USDA Animal and Plant Health Inspection Service
Plant Protection and Quarantine

Movement of Mangosteen, *Garcinia mangostana*, from Hawaii into the Continental United States

A Pathway-initiated Risk Assessment

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Executive Summary

This document assesses the risks associated with the movement of fresh fruit of mangosteen, *Garcinia mangostana* L., from Hawaii into the continental United States. A search of both print and electronic sources of information identified six pests of quarantine significance to mangosteen that exist in Hawaii and could be introduced into the continental United States in commodity consignments.

A Consequences of Introduction value was estimated by assessing five elements that reflect the biology and ecology of the pests: Climate-Host Interaction, Host Range, Dispersal Potential, Economic Impact, and Environmental Impact. A Likelihood of Introduction value was estimated by considering the quantity of the commodity imported annually and the potential for pest introduction and establishment. The two values were summed to estimate an overall Pest Risk Potential, which is an estimation of risk in the absence of mitigation measures.

The following table depicts quarantine-significant pests considered as likely to follow the import pathway.

Risks Associated with the Introduction of Quarantine-significant Pests of Mangosteen from Hawaii

Pest	Consequences of Introduction	Likelihood of Introduction	Pest Risk Potential
DIPTERA			
Tephritidae			
Bactrocera dorsalis (Hendel)	High (14)	High (15)	High (29)
Ceratitis capitata (Wiedemann)	High (15)	High (15)	High (30)
HOMOPTERA			
Pseudococcidae			
Dysmicoccus neobrevipes Beardsley	High (13)	Medium (11)	Medium (24)
Maconellicoccus hirsutus (Green)	High (14)	Medium (11)	Medium (25)
Pseudococcus cryptus Hempel	High (13)	Medium (11)	Medium (24)
THYSANOPTERA			
Thripidae			
Thrips florum Schmutz	Medium (12)	Medium (13)	Medium (25)

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I. Introduction

This risk assessment has been prepared by the United States Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS), Plant Protection and Quarantine (PPQ), Center for Plant Health Science and Technology (CPHST), Plant Epidemiology and Risk Analysis Laboratory (PERAL) to examine plant pest risks associated with the movement of fresh fruit of mangosteen, *Garcinia mangostana* L., from Hawaii into the continental United States. Estimates of risk are expressed in terms of High, Medium, or Low. This risk assessment is "pathway-initiated" in that it is based on the potential pest risks associated with the commodity as it enters the continental United States.

The International Plant Protection Convention (IPPC) of the United Nations Food and Agriculture Organization (FAO) provides guidance for conducting pest risk analyses. The methods used to initiate, conduct, and report this pest risk assessment are consistent with guidelines provided by the IPPC (IPPC, 1996). Biological and phytosanitary terms (*e.g*., introduction, quarantine pest) conform to those outlined in FAO (2002).

Pest risk assessment is one component of an overall pest risk analysis. The IPPC describes three stages in pest risk analysis (IPPC, 1996). This document satisfies the requirements of Stages 1, Initiation, and 2, Risk Assessment. Details of the methodology and rating criteria can be found in the template document, Guidelines for Pathway-Initiated Pest Risk Assessments, Version 5.02 (USDA, 2000).

The IPPC defines pest risk assessment as "determination of whether a pest is a quarantine pest and evaluation of its introduction potential;" quarantine pest is defined as "a pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled" (IPPC, 1996). Thus, pest risk assessments should consider both the Consequences and Likelihood of Introduction of quarantine pests. These issues are addressed in this document.

Mangosteen (Fig. 1) is native to southeast Asia (Morton, 1987). Major producers include Thailand (130,000 tonnes from 15,000 ha in 1995), Malaysia (27,000 tonnes from 2200 ha in 1987), the Philippines (2270 tonnes from 1130 ha in 1987), and Indonesia (2500 tonnes in 1987) (Downton & Chacko, 1997). Thailand is the major supplier of international markets with exports valued at $5 million. Major markets are Singapore, Japan, Hong Kong, and Europe. In the United States, this tree crop is still rare in Hawaii, and has not been successfully established in California or Florida (Morton, 1987). Fruits with sepals (calyx, stigma lobes) attached are individually wrapped in tissue paper and packed 24-30 in cardboard boxes or light wooden crates with packing materials, such as excelsior (Morton, 1987; Downton & Chacko, 1997).

Figure 1. Mangosteen, *Garcinia mangostana* L.
(painting by M.J. Dijkman; source: Morton [1987])

II. Risk Assessment

2.1 Initiating Event: Proposed Action

This risk assessment was developed in response to a request by the Hawaii Department of Agriculture for USDA authorization to permit imports of fresh fruit of mangosteen into the continental United States. Entry of this commodity into the continental United States presents the risk of introducing exotic plant pests. Title 7, Part 318, Section 13 of the United States Code of Federal Regulations (7 CFR §318.13) provides regulatory authority for the movement of fruits and vegetables from Hawaii into the continental United States.

2.2 Assessment of Weed Potential of Mangosteen (*Garcinia mangostana*)

This step examines the potential of the commodity to become a weed after it enters the continental United States (Table 1). If the assessment indicates significant weed potential, then a "pest-initiated" risk assessment is conducted.

Table 1. Assessment of the Weed Potential of Mangosteen.

Commodity: Mangosteen (*Garcinia mangostana*) (Clusiaceae).

Phase 1: Mangosteen occurs in Hawaii and Puerto Rico (USDA, 2003a).

Phase 2: Is the species listed in:

- No — *Geographical Atlas of World Weeds* (Holm *et al*., 1979)
- No — *World's Worst Weeds* (Holm *et al*., 1977) or *World Weeds: Natural Histories and Distribution* (Holm *et al*., 1997)
- No — Report of the Technical Committee to Evaluate Noxious Weeds; Exotic Weeds for Federal Noxious Weed Act (Gunn and Ritchie, 1982)
- No — *Economically Important Foreign Weeds* (Reed, 1977)
- No — Weed Science Society of America Composite List of Weeds (WSSA, 2003)
- Yes — Is there any literature reference indicating weediness, *e.g*., AGRICOLA, CAB, Biological Abstracts, AGRIS; search on "species name" combined with "weed."

Phase 3: *Garcinia mangostana* is listed by Randall (2003) as a weed of the status naturalized or introduced, indicating minimal weed potential. The species is present in Hawaii and Puerto Rico, where it is of value as a tree crop; there is no indication that it constitutes a pest of any economic or ecological significance. Mangosteen is a plant of the humid tropics. Traditional growing areas are within 10° of the equator, but the presence of orchards in Australia (Queensland), Madagascar, Honduras, and Brazil indicate that the potential range of the plant extends to 18° latitude in warm, frost-free areas (CABI, 2003). Its ability to naturalize and establish permanent populations in the continental United States is doubtful. The importation of fresh mangosteen should not increase the risk of spreading this plant beyond its present range in the United States. A pest-initiated risk assessment for the species is not necessary.

2.3 Previous Risk Assessments, Current Status, and Pest Interceptions

There are no previous risk assessments for mangosteen from Hawaii. Currently, mangosteen exports from Hawaii are not authorized by 7 CFR §318.13. Table 2 summarizes pest interceptions on *Garcinia mangostana* from Hawaii.

Table 2. PPQ Interceptions on *Garcinia mangostana* from Hawaii (1985-2000).[1]

Organism	Plant Part Infested	Location of Interception	Purpose	Number of Interceptions
INSECTS				
DIPTERA				
Tephritidae				
Tephritidae, species of	Fruit	Baggage	Consumption	1
HOMOPTERA				
Coccidae				
Coccus viridis (Green)	Leaf	Baggage	Consumption	2

[1]Records from the PPQ Port Information Network (PIN 309) database.

2.4 Pest Categorization–Identification of Quarantine Pests and Quarantine Pests Likely to Follow the Pathway

Table 3 lists pests associated with mangosteens that also occur in Hawaii. This list includes information on the presence or absence of these pests in the United States, the affected plant part(s), the quarantine status of the pest with respect to the United States, an indication of the pest-host association, and pertinent references for pest distribution and biology.

Table 3. Pests in Hawaii Associated with Mangosteen (*Garcinia mangostana*).

Pest	Geographic Distribution[1]	Plant Part Affected[2]	Quarantine Pest[3]	Likely to Follow Pathway	References
ARTHROPODS					
ACARI					
Tarsonemidae					
Polyphagotarsonemus latus (Banks)	HI, US	F, L	No	Yes	Anon., 2003; CABI, 2003
Tetranychidae					
Oligonychus coffeae (Nietner)	HI, US (FL)	L	No	No	CABI, 2003; Nishida, 2002; Wongsiri, 1991
COLEOPTERA					
Nitidulidae					
Carpophilus dimidiatus (F.)	HI, US	F, L, Sd	No	Yes	CABI, 2003; Yunus & Ho, 1980
Scolytidae					
Xylosandrus compactus (Eichhoff)[4]	HI, US	S	[Yes]	No	CABI, 2003
DIPTERA					
Drosophilidae					
Drosophila immigrans Sturtevant	HI, US	F	No	Yes	CABI, 2003; Yunus & Ho, 1980
Drosophila melanogaster Meigen (= *D. ampelophila* Loew)	HI, US	F	No	Yes	CABI, 2003; Nishida, 2002; Yunus & Ho, 1980
Tephritidae					
Bactrocera dorsalis (Hendel)	HI	F	Yes	Yes	Burikam *et al.*, 1992; CABI, 2003
Ceratitis capitata (Wiedemann)	HI, US (CA)	F	Yes	Yes	CABI, 2003; Liquido *et al.*, 1991
HOMOPTERA					
Aphididae					
Toxoptera aurantii (Boyer de Fonscolombe)	HI, US	I, L, S	No	No	CABI, 2003; Yunus & Ho, 1980
Coccidae					
Ceroplastes floridensis Comstock	HI, US	L, S	No	No	CABI, 2003; Hamon & Williams, 1984; USDA, 2003b
Coccus viridis (Green)	HI, US (FL)	F, L, S	[Yes]	No[5]	CABI, 2003; PPQ interception

Pest	Geographic Distribution[1]	Plant Part Affected[2]	Quarantine Pest[3]	Likely to Follow Pathway	References
Pulvinaria psidii Maskell	HI, US	F, L, S	No	Yes	CABI, 2003; USDA, 2003b
Vinsonia stellifera (Westwood)	HI, US (AL, FL, GA)	L, S	[Yes]	No	Hamon & Williams, 1984; Kosztarab, 1997; Nishida, 2002; USDA, 2003b; Williams & Watson, 1990
Diaspididae					
Aspidiotus destructor Signoret	HI, US (CA, FL)	F, L, S	No	Yes	CABI, 2003; Dekle, 1965
Chrysomphalus aonidum (L.) (= *C. ficus* Ashmead)	HI, US	F, L, S	No	Yes	CABI, 2003; Dekle, 1965
Diaspis boisduvalii Signoret	HI, US	F, L	No	Yes	Petty *et* al., 2002; USDA, 2003b
Parlatoria ziziphi (Lucas)	HI, US (MS)	F, L, S	Yes	No[6]	CABI, 2003; PPQ interception
Pseudococcidae					
Dysmicoccus neobrevipes Beardsley	HI, US (FL)	F, L, S	[Yes]	Yes	Anon., 2003; Miller & Miller, 2002; Rohrbach *et al*., 1988; USDA, 2003b
Maconellicoccus hirsutus (Green)	HI, US (CA, FL)	F, I, L, S	Yes	Yes	CABI, 2003; PPQ interception
Planococcus citri (Risso)	HI, US	F, R, S	No	Yes	CABI, 2003; Chay-Prove *et al*., 2001
Pseudococcus cryptus Hempel (= *P. citriculus* Green)	HI	F, L, R	Yes	Yes	Avidov & Harpaz, 1969; Ben-Dov, 1993, 1994; PPQ interception
Pseudococcus viburni (Signoret)[4]	HI, US	F	No	Yes	USDA, 2003b
HYMENOPTERA					
Formicidae					
Tapinoma melanocephalum (F.)[4]	HI, US (FL)	F, L	No	Yes	CABI, 2003
Technomyrmex albipes (F. Smith)[4]	HI, US (CA, FL)	F	No	Yes	Deyrup, 1991
Wasmannia auropunctata (Roger)[4]	HI, US (CA, FL)	F, L, S	No	Yes	Nickerson, 1983
LEPIDOPTERA					
Gracillariidae					
Phyllocnistis citrella Stainton	HI, US (AL, CA, FL, LA, TX)	F, L, S	[Yes]	No[7]	CABI, 2003; Heppner, 1995; Nagamine & Heu, 2000; Yunus & Ho, 1980

Pest	Geographic Distribution[1]	Plant Part Affected[2]	Quarantine Pest[3]	Likely to Follow Pathway	References
Noctuidae					
Eudocima fullonia (Clerck)	HI	F	Yes	No[8]	Anon., 2003; Nishida, 2002
Stictoptera cucullioides (Guenée)	HI	L	Yes	No	Yunus & Ho, 1980; Zhang, 1994
THYSANOPTERA					
Thripidae					
Scirtothrips dorsalis Hood	HI	F, I, L, S	Yes	No[9]	CABI, 2003; Wongsiri, 1991
Selenothrips rubrocinctus (Giard)	HI, US (FL)	F, I, L	No	Yes	CABI, 2003
Thrips florum Schmutz	HI, US (FL)	F, I, L	[Yes]	Yes	Hill, 1983; Nakahara, 1994; Swaine & Corcoran, 1975; Yunus & Ho, 1980
FUNGI					
Fusarium solani (Martius) Sacc.[10] (Ascomycetes: Hypocreales)	HI, US	R, S	No	No	CABI, 2003
Gliocephalotrichum bulbilium J.J. Ellis & Hesseltine (Hyphomycetes)	HI, US (LA)	F	No	Yes	Lim & Sangchote, 2003; SBML, 2003
Glomerella cingulata (Stonem.) Spauld. & Schrenk (Ascomycetes)	HI, US	F, I, L, S, Sd	No	Yes	CABI, 2003
Lasiodiplodia theobromae (Pat.) Griffiths & Maubl. (= *Botryodiplodia theobromae* Pat.) (Ascomycetes: Xylariales)	HI, US	F, I, L, R, S, Sd	No	Yes	CABI, 2003; SBML, 2003
Macrophomina phaseolina (Tassi) Goidanich (Coelomycetes)	HI, US	F, I, L, R, S, Sd	No	Yes	CABI, 2003; SBML, 2003
Pestalotia sp.[4] (Coelomycetes: Melanconiales)	HI	L	Yes	No	
Rhizopus stolonifer (Ehrenb.) Lind (= *R. nigricans* Ehrenb.) (Zygomycetes: Mucorales)	HI, US	F	No	Yes	Morton, 1987; SBML, 2003

Pest	Geographic Distribution[1]	Plant Part Affected[2]	Quarantine Pest[3]	Likely to Follow Pathway	References
NEMATODE					
Tylenchulus semipenetrans Cobb (Tylenchulidae)	HI, US	R	No	No	CABI, 2003; Chawla *et al.*, 1980

[1]Distribution (specific states are listed only if distribution is limited): AL = Alabama; CA = California; FL = Florida; GA = Georgia; HI = Hawaii; LA = Louisiana; MS = Mississippi; TX = Texas; US = continental United States (widespread)
[2]Plant Parts: F = Fruit; I = Inflorescence; L = Leaf; R = Root; S = Stem; Sd = Seed
[3]Brackets indicate that the species, although not fitting the definition of a quarantine pest (IPPC, 2002), is actionable (APHIS, PPQ, National Identification Services).
[4]*P. Conant*, Hawaii Department of Agriculture, *in litt*.
[5]Association with *Garcinia mangostana* fruit is based on four U.S. port interceptions (PIN 309). Given the lack of corroborating evidence, these records are considered inadequate to reflect the true host association of the species.
[6]The host range of this species appears to be restricted to Rutaceae, particularly *Citrus* spp.; records from other hosts are questionable (Dekle, 1976; Blackburn & Miller, 1984).
[7]Although this pest has been reported to mine the rinds of citrus fruits (Heppner, 1995), there is no evidence that the fruit of mangosteen is similarly attacked.
[8]Damage results from feeding by adult moths (CABI, 2003), which are not likely to remain with harvested fruit.
[9]Pest associated only with young fruit (Anon., 2003).
[10]Ambrosia fungus associated with *Xylosandrus compactus* in host plants in Hawaii (CABI, 2003).

Quarantine-significant pests that are reasonably expected to follow the pathway (*i.e.*, be included in shipments of mangosteen fruit) are subjected to Steps 5-7 (USDA, 2000) in the following sections of this risk assessment. These pests are listed in Table 4. Organisms listed in Table 3 at the level of genus only are not considered for further analysis as their identities are not clearly defined to ensure that the risk assessment is performed on a distinct organism (IPPC, 2001).

Table 4. Quarantine Pests Selected for Further Analysis.

ARTHROPODS
Bactrocera dorsalis (Hendel) (Diptera: Tephritidae)
Ceratitis capitata (Wiedemann) (Diptera: Tephritidae)
Dysmicoccus neobrevipes Beardsley (Homoptera: Pseudococcidae)
Maconellicoccus hirsutus (Green) (Homoptera: Pseudococcidae)
Pseudococcus cryptus Hempel (Homoptera: Pseudococcidae)
Thrips florum Schmutz (Thysanoptera: Thripidae)

2.5 Consequences of Introduction—Economic/Environmental Importance

Potential Consequences of Introduction are rated using five Risk Elements: Climate-Host Interaction, Host Range, Dispersal Potential, Economic Impact, and Environmental Impact. These elements reflect the biology, host ranges, and climatic/geographic distributions of the pests. For each Risk Element, pests are assigned a rating of Low (1 point), Medium (2 points), or High (3 points) (USDA, 2000). A Cumulative Risk Rating is then calculated by summing all Risk Element values. Table 5 summarizes the values determined for the Consequences of Introduction for each pest.

Consequences of Introduction: *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae)	**Risk Value**
Risk Element #1: Climate-Host Interaction Except for adventive populations in Guam and Hawaii, *B. dorsalis* is restricted to subtropical and tropical Asia (White & Elson-Harris, 1992). It is estimated that this species could establish in the continental United States in areas corresponding to Plant Hardiness Zones 9-11.	Medium (2)
Risk Element #2: Host Range This species is extremely polyphagous. Recorded hosts include *Coffea* sp. (Rubiaceae), *Ficus* sp. (Moraceae), *Prunus* spp. (Rosaceae), *Eugenia uniflora* (Myrtaceae), *Mangifera* spp. (Anacardiaceae), *Citrus* spp. (Rutaceae), *Areca catechu* (Arecaceae), *Chrysophyllum cainito* (Sapotaceae), *Cucumis* spp. (Cucurbitaceae), *Dimocarpus longan* (Sapindaceae), *Diospyros kaki* (Ebenaceae), *Flacourtia indica* (Flacourtiaceae), *Punica granatum* (Punicaceae), *Ziziphus* spp. (Rhamnaceae), *Annona* spp. (Annonaceae), *Averrhoa carambola* (Oxalidaceae), *Carica papaya* (Caricaceae), *Malpighia glabra* (Malpighiaceae), *Muntingia calabura* (Elaeocarpaceae), *Persea americana* (Lauraceae), *Terminalia catappa* (Combretaceae), *Musa* x *paradisiaca* (Musaceae) (CABI, 2003); *Passiflora mollisima* (Passifloraceae), *Juglans hindsii* (Juglandaceae), *Quassia simarouba* (Simaroubaceae), *Solanum seaforthianum* (Solanaceae), *Clausena lansium* (Rutaceae) (White & Elson-Harris, 1992), and *Garcinia mangostana* (Clusiaceae) (Burikam *et al*., 1992).	High (3)
Risk Element #3: Dispersal Potential Females deposit 3-30 eggs per host fruit; total fecundity per female may exceed 1000 eggs (Fletcher, 1989a). There are several generations per year. Adult flight of *B. dorsalis* shows that it is capable of flying distances up to 65 km (Fletcher, 1989b); the transport of infested fruit are the major means of movement and dispersal to previously uninfested areas (CABI, 2003). Like other dacine tephritids, *B. dorsata* exhibits high reproductive and dispersal potentials.	High (3)
Risk Element #4: Economic Impact Economic losses resulting from attack by this pest are of three kinds (Harris, 1989): 1) downgrading of quality caused by oviposition "stings," which spoil the appearance of fruits, including those unfavorable for larval survival; 2) fruit spoilage caused by larval tunneling and the entry of organisms of decay; and 3) indirect damage in the form of lost markets resulting from the imposition of quarantine restrictions. In Hawaii, annual losses in major fruit crops caused by *B. dorsalis* may exceed 13%, or $3 million (Culliney, 2002). The fly is a quarantine pest for numerous countries (PRF, 2004), suggesting that its introduction could result in a loss of foreign markets for various U.S.-grown commodities.	High (3)
Risk Element #5: Environmental Impact Because of its extremely broad host range, *B. dorsalis* represents a potential threat to plants listed as Threatened or Endangered, Title 50, Part 17, Section 12 of the United States Code of Federal Regulations (50 CFR §17.12), which also occur in the southern areas of the continental United States (*e.g.*, *Prunus geniculata*, *Ziziphus celata*). As the species is a pest of numerous crops of economic significance in the continental United States (*e.g.*, apple, peach, pear, citrus), its entry and establishment could stimulate the initiation of chemical or biological control programs, as has occurred in Hawaii (Clausen, 1978b).	High (3)

Consequences of Introduction: *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae)	**Risk Value**
Risk Element #1: Climate-Host Interaction *Ceratitis capitata* is found in southern Europe and west Asia, Africa, South and Central America, and Australia (CABI, 2003). This species has the capacity to tolerate colder climates better than most other fruit fly species (Weems, 1981). It is estimated that *C. capitata* could become established in the areas of the United States corresponding to Plant Hardiness Zones 8-11.	High (3)
Risk Element #2: Host Range This pest has been recorded from a wide variety of host plants in several families, including *Coffea* sp. (Rubiaceae), *Capsicum annuum* (Solanaceae), *Citrus* spp. (Rutaceae), *Malus pumila* and *Prunus* spp. (Rosaceae), *Ficus carica* (Moraceae), *Psidium guajava* (Myrtaceae), *Theobroma cacao* (Sterculiaceae), *Phoenix dactylifera* (Arecaceae), *Mangifera indica* (Anacardiaceae) (CABI, 2003), and *Garcinia mangostana* (Clusiaceae) (Liquido *et al*., 1991).	High (3)
Risk Element #3: Dispersal Potential Females may deposit as many as 800 eggs in a lifetime, although 300 is the more typical number (Weems, 1981). Eggs are inserted into host fruit in small batches of one to 10. The species is multivoltine, the number of generations per year being determined mainly by temperature (Fletcher, 1989a). Adult flight (with a range of 20 km or more) (Fletcher, 1989b), and the transport of infested fruit, are the major means of movement and dispersal to previously uninfested areas (CABI, 2003).	High (3)
Risk Element #4: Economic Impact *Ceratitis capitata* is an important pest in Africa and has spread to almost every other continent to become the single most important pest species in its family. In Mediterranean countries, it is particularly damaging to citrus and peach crops. It may also transmit fruit-rotting fungi (CABI, 2003). The species is of quarantine significance worldwide, especially in Japan and the United States. Its presence, even as temporary adventive populations, can lead to severe additional constraints for export of fruits to uninfested areas throughout the world. In this respect, *C. capitata* is one of the most significant quarantine pests for any tropical or warm temperate areas in which it is not yet established (CABI, 2003).	High (3)
Risk Element #5: Environmental Impact As it represents a significant threat to citrus and peach production, the wider establishment of *C. capitata* in the continental United States would undoubtedly trigger the initiation of chemical or biological control programs, as has occurred in California (Carey, 1991) and Hawaii (Clausen, 1978b). This species is highly polyphagous and has the potential to attack plants listed as Threatened or Endangered (*e.g*., *Opuntia treleasei*, *Prunus geniculata*).	High (3)

Consequences of Introduction: *Dysmicoccus neobrevipes* Beardsley (Homoptera: Pseudococcidae)	**Risk Value**
Risk Element #1: Climate-Host Interaction *Dysmicoccus neobrevipes* occurs throughout Central America, northern South America, the Caribbean, Indo-China, the Philippines, Oceania, and Florida in the continental United States (Ben-Dov, 1994; CABI, 2003; Miller & Miller, 2002). Outside of greenhouse or other artificial situations, this species could survive in the warmer, southern parts of the United States Plant Hardiness Zones 9-11.	Medium (2)

Risk Element #2: Host Range This species is extremely catholic in its host plant preferences, which extend across 31 families. Hosts include *Ananas comosus* (Bromeliaceae), *Malus pumila* (Rosaceae) (CABI, 2003); *Colocasia esculenta* (Araceae), *Ficus* sp. (Moraceae), *Musa paradisiaca* (Musaceae), *Opuntia ficus-indica* (Cactaceae), *Pritchardia* sp. (Arecaceae), *Acacia koa* and *Samanea saman* (Fabaceae), *Helianthus annuus* (Asteraceae) (Nakahara, 1981); *Agave sisalana* (Agavaceae), *Cucurbita maxima* (Cucurbitaceae), *Zea mays* (Poaceae), *Heliconia latispatha* (Heliconiaceae), *Citrus* spp. (Rutaceae), *Lycopersicon esculentum* (Solanaceae), and *Garcinia mangostana* (Clusiaceae) (USDA, 2003b).	High (3)
Risk Element #3: Dispersal Potential Ito (1938) reported females of the "gray form" of *D. brevipes* (considered by Beardsley [1959] to be *D. neobrevipes*) to produce an average of 347 progeny. Life span averaged about 95 days, and several generations per year were indicated. As in all Coccoidea (Gullan & Kosztarab, 1997), the main dispersal stage of mealybugs is the first-instar crawler, which may be locally transported by wind or other animals. Dispersal over longer distances is accomplished through the movement of infested plant materials in commerce (Williams & Granara de Willink, 1992).	High (3)
Risk Element #4: Economic Impact *Dysmicoccus neobrevipes* attacks a number of valuable commercial crops, and is a particularly serious pest of pineapple, *Ananas comosus* (Rohrbach *et al*., 1988). Like *D. brevipes*, it is a vector of the virus causing pineapple wilt disease. Feeding by large mealybug populations may cause a loss of host plant vigor. Honeydew deposited on leaves and fruit by mealybugs serve as a medium for the growth of black sooty molds, which interfere with photosynthesis and reduce the market value of the crop. Insecticides are often applied to control these mealybugs (or the attending ants) that aid in their spread and interfere with their biological control (Jahn *et al*., 2003). Although *D. neobrevipes* is a quarantine pest for Korea and New Zealand (PRF, 2004), it is established in the United States and under no apparent official control. Additional introductions of the mealybug are not likely to result in the loss of foreign markets for commodities, such as citrus.	Medium (2)
Risk Element #5: Environmental Impact Further introductions of *D. neobrevipes* would likely result in the initiation of chemical or biological control programs, as has occurred in Hawaii and Puerto Rico (Bartlett, 1978). The species is polyphagous, and has the potential to infest plants listed as Threatened or Endangered (*e.g*., *Opuntia treleasei*, *Cucurbita okeechobeensis* ssp. *okeechobeensis*).	High (3)

Consequences of Introduction: *Maconellicoccus hirsutus* (Green) (Homoptera: Pseudococcidae)	**Risk Value**
Risk Element #1: Climate-Host Interaction *Maconellicoccus hirsutus* is probably native to southern Asia (CABI, 2003). Its range extends from south, southeast and east Asia, the Philippines, Indonesia, Australia, Lebanon, Africa, northern South America, parts of North America (including California and Florida in the United States), and the Caribbean. It should be able to establish in the southern United States Plant Hardiness Zones 9-11.	Medium (2)
Risk Element #2: Host Range This species is extremely polyphagous. It has been recorded on plants in over 200 genera from 73 families, showing some preference for hosts in the Malvaceae, Fabaceae, and Moraceae (CABI, 2003). Primary hosts include species of *Hibiscus* and *Gossypium* (Malvaceae), *Artocarpus* spp. (Moraceae), *Persea americana* (Lauraceae), *Annona* spp. (Annonaceae), *Citrus* spp. (Rutaceae), *Averrhoa carambola* (Oxalidaceae), *Passiflora edulis* (Passifloraceae), *Musa paradisiaca* (Musaceae), *Theobroma cacao* (Sterculiaceae), *Vitis*	High (3)

vinifera (Vitaceae), *Bougainvillea* sp. (Nyctaginaceae), and *Boehmeria nivea* (Urticaceae). Other hosts include *Asparagus officinalis* (Liliaceae), *Brassica oleracea* (Brassicaceae), *Codiaeum variegatum* (Euphorbiaceae), *Malus sylvestris* (Rosaceae), *Coffea arabica* (Rubiaceae), *Lycopersicon esculentum* (Solanaceae), *Phoenix* spp. (Arecaceae), *Terminalia catappa* (Combretaceae), *Syzygium cumini*, *Psidium guajava* (Myrtaceae), *Zea mays* (Poaceae), *Parthenium hysterophorus* (Asteraceae), *Chenopodium album* (Chenopodiaceae) (CABI, 2003), *Clitoria ternatea* (Fabaceae), *Cucurbita* spp. (Cucurbitaceae), *Eryngium foetidum* (Apiaceae), *Euphorbia* spp. and *Manihot esculenta* (Euphorbiaceae), *Opuntia* sp. (Cactaceae), *Prunus persica* (Rosaceae), and *Ziziphus* spp. (Rhamnaceae) (Meyerdirk *et al*., 2003). The mealybug has been intercepted at U.S. ports at least 17 times on mangosteen fruit (PIN 309), suggesting an association with that host species.	
Risk Element #3: Dispersal Potential Fecundity ranges from about 80 to over 600 eggs per female (Meyerdirk *et al*., 2003). There may be as many as 15 generations per year (CABI, 2003). Local dispersal is accomplished by movement of the first-instar crawler, most efficiently via air, water, or on animals (CABI, 2003). All stages may be dispersed over longer distances through the transport of infested plant materials.	High (3)
Risk Element #4: Economic Impact *Maconellicoccus hirsutus* attacks a wide range of (usually woody) plants, including agricultural, horticultural, and forest species (CABI, 2003). Feeding on young growth causes severe stunting and distortion of leaves, thickening of stems, and a bunchy-top appearance of shoots; in severe cases the leaves may prematurely fall. Honeydew and sooty mold contamination of fruit may reduce its value. In Grenada, estimated annual losses to crops and the environment from this mealybug were US$3.5 million before biological controls were implemented (CABI, 2003). Other crops seriously damaged by *M. hirsutus* include cotton in Egypt, with growth sometimes virtually halted; tree cotton in India, with reduction in yield; the fiber crop *Hibiscus sabdariffa* var. *altissima* (roselle) in India and Bangladesh, with reduction in yields of between 21 and 40%; and grapes in India, with up to 90% of bunches destroyed. The mealybug is a quarantine pest for Brazil, Chile, Colombia, Costa Rica, Korea, New Zealand, Panama, and Uruguay (PRF, 2004), suggesting that its widespread establishment in the United States could result in a loss of foreign markets for various commodities.	High (3)
Risk Element #5: Environmental Impact The extreme polyphagy of this pest predisposes it to attack plants in the continental United States listed as Threatened or Endangered (*e.g*., *Clitoria fragrans*, *Cucurbita okeechobeensis* ssp. *okeechobeensis*, *Eryngium* spp., *Euphorbia telephioides*, *Manihot walkerae*, *Opuntia treleasei*, *Prunus geniculata*, *Ziziphus celata*). As it is a potential threat to a number of crops of considerable economic value in the United States, such as citrus and grape, additional introductions of *M. hirsutus* would likely lead to the initiation of chemical or biological control programs. The species has been targeted for biological control in other countries, such as Egypt and India, into which it has been introduced (Bartlett, 1978).	High (3)

Consequences of Introduction: *Pseudococcus cryptus* Hempel (Homoptera: Pseudococcidae)	**Risk Value**
Risk Element #1: Climate-Host Interaction This species exhibits a subtropical to tropical distribution (Ben-Dov, 1994). It occurs in Kenya and Zanzibar in Africa; Israel to Japan in the east; parts of South and Central America; the Caribbean; and various island groups of the Pacific. It should be able to establish in the warmer, southern parts of the continental United States Plant Hardiness Zones 9-11.	Medium (2)

Risk Element #2: Host Range *Pseudococcus cryptus* has been recorded on hosts in more than 20 families, including *Mangifera indica* (Anacardiaceae), *Plumeria* sp. (Apocynaceae), *Dahlia* sp. (Asteraceae), *Hevea brasiliensis* (Euphorbiaceae), *Persea americana* (Lauraceae), *Erythrina* sp. (Fabaceae), *Crinum asiaticum* (Liliaceae), *Artocarpus altilis* (Moraceae), *Musa* sp. (Musaceae), *Psidium guajava* (Myrtaceae), *Cocos nucifera* (Arecaceae), *Pandanus upoluensis* (Pandanaceae), *Passiflora foetida* (Passifloraceae), *Piper methysticum* (Piperaceae), *Coffea* spp. (Rubiaceae), *Citrus* spp. (Rutaceae) (Ben-Dov, 1994); *Hibiscus* sp. (Malvaceae), and various Orchidaceae (Hill, 1983). In laboratory tests, the species has been found to complete development on *Pyrus* spp., *Malus pumila*, and *Cydonia oblonga* (Rosaceae), *Solanum tuberosum* (Solanaceae), *Aralia cachemirica* (Araliaceae), and *Eugenia* spp. (Avidov & Harpaz, 1969). The mealybug has been intercepted at U.S. ports on at least 204 occasions on mangosteen fruit (PIN 309).	High (3)
Risk Element #3: Dispersal Potential Avidov & Harpaz (1969) outlined the reproductive biology of this species. Fecundity ranges from 200-500 eggs per female; at least six generations per year have been recorded. The insect is only capable of limited dispersal under its own power. Long-distance spread would be accomplished via the movement of infested plant materials.	High (3)
Risk Element #4: Economic Impact *Pseudococcus cryptus* is major pest of citrus (Hill, 1983). The insect produces copious quantities of honeydew, on which sooty molds develop, sometimes reaching a thickness of 5-8 mm (Avidov & Harpaz, 1969). In heavy infestations, entire trees may be contaminated, and leaves and fruit prematurely shed. High population densities on coconut palm may cause drying of the inflorescence and button shedding (Moore, 2001). The pest is regarded as a major threat to U.S. agriculture (Miller *et al*., 2002). In Israel, both biological and chemical controls have succeeded in maintaining populations below economically damaging densities (Avidov & Harpaz, 1969; Blumberg *et al*., 2001). Introduction of this mealybug into the continental United States could result in a loss of domestic markets for various commodities.	High (3)
Risk Element #5: Environmental Impact Although it attacks a broad range of plant species, *P. cryptus* is not expected to pose a threat to vulnerable native plants in the continental United States; close relatives of some of its known hosts that occur in Puerto Rico (*i.e*., *Eugenia haematocarpa*, *E. woodburyana*, *Solanum drymophilum*) are listed as Endangered in 50 CFR §17.12. As it is a known pest of citrus, its introduction into the citrus-growing regions of the continental United States could spur the initiation of chemical or biological control programs, which has occurred in response to the introduction of other mealybug species (Bartlett, 1978).	Medium (2)

Consequences of Introduction: *Thrips florum* Schmutz (Thysanoptera: Thripidae)	**Risk Value**
Risk Element #1: Climate-Host Interaction The distribution of *T. florum* extends from south, southeast, and east Asia, Oceania, and Australia (Hill, 1983; Nakahara, 1994; Hua, 2000). In the Western Hemisphere, the species occurs in the Caribbean and in the southeastern United States. From this subtropical to tropical distribution, it is estimated that it would be able to establish in the southern areas of the continental United States Plant Hardiness Zones 9-11.	Medium (2)

Risk Element #2: Host Range This thrips has been recorded on *Musa* x *paradisiaca* (Musaceae), *Syzygium jambos* (Myrtaceae) (Hill, 1983); *Gardenia angusta* (Rubiaceae) (Halbert, 1996); *Allium cepa* (Liliaceae) (CABI, 2003); *Citrus limon* (Rutaceae) (Hua, 2000); *Pyrus* sp. and *Malus* sp. (Rosaceae); *Passiflora* sp. (Passifloraceae) (Abraham *et al*., 1970); *Dendranthema morifolium* (Asteraceae) (Anon., 1988); and *Sesamum* sp. (Pedaliaceae) (Karuppaiyan, 1998), as well as *Garcinia mangostana* (Clusiaceae) (Yunus & Ho, 1980).	High (3)
Risk Element #3: Dispersal Potential No information is available on the reproductive biology or dispersal capacity of this species. Long-distance dispersal would be presumably achieved by passive means, as a component of the so-called aerial plankton (Glick, 1939), or through the movement of infested plant materials. Because of the uncertainty surrounding the dispersal potential of this pest, risk associated with this element is estimated to be High.	High (3)
Risk Element #4: Economic Impact Little information is available concerning the damage caused by *T. florum*. Hill (1983) lists the species as a minor pest of banana and rose apple (*S. jambos*). Feeding on banana produces greyish blotching and brown eruptions on the peel, a condition known as "corky scab" (Sivakumar & Mohanasundaram, 1971; Swaine & Corcoran, 1975). In severe infestation, fruits may split open (Anon., 1998). (No reports of this thrips feeding on mangosteen fruit are known.) Control measures include bud injection with insecticides and bagging the inflorescence with insecticide-impregnated polyethylene bags. As this thrips was long considered a synonym of *T. hawaiiensis*, some of the damage attributed to the latter species may have been caused by *T. florum* (Nakahara, 1994). As it is established in the continental United States, and under no apparent official control, further introductions are not considered likely to result in a loss of markets beyond those presently closed.	Medium (2)
Risk Element #5: Environmental Impact As no close relatives of known hosts are listed in 50 CFR §17.12, *T. florum* is not expected to pose a significant threat to Endangered native plants in the continental United States. As this thrips represents a potential threat to citrus, pear, and apple production, additional introductions into the continental United States could stimulate the initiation of chemical or biological control programs, as has occurred in Hawaii and elsewhere (Clausen, 1978a).	Medium (2)

Risk values determined for the Consequences of Introduction for each pest are summarized in Table 5.

Table 5. Risk Rating for Consequences of Introduction (Mangosteen, *Garcinia mangostana*, from Hawaii).

Pest	Risk Element 1 Climate/ Host Interaction	Risk Element 2 Host Range	Risk Element 3 Dispersal Potential	Risk Element 4 Economic Impact	Risk Element 5 Environmental Impact	Cumulative Risk Rating
Bactrocera dorsalis (Hendel)	Medium (2)	High (3)	High (3)	High (3)	High (3)	High (14)
Ceratitis capitata (Wiedemann)	High (3)	High (3)	High (3)	High (3)	High (3)	High (15)
Dysmicoccus neobrevipes Beardsley	Medium (2)	High (3)	High (3)	Medium (2)	High (3)	High (13)
Maconellicoccus hirsutus (Green)	Medium (2)	High (3)	High (3)	High (3)	High (3)	High (14)
Pseudococcus cryptus Hempel	Medium (2)	High (3)	High (3)	High (3)	Medium (2)	High (13)
Thrips florum Schmutz	Medium (2)	High (3)	High (3)	Medium (2)	Medium (2)	Medium (12)

2.6 Likelihood of Introduction—Quantity Imported and Pest Opportunity
The Likelihood of Introduction is a function of both the quantity of the commodity imported annually and pest opportunity, which consists of five criteria that consider the potential for pest survival along the pathway (USDA, 2000) (Table 6).

Quantity of commodity imported annually
The rating for the quantity imported annually is based on the amount reported by the exporter, and is then converted into standard units of 40-foot-long shipping containers. The projected initial volume of mangosteen fruit to be shipped from Hawaii to the continental United States is estimated to be no more than 13.5 tonnes (Conant, 2002), which would not fill a single standard 40-foot-long shipping container.

Survive post-harvest treatment
The fruit flies, *Bactrocera dorsalis* and *Ceratitis capitata*, as internal pests, would be expected to survive minimal post-harvest treatment, such as washing and culling, especially if the infestation did not create obvious damage. The remaining pests, the mealybugs, *Dysmicoccus neobrevipes*, *Maconellicoccus hirsutus*, and *Pseudococcus cryptus*, and *Thrips florum*, are external feeders, and have less of a probability of surviving post-harvest treatments; however, depending on their stage (egg, larva or nymph, adult) or instar, these diminutive insects might find shelter on fruit. For example, many scale insects (Coccoidea, the group of Homoptera, to which mealybugs belong) prefer tight, protected areas, such as cracks and crevices (Kosztarab, 1996). Their cryptic behavior, small size (most scales are less than 5 mm long) (Gullan & Kosztarab, 1997), and water-repellent, waxy coverings, can make them difficult to see or dislodge, particularly if mangosteen fruit is harvested with sepals attached. Many thrips seek protection in narrow crevices on their hosts, and there is little wandering from these sites (Lewis, 1973). *Thrips florum*

is tiny (adult length: 1.15-1.51 mm; Nakahara, 1994), and could be difficult to detect on, or remove from, mangosteen, particularly if concealed beneath the sepals.

Survive shipment
Mangosteen fruit is typically stored at 13°C; the ideal temperature range for shipping is 13-25°C (Downton & Chacko, 1997). Under such benign conditions, all pests are expected to have a High probability of surviving shipment.

Not detected at a port-of-entry
As with assessing the risk of mangosteen pests surviving post-harvest treatment, estimating the risk that these pests will not be detected at a port-of-entry involves consideration of pest size, mobility, and degree of concealment. Again, depending on the age of infestation, *B. dorsalis* and *C. capitata* could have a High probability of escaping detection at a port-of-entry, and unless the fruit is cut open, the fruit fly-infested fruit may go unrecognized (White & Elson-Harris, 1992). Large, conspicuous infestations could lead to the easy detection of mealybugs. Sparser populations of these small insects and the thrips would be more difficult to discover, particularly if concealed on fruit (*e.g.,* under sepals) or in packing materials.

Moved to a habitat suitable for survival
Mangosteens from Hawaii are likely to be sold in every state. If it is assumed that the demand for the fruit is proportional to the size of the consumer population in potential markets, then imports might be concentrated more in some regions of the United States than in others; these regions might not all be conducive to the pest's survival. Countries in east and southeast Asia (*e.g*., China, Brunei) are reported to be large markets for mangosteens from Thailand (Anon., 2003), which is the largest producer (Downton & Chacko, 1997). Asian groups, therefore, would likely constitute the major markets for mangosteen in the United States. Seven states, having 50% of the total U.S. Asian population (USCB, 2003: Table 21), contain areas within Plant Hardiness Zones 9-11; and 17 (58% of the total Asian population) contain areas within Plant Hardiness Zones 8 and above. Assuming that any infestations would be randomly distributed among consignments, the pests are estimated to present a Medium risk of moving to habitat suitable for survival.

Come into contact with host material suitable for reproduction
Assessment of the probability that a plant pest will come into contact with host material must take into account the availability, in time and space, of its host plants, particular plant parts that the pest might feed on or use for reproduction, and the pest's inherent powers of movement, which allow it to successfully find and colonize hosts. Hosts of the pests, in addition to citrus, are all highly polyphagous, and include temperate-zone or widely cultivated plants (USDA, 2003a); these hosts are available throughout the potential geographic range in the continental United States.

As mangosteen fruits are imported for consumption only, they would be expected to have a limited chance of introduction into the natural or agricultural environments in which alternate hosts might be found. Because of the high dispersal potentials, and considerable flight ranges of the two fruit fly species (Fletcher, 1989b), the risk associated with the likelihood of the fruit fly species coming into contact with host material is considered to be High.

Other pests potentially accompanying mangosteen consignments from Hawaii, such as the scale insects *D. neobrevipes*, *M. hirsutus*, and *P. cryptus*, have limited powers of dispersal; as a result, they lack the ability to quickly locate hosts. For these insects to successfully become established in a new environment, at least two necessary conditions must co-occur: close proximity of susceptible hosts, and presence on imported fruit of crawlers or other mobile forms to transfer to new hosts (Miller, 1985; Blank *et al*., 1993). Since these circumstances are highly unlikely to co-occur (Miller, 1985), there is a Low risk of contacting suitable host material.

There is no reason to assume *a priori* that even the somewhat more mobile, flight-capable *T. florum* would have a high probability of finding its requisite host material, even if it occurred near ports-of-entry, produce distribution centers, grocery stores, markets, kitchens, or landfills. Superimposed on the question of host access is that concerning the influence of the many mortality factors (*e.g*., predators or unfavorable ambient conditions, such as extremes of temperature or humidity) present in any environment (and the stochasticity often operating in these) (Mack *et al*., 2000). Based on what has been observed regarding the success of invasive organisms, the probability that non-indigenous species, such as insects, becoming established, once they enter the United States, is estimated to be no more that 1% (Williamson & Fitter, 1996).

Dysmicoccus neobrevipes, *M. hirsutus*, and *T. florum* have all established populations in the continental United States. These species have a High probability of coming into contact with host material suitable for reproduction; this is clearly demonstrated by the fact that they have already done so. The risk arising from their likelihood of contacting hosts is estimated to be High.

The risk values determined for the Likelihood of Introduction for each pest are summarized in Table 6.

Table 6. Risk Rating for Likelihood of Introduction of Mangosteen, Garcinia mangostana, from Hawaii.

Pest	Quantity imported annually	Survive post-harvest treatment	Survive shipment	Not detected at port–of-entry	Moved to suitable habitat	Contact with host material	Cumulative Risk Rating
Bactrocera dorsalis (Hendel)	Low (1)	High (3)	High (3)	High (3)	Medium (2)	High (3)	High (15)
Ceratitis capitata (Wiedemann)	Low (1)	High (3)	High (3)	High (3)	Medium (2)	High (3)	High (15)
Dysmicoccus neobrevipes Beardsley	Low (1)	Medium (2)	High (3)	Medium (2)	Medium (2)	Low (1)	Medium (11)
Maconellicoccus hirsutus (Green)	Low (1)	Medium (2)	High (3)	Medium (2)	Medium (2)	Low (1)	Medium (11)
Pseudococcus cryptus Hempel	Low (1)	Medium (2)	High (3)	Medium (2)	Medium (2)	Low (1)	Medium (11)
Thrips florum Schmutz	Low (1)	Medium (2)	High (3)	Medium (2)	Medium (2)	High (3)	Medium (13)

2.7 Conclusion—Pest Risk Potential and Pests Requiring Phytosanitary Measures

The summation of the values for the Consequences of Introduction and the Likelihood of Introduction yields Pest Risk Potential values (USDA, 2000) (Table 7). This is an estimate of the unmitigated risks associated with this importation.

Table 7. Pest Risk Potential.

Pest	Consequences of Introduction	Likelihood of Introduction	Pest Risk Potential
Bactrocera dorsalis (Hendel)	High (14)	High (15)	High (29)
Ceratitis capitata (Wiedemann)	High (15)	High (15)	High (30)
Dysmicoccus neobrevipes Beardsley	High (13)	Medium (11)	Medium (24)
Maconellicoccus hirsutus (Green)	High (14)	Medium (11)	Medium (25)
Pseudococcus cryptus Hempel	High (13)	Medium (11)	Medium (24)
Thrips florum Schmutz	Medium (12)	Medium (13)	Medium (25)

Pests with a Pest Risk Potential value of Low do not require mitigation measures, whereas a value within the Medium range indicates that specific phytosanitary measures may be necessary. The PPQ Guidelines state that a High Pest Risk Potential means that specific phytosanitary measures are strongly recommended, and that port-of-entry inspection is not considered sufficient to provide phytosanitary security.

III. Risk Mitigation Options

1. Irradiation treatment at a dose of 400 Gy (7 CFR §305.31a) for all quarantine-significant insect pests.

2. Irradiation treatment at a dose of 150 Gy (7 CFR §305.31a) for *Bactrocera dorsalis* and *Ceratitis capitata*; warm, soapy water wash and brushing (T102-c, PPQ Treatment Manual) for *Dysmicoccus neobrevipes*, *Maconellicoccus hirsutus*, *Pseudococcus cryptus*, and *Thrips florum*.

3. Irradiation treatment at a dose of 150 Gy (7 CFR §305.31a) for *Bactrocera dorsalis* and *Ceratitis capitata*; inspection for *Dysmicoccus neobrevipes*, *Maconellicoccus hirsutus*, *Pseudococcus cryptus*, and *Thrips florum*.

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