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TERRESTRIAL ARTHROPOD SURVEYS ON PAGAN ISLAND, NORTHERN MARIANAS

Pacific Biological Survey

Final Report **November 2010**

Terrestrial Arthropod Surveys on Pagan Island, Northern Marianas

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EXECUTIVE SUMMARY

This report is part of the "Marianas Expedition Wildlife Survey 2010" (MEWS 2010), a U.S. Fish & Wildlife Service (USFWS) project funded by the Department of Defense - U.S. Marines and is tasked to gather natural resource information on fish and wildlife in the Mariana Islands. This information is required by federal regulations to properly determine the potential impacts that will occur due to the shifting of significant military resources from Okinawa to the Territory of Guam and the Commonwealth of the Northern Mariana Islands. As part of this military build-up, Pagan is under consideration as a live fire training area.

This report gives the results of a terrestrial arthropod survey conducted by USFWS and NAVPAC personnel on Pagan in the month of July 2010 and gives details on significant findings resulting from material collected on that survey. In addition, a full checklist of terrestrial arthropods known from Pagan Island is given based on the current survey material as well as previous published records. An appendix gives a full bibliography of articles dealing with Pagan arthropods.

Staff from the U.S. Fish and Wildlife Service, Pacific Islands Office, and the U.S. Navy conducted collections of terrestrial arthropods from 9-21 July 2010 using a variety of collecting methods including Malaise flight intercept traps, yellow water pan traps, pitfall traps, peanut butter traps for ants, aerial sweep netting, aquatic dip netting, aspirating, and hand collections.

Thousands of terrestrial arthropod specimens resulted from these collections, which were sorted by the collectors to order (to class for non-insects) and delivered to the Bishop Museum for identification. A team of entomologists at the Bishop Museum identified a total of 288 different taxa of terrestrial arthropods based on the survey, which included 228 new island records for Pagan (doubling the number of arthropods previously recorded from Pagan) bringing the total number of terrestrial arthropod species known from Pagan to 416. The full list of identified arthropods is given in Appendix II and includes all previously published terrestrial arthropod records for Pagan as well as the new records identified during this study.

To put the arthropod fauna into a proper historical context in order to better understand their possible biological status on the island (e.g., endemic, native, nonindigenous), a history of human habitation as well as previous collecting expeditions is given. The vast majority of identified terrestrial arthropods are most likely nonindigenous, having arrived on Pagan via a variety of mechanisms including transport by humans, supply shipments, and commerce. Verification of true status requires study of the known distributions and potential vagility of each species, which was outside the scope of this report.

Although the island has undergone numerous geophysical and human land use changes resulting in what we are calling a synanthropic arthropod fauna, there are still pockets of native arthropods that survive. Eight endemic species are recorded, three of them are new to science. In addition, one new genus was found.

The littoral zone has been a neglected area for previous collectors, and a number of new marine and littoral faunal records have resulted from collecting during this survey.

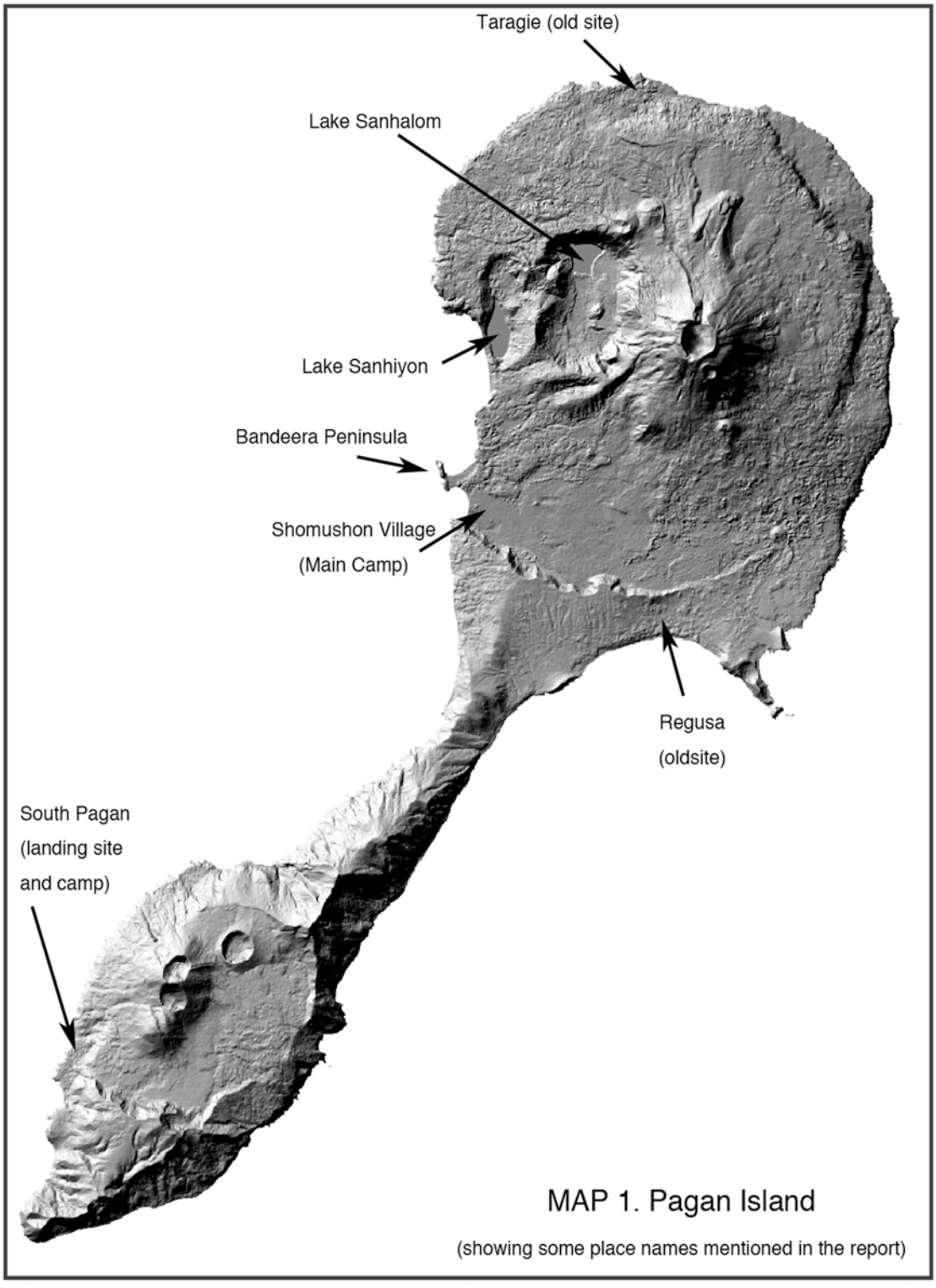
None of the arthropods identified are any threat to the megapode or fruit bat populations on the island. The crazy ant, *Anoplolepis gracilipes*, may pose a potential threat to food resources of the bat and megapodes if the populations on the island ever form what are called supercolonies. Their population levels now are large but not dangerous.

BACKGROUND

Pagan Island (Map 1) is the largest and most complex biologically and geographically among the northern islands of the Commonwealth of the Northern Mariana Islands (CNMI). The island was named "Pagan" by Jesuits who traveled through the Marianas in the 1600s. The name is one of the Christian names they gave to many of the islands in the Northern Marianas. Since its first visitation by western Europeans in 1695, Pagan has gone by many names including the following: Agan, Ile de Saint Ignace, Pagaon, Pagara, Pagon, Paygan, Pragan, Prajan, Pemplie de Volcans, Remplie de Volcaus, San Ignace, and Saint Ignace (Bryan, 1971).

It is an active volcanic island (18.10°N 145.76°E) approximately 320 kilometers north of Saipan. It contains three volcanic cones, the highest of which and most active, Mount Pagan in the northern part of the island, is 569.9 m [1870 ft] and whose last major eruption was in 1981, which had ash deposits and lava flows that covered or partially covered the village buildings and airfield and affected the shorelines of the two lakes in the northwestern portion of the island. A smaller eruption in 2006 deposited ash in the surrounding areas. The other two volcanoes are located in the southern portion of the island and last erupted approximately 150 years ago.

Fig. 1. Pagan viewing south, showing Lake Sanhiyon in foreground, separated from ocean by thick sand. Photo: Dan Polhemus.



MAP 1. Pagan Island

(showing some place names mentioned in the report)

There are two natural lakes on the island, both in the north part and both containing brackish water. They were formed approximately 200 years ago (Asakura *et al*., 1994). The outer lake (Laguna Sanhiyon) [Fig. 1] is separated from the ocean by an approximately 50-meter wide berm of sand. The inner lake (Laguna Sanhalom) [Fig. 2] at one time had a hot mineral spring (see newspaper feature article by Ronck, 1975 for photos and description), the surface portion of which disappeared after the eruption of Mount Pagan in 1981 (warm water still percolates into the lake from below the surface). Trusdell (2009) gives a concise summary of the geology of the island.

Fig. 2. Lake Sanhalom, Northern Pagan. Photo: Dan Polhemus.

GENERAL HISTORY

Because changes in ecosystems due to anthropogenic factors play a large part in the constituency of the vegetative and zoological composition of an island, we here present a short history of habitation and human activities on Pagan.

Human habitation has been intermittent on the island, owing primarily to factors such as volcanic eruptions and various commercial interests over time. Archeological surveys and linguistic research suggest that the Marianas were first colonized about 3500 years ago. Little archeology has been done on Pagan owing to few good sites remaining after volcanic eruptions and poor dating sources (e.g., there is no clay and pottery had to be imported from the southern islands) (Russell, 1998). Despite this, research on a site on the eastern coast of Pagan suggested it was occupied by 1300 C.E. (Egami & Saito, 1973).

After the Spanish explorer Magellan sailed through the area in 1521 on his famous circumnavigation of the world, Spain declared the archipelago as a royal possession. However, for the next 140 years the islands were virtually neglected as Spanish activities there were few. In 1668, a Jesuit mission was established on Guam and not long after its founding, priests began traveling northward from island to island in their attempts to convert the native Chamorros to Christianity. Seeing that the remote ventures to the islands to the north of their Guam base was becoming ineffectual in procuring efficient conversions, the Spanish began a program called the *reducción*, which relocated residents scattered on all the northern islands to one island: Saipan. The residents of Pagan were relocated to Saipan in 1697 and, except for the rare exploratory expeditions of the 19th century that sailed in to the area to make hydrographic studies, the island slipped into obscurity once again.

In 1865 a serious attempt to re-introduce residents to Pagan was initiated by American George Johnson, who brought 265 Carolinians to Pagan to produce copra. This adventure was short-lived, though, as all the Pagan residents were sent to Saipan in 1869. The reasons are unclear as to why the copra production was abandoned on Pagan but they could well have been economic (Russell, 1998) since the northern islands were too far removed from the economic center of Guam to sustain commercially viable operations.

In 1899 Germany purchased from Spain all the islands north of Guam, and their administration was headquartered on Saipan. The 1899 census by the Germans gave the population of Pagan then as 75 (Spennemann, 1999). In May 1901, Governor G. Fritz visited the northern islands and made observations on the general geology and volcanic activity (Fritz, 1902). Further observations, including those on the fauna and flora, were made by the Czech zoologist and parasitologist Stanislaus Prowazek (1913).

World War I saw a changeover of administration of the islands from Germany to the Japanese. In 1914, the islands of the northern Marianas became part of the Japanese Mandated South Seas Islands through action of the League of Nations. A number of Japanese scientists made expeditions during the 1930s and published accounts of the flora (e.g., Hosokawa, 1934), submarine topography (Tayama, 1936), volcanic geology (Tanakadate, 1940) as well as insects (see below for more details). During World War II, the Northern Marianas were of little strategic or tactical value except Pagan. The Japanese constructed an airfield on Pagan as well as associated troop barracks, storage bunkers for bombs and fuel, and pillboxes and air-raid shelters. Manning this base were

over 2000 Japanese troops (Richard, 1957). After the surrender of the Japanese garrison in September 1945, the Japanese were returned home and the surviving Chamorros were all taken to Saipan due to extreme food shortages.

After World War II, the islands of the Marianas were administrated by the United States Trust Territory. Several field projects were carried out on the fauna and flora; and the military funded research on the geology. A small military contingent remained on the island to maintain the airfield (Corwin *et al*., 1957).

In 1948, Chamorros and Carolinians decided to start up commercial operations in the Northern Marianas again; and in 1951, 57 Chamorros were brought to Pagan to produce copra. Copra production waxed and waned and eventually was abandoned altogether by the 1970s; the remaining residents were maintained with supplies brought in from government-run "field trip" ships a few times a year. The volcanic eruption of Mount Pagan in 1981 forced the 53 residents of the island to flee to Saipan. The resultant lava flows and ash destroyed much of the vegetation of the northern part of the island and covered the airfield. The recent 2006 eruption again caused a significant amount of ash and lava to cover the northern portion of the island so that there is a conspicuous lack of vegetation and associated life forms in the immediate vicinity of the volcano.

PREVIOUS EXPEDITIONS TO PAGAN SURVEYING TERRESTRIAL ARTHROPODS

Little attention has been paid to Pagan with respect to the island's terrestrial invertebrate fauna. Most explorers who had visited Pagan had either looked upon it from the ship and made notes to charts, or upon landing, made only ethnological and geological observations or commented on the vertebrate fauna [large mammals such as pigs having been introduced to the island not long after Magellan's sail through the island chain in the 1500s (Rodda, 2009)].

Fig. 3. The first insect collector on Pagan. "Mariano" who accompanied Alfred Marche on his trip there in December 1887 (from Marche, 1982).

The first collection of insects was apparently made in 1887 by Antoine-Alfred Marche (1844–1898), a naturalist and ethnologist at the Musée de l'Homme in Paris. He had previously made trips to Africa, the Philippines, and Guam to do ethnology research and had published accounts of his travels there. His trip to the Marianas in 1887–1888 was to be his last. In Manila shortly after arriving, he hired a collector, Mariano (Fig. 3) and a cook and headed north to stop at various of the Mariana Islands. His account of his December 1887 stay on Pagan during his trip through the Marianas [translated into English in 1982 from the original (Marche, 1891) in a little-known French journal] gives a detailed description of the island and is accompanied by the first known photograph of Mount Pagan (Fig. 4) however, he says little of the biology of Pagan (Marche, 1982: 20):

> "On Pagan, there are only a few Carolinians settled there to harvest coconuts, which trade is carried on by Captain William. Hunting gave me meager results; birds are scarce; before the great typhoon of 1884, they were in far greater number. No mammal, except for some pigs and wild goats. Fresh water appears to be completely lacking on this island."

He concluded his report of Pagan by giving an account of the material he collected (Marche, 1982: 22):

> "Upon my return to Guam, I prepared and sent my second shipment which contained eleven objects for the Ethnographic Museum, about 200 skinned birds, 450 mollusks in alcohol, 300 skins, plus 500 insects in paper and in alcohol and about 100 species of plants with flowers and fruits."

Fig. 4. First known photograph of Mount Pagan, taken by Alfred Marche in 1887 (from Marche, 1982).

Although some of the birds he collected were studied by Oustalet (1895–1896), no one has apparently bothered to trace the current whereabouts or existence of his insect collections, which may still be in the Musée de l'Homme in Paris.

After Germany purchased the Marianas from Spain and began their governance, two surveys were conducted that made natural history observations: Fritz (1902) and Prowazek (1913). The latter gave a detailed report on the history, culture, and fauna and flora of the Marianas but gave sketchy remarks concerning arthropods. Prowazek (1913) discussed a number of species as occurring in the Marianas but does not specifically list species occurring on Pagan.

When the Japanese administered the Pacific islands acquired through the League of Nations, scientific expeditions were made in the 1930s to survey the natural history of their newly acquired possessions in the Pacific. One of these was the Esaki Micronesian Expeditions from 1936–1940, which resulted in a number of publications by specialists including descriptions of many new species and the first published records of arthropods from Pagan. Professor Teiso Esaki, entomologist at Fukuoka University, was in charge of entomological investigations for the Japanese administration of Micronesia before World War II. Almost 80 publications were generated from these surveys, although most dealt with islands other than the northern Marianas.

As part of these expeditions, the first collecting trip specifically to Pagan was made in April 1940 by Fukuoka University entomologist Keizo Yasumatsu (Fig. 5) and scientific records of arthropods from that trip were published in Yasumatsu (1940). It included few records as the publication was only meant to be a short narrative of the collecting trip. However, many other publications by Japanese colleagues on Pagan arthropods soon followed, mostly basing their results on material collected by Yasumatsu and his student Seiichiro Yoshimura during this trip in April 1940.

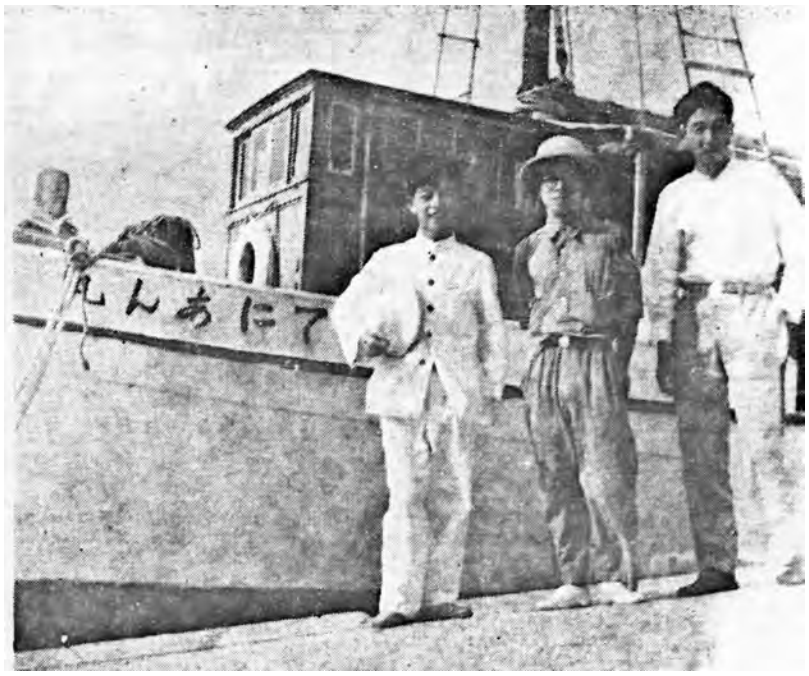


Fig. 5. Esaki Micronesian Expedition to Pagan, April 1940. Keizo Yasumatsu, center (from Yasumatsu, 1940).

In 1946, shortly after the end of World War II, the Pacific Science Board of the U.S. National Research Council was established. It was set up to "aid the scientists of America who wish to engage in scientific investigations for which there is a need in the Pacific area, to advise governmental and other agencies on scientific matters pertaining to the Pacific, and to further international cooperation in the field of Pacific science." The Pacific Science Board cooperated with the U.S. Navy in investigating certain problems that both felt were a priority for the Pacific area. One of these was finding ways to control insect and related pests in Micronesia. The Insect Control Committee for Micronesia (ISSM) was thus established and its priority research areas included research on the following pests: (1) the giant African snail; (2) the rhinoceros beetle; (3) the banana root borer; and (4) the Saipan coconut beetle (Bryan, 1949). The ICCM employed a staff entomologist, Daniel B. Langford, who made trips to Micronesian islands from October 1947 to October 1949. He only visited Pagan on a trip from 5–18 May 1948 that also included the islands of Anatahan, Alamagan, and Agrihan. It is not known how long he spent on Pagan and what if any arthropods he may have collected.

In 1953, the entomological work of the Pacific Science Board and the office of Naval Research were taken over by the Bishop Museum in Honolulu and with the funding assistance of two grants from the National Science Foundation, the series *Insects of Micronesia* was begun (Gressitt, 1954). The hundreds of resulting articles in 19 volumes offer to date the most detailed taxonomic accounts of insects occurring in Micronesia, and many of these include records and descriptions of arthropods from Pagan. The series was discontinued as a separate series by Bishop Museum in the 1990s but was turned over to the University of Guam, which continues to publish articles in the series within their journal *Micronesica*; the last of which was on lauxaniids (Sasakawa, 2009).

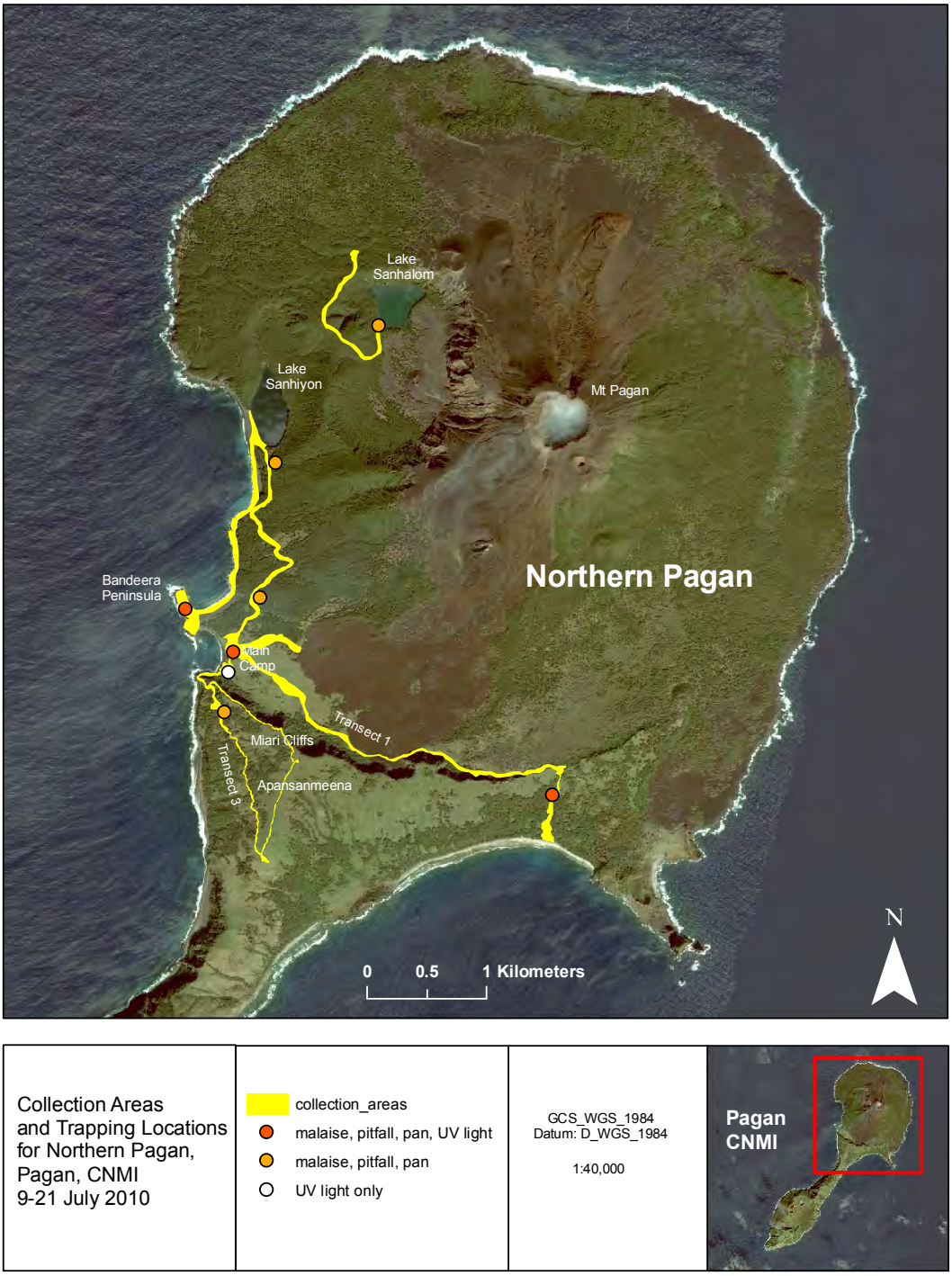
As part of the U.S. Army Corps of Engineers' "Post Hostilities Mapping Program" a geological survey was conducted of Pagan in the 1950s, the results of which were published in Corwin *et al*. (1957). Along with the detailed geological report and mapping, plants were listed and animals observed and discussed in the narrative. However, remarks on arthropods were brief:

> "More than a hundred species of insects, several spiders, two scorpions, two isopods, and a few worms, centipedes, and millipedes have been collected. Of these only a few may be classed as pests. Two species of flies are common and very annoying. Cockroaches and large beetles may do some damage to supplies. Mosquitoes are chiefly nocturnal varieties and are harmless. Stinging wasps are numerous in many groves of Casuarina trees. Although rarely fatal, the bites of the scorpions and one large variety of centipede may cause considerable discomfort" (Corwin *et a*l., 1957: 109).

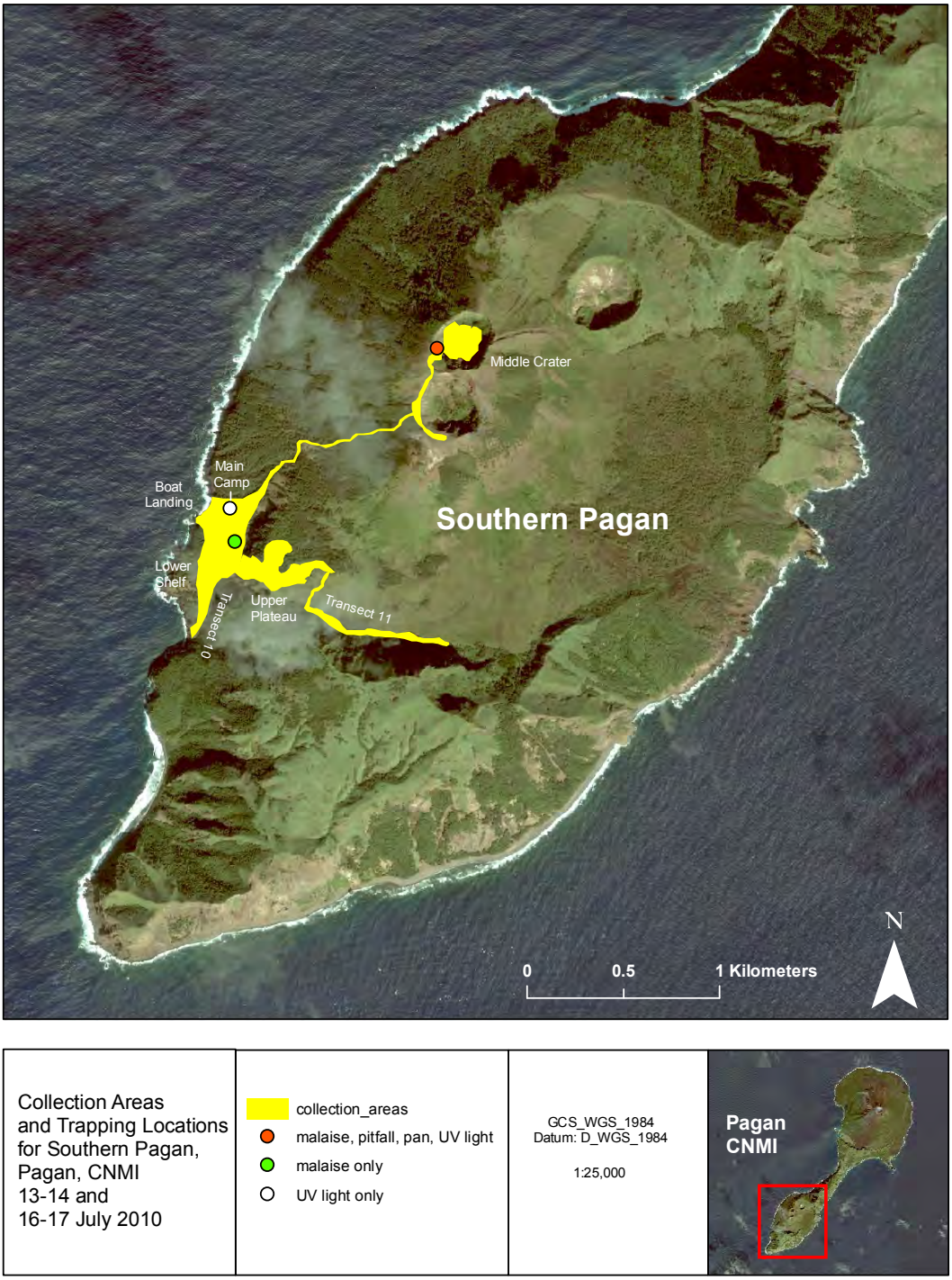
The Natural History Museum and Institute in Chiba, Japan conducted a biological expedition to the northern Marianas in 1992 and results were published in a single volume (Asakura & Furuki, 1994). This was the last formal expedition to Pagan to survey arthropods prior to the current survey. The volume contains dozens of articles on the results of this expedition and contains a checklist (Miyano, 1994) that forms the basis for the current checklist in this report.

Since then, Pagan has only had sporadic visits primarily for floristic or vertebrate surveys, or for geological concerns; with little work done on arthropods. One report

(Cruz *et al*., 2000) mentions insects being collected opportunistically on Pagan but no specific records were listed in the report.



Map 2. Collection sites on northern Pagan, 9-21 July 2010.
Colored dots are sites where traps were set.
Yellow lines indicate collecting while hiking.



Map 3. Collection sites on southern Pagan, 13–17 July 2010.
Dots are sites where traps were set.
Yellow lines indicate collecting while hiking.

CURRENT SURVEY AND LIST OF COLLECTING SITES

The current survey was conducted by three NAVPAC personnel (Cory Campora, Stephan Lee, Justin Fujimoto) and USFWS staff members (Christa Russell, Mike Richardson) from 6 to 21 July. A few specimens made prior to the main arthropod survey (collected by E. Wosh on 25 June [during a herpetological survey] on south Pagan) were also included in the identifications. Additionally, Dan Polhemus of USWFS (not a part of this survey contract) made a separate survey to assess the aquatic insect fauna on Pagan and the results of his survey are incorporated herein. Specimens were collected by hand and sweep net from a variety of localities, usually while hiking from one locality to another. However, the majority of specimens were collected through various trapping methods, which were set up at specific localities and these are indicated below. A total of 10 sites employed various trapping methods and are detailed below.

LIST OF COLLECTING SITES

Site 1 [= Campora field notes site 4] [Fig. 6]

Northern Pagan, Main Camp (old Shomushon village), near runway, 9 July 2010 and 16 July. Collectors: Mike Richardson, Christa Russell, Stephan Lee, Justin Fujimoto, Cory Campora. [GPS: 18.12346°N, 145.760640°E]
Traps:
Malaise: 1 trap (9–10; 16–17 July collecting period)
Pitfall traps: 5 traps (9–10; 16–17 July collecting period)
Blacklight: 1 trap (night of 9, 16 July collecting period)
Additional collecting methods employed: general collecting.

Site 2 [= Campora field notes site 6] [Fig. 7]
Northern Pagan, Lake Sanhalom (west side), 10 July 2010. Collectors: Mike Richardson, Christa Russell, Stephan Lee, Justin Fujimoto, Cory Campora. [GPS: 18.14814°N, 145.771950°E]
Traps:
Malaise: 1 trap (10–11 July collecting period)
Pitfall: 5 traps (10–11 July collecting period)
Pan traps: 5 traps (10–11 collecting period)
Additional collecting methods employed: aerial sweep netting, general collecting, aquatic dip netting.

Fig. 6. View of Collection Site 1: Main camp near Shomushon village, looking north.

Fig. 7. Collection Site 2: Lake Sanhalom, southwest side, showing Malaise trap and yellow pan traps

Site 3 [= Campora site 10] [Fig. 8]
Isthmus on Pagan, Trail along coast from main camp (megapode transect #3). 12 July. Collectors: Mike Richardson, Christa Russell, Stephan Lee, Justin Fujimoto, Cory Campora. [GPS: 18.11891°N, 145.759970°E]
Traps:
Malaise: 1 trap (12–13 July collecting period)
Pitfall: 5 traps (12–13 July collecting period)
Pan traps: 5 traps (12–13 collecting period)
Additional collecting methods employed: general collecting

Fig. 8. Collection site 3. Megapode transect #3 along west coast south from Main Camp, showing Malaise trap set up.

Site 4 [= Campora site 12] [Fig. 9]
Southern Pagan, South Camp area, southern end of island (megapode transect #10). 13 July 2010. Collectors: Mike Richardson, Christa Russell, Stephan Lee, Justin Fujimoto, Cory Campora. [GPS: 18.064313°N, 145.715226°E]
Traps:
Malaise: 1 trap (13–14 July collecting period)
Pitfall traps: 5 traps (13–14 July collecting period)
Blacklight: 1 trap (night of 13 July collecting period)
Additional collecting methods employed: general collecting, aerial sweep netting.

Fig. 9. Collection Site 4. Southern Pagan camp site. Traps were set nearby.

Site 5 [= Campora site 16] [Fig. 10]
Northern Pagan, Bandeera Peninsula. 15 July 2010. Collectors: Mike Richardson, Christa Russell, Stephan Lee, Justin Fujimoto, Cory Campora. [GPS: 18.126670°N, 145.756860°E]
Traps:
Malaise: 1 trap (15–16 July collecting period)
Pitfall: 5 traps (15–16 July collecting period)
Pan traps: 5 traps (15–16 collecting period)
Blacklight: 1 trap (night of 15 July collecting period)
Additional collecting methods employed: none.

Fig. 10. Collection Site 5. Top of Bandeera Peninsula, looking east toward an active Mount Pagan, showing Malaise trap in place.

Site 6
Southern Pagan, Main camp. 15–16 July 2010. Collectors: Mike Richardson, Christa Russell, Stephan Lee, Justin Fujimoto, Cory Campora. [GPS: 18.065892°N, 145.714867°E]
Traps:
Blacklight: 1 trap (night of 15 July collecting period)
Additional collecting methods employed: none.

Site 7 [Fig. 11]
Southern Pagan, Middle crater. 15–16 July 2010. Collectors: Mike Richardson, Christa Russell, Stephan Lee, Justin Fujimoto, Cory Campora. [GPS: 18.073481°N, 145.725095°E]
Traps:
Malaise: 1 trap (15–16 July collecting period)
Pitfall: 5 traps (15–16 July collecting period)
Additional collecting methods employed: aerial netting off of vegetation

Fig. 11. Collection Site 7. Southern Pagan, middle crater, showing Malaise trap in place.

Site 8
Northern Pagan, south of Lake Sanhiyon, Ironwood forest. 17–19 July 2010. Collectors: Mike Richardson, Stephan Lee, Justin Fujimoto. [GPS: 18.137694°N, 145.76903°E]
Traps:
Malaise: 1 trap (17–19 July collecting period)
Pan traps: 5 traps (17–19 collecting period)
Pitfall traps: 5 traps (17–19 July collecting period)
Additional collecting methods employed: aerial netting off of vegetation.

Site 9
Northern Pagan, Somushon village, north of motor pool. 17–18 July 2010. Collectors: Mike Richardson, Stephan Lee, Justin Fujimoto. [GPS: 18.127526°N, 145.762736°E]
Traps:
Malaise: 1 trap (17–18 July collecting period)
Pan traps: 5 traps (17–18 collecting period)
Additional collecting methods employed: aerial netting off of vegetation.

Site 10 [Fig. 12]
Eastern central Pagan, coconut grove. 20–21 July 2010. Collectors: Mike Richardson, Stephan Lee, Justin Fujimoto. [GPS: 18.112823°N, 145.785874°E]
Traps:
Malaise trap: 1 trap (20-21 July collecting period)
Pan traps: 5 traps (20–21 collecting period)
Additional collecting methods employed: aerial netting off of vegetation.

Fig. 12. Collection Site 10. Coconut grove on east side of island, showing Malaise trap in place.

SAMPLING METHODS

Collecting on Pagan was done with Malaise trapping, yellow water pan trapping, pitfall traps, ultra-violet light traps, and aerial sweep nets. Malaise traps, pan traps and pitfall traps were set up in various locations (see Maps 2, 3) to allow sampling in various vegetative habitats. The ultra-violet light trap was set up near the main camp to allow easy access during evening collecting. Aerial sweep netting and hand collecting were conducted along transects and trails as indicated in yellow on the maps.

Descriptions of some of the collecting methods employed during this survey include the following:

1. Malaise traps—Malaise traps are among the most productive samplers in terms of species richness and number of specimens captured. Flying insects approach the central panel of the trap and attempt to avoid it either by dropping to the ground or flying upward. Those flying upward (the vast majority) are funneled into the collecting head of the trap where they are killed. The collecting head is attached to the higher end of the trap. Insects caught at the top, are killed by drowning in a collecting canister of 95% ethanol. Those dropping to the ground can be collected in water pan traps.

2. Water pan traps—Shallow plastic pans (often yellow or white) are placed on the ground or in trees to sample arthropods. The pans are filled with water and a surfactant (soap solution) to allow trapped specimens to sink to the bottom of the pan and drown. They are attractive to flying insects in both open areas and forest canopy.

3. Pitfall traps—These consist of small plastic cups placed into the ground with the rim level with the surface. Pitfall traps collect most ground dwelling arthropods either through adventive encounters to the trap or by baits. Arthropods fall into the trap and a propylene glycol solution in the bottom of the cup kills the trapped arthropods.

4. Aerial nets—Aerial sweep nets with a fine mesh to collect smaller Diptera and Hymenoptera are used to sample arthropods on vegetation, leaf litter, littoral habits, beaches, and rocky intertidal reefs.

5. Hand collecting—Hand collecting, with or without the use of an aspirator, are used for collecting arthropods on specific species of plants and to collect arthropods that are difficult to collect using other techniques—such as those on craggy rock faces, in small holes and crevices or on muddy substrates.

6. UV light traps—Ultra-violet (UV) light traps are used to collect flying insects at night. Insects are attracted to the ultra-violet light reflecting off of a white sheet and are collected off the sheet by hand or aspirator. These are especially good for collecting night flying Lepidoptera (moths) as well as certain beetles and some aquatic Diptera.

7. *Peanut butter bait*—Spreading peanut butter on sticks or cards as a bait attracts both sugar-loving and oil-loving ants, which can easily be transferred to collecting containers. Peanut butter baiting was used sporadically during the survey.

SURVEY RESULTS

Out of thousands of specimens collected during this survey, some 288 species of terrestrial arthropods were identified [see quick summary in Table 1]. Previous to this survey, 188 species of arthropods were published as occurring on Pagan Island. The current survey brings the total known species to 416 and includes 228 new records to the island. A full list of arthropods previously known from the literature from Pagan and those identified during this survey is given in Appendix II.

Table 1. Quick Summary of Results of Identifications by Order
(orders in red are new order or class records to Pagan)

order or class	prev	this	total	new records
Acarina (mites, ticks)	12	3	15	**3**
Araneae (spiders)	11	36	43	**33**
Blattaria (roaches)	5	4	7	**2**
Chilopoda (centipedes)	1	2	2	**1**
Coleoptera (beetles)	23	41	57	**34**
Collembola (springtails)	4	6	9	**5**
Dermaptera (earwigs)	0	2	2	**2**
Diplopoda (millipedes)	0	2	2	**2**
Diptera (flies, gnats, midges)	21	69	82	**61**
Embiida (web spinners)	0	1	1	**1**
Hemiptera (true bugs)	20	12	31	**10**
Homoptera (aphids, scale insects)	16	7	20	**5**
Hymenoptera (wasps, bees, ants)	42	47	69	**25**
Isopoda (sow bugs, pill bugs)	2	1	2	**0**
Isoptera (termites)	0	1	1	**1**
Lepidoptera (moths, butterflies)	10	17	22	**12**
Mantodea (mantids)	1	1	1	**0**
Neuroptera (lacewings)	3	8	9	**6**
Odonata (dragonflies, damselflies)	4	3	4	**0**
Orthoptera (crickets, grasshoppers)	3	14	15	**12**
Phasmatodea (walking sticks)	1	0	1	**0**
Pseudoscorpionida (pseudoscorpions)	3	2	5	**2**
Psocoptera (book lice, bark lice)	1	8	9	**8**
Scorpionida (scorpions)	2	1	2	**0**
Siphonaptera (fleas)	1	0	1	**0**
Thysanoptera (thrips)	2	2	4	**2**
Thysanura (bristletails, silverfish)	0	1	1	**1**
totals	**188**	**288**	**416**	**228**

The current survey lists 5 new order records (Dermaptera, Diplopoda, Embiida, Isoptera, and Thysanura), 99 new family records, and 228 new species records for Pagan. We were able to identify most all of the material collected except for groups that entailed special preparation and taxonomic expertise (e.g., Acarina; Collembola; Homoptera [Coccoidea];

Thysanoptera). However, even in those groups, we were able to identify at least to family the larger and better-known taxa. Brief overviews of the orders of arthropods encountered are given below with reference made to the more common or interesting taxa. Significant finds are described in more detail in the next section.

Pagan shows a fairly normally composed arthropod community with most elements represented that would be expected given the amount of human activity that has taken place over its history; thus the island's fauna can be said to be primarily synanthropic with pockets of native populations still surviving. A fairly high proportion of the arthropod fauna are introduced or are native elements of widespread species. Despite the large number of introduced taxa, it is significant that there are 8 endemic arthropods that are known only from Pagan (5 previously described; 3 new undescribed endemic taxa found during this survey). Further study is needed to determine the relative health of these populations. A few of these previously recorded endemic species were re-collected during this survey, indicating that at least some still survive despite the human-induced perturbations and volcanic activity.

Some species previously recorded were not found in this survey and, in some cases, it could be a result of land use changes that currently do not support resources that would have otherwise been there to allow a organism to survive; or, more probable, that sampling was not done in enough areas to be able to re-collect these taxa. In addition, soil sampling and use of Berlese or Tullgren funnels were not employed on this project, which can help with obtaining microscopic soil and ground dwelling organisms such as pseudoscorpions, mites, springtails, and small beetles and immature stages of many holometabolous orders of insects.

A note on place-names

Many of the names on the labels of material collected by Yasumatsu in 1940 and published in subsequent papers by Japanese colleagues as well as other scientists are no longer used and their current equivalents are difficult to decipher since no one has tried to trace them previously and some localities do not exist any longer. Based on a manuscript list of names provided to one of us (LGE) by a Pagan resident in the 1970s and the report by Pangelinan & Kapileo (1970) comparing with the Japanese transliterations of these names by Yasumatsu ands others, we here give a list of a few of the old names used by Yasumatsu and their current equivalents in the hopes it will help pinpoint collecting localities for future workers.

Old Yasumatsu Name	**Current Equivalent**	**General location (all North Pagan)**
Song-Song	Shomushon	Main village
Laguna	Laguna Sanhiyon	outer lake; also name of the village there
Regusa	Regusa, Rugusa Degusa	location on eastern coast; site of old Japanese hospital
Tarague, Darage	Taragie, Tarague	old village on N coast; archaeological site
Males, Malasu	Maras, Marasu	location on NW coast between Laguna Sanhiyon and Tarague
Abansantate	Apasanmeena	location near isthmus

TAXON ACCOUNTS

ACARINA (mites, ticks) [Fig. 13]

Few mites were collected in this survey, with those recovered being primarily in the pitfall traps. Only the ixodid (unverified identification but probably represents the cattle tick *Boophilus microplus)*, the bee mite (*Pyemotes* sp.; cf. Fig. 13) and an oribatid soil mite were recorded in this survey. Previous surveys (which involved mite specialists) recorded 12 species from Pagan. Further specialized collecting including soil samples and Berlese funnels and identification of properly prepared specimens should identify many more acari from the island. The *Pyemotes* mite was collected from a tenebrionid beetle, which had 30 or so specimens attached to its body. The mites were attached to the body under the wings and covered the thoracic and abdominal region.

Fig. 13. *Pyemotes* bee mite. **New Island Record.** Photo: Wikipedia.

ARANEAE (spiders) [Fig. 14]

Few spiders had been previously recorded from Pagan. The only publication on spiders from Pagan (Yoshida *et al*., 1996) listed 11 species in 8 families. Collections from this survey significantly increased the known spider fauna with 33 new species records of taxa from the island bringing the number of species known from Pagan to 43 in 22 families. Most are common widespread species in the Pacific. One conspicuous spider, the common cane spider, *Heteropoda* sp. (Fig. 14) was found in numbers under fallen logs in a mixed forest in north Pagan. These spiders are free-living predators that do not spin webs. They naturally occur on the forest floor but sometimes enter buildings. They usually prey on ground dwelling insects such as cockroaches, crickets, and silverfish.

BLATTARIA (roaches)

Previous to this survey, five roaches had been recorded from Pagan. All are synanthropic species that are widespread with humans and commerce. This survey only found three species with one new record, the widespread Pacific beetle roach, *Diploptera dysticoides*. Unlike other roaches, beetle roaches are not normally found in buildings but instead prefer leaf litter and soil.

Fig. 14. *Heteropoda* sp. (Sparassidae) flushed out from under a log on Megapode Transect #3. **New Island Record.** Photo: Cory Campora.

CHILOPODA (centipedes)

Centipedes are fairly ubiquitous in faunal surveys and are another component of a synanthropic fauna. Previous narratives of Pagan mention "centipedes" (e.g., Corwin, 1957); and two taxa were recovered in this survey: an undetermined member of the Geophilomorpha, and a *Scolopendra* sp., a genus that contains some of the larger taxa of this group of arthropods. *Scolopendra* are commonly transported in shipping from island to island throughout the Pacific.

COLEOPTERA (beetles) [Fig. 15]

Beetles are among the most diverse groups of insects in the world and as such also are among the most diverse in faunal surveys of specific areas such as islands. Previous to this survey, 23 species were recorded from Pagan, all fairly widespread species. We identified 41 taxa collected on this survey, with 34 new records for the island, bringing the total number of beetles known from Pagan to 57. Of these, the following are new family records to the island: Aderidae, Anthribidae, Bostrichidae, Cleridae, Corylophidae, Laemophloeidae, Melyridae, Mordellidae, Nitidulidae, Platypodidae, Salpingidae, Silvanidae, and Staphylinidae. The vast majority of species identified during this survey are nonidigenous taxa. Some of the coccinellid species listed were probably

introduced at one time to control aphids on crops (the beetle immatures are predaceous on aphids) when commercial agriculture was prevalent on the island.

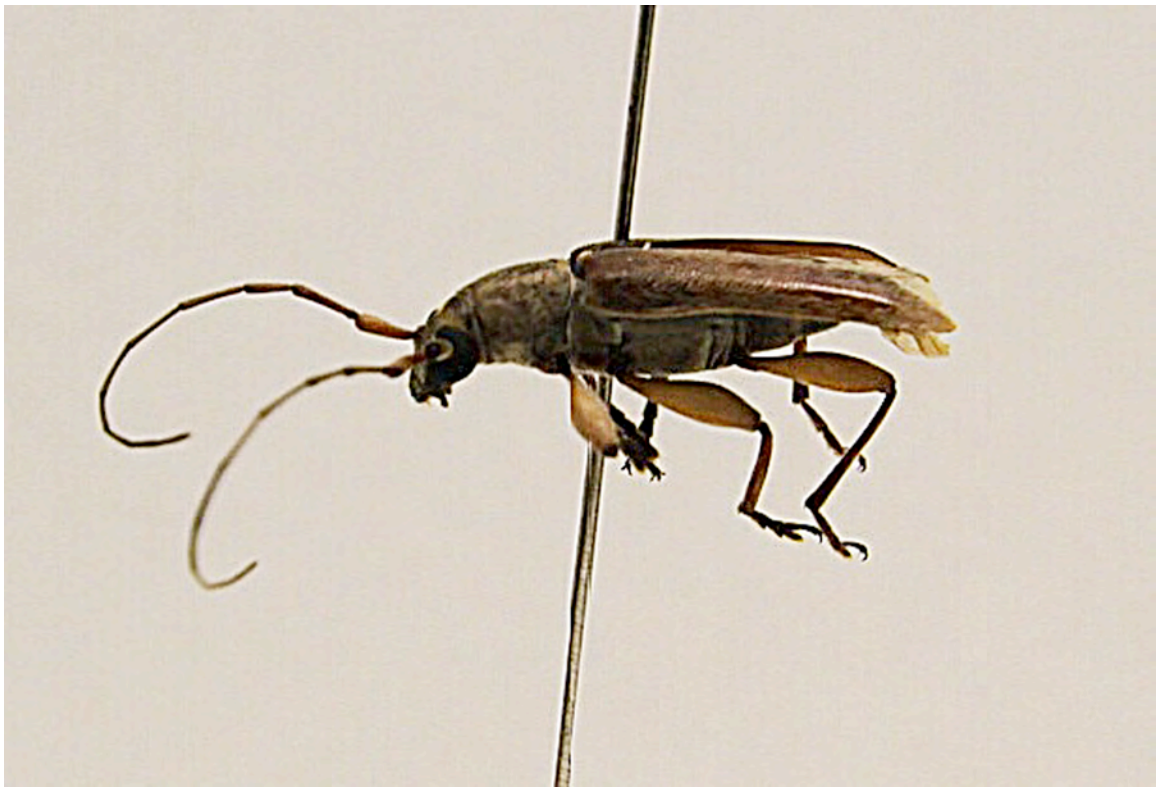


Fig. 15. The long-horned beetle, *Cersium unicolor unicolor* (Cerambycidae). Photo: Darcy Oishi.

COLLEMBOLA (springtails) [Fig. 16]

Springtails are often neglected in faunal surveys due to their small size but they are a major component of any ecosystem and are a potentially significant and biodiverse group of arthropods. Previous to this survey, only 4 species were recorded from Pagan including one endemic species (*Sira fuscana* Uchida, 1944) [Fig. 15]. Pan and pitfall traps recovered species of Collembola during this survey, and we were able to identify 6 species (including the endemic *Sira fuscana*) and confirm 5 new island records. Time needed to properly slide mount and key species was not enough to allow us to identify material to any finer resolution than what is represented in Appendix II, but we expect with future research and collecting, especially soil sampling utilizing Berlese funnels to extract arthropods, there will be additional new records for the island.

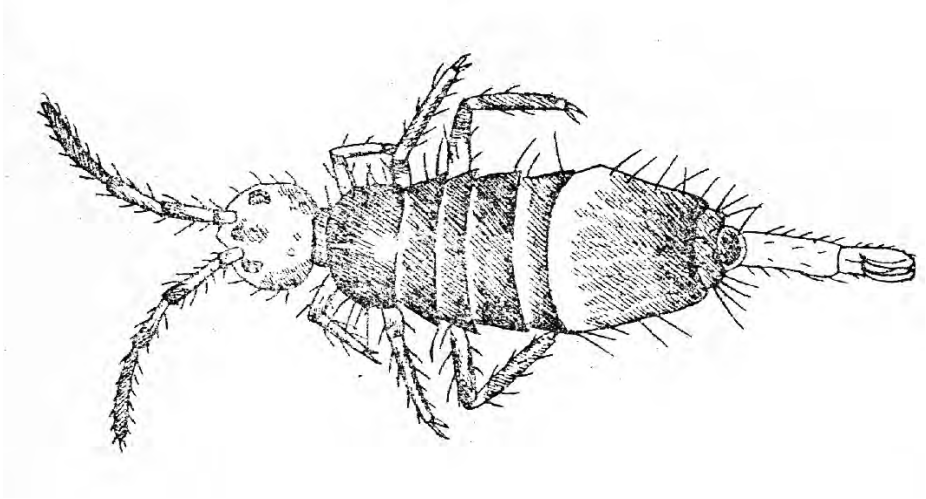


Fig. 16. *Sira fuscana* Uchida, an endemic springtail from Pagan (original illustration from Uchida, 1944).

DERMAPTERA (earwigs) [Fig. 17]

No earwigs were found previous to this study. Two species of earwigs were collected in this study and mark the first records of the order from Pagan. One species, *Euborellia stali* [Anisolabididae], is cosmopolitan and known from many localities in the western Pacific, Japan, and SE Asia as well as also being found in Africa and India. It was probably introduced to Pagan through the shipping of supplies. The other (Fig. 17) is as an undetermined labidiid, but is conspicuous with its huge caudal forceps. Earwigs are omnivores and will eat many types of organic matter.

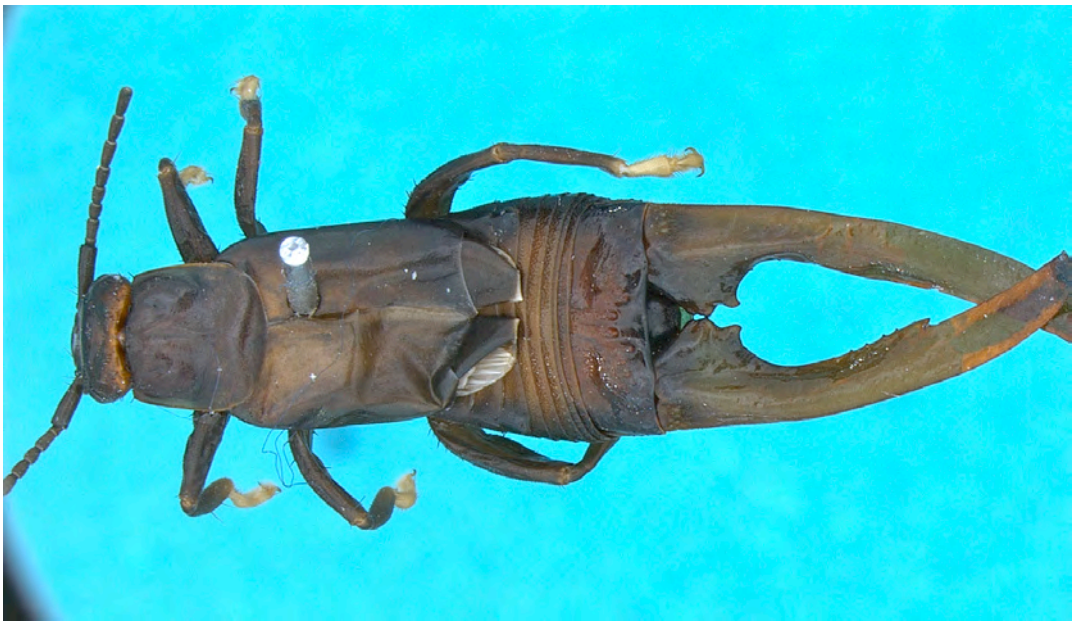


Fig. 17. An undetermined labidiid earwig from Pagan. Photo: Darcy Oishi.

DIPLOPODA (millipedes) [Fig. 18]

Fig. 18. *Trigoniulus corallinus*, the rusty millipede. **New Island Record**.

No millipedes had previously been recorded from Pagan. Two species are recorded for Pagan for the first time based on collection made during this survey. One species, the rusty millipede, *Trigoniulus corallinus* (Fig. 18), was collected and identified. The species is native to Thailand and Burma but has been introduced to many areas of the Pacific and Indian Ocean, and also the west Indies and North America (Shelley *et al*., 2006). The other species, *Harpaphes haydeniana* is the common yellow spotted garden millipede found throughout North America but not known previously from the west Pacific. Millipedes live in the soil and are detritovores and scavengers. Since this survey did not do soil sampling, we expect more species to be found through further more focused collecting for this group.

DIPTERA (flies, gnats, midges) [Figs. 19, 20]

Fig. 19. New genus and new species of hydrophorine dolichopodid fly from rocky shores on Pagan. **New Island Record**. Photo: Neal Evenhuis.

In previous surveys, flies were not well recorded with only 21 species in 10 families being published. We identified 69 different species of Diptera in 29 families that were collected during this survey, with 61 of them new records to Pagan, bringing the total number of Diptera species known from Pagan to 82. Of these, the following 19 families are new records to the island: Anthomyzidae, Canacidae (beach flies), Cecidomyiidae (gall midges), Ceratopogonidae (biting midges), Chamaemyiidae, Chironomidae (midges), Chloropidae (frit flies, eye gnats), Drosophilidae (pomace flies), Ephydridae (shore flies), Keroplatidae (predaceous gnats), Limoniidae (crane flies), Milichiidae, Nannodastidae, Phoridae (coffin flies), Platystomatidae, Psychodidae (moth flies), Sciaridae (fungus gnats), Sphaeroceridae (wrack flies), and Syrphidae (flower flies). The probable reason for the significantly large amount of new faunistic information on Diptera is that few workers bother to identify

Diptera outside of the nuisance, agricultural pest, or disease-causing species and leave the others undetermined. In this report, we have made a special effort to identify as many taxa as possible of this order to better show its true representation in the fauna.

Many of the species listed are synanthropic or associated with agricultural crops as pests or biological control agents. However, the discovery here of a few new taxa and the recollection of a previously recorded endemic taxon indicate that, despite the tremendous amount of human and volcanic impact on the island, there are still pockets of native species that are surviving. See below under SIGNIFICANT FINDINGS for more details on the new marine taxa found (e.g., Fig. 19).

Fig. 20. The ubiquitous *Musca sorbens*, also known as the dog dung fly. One of the most common and most annoying insects on Pagan.

EMBIIDA (web spinners)

No web spinners had been previously recorded from Pagan. The species collected and identified in this survey marks the first record of this species from Pagan. *Oligotoma humbertiana* is a common widespread species in southern and eastern Asia and the western Pacific that is commonly introduced in islands through transport of soils.

HEMIPTERA (true bugs)
(sometimes referred to as "Heteroptera" and encompassing the Homoptera)

The true bugs include many plant and agricultural pests, therefore attention has been paid to them in previous studies. Twenty taxa in 6 families had been identified from Pagan

previous to this survey. Collections made here have resulted in identifications of 12 species, 10 of which are new records. Of these, one new undescribed endemic species was discovered by Dan Polhemus and is tentatively placed in the dumping-ground genus *Lygus* until further research can pinpoint its true generic status. Polhemus also identified marine Hemiptera, all new records to the island [see his report: Polhemus (2010) for details]. It is probable that collections made at the shore and in the littoral zone had not been conducted previously so all marine-associated arthropods were not recorded previous to this study. Many of the aquatic forms are widespread taxa with the ability to colonize tropical island habitats. With the material identified during this project, the total number of Hemiptera known from Pagan now stands at 31 species in 13 families.

HOMOPTERA (sucking bugs, aphids, scale insects)
(some have split this order into Auchenorrhyncha and Sternorhyncha)

Homopterans are primarily sap sucking bugs that include the aphids, mealybugs, and scale insects. Previous to this survey, 16 homopterans had been recorded in the literature. We identified 7 species, of which 5 are new records for the island. The total known homopteran fauna on Pagan is now 20 species. The new record of the leafhopper *Acertagallia* (Cicadellidae) may represent a recent introduction, as it was found in a number of collections so is well established on the island. As such, one would expect that it would have been collected previously. Leafhoppers are known to transmit plant diseases but nothing is known of the hosts or biology of the specimens collected during this study.

The collecting techniques utilized during this survey did not collect the scale insects and mealybugs that are normally easily identifiable. With regard to those smaller specimens that were found in the material collected, given the time available between delivery of material and the due date for the report, the resolution for some of the identifications of aphids and scale insects which normally require slide preparation and mounting for identification was not necessarily to species level.

HYMENOPTERA (wasps, bees, ants, parasitica) [Figs. 21, 22, 23, 32]

Hymenoptera included some of the most commonly encountered insects on the island. Previous to this survey, 42 species in 12 families had been identified and published. We have identified 47 species based on the current collections, of which 25 are new island records bringing the total hymenopteran fauna known on Pagan to 69 species in 20 families.

The social wasps recorded were no doubt introduced to the islands long ago as they are found in some of the earliest surveys. A few of these wasps will enter buildings and form nests [see Fig. 21], but others prefer to build nests in the forests which are closer to potential prey which they use to nourish their young.

Fig. 21. Social and solitary wasp nests (undetermined spp.) in abandoned building in Shomushon village. Photo: Jennifer Stauffler.

One of the most commonly collected groups during this survey were ants. They not only were tops in numbers of specimens but also had the highest species-diversity per family for any arthropod known from Pagan. This is no doubt due to the extreme success ants have at invading and colonizing new habitats such as islands.

Fig. 22. *Anoplolepis gracilipes*, the crazy ant, worker caste. Photo: Antweb.

Fig. 23. *Tetramorium smithi*, worker caste. **New Island Record**. Photo: Will Haines.

Previous to this study, 18 species of ants were known from Pagan, mainly all widespread species. During this survey, we identified 25 species including 10 new island records, bringing the total known number of ants from Pagan to 28. None of these species are endemic to the island and only a few may be native; the remainder are alien introductions. Their presence poses the greatest threat to the native ecosystem as many species are either predaceous on other invertebrates while others are seedeaters. Any unchecked predator can cause deleterious effects on plant and animals though depletion of resources and destruction of the flora. Although the most pervasive species found on Pagan and collected in huge numbers (hundreds) in some of the traps (see Fig. 32), the crazy ant, *Anoplolepis gracilipes* (Fig. 22), is not a major threat now but given its capacity to form what are called "supercolonies" in island ecosystem situations, it may become a serious pest [see SIGNIFICANT FINDINGS below for more information.

Five species of bees were previously recorded from Pagan (including one endemic megachilid bee) but were not as commonly collected during this survey (only 1 was identified, the common honeybee *Apis mellifera*). This may be due to competition with other more aggressive insects such as the social wasps and ants, both of which can either attack and overcome bees or outcompete for food resources or even deplete them.

ISOPODA (sow bugs, pill bugs, roly-polys, wood lice) [Fig. 24]

Two unnamed taxa of terrestrial isopods have previously been recorded from Pagan. During this survey, we collected one unnamed species in the family Armadillidae (pill bugs). These crustaceans are debris feeders and are harmless (they are not pestiferous or

of any medical importance). They require moisture to survive so will be found in moist soil or under rocks or debris. They are nocturnal in feeding habits and not usually seen during the day unless an overabundance in populations causes them to expand into human habitations in search of moisture and shelter. Pill bugs are easily separated from their close cousins, the cosmopolitan wood lice (Porcellionidae) by the fact that pill bugs can roll up into a ball, wood lice cannot.

Fig. 24. Species of Armadillidae, a pill bug. Photo: Bugguide.net.

ISOPTERA (termites)

Termites are cosmopolitan but none had previously been recorded from Pagan. The discovery of the subterranean termite *Rhinotermes inopinatus* marks the first record of termites from Pagan. The species is a common widespread species found throughout the Pacific.

LEPIDOPTERA (moths, butterflies) [Figs. 25, 26]

Butterflies and moths are conspicuous insects in any arthropod survey. Although many lepidopterans are large and showy, there are not very many species known from Pagan. Previous to this study, only 10 species in 4 families had been published. During this study, using a variety of trapping methods as well as hand collecting, we have identified 17 species, of which 12 are new island records. The lepidopteran fauna on Pagan is now 22 species in 11 families.

Fig. 25. The widespread Blue-branded king crow butterfly, *Euploea eunice*, female. The caterpillars feed on fig trees. Photo: Darcy Oishi.

Fig. 26. The widespread (throughout the Pacific) Common eggfly butterfly, *Hypolimnas bolina*, female. Caterpillars feed on a variety of plants. **New Island Record.** Photo: Darcy Oishi.

One new record, the butterfly *Hypolimnas bolina* (Fig. 26), is a very widespread Pacific species, and it is unusual that is had not been recorded previously from Pagan. It was commonly collected during this survey, so has most likely been established on the island for some time.

Light trapping was conducted at two sites during this survey, which is the best method for collecting night flying insects such as moths. Despite the trapping, only a relatively few specimens of moths were identified during this survey, which most likely was as direct result of trapping during bad weather and/or bright, moonlit nights.

Some of the species identified based on collections made during this study (*Endotricha* sp., *Asymphrodes* sp., and *Anocharis* sp.) belong to large genera that are very diverse in the Pacific, so there is a high probability that eventual species-level identification may show that some are native or even endemic species on Pagan.

MANTODEA (mantids)

Only one species of praying mantis, *Orthodera burmeisteri*, a widespread species throughout the Pacific was previously recorded from Pagan and was also collected on this survey. Mantids are general predators and a natural component of most ecosystems. However, the species here was undoubtedly introduced long ago to the island. Mantids produce egg sacs (oothecae), a foam-like substance is produced by the mantid surrounding the eggs that hardens and protects the eggs while they are developing. These oothecae are usually attached to twigs or leaves.

Fig. 27. Ant lion larva from Pagan attacking crazy ant. Photo: Darcy Oishi.

NEUROPTERA (lacewings, ant lions) [Fig. 27]

Previous to this study, three species of neuropterans, two lacewings and an ant lion, were known from Pagan. Collections made during this study have identified 6 new species records including the first record of a brown lacewing (Hemerobiidae). In addition, larvae and adults of ant lions were collected, of which the adult was identified as a species of *Myrmeleon*, which is a new record to the island.

ODONATA (dragonflies, damselflies) [Fig. 28]

Four species of odonates were previously recorded from Pagan: one damselfly (*Ischnura aurora*) and three dragonflies. Three of the four species were recovered during this study. Dan Polhemus (pers. comm.) indicated that two of the three dragonflies may include a misidentification, so that there really may only be 3 species that occur from the island. A conspicuous absence on Pagan is the widespread and long-distance flier, *Pantala flavescens*. It occurs on most Pacific islands and is known to fly more than 1500 km over oceans to get from one freshwater source to another. The species is known from other islands in the Marianas but has not been seen on Pagan.

Fig. 28. The dragonfly *Diplacodes bipunctata*, male, from American Samoa. Photo: Dan Polhemus.

ORTHOPTERA (crickets, grasshoppers) [Figs. 29, 30]

Only three orthopterans were previously recorded from Pagan prior to this survey. Based on collections made during this project, 15 taxa have been identified including 14 new records. These include six acridids (grasshoppers), two katydids, three gryllids (crickets),

two tetrigid grasshoppers, and the rare ant inquiline, *Myrmecophilus leei*. See below under SIGNIFICANT FINDINGS for more details on this last species.

Fig. 29. Unidentified tetrigid grasshopper. **New Island Record.** Photo: Darcy Oishi

Fig. 30. The ant inquiline, *Myrmecophila leei*. **New Island Record.** Photo: Neal Evenhuis

PHASMATODEA (walking sticks, stick insects)

One species of stick insect, the widespread *Acanthograeffea denticulata*, was previously recorded from Pagan. No collections of this or any other stick insects were made during this survey, but we expect the species still exists. It is known as a pest of coconut and coconut groves are abundant on Pagan, so it should still be there. This is an introduced

insect that has been on the island for quite a long time. It was first recorded by Yasumatsu (1940) from collections made on Pagan in April 1940.

PSEUDOSCORPIONIDA (pseudoscorpions)

Pseudoscorpions are tiny (usually no more than 2 mm in length) arthropods that live in leaf litter and under tree bark where they prey on microscopic invertebrates. Three species had previously been recorded from Pagan (all taken from soil samples). Two species were identified during this survey, both new records for the island. Pseudoscorpions are not commonly found on tropical islands so the finding of all these different species on Pagan is notable. Further research should be carried out to determine why.

PSOCOPTERA (book lice, bark lice)

Bark lice are common forest dwellers where they are found in leaf litter or under decaying bark of trunks, logs, or twigs. One species, *Caecilius analis* was previously recorded (Thornton, 1981) but not collected during this survey. However, eight other species were identified from collections made during this survey, which are all new records for the island. As these species are a common and diverse group on other Pacific islands, we believe further more rigorous collecting focusing on this group should produce more species records from Pagan.

SCORPIONIDA (scorpions) [Fig. 31]

Previous records report two species of scorpions (one unnamed) from Pagan. One of these two species, *Liocheles australasiae* (Fig. 31) was found in one of the craters on south Pagan and identified during this survey. It is a small (ca. 2 cm long), common and widespread species throughout the Pacific islands. The sting of scorpions can be painful in some species but is rarely fatal. The sting of *Liocheles australasiae* is no worse than a bee sting. The paucity of material of collected during this survey despite the numerous pitfall traps throughout the island lends support to the presumption that their presence is very rare and as such they pose no threat or danger to humans or other animals on Pagan.

Fig. 31. The scorpion, *Liocheles australasiae*, commonly found throughout the Pacific. Approximately 2 cm long. Photo: Ryo Kenzaki.

SIPHONAPTERA (fleas)

The only known flea recorded from Pagan is the cat flea. It was not collected on this survey, but feral cats still abound on the island and it is presumed that the associated fleas still occur there as well.

THYSANOPTERA (thrips)

Two species of thrips were previously recorded from Pagan. Two thrips were found in the material collected but only one could be identified to species level due to time constraints. More specimens should be expected, as thrips are ubiquitous arthropods in all island faunas. Specialized collecting techniques focusing directly on host plants may be necessary to secure specimens for study. Thrips are known to be pests on crops. It is not known whether or not the two species previously recorded or the one collected in this study are pestiferous.

THYSANURA (bristletails, silverfish)

Silverfish are ubiquitous creatures usually associated with human habitation. They are detritus feeders and are pests in offices and libraries where they feed on paper.

SIGNIFICANT FINDINGS

Invasive species

HYMENOPTERA: FORMICIDAE
ANOPLOLEPIS GRACILIPES (SMITH, 1857) [Figs. 22, 32]

Probably the most prevalent arthropod in the survey is the crazy ant, *Anoplolepis gracilipes*. This highly invasive species is found worldwide and in some places where it has become introduced (e.g., Christmas Island in the Indian Ocean), it forms supercolonies (Abbott, 2006). These are multiple colonies with queens but no competition or aggravated behavior takes place between colonies allowing high densities of the ants in small areas where they can devastate plant and invertebrate biota to use as food resources for the burgeoning nests. No supercolonies were observed on Pagan; however, the high levels of abundance of the ants in pitfall and pan traps (e.g., Fig. 32) may be an indicator that this species may eventually form a supercolony on Pagan.

Fig. 32. Single sample of the crazy ant, *Anoplolepis gracilipes,* collected from a pitfall trap on Pagan. Photo: Darcy Oishi.

Selected Rare, New, or Unusual Species

DIPTERA: DOLICHOPODIDAE
HYDROPHORINAE - NEW GENUS, NEW SPECIES [Fig. 19]

A new genus and species of hydrophorine marine dolichopodid fly was collected off rocks on the west coast of Pagan. This is the first record for Pagan of this new taxon, which is otherwise known only from Guam. It should also occur on the islands between Guam and Pagan but have yet to be collected. Recent collections on Saipan by Dan Polhemus in September 2010 did not find any.

This taxon is found along rocky shores in the splash zone (Fig. 33). It is predaceous on other small invertebrates both as immatures and adults. Immatures were not found but should be found in small rock holes and crevices in association with algae and other littoral invertebrate organisms.

Fig. 33. Rocky shoreline on south side of Bandeera peninsula where a new genus of marine dolichopodid flies was collected. Photo: Dan Polhemus.

ORTHOPTERA: MYRMECOPHILIDAE
MYRMECOPHILA LEEI KISTNER & CHONG 2007 [FIG. 30]

This rare and unusual creature is an inquiline in ant nests. It was found associated with *Anoplolepis* on the south portion of Pagan and is the first record of this family from the island. It appearance here on Pagan is unusual in that, previous to this survey, it was originally described and known only from mainland Malaysia. It is most likely that this is

much more widespread than previously known but has been neglected in previous collections because of its superficial resemblance to immature cockroaches. Samples from collecting on other areas between SE Asia and Pagan should be checked for this interesting ant inquiline.

THREATS TO FRUIT BATS OR THE MEGAPODE FAUNA

No direct threats to either megapodes or the fruit bat were found in this survey. Theoretically, predator and parasitic arthropods that deplete food resources may have an indirect affect on populations, but there is no evidence to suggest this has or will happen in the near future by any of the arthropods identified in this survey.

ACKNOWLEDGMENTS

The staff of the library and archives of the Bishop Museum and Hamilton Library at the University of Hawaii at Manoa assisted with obtaining some of the literature. Al Samuelson (beetles) and Kelly Miller (embiids) kindly assisted with identifications. Dan Polhemus allowed use of information from his aquatic insect survey report in this overall arthropod report. Maps 2 and 3 were prepared by Cory Campora. Many of the photos used in this report were kindly provided by Christa Russell, Cory Campora, and Dan Polhemus. Eiko Lynch assisted with transliterating the 1940 Yasumatsu localities. We especially acknowledge the efforts of the collectors of this survey, Christa Russell, Mike Richardson, Cory Campora, Stephan Lee, and Justin Fujimoto. Neither erupting volcanoes, sweltering heat during "death marches" across the island, charging bulls, constant companionship of "overly attentive" flies, thousands of ants billowing out of nests, nor spam, spam, and even more spam did not deter them from their goal of making an extensive and successful survey of the island of Pagan in only a few days.

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APPENDICES

APPENDIX I.
BIBLIOGRAPHY OF PAGAN TERRESTRIAL ARTHROPODS

The following is a complete list of all known publications specifically listing Pagan terrestrial arthropods including articles that mention arthropods as occurring on the island but without a scientific name. Many more articles list terrestrial arthropods with a low geographical resolution of only "Marianas" or "Northern Marianas". If those articles do not specifically mention Pagan, they are not included below.

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APPENDIX II. CHECKLIST OF PAGAN ARTHROPODS

(taxa in italics are synonyms or misidentifications [that appeared in the literature] of current valid names)

Order/Family	Taxon*	Prev. Publ.	This Study
ACARINA (mites, ticks)			
Ameroseiidae	Ameroseius sp. 2	x	
Eviphididae	Eximiris sp.	x	
Ixodidae	prob. Boophilus microplus		x
Laelapidae	Hypoaspis sp. 1	x	
	Hypoaspis sp. 2	x	
Ologamasidae	Gamasiphis sp. 1	x	
	Gamasiphis sp. 2	x	
Oribatidae	Gen. sp.		x
Podocinidae	Podocinum jamaicense Evans & Hyatt, 1957	x	
Pyemotidae	Pyemotes sp.		x
Rhodacaridae	Rhodacarus sp.	x	
Uropodidae	Metagynella sp. A	x	
	Trigonuropoda sp. B	x	
	Trigonuropoda sp. D	x	
	Uroobovella sp. C	x	
ARANEAE (spiders)			
Anyphaenidae	Gen. sp.		x
Araneidae	Argiope appensa (Walckenaer, 1841)	x	x
	Argiope sp. 2	x	
	Neoscona sp.	x	x
	Neoscona theisi (Walckenaer, 1842)		x
Clubionidae	Gen. sp. 1	x	x
	Gen. sp. 2		x
	Gen. sp. 3		x
Corinnidae	Gen. sp.		x
Gnaphosidae	Gen. sp. 1		x
	Gen. sp. 2		x
Linyphiidae	Gen. sp.		x
Liocranidae	Apostenus sp.		x
Lycosidae	Gen. sp.		x
	Pardosa sp.	x	
	Schizocosa sp. 1		x
	Schizocosa sp. 2		x
	Schizocosa sp. 3		x
Miturgidae	Cheiracanthium sp.		x
Nesticidae	Gen. sp. 1		x
	Gen. sp. 2		x
Ooponidae	Gamasomorpha sp.	x	
Pholcidae	Gen. sp.	x	
Pisauridae	Dolomedes sp.		x
Salticidae	Athamas whitmeei Pickard-Cambridge, 1877		x
	Hasarius adansoni Savigny & Audouin, 1825		x
	Plexippus sp. 1	x	x
	Plexippus sp. 2		x

Order/Family	Taxon*	Prev. Publ.	This Study
ARANEAE (spiders) [continued]			
Salticidae	Plexippus paykulli (Audouin, 1826)		x
	Sassacus sp.		x
	Thorelliola ensifera (Thorell, 1877)		x
Scytodidae	Scytodes sp.	x	
Sparassidae	Heteropoda sp.		x
	Olios sp.		x
Tengellidae	Gen. sp.		x
Tetragnathidae	Gen. sp.		x
Theridiidae	Argyrodes sp.	x	
	Coleosoma floridanum Banks, 1900	x	
Thomisidae	Thomisius sp.		x
	Gen. sp.		x
Titanoecidae	Gen. sp.		x
	Titanoeca? sp.		x
Zodariidae	Zodarion? sp.		x
BLATTARIA (roaches)			
Blaberidae	Diploptera dytiscoides (Serville, 1838)		x
Blatellidae	Blatella lituricollis (Walker, 1868)	x	
	Onychostylus notulatus (Stål, 1861)	x	
Blattidae	Periplaneta americana (Linnaeus, 1758)	x	x
	Periplaneta australasiae (Fabricius, 1775)	x	x
Pycnoscelidae	Pycnoscelus indicus (Fabricius, 1775)	x	
	Pycnoscelus surinamensis (Linnaeus, 1758)		x
CHILOPODA (centipedes)			
Scolopendridae	Scolopendra? sp. *"centipede"*	x	x
	Geophilomorpha gen. sp.		x
COLEOPTERA (beetles)			
Aderidae	Aderus sp.		x
Anthribidae	Araecerus fasciculatus (De Geer, 1775)		x
	Araecerus vieillardi (Montrouzier, 1860)		x
Bostrichidae	Xylopsocus capucinus (Fabricius, 1787)		x
	Xylothrips flavipes (Illiger, 1801)		x
Buprestidae	Agrilus auriventris Saunders, 1873	x	
Carabidae	Agadroma sp.		x
	Gnathaphanus licinoides Hope, 1842	x	x
	Stenolophus smaragdulus (Fabricius, 1798)	x	
Cerambycidae	Ceresium unicolor unicolor (Fabricius)		x
	Micronesiella mariana (Gressitt, 1956) *Sciadella mariana*	x	
	Phloeopsis meridiana (Ohbayashi, 1941) *Sciadella meridiana*	x	
	Prosoplus marianarum Aurivillus, 1908	x	
Chrysomelidae	Brontispa mariana Spaeth, 1937 *Planispa castaneipennis* Chujo, 1937	x	
	Gen. sp.		x

Order/Family	Taxon*	Prev. Publ.	This Study
COLEOPTERA (beetles) [continued]			
Cleridae	Necrobia rufipes (De Geer, 1775)		x
Coccinellidae	Coleophora inaequalis (Fabricius, 1775)	x	x
	Cryptolaemus montrouzieri Mulsant, 1853	x	
	Menochilus sexmaculatus (Fabricius, 1781)		x
	Nephus roepkei (Fluiter, 1938)		x
	Telsimia nitida Chapin, 1926	x	
Corylophidae	Sericoderus sp.		x
Curculionidae	Camptorrhinus dorsalis (Boisduval, 1835)	x	x
	Curculio sp.		x
	Deretiosus ficae Zimmerman, 1942		x
	Memectetorus cf. setulosus (Boheman, 1859)		x
	Microcryptorhynchus "sp. 2"	x	
	Myllocerus sp.		x
	Rhabdocnemis obscura (Boisduval, 1835)	x	
Dermestidae	Dermestes ater De Geer, 1774	x	x
Elateridae	Conoderus pallipes (Eschscholtz, 1829)	x	x
	Lacon modestus (Boisduval, 1835)		x
	Prodorasterius sp.	x	
	Simodactylus cinnamomeus (Boisduval, 1835)	x	
Endomychidae	Trochoideus desjardinsi Guérin-Méneville, 1857	x	
Laemophloeidae	Laemophloeus sp. nr. minutus		x
Melyridae	Gen. sp.		x
Mordellidae	Dellamora castanea (Boheman, 1858)		x
Nitidulidae	Carpophilus davidsoni Dobson, 1952		x
	Carpophilus sp. nr. davidsoni?		x
	Carpophilus humeralis (Fabricius, 1798)		x
	Carpophilus dimidiatus (Fabricius, 1792)		x
	Carpophilus sp.		x
Platypodidae	Phylloplatypus pandani Kato, 1998		x
Salpingidae	Prostomiinae, gen. sp.		x
Scarabaeidae	Adoretus sinicus Burmeister, 1854	x	x
	Aphodius lividus (Olivier, 1789)	x	x
Scolytidae	Ericryphalus sylvicola (Perkins, 1900)	x	
	Hypothenemus birmanus (Eichhoff, 1878)		x
	Hypothenemus eruditus Westwood, 1836		x
Silvanidae	Cryptamorpha desjardinsi (Guérin-Méneville, 1844)		x
	Silvanus nr. unidentatus (Fabricius, 1792)		x
Staphylinidae	Egadroma sp.		x
Tenebrionidae	Derosphaerus rotundicollis (Castlenau, 1840)		x
	Gonocephalum adpressiforme Kaszab, 1951	x	x
	Gonocephalum sp.		
	Gonocephalum incisum Blanchard, 1853		x
	Palorus papuanus Kaszab, 1939	x	
COLLEMBOLA (springtails)			
Entomobryidae	Gen. sp.		x
	Sira fuscana Uchida, 1944	x	x
Isotomidae	Gen. sp. 1		x

Order/Family	Taxon*	Prev. Publ.	This Study
COLLEMBOLA (springtails) [continued]			
Isotomidae	Gen. sp. 2		x
Neelidae	Neelus minimus (Willem, 1900)	x	
Poduridae	Gen. sp.		x
Sminthuridae	Cyphoderus albinus Nicolet, 1841	x	
	Sminthurides sp.		x
	Sphaeridia pumilis (Krausbauer, 1891)	x	
DERMAPTERA (earwigs)			
Anisolabididae	Euborellia stali (Dohrn, 1864)		x
Labidiidae	Gen. sp.		x
DIPLOPODA (millipedes)			
Trigoniulidae	Trigoniulus corallinus (Gervais, 1847)		x
Xystodesmatidae	Harpaphe haydeniana (Wood, 1864)		x
DIPTERA (flies, gnats, midges)			
Agromyzidae	**Japanagromyza eucalytpi paganensis Spencer, 1963**	x	
	Japanagromyza sp.		x
	Liriomyza nr. brassicae (Riley, 1885)		x
	Melanagromyza atomella Malloch, 1914	x	
	Pseudonapomyza spicata (Malloch, 1914)		x
Anthomyzidae	Amalygdops sp.		x
Calliphoridae	Chrysomya megacephala (Fabricius, 1794)	x	x
	Chrysomya rufifacies (Macquart, 1843)	x	x
	Hemipyrellia tagaliana (Bigot, 1877)		x
Canacidae	Nocticanace peculiaris Malloch, 1933		x
Cecidomyiidae	Cecidomyiinae Gen. sp.		x
	Lestremia sp.		x
Ceratopogonidae	Dasyhelea sp. A		x
	Dasyhelea sp. B		x
	Dasyhelea sp. C		x
	Forcipomyia sp.		x
Chamaemyiidae	Leucopis sp.		x
Chironomidae	Chironomus longilobus (Kieffer, 1916)		x
	Thalassomyia maritima Wirth, 1947		x
Chloropidae	Cadrema pallida (Loew, 1865)		x
	Gen. sp.		x
	Siphunculina nitidissima Kanmiya, 1982		x
Culicidae	Aedes albopictus (Skuse, 1894)	x	x
	Aedes nocturnus (Theobald, 1903)		x
	Aedes saipanensis Stone, 1945		x
	Anopheles subpictus indefinitus (Ludlow, 1904)		x
	Culex annulirostris marianae Bohart & Ingram, 1946	x	
Dolichopodidae	Chrysosoma mariana Bickel, 1994	x	
	Chrysotus sp.		x
	Krakatauia micronesiana Bickel, 1994		x
	Hydrophorinae - New gen. n. sp.		x
	Tachytrechus sp.		x

Order/Family	Taxon*	Prev. Publ.	This Study
DIPTERA (flies, gnats, midges) [continued]			
Dolichopodidae	Thinophilus sp.		x
	Plagiozopelma flavipodex (Becker, 1922)		x
	Sympycninae - New gen. n. sp.		x
Drosophilidae	Drosophila ananassae Doleschall, 1858		x
	Leucophenga nigriventris (Macquart, 1843)		x
Ephydridae	Allotrichoma sp.		x
	Atissa antennalis Aldrich, 1931		x
	Hecamedoides sp.		x
	Paralimna fusca Bock, 1988		x
	Paralimna lineata de Meijere, 1908		x
	Scatella septempunctata Malloch, 1933		x
	Zeros sp.		x
Keroplatidae	**Neoplatyura n. sp.**		x
Lauxaniidae	Homoneura acrostichalis (de Meijere, 1915)	x	x
	Homononeura sp.		x
Limoniidae	Dicranomyia basifusca Alexander, 1919		x
	Dicranomyia obesula Edwards, 1927		x
	Dicranomyia pontophila (Tokunaga, 1940)		x
Lonchaeidae	Lamprolonchaea sp. *Gen. sp.*	x	x
	Lonchaea sp.		x
Milichiidae	Desmometopa gressitti Sabrosky, 1983		x
	Desmometopa tarsalis Loew, 1866		x
	Milichiella lactiepennis (Loew, 1865)		x
Muscidae	Atherigona orientalis Schiner, 1858 *Atherigona excisa (Thomson)*	x	x
	Haematobia exigua (de Meijere, 1903)		x
	Musca domestica Linnaeus, 1758	x	
	Musca sorbens Wiedemann, 1830	x	x
	Orchisia costata (Meigen, 1826)	x	
	Pygophora respondens (Walker, 1859)		x
	Stomoxys calcitrans (Linnaeus, 1758)	x	
Nannodastidae	Nannodastia sp.		x
Phoridae	Dohriphora cornuta (Bigot, 1857)		x
	Megaselia setaria (Malloch, 1912)		x
	Puliciphora sp.		x
Platystomatidae	Scholastes carolinensis Enderlein, 1924		x
Psychodidae	Psychoda mediocris Quate, 1959		x
Sarcophagidae	Sarcophaga gressitti Hall & Bohart, 1951	x	
	Sarcophaga karnyi (Hardy, 1927)	x	
	Sarcophaga misera (Walker, 1849)	x	
	Sarcophaga peregrina (Robineau-Desvoidy, 1830)		x
Sciaridae	Scythropochroa quadrispinosa Steffan, 1969		x
Sphaeroceridae	Coproica hirtula (Rondani, 1880)		x
	Poecilosomella punctipennis (Wiedemann, 1824)		x
	Gen. sp.		x
Syrphidae	Lathyrophthalmus arvorum (Fabricius, 1787)		x
Tephritidae	Bactrocera ochrosiae (Malloch, 1942) *Chaetodacus dorsalis*, misid.	x	

Order/Family	Taxon*	Prev. Publ.	This Study
DIPTERA (flies, gnats, midges) [continued]			
Tephritidae	Euphranta lemniscata (Enderlein, 1911)	x	
	Spathulina acroleuca Schiner, 1868	x	
Ulidiidae	Notogramma cimiciforme Loew, 1868	x	x
	Gen. sp.		
EMBIIDA (web spinners)			
Oligotomidae	Oligotoma humbertiana (Saussure, 1896)		x
HEMIPTERA (true bugs)			
Anthocoridae	Buchaniella sodalis (White, 1878)	x	
	Lasiochilus marianensis Usinger, 1946	x	
	Lasiochilus swezeyi Usinger, 1946	x	
Coreidae	Leptocorixa acuta (Thunberg, 1783)	x	
	Leptoglossus australis (Fabricius, 1774)	x	
	Leptoglossus membranaceus (Fabricius)		
	Melanacauthus margineguttatus Distant, 1911	x	
Deltocephalidae	Balclutha rufofasciata (Merino, 1936)	x	
Gerridae	Halobates flaviventris Eschscholtz, 1822		x
Hermatobatidae	Hermatobates sp.		x
Lygaeidae	**Bedunia pagana Barber, 1958**	x	
	Cligenes marianensis Usinger, 1946	x	
	Nysius pulchellus Stål, 1859	x	
	Pachybrachius nigriceps (Dallas, 1852)	x	
Mesoveliidae	Mesovelia vittigera Horvath, 1895		x
Miridae	Campylomma breviceps Usinger, 1946	x	
	Campylomma brunneicollis Usinger, 1946	x	
	Campylomma lividicornis Reuter, 1912	x	
	Camplyomma nr. wakeana Schuh, 1984		x
	Creontiades pallidifer (Walker, 1873)	x	
	Eurystylus costalis unicolor Poppius, 1911	x	
	Lygocoris kusaiensis (Carvalho, 1956)	x	
	"Lygus" n. sp.		x
	Taylorilygus pallidulus (Blanchard, 1852)	x	
	Trigonotylus dohertyi (Distant, 1904)	x	
Nabidae	Reduviolus capsiformis (Germar, 1837)	x	x
Plataspidae	Coptosoma xanthogramma (White, 1842)		x
Reduviidae	Physoderes minor Usinger, 1946		x
	Scadra rufidens Stål, 1859		x
Saldidae	Saldula palauana Drake, 1961		x
Veliidae	Halovelia bergrothi Esaki, 1926		x
	Microvelia diluta Distant, 1909		x
HOMOPTERA (sucking bugs, aphids, scale insects)			
Aleyrodidae	Gen. sp.		x
	Neomaskellia bergii (Signoret, 1868)	x	
Aphididae	Aphis gossypii Glover, 1877	x	
	Gen. sp.	x	x
Aradidae	Mezira sp.		x

Cicadellidae	Acertagallia sp.		x
Order/Family	**Taxon***	**Prev. Publ.**	**This Study**
HOMOPTERA (sucking bugs, aphids, scale insects) [continued]			
Coccidae	Saissetia coffeae (Walker, 1852) *Saissetia hemisphaericum*	x	
	Saissetia nigra (Nietner, 1861)	x	
	Saissetia oleae (Bernard, 1782)	x	
Diaspididae	Hemiberlesia lataniae (Signoret, 1869)	x	
	Lepidosaphes esakii Takahashi, 1939	x	
Monophlebidae	Icerya aegyptiaca (Douglas, 1890)	x	x
Pentatomidae	Bulbostethus transversalis Ruckes, 1963	x	
	Geotomus pygmaeus (Dallas, 1851)	x	
	Piezodorus hybneri (Gmelin)	x	
Pseudococcidae	Dysmicoccus cocotis (Maskell, 1890) *Dysmicoccus saipanensis* (Siraiwa, 1933)	x	
	Ferrisia virgata (Cockerell, 1893)	x	
Psyllidae	Trioza guama Caldwell, 1942 *Trioza propria* Tuthill, 1951	x	x
Scutelleridae	Coleotichus breddini Shouteden, 1905	x	x
HYMENOPTERA (wasps, bees, ants)			
Agaonidae	Ceratosolen sp.		x
	Liporrhopalum? sp.		x
	Sycoscapter sp.		x
Aphelinidae	Aneristus ceroplastae Howard, 1895	x	
Apidae	Apis mellifera Linnaeus, 1758	x	x
Bethylidae	Scleroderma sp.		x
Braconidae	Apanteles sp.	x	
	Doryctes sp.	x	
	Phaneratoma sp.		x
Elasmidae	Elasmus sp.		x
Eucharidae	Chalcura upeensis Fullaway, 1913	x	
Eulophidae	Hemiptarsenus varicornis (Girault, 1913)		x
	Tetrastichinae Gen. sp.		x
Eumenidae	Delta esuriens (Fabricius) ssp.	x	
	Gen. sp.	x	
	Rhynchium brunneum (Fabricius, 1793)		x
	Subancisatrocerus sp.	x	
Evaniidae	Evania appendigaster (Linnaeus, 1758)	x	x
Formicidae	Anoplolepis gracilipes (Smith, 1857) *Anoplolepis longipes* Jerdon, 1851	x	x
	Camponotus chloroticus Emery, 1897	x	x
	Cardiocondyla kagutsuchi Terayama, 1999		x
	Cardiocondyla obscurior Wheeler, 1929		x
	Cardiocondyla tjibodana Karavaiev, 1935		x
	Hypoponera punctatissima (Roger, 1859)	x	
	Iridomyrmex anceps (Roger, 1863)		x
	Monomorium australicum Forel, 1907		x
	Monomorium chinense Santschi, 1925	x	x
	Monomorium destructor (Jerdon, 1851)	x	x
	Monomorium floricola Jerdon, 1851	x	x

Order/Family	Taxon*	Prev. Publ.	This Study
HYMENOPTERA (wasps, bees, ants) [continued]			
Formicidae	Monomorium sechellense Emery, 1894	x	
	Monomorium fossulatum Wilson & Taylor, 1967		
	Nylanderia bourbonica (Forel, 1886)	x	x
	Odontomachus simillimus (Smith, 1858)	x	x
	Odontomachus haemotodus (Linnaeus, 1758), misid.		
	Paratrechina longicornis (Latreille, 1802)		x
	Pheidole sp. B	x	
	Pheidole nindi Mann, 1919		x
	Pheidole umbonata Mayr, 1870	x	x
	Platythyrea parallela (Smith, 1859)	x	x
	Strumigenys emmae (Emery, 1890)	x	x
	Quadristruma emmae (Emery, 1890)		
	Tapinoma melanocephalum (Fabricius, 1793)	x	x
	Tapinoma sp.	x	x
	Technomyrmex difficilis Forel, 1892		x
	Tetramorium bicarinatum Nylander, 1846	x	x
	Tetramorium lanuginosum Mayr, 1870	x	x
	Tetramorium simillimum (Smith, 1851)	x	x
	Tetramorium smithi Mayr, 1879		x
	Tetramorium tonganum Mayr, 1870		x
Halictidae	Homalictus vexator (Krombein, 1950)	x	
Ichneumonidae	Echthromorpha agrestoria insidiator (Smith, 1863)		x
Ichneumonidae	Echthromorpha agrestoria conopleura Krieger, 1909	x	
	Echthromorpha conopleura Krieger, 1909		
	Trathala flavoorbitalis (Cameron, 1907)	x	
Megachilidae	**Heriades paganensis Yasumatsu, 1942**	x	
	Eriades sp.		
	Megachile laticeps Smith, 1853	x	
	Megachile fullawayi Cockerell, 1914	x	
Mymaridae	Gen. sp.		x
Pompilidae	Paracyphononyx pedestris (Smith, 1855)		x
Scelionidae	Scelio sp.		x
Sphecidae	Chalybion bengalense (Dahlbom, 1845)	x	x
	Liris aurulenta (Fabricius, 1787)	x	
	Liris opulenta (Le Peletier, 1845)		
	Liris aurata (Fabricius, 1787)	x	x
	Motes manilae (Ashmead, 1905)	x	
	Sceliphron nr. laetum Smith, 1856		x
	Trypoxylon nr. thaianum Tsuneki, 1961	x	x
Trichogrammatidae	Trichogramma sp.		x
Vespidae	Delta esuriens (Fabricius, 1787)		x
	Odynerus paganensis Yasumatsu, 1945	x	
	Odynerus mariannensis Bequaert & Yasumatsu		
	Odynerus haemorrhoidalis quinquecinctus (Fabr.)	x	
	Pachyodynerus nasidens (Latreille, 1832)		x
	Polistes olivaceus (de Geer, 1773)	x	x
	Ropalidia marginata sundaica van der Vecht, 1941	x	

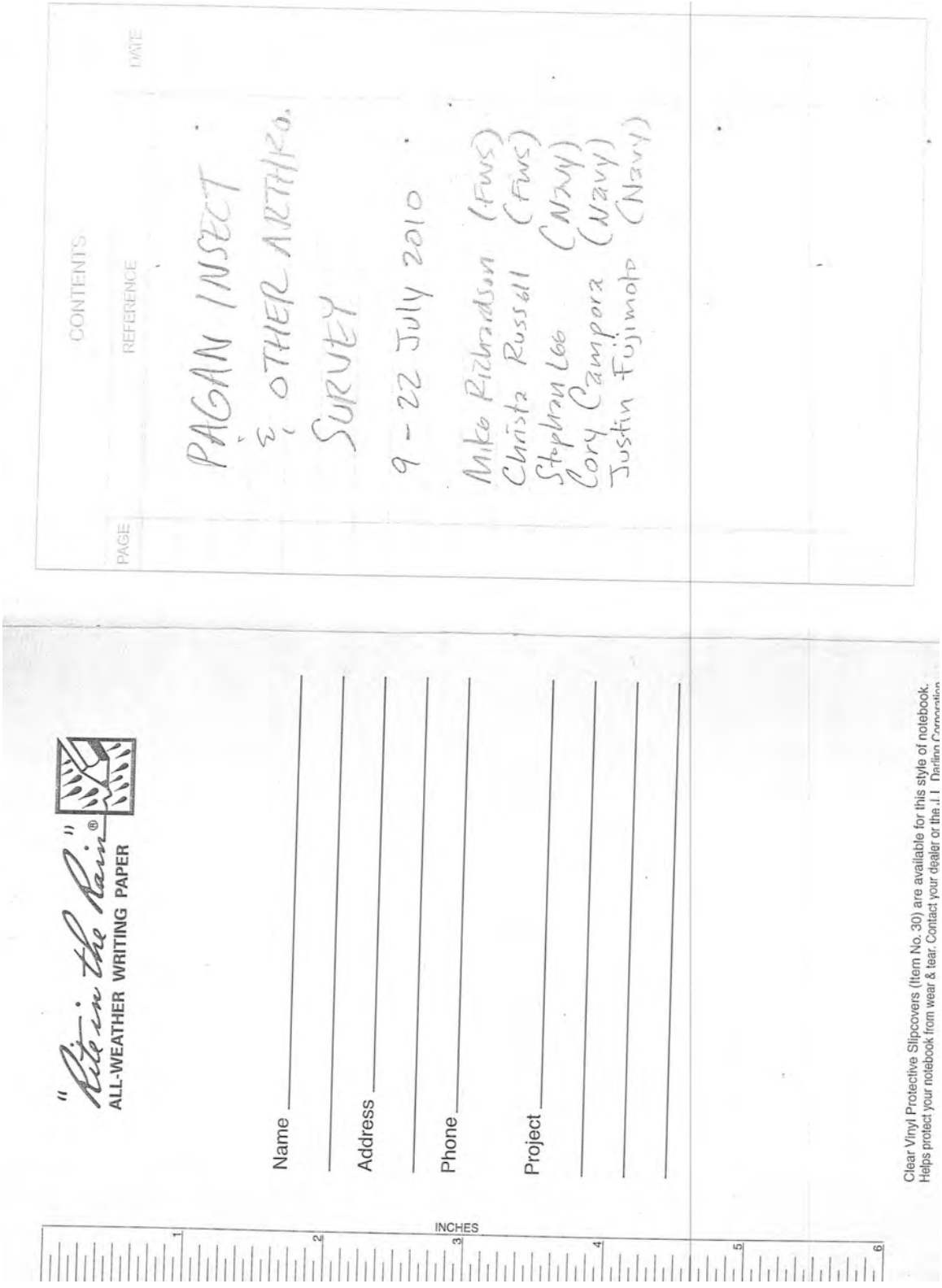
Order/Family	Taxon*	Prev. Publ.	This Study
ISOPODA (sow bugs, pill bugs, wood lice)			
Armadillidae	Gen. sp. 1	x	x
Fam.	Gen. sp. 2	x	
ISOPTERA (termites)			
Rhinotermitidae	Prorhinotermes inopinatus Silvestri		x
LEPIDOPTERA (moths, butterflies)			
Cosmopterygidae	Asymphorodes sp.		x
	Gen. sp.		x
Crambidae	Autocharis sp.		x
Geometridae	Chloroclystis scintillata Prout, 1932		x
	Scopula homodoxa Meyrick, 1886		x
Hesperiidae	Badamia exclamationis (Fabricius, 1775)	x	x
Lycaenidae	Petrelaea dana (de Niceville, 1884)		x
Noctuidae	Achaea serva (Fabricius, 1775)	x	
	Callopistria maillardi (Guenée, 1862)	x	x
	Earias ochrophylla Turner, 1902	x	
	Melanitis leda (Linnaeus, 1758) ssp.	x	x
	Mocis fragalis (Fabricius, 1775)	x	
	Mocis undata (Fabricius, 1775)	x	
Nymphalidae	Euploea eunice (Quoy & Gaimard, 1824)	x	x
	Hypolimas bolina (Linnaeus, 1758)		x
Papilionidae	Papilio polytes Linnaeus, 1758 ssp.	x	x
	Papilio xuthus Linnaeus, 1767	x	
Pterophoridae	Gen. sp.		x
Pyralidae	Cryptolabes sp.		x
	Endotricha sp.		x
	Etiella nr. grisea Hampson, 1903		x
Tineidae	Erecthias sp.		x
MANTODEA (mantids)			
Mantidae	Orthodera burmeisteri Wood-Mason, 1889	x	x
NEUROPTERA (lacewings, ant lions)			
Chrysopidae	Brinckochrysa scelestes (Banks, 1911)		x
	Chrysoperla externa (Haqen, 1861)		x
	Chrysoperla krakatauensis Tsukaguchi, 1988	x	
	Mallada basalis Walker, 1852 *Chrysopa basalis* Walker	x	
	Plesiochrysa oceanica (Walker, 1852) *Chrysopa oceanica* Walker		x
Hemerobiidae	Gen. sp.		x
Myrmeleontidae	Distoleon bistrigatus (Rambur, 1842)	x	
	Myrmeleon sp.		x
ODONATA (dragonflies, damselflies)			
Agrionidae	Ischnura aurora (Brauer, 1865)	x	x
Libellulidae	Diplacodes bipunctatus (Brauer, 1865)	x	x

Order/Family	Taxon*	Prev. Publ.	This Study
ODONATA (dragonflies, damselflies) [continued]			
Libellulidae	Macrodiplax cora (Brauer, 1867)	x	
	Rhyothemis regia chalcoptilon (Brauer, 1867)	x	x
ORTHOPTERA (crickets, grasshoppers)			
Acrididae	Aiolopus thalassinus dubius Willemse, 1923		x
	Aiolopus thalassinus tamulus (Fabricius, 1781)	x	x
	Cyrtacanthridinae Gen. sp. 1		x
	Cyrtacanthridinae Gen. sp. 2		x
	Cyrtacanthridinae Gen. sp. 3		x
	Locusta migratoria manilensis (Mayen, 1835) *Locusta migratoria*	x	x
	Valanga excavata (Stål, 1861)		x
	Valanga nigricornis nr. ssp. carolinensis		x
Conocephalidae	Euconocephalus nasutus (Thunberg, 1815)	x	
Gryllidae	Gryllodes sigillatus (Walker, 1859)		x
	Gryllus sp.		x
	Teleogryllus oceanicus (Le Guillou, 1841)		x
Myrmecophilidae	Myrmecophilus leei Kistner & Chong, 2007		x
Tetrigidae	Gen. sp. 1		x
	Gen. sp. 2		x
Tettigoniidae	Mecopoda elongata (Linnaeus, 1758)		x
PHASMATODEA (walking sticks)			
Phasmatidae	Acanthograeffea denticulata (Redtenbacher, 1908)	x	
PSEUDOSCORPIONIDA (pseudoscorpions)			
Atemnidae	Oratemnus samoanus		x
Chernetidae	Smeringochernes guamensis Beier, 1957	x	
	Tyrannochthonius chamarro Chamberlin, 1947	x	
Olpiidae	Beierolpium oceanicum (With, 1907)	x	
Undetermined	Gen. sp.		x
PSOCOPTERA (book lice, bark lice)			
Archipsocidae	Archipsocus sp.		x
Caeciliidae	Caecilius analis Banks, 1931	x	
	Caecilius sp. nr. marianus Thornton et al., 1972		x
Ectopsocidae	Ectopsocus sp.		x
Lepidopsocidae	Lepidopsocus sp.		x
Myopsocidae	Phlodotes sp.		x
Peripsocidae	Peripsocus sp.		x
Pseudocaciliidae	Pseudocaecilius sp.		x
Psocidae	Ptycta sp.		x
SCORPIONIDA (scorpions)			
Ischnuridae	Liocheles australasiae (Fabricius, 1775)	x	x
Fam.	Gen. sp.	x	

Order/Family	Taxon*	Prev. Publ.	This Study
SIPHONAPTERA (fleas)			
Pulicidae	Ctenocephalides felis felis (Bouché, 1835)	x	
THYSANOPTERA (thrips)			
Phlaeothripidae	Allothrips megacephala Hood, 1908		x
	Allothrips sp.	x	
	Phlaeothripinae Gen. sp.		x
	Dexiothrips madrasensis (Ananthakrishnan, 1964)	x	
THYSANURA (bristletails, silverfish)			
Fam.	Gen. sp.		x
TOTALS		**188**	**288**
Grand total of species known from Pagan -- 416			

*Taxa listed in **boldface** are endemic species known only from Pagan Island.

APPENDIX III. CORY CAMPORA FIELD NOTES



1.) Pagan, CNMI
Lake Sanhiyon (saltwater lake)
9 July 2010
M. Richardson, C. Russell, S. Lee,
J. Fujimoto, and C. Campora

- Sweep Netting
- Aquatic Dip Netting
- General Collecting

2.) Pagan, CNMI
Rocky Coast from Lake
Sanhiyon south to Bandeera
Peninsula
9 July 2010
M. Richardson and S. Lee

- Sweep Netting
- General Collecting
- Collecting from rocky pools

3.) Pagan, CNMI
Ironwood forest south of
lake Sanhiyon (swordfern
understory)
9 July 2010
C. Campora, J. Fujimoto, and
C. Russell

- sweep netting
- general collecting

4.) Pagan, CNMI
Main Camp near runway –
mixed (grassy field/ironwood
9 July 2010
M. Richardson, C. Russell, S. Lee,
J. Fujimoto, and C. Campora

- Malaise trap (9–10 July)
- Pitfall traps (5) (9–10 July)
- Blacklight (night of 9 July)

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5.) Pagan, CNMI
Base of Mizri Cliff (megapode transect 1)
mixed native forest
10 July 2010
M. Richardson, C. Russell, S. Lee,
J. Fujimoto, and C. Campora

- Sweep netting
- General collecting

6.) Pagan, CNMI
Lake Sanhalom, West side (freshwater)
10 July 2010
M. Richardson, C. Russell, S. Lee,
J. Fujimoto, and C. Campora

- Sweep Netting
- General Collecting
- Aquatic Dip Netting
- Malaise trap (10–11 July)
- Pitfall traps (5) (10–11 July)
- Pan traps (5) (10–11 July)

7.) Pagan, CNMI
Trail South along Coast from Main Camp
(megapode transect #3) mixed native forest
11 July 2010
M. Richardson, C. Russell, J. Fujimoto,
S. Lee, and C. Campora

- Sweep netting
- general collecting

~~8.) Pagan, CNMI
Plateau above Mizri Cliffs
Savannah / non native
11 July 2010
M. Richardson, S. Lee, and C. Campora~~

~~- Sweep netting
- general collecting~~

9.) Pagan, CNMI
Bandeera Peninsula
11 July 2010
M. Richardson and S. Lee

- sweep netting
- general collecting

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10.) Pagan, CNMI
Trail south along coast from main camp – (Megapode transect 3) mixed native forest
12 July 2010
M. Richardson, C. Russell, S. Leo, J. Fujimoto, and C. Campora

- malaise trap (12-13 July)
- pitfall traps (5) (12-13 July)
- pan traps (5) (12-13 July)
- general collecting

11.) Pagan, CNMI
Plateau above Miari Cliff "Apansanmeena" – grassland or savannah
12 July 2010
M. Richardson, C. Campora, and S. Leo

- general collecting
- sweep netting

12.) Pagan, CNMI
Southern end of Island, south camp area (megapode transect #10)
13 July 2010
M. Richardson, C. Russell, S. Leo, J. Fujimoto, and C. Campora

- Malaise trap (13-14 July)
- blacklight (night of 13th)

13.) Pagan, CNMI
Southern end of island, upper plateau above camp area, Native Forest
13 July 2010
M. Richardson, C. Campora, and J. Fujimoto

- general collecting
- sweep netting

14.) Pagan, CNMI
Southern end of island, upper plateau, mixed native forest at base of cliff (megapode transect #11)
14 July 2010
C. Campora, J. Fujimoto, and C. Russell

- general collecting
- sweep netting

15.) Pagan, CNMI
Southern end of island, South volcano, forest inside caldera
14 July 2010
M. Richardson

- general collecting
- sweep netting

16) Pagan, CNMI
Bandeera Peninsula - coastal
15 July 2010
M. Richardson, C. Russell, J. Fujimoto, S. Lee, and C. Campora

- malaise trap (15-16 July)
- pan traps (5) (15-16 July)
- pitfall traps (5) (15-16 July)
- blacklight (night of 15 July)

17.) Pagan, CNMI
Ironwood forest bordering airfield
16 July 2010
C. Campora

- sweep netting

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18.) Pagan, CNMI
Lower main camp, near base of Miari cliff
16 July 2010
C. Campora

- blacklight

19.) Pagan, CNMI
Southern end of island, South Volcano, inside caldera
16 July 2010
M. Richardson, S. Lee, and J. Fujimoto

- malaise trap (16-17 July)
- blacklight (night of 16 July)
- general collecting
- sweep netting
- pitfall traps (5) (16-17 July)
- pan traps (5) (16-17 July)

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