Entomological research status and perspective in the Caribbean Basin[1]

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ABSTRACT

The Caribbean Basin provides ample opportunity for entomological research. This study used literature reviews, metadata analysis and a survey to understand the dynamics and characteristics of published entomological research in the region. A literature review of the last 10 years of Caribbean entomological research demonstrated the influence of external funds and scientists, with most published research being done in collaboration with scientists outside of the Caribbean. Using metadata analysis from country-specific searches, it was possible to deduce research themes for each country, and while there were a lot of similarities such as work on mosquito-borne diseases, there were also differences. In terms of key areas of research, those relating to biological systematics and pest control were the most important. Agricultural entomology research was limited to only 17% of the articles. A 100-year review of Puerto Rican entomology research corroborated the relative decline in published agricultural entomology research. Agriculture and agricultural research remain important in the region but limited amounts of agricultural entomology research are being published in scientific journals. Reasons for this are given and the opportunities of alternative dissemination mechanisms such as ResearchGate and Google Scholar are discussed.

Key words: Caribbean, entomology, research, publications, metadata

RESUMEN

Estado de la investigación entomológica y perspectivas en la Cuenca del Caribe

La Cuenca del Caribe provee muchas oportunidades para la investigación entomológica. Este estudio utiliza una revisión de literatura, un análisis de metadatos y una encuesta para entender la dinámica y las características de la investigación entomológica publicada en la región. La revisión de la literatura de los últimos 10 años de investigación entomológica en el Caribe demuestra la influencia de fondos externos y científicos del exterior; la mayoría de las investigaciones publicadas se hicieron en colaboración con científicos de fuera del Caribe. Con el uso de análisis de metadatos de búsquedas específicas por país, fue posible deducir los temas de investigación por país y aunque hay muchas similitudes, como el trabajo relacionado a enfermedades causadas por mosquitos, también

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hay diferencias. En términos de áreas claves de investigación, las más importantes son las relacionadas a sistemática biológica y control de plagas. La investigación entomológica agrícola se limita a solo un 17% de los artículos. La revisión de 100 años de investigación entomológica en Puerto Rico confirma la disminución relativa en investigación entomológica agrícola publicada. La agricultura y la investigación agrícola siguen siendo importantes en la región, pero se están publicando cantidades limitadas de investigaciones entomológicas agrícolas en revistas científicas. Se discuten las razones y oportunidades para utilizar mecanismos de diseminación alternativos tales como ResearchGate y Google Scholar.

Palabras clave: Caribe, entomología, investigación, publicaciones, metadatos

INTRODUCTION

The Caribbean region is characterized by island states with cultural, political and historical ties to Europe and to the United States of America. These geographical and sociopolitical realities have generated various research groupings and linkages within the Caribbean and beyond. These connections and spheres of influence have affected what research is conducted and how the resulting information is disseminated. The divisions are augmented by differences in language and in relationships with former colonial powers.

There are many important areas of entomological research in the Caribbean. This region is one of the world's hotspots for biodiversity and endemism due to the biogeography of island chains, physical diversity and tropical location (Helmer et al., 2002). It is also a region that has suffered environmental degradation and the influx of invasive species (Anadón-Irizarry et al., 2012). The production of sugarcane and other plantation crops by colonial powers has also had a great effect on entomological research in the region (McCook, 2002). From the middle of the 17th century to mid-20th century, the Caribbean was a world leader in sugar production. Such a concentrated production of one crop inevitably led to pest problems and this necessitated the establishment of crop protection research programs. The Caribbean colonies also made efforts to contend with insects detrimental to human and animal health (McNeill, 2010). Biting flies, which included mosquitoes, drove them to commit research resources to understand how to reduce the impact of these insects. In addition to Caribbean-specific research related to regional biodiversity, agriculture and human health issues, it should be recognized that the region also has some world-class universities that do a wide range of basic entomological research not necessarily specific to the Caribbean.

How does one evaluate the status of entomological research in the Caribbean? Due to the nature of the region, there are inherent chal-

lenges because of the fragmented nature of research activities and barriers to broad dissemination of results. Online academic databases and the application of metadata have helped greatly in making published work accessible and searchable, although not all research is found in academic databases. Where else can research output from the Caribbean be found and do these alternative dissemination methods capture all of the entomological research being generated in various institutions around the region?

Determining the time period for the review of entomological research in the Caribbean is not straightforward. Formal research has been going on in the Caribbean for hundreds of years but what time period reflects contemporary entomological research? Definitely, the Caribbean is in a post-sugarcane research environment after the industry largely collapsed in the middle of the 20st century (Mitchell, 2005). Are we also in a post-agricultural environment as imports from the United States increase (Ford et al., 2007; Walters and Jones, 2012) and as trade agreements with Europe are terminated (Clegg, 2005; Trotman et al., 2009)?

In determining influences on current research interests, one not only has to consider the current landscape but also the tools available to examine this landscape. In the last 10 to 20 years, huge advances have been made in molecular biology techniques (e.g., use of polymerase chain reaction) and the capacity and analytical power of computers. These advances have given a boost to molecular systematics, which has led to increased research in this field and renewed interest in the world's biodiversity hotspots such as the Caribbean. To help understand the influence of changes in research landscape and tools, Puerto Rico was used as a case study to see how these changes may have impacted entomological research going back 100 years.

MATERIALS AND METHODS

Caribbean Region Literature Review

The Academic Search Complete collection of databases accessed through the library of the Agricultural Experiment Station, University of Puerto Rico, was used to conduct a literature review of the last 10 years of entomological research in the Caribbean. The literature review was designed to capture as many fields of entomological research as possible, specifically looking at biological, agricultural and medical research. The specific databases within Academic Search Complete that were selected for this review are Agricola; Academic Search Complete; Environment Index; Fuente Académica; MasterFILE Premier; MEDLINE; GreenFILE; Library, Information Science & Technology

Abstracts; Readers' Guide Full Text Mega (H.W. Wilson); Library Literature & Information Science Full Text (H.W. Wilson); General Science Full Text (H.W. Wilson); Applied Science & Technology Full Text (H.W. Wilson); Biological & Agricultural Index Plus (H.W. Wilson); and Social Sciences Full Text (H.W. Wilson).

The period of search was from January 2006 to December 2015 and it was restricted to peer-reviewed journals. Boolean search terms were used and the options of applying equivalent subjects and relevant words were selected. The search terms for the Caribbean-wide review were **'(entomology OR insects) AND (Caribbean OR "West Indies")'**. A test review was also done using the French, Spanish and Dutch equivalent of these words (e.g., *Caribe* and *entomologie*). Only a few additional papers were revealed using the Spanish terms, but all were from Colombia and were discarded for the purpose of this review.

All resulting scientific papers generated by the search were reviewed. Only papers where actual research had been conducted in the Caribbean were considered. This excluded work done in Central America, Mexico and the Gulf Coast of the United States of America (including Florida). It also excluded South America apart from French Guiana, Suriname and Guyana, which are generally considered part of the Caribbean. The selected papers were assessed to determine the research topic, the language, the authors' nationalities and the funding sources. The research topic of the paper was categorized using the broad categories of 'ecosystem studies,' 'pest control,' 'pure biology' or 'systematics.' Pest control included agricultural, medical and urban entomology research. An additional filtering of the papers was done to identify those that were specifically agricultural in nature or those that covered the topic of invasive species.

Country Specific Literature Review Using Metadata

To review entomological research specific to a country, changes were made to the search terms. The **'(Caribbean OR "West Indies")'** search term was replaced by the names of specific countries, including the Spanish or French versions (e.g., **"French Guiana" OR Guyane**). In addition, shortened versions of a country were also used (e.g., **"United States Virgin Islands" OR "U.S. Virgin Islands" OR "US Virgin Islands" OR USVI**). No other changes were made to the parameters of the literature search. Due to time constraints, the individual scientific papers generated by the literature reviews were not evaluated in the same way as the regional study. Instead, accompanying metadata was used (Thesaurus, Subject, Publication and Language metadata) to determine the papers' topics. From this, major research themes were deduced for each country.

In addition to the country-specific review of Academic Search Complete, the same search terms were used to look for country-specific research papers using ResearchGate. This review was done to establish a point of reference for the Academic Search Complete search and to examine whether this scientific social network was being adopted by countries in the Caribbean.

Historical Review of Puerto Rican Entomological Research

This review was conducted using Google Scholar, which offered greater availability of older entomological publications than either Academic Search Complete or ResearchGate. Not all of the results generated by the search were research documents; also included were published field observations and technical reports. The last hundred years were divided into four time periods starting from 1916. Each time period consisted of 25 years. The search term used for the review was **'(entomology or insects) AND "Puerto Rico"'** and the search was limited to articles and did not include citations or patents. The results were then sorted by relevance. A random number generator in Excel was used to randomly extract three articles from each of the first 10 pages to produce a total of 30 articles. The articles were categorized by research topic using the four aforementioned topics (ecosystem studies, pest control, pure biology or systematics). The papers were also categorized according to research concern: agriculture, invasive species, human or animal health, sugarcane insects or forest biology.

Assessment of the State of Agriculture

In trying to determine the influence of Caribbean agriculture on the amount of agricultural entomology research being conducted, a review was made of agricultural production in the Caribbean. This was done using FAOSTAT (FAO, 2013), where only the island states of the Caribbean were included. The production figures of the most important crops of the Caribbean were compared with production of those crops in Mexico and those in the state of Florida, USA. The data for Mexico came from FAOSTAT while the data for Florida came from Florida Department of Agriculture and Consumer Services (USDA NASS 2013). Additionally, data from Cuba was extracted from the Caribbean data to get a sense of agricultural production from the largest island in the region.

Online Survey and Questionnaire to Assess Research Output and Dissemination of Results

An online review of all the Caribbean institutions likely to have a mandate to conduct agricultural entomology research was made. This

was done to get an estimate of the number of agricultural research institutions in the region and to compare this with the number of agricultural entomology papers found in the literature search.

In support of the online survey, a questionnaire was sent out to 28 regional entomologists. The questionnaire was designed to gather information on the types of research being conducted in the region, the opportunities and constraints, the influence of researchers outside the region, levels of collaboration, and ease of disseminating or collecting research data from the region. To facilitate the survey, the questionnaire was shared using the online survey website, Survey Monkey.

RESULTS AND DISCUSSION

Regional Literature Review

The search of Academic Search Complete databases returned a total of 308 scientific papers. An initial review indicated that only 117 were based on research conducted in the Caribbean; 113 of these were in English while four were published in Spanish. Of the 117 papers, 40% presented research in the field of systematics while 38% presented research in pest control, 12% in pure biology and 10% in ecosystem studies. The pest control work was evenly divided between agricultural and human or animal health studies. When assessed in terms of agricultural research, only 17% of the papers presented research in this area; 12% focused on invasive pest species.

The 117 papers were published in a total of 64 journals with the five most popular journals being Zookeys (13 papers), Florida Entomologist (9), Acta Tropica (8), Medical & Veterinary Entomology (7) and Evolution (4). Four of the nine papers in Florida Entomologist concerned research on invasive insect species.

Authors came from a total of 37 countries (the ten most common are shown in Table 1) with the United States dominating the ranks, especially in terms of first authors. Fifty-three percent of the papers had at least one Caribbean author and 14% had Caribbean authors only, which means that 86% of the published research was done in collaboration with international scientists. Exclusive collaboration between Caribbean countries (i.e., no international authors) was only found in 3% of the published work. European authors were involved in 32% of the papers, and these were published in collaboration with Caribbean authors in 58% of the cases. North American authors were involved in a higher percentage of papers (60%) but the level of collaboration with Caribbean authors was lower (23%).

In terms of funding, 47% of all published research was funded exclusively by the United States of America. An additional 20% of the

TABLE 1.—*Ten most common authors' countries of origin.*

Countries	Number of Papers[1]	
	Total (%)	First Author (%)
United States of America	63 (54%)	57 (49%)
Trinidad and Tobago	23 (20%)	11 (9%)
France	14 (12%)	6 (5%)
Cuba	10 (9%)	7 (6%)
Austria	9 (8%)	7 (6%)
Canada	7 (6%)	4 (3%)
United Kingdom	7 (6%)	4 (3%)
Martinique	7 (6%)	1 (1%)
Germany	5 (4%)	4 (3%)
Puerto Rico	5 (4%)	3 (2%)

[1]Some of the papers had authors from multiple countries.

research was partially funded by the USA. The next highest source of funding came from Europe where 23% of the research was at least partially funded (14% with European funds exclusively). Caribbean funds were used in 16% of the published research (9% with only Caribbean funding). Another significant source of funding came from international institutions such as the International Atomic Energy Agency. These institutions contributed funds to 18% of the published research.

There is no denying the importance of the United States of America to published research in the Caribbean during the last 10 years. Researchers from the USA collaborated in 60% of all published work and exclusively authored 44% of the 117 papers. Funding followed this trend. European scientists were also active in the region's entomological research, with most of their research done in collaboration with Caribbean scientists. There was very little collaboration between Caribbean countries when international researchers were not involved.

In terms of selected topics, biological systematics and pest control were the main areas of research with these two topics accounting for nearly 80% of the papers. Biological systematics at 40%, was a slightly more popular research topic than pest control (38%). This changes when you separate the papers into those with a Caribbean author and those without. When a Caribbean author is involved, 75% of the papers present research on pest control matters and only 21% on biological systematics. This is reversed when there are no Caribbean authors; only 25% concern pest control while 61% document systematic research. From this set of results, it shows that Caribbean researchers are far more likely to dedicate efforts to solving pest problems than to study speciation and diversity.

International interest in conducting research in the Caribbean provides an opportunity to support local scientists and their research

programs. For example, when the Pink Hibiscus Mealybug, *Maconellicoccus hirsutus* (Green), arrived in the Caribbean, USDA APHIS sent scientists to help control the pest species, and the Eastern Caribbean received two years of training and technical assistance on this insect and its control. Fostering connections with international scientists aligned with local research interests can be of great benefit but should be managed so that it can provide maximum benefit to all. For engagement with foreign scientists, universities and research stations could develop protocols such as ensuring that duplicate specimens are deposited in local collections. Fast tracking of paperwork and facilitation of lodging and transport could also benefit international scientists.

Country Specific Literature Searches and Use of Metadata to Analyze the Results

When the same search of the Academic Search Complete databases is conducted using the names of specific countries rather than "Caribbean" or "West Indies," a greater number of total publications appear. In terms of quantity, Cuba generated the highest number of scientific papers by a considerable margin (Table 2). The four countries with the highest number of publications were Cuba, Puerto Rico, French Guiana and Trinidad, accounting for 79% of all papers found. When the same search was conducted using ResearchGate, fewer papers were found but the same four countries dominated output. Cuba's contribution to the number of ResearchGate publications dropped significantly in comparison to the Academic Search Complete publications, which indicates that Cuba's adoption of ResearchGate has not been as high as in other countries.

In terms of languages, 70% of the papers were in English and 30% in Spanish. For all countries other than Cuba, English was by far the dominant language. This was the reverse in Cuba where two-thirds of the papers were in Spanish, a reflection of the number of scientific journals published in that country.

The search results were also examined using two metadata categories – Subject and Thesaurus. The Subject classification presents key words and the Thesaurus classification includes other relevant words describing the research. This analysis is descriptive in nature and can be used to identify research themes of a country. For example, when looking at the search results for papers where Puerto Rico is cited, the most common Subject words are "Insects," "Population biology," "Rain forests," "Fall armyworm," "Food chains (ecology)," "Hurricanes," "Arthropoda." "Insect genetics," "Insects – adaptation" and "Plant canopies." The most common Thesaurus words are "Fall armyworm," "Honeybees," "Dengue viruses," "Lepidoptera," "*Aedes aegypti,*" "Phy-

TABLE 2.—*Number of papers naming specific Caribbean countries.*

		Number (%)				Number (%)	
Rank	Country	Academic Search Complete	Research Gate	Rank	Country	Academic Search Complete	Research Gate
1	Cuba	537 (41%)	109 (21%)	7	Guyana	40 (3%)	34 (7%)
2	Puerto Rico	240 (18%)	99 (19%)	8	Guadeloupe	37 (3%)	15 (3%)
3	French Guiana	149 (11%)	72 (14%)	9	Martinique	29 (2%)	6 (1%)
4	Trinidad	115 (9%)	73 (14%)	10	Suriname	17 (1%)	17 (3%)
5	Jamaica	78 (6%)	37 (7%)	11	U.S. Virgin Islands	10 (1%)	13 (3%)
6	Dominican Republic	62 (5%)	22 (4%)	12	Haiti	9 (1%)	11 (2%)

logeny," *"Bacillus thuringiensis,"* "Beetles; Evolution (biology)" and "Habitat (ecology)." From these, one can surmise that the main themes of published research in the last ten years in Puerto Rico are ecosystem studies, Mosquito-borne diseases, systematics, honeybees and Bt resistance in fall armyworm. Table 3 presents the research themes for 12 Caribbean countries cited in the research papers unearthed by the database search.

Table 3 highlights the fact that many countries share the same research priorities. Mosquito-borne diseases, studies into systematics, and agriculture are themes that emerge for most countries. Having said that, individual countries do show differences in what research gets conducted. In French Guyana, for example, most of the research focuses on rainforest ecosystem studies. Jamaica hosts a lot of research on the coffee berry borer and Trinidad & Tobago is an important center for work on mosquito-borne diseases. Much of this has to do with the interests of scientists in these countries and prolific scientists can greatly influence the published output of a country. Dr. Dave Chadee from the University of the West Indies in Trinidad specializes in mosquito-borne disease research, and of the 23 scientific papers from Trinidad and Tobago identified in the regional search, 17 had his name on them. In the case of Cuba, agricultural entomology is a major research theme and the island has at least eight agricultural research journals.

Puerto Rican Historical Case Study

Puerto Rico has a long entomology research tradition with an extensive body of work stretching back more than 100 years. This study went back to 1916 and tracked the evolution of published entomolo-

TABLE 3.—*Country specific research themes over the last 10 years.*

Country	Research Themes
Cuba	Agriculture, Biological control, Mosquito-borne diseases
Puerto Rico	Ecosystem studies, Mosquito-borne diseases, Systematics, Honeybees, Bt resistance in fall armyworm
French Guiana	Ecosystem studies, Ants, Rainforest studies
Trinidad & Tobago	Mosquito-borne diseases
Jamaica	Control of Coffee Berry Borer, Systematics
Dominican Republic	Systematics, Orchid bees & other insects found in amber
Guyana	Ecosystem studies, Systematics, Rainforest studies
Guadeloupe	Mosquito-borne diseases, Agriculture, Ecological studies
Martinique	Mosquito-borne diseases, Agriculture (bananas)
Suriname	No clear themes
U.S. Virgin Islands	Ecology of termites
Haiti	Study of longhorn beetles (Cerambycidae), Mosquito-borne diseases

gy research. Much has changed over the last 100 years, not least the length and complexity of the article titles. 'Cotton Insects in Porto Rico' was published in 1920 while 'Population genetics with RAPD–PCR markers: the breeding structure of *Aedes aegypti* in Puerto Rico' was published 76 years later. At the beginning of the last century, the published work included general economic entomology field reports; descriptions of new species; and newly developed research or control methodologies. As time progressed, research became more focused and utilized a greater range of tools.

Table 4 shows the shift in research topics over the last 100 years. From 1916 to 1940, 83% of all research articles were concerned with pest control. In the last 25 years, this percentage has dropped to 60%. Systematics, on the other hand, has grown, and over the last 50 years exceeded 20% of all published work (e.g., Segarra et al., 2014; Segarra-Carmona et al., 2014). In terms of agricultural entomology research, there has been a decline in the last hundred years. From 1916 to 1940, three quarters of the papers presented agricultural entomology research with 32% on sugarcane pests. In the last 25 years, less than half the articles were concerned with agricultural entomology. The topic of invasive species, on the other hand, has become a more important research topic (e.g., Estévez de Jensen et al., 2006; Klassen et al., 2006); 17% of the papers in the last 25 years have presented research on this topic. Health-related topics have remained important over the years, representing at least 20% of all entomology papers published in the last 75 years.

Decline of Agriculture and Agricultural Research?

In the initial regional literature review, agricultural entomology research papers only represented 17% of the papers found. This relative lack of importance was not always the case as shown in the historical review of Puerto Rican literature. Is the decline in published agricultural entomology research linked to a decline in agriculture in the region? Certainly there has been a significant decline in plantation crops such as sugarcane or bananas, and domestic food production has al-

TABLE 4.—*Relative frequency of published entomology research topics in Puerto Rico over the last 100 years.*

Time Period	Ecosystem	Pest Control	Pure Biology	Systematics
1916-1940	10%	83%	7%	0%
1941-1965	0%	77%	10%	13%
1966-1990	3%	62%	14%	21%
1991-2016	13%	60%	3%	23%

ways been somewhat marginalized (Trotman et al., 2009). An effort by regional governments to diversify their economies has added pressure on the agricultural sector, and an increasing reliance on food imports has taken place (Kendal and Petracco, 2009). In this environment, one can understand why agriculture and the research to support it may have declined.

To determine the present state of Caribbean agriculture, production data from FAO was retrieved and measured against other regional production centers – namely Mexico and Florida. Table 5 gives the production data for the most important crops and crop groups in the region. This data shows that the region still has a significant agricultural base; and for a number of crops, Caribbean production exceeds that of Mexico and Florida, especially in roots and tubers. Production of banana, papaya, pineapples and cucurbits are also similar to the production of Mexico, despite having only 12% in land area. Unsurprisingly, Cuba contributes much to Caribbean production.

Caribbean Agricultural Research Institutions

The FAO production data suggests that the Caribbean has an agricultural sector that is large enough to stimulate and support signifi-

TABLE 5.—*Production (1,000 tonnes) for key Caribbean crops, 2013.*

Crop	Caribbean*	Cuba	Mexico	Florida
Land Area (km²)	*239,681*	*109,884*	*1,972,550*	*170,304*
Sugarcane	24,707	16,100	61,182	13,063
Roots and Tubers	3,829	1,581	1,891	—
Cereals	2,503	1,104	33,210	258 (corn) 31 (wheat)
Banana	1,958	150	2,128	—
Rice, paddy	1,568	673	180	—
Cassava	1,135	514	24	—
Sweet potatoes	1,105	396	43	43
Tomatoes	1,014	678	3,283	458
Papayas	749	198	765	—
Citrus Fruit	707	169	7,613	10,200
Coconuts	678	65	1,064	—
Mangoes	673	410	1,902	—
Pineapples	647	86	772	—
Pumpkins, squash & gourds	527	412	545	394 (watermelon) 55 (squash)
Avocados	455	4	1,468	—
Beans, dry	283	130	1,295	—
Cabbages & other brassicas	222	120	202	139 (cabbage)

*Includes only Caribbean islands

cant entomology research endeavors. After an online review of the institutions with an agricultural research mandate in the Caribbean, it seems that there are also enough centers to host considerable research. The larger institutions include the Caribbean Agricultural Research and Development Institute (CARDI), a regional organization mandated to serve the agricultural research needs of the Caribbean Community (CARICOM); the University of Puerto Rico – Mayagüez Campus; the University of the West Indies – St. Trinidad campus; and INRA (French agricultural research institution) & CIRAD (French international development agency) in the French departments of Guadeloupe and Martinique. Cuba has a number of research institutes and universities, which include the Instituto de Investigaciones Fundamentales en Agricultura Tropical (INIFAT), Instituto de Investigaciones de Sanidad Vegetal (INISAV), Instituto Nacional de Ciencias Agrícolas (INCA) and Universidad Agraria de la Habana (UNAH).

In addition to the large regional institutions, there are a number of smaller ones that conduct agricultural research. Principally, these are universities and research units associated with Ministries of Agriculture. In Suriname, there is the Centre for Agricultural Research (CELOS), and in the Dominican Republic, the Instituto Superior de Agricultura (ISA), which is now a university. In Guyana, there are the University of Guyana and the National Agriculture Research and Extension Institute (NAREI). Much of the research is applied or student focused. All told, there are more than 40 centers in the region. In searching the Academic OneKeys databases for agricultural entomology research, we found 194 research papers published over the last 10 years. This equates to less than one paper every two years per research center, which is obviously low. Why is so little work being published? Is it that there is not much entomological research being conducted or is it that research is not being published?

Declining Amount of Entomological Research?

In response to an online questionnaire and in face-to-face interviews, 10 entomologists from five countries gave their opinions on whether there was more entomology research being done now than 10 to 20 years ago. One replied that he thought there was more research, four said that they thought not and five said that they weren't sure or that they felt that the amount of research was basically the same. This feedback would indicate that there has not been an obvious and dramatic decline in the amount of entomological research.

Other comments shared by the respondents pointed to some challenges. A lack of resources was given as reason for fewer hiring opportunities as well as restrictions on research. Unsurprisingly, there were

also comments on how some entomologists were leaving the region and the profession. Many mentioned the lack of taxonomists in the Caribbean. On a positive note, students in the region still show a high level of interest in entomology.

Challenges to International Publishing

It is not easy publishing in international journals. Standards are high and editors can be choosy about what they publish, especially when a journal's impact factor has such a large influence. The material has to be of high quality and of broad interest. The process of preparing and editing a research paper is also very laborious and time consuming and many researchers struggle to fit it into their work schedules.

Cost is another important consideration. For papers published with subscription-based access, fees are relatively low, around $100 per page. Some journals also offer open access publishing but their fees are much higher and can reach $3,000 USD per published paper. The pricing structure of these journals creates a Catch 22 situation. On the one hand, publishing for subscription-based access is very reasonable, but on the other, the costs for those trying to access the work are high. You may publish your work, but who, in the Caribbean, will pay for the cost of reading it? One-day access to one paper from the Journal of Economic Entomology costs $39. This pricing dynamic may contribute to regional scientists not willing or able to interact with this mechanism of sharing scientific work. One survey respondent confirmed this:

"If the publications aren't free access it's very difficult for me to get them. If were (sic) not by some friends in the USA, it would be very difficult to get access to information and collaboration."

Local Dissemination of Research

If research is not being published in large international scientific journals, then are research results being shared through local means? The main regional institutions have formal mechanisms for disseminating research findings. The University of Puerto Rico produces *The Journal of Agriculture of the University of Puerto Rico*, a biennial, bilingual, open access publication. *Tropical Agriculture* is published by the University of the West Indies and has subscription-based access although abstracts can be accessed at the journal's website. The journal targets international researchers who dominate publications. Both CIRAD and INRA have an open access policy and their published research output is available on their respective websites – AgriTrop and ProdINRA. These give access to a huge number of publications but most are not associated with the Caribbean. Cuba has put a lot of re-

sources into disseminating agricultural research. The island boasts at least eight journals that publish agricultural research. These include the *Cuban Journal of Agricultural Science, Cultivos Tropicales, Revista Cubana de Ciencia Agrícola, Revista Fitosanidad* and *Revista Ciencias Técnicas Agropecuarias*. The Cuban articles are open access and generally published in Spanish. CARDI has the online CARDI Review, which presents the organization's research. It is an irregular publication (in 2015 there were three issues, while in 2014 there were none).

Smaller institutions also find ways of sharing some of their results. For example, the Food Crop Research Department, under the Ministry of Agriculture of Barbados, has a number of research publications on its website. The Jamaican Ministry of Agriculture shares abstracts of research work done by the Research and Development Division. In the Dominican Republic, the Instituto Dominicano de Investigaciones Agropecuarias y Forestales (IDIAF) publishes research results in summary documents. The University of the Virgin Islands shares research posters and papers online. The challenge of these other outlets is that individual studies are hard to find because they do not appear in database searches or even general online searches. One would have to go to the institution's website or use very specific search terms in an online search. For practical purposes, this research is hidden. Again, the survey received feedback that corroborated this:

"The information is not readily available as there is limited access to most of the information. Much of the information is not published and is kept within the institutions."

Regional Meetings and Collaborative Efforts

The level at which a lot of the research seems to be shared is through national and regional meetings and conferences. There are various entities such as the Caribbean Food Crops Society (CFCS) and the Caribbean Animal Health Network that organize meetings and other events where research is presented. Some events like the CFCS annual meeting produce proceedings, which are very useful for further regional dissemination of the work. For now, the CFCS proceedings are not digitized or available online in a searchable format but this will soon change. This online access needs to happen if the work is to be shared beyond the networks of the people who attend these meetings.

Professional collaborations are another way in which research is shared between countries. Many resources have been spent on connecting researchers and other stakeholders in the Caribbean. The United States again plays an important role in this, in part because of a policy of managing potential phytosanitary problems through pre-

emptive measures. There is also the role of regional and international institutions, a reflection of the fact that there are so many independent states in the Caribbean. IICA, for example, has a mandate to serve all the Americas and represents 34 countries. Forty percent of these countries are in the Caribbean, making this institution particularly active in the region. Table 6 lists some of the institutions active in regional collaboration and also some specific initiatives that facilitate the spread of entomology research.

These collaborations are important initiatives, especially because they are usually supported externally and leverage local funds. The initiatives often have a bias towards applied research and to specific fields of entomology such as invasive species (e.g., fruit fly control). This is to be expected since many of the regional and international entities have a strong mandate to support development and economic growth.

Improving Dissemination of Entomology Research in the Caribbean – Google Scholar and ResearchGate

Developments in Internet technology have generated new possibilities for disseminating scientific research and these could prove of great benefit for sharing data in the Caribbean. Google Scholar and ResearchGate are two of the more important initiatives.

Google Scholar is an offshoot of the Google online search engine that identifies a broad array of scientific publications from a multiple of sources. It represents an opportunity for universities and researchers associated with universities to make their work broadly available. The material does not have to have been formally published elsewhere but there are limits to what is accepted. Conference papers, dissertations and technical reports are fine but news articles or book reviews are not. Universities should use compatible software such as Eprints to host institutional research papers. Individual, university-affiliated researchers can also share their work independently using their university website. The articles should be in pdf format and follow the normal structure of an academic publication – i.e., title, authors' names and affiliations, abstract, and bibliography – so that the search 'robots' can locate them and make them available.

ResearchGate, a free, social online site for researchers, serves to connect the scientific community through the ability to find people, share work and ask questions. While the participants must be associated with a recognized institution or be confirmed as a published researcher, there is a lot of flexibility in what they can share. This includes scientific articles, data sets, proposals, research methodologies and presentations -materials and formats that usually would not be found in traditional scientific journals.

TABLE 6.—*Institutions and collaborative initiatives in the Caribbean.*

Institutions	Initiatives
Food and Agricultural Organization (FAO)	Caribbean Food Crops Society
Inter-American Institute for Cooperation on Agriculture (IICA)	Caribbean Invasive Alien Species network
Caribbean Agriculture Research and Development Institute (CARDI)	Caribbean Plant Health Directors (CPHDF)
University of the West Indies (UWI)	The Greater Caribbean Safeguarding Initiative (GCSI)
Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD)	Caribbean Pest Diagnostic Network
Institut National de la Recherche Agronomique (INRA)	Caribbean Taxonomic Network of BioNET-INT.
CABI International	Florida International Volunteer Corps (FAVACA)
United States Department of Agriculture (USDA)	Caribbean Animal Health Network
Pan American Health Organisation (PAHO)	Working groups (e.g., fruit fly fraternity)
University of Florida	
University of Puerto Rico	
Caribbean Agricultural Health & Food Safety Agency	

The ability for individuals to share research information at no cost, in formats that are not as demanding to prepare, could be transformational. This is particularly true in the Caribbean where research is being done but not shared and where existing collaborative initiatives favor certain areas of research and not others. In a recent issue of the CARDI Review, the editor commented on the state of the Review.

"Issues of CARDI Review are becoming few and far between. The reason for this is simply that our small staff is simply too busy to put together frequent issues. I have noticed many pieces of work that could be published in CARDI Review and if time permits, I will redouble my efforts to get the authors of these works to submit articles."

How much easier would it be for the owners of these unpublished works to utilize ResearchGate or Google Scholar to share that information themselves? Granted, it would be necessary to establish quality control measures, institutional reviews and protocols on how to engage with these publishing alternatives, but these would be fairly simple tasks. In short, it would be possible to have the entire output of Caribbean researchers made freely available in a structured and easily accessible format.

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