Micronesica Supp. 6: 5–27. 2002

Exotic Pests of Plants: Current and Future Threats to Horticultural Production and Trade in Florida and the Caribbean Basin

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Abstract—The threat of exotic pest organisms to horticultural industries and to imports and exports of agricultural products in the Caribbean Basin and Florida is extremely serious. The rate of establishment of exotic pests in Florida exceeds that in California and rivals that in Hawai‘i. During the past 2 decades, Asia has become almost as important as the neotropics as a main source of invaders, and there has been an increase in establishment rates for species belonging to the Acari, Homoptera and Thysanoptera. Efforts to contain and eradicate newly established immigrant pest populations have been limited to only a few major pests. We determined that roughly 130 significant exotic arthropod pests are present in the Caribbean, *sensu lato,* but not yet in Florida, as well as substantial numbers external to the Caribbean Basin.

The United States has relied on inspection of arriving cargo and passengers at the port of entry as one of the main approaches to exclusion of exotic pests. Since volumes of arriving cargo are doubling every six years , this approach is no longer adequate. Thus the National Plant Board asserted that the U.S. safeguarding system should shift primary reliance from port-of-entry inspection to off-shore actions, including risk mitigation in production areas, certification of pest-free status at point of origin and pre-clearance at the port of export. Off-shore risk can be mitigated by area-wide biologically-based suppression, creation of pest-free production areas and inspection, treatment (if necessary) and certification at the port of export. Most compelling for Florida would be the regionalization of pest exclusion programs throughout the Caribbean Basin, because a dangerous organism that establishes in one of the countries quickly endangers the entire Basin.

Introduction

Rapid globalization of trade and tourism has dramatically increased the spread of harmful invasive organisms. We have entered an era of unprecedented travel by exotic invasive organisms. The greatest harm being done by non-indigenous invasive organisms is occurring in the Pacific and Caribbean regions. Florida, which lies next to the Caribbean Basin, is impacted profoundly by numerous exotic invasive pests and diseases of crops and livestock.

The main reasons for Florida's vulnerability are (1) the high and progressively mounting volumes of products of agricultural concern and numbers of passengers arriving at Miami, Ft. Lauderdale, and 13 other ports-of-entry, (2) extensive smuggling, (3) the progressively increasing volumes of agricultural development, trade and tourism in Caribbean Basin countries, and (4) weak systems for safeguarding plant and animal resources against pests in many of these countries (Ambrose 1999, Pantoja 1999). Consequently, many exotic pests from distant regions are able to gain footholds in the Caribbean Basin, and subsequently penetrate into Florida (Shannon 1999).

Examples of Harmful Pests Recently Established in Florida

The tropical bont tick, *Amblyomma variegatum* (Fabricius), a vector of heart water disease in Africa, is established on several Caribbean islands (Food & Agriculture Organization 2001). Also classical swine fever is at Florida's doorstep in the Dominican Republic (Animal & Plant Health Inspection Service 1999). Experience has shown that when such dangerous pests become widespread in the Caribbean, they eventually penetrate U.S. quarantines and create major problems in Florida and other States.

The number of non-indigenous species established in Florida (Table 1) includes ca. 925 vascular plant species, ca. 1000 insect species, 6 freshwater snail species, 40 land snail species, and a total of 72 species of vertebrates (Office of Technology Assessment 1993).

It is instructive to consider examples of harmful exotic arthropods that established fairly recently in Florida. Particularly damaging to the economies of the Caribbean countries and to Florida was the sudden introduction, in the mid-1980s, from the Mediterranean into the Greater Caribbean Basin of a new whitefly, variously known as Biotype B of *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae), and as *B. argentifolii* Bellows and Perring (Homoptera: Aleyrodidae). Within 5 years this pest was spread throughout the entire Western Hemisphere, apparently on ornamental plants (Brown et al. 1995, Schuster et al.

Table 1. Estimated Numbers of Non-Indigenous Species (NIS) in Florida

Group	Established NIS	Total
Vascular Plants	ca. 925	3,450
Insects[1]	ca. 1,000	ca. 12,500
Freshwater snails	6	98
Land snails	40	140
Freshwater fish	19	80
Amphibians	3	55
Reptiles	22	100
Birds	11 + 140 "flying exotics"	607
Land mammals	17	70

[1]Frank, J. H. and E. D. McCoy. 1995.

Source: Office of Technology Assessment, U.S. Congress. 1993.

1990). *B. argentifolii* is almost identical morphologically to *B. tabaci* Biotype A. On the other hand, *B. argentifolii* differs sharply from Biotype A of *B. tabaci* by feeding and reproducing explosively on tomato and other solanaceous crops, and by the toxicity of its saliva. This toxic saliva causes irregular ripening of tomato fruit and silvering of squash leaves. Additionally, *B. argentifolii* is a highly efficient vector of geminiviruses and, generally, has displaced *B. tabaci* throughout the southern and western U.S. (Schuster et al. 1993).

Prior to the appearance of *B. argentifolii*, only three viruses were known to infect tomato in the Western Hemisphere, but none occurred in the United States. However within ten years, 17 highly damaging geminiviruses had appeared and were causing enormous losses in tomato production throughout the Western Hemisphere (Polston & Anderson 1997). For example, just prior to 1992, whitefly-transmitted tomato yellow leaf curl virus (TYLCV) was introduced on tomato transplants from Israel into the Dominican Republic. One year later this whitefly-geminivirus combination destroyed tomato production in the Dominican Republic (Polston et al. 1994). TYLCV soon appeared in Jamaica and Cuba, and in 1997 it was discovered in Florida (Polston et al. 1999). In order to prevent major losses in tomato production in Florida, the whitefly population has to be kept below about 1 whitefly per ten tomato plants, which, in turn, has increased expenditures in tomato production by more than $200 per acre (D. R. Seal, personal communication).

Bean golden mosaic virus (BGMV), a whitefly-transmitted geminivirus, was widespread throughout the Greater Caribbean Basin by 1990 (Brunt et al. 1990). BGMV appeared in south Florida immediately after the passage of Hurricane

Andrew, August 24, 1992 (Blair et al. 1995). For several years, until control measures could be developed, the yields of entire fields of bush and pole beans were lost to this terrible whitefly-transmitted virus (Stavely et al. 1996).

Black Sigatoka, a terrible disease of banana, is caused by a leaf spot fungus, *Mycosphaerella fijiensis;* anamorph: *Paracercospora fijiensis.* This pathogen was first described from Fiji in 1963. By 1972 it had spread to Honduras in the Caribbean Basin, and it spread widely throughout the entire Caribbean Basin. In 1998 Black Sigatoka was first found in Florida (Ploetz & Mourichon 1999). About 25-40 fungicide sprays per season are needed to combat this disease in banana production (Ploetz 2001).

The Asian citrus canker bacterium, *Xanthomonas axonopodis* pv. *citri,* has been established in South America for about one century. In 1995 canker was found on citrus near Miami International Airport. The dispersal of the pathogen coincides with periods of heavy rainfall, strong winds and growth flushes (Gottwald et al. 1997). More than $200 million has already been spent on the eradication program in which 1.9 million trees have been destroyed, one-third in urban yards. The eradication program for this disease has required severe restrictions on harvesting and marketing of fruit, the destruction of nearly 85 percent of the lime acreage in south Florida, and the quarantine of about 1,300 acres of citrus in six counties (Florida Citrus Mutual and Florida Fruit and Vegetable Association 2001). In attempting to eradicate this disease, inspectors have routinely entered private properties without first obtaining permission from the owners. Angry citizens in urban areas challenged the authority of the State Department of Agriculture and Consumer Services to conduct search and seizure operations without court-issued warrants. In November 2000, the eradication program was halted by a court order. State officials are attempting to devise a scheme of notification and compensation that will gain approval of the Court and the Legislature by mid-June. Thus the entire dry season has been forfeited. Currently more than 5,000 symptomatic trees are loading the wet winds with infectious inoculum (Florida Citrus Mutual and Florida Fruit and Vegetable Association 2001).

The citrus leafminer, *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae), greatly facilitates infection by the citrus canker bacterium, and is highly damaging to the new flushes of leaves. It originated in tropical Asia, spread to Japan during the 1600s and between 1993-1995 appeared almost simultaneously on the Mediterranean coast of Europe, the Middle East, North Africa and Reunion Island. The citrus leafminer was discovered in south Florida in 1993 and rapidly spread throughout the State (Peña 1998).

The brown citrus aphid, *Toxoptera citricida* (Kirkaldy) (Homoptera: Aphididae), had been present throughout the Caribbean Basin long before 1995, when it first entered Florida. In Florida, a small percentage of citrus trees have always been infected with various strains of citrus tristeza virus. However, now, the rapid spread of this aphid vector of this destructive virus is causing the industry to replace millions of trees grafted onto tristeza-susceptible sour orange rootstock (Knapp et al. 1996).

The melon thrips, *Thrips palmi* Karny (Thysanoptera: Thripidae), originated in Southeast Asia. *T. palmi* reached Hawai'i in 1982, and the Caribbean in 1988 (Capinera 2000), where it rapidly became widely distributed. The pest entered Florida in 1990 and immediately caused tremendous losses in production of cucurbits, eggplant, pepper and bean. *T. palmi* creates hardship for producers who export ficus and other ornamental plants to Europe (Seal 1997).

The cycad aulacaspis scale, *Aulacaspis yasumatsui* Takagi (Homoptera: Diaspididae), was first described from Thailand (Pena and Baranowski 1999). *A. yasumatsui* was found in Miami, Florida in 1996, infesting cycads grown as ornamentals. King-sagos, *Cycas revoluta* Thumberg, the most popular cycad planted in this area, are heavily infested. The rampant increase and spread of this scale insect threatens the survival of several rare and endangered species in important world collections at Fairchild Tropical Garden and Montgomery Botanical Center. Additionally the pest is damaging to the large concentration of nurseries in southern Florida that grow and ship cycads throughout the U. S. and abroad.

The Mediterranean fruit fly, *Ceratitis capitata* Wiedemann (Diptera: Tephritidae), is one of the world's most destructive pests, affecting a wide range of fruits and vegetables. The medfly originated in tropical West Africa. It arrived in Costa Rica around 1901; however, and its northward advance has been halted by means of a sterile insect barrier near the border of Guatemala and Mexico. Since 1929, incipient medfly infestations in Florida have been eliminated on about 15 separate occasions (Knapp 1998). Currently, sexually sterile male med-

Figure 1. The Greater Caribbean Basin

flies are being released around international airports in Florida as a preventive measure (Animal & Plant Health Inspection Service 1998).

Clearly large numbers of exotic pests first become established in the Caribbean Basin before penetrating into Florida, where many are highly damaging to the horticultural industries and natural ecosystems.

Caribbean Basin as a Staging Area for the Invasion of Florida

The Greater Caribbean Basin (GCB) (Fig. 1) is of great importance to the U.S. both as a trading partner and a tourist destination. According to Brown (1999), the GCB – for economic purposes – consists of altogether about 35 political entities including Colombia, Venezuela, Guyana, Suriname, and French Guyana, all Central American countries, all Caribbean islands, but excluding Mexico. However from a biological perspective, we include Mexico in the Caribbean Basin, *sensu lato.*

To better understand the problem of invasive species in the Caribbean Basin, it is helpful to recall some history of the development of commerce, agriculture

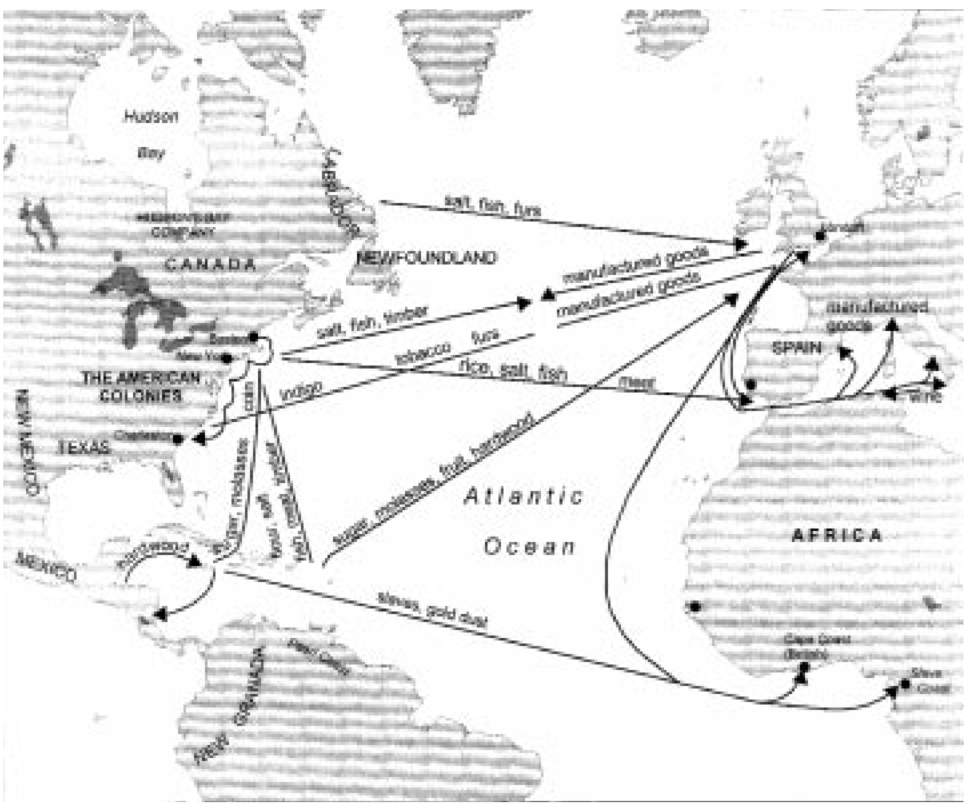

Figure 2. British trade relationships among the Caribbean Basin, Europe, Africa and North America in the early 1700s. Redrawn from Roberts (1998) with permission.

and immigration to this area. The historian, Roberts (1998) notes that during the 1600s and 1700s, Europe derived far greater benefit from Caribbean agriculture, especially sugar production, than from all ventures in South and North America (Fig. 2). Sugarcane originated in Southeast Asia and has been grown in Asian countries for sugar production for about 2,500 years. Europeans first enjoyed sugar when sugarcane was introduced to Europe by Arabs in the 8th century following the Arab conquest of North Africa, Spain and Sicily.

Spanish pioneers started large-scale agriculture in the Caribbean. Initially they focused on the production of fruit and cattle. Sugar production, being a labor-intensive operation, was hampered in Spanish colonies, because the indigenous people had been decimated by European diseases and mistreatment. The Spaniards occupied the Greater Antilles, and were unable to prevent English, French and Dutch captains from basing their parasitic industries of piracy and smuggling in the Lesser Antilles. The English and French soon developed sugar plantations in the Lesser Antilles.

The English and Dutch brought millions of slaves from Africa to provide the manual labor, and some were sold to plantations in Spanish possessions. Britain began abolishing slavery in 1833, thereafter significant numbers of laborers from India and China, as well as other Asian countries, were brought to the Caribbean as indentured servants. Thus Caribbean people have family connections throughout the world, which are factors in tourism and trade.

Experience has shown that the Caribbean serves as an assembling and staging area for the invasion of Florida (Shannon 1999). Many Caribbean countries have weak systems for safeguarding plant and animal resources against pests (Ambrose 1999, Pantoja 1999). Consequently, many exotic pests from distant regions are able to gain footholds to spread throughout the Caribbean Basin, and subsequently to penetrate into Florida.

Significant Pathways of Entry of Exotic Organisms

According to Zadig (1999) the potential for introducing pests moves from highest to lowest in the following order: (1) smuggled products, (2) air cargo (especially perishable plant materials), (3) reefer cargo, (4) passenger baggage and (5) cruise ships. Also, ballast water, private aircraft and watercraft, garbage and international mail represent very important means of pest entry. Zadig (1999) concluded that about ten times more exotic pests brought in perishable cargo penetrate quarantines than those brought by travelers.

Increasing Imports of Perishable Products and Entry of Plant Pests

Each year the U.S. imports about 37 billion dollars' worth of agricultural products (Table 2). In 1998 the U.S. imported almost 5 billion dollars' worth from the Greater Caribbean Basin. Thus the GCB ranked second as a source of agricultural products, behind Canada, but ahead of Mexico. One billion dollars' or

Table 2. Major suppliers of U.S. agricultural commodity imports, 1998.

Imports From:		U.S. Imports ($Billion U.S.)
All countries		37.1
1	Canada	7.8
2	Greater Caribbean Basin[1]	4.9
3	Mexico	4.7
4	Italy	1.4
5	Indonesia	1.4
6	Netherlands	1.4
7	France	1.3
8	Colombia	1.3
9	Brazil	1.2
10	Australia	1.1
11	New Zealand	1.0
12	Germany, Chile, Costa Rica, Thailand, China	Just less than 1.0 each

[1]Includes all the Caribbean islands, Colombia, Venezuela, Guyana, Suriname, and Central American countries including Panama, but not Mexico.

Source: Brown, R.N., Jr. 1999.

Table 3. Agricultural products imported into the United States from the Greater Caribbean Basin and the world.

Imported from	Greater Caribbean Basin (GCB)	World	Percent from GCB
	———Millions U.S. Dollars———		
Total Agricultural Products	3,930	37,073	10.6
Total Unprocessed	1,600	8,445	18.9
Bananas, Plantains	812	1,201	67.6
Drugs, Crude/Natural	3	529	0.6
Fruits, Fresh/Frozen	218	1,589	13.7
Nuts and Preparations	16	629	2.5
Vegetables, Fresh/frozen	123	2,632	4.7
Seeds, Field/Garden	9	424	2.1
Cut Flowers	387	614	63.0
Nursery Stock	27	466	5.8
Other (Not Specified)	3	358	0.8

Source: Brown, R.N., Jr. 1999.

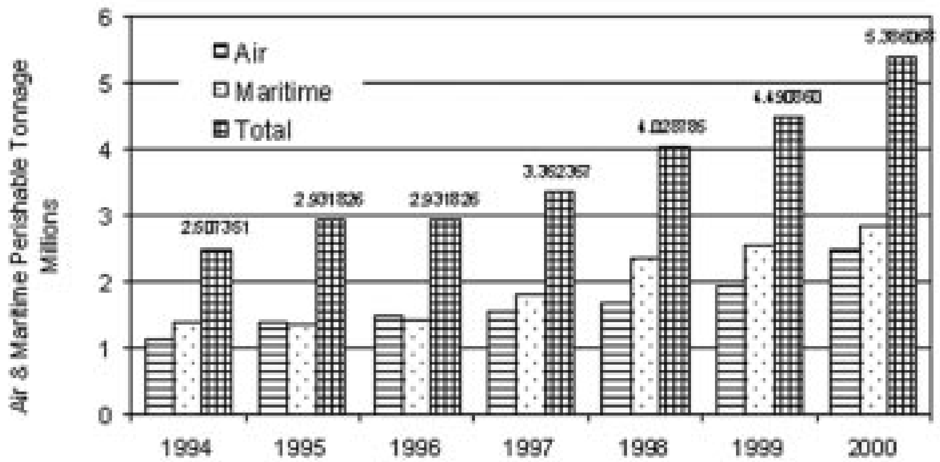

Figure 3. Tonnage of perishable products imported into Florida as air and maritime cargo. Source: Book of International Trade, U.S. Department of Commerce.

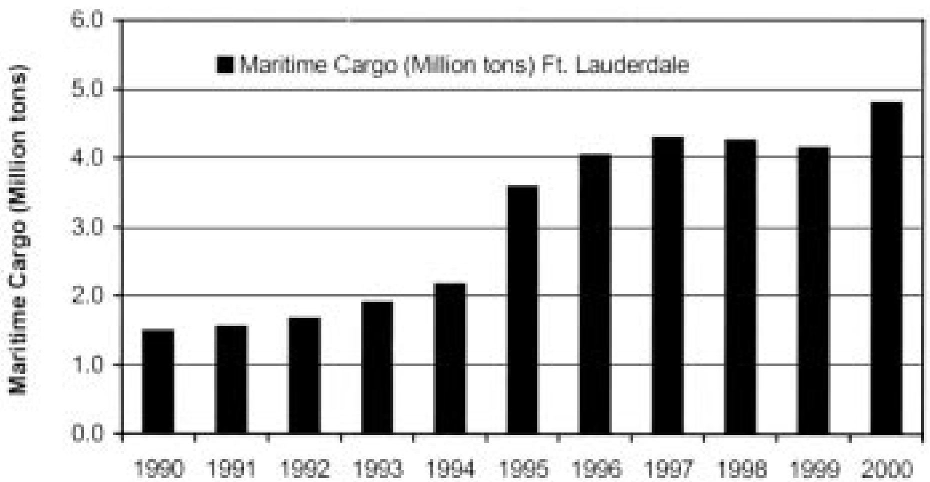

Figure 4. Growth in volume of maritime cargo entering Port Everglades, Ft. Lauderdale. Source: USDA-APHIS-PPQ, Port Authorities, USDA Work Accomplishment Data (WADS). Declines in 1999 resulted from destruction by Hurricane Mitch of many production areas in Central America, and changes in world trade economies.

more worth of imports, each, come from the Asian countries of Indonesia, China and Thailand.

Of special significance, as possible carriers of exotic pests, are unprocessed imports. Although less than one-fifth of these come from the GCB, nearly two-thirds of U.S. imports of bananas and cut flowers come from the GCB (Table 3). The volume of perishable products imported into Florida by air and water continues to grow strongly, having doubled in the last 6 years (Fig. 3).

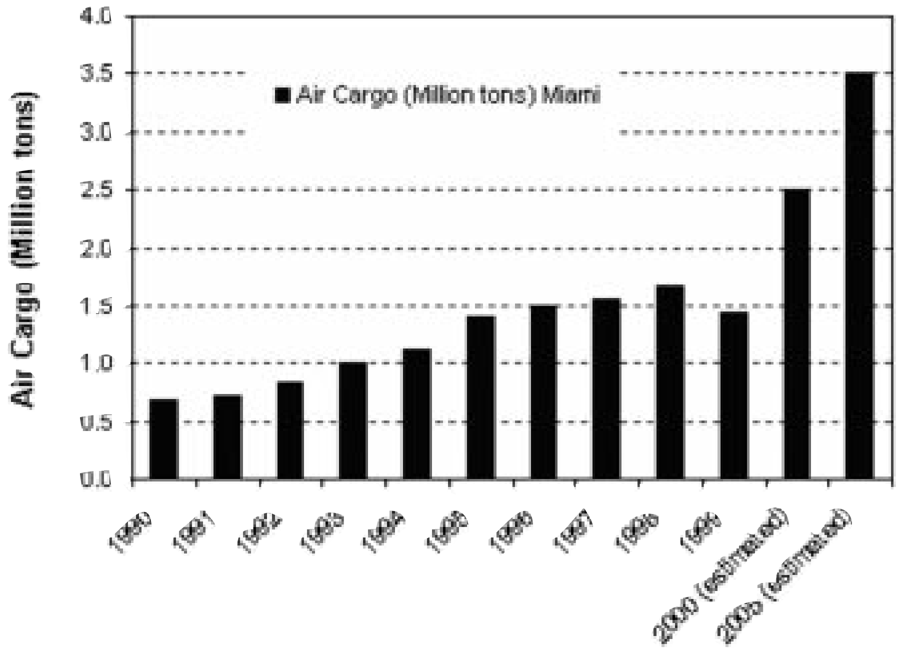

Figure 5. Growth in volume of air cargo entering Miami. Source: USDA-APHIS-PPQ, Port Authorities, USDA Work Accomplishment Data (WADS).

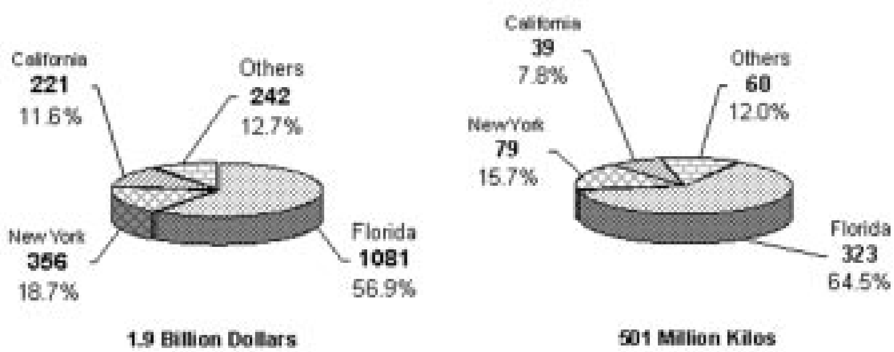

Figure 6. Value and volume of perishable products imported via air cargo into the USA in 1999. Source: Book of International Trade, U.S. Department of Commerce.

Similarly the volume of maritime cargo entering Ft. Lauderdale (much of which consists of fresh fruits and vegetables) is doubling about every six years (Fig. 4). Declines in 1999 resulted from destruction by Hurricane Mitch of many production areas in Central America, and changes in world trade economies. Also the growth in volume of air cargo at Miami International Airport is doubling at roughly six-year intervals (Fig. 5). About three-fifths of perishable products imported via air cargo in 1999 entered the U.S. through Florida's 15 ports-of-entry (Fig. 6).

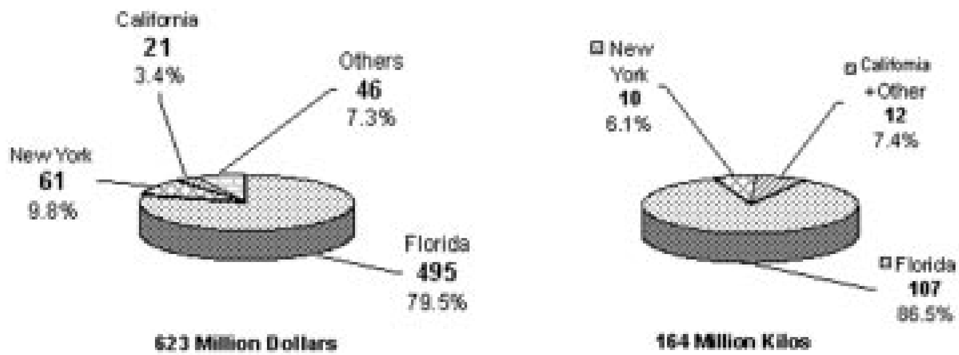

Figure 7. Imports by State of cut flowers into USA via air cargo. In 1999 these imports totaled 164 million kilograms valued at $623 million. Source: USDA-APHIS-PPQ.

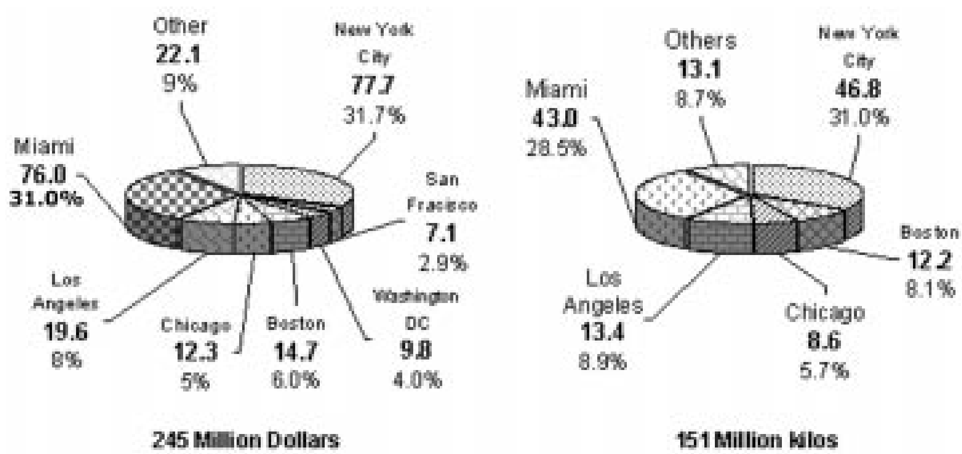

Figure 8. Imports of fruits and vegetables into USA via air cargo. In 1999 these imports totaled 151 million kilos valued at $245 million. Source: USDA-APHIS-PPQ.

Cut flowers are believed to serve as a particularly significant pathway for the entry of pests into Florida, and around 80% of cut flowers enter the U.S. as air cargo into Florida (Fig. 7). In 1999 these imports of cut flowers via airfreight totaled 164 million kilograms and were valued at $623 million. Large quantities of fresh fruits and vegetables are imported by air, and in 1999 almost as much of this volume entered through Miami as through New York (Fig. 8).

The growth in the number of interceptions of pests of quarantine significance at Florida's 15 ports-of-entry (Fig. 9) during the past six years has been greater than the growth in the volume of imports. In 2000 a total of 21,530 quarantine significant pests were intercepted at Florida's 15 ports-of-entry. The trend in growth of imports is mirrored in the growth in numbers of pest interceptions on fresh fruits and vegetables at Port Everglades, Ft. Lauderdale (Fig. 10).

Table 4. Growth in quarantine-significant pest interceptions and passenger baggage seizures at Miami.

Year	Quarantine-Significant Pest Interceptions in Miami				Baggage Seizures
	Air Cargo	Plant Inspection Station	International Mail Facility	Maritime Cargo	
1994	4,453	1,188		533	
1995	5,160	1,032		485	68,063
1996	6,041	1,232		1,519	82,387
1997	7,166	1,527	152	1,840	79,723
1998	8,724	1,592	186	1,459	89,802
1999	5,549	1,901	65	1,206	
2000	6,754	2,778	516	1,624	

Source: USDA-APHIS-PPQ.

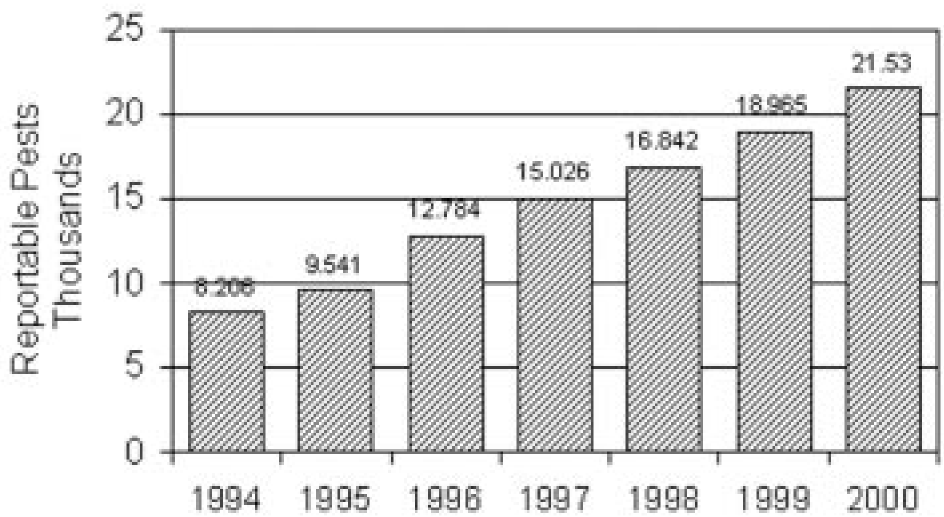

Figure 9. Interceptions of quarantine-significant pests at all ports-of-entry in Florida. Source: USDA-APHIS-PPQ.

At Miami, the number of pests of quarantine significance has continued to increase in air and maritime cargo, on plants imported for propagation, in international mail and passenger baggage (Table 4). Currently there are about 11,600 pest interceptions per year at Miami and about 1,500 at Ft. Lauderdale for a total of 13,000 out of the 21,530 for the entire State. Thus 65% of total pest interceptions occur in these two southern ports-of-entry, where conditions for establishment are favorable year-round.

Table 5. Establishment of exotic arthropods in California, Florida and Hawai‘i.

State	Period	No. Established	Average/Year	Reference
California	1955-88	208	6.3	Dowell and Gill (1989)
Florida	1970-89	270	14.2	Frank and McCoy (1992)
Hawai‘i	1962-76	287	19.1	Beardsley (1979)

Intercontinental and inter-island U.S. mail may be a significant pathway for movement of exotic pests. Indeed, the number of quarantine-significant pests found in international mail at Miami reached a record high of 516 in 2000 (Fig. 11). This suggests that reciprocal exchanges of mail between the U.S. mainland, Puerto Rico, the U.S. Virgin Islands, Hawai‘i, and U.S. islands in the Pacific, may also serve as significant pathways for the introduction of exotics. Since it is illegal to open first class U.S. mail, perhaps an appropriate quarantine treatment should be considered to block this pathway.

The Rates of Establishment and Origins of Immigrant Species

The rate at which exotic arthropods become established in Florida has been tracked since 1970 (Frank & McCoy 1992). Since 1986 this task has fallen to Dr. Michael Thomas, Florida Department of Agriculture and Consumer Services, who found that between 1986 and 1999 the number of exotic species established each year varied between 4 and 21 (Thomas 2000).

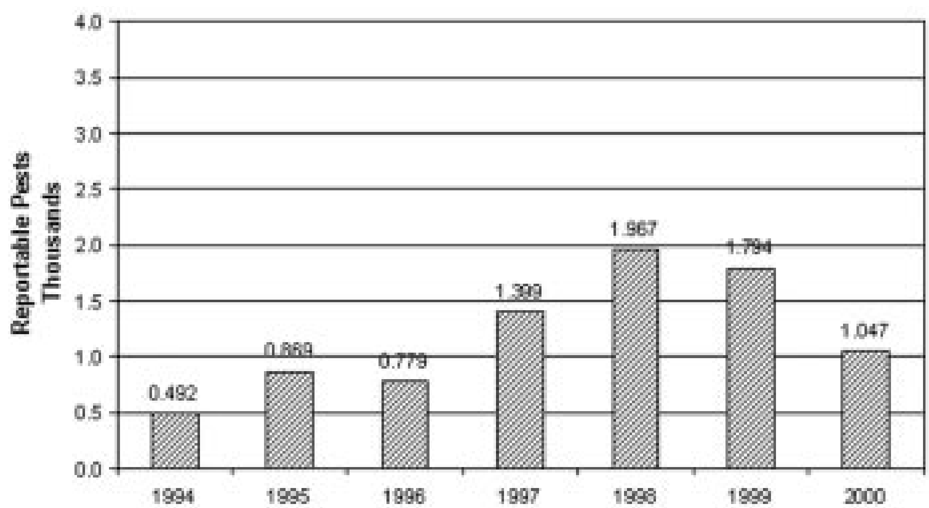

Figure 10. Interceptions of quarantine significant pests at Port Everglades, Ft. Lauderdale, Florida. The recent decline in reportable pests is the result of a major fresh produce importer shifting shipments to other ports, and to phytosanitary improvements in arriving cargo. Source: USDA-APHIS- PPQ.

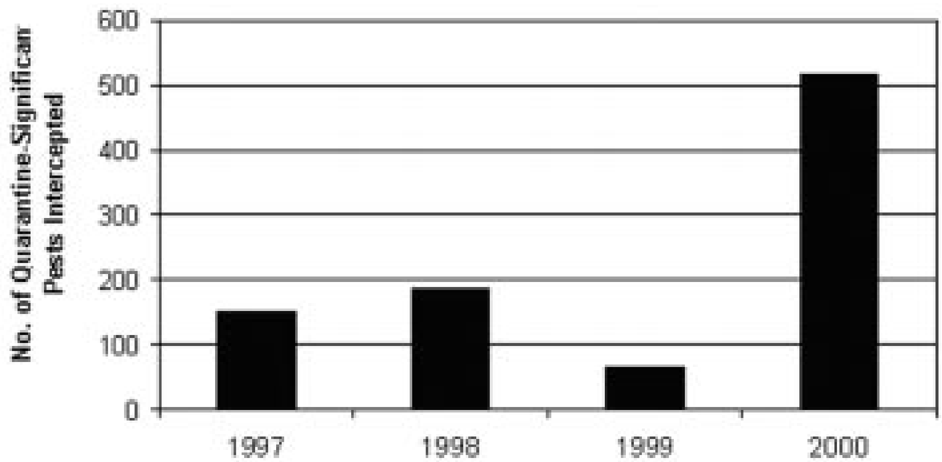

Figure 11. Growth of number of interceptions of quarantine significant pests in mail shipments from abroad at the Miami Inspection Station. Source: USDA-APHIS-PPQ.

As many exotic arthropods become established each year in Florida as in the rest of the continental U.S. (Frank & McCoy 1992). However, as shown in Table 5, the average annual number of species that became established in Florida between 1970 and 1989 was more than twice as great as in California, but only two-thirds as great as in Hawai‘i. More recently, Thomas (2000) found that 150 exotic arthropod species established in Florida from 1986 through 2000. Thus the rate of establishment in Florida of exotic arthropod species may have declined somewhat during the past decade. Whereas about one-third of the 7,764 insect species established in Hawai‘i are recent exotics (Miller and Eldredge 1996), only about one-twelfth of the 12,500 insect species established in Florida can be classified as exotic in origin (Frank & McCoy 1995).

Thomas (2000) found that from 1986 through 1999, the number of exotic species established in Florida in various orders of Arthropods included 10 species of Acari, 45 species of Homoptera, 37 species of Coleoptera, and 14 species of Thysanoptera. When comparing the number of exotic species in various orders established in Florida for the period 1970 to 1989 to corresponding numbers for 1986 to 1999, Thomas (2000) found that the numbers established have declined slightly for species in Coleoptera and strongly for species in Lepidoptera, but have increased for species in Acari, Homoptera and Thysanoptera. In addition, Thomas (2000) found that during the 15 years from 1986 through 1999, 68 of the immigrant species had come from the Neotropics and 62 had come from Asia. Moreover when Thomas (2000) compared the origins of immigrant species for this recent period to those from 1970 to 1989, he found the number of recent immigrant species from Asia has doubled, and the number from the Neotropics has declined from 65 percent to 50 percent. Thus Asia has almost overtaken the Neotropics as the primary origin of immigrant arthropods in Florida.

Table 6. Numbers of significant pest species of arthropods in various Orders, that threaten Florida's horticultural industries, and that were present in the Greater Caribbean Basin or external to this Basin in 2000.

	Acari	Coleo-ptera	Diptera	Hemi-ptera	Homo-ptera	Hymeno-ptera	Iso-ptera	Lepido-ptera	Ortho-ptera	Thysano-ptera
Carib.	12	14	35	11	16	2	16	15	1	7
External	7	18	28	21	23	-	-	31	1	4

Exotic Pest Threats to Florida In and External to the Caribbean Basin

In an effort to identify exotic arthropod pests that threaten Florida's horticultural industries, we have been examining published reports in the literature, as well as interception records. This process has been more thorough with respect to the Caribbean than for the world external to the Caribbean, and we will publish these lists of species elsewhere. Table 6 shows the numbers and general location of exotic pest species in various arthropod orders that significantly threaten Florida's horticultural industries. Clearly, a very significant array of serious pests are already assembled in the Caribbean region, and as expected, a dangerous array of exotic pests exists external to the Caribbean Basin. Moreover it is important to recognize that many species in distant regions with the potential to become major pests in the Caribbean do not reveal their harmful characteristics until after they have spread from their centers of origin into new environments (National Plant Board 1999).

Examples of exotic arthropod pest species considered to be significant threats to Florida's horticultural industries are listed in Table 7.

Table 7. Examples of exotic pests that threaten Florida's horticultural industries.

Acari	*Eutetranychus orientalis* (Klein), Oriental red mite (Tetranychidae).
Coleoptera	*Diabrotica speciosa* (Germar), a cucurbit beetle (Chrysomelidae).
Diptera	*Ceratitis capitata* Wiedemann, Mediterranean fruit fly (Tephritidae).
Hemiptera	*Anoplocnemis curvipes* (Fabricius), tip wilter bug (Coreidae)
Homoptera	*Picturaphis vignaphilus* Blanchard, a bean aphid (Aphididae)
Isoptera	*Incisitermes incisus* (Silvestri), a drywood termite (Kalotermitidae)
Lepidoptera	*Maruca vitrata* (Fabricius), bean pod borer (Crambidae)
Orthoptera	*Gryllotalpa africana* Palisot de Beauvois, African mole cricket (Gryllotalpidae)
Thysanoptera	*Scirtothrips aurantii* Faure, South African citrus thrips (Thripidae)

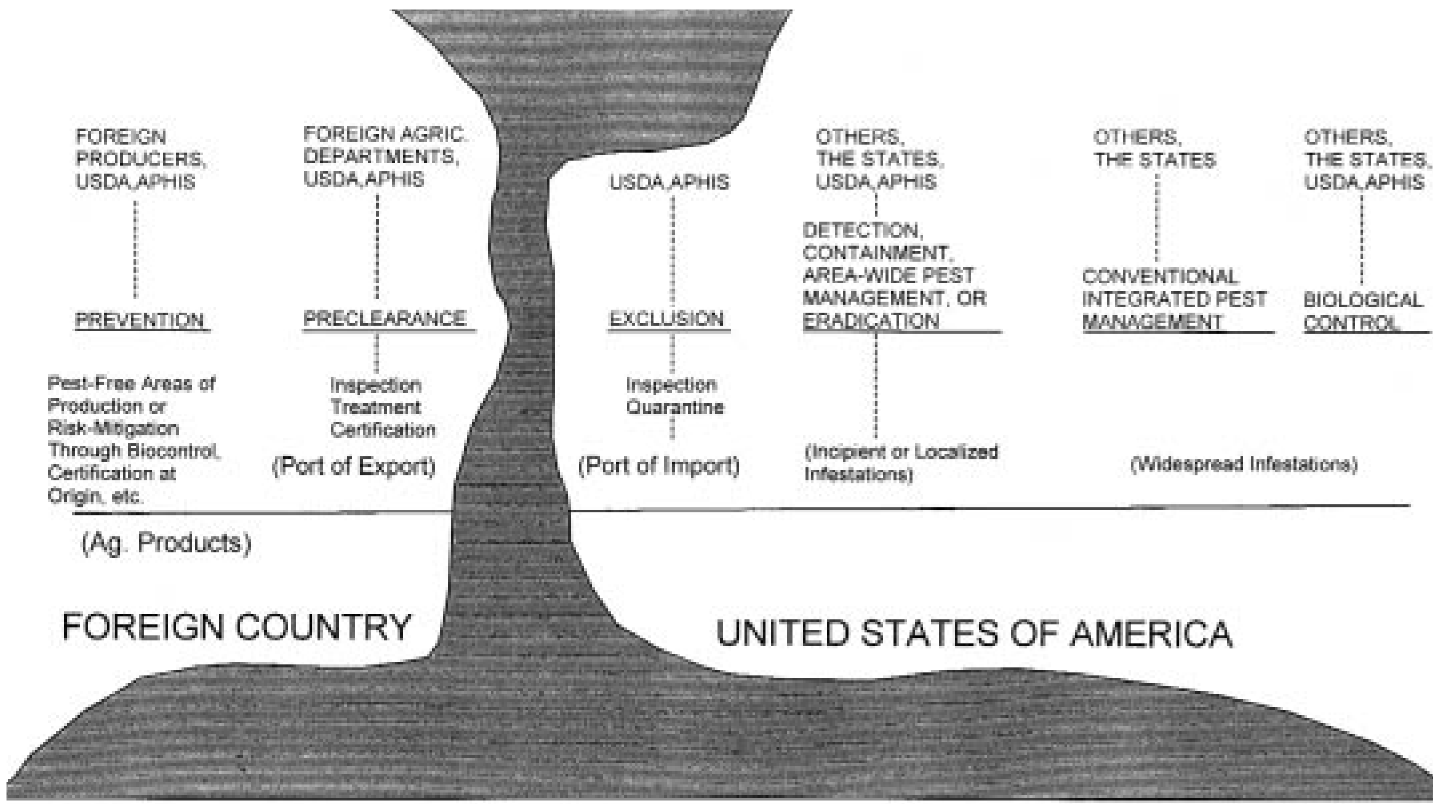

Figure 12. Off-shore and in-country strategies for meeting exotic pest threats.

Greater Shift to Off-Shore Strategies to Assure Exclusion of Exotic Pests

For a full century the United States has relied on inspection of arriving cargo and passengers at the port of entry as a primary exclusionary strategy (Fig. 12). However, volumes of arriving cargo are doubling every five to six years (Zadig, 1999), and it is not possible to increase similarly the human and other resources devoted to inspection at ports-of-entry. Clearly exclusion at the port-of-entry is no longer sufficient to protect U.S. plant resources, even though a number of emerging technologies are likely to facilitate safeguarding activities (Batkin 1999). Thus, in order to stem the influx of exotic pests into the U.S., the National Plant Board (1999) asserted that the most important change needed for the U.S. safeguarding system is to shift primary reliance from exclusion at the port of entry to off-shore actions. Thus the U.S. safeguarding system should place strong emphasis on off-shore pest risk mitigation in the areas of production and their surroundings, certification at the point of origin, and pre-clearance at the port of export (Fig. 12).

An instructive example of off-shore pest risk mitigation is the biological control program to suppress the pink hibiscus mealybug, *Maconellicoccus hirsutus* (Green) (Homoptera: Pseudococcidae), throughout the Caribbean Basin. This Asian pest rapidly spread throughout the Basin, where it attacks several hundred species of plants. During the mid-1990s federal and state entomologists felt that this pest's invasion of Florida was both imminent and inevitable (Chang and Miller 1996). However, under the leadership of Dr. Dale Meyerdirk, APHIS-PPQ, cooperative programs have been established with various Caribbean Basin countries to mass rear and release two species of parasitoids. These parasitoids have strongly reduced the density of pink hibiscus mealybug populations on a broad scale, and the pest has not invaded Florida (Meyerdirk 1999). This program helps to demonstrate the superiority of area-wide pest suppression over conventional field-by-field suppression (Klassen 2000; Lindquist 2000; Mumford 2000), and power of area-wide pest management as a phytosanitary measure (Griffin 2000).

Another highly important approach to off-shore mitigations is the creation of pest-free areas. Indeed countries which export raw agricultural commodities can effectively remove the threat of exotic pests to the importing country by creating and maintaining pest-free areas (Malavasi et al. 1994, Rohwer 1992). A pest-free area is one that lacks a quarantine-significant pest species, and is separated from infested areas by natural or artificial barriers. There are two types of pest-free areas: (1) pest-free zones are large geographic areas, such as the entire country of Chile, that is certified free of tropical fruit flies of economic importance, and (2) pest-free production fields, that require the demonstrated suppression of quarantine pests to non-detectable levels.

In the Caribbean Basin, a number of zones free of plant and animal pests have been or are in the process of being created. Thus an international effort is underway to clear the Suriname fruit fly, *Bactrocera carambolae* Drew & Hancock (Diptera: Tephritidae), from northern South America. A number of the

Lesser Antilles have been certified fruit-fly free (Gomez 1999). The new world screwworm, *Cochliomyia hominivorax* (Coquerel) (Diptera: Calliphoridae), has been cleared from Mexico and Central America with a barrier to reinvasion maintained at the Darien Gap, Panama (Thomas 2000). This parasite of man and warm-blooded animals is in the process of being eradicated from Jamaica, but no eradication programs in Cuba or south of the Darien Gap have been initiated. Further, a program to eradicate classical swine fever is underway in the Dominican Republic (Animal & Plant Health Inspection Service 1999), and a concerted effort is underway to rid the Caribbean islands of the tropical bont tick (Food & Agriculture Organization 1999).

Requirements to establish pest-free fields of crop production include a sensitive detection program, suppression of the quarantine-significant pest to non-detectable levels, strict control of the fields, and safeguards to prevent infestation during packing and transit to the port of export (Riherd 1993, Riherd et al. 1994, Malavasi et al. 1994). Florida is able to export grapefruit to Japan by creating pest-free grapefruit groves in about 22 counties; thus the entire process of production, packing and transit is supervised by inspectors from Japan. Official protocols for pest-free fields can be found in Gomez (1999).

The concept of pest-free fields was pioneered against the Mexican fruit fly in States bordering Mexico (Knipling 1979). Also, up to July 1 of each year, fields in the San Joaquin Valley of California are certified free of the walnut husk fly, *Rhagoletis completa* Cresson (Diptera: Tephritidae), in part because adults of this pest do not emerge prior to mid-July (Yokoyama et al. 1991).

A more recent highly significant development has been the continuous area-wide release of sexually sterile male medflies over the Los Angeles Basin (California Department of Food & Agriculture 2001) and around high-risk ports in southern Florida (Animal & Plant health Inspection Service 1998, J. Stewart, personal communication).

APHIS is involved in a variety of pre-clearance programs in the Caribbean Basin including the automobile ferry between the Dominican Republic and Puerto Rico; where luggage is checked with X-ray machines; export/import protocols to prevent movement of the pink hibiscus mealybug between all CARICOM countries, pre-clearance of horticultural products and methyl bromide treatment of some at Kingston, Jamaica; pre-clearance of root crops in Barbados, and of pineapple and vegetables in Guyana; hot water treatment of mango in Haiti and Mexico; and fumigation of avocado and citrus in Mexico (Gomez 1999).

Conclusion

Clearly a sufficient number of highly effective programs in off-shore pest mitigation and pre-clearance are in operation to fully justify the extensive implementation of off-shore strategies. Griffin (2000) has explained that both the International Plant Protection Convention (IPPC) and the Sanitary and Phytosanitary Measures Agreement (SPS) “are structured to accept and encourage area-wide pest management as a tool for promoting safe trade and contributing as much as possible to the complementary goals of food security and economic security for all countries."

A safeguarding strategy for the Caribbean Basin has been proposed by Mike Shannon, the APHIS Director in Florida (Shannon 1999), this would involve identifying the significant threats both within and external to the Caribbean Basin, building coalitions around the threats, upgrading the safeguarding systems of all Caribbean countries, establishing surveillance programs for key threats, and providing research support for priority areas. Most compelling for Florida would be the regionalization of pest exclusion programs throughout the Caribbean Basin, because a dangerous organism that establishes in one of the countries quickly endangers the entire Basin. Since the U.S. is the leader in the development of the Free-Trade Agreement of the Americas, the U.S. should take the lead in establishing a comprehensive regional pest exclusion program. Such a regional exclusion program would develop regional strategies for stemming the flow of exotics from Asia and other continents into the Caribbean Basin.

Acknowledgements

We are very grateful to the following for providing important information: M. C. Thomas and C. Riherd, Florida Department of Agriculture and Consumer Services, M. Shannon and Lee Newport, Animal and Plant Health Inspection Service, U.S.D.A., and Robert V. Dowell and Dorothea Zadig, California Department of Food and Agriculture. Invaluable assistance in preparing the figures was given by Min Zhang and Karen Minkowski, University of Florida. Invaluable support and encouragement was provided by K. Rohrbach and L. LeBeck, University of Hawai'i and by R. Muniappan, University of Guam. D.F. Davis identified the need for this study and provided resolute support.

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