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Host Range of the Newly Invasive Mealybug Species *Paracocccus Marginatus* Williams and Granara De Willink (Hemiptera: Pseudococcidae) in Two Ecological Zones of Ghana

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Abstract The papaya mealybug *Paracoccus marginatus* Williams and Granara De Willink (Hemiptera: Pseudococcidae) has a wide host range and great potential to cause damage to economically important fruits, vegetables, and ornamental plants. It has already caused serious damage to the papaya industry since it invaded Ghana lately in 2009. To determine the host range of this mealybug species, host plants were sampled in 3 districts in the Eastern region and Legon in the Greater Accra region of Ghana. A total of 50 plant species in 20 families were identified as host of *P. marginatus*, including economically important hosts such as *Carica papaya*, *Manihot esculenta*, *Mangifera indica*, *Solanum melongena Citrus sp* and *Theobroma cacao*. Favourite hosts included *Carica papaya, Manihot esculenta, Solanum melongena*, *hibiscus sp*, *Jathropha sp*, *Plumeria sp*, *Abutilon indicum* and *Adansonia digitata.* Three new families, Plumbaginaceae, Bombaceae, and Lythraceae and eight new plant species; *Launaea taraxacifolia*, *Euphorbia heterophylla*, *Codiacum variegatum*, *Codiacum aucubae-folium*, *Securinega virosa*, *Adansonia digitata*, *Lagerstroemia indica*, and *Plumbago auriculata* were identified as hosts of *P. marginatus. Paracoccus marginatus* was also found to co-exist with other mealybug species in some economically important host plants. The wide host range of *P. marginatus* calls for quick action to be taken in other to reduce its devastating impact on economically important food crops, fruits, and vegetables in Ghana and to prevent its spread to other African countries.

Keywords *Paracoccus marginatus,* Favourite Hosts, Wide Host Range, Eastern Region, Greater Accra Region, Ghana

1. Introduction

The Papaya mealybug *Paracoccus marginatus* Williams and Granara De Willink (Hemiptera: Pseudococcidae) is a native to Mexico and Central America[1,2]. It invaded Ghana lately in 2009[3]. Due to its invasion, about 85% of all papaya farms in the papaya growing regions which were under cultivation prior to *P. marginatus* invasion have been devastated thereby shrinking the papaya orchards from 2,500 ha to about 380 ha[4]. In other parts of the world, over 60 species of host plants including some economically important fruits, vegetables and ornamental plants have been recorded as hosts of *P. marginatus* in 22 plant families [1,2]. It is therefore important to study the host range of this mealybug species in Ghana, especially in the Eastern region where it has already caused serious damage to papaya production, and where mixed cropping is a common practice by most farmers.

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In the Eastern region of Ghana, most farmers practice mixed cropping with crops such as papaya, cassava, and maize which have all been reported as hosts of the papaya mealybug[5]. Several species of weeds have also been found to be hosts of the papaya mealybug[6]. During preliminary survey lately in June 2010 in the Eastern region of Ghana, several host plants were found to harbour mealybugs that look similar to the papaya mealybug. Interestingly, some of these host plants were found within papaya plantations. In Legon in the Greater Accra region, signs of *P. marginatus* infestation were also eminent.

Understanding of the host range of *P. marginatus*, would therefore help farmers to adopt good cultural practices such as exclusion of these alternative hosts within and around their farms. In addition, knowing the host range of the papaya mealybug, will aid in biological control by providing information on other alternative host plants to serve as targets. This study was therefore undertaken to establish the host range of *P. marginatus* in the Eastern and Greater Accra regions of Ghana.

2. Materials and Methods

2.1. Study Area

The study was carried out in the Eastern and Greater Accra regions of Ghana (Figure 1). The Eastern region lies in the forest zone, while most parts of Greater Accra are in the coastal savanna zone[7]. These two regions are involved in the commercial production of papaya[8], one of the major hosts of *P. marginatus*[1]. The temperature range of between 30 and 35 ℃ in February and March in these regions[7] is ideal for the development of *P. marginatus*[9]. The Eastern region is noted for its large scale cultivation of cash crops, stable food crops, fruits, and vegetables. Also found in the Eastern region are Botanical gardens such as the Aburi gardens. Greater Accra region on the other hand, is noted for its large scale production of horticultural crops[10]. The University of Ghana, Legon campus, for example, contain different types of ornamentals as well as other horticultural crops.

In the Eastern region, the study locations were Suhum-Kraboa-Coaltar, Akuapim South, and West Akim districts (Figure 1). At the Suhum-Kraboa-Coaltar district, the study was carried out at Kraboa and Amedi, while at the Akuapim South district, the study was carried out at Akraman and Nsawam areas. Adeiso was chosen as the study location for the West Akim district. In the Greater Accra region on the other hand, the study was carried out at the University of Ghana, Legon campus, Accra (Figure 1). Within the University, five sites were selected for host range studies. These were; the Botanical garden, University farm, Sinna Garden at the Department of Crop Science, Department of Animal Biology and Conservation Science (DABCS) and Department of Botany. These locations were selected based on the availability of ornamentals and other horticultural crops

Figure 1. Map of study regions and sites

2.2. Sampling and Sorting of Mealybugs and Associated Host Plants

The sampling of mealybugs and associated host plants was carried out from July 2010 to March 2011. In each of the selected sites in the two regions, a systematic sampling technique was used with focus on fruits, vegetables, and ornamental plants including weeds especially on sites located around papaya farms. For each selected plant, a 30 cm long twig was sampled including the reproductive parts in the case of flowering plants (since most mealybug species attack reproductive portions of plants and also to ease the identification of the different host plants) with the use of a sharp knife to prevent damage to the specimens. However, small plants were sampled whole. Each twig was placed in well labeled plastic paper bags containing a collection number, the locality, date of collection, name of collector and notes on the host plant and its habitat. Paper bags containing the different specimens were placed in a large and hard card box to prevent damage to plant parts and/or mealybug specimens and transferred to the ARPPIS laboratory for sorting.

Using a camel hair brush, mealybugs were brushed onto a counting tray, counted and recorded. Host plants with high abundance of > 30 adult females per sampling unit in repeated sampling were considered to be the most preferred host plants for *P. marginatus*. Random samples of mealybugs from the various host plants were later collected into well label vials containing 70% alcohol. Vials containing mealybugs from the same host plant were given the same label as that of the paper bag containing the host plant from which they were collected. All mealybug specimens were transferred to the insect Museum at DABCS, University of Ghana, Legon, while samples of the host plants were transferred to the Herbarium of the department of Botany, University of Ghana for identification.

2.3. Identification of Mealybugs and Associated Host Plants

The following materials were used in the mealybug identification process: alcohol series (70%, 80%, 95%, and absolute), potassium hydroxide (KOH) (10%), acetic acid, acid fusion, clove oil, Canada balsam, distilled water, glass microscope slides and cover glasses (slips). Using a sharp probe, a small incision was made on the side of the abdomen. Mealybug specimens were then cleared by heating in KOH (10%) and later wash-off using distilled water. The body contents were teased out with the help of a small spatula. The specimens were then passed through the following alcohol series; 80%, 95% and absolute alcohol (to remove left over wax) and later, to acetic acid for another 10 minutes. From acetic acid, specimens were soaked in acid fusion for 30 minutes, and then transferred in to clove oil. The specimens were later transferred on to slides and few drops of Canada balsam added. After completion of the mounting process under a dissecting microscope, the slides were dried on a slide warmer and later observed under a microscope. Morphological keys by Miller and Miller[6] were used to distinguish *P. marginatus* from other mealybug samples. This process of slide preparation for identification was carried out

only as a confirmation after using field characteristics, and color change after 24 hours in 70% alcohol as the initial stage in the identification process.

In the case of host plants, after taking photos of the fresh samples, the plant specimens were dried with a plant press using the method described by Bowles[11] and later identified in the Herbarium at the department of Botany, University of Ghana, Legon.

3. Results

3.1. Host Range of *P. Marginatus* in Akraman and Nsawam

A total of 29 plant species in 12 plant families were recorded to be host of *P. marginatus* in the Akraman and Nsawam areas (Table 1). Of the recorded plant species, 16 (55%) were vegetable, food and fruit crops, belonging to 9 plant families, while 8 (28%) were weeds or wild plants and the rest 5 (17%) were ornamental plants. The family Fabaceae or Leguminaceae recorded the highest numbers of host plants followed by Euphorbiaceae, Solanaceae and Malvaceae, respectively.

3.2. Host Range of *P. Marginatus* in Krabo and Amedi

In Krabo and Amedi, 26 plant species representing 12 plant families were recorded as hosts of *P. marginatus* (Table 2). Of these, 15 (58 %) were vegetable, fruit and food crops, 7 (27 %) were weeds and the rest 15 % ornamental plants. The highest number of host plants were recorded in the family Solanaceae followed by Euphorbiaceae and Malvaceae.

3.3. Host Range of *P. Marginatus* at Adeiso in the South Akim District

At Adeiso, a total of 20 plant species in 8 plant families were recorded as hosts (Table 3). There were 8 individual species of weed hosts (40%), and 8 hosts which were vegetable, fruit and food crops (40%) and four ornamental plants (20%). The highest numbers of host plants were recorded in the family Euphorbiaceae, followed by Malvaceae and Solanaceae. The rest of the families had less than three host plants.

3.4. Host Range of *P. Marginatus* at Legon in the Greater Accra Region

A total of 39 plant species comprising 16 plant families were recorded (Table 4). Of these, 19 (48.7 %), were ornamental plants, 13 (33.3 %) vegetable, fruit and food crops and 7 (18 %), weeds and wild plants. The family Euphorbiaceae, recorded the highest number of host plants, followed by the family Malvaceae, Leguminaceae or Fabaceae, Apocynaceae and Malvaceae, respectively. The rest of the families had just one or two representatives.

Table 1. Host plants and associated families for *P. marginatus* at Akraman and Nsawam

Family	Scientific name	Common name	Host plant category
Caricaceae	**Carica papaya*	Papaya, pawpaw	Fruit crop
Anacardiaceae	*Mangifera indica*	Mango	Fruit crop
Apocynaceae	**Plumeria alba*	Wild frangipani, White Plumeria	Ornamental
	**Plumeria rubra*	Frangipani, Red Plumeria	Ornamental
Euphorbiaceae	**Manihot esculenta*	Cassava	Food crop
	**Jatropha curcus*	Jatropha	Ornamental
	Euphorbia hirta	Asthma weed, cats hair	Weed
	Euphorbia heterophylla	Fire plant, painted euphorbia	Weed
	Hura crepitans	Sandbox tree,	Ornamental
Asteraceae	*Wedelia trilobata*	Weed	Weed
Convolvulaceae	*Ipomoea batatas*	Sweet potatoes	Food crop
Leguminaceae /Fabaceae	*Cajanus cajan*	Pigeon pea	Food crop
	Glyricidia sepium	Cacao shade	Ornamental
	Phaseolus vulgaris	Broad beans	Food crop
	Vigna ungiculata	Cowpea	Food crop
	Arachis hypogaea	Groundnuts	Food crop
	Phaseolus atropurpureus	Bean, French bean,	weed
Malvaceae	*Abelmoschus esculentus*	Okro or Okra	Vegetable crop
	**Abutilon indicum*	Country-mallow	Weed
	Sida sp.	Sida	Weed
Solanaceae	*Capsicum annum*	Sweet pepper	Vegetable crop
	Capsicum fructescens	Chili pepper	Vegetable crop
	Lycopersicon esculentum	Tomato	Vegetable crop
	**Solanum melongena*	Egg plant	Vegetable crop
Compositae	*Tridax procumbens*	Coat buttons, tridax daisy	Weed
	Launaea taraxacifolia	Wild lettuce	Weed
Cucurbitaceae	*Luffa cylindrical*	Pumkin	Vegetable crop
	Curcubita sp	Pumpkin, Squash	Vegetable crop
Rutaceae	*Citrus* sp.	Citrus	Fruit crop

Major host plants *Host range of* P. marginatus *in Krabo and Amedi

Table 2. Host plants and associated families for *P. marginatus* at Krabo and Ameidi areas

Family	Scientific name	Common name	Host plant category
Caricaceae	**Carica papaya*	Pawpaw, papaya	Fruit crop
Anacardiaceae	*Mangifera indica*	Mango	Fruit crop
Euphorbiaceae	*Euphorbia hirta*	Asthma weed, cats hair	weed
	**Jatropha curcus*	Jatropha	Ornamental
	Hura crepitans	Sandbox tree	Ornamental
	Euphorbia heterophylla	Fire plant, painted euphorbia	Weed
	Manihot esculenta	Cassava	Food crop
Apocynaceae	**Plumeria rubra*	Frangipani, Red Plumeria	Ornamental
	**Plumeria alba*	Wild frangipani, White Plumeria	Ornamental
Convolvulaceae	*Ipomoea batatas*	Sweet potatoes	Food crop
	Ipomoea sp.	Morning glory	weed
Leguminaceae /Fabaceae	*Phaseolus vulgaris*	Broad beans	Food crop
	Vigna ungiculata	Cowpea, rope bean	Food crop
Malvaceae	*Abelmoschus esculentus*	Okro or Okra	Vegetable
	**Abutilon indicum* .	Country-mallow	Weed
	Sida sp.	Sida	Weed
Solanaceae	*Capsicum annum*	Sweet pepper	Vegetable crop
	Capsicum fructescens	Chili pepper	Vegetable
	L. esculentum	Tomato	Vegetable
	**Solanum melongena*	Egg plant	Vegetable
	Solanaum torvum	Turkey berry	Vegetable
Compositae	*Tridax procumbens*	Tridex	Weed
	Launaea taraxacifolia	Wild lettuce	Weed
Cucurbitaceae	*Curcubita* sp.	Pumkin	Vegetable crop
Lauraceae	*Persea Americana*	Pear or Avocado	Fruit crop
Sterculiaceae	*Theobroma cacao*	Cocoa	Tree crop

***Major host plants**

Table 3. Host plants and associated families for *P. marginatus* at Adeiso

Family	Scientific name	Common name	Host plant category
Caricaceae	**Carica papaya*	Papaya, pawpaw	Fruit crop
Euphorbiaceae	*Euphorbia heterophylla*	Fire plant, painted euphorbia	Weed
	Euphorbia hirta	Asthma weed, cats hair	Weed
	**Jatropha curcus*	Jatropha	Ornamental
	Hura crepitans	Sandbox tree	Ornamental
	Manihot esculenta	Cassava	Food crop
Apocynaceae	**Plumeria rubra*	Frangipani, Red Plumeria	Ornamental
	**Plumeria alba*	Wild frangipani, White Plumeria	Ornamental
Convolvulaceae	*Ipomoea batatas*	Sweet potatoes	Food crop
	Ipomoea sp.	Morning glory	Weed
Malvaceae	*Abelmoschus esculentus*	Okro or Okra	Vegetable crop
	**Abutilon indicum*	Country-mallow	Weed
	Sida sp.	Sida	Weed
Solanaceae	*Lycopersicon esculentum*	Tomato	Vegetable crop
	**Solanum melongena*	Egg plant	Vegetable crop
	Solanaum torvum	Turkey berry	Vegetable crop
Compositae	*Tridax procumbens*	Tridex	Weed
	Launaea taraxacifolia	Wild lettuce	Weed
Cucurbitaceae	*Luffa cylindrical*	Sponge gourds	Vegetable crop
	Phaseolus atropurpureus	Purple bean, bean	weed

***Major host plant Host range of *P. marginatus* at Legon in the Greater Accra region of Ghana**

Table 4. Host plants and associated families for *P. marginatus* at Legon, University of Ghana campus

Family	Scientific name	Common name	Host plant category
Caricaceae	**Carica papaya*	Papaya, pawpaw	Fruit crop
Euphorbiaceae	*Codiaeum variegatum*	Croton	Ornamental
	Codiaeum punctatum	Regular gold dust croton	Ornamental
	Euphorbia heterophylla	Fire plant, painted euphorbia	Weed
	Cadiacum aucubaefolium	Croton plant	Ornamental
	Acalypha wilkensiana	copperleaf	Ornamental
	Euphorbia hirta	Asthma weed, cats hair	Weed
	**Jatropha multifida*	Jatropha, coralbush	Ornamental
	**Jatropha curcus*	Jatropha	Ornamental
	Hura crepitans	Sandbox tree	Ornamental
	Securinega virosa	Common bush weed	Ornamental
	Euphorbia milli	Christ's thorn	Ornamental
Apocynaceae	**Plumeria rubra*	Frangipani, Red Plumeria	Ornamental
	**Plumeria alba*	Wild frangipani, White Plumeria	Ornamental
	Nerium oleander	Rose bay	Ornamental
	Allamanda cathartica	Golden trumpet	Ornamental
Anacardiaceae	*Mangifera indica*	Mango	Fruit crop
Annonaceae	*Annona* sp.	Custard apple	Fruit crop
Convolvulaceae	*Ipomoea batatas*	Sweet potatoes	Food crop
Leguminaceae /Fabaceae	*Cajanus cajan*	Pigeon pea	Food crop
	Cassia sp.	Golden shower	Ornamental
	Gliricidia sepium	Gliricidia	Ornamental
	Phaseolus vulgaris	Broad beans	Food crop
Malvaceae	*Abelmoschus esculentus*	Okro or Okra	Vegetable crop
	**Hibiscus rosa sinensis*	Hibiscus, China rose	Ornamental
	**Abutilon indicum*	Country-mallow	Weed
	Sida sp.	Sida	Weed
	**Malvaviscus penduliflorus*	Sleeping hibiscus, sleepy mallow	Ornamental
Solanaceae	*Capsicum fructescens*	Chili pepper	Vegetable crop
	Lycopersicon esculentum	Tomato	Vegetable crop
	**Solanum melongena*	Egg plant	Vegetable
Lamiaceae	*Ocimum sanctum*	Holy Basil	Vegetable
Compositae	*Launaea taraxacifolia*	Wild lettuce	Weed
Cucurbitaceae	*Luffa cylindrical*	Sponge gourds	Vegetable crop
	Phaseolus atropurpureus	Purple bean, bean	weed
Lauraceae	*Persea Americana*	Pear	Fruit crop
Bombacacea	**Adansonia digitata*	baobab	Wild plant
Lythraceae	*Lagerstroemia indica*	Crape myrtle	Ornamental
Plumbaginaceae	*Plumbago auriculata*	Cape leadwort	Ornamental

***Major host plants**

3.5. Occurrence of *P. Marginatus* with other Mealybug Species on Some Economic Host Plants

Data on host range studies revealed the co-existence of *P. marginatus* and other mealybug species such as *Pseudococcus longispinus* (Targioni Tozzetti), *Phenacoccus solani* Ferri, *Rastrococcus invadens* (Green), *Phenacoccus manihoti* Matile-Ferrero, and *Ferrisia virgata* (Cockerell) on some important economic crops (Table 5).

4. Discussion

The large host range of *P. marginatus* at Legon relative to the other sampling sites was probably due to the large number of diverse ornamental plants, which were also recorded as the highest category of host plants in this location. The highest number of vegetable, fruits and food crops serving as host for *P. marginatus* was recorded in the three districts in the Eastern region of Ghana. The above results were expected since the Eastern region of Ghana is noted for its large scale production of agricultural crops, and Legon for its diverse ornamental plants[7,10]. Overall, four families namely; Euphorbiaceae, Solanaceae, Malvaceae, and Fabaceae or Leguminaceae were found to contain the largest number of host plants. This confirms the findings of several host range studies of *P. marginatus*[6,12-15]. In Legon, the position of the Solanaceae family was taken over by the family Apocynaceae, with host plants entirely ornamental as opposed to the family Solanaceae which was made up of food crops such as egg plants, tomatoes and sweet pepper. In

all the sampling sites in the two regions, the family Euphorbiaceae emerged as the family with the highest number of host plants. Many species of this family are known to produce milky sap containing latex[16]. The family Apocynaceae is also known to contain many latex producing plants[17]. Besides members of these two families, many other plants identified as hosts of *P. marginatus* were latex containing plants. Examples include *C. papaya*, *A. digitata, I. batatas*, and *M. indica*. The host preference of *P. marginatus* thus seems to be influenced by the presence of latex.

Table 5. Association of P.marginatus and other mealybug species on some economically important host plants

Host plant	Mealybug species	Common name
Papaya	*P. marginatus*	PM
	P. solani	SM
	P. longispinus	LM
Cassava	*P. marginatus*	PM
	P. manihoti	CM
Mango	*P. marginatus*	PM
	R. invadens	MM
	P. longispinus	LM
Pear (Avocado)	*P. marginatus*	PM
	F. virgata	-
Plumeria sp	*P. marginatus*	PM
	R. invadens	MM
	F. virgata	-
	P. longispinus	LM
Tomato	*P. marginatus*	PM
	P. longispinus	LM
Nerium oleander	*P. marginatus*	PM
	R. invadens	MM
	P. longispinus	LM
Cocoa	*P. marginatus*	PM
	P. longispinus	LM

PM = Papaya mealybug, LM = Longtail mealybug, MM = Mango mealybug, SM = Solanum mealybug, CM = Cassava mealybug

In general, a total of 50 host plants in 20 families were identified as host of the polyphagous *P. marginatus.* Earlier studies by Owusu *et al*.[18] reported over 25 and 26 plants in the Greater Accra and Eastern regions respectively as hosts of mealybugs, with *P. marginatus* being the most common mealybug species in these locations. However, studies elsewhere have reported *P. marginatus* to have a host range of over 60 species of host plants, in over 25 families[1,6]. The reason for the low number of host plants, might be that *P. marginatus* was recently introduced in Ghana and is yet to established itself on other plant species. The host range is likely to increase with increase plant diversity and with time after invasion of an area as *P. marginatus* become more established. Three families; Plumbaginaceae, Bombaceae, and Lythraceae which were found to contain host plants of *P. marginatus*, were not found in the literature reviewed. Host plants not also listed in literature but which were found during this study include; *Launaea taraxacifolia*, *Euphorbia heterophylla*, *Codiacum variegatum*, *Codiacum aucubaefolium*, *Securinega virosa*, *Adansonia digitata*, *Lagerstroemia indica*, and *Plumbago auriculata*.

Results on host preference revealed the following host plants as preferred hosts of *P. marginatus; C. papaya*, *Plumeria sp*, *S. melongena, J. curcus and J. Multifida, A. digitata, A. indicum, M. esculenta and Hibiscus sp.* Meyerdirk *et al*.[1] listed *C. papaya* and *P. hysterophorus*, while Muniappan *et al*.[2] reported on *Euphorbia sp*, *M. esculenta*, *I. batatas* and *C. papaya* as being suitable hosts. Caraphin News[13] listed *Jatropha sp*., *Acalypha* sp., *Hibiscus* sp. and *A. muricata* as being suitable hosts.

The findings of this study are vital in term of the management of *P. marginatus* using Integrated Pest Management (IPM) practices. *Abutilon indicum* found to be a major host plant of *P. marginatus*, is a weed, while *A. digitata* is a wild plant. *Jatropha* sp. is a common plant in the Eastern region of Ghana used to demarcate boundaries, while *M. esculenta* is one of the major staple food crops and *Plumeria sp*. is commonly used as a shade in grave yards. This therefore means weed control alone will not be enough as a control measure for *P. marginatus*. Since *M. esculenta* is one of the suitable hosts of *P. marginatus*, then rapid action is needed to preserve this important staple food crop and to prevent farmers from using chemical control which may eliminate the already present parasitoid, *Apoanagyrus* (*Epidinocarsis*) *lopezi* introduced in the 1990's against the cassava mealybug, *P. manihorti*[19]. Biological control of pests on all the major host plants therefore remains the best option.

The co-existence of *P. marginatus* with other mealybug species implies biological control focused only on *P. marginatus,* might not be the solution. However, most of the other species did not occur on high densities in most of the host plants as *P. marginatus* since they probably might have established associated natural enemies. This is in line with Owusu *et al*.[18] who reported high mean occurrences of *P. marginatus* compared with other mealybug species in both the Eastern and Greater Accra regions of Ghana.

5. Conclusions

Paracoccus *marginatus*, was found to have a wide host range of over 50 species of host plants in 20 families including economically important fruits, vegetables, and ornamental plants as well as weed host. Three new families; Plumbaginaceae, Bombaceae, and Lythraceae and eight new plant species; *Launaea taraxacifolia*, *Euphorbia heterophylla*, *Codiacum variegatum*, *Codiacum aucubaefolium*, *Securinega virosa*, *Adansonia digitata*, *Lagerstroemia indica*, and *Plumbago auriculata* were identified. The host range was thought to be influenced by the presence of latex and it is likely to increase with time as *P. marginatus* become more established.

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