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The Cuba-Florida plant-pest pathway

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Abstract. Recent shifts in US policies towards Cuba suggest a relaxation or lifting of the embargo may occur in the near future. With the prospects of open travel and trade with Cuba come concerns over the introduction of agricultural pests. In an effort to assess these concerns the distribution-based introduction risk of pests listed in the 2015 Cooperative Agricultural Pest Survey's (CAPS) list of priority pests of economic and environmental importance is reviewed. Of the 59 pests on the CAPS priority pest list, 20 have been recorded in the literature as being present in the Caribbean Basin, South America and Central America. For these 20 New World pests a commodity and distribution-based risk rating was assigned to describe their potential for introduction through the Cuba-Florida pest pathway. The highest rating was given to the six listed pests currently reported as being present in Cuba, and potential for introduction and subsequent impact of these six pests on Florida agriculture is discussed. In addition to the pests found on the 2015 CAPS priority pest list, information regarding pests of concern in the family Tephritidae and the Old World bollworm *Helicoverpa armigera* (Hübner), is also included, as is a description of the Cuban plant health and regulatory structure. The significance of plant-pest introductions between Cuba and Florida is discussed, with an emphasis on proactive engagement in research and collaboration to address these issues.

Key words. Invasive species, Biosecurity, Caribbean, *Helicoverpa armigera*, Plant pests, Cooperative Agricultural Pest Survey, Embargo.

Resumen. Las nuevas políticas de los Estados Unidos hacia Cuba sugieren la posibilidad de que el embargo será suavizado o levantado en un futuro próximo. Asociada a la posible apertura del comercio con Cuba está la preocupación por la introducción de nuevas plagas agrícolas. En un esfuerzo por atender dicha preocupación, y tomando como base su distribución geográfica, este trabajo analiza las plagas comprendidas en la lista del 2015, elaborada por el Programa de Monitoreo de Plagas Agrícolas (CAPS Cooperative Agricultural Pest Survey), la cual incluye aquellas que han sido consideradas prioritarias por la importancia económica y ambiental que supone su riesgo. La literatura reporta que 20 de las 59 plagas listadas están presentes en el Caribe, Centro y Sudamérica. A cada una de estas veinte plagas del Nuevo Mundo le fue asignada una categoría de riesgo que describe la posibilidad de introducción por la vía Cuba-Florida. La categoría de riesgo más alta fue atribuida a seis especies que han sido registradas en Cuba. Los autores discuten el potencial de introducción y los posibles efectos que éstas pueden causar en la agricultura de Florida. Además de las plagas clasificadas en la lista CAPS 2015, el artículo incluye información acerca de las que corresponden a la familia Tephritidae, así como del gusano cogollero *Helicoverpa armigera* (Hübner). A la vez, analizan el sistema de sanidad vegetal y la estructura regulatoria en Cuba. El artículo finaliza con una discusión sobre la importancia de los riesgos de introducción de plagas entre Cuba y Florida, haciendo énfasis en la necesidad de contar con un enfoque proactivo de investigación y colaboración entre ambos países para atender este problema.

Introduction

Recent occurrences of economically significant quarantine pests in the Caribbean, including detections of the major lepidopteran pest, the Old World bollworm *Helicoverpa armigera* (Hübner) (Kriticos et al. 2015) and Mediterranean fruit fly *Ceratitis capitata* (Wiedemann) (APHIS 2015) in both Puerto Rico and the Dominican Republic, suggest that among the Caribbean Basin countries with whom US has open trade and travel, the agricultural-pest situation is constantly changing. Despite its geographic proximity, Cuba has been functionally isolated from the United States since the Cuban Revolution and the subsequent commercial, economic, and trade embargo. The volume of international trade between countries can serve as a proxy for propagule pressure and is strongly correlated with the number of invasive alien species found in a particular region (Westphal 2008). A recent shift in US administration policy, including several official statements by President Obama, signals the improvement of US-Cuba relations and the potential for an eventual lifting of the embargo (e.g., The White House 2014). In this context, it is important to understand and plan for the potential new plant pest introductions from Cuba.

While there is very little actionable information about plant pests in Cuba, we use the Cooperative Agricultural Pest Survey's (CAPS) 2015 priority pest list, which identifies pests of economic and environmental importance, as a proxy. We examined the 59 plant pests of concern included on this list, and assessed their geographic distribution using a literature review (Table 1, Table 2). The potential impacts to Florida of the six pests recorded as present in Cuba, as well as the tephritid fruit flies and the invasive moth species *Helicoverpa armigera* are reviewed. These results are used to discuss the implications that lifting the embargo may have upon the Cuba-Florida pest pathway, and to highlight the potential risks associated with the US-Cuba knowledge gap on plant pest information.

Methods

The Cooperative Agricultural Pest Survey (CAPS) is a cooperative effort between federal (USDA-APHIS-PPQ) and state Department of Agriculture entities. The Cooperative Agricultural Pest Survey compiles a "CAPS priority pest list", revised yearly, of the major pests of economic and environmental concern to the United States targeted for survey. A literature review on pest distribution and host range was conducted for all 59 species on the 2015 list to determine the increased potential for pest introduction into the US following a lifting of the embargo. Pests known to occur in Cuba were rated "very-high-risk"; pests occurring in the Caribbean Basin were rated "medium-risk" but were raised to "high-risk" if they are predominantly pests of crops that are widely planted or an economically important part of Florida agriculture. Pests found in the western hemisphere outside of the Caribbean Basin were considered "low-risk" but elevated to "medium-risk" if they were predominantly pests of crops that are widely planted or an economically important part of Florida agriculture. It is important to note that all pests on the CAPS list are priority pests of some economic importance, and the attributed risk level given is only an indication of the combined potential for introduction through Cuba and the economic significance of the host plant to Florida agriculture.

Two additional pests, namely the fruit flies of the family Tephritidae, and the pest moth species *Helicoverpa armigera*, are also included. These pests were highlighted due to their recent detections in locations near Cuba coupled with their potential for severe economic losses following establishment. Their inclusion is also instructional, as they provide insights into how Cuba's regulatory and agricultural systems concur and differ in handling these pest risks.

Summary of Findings

Table 1 summarizes the results, excluding the 39 out of 59 pests that had no record of establishment in the Caribbean Basin or South and Central America. Analyses of the remaining 20 pests on the CAPS priority pest list identified six species as "very-high-risk", meaning they were present in Cuba and are pests of crops of importance to Florida. Lifting the embargo of Cuba is expected to significantly increase the likelihood of introduction of these pests to Florida. The CAPS priority list also contained eight pests identified as "high-risk" due to their presence in the Caribbean Basin as well as their status as pests of commodities of economic significance to Florida. The possibility that some of these pests are present in

Table 1. Analysis of distribution and host data of 2015 CAPS Priority Pest List – Pests of Economic and Environmental Importance.

Common Name	Scientific name	Cuba (Y/N)	Greater Caribbean Basin (Excluding Cuba)	Central and South America (excluding Caribbean Basin)	Host Commodity(s)	Rating
Giant African snail	*Lissachatina fulica*	Y	Anguilla, Antigua and Barbuda, Barbados, Dominica, Guadeloupe, Martinique, Netherlands Antilles, Saint Lucia, Trinidad and Tobago, U.S. Virgin Islands, Colombia, Venezuela, Florida (under eradication)	Argentina, Bolivia, Brazil, Ecuador, Paraguay, Peru	Polyphagous	Very-High-Risk
Tomato fruit borer	*Neoleucinodes elegantalis*	Y	Grenada, Jamaica, Trinidad and Tobago, Colombia, Venezuela, Suriname, French Guiana, Guyana	Argentina, Brazil, Ecuador, Paraguay, Peru, Uruguay	Solanaceous	Very-High-Risk
Cotton seed bug	*Oxycarenus hyalinipennis*	Y	Bahamas, Cayman Islands, Dominican Republic, Puerto Rico, Turks and Caicos.	Argentina, Bolivia, Brazil, Paraguay	Cotton	Very-High-Risk
Veronicellidae: Bean Slug	*Sarasinula plebeia*	Y	Jamaica, Dominica, St. Lucia, Puerto Rico, Virgin Islands, Belize, El Salvador, Honduras, Nicaragua, Panama, Colombia, Costa Rica, Guatemala, Venezuela	Brazil, Chile	Polyphagous	Very-High-Risk
Veronicellidae: Cuban Slug	*Veronicella cubensis*	Y	Antigua, the Bahamas, Barbados, Dominica, Dominican Republic, Haiti, Jamaica, Puerto Rico, St. Croix, St. Kitts and Nevis	Not Recorded	Polyphagous	Very-High-Risk
Veronicellidae: Sloan's Slug	*Veronicella sloanei*	Y	Barbados, Dominica, Dominican Republic, Jamaica, St. Lucia, St Vincent, the Bahamas, Cayman Islands, Guadeloupe, Colombia, Honduras, Nicaragua	Not Recorded	Polyphagous	Very-High-Risk
Cucurbit beetle	*Diabrotica speciosa*	N	Colombia, Venezuela , French Guiana	Argentina, Bolivia, Brazil, Ecuador, Paraguay, Peru, Uruguay	Corn, Small Grains, Soybean	High-Risk
Old world bollworm	*Helicoverpa armigera*	N	Puerto Rico and the Dominican Republic	Argentina, Brazil and Paraguay	Polyphagous	High-Risk
No common name, an ambrosia beetle	*Megaplatypus mutatus*	N	Venezuela, French Guiana	Argentina, Bolivia, Brazil, Paraguay, Peru, Uruguay	Various tree species	High-Risk
Needle blight of pine	*Mycosphaerell a gibsonii*	N	Jamaica, Costa Rica, Honduras, Nicaragua	Brazil, Chile	Pine	High-Risk

Cuba but unreported in the literature or that they can become established in Cuba before taking advantage of the new pathway of introduction into Florida, justifies the "high-risk" rating. While detailed information on pests assigned a "high-risk" rating is not given in the following section these pest deserve particular attention. The fact that they are present in the region but not reported as established in Cuba places them in a category of potentially unreported pests of Cuban agriculture, with a higher likelihood

Table 1. Continued.

Common Name	Scientific name	Cuba (Y/N)	Greater Caribbean Basin (Excluding Cuba)	Central and South America (excluding Caribbean Basin)	Host Commodity(s)	Rating
Bacterial Wilt; Southern Bacterial Wilt	*Ralstonia solanacearum* race 3 biovar. 2	N	Guadeloupe, Costa Rica, Guatemala, Colombia, Venezuela	Peru, Argentina, Bolivia, Brazil, Chile, Uruguay,	Solanaceous	High-Risk
Guatemalan potato tuber moth	*Tecia solanivora*	N	Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama, Colombia, Venezuela	Ecuador	Solanaceous	High-Risk
Tomato leaf miner	*Tuta absoluta*	N	Colombia, Venezuela, Costa Rica , Panama	Argentina, Bolivia, Brazil, Chile, Paraguay, Uruguay	Solanaceous	High-Risk
Bacterial blight, Bacterial leaf streak	*Xanthomonas oryzae pv. oryzae & X. oryzae pv. Oryzicola*	N	Costa Rica, El Salvador, Honduras, Panama, Colombia, Venezuela	Bolivia, Ecuador	N/A	High-Risk
Chinese slug	*Meghimatium pictum*	N	Not Recorded	Argentina and Brazil	Polyphagous	Medium-Risk
No common name, a palm borer	*Paysandisia archon*	N	Not Recorded	Brazil, Argentina, Paraguay, Uruguay	Palm	Medium-Risk
Mal del ciprés (Cypress mortality)	*Phytophthora austrocedrae*	N	Not Recorded	Argentina (Patagonia), Chile	Juniper	Low-Risk
Rotbrenner	*Pseudopezicula tracheiphila*	N	Not Recorded	Brazil	Grape	Low-Risk
Tremex woodwasp	*Tremex fuscicornis*	N	Not Recorded	Chile	Oak	Low-Risk
Honeydew moth	*Cryptoblabes gnidiella*	N*	Not Recorded	Brazil, Uruguay	Grape, Citrus	Undetermined*

The Greater Caribbean Basin (GCB) is broadly defined as the political entities that contact the Caribbean Sea. This includes the Caribbean Islands as well as portions of Central America (Belize, Guatemala, Honduras, El Salvador, Panama, Nicaragua, and Costa Rica), South America (Colombia, French Guiana, Guyana, Suriname and Venezuela) and North America (Mexico and the United States of America). The United States is represented by the state of Florida (USA) as only the southern portion of the state is considered part of the GCB. For our purposes, overseas territories in the GCB are treated the same as independent countries.

*The CAPS Data sheet for this pest cites AQAS records of interceptions on material originating from Cuba; as such its risk rating is listed as "undetermined" due to incomplete information.

of future detection on the Island relative to other pests not present in the region. Pests in the "high-risk" category should be among priority targets for future surveys in Cuba.

Of the remaining pests, two were marked as medium-risk, due to their presence in South and/or Central America and absence from the Caribbean Basin. The remainder of the CAPS list was rated low-risk, primarily because these pests were not known to have established in the western-hemisphere south of Florida. There are three exceptions: *Phytophthora austrocedrae* (Gresl. and E.M. Hansen), *Pseudopezicula tracheiphila* (Müll.-Thurg) and *Tremex fuscicornis* (F.) Their location and host commodity suggest that the lifting of the embargo would have a negligible impact on the likelihood of introduction and establishment of these pests in Florida.

According to AQAS interception data cited in a CAPS data sheet (CAPS 2013), the honeydew moth, *Cryptoblabes gnidiella* (Millière) (Lepidoptera: Pyralidae), has been intercepted on products originating from Cuba. However, *C. gnidiella* is not listed in the checklist of Cuban Lepidoptera (Aguila et al. 2012), nor is its occurrence on the island referenced in additional literature. As such its presence in Cuba is possible but not confirmed. Its rating is listed in table 1 as "undetermined".

In addition to the pests identified from the CAPS 2015 priority pest list as "very-high-risk", the tephritid fruit flies and the Old World bollworm, *Helicoverpa armigera,* are included in our review. The tephritid fruit flies as a group are of significant concern, especially in the Caribbean region, but were not addressed in the CAPS priority pest list. They were selected primarily due to their potential for harm, their host range and introduction pathway (fruit is grown widely in Cuba, and is frequently transported by passengers), their distribution (the genus *Anastrepha* is widespread in the Caribbean Basin; recent interceptions of *Ceratitis capitata* have occurred in Puerto Rico and the Dominican Republic), and a long history of managing and surveying for this pest in Cuba. *Helicoverpa armigera* is given additional attention here due to its status as one of the most damaging crop pests in the world. Additional justification for inclusion include its recent discovery in Puerto Rico and the Dominican Republic, the difficulty in identifying this pest, the nature of its discovery in Brazil and the fact that Cuba's unique agro-ecological approach to pest management may lead to a difference in impact and concern for this pest.

Descriptions of "Very-High-Risk" Pests

What follows is a brief summary of pests from the 2015 CAPS priority pest list that have been ranked "very-high-risk", suggesting that an increase in trade and travel between the US and Cuba would significantly increase Florida's exposure to these pests.

Giant African Snail, *Lissachatina fulica* (Bowdich). The giant African snail is considered one of the most damaging invasive species in the world, recorded as capable of feeding on hundreds of plant species (Venette and Larson 2004). The World Conservation Union classifies *Lissachatina fulica* (Bowdich) as one of the world's top 100 invasive species (ISSG 2003). The 1969 eradication of *L. fulica* from Florida took 10 years and cost USD 1 million, though it prevented an estimated USD 11 million in annual crop losses (over USD 60 million in 2015 dollars) (USDA 1982, Smith and Fowler 2003). A large population of *L. fulica* was detected in 2011 in Miami, Florida, and eradication efforts are currently underway. Establishment of this pest in Havana, Cuba, was reported in 2014, in an area roughly 1 km2 (Vázquez and Sanchez 2014). *Lissachatina fulica* poses a public health threat, as it is a vector of the rat lungworm *Angiostrongylus cantonensis* (Chen), a nematode parasite capable of causing eosinophilic meningitis in humans (Smith et al. 2011). Current eradication efforts in Florida rely on the molluscicide metaldehyde. Use of metaldehyde in Cuba may be difficult considering the urban setting and the risk of incidental mortality of native Cuban snail species, many of which are endemic and/or rare. Establishment in Cuba is problematic for Florida considering that the expensive eradication effort in Miami may be negated by future accidental introductions caused by travel and trade from Cuba.

Tomato Fruit Borer, *Neoleucinodes elegantalis* (Guenée). The tomato fruit borer *Neoleucinodes elegantalis* (Guenée) (Lepidoptera: Crambidae) is widespread in the Caribbean as well as South and Central America (Molet 2012). It attacks plants belonging to the family Solanaceae, including weed species as well as cultivated crops such as tomato *Solanum lycopersicum* L. and eggplant *Solanum melongena* L. (Diaz and Solis 2007). Estimates of yield losses on solanaceous crops range from 50% to 90% (De Moraes and Foerster 2014) with a single larva capable of rendering the fruit unsuitable for market. The presence of this pest in Cuba is alarming, as tomato is a valuable crop grown in Florida, particularly in the southern half of the state. Florida provides nearly half of the total (imported and domestic) winter supply of fresh tomatoes to the rest of the country and almost all the U.S. grown fresh market tomatoes consumed from October to June (Mossler et al. 2000). The pathway for this pest is introduction via trade of infested fruits, with 989 and 79 of the 1,150 interceptions recorded in the USDA AQAS database (as of April, 2012) involving fruits of *Solanum* spp. and *Capsicum* spp., respectively (Molet 2012a).

The potential exists for Cuba to become a supplier of winter vegetables to the U.S., including tomatoes, creating a pathway for introduction of *N. elegantalis*. Prior to the embargo Cuba was a major supplier of winter vegetables to the United States (US International Trade Commission 2001). In 2013 Cuba had a tomato yield of 12,489.408 kilograms per hectare whereas the 2013 United States yield was 83,843.189 kilograms per hectare (FAO STAT 2015). The difference in yield per hectare suggests that Cuban tomato production is underdeveloped and that additional inputs and investment, driven by access to the US winter vegetable market, could make Cuba a major exporter of tomatoes to the United States (US International Trade Commission 2001). Such an arrangement would increase the risk of the introduction of pests of solanaceous crops, of which *N. elegantalis* is of particular concern.

Cotton Seed Bug, *Oxycarenus hyalinipennis* (Costa). The cotton seed bug *Oxycarenus hyalinipennis* (Costa) is a pest of cotton and other plants in the family Malvaceae (Ananthakrishan et al. 1982). It has a cosmopolitan distribution, although, with the exception of an eradicated population in the Florida Keys, it is currently absent from North America. It was first detected in Cuba in 1993 (Grillo Ravelo 1993) and has been detected widely across the Caribbean Basin (Halbert and Dobbs 2010). Due to factors including climate and host availability, *O. hyalinipennis* was identified by Holtz (2006) as having a high likelihood of establishment if it were to be introduced into the southern United States. Wild cotton grows in the southern tip of the Florida peninsula and can serve as a potential host for this pest post-introduction. While Florida's cotton industry would be impacted by *O. hyalinipennis* establishment a larger concern would be its spread outside of Florida and into the cotton belt.

Between 1984 and 2011, there were 570 interceptions of *O. hyalinipennis* at US ports, 70 percent of which occurred after 2000 (USDA 2010a). While transportation of malavaceous host materials from Cuba to Florida may be of low volume, 84 percent of interceptions occurred on non-host plants, and 26 percent of interceptions were recorded in luggage (USDA 2010a). Already the relaxation of travel restrictions has increased the amount of return travel from Cuba to Florida, while potential lifting of trade restrictions would increase the volume of cargo; both of which increase the exposure of Florida to Cuba's established *O. hyalinipennis* population.

Leatherleaf Slugs: *Sarasinula plebeia* (P. Fischer), *Veronicella cubensis* (Pfeiffer), *Veronicella sloanei* (Cuvier). The gastropod family Veronicellidae, commonly referred to as the leatherleaf slugs, contains several slug species that are considered pests of agriculture as well as vectors of human diseases. Leatherleaf slugs are polyphagous, though field conditions and seasonality will determine if they reach pest status in an agricultural setting. Crop losses between USD 27 and 45 million annually have been reported in Central America from these pests (Rueda et al. 2002). Maceira (2003) reviewed the Veronicellidae of Cuba and identified five species as being present on the island: *Veronicella cubensis* (Pfeiffer), *Veronicella tenax* (Baker), *Veronicella sloanei* (Cuvier), *Leidyula floridana* (Leidy) and *Sarasinula plebeia* (P. Fischer). Difficulty in identifying leatherleaf slugs to species based on dorsum color and pattern has led to frequent misidentification and taxonomic confusion (Maceira 2003).

Sarasinula plebeia is considered to be the most important bean pest in Central America, where in some areas the cultivation of beans has been abandoned due to the presence of this slug (Rueda et al. 2002). The Cuban Slug *Veronicella cubensis* damages a wide range of ornamental and agricultural plants in regions where it has established (USDA 2006) and can also be a nuisance in urban and suburban areas (Cowie et al. 2009). *Veronicella sloanei* is a pest in gardens and nurseries (Clarke and Fields 2013) where it attacks a variety of plants. In the Caribbean it is considered a significant pest (Fields and Robinson 2004).

Leatherleaf slugs are intermediate hosts of parasitic nematodes, of the genus *Angiostrongylus* in particular, which can cause eosinophilic meningitis in humans (Koo et al. 1988). The typical life cycle of the nematode begins with infection in rats of first stage larvae, which are then passed out as feces. Subsequently, the rat feces are ingested by slugs, where the nematodes develop until they reach the infective life stage. Human infection comes from oral ingestion of either the slug or accidental ingestion of mucus (Pien and Pien 1999).

The primary pathway for entrance is via commerce, as these pests have not been intercepted on passenger baggage (USDA 2010b). The USDA new pest response guidelines for tropical terrestrial gastropods lists the breakdown of interceptions of all tropical terrestrial gastropods (190 interceptions from 1985-2009) as follows: 46 percent via airport, 24 percent at inspection stations, 12 percent at pre-departure stations (all of which occurred in Hawaii), 10 percent at maritime stations and 8 percent at land borders. A significant portion of the 190 interceptions originated in the greater Caribbean Basin (USDA 2010b).

Additional Pests. The opening of a new pest pathway between Cuba and the United States changes the risk profile for a wide range of pests well beyond those included in the CAPS priority pest described previously. A comprehensive risk assessment of all potential pests affected by the lifting of the embargo is beyond the scope of this paper. This section intends to highlight two particular pest groups that may provide insights into the particulars of the Cuban approach to agriculture, the Cuban regulatory structure, and the various pathways for introduction with regards to the Cuba-Florida pest pathway.

The tephritid fruit flies were selected primarily due to their potential for harm, their host range and distribution (the genus *Anastrepha* is widespread in the Caribbean Basin and there have been recent interceptions of *Ceratitis capitata* in Puerto Rico and Dominican Republic). Additionally the history of Cuba's trapping and controlling for this pest group provides insight into Cuba's plant protection capabilities.

The Lepidopteran pest, *Helicoverpa armigera*, also known as the Old World bollworm, was selected due to its status as one of the most damaging crop pests in the world. Its recent discovery in Puerto Rico and the Dominican Republic and the interception of trapped specimens in Florida, suggests possible introduction through the Caribbean Basin. The difficulties in identifying this pest, as made evident by its delayed detection in Brazil, along with Cuba's unique agro-ecological farming system raise additional concerns which are discussed.

Tephritid Fruit Flies. Given their connection to the Caribbean, both Cuba and Florida share a common concern for tephritid fruit flies. In both locales the establishment of this pest group can cause significant loss of a wide range of fruit crops and limit the ability to sell these fruits abroad. The interest and concern of the United States over fruit flies in Cuba has a long history. Records from the 1920s detail efforts by the USDA to determine the status of fruit flies on the Island after a shipment of infested citrus from Mexico was observed by a US government official during a period when Cuba had quarantined all Mexican citrus (USDA 1925).

Amongst the tephritid fruit flies the genera *Anastrepha, Bactrocera* and *Ceratitis* are of the greatest concern. The Mediterranean fruit fly, *Ceratitis capitata,* is considered one of the most damaging fruit pests in the world. Though it has not established in Florida, multiple outbreaks have occurred in 1929, 1956-57, 1962-63, 1981, 1997-98, and 2010-11. All of these outbreaks, as well as additional outbreaks in Texas and California, have been successfully eradicated at considerable expense. The maintenance of a widespread and frequently monitored network of traps is required to detect outbreaks early enough for eradication to be feasible. Cuba is at particular risk of exposure to *Ceratitis capitata* due to the presence of this pest in Central America and its recent detection in the Dominican Republic and Puerto Rico (where it is considered "absent: eradicated") (EPPO 2014, NAPPO 2015).

At least five species of the genus *Anastrepha* are present in Cuba: *A. insulae* Stone*, A. interrupta* Stone*, A. obliqua* (Macquart)*, A. ocresia* (Walker) *and A. suspensa* (Loew) (Alayo and Garcia 1983, Norrbom et al. 1999). Though it should be noted that the publication, the Annotated List of the Diptera of Cuba (Lista anotada de los dipteros de Cuba) is over 30 years old, and though regular fruit fly surveys have occurred since its publication, it is difficult to find more recent published information. Vázquez et al. (1999) acknowledges that the total number of *Anastrepha* species present in Cuba is likely higher than what has been recorded, and certainly this is an area in need of additional surveying. Two of the five *Anastrepha* species found in Cuba, *A. suspensa* and *A. interrupta,* are also found in Florida, while *A. obliqua* and *A. ocresia* were formerly present in Florida (Steck 2001). The Mexican fruit fly, *Anastrepha ludens* (Loew)*,* has not established in either Cuba or Florida, and is of particular concern due to its preference for grapefruit.

The genus *Bactrocera,* of which the Oriental fruit fly *Bactrocera dorsalis* (Hendel) and the melon fruit fly *Bactrocera cucurbitae* (Coquillett) are the most significant pests, has not been recorded in Cuba, and is not widely associated with the Caribbean region. The carambola fruit fly, *Bactrocera carambolae* Drew and Hancock, may be a member of this genus capable of taking advantage of the Cuba-Florida pest pathway, as it is established in French Guiana, Guyana and Suriname (EPPO 2014). While *Bactrocera dorsalis* is not known to be established in Cuba or the Caribbean Basin, in August of 2015 it was detected in traps set in southern Miami-Dade County. This outbreak led to the declaration of an agricultural state of emergency and threatened the area's USD 1.6 million (annual) fruit industry. Eradication efforts in the United States have had a high rate of success, primarily due to the consistent trapping and monitoring which allows for early detection and response. The Oriental fruit fly outbreak in Miami, Florida was declared eradicated in February of 2016. While the route of introduction for the 2015-2016 Oriental fruit fly outbreak in Miami is not known, introductions in the Caribbean basin, particularly in countries without the ability found in Florida to respond quickly and successfully to eradicate the pest, are cause for concern. Conversely, had Florida failed to eradicate the 2015-2016 Oriental fruit fly outbreak, its establishment would be of great concern to Cuba, which produces substantial quantities of tropical fruits and possesses a climate and host plant population favorable for *B. dorsalis* establishment. As such, the 2015-2016 Oriental fruit fly outbreak in Miami serves to highlight the shared biosecurity interests between Florida and Cuba.

Vázquez et al. *(*1999) provides a description of the Cuban approach to fruit fly management. The presence of *Ceratitis capitata* in neighboring countries provides the impetus for the Cuban program of fruit fly control. Similar to the US approach, trapping and fruit inspection is critical with 5325 traps serviced, and 586,100 Hectares inspected in 1997 (Vázquez et al. 1999). Similar restrictions on the importation of fresh fruit are also in place (Vázquez et al. 1999, CNSV 1994). According to Vázquez et al. (1999) the lack of major fruit fly outbreaks on the island as well the absence of fruit fly larvae detection on Cuban exports is evidence of the success of the Cuban approach to fruit fly control.

Fruit flies in general are of high concern due to their pathway for introduction. Interceptions are frequently made when travelers attempt to move infested fruit across the border. While Cuba may have an effective system in place for monitoring and control of fruit flies, it is the likely occurrence of travelers returning from a visit to Cuba with fresh fruit stowed in their baggage that suggests this pest group should be watched carefully, especially as tourist travel between Florida and Cuba increases in the near future.

The Old World Bollworm, *Helicoverpa armigera* (Hübner). *Helicoverpa armigera*, or the Old World bollworm, is considered one of the most economically significant lepidopteran pests of agriculture with damage estimated at up to USD 2 billion a year globally (Tay et al. 2013). It is believed that approximately 1 to 2 million years ago, *H. armigera*, or its ancestor, made it to the New World, where it subsequently evolved into *Helicoverpa zea* (Boddie) (Behere et al. 2007). While the two species are closely related and phenotypically nearly indistinguishable, *H. armigera* is considered a more significant crop pest, due in part to its greater propensity towards developing resistance to pesticides (Behere et al. 2007). It is believed that *H. armigera* had been present in the New World for several years prior to its discovery in 2013, but was not noticed as it was mistaken for *H. zea*. During the 2011/12 and 2012/2013 growing seasons in Brazil there were higher than normal infestations of what was presumed to be *H. zea*. The realization that *H. armigera*, and not *H. zea,* was causing the problems in Brazil only came about after repeated infestations occurred which were not effectively controlled with pesticides. Further molecular studies by Tay et al. (2013) confirmed that the *Helicoverpa* species was in fact *H. armigera*, marking the first establishment of this species in the New World.

The story of *Helicoverpa armigera's* establishment and delayed discovery in Brazil is instructional when considering the potential for this pest to arrive in Cuba. *H. armigera* has been detected in Puerto Rico and the Dominican Republic and it is not known if it is present on other islands in the Caribbean (USDA 2014a, 2014b). Modeling of climate and host crop presence by Kriticos et al. (2015) suggests that the Caribbean Basin, and Cuba in particular, are suitable for *H. armigera* establishment. In Brazil it was the resistance to pesticides and reoccurrence on treated fields that alerted growers to the presence of *H. armigera*. In Cuba, where pesticides are not as heavily used, and where control of lepidopteran pests is generally obtained through augmentive releases of biocontrol agents such as *Trichogramma* spp., it is very possible that *H. armigera* would go unnoticed due to a mitigated impact below levels which would draw attention as well as misidentification as *H. zea*. Even if *H. armigera* does not become a significant pest in Cuba, knowledge of its presence is important for Florida, which relies on pesticides for control, and which would experience difficulty controlling this pest. Establishment in Florida would almost certainly lead to future spread into the rest of the United States where it could potentially impact crops that account for over USD 78 billion annually (Kriticos et al. 2015).

Since 1984 in the mainland United States there have been 7,203 interceptions identified as belonging to the genus *Helicoverpa,* of which 1,017 have been identified as the species *H. armigera* (Kriticos et al. 2015). In recent years there has been an increase in interceptions of *H. zea*, which, along with the number of additional congeneric species and the difficulty in making identifications, suggests the number of interceptions of *H. armigera* could be under-reported (Kriticos et al. 2015). On June 17th 2015 a single adult male *H. armigera* was recovered in Bradenton, Florida, in a CAPS pheromone trap (Hayden and Brambila 2015). While this does not constitute an establishment of the Old World bollworm in Florida, it does highlight the imminent threat posed by this pest and points to a pathway into the US via the Caribbean Basin rather than through Central America. Knowledge of the presence of *H. armigera* in Cuba is hindered due to lack of opportunities for direct communication and collaboration, as such it is hoped that information can be obtained through countries that are able to freely communicate with Cuba (USDA 2014b).

Cuban Pest Management and Plant Health Regulatory Structure.

Cuban agriculture falls under the responsibility of the Ministry of Agriculture, which is analogous to the USDA. Under the supervision of the Ministry of Agriculture is the National Center for Plant Protection (Centro Nacional de Sanidad Vegetal, CNSV). Serving as Cuba's National Plant Protection Organization (NPPO, the US counterpart being USDA-APHIS-PPQ), the CNSV is responsible for plant protection, the registration of pesticides, plant quarantine and technical services. The Insitituto de Investigaciones de Sanidad Vegetal (INISAV) is the research arm of the CNSV, with roles analogous to USDA-APHIS-PPQ-CPHST and USDA-ARS. Created by resolution 596/76 on the 15th of December, 1977, INISAV is tasked with providing scientific, technical and methodological support to the CNSV. Fundamental to INISAV's mandate is a focus on sustainability and reducing environmental risk. Underneath the CNSV are the 15 Provincial directorates of plant protection, which maintain provincial laboratories (laboratorio provincial de sanidad, LAPROSAC), which are in some ways analogous to US county extension offices (albeit with a greater directorial role) in that they are tasked with distributing techniques and methodologies to the agricultural operations in the province (Vázquez 2006). Additional facilities scattered throughout the country includes over 200 CREEs (Center for the Reproduction of Entomophages and Entomopathogens) and several bio-pesticide plants, each producing a variety of pest control products for use in their respective regions.

Cuba's limited ability to purchase pesticide and fertilizer inputs has driven its development and reliance on IPM techniques, as described in detail by Nicholls et al. (2002). In the 1970s, Cuba established the National System of Plant Protection, which consisted of regional pest monitoring stations. The overall effect of these stations was a substantial reduction in the need to import pesticides. The decline and fall of the Soviet Union meant the loss of a major trading partner and source of subsidization which greatly reduced the ability of Cuba to acquire pesticide and fertilizer inputs, further pushing the island's agriculture towards organic methods and biological control of pests (Nicholls et al. 2002). Cuba had focused much of its initial biological control effort on sugar cane, its most important crop for the past two centuries. The sugar cane borer, *Diatraea saccharalis* (Fabricius), was combated by extensive rearing of the tachinid parasitoid *Lixophaga diatraeae* (Townsend), with 81 million individual flies produced in 1995 (Fuentes et al. 1998). The successes of the CREEs in regard to sugar cane was in a sense a proof of concept, with the CREEs expanding to produce a variety of other arthropod biocontrol agents, including *Trichogramma* sp. (24.6 million individuals produced in 1995) and Eucelatoria sp. (20 million individuals produced in 1995) for control of lepidopteran pests (Fuentes et al. 1998). Additionally, the artisanal production of Neem and Bt bio-pesticide products adds to the control options in the Cuban agro-ecological system.

Cuba's technical and scientific ability is considerably greater than the rest of the region, as evidenced by the level of training and education attained by the technicians and producers, facilitated by the extension-like activities of the regional stations of the State Plant Health System (Vázquez 2006). Cuban-produced plant health research can be found in the journals *Fitosanidad* (Plant Health), published by INISAV and *Proteccion Vegetal* (Plant Protection) published by the National Center for Animal and Plant Health (CENSA). Both journals provide English abstracts of their articles and can be easily accessed online.

The structure of the Cuban agricultural economy is tightly connected to its plant-pest situation. The current agro-ecological system that developed in response to a loss of access to chemical inputs is significantly different from the input-heavy industrial system of agriculture practiced in Florida and much of the developed world. As Cuba gains access to US markets, the increase in demand as well as revenue will likely mean a call for higher yields. If the incentives for continued organic production are not high enough, Cuba may shift away from the agro-ecological model towards more input-intensive agricultural production (Kost 2004). The impact of such a shift on the plant pest and disease situation in Cuba remains to be seen, but is likely to be worth consideration.

Discussion

We used the CAPS 2015 priority pest list (economic and environmental) to assess the potential for new pest introductions to the US from Cuba. Our review of the literature regarding distribution data for pests on the CAPS 2015 priority pest list has identified 20 of the 59 pests (33.9%) as being present in the New World. Fourteen of these 20 New World pests are present in the Caribbean basin with six of these reported as being present in Cuba and one whose presence in Cuba is listed as "undetermined". Cuba's largest neighboring islands (by population and land area), Puerto Rico, Jamaica and Hispaniola (the Dominican Republic and Haiti), may be useful as a point of reference. Cuba has six of the priority pests reported as present according to the literature, compared to four in Puerto Rico, four in Hispaniola, and four in Jamaica. None of the CAPS pests in the Caribbean basin were unique to Cuba, and all six of the pests found in Cuba can also be found in at least one of these three reference islands. Conclusions are difficult to draw from this comparison as the pests reported as present may be artificially low in countries with less resources to monitor pests. A counter-intuitive conclusion may be that a higher number of reported pests are due to Cuba's greater technical ability for surveillance and monitoring, rather than lax phytosanitary regulations and enforcement.

Our analysis highlights the potential for several novel plant pest introductions from Cuba, but it is important to note several limitations of our study. First, the 2015 CAPS pest list is neither an exhaustive list of all possible pests found in Cuba nor does it contain all pests likely to enter Florida through Cuba. As such, we do not present a comprehensive analysis of potential pest issues related to the relaxation of the embargo. Second, our reliance on merely distribution and host preference to determine likelihood of introduction is a potential shortcoming in our methods. Actual likelihood of pest introduction and establishment is heavily influenced by other factors such as the pathway of introduction and the habitat suitability – factors that we did not fully consider here. Finally, the CAPS 2015 priority pest list was not designed to be region specific and tends to focus on the most important pests of national economic consequence. Thus, the 59 pests listed would differ significantly from a hypothetical Florida-specific list of priority pests. Nonetheless, we believe that this list provides a suitable basis for assessing the expected likelihood of novel plant pest introductions following removal of the US embargo on Cuba – information that is essential to inform policy choices at both the US federal and Florida levels.

Prior to the embargo, the United States was Cuba's largest trading partner, and there is potential for a return to this status if the embargo were to be lifted. A post-embargo Cuba will likely see the United States develop as a crucial market for its agricultural commodities, particularly in the form of winter fruits and vegetables. A dependency on the US market may evolve, especially if investments are made to develop Cuban agriculture towards higher yields to meet the demand. According to Kost (1998) the main products for potential import into the United States are sugar and cigars as well as a potential niche market for organic produce. Pests may also be introduced via packing materials, containers and passenger baggage, thus the assumption that only host-plant material can serve as a vector for pest introduction is not valid. The impact of quarantine on Cuban agricultural goods due to the establishment or

Table 2. References for species distribution data as presented in Table 1.

Species Name	Species Distribution Literature Cited
Cryptoblabes gnidiella	**CAPS (unattributed). 2013.** CPHST pest datasheet for *Cryptoblabes gnidiella*. USDA-APHISPPQ-CPHST. (Available at ~ https://caps.ceris.purdue.edu/webfm_send/2168. Last accessed April 21, 2016.)
Diabrotica speciosa	**EPPO. 2014**. PQR database. Paris, France: European and Mediterranean Plant Protection Organization. (Available at ~ http://www.eppo.int/DATABASES/pqr/pqr.htm. Last accessed April 21, 2016.)
Helicoverpa armigera	**Sullivan, M., and T. Molet. 2007.** CPHST pest datasheet for *Helicoverpa armigera*. USDA-APHIS-PPQ-CPHST. (Available at ~ https://www.aphis.usda.gov/plant_health/plant_pest_info/owb/downloads/owb-factsheet.pdf. Last accessed May 20, 2016.)
Lissachatina fulica	**EPPO. 2014.** PQR database. Paris, France: European and Mediterranean Plant Protection Organization. (Available at ~ http://www.eppo.int/DATABASES/pqr/pqr.htm. Last accessed April 21, 2016.)
Megaplatypus mutatus	**EPPO. 2014**. PQR database. Paris, France: European and Mediterranean Plant Protection Organization. (Available at ~ http://www.eppo.int/DATABASES/pqr/pqr.htm. Last accessed April 21, 2016.)
Meghimatium pictum	**Molet, T. 2014.** CPHST pest datasheet for *Meghimatium pictum*. USDA-APHIS-PPQ-CPHST. (Available at ~ http://download.ceris.purdue.edu/file/2556. Last accessed May 20, 2016)
Mycosphaerella gibsonii	**Sullivan, M. 2010.** CPHST pest datasheet for *Mycosphaerella gibsonii*. USDA-APHIS-PPQ-CPHST. (Available at~ https://download.ceris.purdue.edu/file/586. Last accessed May 20, 2016.)
Neoleucinodes elegantalis	**Molet, T. 2012a.** CPHST pest datasheet for *Neoleucinodes elegantalis*. USDA-APHISPPQ-CPHST.(Available at ~ https://caps.ceris.purdue.edu/webfm_send/1853. Last accessed April 21, 2016.) **Aguila, R.N., and A.B. Canamero. 2012**. A list of Cuban Lepidoptera (Arthropoda: Insecta). Zootaxa 3384: 1-59

detection of a pest could deal a significant blow to the Cuban economy, similar to what has been experienced by other nations in the region which have had their goods placed under quarantine due to pest detections (for example, Dominican Trade and Industry Secretary José del Castillo Saviñón attributed a loss of USD 61 million due to the 2015 outbreak of *Ceratitis capitata*). While American companies can benefit from the opening of the Cuban market, the costs of an introduced pest from Cuba into Florida will diminish the net economic benefits derived from this policy change.

As signees of the World Trade Organization International Plant Protection Convention Agreement on the Application of Sanitary and Phytosanitary (SPS) Measures, both Cuba and the United States are under a legal obligation to communicate SPS concerns and to ensure that when international standards

Table 2. Continued.

Oxycarenus hyalinipennis	**USDA-APHIS. 2011.** New pest response guidelines: Cotton Seed Bug. (Available at ~ https://www.aphis.usda.gov/import_export/plants/manuals/emergency/downloads/nprg-cotton_seed_bug.pdf. Last accessed May 3, 2016.) **Molet, T., and L.D. Jackson. 2011**. CPHST pest datasheet for *Oxycarenus hyalinipennis*. USDA-APHIS-PPQ-CPHST. (Available at ~ https://download.ceris.purdue.edu/file/939. Last accessed May 20, 2016)
Paysandisia archon	**EPPO. 2014.** PQR database. Paris, France: European and Mediterranean Plant Protection Organization. (Available at ~ http://www.eppo.int/DATABASES/pqr/pqr.htm. Last accessed April 21, 2016.)
Phytophthora austrocedrae	**Mackesy, D., and Sullivan, M. 2013.** CPHST pest datasheet for *Phytophthora austrocedrae*. USDA-APHIS-PPQ-CPHST.(Available at ~ https://caps.ceris.purdue.edu/dmm/2136. Last accessed May 20, 2016)
Pseudopezicula tracheiphila	**Costanzo, T., and Sullivan, M. 2013.** CPHST pest datasheet for *Pseudopezicula tracheiphila*. USDA-APHIS-PPQ-CPHST (Available at ~ https://download.ceris.purdue.edu/file/2213. Last accessed May 20, 2016.)
Ralstonia solanacearum race *3* biova*r 2*	**Sullivan, M., Daniells, E., Southwick, C., and Mackesy, D. 2013.** CPHST pest datasheet for *Ralstonia solanacearum* race 3 biovar 2. USDA-APHIS-PPQ-CPHST. (Available at ~ https://download.ceris.purdue.edu/file/1610. Last accessed May 20, 2016.)
Tecia solanivora	**Molet, T. 2012c.** CPHST pest datasheet for *Tecia solanivora*. USDA-APHIS-PPQ-CPHST. (Available at ~ https://download.ceris.purdue.edu/file/187. Last accessed May 20, 2016.)
Tremex fuscicornis	**USDA-APHIS. 2011b**. New pest response guidelines: Tremex Wood Wasp (*Tremex fuscicornis* (F.)). USDA–APHIS–PPQ–EDP Emergency Management, Riverdale, Maryland. (Available at ~http://www.aphis.usda.gov/ import_export/plants/manuals/online_manuals.shtml. Last accessed April 21, 2016)
Tuta absoluta	**USDA–APHIS. 2011c.** New pest response guidelines: tomato leafminer (*Tuta absoluta*). USDA–APHIS–PPQ–EDP Emergency Management, Riverdale, Maryland. (Available at ~ https://www.aphis.usda.gov/import_export/plants/manuals/emergency/downloads/Tuta-absoluta.pdf. Last accessed May 3, 2016.)
Veronicellidae (including *Sarasinula plebeia, Veronicella cubensis* and *Veronicella sloanei*)	**Molet, T. 2011.** CPHST pest datasheet for Veronicellidae spp. USDA-APHISPPQ-CPHST. (Available at ~ https://download.ceris.purdue.edu/file/867. Last accessed May 20, 2016.)
Xanthomonas oryzae pv. oryzae and *X. oryzae pv. Oryzicola*	**Sullivan, M., Daniells, E., and Southwick, C. 2011.** CPHST pest datasheet for *Xanthomonas oryzae* pv. *oryzae*. USDA-APHIS-PPQ-CPHST. (Available at ~ https://download.ceris.purdue.edu/file/1503. Last accessed May 20, 2016.)

for plant health are met, that trade will not be obstructed by said concerns. Portions of the agreement will provide a framework for solving SPS conflicts involving plant pests between the US and Cuba. Article 5 of the agreement is notable in that it compels both parties to conduct a more comprehensive investigation of existing information regarding plant-pest risks (akin to the much narrower analysis we have conducted), and provides a stopgap provision for situations where scientific information is insufficient (WTO 2015). If the US decides there is a lack of sufficient information regarding the plant-pest situation in Cuba the latitude available to the US to apply restrictions during an undefined "reasonable amount of time" may have the combined effect of reducing the risk of pest introductions immediately following the lifting of the embargo and of encouraging collaborative generation and exchange of the requisite scientific information to avoid or lift any restrictions to trade.

It is estimated that in the United States exotic invasive species cause USD 120 billion in damages per year (Pimentel et al. 2005), and cause significant reductions in biodiversity (Wilcove et al. 1998). The Caribbean region hosts an estimated 130 significant arthropod pest species that have not yet established in Florida (Klassen et al. 2002). Florida has already experienced the introduction of several pests and diseases that are believed to have entered through the greater Caribbean Basin pest pathway, including *Cactoblastis cactorum* (Berg) (Marsico et al. 2011), whitefly-transmitted yellow leaf curl virus (Polston et al. 1999), black sigatoka disease *Mycosphaerella fijiensis* Morelet (Ploetz and Mourichon 1999), and the Caribbean fruit fly *Anastrepha suspensa* (Norrbom et al. 1999). More recently, the taro planthopper *Tarophagus colocasiae* (Matsumura), a pest of cultivated and ornamental aroids, was detected in Jamaica in 2011, Cuba in 2014 and subsequently detected in Florida in June of 2015 (Halbert and Bartlett 2015).

The importance of the Caribbean region as a pest pathway is acknowledged through the establishment by the USDA-APHIS-PPQ of the greater Caribbean safeguarding initiative (GCSI), a collaborative undertaking to harmonize efforts to mitigate pest risk by identifying pest threats, preemptively developing control methods and conducting mutually beneficial research. The GCSI identifies Florida as the primary entryway into the United States for pests from the region, and considers the state a part of the greater Caribbean region. At the state level the "Don't Pack a Pest" program is an outreach effort by the Florida Department of Agriculture and Consumer Services, funded by USDA-APHIS-PPQ, which collaborates with several Caribbean countries to remind passengers not to pack prohibited items that may contribute to the introduction of a plant pest or invasive species. Cuba is notably missing as a participant in both these initiatives and the integration of Cuba into these programs, as well as further collaboration and knowledge exchange between both countries will be crucial as trade and travel to the island increases.

Two factors help to mitigate the increase in risk of pest-introductions to Florida following a lifting of the embargo. First, Cuba has a well-developed regulatory structure, including high levels of technical ability and education, especially when compared to the rest of the region. Second, all CAPS priority pests found in Cuba are present on other Caribbean countries with whom the US has normal trade and travel policies, suggesting that Cuba's contribution to the overall risk from the region is dependent more on trade volume than on any Cuba-specific quality. The embargo has no effect on preventing the introduction of species capable of natural migration or wind-assisted spread over long distances. For these pests, the Tephritidae and *H. armigera* for example, increased collaborative relationships with Cuba would be beneficial in terms of monitoring natural spread and anticipating introductions.

While typically a potential pest receives attention due to high interception numbers, the pest situation with Cuba is atypical in that the interception data used as a basis for decisions regarding pest risks is essentially non-existent due to the near absence of trade under the embargo. Rather than waiting until after the embargo is lifted to acquire interception data upon which one could base a response, a proactive approach will require the development of a strong knowledge base regarding the plant-pest situation in Cuba both as a reaction to recent policy changes, and in anticipation of changes to come. Comprehensive and effective phytosanitary biosecurity will be a crucial component to the economic stability, viability and vitality of a post embargo US-Cuban relationship. Though the policies governing the relaxation of trade and travel are made at the federal level, the opening of the Cuba-Florida plant pest pathway will disproportionately impact Florida. A prudent policy response would involve Florida spearheading an effort to understand and mitigate the plant pest risks involved so as to better protect its more than 100 billion dollar agriculture industry.

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