crevices, stream bank overhang concavities, or even trees, most often near water sources. This species has been found throughout the Bicol faunal sub-region, including genetically confirmed specimen identifications from Polillo and Catanduanes islands (Welton et al 2014). An individual of this species was collected near the mangrove area in Sitio Bogtong, Lahuy Island of the CIG.

Common name(s): Enteng's Monitor Lizard
Current population trend: Unknown
Conservation status: Unknown

Reptilia (snakes)

Colubridae

Coelognathus manillensis (Jan 1863)
(Figure 17)

Specimens of *Coelognathus manillensis* were encountered while active on the ground of low elevation forests of Sitio Nipa on Lahuy Island and neighboring Guinahoan Island. This large-bodied species of the rat snake is a part of a group of endemic species considered widely distributed throughout the Philippines (McCleod et al 2011; Brown et al 2013; Leviton et al 2018). There is paucity of knowledge

Figure 16. *Varanus dalubhasa* Photo: copyright MACl

Figure 17. *Ceolognathus manillensis* Photo: copyright RMB and JBF

of the taxonomy, distribution, and habitat requirements of this species (Brown et al 2012).

Common name(s): Philippine rat snake
IUCN conservation status: Unknown
Current population trend: Unknown
Conservation status (Recommended): “Data Deficient” (Brown et al 2012)

Colubridae

***Chrysopelea paradisi* (Boie 1827)**
(Figure 18)

An individual of *Chrysopelea paradisi* was collected on a tree at the Cotivas Island. This “flying snake” (McCleod et al 2011) is widely distributed in the Philippines (Leviton 1964; Sanguila et al 2016; Leviton et al 2018) and is a diurnal, entirely arboreal species commonly seen in both primary and secondary tropical moist forests up to 1,500 m elevation (Cox et al 1998). It has been recorded from coconut plantations adjacent to forests, rural villages, tree-shaded gardens, and within the attics of old houses (Stuebing and Inger 1999). There are no major threats impacting this species across its general range, however, in some parts of the Philippines, localized risks are present in the form of deforestation. This species occurs in some of protected areas, but further research is needed on the status of populations on heavily deforested Philippine islands. The taxonomy of this widespread snake also needs resolution (IUCN 2019).

Common name(s): Paradise tree snake, paradise flying snake, garden flying snake
Current population trend: Stable
Conservation status: “Least Concern” (LC; IUCN, 2019)

Colubridae

Dendrelaphis marenae (Vogel and Van Rooijen 2008)
(Figure 19)

Dendrelaphis marenae, a common Philippine endemic, is frequently observed along forest edges, residential areas, and agricultural areas (Brown et al 2012; Devan-Song and Brown 2012; Brown et al 2013). This widespread habitat generalist species (Brown et al 2012) is active during the day on the ground but is often encountered while sleeping in bushes or understory trees at night (Leviton 1968). A specimen of this species was collected on bushes at Catanauan Island.

Figure 19. *Dendrelaphis marenae* Photo: copyright RMB and JBF

Common name(s): Maren’s bronzeback, Asian tree snake
IUCN conservation status: Unknown
Current population trend: Unknown
Conservation status (recommended): “Least Concern” (LC; Brown 2012)

Colubridae

***Dendrelaphis luzonensis* (Leviton 1961)**
(Figure 20)

Specimens of *Dendrelaphis luzonensis* Leviton 1961 were collected on understory vegetation at Catanauan Island and in shrubbery vegetation of Sabitang-Laya Island. This species is widespread and semi-arboreal, and it is most commonly encountered asleep in low-elevation forest edges, shrubs, and agricultural areas (Brown et al 2012, 2013). The distinction between *D. luzonensis* and *D. philippinensis* (*sensu* van Rooijen and Vogel 2012) is unreliable and, somewhat, arbitrarily based on geography, and it is, thus, with some uncertainty that we assign the Caramoan population to *D. luzonensis.*

Common name(s): Luzon bronzeback, green tree snake, common bronzeback, common tree snake
IUCN conservation status: Unknown
Current population trend: Unknown
Conservation status (recommended): “Least Concern” (LC; Brown 2012)

Figure 18. *Chrysopelea paradisi* Photo: copyright RMB and JBF

Figure 20. *Dendrelaphis luzonensis* Photo: copyright RMB and JBF

Colubridae

***Lycodon muelleri* (Duméril, Bibron & Duméril, 1854)**
(Figure 21)

Lycodon muelleri, a species of wolf snake, is commonly observed throughout Luzon (Brown et al 2000, 2013; Siler et al 2011), particularly in lower strata of vegetation, in riparian habitats near rivers and streams (Brown et al 2013) and forest floor of secondary growth forests (Siler et al 2011). A specimen was collected on a tree near an almost dried stream in Sitio Nipa of Lahuy Island. This species is potentially threatened by habitat loss due to deforestation, due to conversion of land to agricultural use and logging. The species has been recorded from protected areas on Luzon and Polillo islands and from proposed protected areas on Mindoro Island. Further research is needed to better determine the dependence of the species on forested areas (IUCN 2019).

Common name(s): Muller's wolf snake
Current population trend: Stable
Conservation status: "Least Concern" (LC; IUCN 2019)

Elapidae

***Laticauda colubrina* (Schneider, 1799)**
(Figure 22)

Laticauda colubrina is occasionally observed near shore on small reefs (Devan-Song and Brown 2012). Specimens of this species were collected, specifically in Bogtong Bay of Lahuy Island, near coral communities of Sabitang-Laya Island, and on rock crevices in Lahos Island.

Common name(s): Yellow-lipped sea krait, Colubrine sea krait, banded sea snake
Current population trend: Unknown
Conservation status: Unknown

Homalopsidae

***Cerberus schneiderii* (Schlegel, 1837)**
(Figure 23)

Individuals of *Cerberus schneiderii* were collected in at Sitio Nipa of Lahuy Island, near a resort of the southern part of Lahuy Island, Sabitang-Laya Island, and Guinahoan Island. This dog-faced water snake is commonly seen in coastal areas, estuaries, and mangroves of Southeast Asia (1970), particularly in Malaysia, Indonesia, and the Philippines (Alfaro et al 2008; Brown et al 2013b).

Common name(s): Dog-faced water snake, Schneider's bockadam, southeast Asian bockadam
IUCN conservation status: Unknown
Current population trend: Unknown

Species richness and β-diversity of the herpetofauna in the CIG

Species richness (*s*) was highest in two sites, Sitio Nipa at the northern part of Lahuy Island ($s = 8$) and Catanauan Island ($s = 8$), followed by Sitio Bogtong of Lahuy Island ($s = 6$) and least in Tanasac ($s = 1$) and Lahos Island ($s = 2$). To date, overall herpetological species richness (*s*) in the CIG stands at 21 species (Table 1).

Beta diversity (β-diversity) of the CIG, based on the reformulated beta diversity index of Ricotta (2008) was 0.84 (Table 1). This degree of diversity reflects the amount of variation in amphibian and reptilian community species composition among the nine small island sites in the CIG. This level of β-diversity indicates that there is relatively high degree of differentiation or faunal turnover (the change in species composition between two or more habitats (Whittaker 1960; Koleff et al 2003; Magurran 2004) among these sites. Hence, it can be further inferred that the spatial structure of assemblages of the amphibians and reptiles has almost 80% possible impact on the ecological processes, such as competition and coexistence (Fargione and Tilman 2002), dispersal (Seidler and Plotkin 2006), or environmental control (Legendre et al 2005). It may also mean that there is a relatively strong link between local scale diversity (alpha diversity) and the regional

Figure 21. *Lycodon muelleri* Photo: copyright: RMB and JBF

Figure 22. *Laticauda colubrina* Photo: copyright: RMB and JBF

Figure 23. *Cerberus schneiderii* Photo: copyright: RMB and JBF.

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Table 1. Families and species of amphibians (anurans) and reptiles (lizards and snakes) from Caramoan Island Groups (CIGs), Philippines [E] means Philippine endemic species.

Taxa	Site								
	1-SL	2-B	3-T	4-Ct	5-LS	6-LN	7-G	8-LJ	9-Cn
Amphibia									
Bufonidae									
Rhinella marina (Linnaeus, 1758)		●		●	●	●	●		●
Dicroglossidae									
Fejervarya vittigera (Wiegmann, 1834) [E]					●	●			
Rhacophoridae									
Polypedates leucomystax (Gravenhorst, 1829)		●							
Reptilia (lizards)									
Agamidae									
Bronchocela marmorata Gray 1845 [E]						●			
Hydrosaurus pustulatus (Eschscholtz, 1829) [E]									●
Gekkonidae									
Gekko mindorensis Taylor, 1919 [E]			●	●					
Gekko gecko (Linnaeus 1758)					●	●			
Lepidodactylus sp.				●					
Hemidactylus frenatus Duméril and Bibron, 1836						●			●
Pseudogekko hungkag Brown, Meneses, Wood, Fernandez, Cuesta, Clores, Tracy Buehler and Siler 2020. [E]								●	
Scincidae									
Eutropis borealis (Brown and Alcala 1980)									●
Parvoscincus decipiens (Boulenger, 1895) [E]									●
Brachymeles c.f. *bonitae* Duméril & Bibron, 1839		●		●					●
Emoia atrocostata (Lesson 1830)		●							
Varanidae									
Varanus dalubhasa Welton, Travers, Siler & Brown, 2014 [E]		●							
Reptilia (snakes)									
Colubridae									
Coelognathus manillensis Jan 1863						●	●		
Chrysopelea paradisi (Boie 1827)				●					
Dendrelaphis marenae Vogel and Van Rooijen 2008									●
Dendrelaphis luzonensis Leviton 1961 [E]	●								●
Lycodon muelleri Duméril, Bibron & Duméril, 1854 [E]						●			
Elapidae									
Laticauda colubrina (Schneider, 1799)	●	●						●	
Homalopsidae									
Cerberus schneiderii (Schlegel, 1837)	●				●	●	●		

species pool (gamma diversity) (Whittaker 1972). In effect, based on the β-diversity index, the biogeographic affinities of the amphibian and reptilian taxa of the CIG was relatively high.

As explained by the Brown et al (2013) in their discussion of PAIC diversification model, the Bicol Peninsula is part of the Philippine Mobile Belt along with Eastern Mindanao, Leyte and Mindoro, that contributes to the major geological features and approximate tectonic evolution of the archipelago (Hall 1996, 1998; Yumul et al 2003, 2009). The dry landmass of the Bicol Peninsula is surrounded by the 120-m submarine bathymetric contour indicating late Pleistocene seashores), and its fauna was often considered depauperate, perhaps indicative of the prevailing "fringing" archipelago view of the Philippines (Dickerson 1928; Delacour and Mayr 1946; Darlington 1957; Leviton 1963; Brown and Alcala 1970). As part of a fringing archipelago, the Bicol Peninsula where CIG must be a part of the hierarchical temporal structure of landmass connectivity during the Pleistocene. The land connections correspond to the estimate of underwater 120-m bathymetric contours (Kloss 1929; Inger 1954; Heaney 1985; Voris 2000). Such landmass connectivity has been hypothesized to have contributed to species diversification among PAICs (Brown and Diesmos 2009; Brown et al 2013). Further studies are needed to confirm the dominant role of the Philippine PAICs that lead to high levels of vertebrate endemism (Heaney 1985; Dickinson et al 1991; Brown et al 2002, 2009), specifically how these PAICs are crucial in partitioning and maintaining diversity, possibly associated with processes of speciation (Brown et al 2013). In the present study, eight of the 22 species of amphibians and reptiles in the CIG are known Philippine endemic species (or found exclusively in the Philippines). It is worth exploring the possible explanations given by the PAIC model particularly the outer PAIC-level mechanism (fluctuating sea levels) causing land connection–isolation cycles and the inner level mechanism (fluctuating habitats) creating terrestrial habitat connection–isolation cycles (Brown et al 2013) which could have happened also in small island systems, contributing to beta diversity, and faunal composition variation among mainland Luzon, the Bicol Peninsula, and the CIG.

Community similarity and biogeographical affinities of the reptilian and amphibian taxa in the CIG

When the sites were clustered into four locations to compute the community similarity index based on the extended approach of the Sørensen similarity index (Diserud and Ødegaard 2007), the community similarity index of the CIG was 0.545 (Table 1). This index value implies that the CIG has moderate overlap of amphibian and reptilian species composition. The multiple-site similarity measure ranges from 0 to 1, with 1 indicating complete similarity (Diserud and Ødegaard 2007).

Discussion

This herpetofaunal survey addressed the knowledge void concerning amphibian and reptile communities of the CIG, which is separated from the Caramoan Peninsula by the Maqueda Channel. The study aimed to address the following objectives: (i) identify the species of amphibians and reptiles in the CIG, (ii) determine the species richness, community similarity, and biogeographical affinities of the assemblage of reptilian and amphibian taxa, (iii) characterize species compositions of reptile and amphibian reptiles communities on small islands of the CIG in light of the based on the PAIC diversification model predictions, and (iv) develop biodiversity information products specific to the unique herpetofauna of the CIG.

At present, there are no available records of the levels of endemic vertebrate diversity in the small, isolated islands of the CIG; hence, this study is significant because it contributes new information on the level of endemism patterns and species diversity of the country in general, biodiversity of Luzon's poorly known Bicol Peninsula (Brown et al 2020), and of the CIG in particular. Using the standard field-based methodology for survey work, the results of the present study provides baseline information for postulating phylogenetic hypotheses for some herpetofaunal elements, which may ultimately offer insights into character evolution and diversification of lineages.

Twenty-two species of amphibians and reptiles in the CIG (three amphibians, 12 lizards, and seven snakes), representing new island records, were documented from the nine small island sites. Two species' identifications are tentative, based on morphology only to date, and, thus, confirmation of identifications with genetic data will be necessary; these should be the subjects of further taxonomic analysis. One novel species, *Pseudogekko hungkag* (Brown et al 2020) was also observed one of the islands. The three species of amphibians in the CIG belong to one class, one order, three families, and three genera. On the other hand, the 17 species of reptiles belong to two classes, two orders, eight families, seven families, and sixteen genera.

The overall species richness (s) in the CIG is 22, being highest in the farthest sites, Sitio Nipa at the northern part of Lahuy Island ($s = 8$) and Catanauan Island ($s = 8$). The least is in the smallest islands, Tanasac ($s = 1$) and Lahos Island ($s = 1$). When compared with other extensive studied island groups in the Philippines, particularly the Romblon Island Group, which has a total record (combined field surveys and historical museum records) of 55 amphibians and reptilian species, the herpetological species diversity of CIG is comparable because in the Romblon Island Group the latest field surveys showed 26 new records (Siler et al 2012; Meneses et al 2020). The same trends can be inferred from the current study, and our findings contribute greatly to knowledge of the unique herpetological community structure of the CIG, with the new records of 22 species for Bicol Peninsula. The data also provide the basis for further studies about the peninsula's diversity in comparison to small offshore islands. There are several small isolated islands in the CIG that have not yet been explored (Matukad, Cagbanilad, Haponan, and Balibagan islands and other parts of Lahuy Island). It is possible that research in the area, as well as continued exploration of the CIG, will result in fine-scale distribution records and the possibility of discovering new, endemic taxa. Many groups of amphibians and reptiles in CIG also need further taxonomic analysis.

Computed β-diversity of the CIG reflect a relatively high degree of faunal turnover among islands, the computed community similarity index imply that the CIG has moderate overlap of amphibian and reptilian species composition and biogeographic affinities are relatively high and could be due to either community nestedness or biogeograohic turnover (Harrison et al 1992; Baselga et al 2007). This may mean that species composition of small assemblages is a moderate subset of the species composition of larger assemblages (Wright and Reeves 1992). Given the nested pattern of species distributions expected in small archipelagos (common species occurring in all sites and rare species that tend to occur only in the richest sites), it is interesting not that we did not find high numbers of area- or microhabitat-restricted taxa. Although this could be the result of the small scale of this small island group, it also may indicate only moderate levels of selective local extinction and/or differential taxon-specific colonization along environmental gradients (Wright and Reeves 1992; Gaston and Blackburn 2000; Ulrich et al 2009). Species turnover, inferred from our similarity index calculations, suggests that a moderate rate of replacement of some species by others may have occurred, giving rise to segregated species occurrence in which many species will never cooccur together (Ulrich and Gotelli 2007; Diserud and Ødegaard 2007). This pattern is usually attributed to environmental sorting (Baselga 2010) and interaction mechanisms (van der Putten et al 2013) as well as limited dispersal abilities of individual species (Seidler and Plotkin 2006) or historical differences among sites (Baselga et al 2012).

In the context of the PAIC model, community similarity of the amphibians and reptiles in the CIG suggests more research is badly needed to understand the relationship among community similarity and diversity with environmental (habitat) variability, including productivity gradients, rainfall patterns, spatial microhabitat heterogeneity (Balete et al 2011; Duya et al 2011; Brown et al 2013), and disturbance gradients (Rickart et al 2007, 2011). Lastly, the findings of the current study provide baseline information in formulating research hypotheses for studying biogeography and species distributions in the CIG based on its unique, patchy herpetological microhabitat patterns.

Further studies are needed to confirm the dominant role of the Philippine PAICs that lead to high levels of vertebrate endemism, specifically how these PAICs are crucial in partitioning and maintaining diversity, possibly associated with processes of speciation at fine geographic scales. In the present study, eight of the 22 species of amphibians and reptiles in the CIG are known Philippine endemic species (or found exclusively in the Philippines). It may be worth exploring PAIC model predictions in these small island archipelagos, particularly testing predictions of fluctuating sea level mechanisms which may have caused land connection–isolation cycles. The predictions may be combined with interior habitat fluctuations which may have co-occurred during Pleistocene glaciations, creating terrestrial habitat connection–isolation cycles (Brown et al 2013).

In the context of the PAIC model used as framework for the present study, community similarity of amphibians and reptiles in the CIG is a topic warranting further study to ascertain whether correlations with ecological and environmental variation (productivity gradients, rainfall patterns, habitat heterogeneity) and disturbance gradients may impact spatial patterns of species distributions. Lastly, the findings of the current study provide numerous avenues for formulating hypotheses relating to biogeography and species distributions on a fine scale—all of which has been virtually unstudied in the context of the PAIC paradigm's emphasis on union into a large island or amalgamations (Inger 1954; Heaney 1985; Brown and Diesmos 2009).

Conclusions

The present study is an important contribution for better understanding mechanisms that may drive land vertebrate species diversification in the Philippine archipelago and the evolutionary origins of many Philippine vertebrates. Biodiversity in the Philippine archipelago is vastly underestimated (Brown and Diesmos 2009); hence, the present study should be extended not only to the other unexplored island of the CIG, but also to the mainland of Caramoan Peninsula, particularly on the Caramoan National Park so that truly holistic, multidisciplinary, and informed conservation management can be implemented and based, in part, on the unique assemblages of amphibians and reptiles of the Caramoan Peninsula.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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