Mini Risk Assessment
Fruit Piercing Moth: *Eudocima fullonia* Green
[Lepidoptera: Noctuidae]

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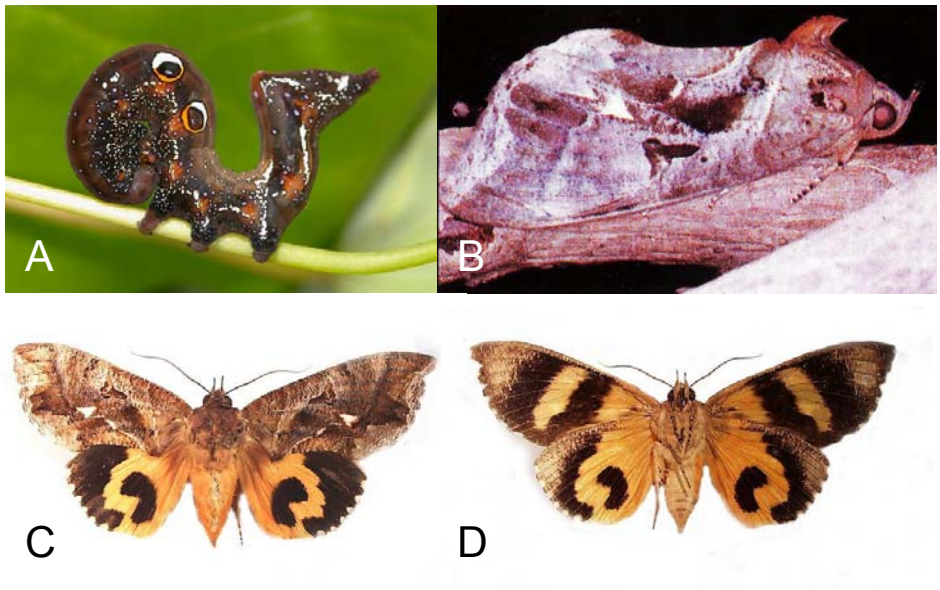

Figure 1. *E. fullonia*: (A) larva; (B) adult female at rest; (C) adult female dorsal view; and (D) adult female ventral views.
[Images courtesy of (A) J. Otto, http://linus.socs.uts.edu.au/~don/larvae/cato/fullon.html); (B) Apte (1999); (C-D) CSIRO (2004).]

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Introduction

Eudocima fullonia, also known as the fruit-piercing moth is a significant pest of citrus and several commercial fruit crops (Baptist 1944, CAB 2004). This insect occurs in Africa, Asia, Oceania, but is native to the Indo-Malaysian region (Baptist 1944, APPC 1987, CABI/EPPO 2001). Unlike most other moths, *E. fullonia* uses its proboscis to puncture fleshy plant parts, typically fruit, to feed (Bänziger 1982). Larvae have no such requirement, so host plants typically differ between larval and adult stages. Larvae are primarily foliage feeders of several wild trees, shrubs and vines within the families Menispermaceae and Fabaceae.

Although *E. fullonia* is present in Hawaii and the Northern Mariana Islands (Comstock 1963, CABI/EPPO 2001), it is not currently known to occur in the conterminous United States. Several commodities pest risk assessments mention *Eudocima fullonia* as a surface feeder of fruit (e.g., grapes from Korea; pears from China) but conclude that this pest is not likely to remain with commodities during processing and shipment (Cave and Lightfield 1997, Hanken 2002). The purpose of this "mini" risk assessment is to evaluate several factors that contribute to risks posed by *E. fullonia* and apply this information to the refinement of sampling and detection programs.

1. **Ecological Suitability**. **Rating: Medium.** *Eudocima fullonia* is present in Africa, Asia, and Oceania . Appendix A provides a detailed list of the reported worldwide distribution of this noctuid moth. In general, *E. fullonia* currently occurs in dry or tropical climates and may be encroaching upon warm temperate climates with dry winters (CAB 2004). Bänziger (1987) considers this insect primarily a tropical, lowland species, but this description is inconsistent with observations of the insect in Japan and Korea (Appendix A-Table A1). Based on our analysis of the currently reported worldwide distribution, it appears that *E. fullonia* is most closely associated with biomes characterized as: temperate broadleaf and mixed forests; tropical and subtropical grasslands, savannas and shrubs; and tropical and subtropical moist broadleaf forests. Consequently, we estimate that approximately 30% of the continental US would have a suitable climate for *Eudocima fullonia* (Fig. 2). See Appendix A for a more complete description of this analysis.

   Based on available information about the geographic distribution of this pest, the presence of *E. fullonia* in Mongolia (Appendix A, Table A1) is questionable for several reasons. A distribution map produced by the Commonwealth Institute of Entomology places the insect in Mongolia based on a non-refereed citation from Wu who reported the insect from Amurland in the Russian Far East (CIE 1977). A review by Zhang (1994) does not include Mongolia in the geographic distribution of *E. fullonia*. Finally, Mongolia has a very different climate than any

other country where *E. fullonia* is known to occur. If Mongolia is a correct record, then we would have to include all of the following five biomes: boreal forests; desert and xeric shrublands; montagne grasslands; temperate coniferous forests; and temperate grasslands, savannas and shrublands. Mongolia was omitted from our climate analysis.

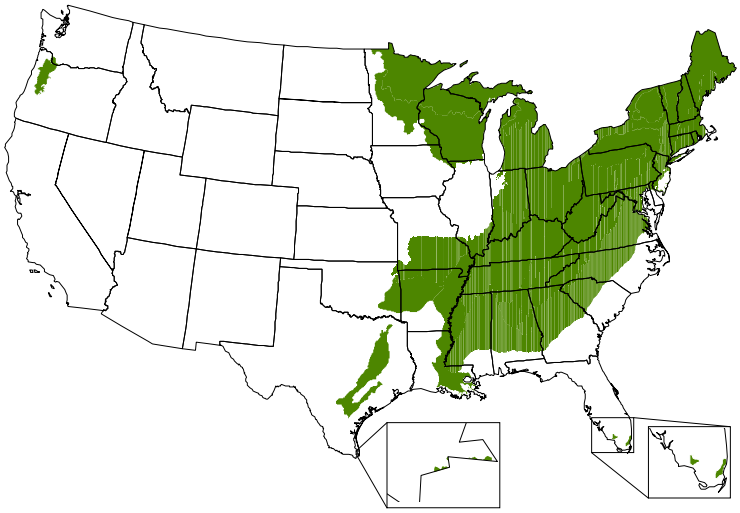

Figure 2. Predicted distribution (green) of *Eudocima fullonia* in the contiguous US.

Figure 2 illustrates where *E. fullonia* is most likely to encounter a suitable climate for establishment within the continental US. This prediction is based only on the known geographic distribution of the species. Because this forecast is based on coarse information, areas that are not highlighted on the map may have some chance of supporting populations of this exotic species. However, establishment in these areas is less likely than in those areas that are highlighted. Initial surveys should be concentrated in the higher risk areas and gradually expanded as needed.

2. **Host Specificity/Availability. Rating: Low/High.** *Eudocima fullonia* reportedly feeds on more than 100 plant species in over 34 families (Table 1). Many hosts are wild and native to the tropics, though several are cultivated. Host plants for the adult fruit-piercing moth include several economically important fruits such as citrus, apple, pear, stone fruit, grape, melon, tomato, mango, papaya, pineapple, and strawberry. Larvae of *E. fullonia* tend to feed on foliage of wild hosts, typically trees, shrubs and vines, within the families Menispermaceae and Fabaceae. See Appendix E for more information on life stages and feeding behavior of *E. fullonia*.

Table 1. Host plants of *Eudocima fullonia*:

Hosts	References
akebia, five-leaf (*Akebia quinata*)	(Shiraki 1952)
akebia,three-leaf (*Akebia trifoliata*)	(Shiraki 1952)
Albertisia ferruginea[1]	(Bänziger 1982)
albutra[1] (*Arcangelisia flava*)	(Bänziger 1982)
apple (*Malus domestica* 'Granny Smith')	(Waterhouse and Norris 1987)
apple (*Malus* sp.)	(Shiraki 1952, Waterhouse and Norris 1987, Denton et al. 1991, Kessing and Mau 1993, Zhang 1994)
apple, red[2] (*Malus domestica*)	(Denton et al. 1991)
apricot (*Prunus armeniaca*)	(Waterhouse and Norris 1987, Denton et al. 1991, Kessing and Mau 1993, CAB 2004)
baccaurea (*Baccaurea* sp.)	(Bänziger 1982)
banana (*Musa* sp.)	(Baptist 1944, CIE 1977, Maddison 1982, Kumar and Lal 1983, Waterhouse and Norris 1987, Denton et al. 1991, Kessing and Mau 1993, Zhang 1994, Muniappan et al. 1995, CAB 2004, Muniappan et al. 2004, Herbison-Evans and Crossley 2005)
Bandicoot Berry (*Leea indica*)	(Bänziger 1982)
breadfruit (*Artocarpus altilis (= A. incisus)*)	(Cochereau 1977, Waterhouse and Norris 1987, Denton et al. 1991, Kessing and Mau 1993)
bucayo[1] (*Erythrina fusca*)	(Cochereau 1977, Waterhouse and Norris 1987, Kessing and Mau 1993, Muniappan et al. 1993, Fay 1996, Herbison-Evans and Crossley 2005)
cactus	(Denton et al. 1991)
cantaloupe (*Cucumis melo*)	(Cochereau 1977, CAB 2004)
carambola (*Averrhoa carambola* 'Arkin')	(Fay and Halfpapp 1993a)
carambola (*Averrhoa carambola* 'B10')	(Fay and Halfpapp 1993a)
carambola (*Averrhoa carambola* 'B2')	(Fay and Halfpapp 1993a)
carambola (*Averrhoa carambola* 'Fwang Tung')	(Fay and Halfpapp 1993a)
carambola (*Averrhoa carambola* 'Thai Knight')	(Fay and Halfpapp 1993a)
carambola (*Averrhoa* sp.)	(Cochereau 1977)
carambola or star fruit (*Averrhoa carambola*)	(Waterhouse and Norris 1987, Denton et al. 1991, Fay and Halfpapp 1993a, b, Kessing and Mau 1993, Sands et al. 1993, Fay 1994, Fay and Halfpapp 1999, CAB 2004)
Carronia multisepalea[1]	(Fay 1994, Herbison-Evans and Crossley 2005)
Carronia protensa[1, 2]	(Fay and Halfpapp 1993b)

Hosts	References
Carronia sp.[1]	(Muniappan et al. 1993)
cashew nut (*Anacardium occidentale*)	(Baptist 1944, Cochereau 1977, Waterhouse and Norris 1987, Denton et al. 1991, Zhang 1994, CAB 2004)
Citrus sp.	(Baptist 1944, Shiraki 1952, Gupta 1969, CIE 1977, Sandhu et al. 1980, Kalshoven and Van Der Laan 1981, Maddison 1982, Kumar and Lal 1983, Dodia et al. 1986, Bänziger 1987, Commission 1987, Fay and Halfpapp 1993a, b, Sands et al. 1993, Vargo et al. 1993, Fay 1994, Zhang 1994, Kiem 1995, Muniappan et al. 1995, CAB 2004)
cocoa[1] (*Theobroma cacao*)	(Comstock 1963)
coffee (*Coffea* sp.)	(Waterhouse and Norris 1987, Denton et al. 1991, Kessing and Mau 1993)
coffee, arabica (*Coffea arabica*)	(Cochereau 1977, CAB 2004)
coral tree[1] (*Erythrina* sp.)	(Comstock 1963, Cochereau 1977, Bänziger 1982, Maddison 1982, Bänziger 1987, Waterhouse and Norris 1987, Denton et al. 1991, Sands and Broe 1991, Kessing and Mau 1993, Muniappan 1993, Muniappan et al. 1993, Sands et al. 1993, Fay 1994, Zhang 1994, Fay 1996, Sands and Chan 1996, CAB 2004, Muniappan et al. 2004, Smith 2004)
coral tree, pale[1, 2] (*Erythrina pallida*)	(Waterhouse and Norris 1987)
coral tree, variegated[1] (*Erythrina parcellii*)	(Waterhouse and Norris 1987)
coral tree, variegated[1] (*Erythrina variegata*)	(Heu 1988, Hara and Matayoshi 1989)
coralbead[1] (*Cocculus* sp.)	(Muniappan et al. 1993)
coralbead, queen[1] (*Cocculus orbiculatus* (= *Cocculus ferrandianus* = *Cocculus trilobus*))	(Muniappan et al. 1993)
Coscinium blumeanum[1]	(Bänziger 1982)
crabapple, European (*Malus sylvestris*)	(CAB 2004)
crybaby tree[1] (*Erythrina crista-galli*)	(Waterhouse and Norris 1987, Muniappan et al. 1993, Herbison-Evans and Crossley 2005)
custard apple (*Annona reticulata*)	(Waterhouse and Norris 1987, Denton et al. 1991)
Cyclea peltata[1]	(Muniappan et al. 2004)
Cyclia peltata[1]	(Bhumannavar and Viraktamath 2001a)

Hosts	References
dadap[1] (*Erythrina subumbrans* (= *Erythrina lithosperma*))	(Kumar and Lal 1983, Waterhouse and Norris 1987, Muniappan et al. 1993, Fay 1996, CAB 2004)
dadap, drala, ngatae[1] (*Erythrina* sp.)	(Maddison 1982)
Dioscoreophyllum tenerum[1]	(Hargreaves 1936)
Dioscoreophyllum volkensii[1]	(Bänziger 1982)
Diospyros glandulosa	(Bänziger 1982)
Diploclisia glaucescens[1, 3]	(Bänziger 1982, Bhumannavar and Viraktamath 2001a, b)
duiker berry[1] (*Sapium integerrimum* (= *Excoecaria reticulata*))	(Hargreaves 1936)
eggplant or aubergine (*Solanum melongena*)	(Denton et al. 1991, CAB 2004, Muniappan et al. 2004)
Fawcettia sp.[1]	(Muniappan et al. 1993)
Fibraurea chloroleuca[1, 2]	(Bänziger 1982)
Ficus edulis	(Cochereau 1977)
fig (*Ficus* sp.)	(Shiraki 1952, Cochereau 1977, Waterhouse and Norris 1987, Denton et al. 1991, Kessing and Mau 1993)
fig, cluster (*Ficus racemosa*)	(Bänziger 1982)
fig, common (*Ficus carica*)	(CAB 2004)
fig, rough-leafed (*Ficus hispida*)	(Bänziger 1982)
fijian longan (*Pometia pinnata*)	(CAB 2004)
fish berry[1] (*Anamirta cocculus*)	(Baptist 1944, Kalshoven and Van Der Laan 1981, Bänziger 1982, Bhumannavar and Viraktamath 2001a, b)
giant granadilla (*Passiflora quadrangularis*)	(Cochereau 1977, CAB 2004)
Goal lata[1] (*Pericampylus glaucus* (= *Pericampylus incanus*))	(Hargreaves 1936, Baptist 1944, Bänziger 1982)
grape (*Vitis* sp.)	(Shiraki 1952, Yoon and Lee 1974, Bänziger 1982, Denton et al. 1991, Zhang 1994, Muniappan et al. 2004)
grape, wine (*Vitis vinifera*)	(CAB 2004)
grapefruit (*Citrus ×paradisi*)	(Baptist 1944, Comstock 1963, Kumar and Lal 1983, Dodia et al. 1986, Waterhouse and Norris 1987, Denton et al. 1991, Kessing and Mau 1993, CAB 2004)
Grewia tomentosa	(Bänziger 1982)
grumichama (*Eugenia dombeyi*)	(CAB 2004)
guava (*Psidium* sp.)	(CIE 1977, Bänziger 1982, Maddison 1982, Kumar and Lal 1983, Bänziger 1987, Waterhouse and Norris 1987, Denton et al. 1991, Kessing and Mau 1993, Sands et al. 1993)

Hosts	References
guava, common (*Psidium guajava*)	(Cochereau 1977, CAB 2004)
guava, strawberry (*Psidium cattleianum*)	(CAB 2004)
guduchi[1] (*Tinospora cardifolia*)	(Muniappan et al. 2004)
Hypserpa decumbens[1, 4]	(Bänziger 1982, Fay and Halfpapp 1993b, Herbison-Evans and Crossley 2005)
Hypserpa laurina[1, 2]	(Fay and Halfpapp 1993b)
Hypserpa ponapensis[1]	
Hypserpa reticulata[1, 2]	(Fay and Halfpapp 1993b)
Hypserpa sp.[1]	(Muniappan et al. 1993, Fay 1996)
Hypserpa trukensis[1]	
Indian bael[1] (*Aegle marmelos*)	(Sandhu et al. 1980)
Indian cockle[1] (*Cocculus indicus*)	(Hargreaves 1936, Baptist 1944)
jackfruit (*Artocarpus heterophyllus* (= *A. integrifolius*))	(Cochereau 1977, Denton et al. 1991, CAB 2004)
Jamaica cherry (*Muntingia calabura*)	(Bänziger 1982, CAB 2004)
Java-plum (*Syzygium cumini* (=*Eugenia jambolana*))	(Cochereau 1977)
kariba weed (*Salvinia molesta*)	(CAB 2004)
kechapi (*Sandoricum koetjape*)	(CAB 2004)
kiwi (*Actinidia chinensis*)	(CAB 2004)
kiwifruit (*Actinidia* sp.)	(Waterhouse and Norris 1987, Denton et al. 1991, Fay and Halfpapp 1993b, Kessing and Mau 1993)
laui'atolo[1] (*Stephania forsteri*)	(Maddison 1982, Waterhouse and Norris 1987, Kessing and Mau 1993, Muniappan et al. 1993, Herbison-Evans and Crossley 2005)
laurel-leaf snailseed[1] (*Cocculus laurifolius*)	(Bänziger 1982, Poole 1989)
Legnephora sp.[1]	(Muniappan et al. 1993, Fay 1996)
lemon (*Citrus limon* (= *C. limonum*))	(Cochereau 1977, Denton et al. 1991, CAB 2004)
lime (*Citrus aurantifolia*)	(Bänziger 1982)
lime, sweet (*Citrus limettioides*)	(Sandhu et al. 1980)
longan (*Dimocarpus longan*)	(Bänziger 1982, 1987, Waterhouse and Norris 1987, Denton et al. 1991, Fay and Halfpapp 1993a, Kessing and Mau 1993, Sands et al. 1993, Zhang 1994, CAB 2004, Herbison-Evans and Crossley 2005)

Hosts	References
lychee (*Litchi chinensis* (= *Nephelium litchi*))	(Bänziger 1982, Waterhouse and Norris 1987, Denton et al. 1991, Fay and Halfpapp 1993a, b, Kessing and Mau 1993, Sands et al. 1993, Fay 1994, Fay and Halfpapp 1999, CAB 2004, Muniappan et al. 2004, Herbison-Evans and Crossley 2005); (Cochereau 1977)
lychee (*Litchi chinensis* 'Kwai May Pink')	(Fay and Halfpapp 1993a)
lychee (*Litchi chinensis* 'Tai So')	(Fay and Halfpapp 1993a)
machete[1, 2] (*Erythrina berteroana*)	(Waterhouse and Norris 1987)
Malasian apple (*Syzygium malaccense*)	(CAB 2004)
mandarin (*Citrus reticulata*)	(Baptist 1944, Cochereau 1977, Bänziger 1982, Waterhouse and Norris 1987, Denton et al. 1991, Kessing and Mau 1993, CAB 2004)
mango (*Mangifera indica*)	(Baptist 1944, CIE 1977, Cochereau 1977, Kalshoven and Van Der Laan 1981, Bänziger 1982, Maddison 1982, Kumar and Lal 1983, Waterhouse and Norris 1987, Denton et al. 1991, Fay and Halfpapp 1993b, Kessing and Mau 1993, Zhang 1994, CAB 2004, Muniappan et al. 2004)
mangosteen (*Garcinia mangostiana*)[2]	(Bänziger 1982)
melon (*Cucumis* sp.)	(Waterhouse and Norris 1987, Denton et al. 1991, Kessing and Mau 1993)
milla (*Vitex pinnata*)	(Bänziger 1982)
mulungu tree[1, 2] (*Erythrina velutina*)	(Waterhouse and Norris 1987)
nectarine (*Prunus persica var. nectarina*)	(Cochereau 1977, Waterhouse and Norris 1987, Denton et al. 1991, Kessing and Mau 1993)
orange (*Citrus sinensis* 'Blood Red')	(Sandhu et al. 1980)
orange (*Citrus sinensis* 'Jaffa')	(Sandhu et al. 1980)
orange (*Citrus sinensis* 'Mosambi')	(Sandhu et al. 1980)
orange (*Citrus sinensis* 'Navel')	(Waterhouse and Norris 1987, Kessing and Mau 1993, CAB 2004)

Hosts	References
orange (*Citrus sinensis*)	(Baptist 1944, Comstock 1963, Cochereau 1977, Bänziger 1982, Kumar and Lal 1983, Waterhouse and Norris 1987, Denton et al. 1991, Kessing and Mau 1993, Lubulwa and McMeniman 1998, Bhumannavar and Viraktamath 2001a, Muniappan et al. 2004)
orange, calamondin[2] (×*Citrofortunella microcarpa)*	(Denton et al. 1991)
orange, king (*Citrus nobilis*)	(Cochereau 1977)
orange, sour (*Citrus aurantium*)	(Cochereau 1977)
Pachygone ledermannii[1]	(Fay and Halfpapp 1993b)
Pachygone longifolia[1, 2]	(Fay and Halfpapp 1993b)
Pachygone ovata[1]	(Fay and Halfpapp 1993b, CAB 2004, Muniappan et al. 2004)
Pachygone sp.[1]	(Fay 1996)
papaya or papaw (*Carica papaya*)	(CIE 1977, Cochereau 1977, Bänziger 1982, Maddison 1982, Kumar and Lal 1983, Waterhouse and Norris 1987, Denton et al. 1991, Fay and Halfpapp 1993b, Kessing and Mau 1993, Zhang 1994, Lubulwa and McMeniman 1998, CAB 2004)
Parabaena sagittata[1]	(Bänziger 1982)
passion fruit (*Passiflora edulis*)	(Waterhouse and Norris 1987, Denton et al. 1991, Kessing and Mau 1993, CAB 2004)
pauh kijang (*Irvingia malayana*)	(Bänziger 1982)
peach (*Prunus persica* (= *Persica vulgaris*))	(Shiraki 1952, Cochereau 1977, Bänziger 1982, 1987, Waterhouse and Norris 1987, Denton et al. 1991, Kessing and Mau 1993, CAB 2004)
pear (*Pyrus* sp.)	(Shiraki 1952, Zhang 1994, Cave and Lightfield 1997)
pearl vine[1] (*Sarcopetalum harveyanum*)	(Fay and Halfpapp 1993b, Fay 1994, Herbison-Evans and Crossley 2005)
pepper (*Capsicum* sp.)	(Waterhouse and Norris 1987)
pepper, bell (*Capsicum annuum*)	(Cochereau 1977, Denton et al. 1991, CAB 2004)
pepper, green (*Capsicum annuum*)	(Vargo et al. 1993)

Hosts	References
peron	(Kalshoven and Van Der Laan 1981)
persimmon, oriental (*Diospyros kaki*)	(Bänziger 1982, Waterhouse and Norris 1987, Denton et al. 1991, Fay and Halfpapp 1993b, Kessing and Mau 1993, CAB 2004)
pineapple (*Ananas comosus*)	(Cochereau 1977, Waterhouse and Norris 1987, Denton et al. 1991, Kessing and Mau 1993, Lubulwa and McMeniman 1998, CAB 2004)
plantain, french (*Musa paradisiaca* var. *sapientium*)	(Cochereau 1977)
Pleogyne sp. [1]	(Muniappan et al. 1993)
plum (*Prunus domestica*)	(Denton et al. 1991)
plum, black[2] (*Diospyros australis*)	(Denton et al. 1991)
plum, hog (*Spondias axillaris*)	(Bänziger 1982)
pomegranate (*Punica granatum*)	(Baptist 1944, Bänziger 1987, Bhumannavar and Viraktamath 2001a, CAB 2004, Muniappan et al. 2004)
prickly tape vine[1] (*Echinostephia aculeata* (= *Stephania aculeata*))	(Bänziger 1982, Fay 1996, Herbison-Evans and Crossley 2005)
pricklypear (*Opuntia* sp.)	(Cochereau 1977, CAB 2004)
pummelo (*Citrus maxima* (= *C. grandis*))	(Cochereau 1977, Denton et al. 1991, CAB 2004)
putarwali[1] (*Tinospora crispa*)	(Bänziger 1982, 1987, Fay and Halfpapp 1993b)
Pycnarrhena novoguineensis[1, 2]	(Fay and Halfpapp 1993b)
rambutan (*Nephelium lappaceum*)	(Bänziger 1982, CAB 2004)
red cardinal [1, 2] (*Erythrina herbacea*)	(Waterhouse and Norris 1987)
rose apple (*Syzygium jambos*)	(Bänziger 1982)
round-leaf vine[1] (*Legnephora moorei*)	(Bänziger 1982, Fay and Halfpapp 1993b, Fay 1994, Zhang 1994, Herbison-Evans and Crossley 2005)
Rubus sp.	(Bänziger 1982)
Sarcopetalum sp. [1]	(Muniappan et al. 1993, Fay 1994, 1996)
snake vine[1] (*Tinospora smilacina*)	(Baptist 1944, Bänziger 1982, Fay and Halfpapp 1993b, Fay 1994, Sands and Chan 1996, Fay and Halfpapp 1999, Herbison-Evans and Crossley 2005)

Hosts	References
snake vine[1, 2] (*Stephania japonica* var. *discolor*)	(Fay and Halfpapp 1993b)
soursop (*Annona muricata*)	(Cochereau 1977, Denton et al. 1991, CAB 2004, Muniappan et al. 2004)
southern japonica[1] (*Stephania japonica*)	(Bänziger 1982, Waterhouse and Norris 1987, Sands and Brancatini 1991, Fay and Halfpapp 1993b, Sands et al. 1993, Fay 1994, Bhumannavar and Viraktamath 2001a, Muniappan et al. 2004, Herbison-Evans and Crossley 2005)
star apple (*Chrysophyllum cainito*)	(Vargo et al. 1993, CAB 2004)
Stephania bancroftii[1, 2]	(Fay and Halfpapp 1993b)
Stephania dinklagei[1]	(Hargreaves 1936, Bänziger 1982)
Stephania harveyanum[1, 2]	(Fay 1994)
Stephania hernandiaefolia[1]	(Baptist 1944)
Stephania japonica var. *forsteri*[1]	(Sands et al. 1993)
Stephania japonica var. *timoriensis*[1, 5]	(Fay and Halfpapp 1993b, Fay 1996)
Stephania sp.[1]	(Hargreaves 1936, Waterhouse and Norris 1987, Kessing and Mau 1993, Muniappan et al. 1993, Fay 1996)
Stephania wightii[1]	(Bhumannavar and Viraktamath 2001a)
stone fruit (*Prunus* sp.)	(Sands et al. 1993)
strawberry (*Fragaria* sp.)	(Bänziger 1982)
sugar apple or sweetsop (*Annona squamosa*)	(Cochereau 1977, Denton et al. 1991, CAB 2004)
Synclisia ferruginea[1]	(Hargreaves 1936)
tiger's claw[1] (*Erythrina variegata* (= *Erythrina indica* (= *Erythrina variegata* var. *fastigiata*)))	(Hargreaves 1936, Cochereau 1977, Kumar and Lal 1983, Waterhouse and Norris 1987, Muniappan et al. 1993, Vargo et al. 1993, Fay 1996, CAB 2004, Muniappan et al. 2004, Herbison-Evans and Crossley 2005)
tiger's claw[1] (*Erythrina variegata* var. *orientalis*)	(Comstock 1963, Cochereau 1977, Waterhouse and Norris 1987, Kessing and Mau 1993, Muniappan et al. 1993, Sands et al. 1993)
Tiliacora acuminata[1, 2]	(Bhumannavar and Viraktamath 2001b)

Hosts	References
Tiliacora australiana[1]	(Fay and Halfpapp 1993b, Fay 1994)
Tiliacora funifera[1]	(Bänziger 1982)
Tiliacora sp.[1]	(Hargreaves 1936, Kalshoven and Van Der Laan 1981, Bänziger 1982, Kumar and Lal 1983, Waterhouse and Norris 1987, Kessing and Mau 1993, Fay 1994, 1996)
Tiliacora warneckei[1]	(Baptist 1944)
Tinomiscium petiolare[1]	(Bänziger 1982)
Tinospora angusta[1, 2]	(Fay and Halfpapp 1993b)
Tinospora baenzigeri[1]	(Bänziger 1982, 1987, Fay and Halfpapp 1993b)
Tinospora homosepala[1]	
Tinospora sp.[1]	(Waterhouse and Norris 1987, Kessing and Mau 1993, Muniappan et al. 1993, Fay 1994, Zhang 1994, Fay 1996)
Tinospora spp. aff. *glabra*[1]	(Bänziger 1982)
tinospora, Chinese[1] (*Tinospora sinensis*)	(Bänziger 1982, 1987, Fay and Halfpapp 1993b, CAB 2004)
tinospora, gulancha[1] (*Tinospora cordifolia*)	(Baptist 1944, Comstock 1963, Gupta 1969, Bänziger 1982, Fay and Halfpapp 1993b, Bhumannavar and Viraktamath 2001a, b, CAB 2004)
tomato (*Solanum lycopersicum* var. *lycopersicum* (= *Lycopersicon esculentum*))	(Baptist 1944, Shiraki 1952, Comstock 1963, CIE 1977, Cochereau 1977, Maddison 1982, Kumar and Lal 1983, Waterhouse and Norris 1987, Denton et al. 1991, Kessing and Mau 1993, Vargo et al. 1993, Bhumannavar and Viraktamath 2001a, CAB 2004, Muniappan et al. 2004)
Triclisia patens[1]	(Hargreaves 1936)
Triclisia sp.[1]	(Waterhouse and Norris 1987, Kessing and Mau 1993, Muniappan et al. 1993)
vasan vel[1] (*Cocculus hirsutus*)	(Hargreaves 1936, Baptist 1944, Bänziger 1982, Apte 1999, Bhumannavar and Viraktamath 2001a, b, CAB 2004, Muniappan et al. 2004)

Hosts	References
vines of the family Menispermaceae[1]	(Baptist 1944, Gupta 1969, Cochereau 1977, Bänziger 1982, 1987, Denton et al. 1991, Sands and Broe 1991, Fay and Halfpapp 1993b, Kessing and Mau 1993, Muniappan 1993, Muniappan et al. 1993, Sands et al. 1993, Fay 1994, Zhang 1994, Fay 1996, Sands et al. 1996, Sands and Chan 1996, Bhumannavar and Viraktamath 2001a, CAB 2004, Muniappan et al. 2004)
water hyacinth (*Eichhornia* sp.)	(CAB 2004)
watermelon (*Citrullus lanatus* var. *lanatus* (= *Citrullus vulgaris*))	(Cochereau 1977)
white sapote (*Casimiroa edulis*)	(CAB 2004)
wili wili[1] (*Erythrina tahitensis*)	(Waterhouse and Norris 1987, Muniappan et al. 1993)
wiry grape[1] (*Pleogyne australis*)	(Fay 1994, Herbison-Evans and Crossley 2005)
yaanang[1] (*Tiliacora triandra*)	(Bänziger 1982, 1987)

1. Larval host plants.
2. Experimental larval host plants (laboratory).
3. Experimental host in studies by Bänziger (1982) and Bhumannavar (2001b), however Bhumannavar collected larvae in the wild from *D. glaucescens*.
4. Listed by Bänziger (1982) and Herbison-Evans (2005) as a known host, and as an experimental host by Fay (1993b).
5. Considered an experimental host by Fay (1993b), and also as a wild host (Fay 1996).

See Appendix B for maps showing where various hosts occur in the contiguous US.

3. **Survey Methodology. Rating: Low.** Despite the economic significance of *E. fullonia*, tools for sampling its populations remain rudimentary. No semiochemicals have been identified for this insect, so traps baited with attractants are not an option. Moths are attracted to ultraviolet light (reviewed in Martin Kessing and Mau 1993), so blacklight traps might be an option. Dodia et al. (1986) mention the use of blacklight traps; however, they did not comment on their effectiveness. Light traps must be used with caution, because *E. fullonia* may be repelled by certain wavelengths of light (Martin Kessing and Mau 1993). In a small number of cases, orchards were flooded with light to prevent moths from attacking fruit (reviewed in Martin Kessing and Mau 1993).

   Curiously, surveys for this insect commonly depend on visual inspections of orchards at night with flashlights (Yoon and Lee 1974, Fay and Halfpapp 1999). Adults have large eyes that glow red when illuminated making this life stage easy to detect when it is at moderate to high densities (CAB 2004). Fay and Halfpapp

(1999) began their surveys 30 minutes after sundown. Surveys typically lasted for 1 hr (Yoon and Lee 1974, Fay and Halfpapp 1999).

In a regional survey, foliage of host plants was inspected for larvae at ca. 2.5 m (~8 ft) above ground (Fay and Halfpapp 1993b); at a site, 10-25 plants were examined.

The number of plants to be inspected depends on the level of infestation and the desired degree of statistical confidence from the sample. More specifically, if we can assume that (i) larvae or adults on a plant will be found when that plant is inspected, (ii) the number of possible plants to inspect is large; and (iii) plants are selected at random the likelihood of detection depends directly on the proportion of plants that have at least one individual, binomial statistics can be used to calculate the number of plants that should be inspected to detect at least one *E. fullonia* in an area with a desired degree of statistical confidence. Figure 3 illustrates how the number of required samples changes as the proportion of plants with insects and/or the desired degree of statistical confidence changes. In general, more samples are required as the desired probability of detection increases and as the proportion of plants with insects decreases (i.e., the insects become rarer in the environment). These same principles apply whether surveying for adults or larvae.

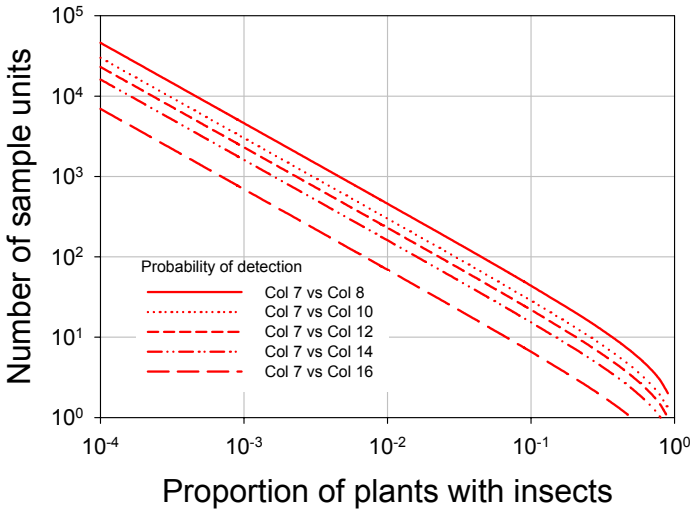

Figure 3. Required number of sample units (whole plants) to be inspected to detect at least one *E. fullonia* in relation to the proportion of plants with adults or larvae, respectively, and the desired probability of detecting the pest when it is present. This figure assumes random sampling from a large environment.

4. **Taxonomic Recognition**. **Rating: Medium.** *Eudocima fullonia* are not likely to be confused with most other noctuids that occur in North America. Larvae are particularly unique (Fig. 1). Some confusion might occur if the range of *E. fullonia* overlaps with the rage of *E. materna*, which occurs in Florida and Texas. Observers may confuse *E. fullonia* adults with other morphologically similar

relatives, *E. homaena* and *E. jordani* (CAB 2004). Neither species currently occurs in the US. Additionally, seven *Eudocima* spp. occur in northeastern Queensland Australia. Fay and Halfpapp (1999) observed six of these species in northeastern Queensland Australia: *E. fullonia*, *E. jordani*, *E. materna*, *E. salaminia*, *E. aurantia*, and *E. cocalus*. Substantial color and pattern variations, especially among larvae, complicate distinctions between closely related *Eudocima* species (Comstock 1963, Apte 1999). The identity of suspect specimens should be determined by a qualified taxonomist.

For a detailed description of the morphology and taxonomy of *E. fullonia*, see Appendix C.

5. **Entry Potential**. **Rating: Low.** *Eudocima fullonia* has not been intercepted by inspectors with the US Department of Agriculture, Animal and Plant Health Inspection Service or the US Department of Homeland Security at US ports of entry between 1985 and 2004 (USDA 2005). Likewise, no specimens of unspecified "*Eudocima* sp." have been reported. A single interception of *Eudocima procus* was noted in Miami on chrysanthemum originating in Colombia. If *Eudocima fullonia* had been intercepted in the last 19 years, it may have been identified simply as "Noctuidae; species of." Unidentified Noctuids have been intercepted, on average, at least 1,813 (±236 standard error of the mean) times between 1985 and 2004 (incomplete records complicate the accuracy of this count) (USDA 2005). However, it seems highly unlikely that all or even most of these specimens were *E. fullonia*. Only 5.8% of all interceptions originated in a country that is known to have *E. fullonia*. If all of the specimens coming from countries known to have *E. fullonia* were, in fact, this insect, a medium rating would be warranted. The most common origins were Thailand (2% of all unspecified Noctuid interceptions), South Africa (0.7%), Hawaii (0.6%), Zimbabwe (0.4%), Kenya (0.4%), New Zealand (0.3%), and Nigeria (0.2%).

   The majority of Noctuid interceptions from all parts of the world have been associated with permit cargo (50%), international airline baggage (30%), and general cargo (13%) (USDA 2005). The majority of Noctuid interceptions were reported from Miami, FL (56%), JFK International airport, NY (14%), Los Angeles, CA (6.7%), Houston, TX (4%), and Dallas, TX (4%). These ports are the first points of entry for infested material coming into the US and do not necessarily represent the final destination of infested material. Movement of potentially infested material is more fully characterized in the next section.

6. **Destination of Infested Material**. **Rating: High.** When an actionable pest is intercepted, officers ask for the intended final destination of the conveyance. Although *Eudocima* sp. were intercepted only once, materials infested with "Noctuidae; species of" were destined for 45 states including the District of Columbia within the contiguous US (USDA 2005). The most commonly reported destinations were Florida (55%), New York (14%), California (11%), and Texas

(9%). Portions of these states, with the exception of California, have climates (based on our predictions) and potential hosts that would be suitable for establishment by *Eudocima fullonia*.

7. **Potential Economic Impact. Rating: High.** *Eudocima fullonia* is considered an important pest of citrus and numerous commercial fruits and vegetables (Cochereau 1977, Waterhouse and Norris 1987). For example, in northeastern Queesnsland, Australia, *E. fullonia* is considered one of the most destructive fruit-piercing moth species attacking carambola, lychee, sweet *Citrus*, mango, kiwi, pawpaws and persimmons (Fay and Halfpapp 1993b, 1999), all highly valuable commodities. An adult will pierce ripening fruits with its proboscis to extract juice. Minor adult feeding directly blemishes fruit, and heavy feeding destroys it. Puncture wounds can also cause premature ripening, fruit drop, rot, and encourage additional damage by secondary pests such as microorganisms and fruit flies. Damage of this nature renders fruits and vegetables unmarketable (Hargreaves 1936, Kalshoven and Van Der Laan 1981, Maddison 1982, Martin Kessing and Mau 1993, Sands et al. 1993, CAB 2004). Thus, adult feeding can reduce the quantity and quality of marketed fruit. In New Caledonia, severe outbreaks occur about every five years, causing considerable losses (Waterhouse and Norris 1987). Direct and indirect damage from the adult stage pest has resulted in up to 50% crop loss for *Citrus*, carambolas, and lychees in northeast Australia (Fay 1994).

   The true economic impact of *E. fullonia* can be difficult to measure, especially when this moth occurs in mixed populations with other *Eudocima* species (Fay and Halfpapp 1999). *Eudocima fullonia* can comprise nearly 90% of moths (average of 81.4% on carambolas, and 95.1% on lychees, respectively) causing damage to fruit.

   Larvae generally do not cause economic damage. Larvae tend to feed on foliage of wild hosts, typically trees, shrubs and vines, within the families Menispermaceae and Fabaceae (Bänziger 1982). In Australia, larvae often feed preferentially on foliage of certain *Tinospora* spp. (family Menispermaceae). The separation of resources for larvae and adults allows *E. fullonia* to extend its period of reproduction and maintain population densities, even during unfavorable climatic conditions(Fay and Halfpapp 1993b). The extent of feeding on larval host plants is not well known, but plants are not considered economically important (Fay and Halfpapp 1993b, Fay 1994).

   Establishment and spread of *E. fullonia* could jeopardize crops, domestic and foreign forest product industries, and the nursery trade.

8. **Potential Environmental Impact. Rating: High.** In general, newly established species may adversely affect the environment by reducing biodiversity, altering species composition, disrupting ecosystem function, jeopardizing endangered or threatened plants, degrading critical habitat, or stimulating use of chemical or

biological controls. *Eudocima fullonia* is likely to affect the environment in many of these ways.

Historically, the introduction of invasive agricultural pests has initiated control measures to avoid lost production (National Plant Board 1999). Consumer preferences for unblemished, high quality produce encourage the use of pesticides, while at the same time, negative public opinion regarding the use of pesticides on fruits and vegetables is a market concern (Bunn et al. 1990). Therefore, the establishment of any new pests of fruits and vegetables destined for fresh markets is likely to stimulate greater use of either chemical or biological controls to ensure market access.

Eudocima fullonia has a wide host range, feeding on foliage of tree, shrub and vine hosts in the larval stage, and on fruits of numerous fruit crops in the adult stage [see 'Host Specificity']. Appendix D summarizes federally listed threatened or endangered plant species (USDA NRCS 2004) found within plant genera known to be hosts (or potential hosts) for *E. fullonia*. Plants listed in Appendix D might be suitable hosts for *E. fullonia*, and thus, could be adversely affected by this insect.

9. **Establishment Potential. Rating: Low.** Our initial predictions suggest that nearly 30% of the US has a climate that could support populations of *E. fullonia* (Fig. 2). Known favored host plants for adults (esp. citrus) are grown in portions of these climatically suitable areas. However, the biology of this insect is fairly complex, and both larval and adults hosts must occur in the same area. The majority of known larval hosts occur in the tropics or sub-tropics. For establishment in the US to be likely, larvae would need to utilize red apple (*Malus domestica*), coralbead (*Cocculus* spp), or erythrina (*Erythrina* spp). Larvae can feed and develop on red apple, but this has only been observed under laboratory conditions (Table 1). The *Cocculus* spp. or *Eythinia* spp. that occur commonly in the United States have not been confirmed as larval hosts. Conversely, those species of *Cocculus* and *Erythrinia* that have been confirmed as larval hosts do not occur in the United States, except perhaps under glasshouse or ornamental conditions. Further, based on available interception records, it appears that this insect is not regularly introduced into the contiguous US. Collectively, these factors contribute to a low likelihood for establishment.

   See Appendix E for a more detailed description of the biology of *E. fullonia*.

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Appendix A. Geographic distribution and comparison of climate zones. To determine the potential distribution of a quarantine pest in the US, we first collected information about the worldwide geographic distribution of the species (Table A1). Using a geographic information system (e.g., ArcView 3.2), we then identified which biomes (i.e., habitat types), as defined by the World Wildlife Fund (Olson et al. 2001), occurred within each country or municipality reported. An Excel spreadsheet summarizing the occurrence of biomes in each nation or municipality was prepared. The list was sorted based on the total number of biomes that occurred in each country/municipality. The list was then analyzed to determine the minimum number of biomes that could account for the reported worldwide distribution of the species. Countries/municipalities with only one biome were first selected. We then examined each country/municipality with multiple biomes to determine if at least one of its biomes had been selected. If not, an additional biome was selected that occurred in the greatest number of countries or municipalities that had not yet been accounted for. In the event of a tie, the biome that was reported more frequently from the entire species' distribution was selected. The process of selecting additional biomes continued until at least one biome was selected for each country. Finally, the set of selected biomes was compared to only those that occur in the US.

Table A1. Reported geographic distribution of *Eudocima fullonia*.

Location	**References**
Africa	(Shiraki 1952, Kalshoven and Van Der Laan 1981, Maddison 1982, Muniappan 1993, Muniappan et al. 1993, Fay 1994, Muniappan et al. 2004)
Africa (central)	(Baptist 1944, Cochereau 1977)
Africa (subtropical)	(Denton et al. 1991, Zilli and Hogenes 2002)
Africa (tropical)	(Baptist 1944, Comstock 1963, Bänziger 1987, Denton et al. 1991, Zilli and Hogenes 2002)
Africa (west)	(Baptist 1944)
Africa, West	(Zilli and Hogenes 2002)
American Samoa	(Comstock 1963, CIE 1977, Cochereau 1977, Waterhouse and Norris 1987, Sands and Broe 1991, Muniappan 1993, Sands et al. 1993, CABI/EPPO 2001, CAB 2004, Muniappan et al. 2004, Herbison-Evans and Crossley 2005)
American Samoa (Tutuila)	(Comstock 1963, Vargo et al. 1993)
Angola	(Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
Angola (Bihé, Coemba)	(CIE 1977)
Asia	(Bänziger 1987, Muniappan 1993, Muniappan et al. 1993, Fay 1996, Muniappan et al. 2004)
Asia (south)	(Kalshoven and Van Der Laan 1981, Denton et al. 1991)
Asia (southeast)	(Maddison 1982, Denton et al. 1991, Sands et al. 1993, Sands and Chan 1996)
Asia (tropical, subtropical)	(Zilli and Hogenes 2002)

Location	References
Australia	(Hargreaves 1936, Baptist 1944, Shiraki 1952, Comstock 1963, Cochereau 1977, Kalshoven and Van Der Laan 1981, Bänziger 1982, Maddison 1982, Denton et al. 1991, Kessing and Mau 1993, Muniappan 1993, Muniappan et al. 1993, Fay 1996, Muniappan et al. 2004)
Australia (east)	(Sands and Broe 1991, Fay and Halfpapp 1993a, Sands et al. 1993)
Australia (Lord Howe Island)	(CIE 1977, Waterhouse and Norris 1987)
Australia (Miallo, Koah, between Deeral and Fishery Falls, Walkamin Research Station, Kamerunga Horticultural Research Station, Kennedy)	(Fay and Halfpapp 1993a)
Australia (New South Wales - Bourke)	(Waterhouse and Norris 1987)
Australia (New South Wales)	(Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
Australia (north)	(Fay and Halfpapp 1993a)
Australia (northeast)	(Fay 1994)
Australia (Northern Territory - Darwin)	(CIE 1977)
Australia (Northern Territory)	(Waterhouse and Norris 1987, Sands et al. 1996, CABI/EPPO 2001, CAB 2004)
Australia (Queensland - Camooweal, Charleville)	(CIE 1977)
Australia (Queensland - Cape York Peninsula)	(Sands and Chan 1996)
Australia (Queensland - near Cairns)	(Fay and Halfpapp 1993b, 1999)
Australia (Queensland - north)	(Fay and Halfpapp 1993a, Fay 1994, Herbison-Evans and Crossley 2005)
Australia (Queensland - southeast)	(Fay 1994, Sands et al. 1996, Fay and Halfpapp 1999)
Australia (Queensland)	(CIE 1977, Cochereau 1977, Waterhouse and Norris 1987, Fay and Halfpapp 1993b, Zhang 1994, Sands et al. 1996, CABI/EPPO 2001, CAB 2004)
Australia (Rockhampton)	(Baptist 1944)
Australia (Western Australia)	(Sands et al. 1996)
Belau	(CAB 2004)
Benin (formerly Dahomey)	(CIE 1977, Waterhouse and Norris 1987, Atachi et al. 1989, CABI/EPPO 2001, CAB 2004)
Bhutan	(CIE 1977, Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
Brunei Darussalam	(CABI/EPPO 2001, CAB 2004)
Cambodia[1]	(Hargreaves 1936, CAB 2004)
Cameroon	(Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
Cameroon (Alaha Kahla, Bitje, Ja River, Yabassi)	(CIE 1977)

Location	References
China	(Shiraki 1952, Comstock 1963, Waterhouse and Norris 1987, Kessing and Mau 1993, Cave and Lightfield 1997)
China (Anhui, Fujian, Guangdong, Guangxi, Hubei, Hunan, Jiansu, Jiangxi, Zhejiang)	(CABI/EPPO 2001, CAB 2004)
China (Hainan)	(CIE 1977, CABI/EPPO 2001, CAB 2004)
China (Hong Kong)	(CIE 1977, Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004, Herbison-Evans and Crossley 2005)
China (Szechwan or Sichuan)	(CIE 1977, CABI/EPPO 2001, CAB 2004)
China (Taiwan formerly Formosa)	(Baptist 1944, Shiraki 1952, CIE 1977, Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
China (Yunnan)	(CIE 1977, CABI/EPPO 2001, CAB 2004)
Christmas Island	(CIE 1977, Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
Congo	(CABI/EPPO 2001, CAB 2004)
Congo, Democratic Republic (formerly Zaire)	(Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
Congo, Democratic Republic (Orientale Province, Kasai, Kivu)	(CIE 1977)
Cook Islands	(CIE 1977, Commission 1987, Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
Côte d'Ivoire	(CIE 1977, CABI/EPPO 2001, CAB 2004)
Federated States of Micronesia	(CABI/EPPO 2001)
Federated States of Micronesia (Caroline Islands)	(Comstock 1963, CIE 1977, Waterhouse and Norris 1987, CAB 2004)
Federated States of Micronesia (Chuuk)	
Federated States of Micronesia (Kosrae)	(Muniappan et al. 1993)
Federated States of Micronesia (Pohnpei)	(Muniappan et al. 1993)
Fiji	(Hargreaves 1936, Baptist 1944, Comstock 1963, Maddison 1982, Bänziger 1987, Commission 1987, Waterhouse and Norris 1987, Sands and Broe 1991, Muniappan 1993, Sands et al. 1993, Zhang 1994, Fay 1996, Sands et al. 1996, Lubulwa and McMeniman 1998, Bhumannavar and Viraktamath 2001b, CABI/EPPO 2001, CAB 2004, Muniappan et al. 2004)
Fiji (Taveuni)	(Cochereau 1977)
Fiji (Vanua Levu Island)	(Kumar and Lal 1983)
Fiji (Viti Levu Island)	(CIE 1977, Cochereau 1977, Kumar and Lal 1983)
French Polynesia	(Comstock 1963, Muniappan et al. 1993, CABI/EPPO 2001, CAB 2004)
French Polynesia (Moorea)	(Cochereau 1977)
French Polynesia (Society Islands)	(Comstock 1963, CIE 1977, Waterhouse and Norris 1987)
French Polynesia (Tahiti)	(Comstock 1963, CIE 1977)

Location	References
French Polynesia (Tubuai Islands)	(CIE 1977, Waterhouse and Norris 1987)
Gabon	(Zilli and Hogenes 2002)
Ghana (formerly the Gold Coast)	(Hargreaves 1936, CIE 1977, Bänziger 1982, Waterhouse and Norris 1987, Zhang 1994, CABI/EPPO 2001, Zilli and Hogenes 2002, CAB 2004)
Guam	(Comstock 1963, CIE 1977, Waterhouse and Norris 1987, Denton et al. 1991, Sands and Broe 1991, Muniappan 1993, Muniappan et al. 1993, Sands et al. 1993, CABI/EPPO 2001, CAB 2004, Muniappan et al. 2004)
Guinea	(CIE 1977)
Guinea (Farmoreah, N'Zérékoré)	(CIE 1977)
India	(Hargreaves 1936, Baptist 1944, Shiraki 1952, Comstock 1963, Cochereau 1977, Bänziger 1982, Maddison 1982, Commission 1987, Waterhouse and Norris 1987, Kessing and Mau 1993, Bhumannavar and Viraktamath 2001a, Muniappan et al. 2004)
India (Andaman Islands)	(CIE 1977, Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
India (Andrha Pradesh, Karnataka, Maharashtra)	(CIE 1977, CABI/EPPO 2001, CAB 2004, Muniappan et al. 2004)
India (Assam, Bihar, Kerala, Madhya Pradesh, Orissa, Rajasthan)	(CIE 1977, CABI/EPPO 2001, CAB 2004)
India (Coimbatore, Bangalore, Raichur)	(Muniappan et al. 2004)
India (Gujarat)	(Dodia et al. 1986, CABI/EPPO 2001, CAB 2004, Muniappan et al. 2004)
India (Hoshiarpur, Jullundur, Ferozepur)	(Sandhu et al. 1980)
India (Indian Punjab)	(CIE 1977, Zhang 1994, CABI/EPPO 2001, CAB 2004)
India (Mumbai)	(Apte 1999)
India (Nicobar Island)	(CIE 1977, Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
India (north)	(Bänziger 1982)
India (Puttarurudraiah)	(CIE 1977)
India (Raichur, Bijapur, Pune, Tirupati)	(Bhumannavar and Viraktamath 2001a)
India (Sikkim)	(CIE 1977, Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
India (Tamil Nadu)	(CIE 1977, Zhang 1994, CABI/EPPO 2001, CAB 2004, Muniappan et al. 2004)
India (Uttar Pradesh)	(Gupta 1969, CIE 1977, Zhang 1994, CABI/EPPO 2001, CAB 2004)
India (West Bengal)	(CABI/EPPO 2001, CAB 2004)
Indoaustralia	(Zilli and Hogenes 2002)
Indomalaysian region	(Muniappan 1993)
Indonesia (Amboina, Bali, Kai Island, Lombok, Nias, Sumba, Tanimbar, Timor)	(CIE 1977)
Indonesia (Bogor, Sukabumi, Lawang)	(Kalshoven and Van Der Laan 1981)

Location	References
Indonesia (Central Java)	(Kalshoven and Van Der Laan 1981)
Indonesia (formerly the Dutch East Indies)	(Hargreaves 1936, Comstock 1963, Waterhouse and Norris 1987, Muniappan et al. 2004)
Indonesia (Irian Jaya or West Irian or Papua Barat)	(CIE 1977, Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
Indonesia (Java)	(Hargreaves 1936, CIE 1977, CABI/EPPO 2001, CAB 2004)
Indonesia (Kalimantan, Moluccas, Sulawesi, Sumatra)	(CIE 1977, CABI/EPPO 2001, CAB 2004)
Indonesia (Maluku)	(CABI/EPPO 2001)
Indonesia (Nusa Tenggara)	(CABI/EPPO 2001, CAB 2004)
Japan	(Baptist 1944, Waterhouse and Norris 1987, Kessing and Mau 1993)
Japan (Aichi prefecture - Nagoya)	(Yazaki 2000)
Japan (Honshu, Kyushu, Shikoku)	(Shiraki 1952, CIE 1977, CABI/EPPO 2001, CAB 2004)
Japan (Kanagawa prefecture)	(Yanagita and Nakao 2003)
Kenya	(Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
Kiribati	
Korea	(Shiraki 1952, Waterhouse and Norris 1987, Kessing and Mau 1993)
Korea (Gensan)	(CIE 1977)
Korea (Koksung)	(Yoon and Lee 1974)
Korea (north)	(Bänziger 1987)
Korea, Democratic Peoples Republic	(CABI/EPPO 2001, CAB 2004)
Korea, Republic of	(CABI/EPPO 2001, CAB 2004)
Laos[1]	(Hargreaves 1936, CAB 2004)
Liberia	(Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
Liberia (12 mi. east of Monrovia)	(CIE 1977)
Madagascar	(Baptist 1944, Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
Madagascar (Diego Suarez, Tananarive)	(CIE 1977)
Malawi	(Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
Malawi (Luchenza, Mt. Mlanje, Mlanje Boma, Port Herald)	(CIE 1977)
Malaysia	(Hargreaves 1936, Comstock 1963, Waterhouse and Norris 1987, Zilli and Hogenes 2002)
Malaysia (Labuan)	(CIE 1977)
Malaysia (Peninsular Malaysia)	(CABI/EPPO 2001, CAB 2004)
Malaysia (Sabah, Sarawak)	(CIE 1977, CABI/EPPO 2001, CAB 2004)
Micronesia	(Denton et al. 1991, Muniappan et al. 1993, Muniappan et al. 2004)

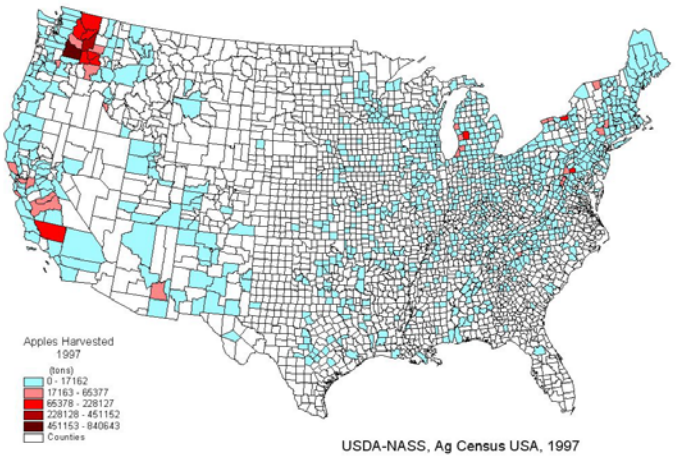
Location	References
Mongolia[2]	(CIE 1977, Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
Mozambique	(Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
Mozambique (Lourenco Marques)	(CIE 1977)
Myanmar (formerly Burma)	(Hargreaves 1936, Commission 1987, Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
Myanmar (Tavoy, Rangoon)	(CIE 1977)
Namibia (formerly South-West Africa)	(Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
Namibia (Grootfontein)	(CIE 1977)
Nepal	(CABI/EPPO 2001, CAB 2004)
Nepal (Phulchoki, Choche Lekh)	(Bänziger 1987)
New Caledonia	(Comstock 1963, Cochereau 1977, Prinsloo and Annecke 1978, Bänziger 1982, Maddison 1982, Kumar and Lal 1983, Bänziger 1987, Commission 1987, Waterhouse and Norris 1987, Denton et al. 1991, Sands and Broe 1991, Muniappan 1993, Muniappan et al. 1993, Sands et al. 1993, Zhang 1994, Muniappan et al. 1995, Fay 1996, Bhumannavar and Viraktamath 2001a, CABI/EPPO 2001, CAB 2004, Muniappan et al. 2004)
New Caledonia (Loyalty Islands)	(Comstock 1963, CIE 1977)
New Zealand	(Maddison 1982, CABI/EPPO 2001, CAB 2004)
Nigeria	(Waterhouse and Norris 1987, Zhang 1994, CABI/EPPO 2001, CAB 2004)
Nigeria (Agege, Ibadan)	(CIE 1977)
Niue	(Commission 1987, Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
Niue (Given)	(CIE 1977)
Norfolk Island	(CABI/EPPO 2001, CAB 2004)
Northern Mariana Islands	(Comstock 1963, Waterhouse and Norris 1987, Muniappan et al. 1995, CABI/EPPO 2001, CAB 2004, Smith 2004)
Northern Mariana Islands (Rota)	(CIE 1977, Muniappan et al. 1993, Sands et al. 1993)
Northern Mariana Islands (Saipan, Tinian)	(Muniappan et al. 1993, Sands et al. 1993)
Oceania (tropical, subtropical)	(Zilli and Hogenes 2002)
Pakistan	(Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
Pakistan (Karachi)	(CIE 1977)
Palau	(CIE 1977, Muniappan et al. 1995, CABI/EPPO 2001)

Location	References
Papua New Guinea	(Comstock 1963, Waterhouse and Norris 1987, Sands and Broe 1991, Kessing and Mau 1993, Sands et al. 1993, Fay 1994, Zhang 1994, Muniappan et al. 1995, Fay 1996, Sands and Chan 1996, CABI/EPPO 2001, CAB 2004)
Papua New Guinea (Louisiade Island, Trobriand Island, Bougainville, New Britain, St. Matthias Island, Vulcan Island)	(CIE 1977)
Philippines	(Comstock 1963, CIE 1977, Waterhouse and Norris 1987, Kessing and Mau 1993, Zhang 1994, CABI/EPPO 2001, CAB 2004)
Réunion	(CIE 1977, Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
Samoa (formerly Western Samoa)	(Hargreaves 1936, Comstock 1963, CIE 1977, Cochereau 1977, Prinsloo and Annecke 1978, Maddison 1982, Waterhouse and Norris 1987, Sands and Broe 1991, Muniappan 1993, Muniappan et al. 1993, Sands et al. 1993, Zhang 1994, Muniappan et al. 1995, Sands et al. 1996, Lubulwa and McMeniman 1998, CABI/EPPO 2001, CAB 2004)
Sao Tome and Principe	(CIE 1977, Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
Sierra Leone	(Hargreaves 1936, CIE 1977, Bänziger 1982, Kumar and Lal 1983, Waterhouse and Norris 1987, Denton et al. 1991, Zhang 1994, CABI/EPPO 2001, CAB 2004)
Singapore	(Comstock 1963, CIE 1977, Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
Solomon Islands	(Waterhouse and Norris 1987, CABI/EPPO 2001, Zilli and Hogenes 2002, CAB 2004)
Solomon Islands (Bellona, Rennell Island, Nggela, Guadalcanal, Kolombangara, New Georgia, Mono, Vella Lavella, Ysabel)	(CIE 1977)
South Africa	(Hargreaves 1936)
Sri Lanka (formerly Ceylon)	(Baptist 1944, Cochereau 1977, Bänziger 1982, Waterhouse and Norris 1987, Zhang 1994, Fay and Halfpapp 1999, CABI/EPPO 2001, CAB 2004)
Sri Lanka (Pelwehera)	(Baptist 1944)
Sri Lanka (Peradeniya)	(Baptist 1944, CIE 1977)
Tanzania	(Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
Tanzania (Amani, Kigoma, Longido, M'Pala)	(CIE 1977)

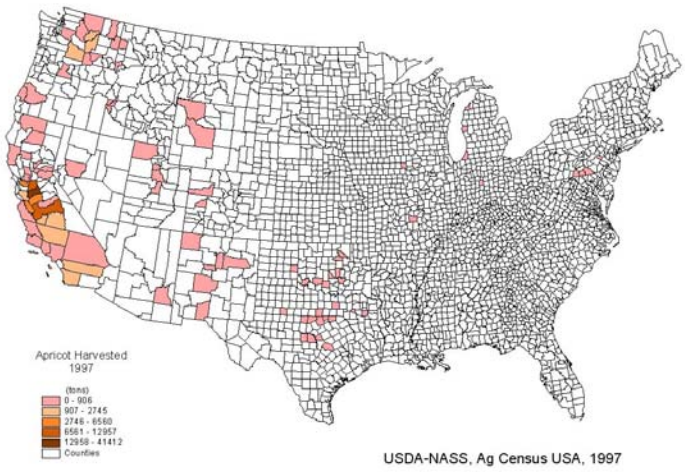
Location	References
Thailand	(Hargreaves 1936, Comstock 1963, CIE 1977, Bänziger 1982, 1987, Commission 1987, Waterhouse and Norris 1987, Denton et al. 1991, Sands and Broe 1991, Fay and Halfpapp 1993a, Kessing and Mau 1993, Fay 1994, Zhang 1994, CABI/EPPO 2001, CAB 2004)
Thailand (Chiang Mai)	(Bänziger 1987)
Togo	(Zilli and Hogenes 2002)
Tonga	(Comstock 1963, CIE 1977, Waterhouse and Norris 1987, Sands and Broe 1991, Sands et al. 1993, Zhang 1994, Muniappan et al. 1995, Sands et al. 1996, Lubulwa and McMeniman 1998, CABI/EPPO 2001, CAB 2004)
Uganda	(Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
Uganda (Bugoma, Mabira Forest, Ruwenzori)	(CIE 1977)
United States of America (Hawaii – Oahu; Kauai; Keaau, Hawaii; Kahului, Maui; Keawa Nui, Molokai)	(Heu 1988, Hara and Matayoshi 1989, Kessing and Mau 1993)
United States of America (Hawaii)	(Waterhouse and Norris 1987, Sands and Broe 1991, Muniappan 1993, Sands et al. 1993, Zhang 1994, Muniappan et al. 1995, Sands and Chan 1996, CABI/EPPO 2001, CAB 2004, Muniappan et al. 2004, Herbison-Evans and Crossley 2005)
Vanuatu (Anatom, Santo, Ambryn, Mallicolo, Pentecôte)	(Cochereau 1977)
Vanuatu (formerly New Hebrides)	(Comstock 1963, CIE 1977, Commission 1987, Waterhouse and Norris 1987, Sands and Broe 1991, Sands et al. 1993, Zhang 1994, CABI/EPPO 2001, CAB 2004, Herbison-Evans and Crossley 2005)
Vietnam	(Hargreaves 1936, Waterhouse and Norris 1987, Kiem 1995, CABI/EPPO 2001, CAB 2004)
Vietnam (AnChan, CaoBang, Chao Cay, Dong Dang, Hoang Suphi, Lao Kay, Tuyen Quang)	(CIE 1977)
Wallis and Futuna	(CIE 1977, Waterhouse and Norris 1987, CABI/EPPO 2001, CAB 2004)
Zimbabwe (formerly Rhodesia)	(Hargreaves 1936, CIE 1977, Waterhouse and Norris 1987, Zhang 1994, CABI/EPPO 2001, CAB 2004)

1. CIE (1977) distribution records for Vietnam, Burma, and Thailand also include Cambodia and Laos.
2. Questionable record. The presence of *E. fullonia* in Mongolia is questioned for several reasons: the original CIE map (1977) citation lists an unspecified historical location of "Amurland"; Zhang (1994) does not include this location in the geographic distribution of *E. fullonia*; and Mongolia is climatically different from all other countries where *E. fullonia* is known to occur.

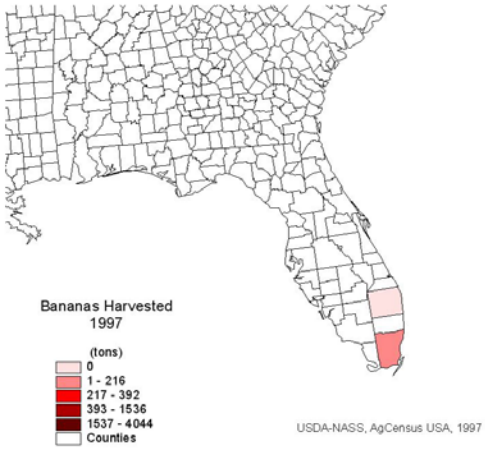
Appendix B. Host distribution for *Eudocima fullonia* in the contiguous US.



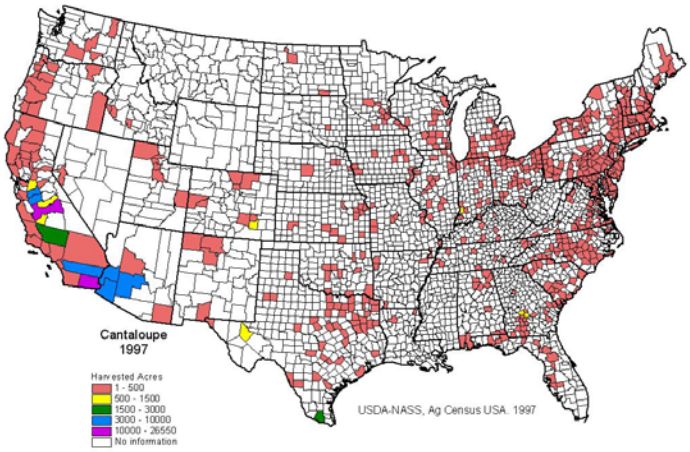
Map 1. Apple (*Malus domestica*)



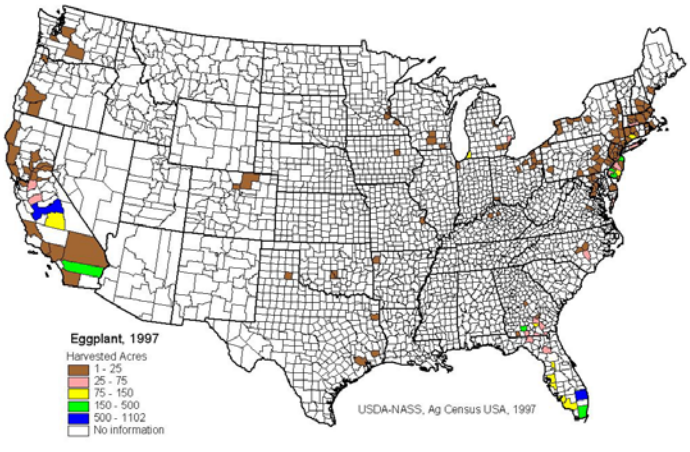
Map 2. Apricot (*Prunus armeniaca*)



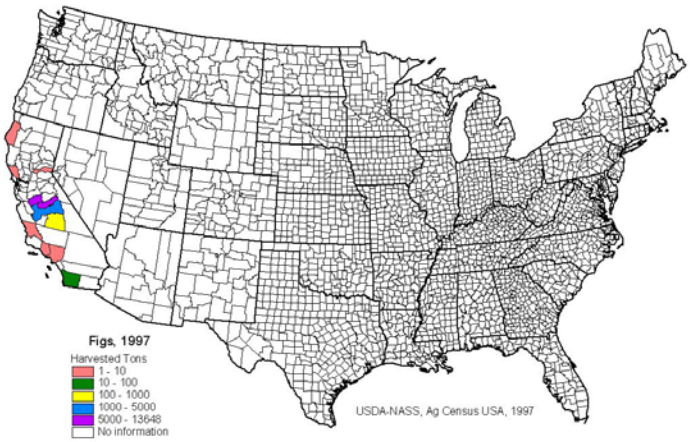
Map 3. Banana (*Musa x paradisiaca*)



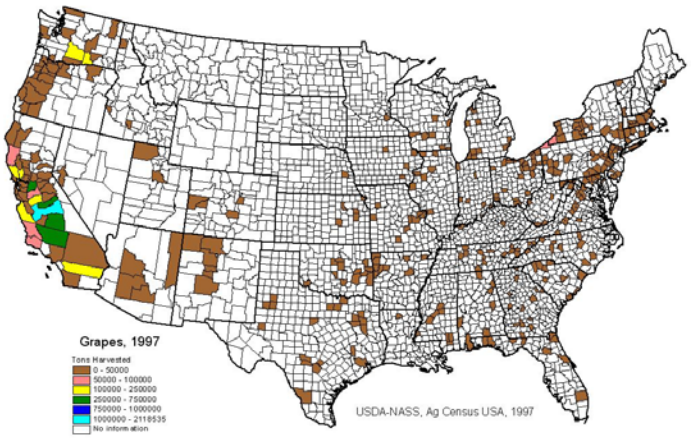
Map 4. Cantaloupe (*Cucumis melo*)



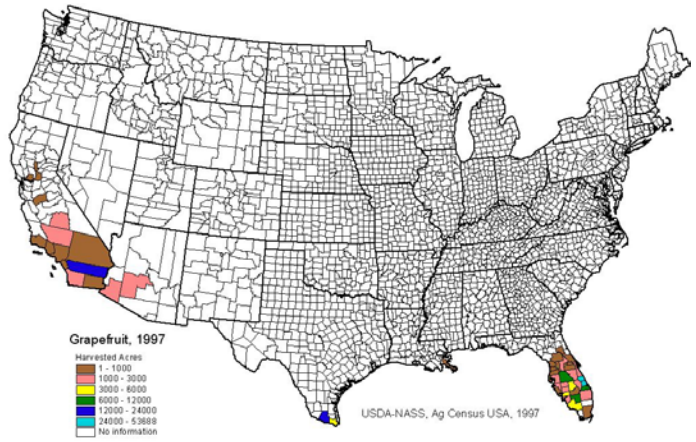
Map 5. Eggplant (*Solanum melongena*)



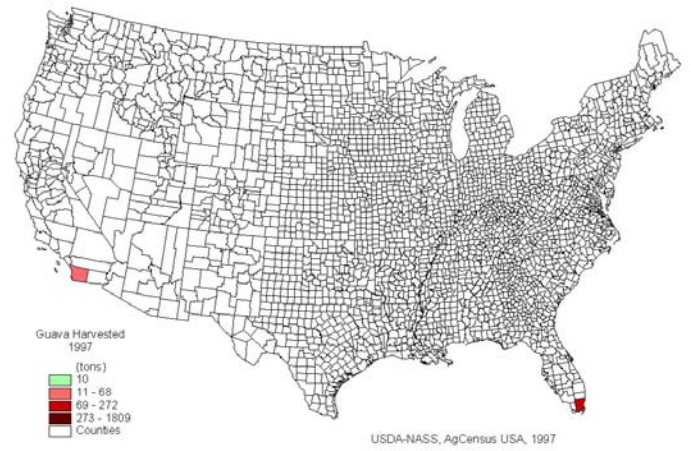
Map 6. Fig (*Ficus carica*)



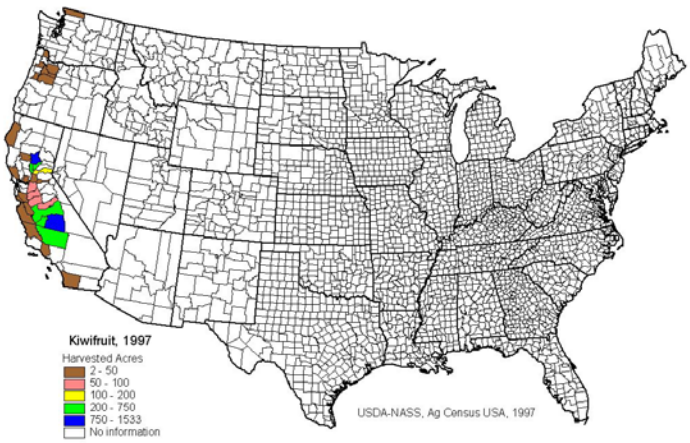
Map 7. Grape (*Vitis* spp.)



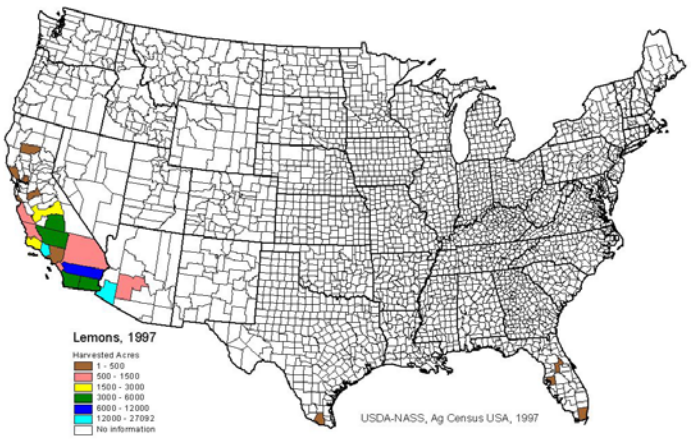
Map 8. Grapefruit (*Citrus x paradisi* [*maxima x sinensis*])



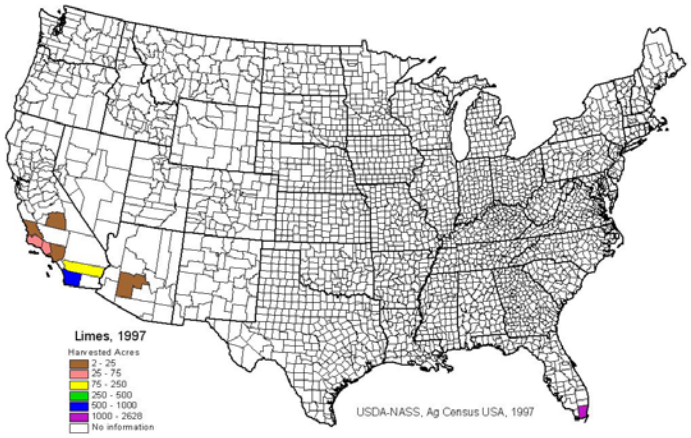
Map 9. Guava (*Psidium guajava*)



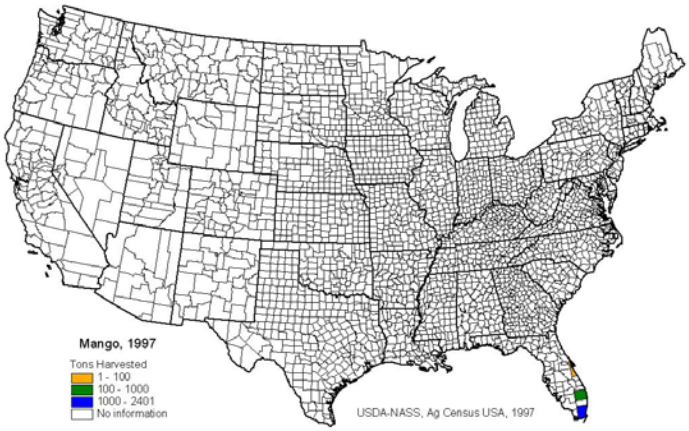
Map 10. Kiwi (*Actinidia chinensis*)



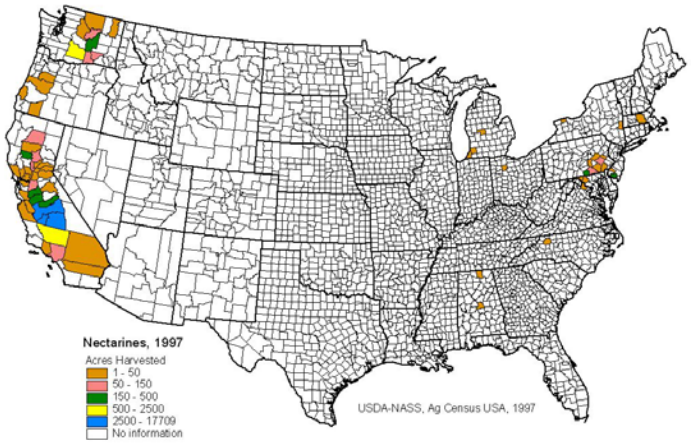
Map 11. Lemon (*Citrus limon*)



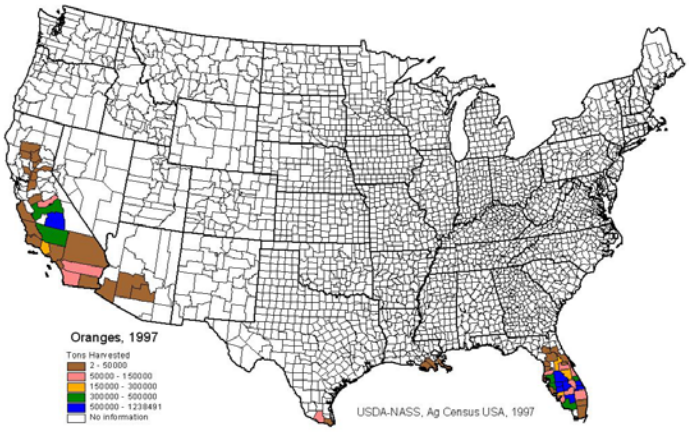
Map 12. Lime (*Citrus aurantifolia*)



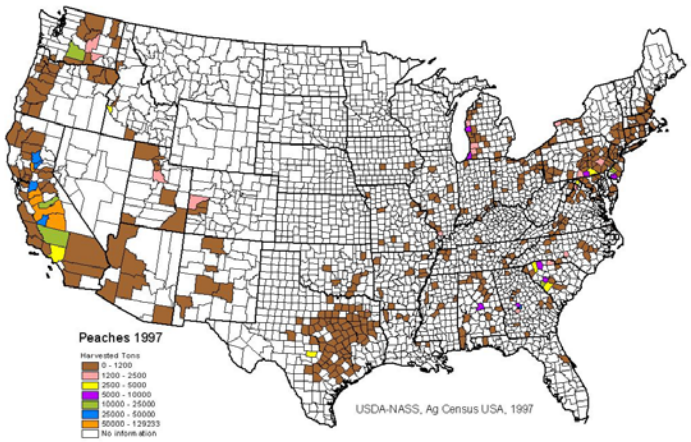
Map 13. Mango (*Mangifera indica*)



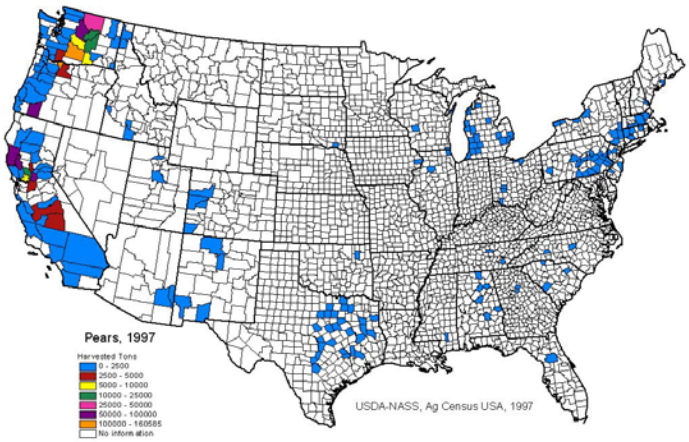
Map 14. Nectarine (*Prunus persica* var. *nucipersica*)



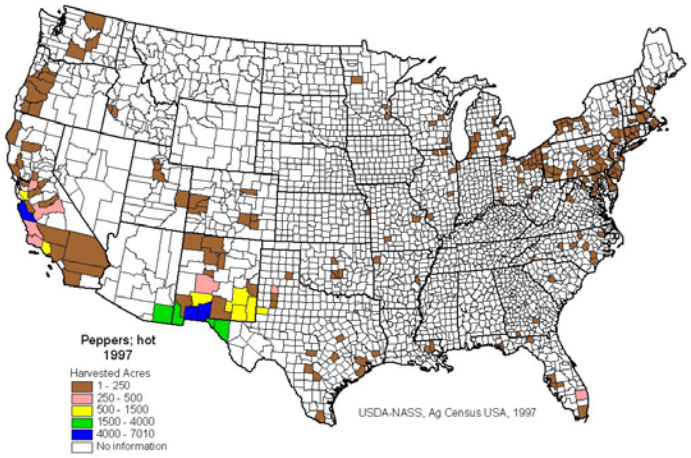
Map 15. Orange (*Citrus* spp.)



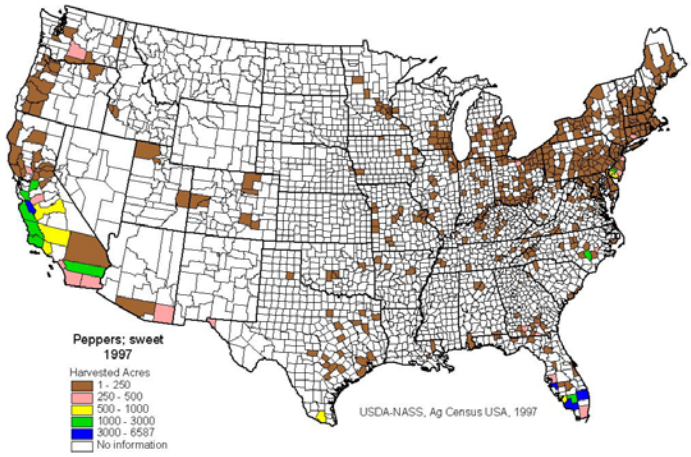
Map 16. Peach (*Prunus persica*)



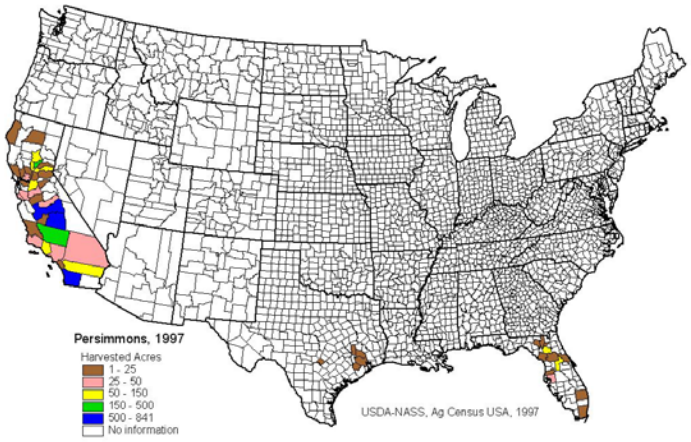
Map 17. Pear (*Pyrus communis*)



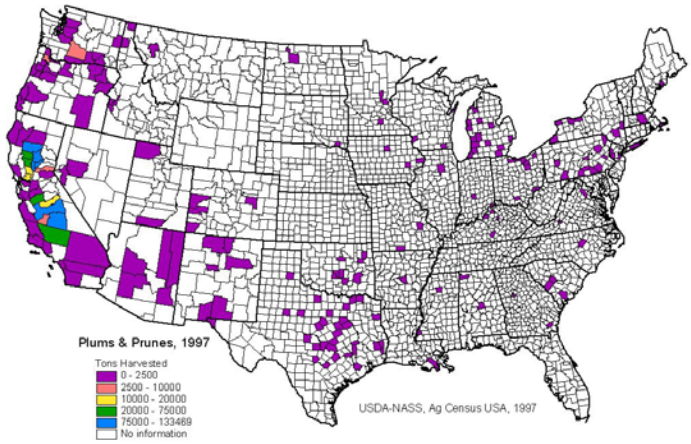
Map 18. Peppers, hot (*Capsicum* spp.)



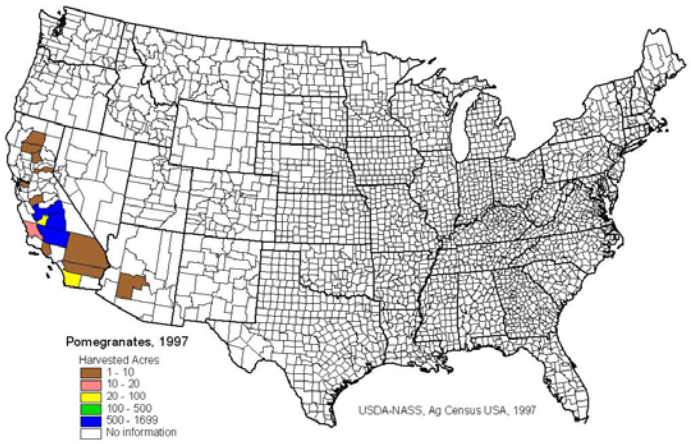
Map 19. Peppers, sweet (*Capsicum annuum*)



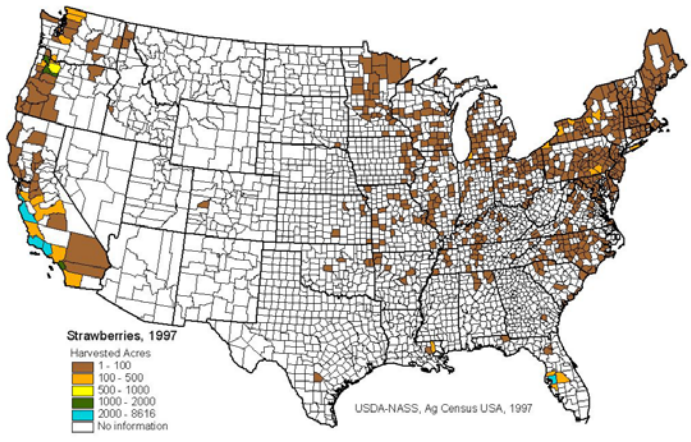
Map 20. Persimmon (*Diospyros* spp.)



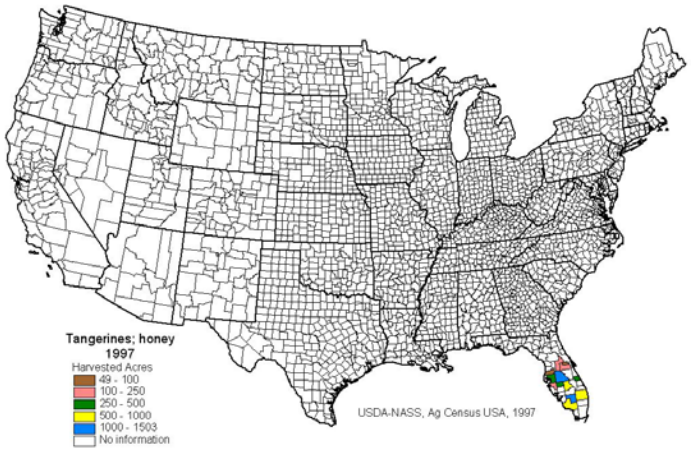
Map 21. Plum & Prunes (*Prunus* spp.)



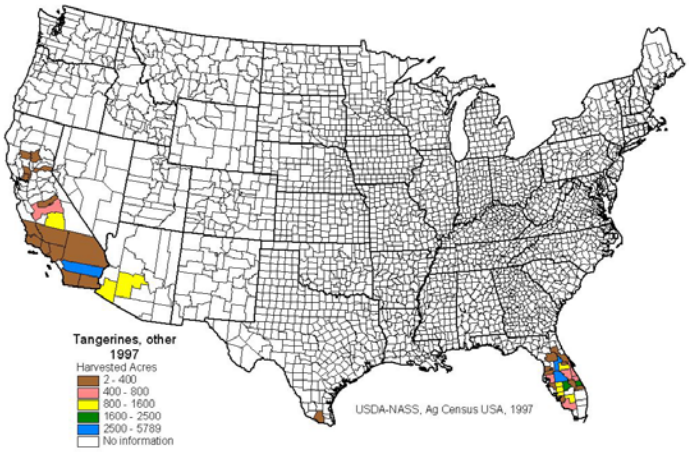
Map 22. Pomegranate (*Punica granatum*)



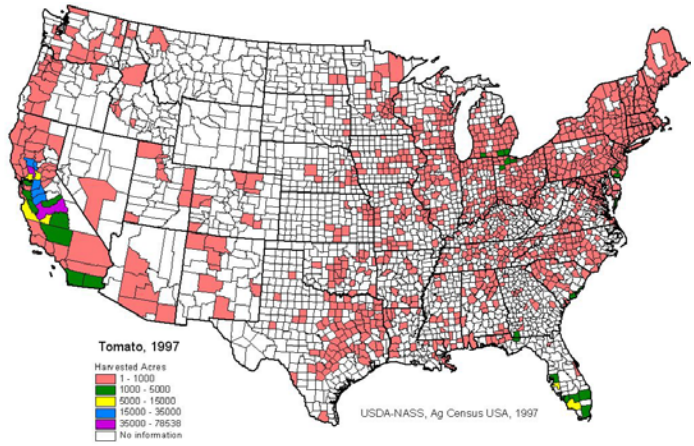
Map 23. Strawberry (*Fragaria* spp.)



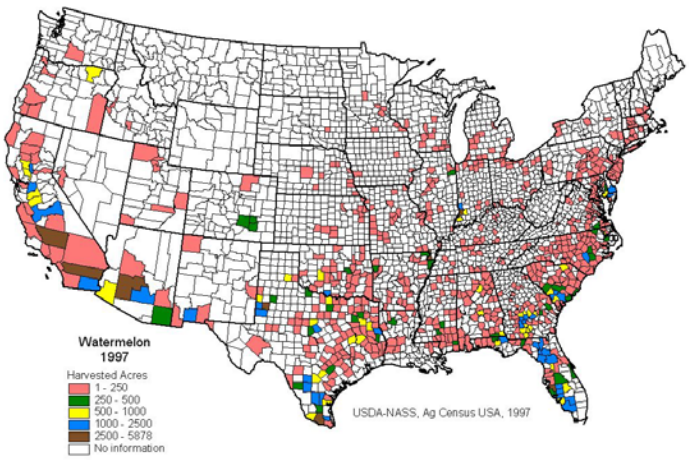
Map 24. Tangerine, honey (*Citrus reticulata*)



Map 25. Tangerine, other (*Citrus reticulata*)



Map 26. Tomata (*Lycopersicon esculentum*)



Map 27. Watermelon (*Citrullus lanatus*)

Appendix C. Taxonomy and morphology of *Eudocima fullonia* Clerck

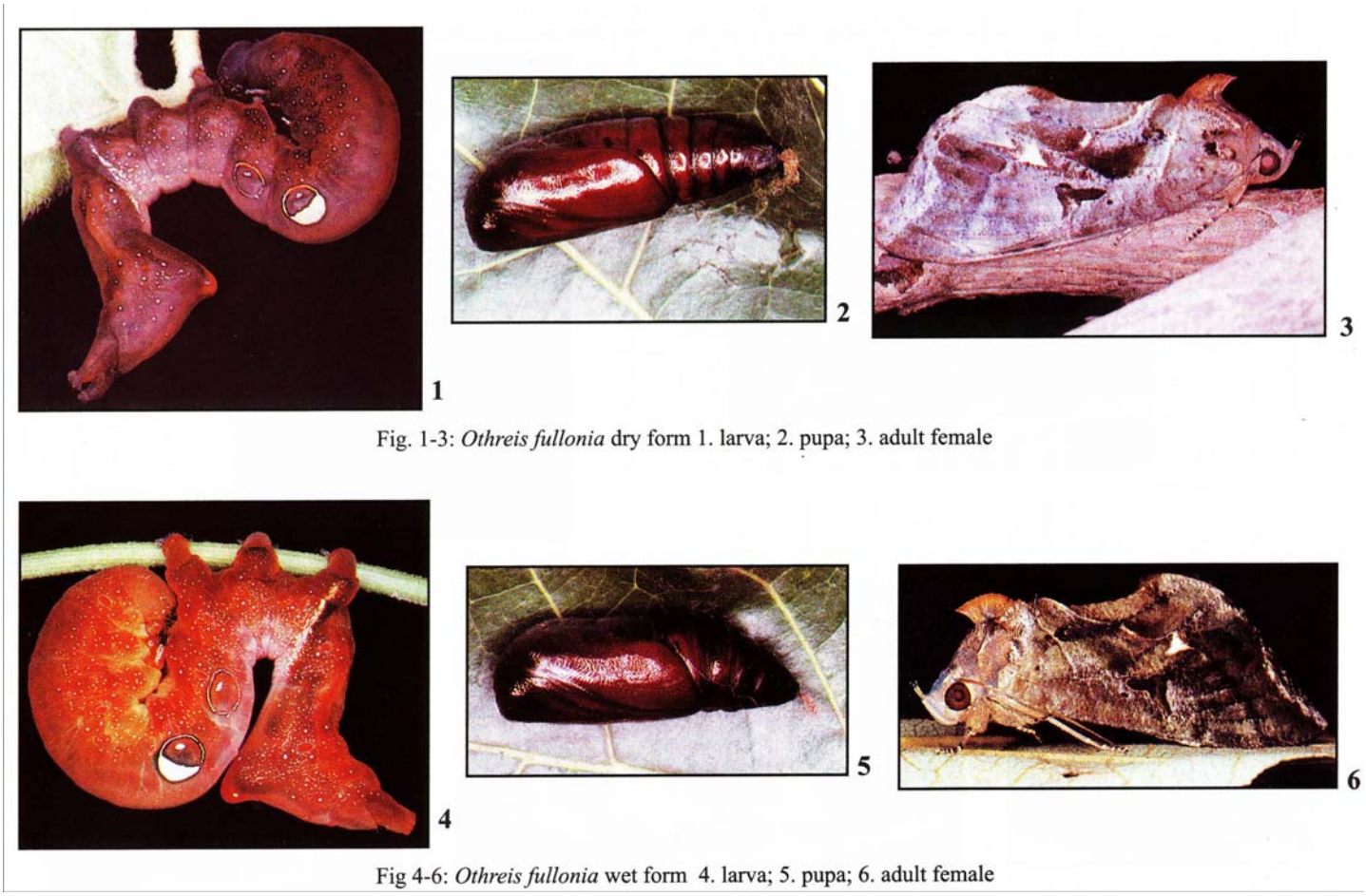


Figure C1. Life stages of the dry and wet forms of *Eudocima* [=*Othreis*] *fullonia* females. [Image reproduced from Apte (1999).]

Eudocima [=*Othreis*] *fullonia* was described by Clerck in 1764 . Subsequent morphological descriptions have been published by Baptist (1944), Comstock (1963) and others.

Synonyms (Poole 1989, Zilli and Hogenes 2002, CAB 2004):

Noctua dioscoreae Fabricius 1775
Ophideres fullonica Linnaeus
Ophideres obliterans Walker [1858]
Othreis fullonia Clerck
Othreis pomona Hübner
Phalaena (=*Attacus*) *fullonica* Linnaeus
Phalaena (=*Noctus*) *phalonia* Linnaeus
Phalaena pomona Cramer 1776
Ophideres fullonia Clerck
Ophideres princeps Boisduval 1832
Ophideres fullonia Clerck
Ophideres fullonia Clerck

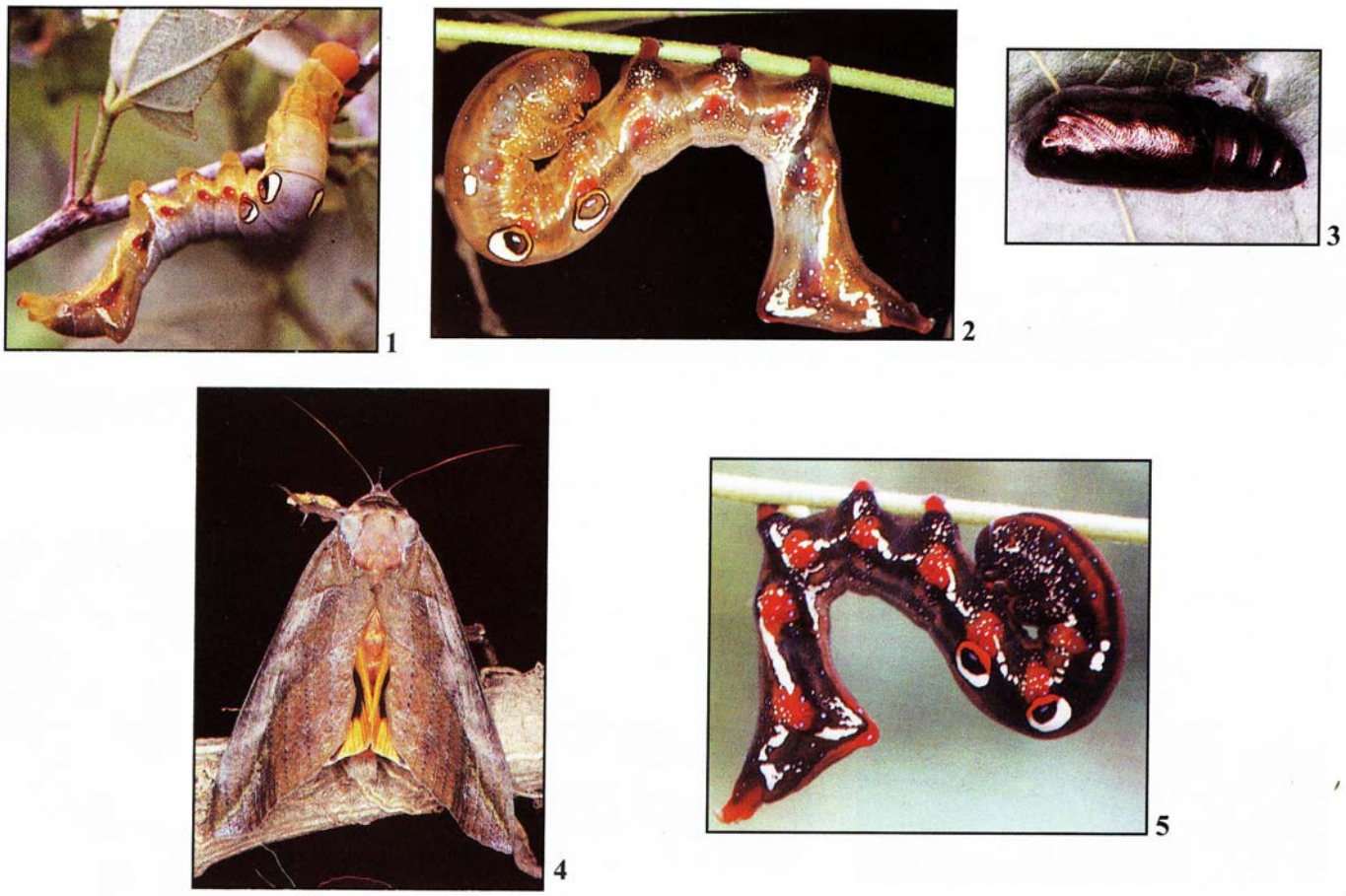


Fig. 1-4: *Othreis fullonia* wet form: 1. larva; 2. larva; 3. pupa; 4. adult male
Fig. 5: *Othreis fullonia* dry form larva

The BNHS and the author gratefully acknowledge sponsorship of the colour printing of this plate by the Mehta Scientific Education and Research Trust

Figure C2. Life stages of the dry and wet forms of *Eudocima* [=*Othreis*] *fullonia* males. [Image reproduced from Apte (1999).]

Diagnostic features

For complete accuracy, the following descriptions are quoted from Comstock (1963) and Baptist (1944).

Adults

Eudocima fullonia "[=*Othreis fullonia*] is one of the biggest species having a wing expanse of 3-3.5 inches. Its head and thorax are reddish brown suffused with plum color; metathoracic tufts and abdomen are orange. In the male the forewing is reddish-brown, usually with a greenish tinge and marked with dark specks along the veins. It is also marked by an oblique antemedial line, usually indistinct but sometimes prominent, and a curved post-medial line which is almost always met by an oblique streak from the apex. The underside of the forewing has the post-medial band orange. The hind wing is orange with a large black lunule beyond the lower angle of the cell and a marginal black band with cilial pale spots extending from costa to vein 2. The female has the forewing much more variegated and striated with dark red brown and greyish-ochre. There is also a

black orbicular speck and a distinct dark reniform mark which sends a spur along the median nervure. A triangular white mark is usually present on the post-medial line below vein 3. The hind wing is as in the male" (Baptist 1944).

Eggs

"The eggs are rounded, and have a vertical striation and are pale yellow when freshly laid" (Baptist 1944).

Larvae

"The young larvae are of a clear green color. There are 4 pairs of abdominal legs, the normal first pair being rudimentary. In the 2nd instar the caterpillars are dark in color but no distinct markings are present; these appear in the later instars. The color in the later instars is dark brown with black markings: there are prominent dark ocelli with pale iris on the 2nd and 3rd abdominal segments: the 8th abdominal segment is dilated and surmounted by a tubercle" (Baptist 1944).

"Mature larvae: Length in its characteristic resting position, 41 mm. Length when extendedin feeding position, 50 mm. Width at 5th segment, 8 mm. Head; width, 4.5 mm. Color, a uniform yellow-green, the mouth parts black and the ocelli brown to black. Body; ground color, leaf green. There is a prominent anal hump, which, in the resting position, is elevated. The 1st to 3rd segments bear several small round white dots. The 4th segment has a large white spot, somewhat reniform, above the spiracle. The 5th and 6th segments have still larger spots, but the lower portions of these have green heart-shaped areas with single white dots in them. All of these spots are on the lateral surface of the larvae. There are several white dots and irregular dashes ranging along the spiracular area. One, in particular, is placed on the side of the anal hump, and is pyramidal in outline. The legs are green proximally, and brown on the terminal segments. The prolegs are green, and the crochets brown. The spiracles are brownish scarlet. The resting posture is unusual, the head being arched under the thoracic segments, and the caudal area elevated and arched ventrally. With the black form of larva it was noted that the spiracles are black, and hence practically indistinguishable. Of the three white figures occuring on the 4th, 5th, and 6th segments of the green form, only those on the 5th and 6th persist, and these are not clearly defined" (Comstock 1963).

Appendix D. Threatened or endangered plants potentially affected by *Eudocima fullonia*.

Eudocima fullonia has the potential to adversely affect threatened and endangered plant species. However, because *E. fullonia* is not known to be established in the US and threatened and endangered plant species do not occur outside the US, it is not possible to confirm the host status of these rare plants from the scientific literature. From available host records, *E. fullonia* is known to feed on species within more than 30 plant families, including Annonaceae, Bromeliaceae, Cactaceae, Caricaceae, Cucurbitaceae, Ebenaceae, Fabaceae, Myrtaceae, Menispermaceae, Musaceae, Passifloraceae, Rosaceae, Rutaceae, Sapindaceae, Sapotaceae, and Solanaceae. From these host records, we infer that threatened and endangered plant species which are closely related to known host plants might also be suitable hosts (Table D1). For our purposes, closely related species belong to the same genus.

E. fullonia larvae reportedly feed on plants within the family Menispermaceae or, when members of Menispermaceae are not abundant, on hosts belonging to Fabaceae (particularly the genus *Erythina*) (Hargreaves 1936, Comstock 1963, Bänziger 1982, Kumar and Lal 1983, Martin Kessing and Mau 1993, Muniappan et al. 1994-95). There are approximately nine genera of Menispermaceae in the conterminous United States. Of these only one genus, *Calycocarpum*, has a species listed as threatened and endangered. *Calycocarpum lyonii*, the cupseed, is threatened in Indiana.

Table D1: Threatened and endangered plants in the conterminous U.S. that are potential hosts for *Eudocima fullonia*.

Reported Hosts	Threatened and/or Endangered Plant		Protected Status[1]	
	Scientific Name	**Common Name**	**Federal**	**State**
Chrysophyllum cainito	*Chrysophyllum oliviforme*	satinleaf		FL (E)
Diospyros australis, *D. glandulosa, D. kaki*	*Diospyros virginiana*	common persimmon		NY (T)
Eugenia dombeyi	*Eugenia confusa*	redberry stopper		FL (E)
	E. rhombea	red stopper		FL (E)
Malus sp., *M. domestica, M. domestica* 'Granny Smith', *M. sylvestris*	*Malus angustifolia*	southern crabapple		FL (T) IL (E)
	M. glaucescens	Dunbar crabapple		NY (E)
Opuntia sp.	*Opuntia arenaria*	El Paso pricklypear		NM (E)
	O. basilaris var. *treleasei* [= *O. treleasei*]	Trelease's beavertail pricklypear	E	CA (E)

Table D1: Threatened and endangered plants in the conterminous U.S. that are potential hosts for *Eudocima fullonia*.

Reported Hosts	Threatened and/or Endangered Plant		Protected Status[1]	
	Scientific Name	Common Name	Federal	State
	O. fragilis	brittle pricklypear		IA (T) IL (E) MI (E) WI (T)
	O. humifusa	devil's-tongue		MA (T)
	O. macrorhiza	twistspine pricklypear		IA (E)
	O. spinosissima	semaphore pricklypear		FL(E)
	O. stricta	erect pricklypear		FL (T)
	O. triacantha	Spanish lady		FL (E)
Passiflora edulis, *P. quadrangularis*	*Passiflora incarnata*	purple passionflower		OH (T)
	P. lutea	yellow passionflower		PA (E)
Prunus sp., *Prunus armeniaca*, *P. domestica, P. persica, P. persica* var. *nectarina*	*Prunus alleghaniensis*	Allegheny plum		MD (T) NJ (E) PA (T)
	P. americana	American plum		NH (T) VT (T)
	P. angustifolia	Chicasaw plum		NJ (E)
	P. geniculata	scrub plum	E	FL (E)
	P. maritima	beach plum		MD (E) ME (E) PA (E)
	P. maritima var. *gravesii*	Grave's plum		CT (E)
	P. nigra	Canadian plum		IA (E)
	P. pumila	sandcherry		AR (T) TN (T)
	P. pumila var. *depressa*	eastern sandcherry		NY (T)
	P. pumila var. *pumila*	Great Lakes sandcherry		NY (E)
	P. pumila var. *susquehanae* [= *P. pumilla var. cuneata*]	Sesquehana sandcherry		OH (T)
Rubus sp.	*R. arcticus* ssp. *acaulis* [= *R. acaulis*]	dwarf raspberry		MI (E)

Table D1: Threatened and endangered plants in the conterminous U.S. that are potential hosts for *Eudocima fullonia*.

Reported Hosts	Threatened and/or Endangered Plant		Protected Status[1]	
	Scientific Name	Common Name	Federal	State
	R. canadensis	smooth blackberry		KY (E) NJ (E)
	R. centralis	Illinois dewberry		IN (E)
	R. chamaemorus	cloudberry		MN (T) NH (E)
	R. cuneifolius	sand blackberry		NH (E) NY (E) PA (E)
	R. flagellaris [= *R. enslenii*]	northern dewberry		IN (E)
	R. nigerrimus	dark raspberry		WA (E)
	R. odoratus	purpleflowering raspberry		IL (E) IN (T)
	R. pubescens	dwarf red raspberry		IL (T)
	R. setosus	setose blackberry		IL (E) IN (E)
	R. whartoniae	Wharton's dewberry		KY (T)

Source of threatened and endangered species: National Plants Database (USDA NRCS 2004)
1. E= Endangered; T=Threatened

Appendix E. Biology of *Eudocima fullonia*

Population phenology

Annual population density is variable depending on such factors as: host availability, host selection (adult oviposition; adult and larval feeding preferences) and quality; annual rainfall and humidity; temperature; presence of natural enemies; and seasonal migration (Cochereau 1977, Maddison 1982, Fay and Halfpapp 1993b, Sands et al. 1993, Fay 1994, Fay and Halfpapp 1999). Adult oviposition choices (e.g., which host plants should receive eggs and where on a plant should eggs be placed) affect the survivorship of larvae (Cochereau 1977, Kumar and Lal 1983, Fay and Halfpapp 1993b, Muniappan et al. 1993, Sands and Chan 1996).

In Fiji, females lay eggs from June to October (Kumar and Lal 1983). The larval population is small between November and May, increases in June, and peaks in August before declining. Moths feed and begin to mate shortly after emergence.

Kumar and Lal (1983) reported stage-specific development times for *E. fullonia* reared on leaves of *Erythrina variegata* and *E. lithosperma* (wild larval hosts in the family Fabaceae) in a laboratory. Results are reproduced (Table E 1). The design of the experiment did not allow for the calculation of a temperature threshold for development.

Table E1. Development times for *E. fullonia* reared on dadap (*Erythrina variegata* and *E. lithosperma*) leaves at 28-33°C [Reproduced from Kumar and Lal (1983).]

Development Stages	Average No. (days±SE)
Egg incubation	4.0±0.0
Larval period:	
first instar	4.2±0.16
second instar	3.6±0.15
third instar	2.6±0.12
fourth instar	3.7±0.35
fifth instar	7.1±0.65
Total larval period	21.2±1.43
Pupal period	17.8±0.64
Egg laying to adult emergence	43.0±2.07
Longevity of adults:	
Male	26.7±0.20
Female	28.5±0.34

Stage specific biology

E fullonia has four developmental stages including egg, larva, pupa and adult. There are five larval instars. Total development time for egg-laying to adult emergence in Fiji is about 43days at 28-33°C, and 31.5 days (temperature not specified) in New Calidonia (Cochereau 1977, Kumar and Lal 1983, Waterhouse and Norris 1987).

Adult
In Africa, total population density seems to affect the sex ratio of *E. fullonia*. In Australia, a sex ratio of 2.3:1 (males:females) was reported on coastal carambolas compared to a 1:1 ratio on tableland fruit. Reasons for the difference in sex ratios between sites is unknown (Fay and Halfpapp 1999).

Adults fly, feed and mate at night (Yoon and Lee 1974, Fay and Halfpapp 1999, CAB 2004). Fruit skin is pierced with the tip of the proboscis and then juice is extracted. Preoviposition occurs within 4-8 days, and longevity is about 26 to 28 days for males and females, respectively (Hargreaves 1936, Kumar and Lal 1983). Moths have been reported to live several months in cooler conditions. *E. fullonia* adults are strong fliers and may migrate over considerable distances (Baptist 1944, CAB 2004).

Egg
Eggs may be laid singly, or in egg masses containing 50-750 eggs. Placement may be on the underside of young leaves, or on any part of the host. Sometimes eggs may be placed on unsuitable hosts, particularly when the population density is high (Waterhouse and Norris 1987). Eggs that are laid singly are scarcely seen in the field (Cochereau 1977, Maddison 1982, Kumar and Lal 1983, Waterhouse and Norris 1987, Sands et al. 1993, Fay 1994). Egg hatch occurs within 3-4 days at 28-33°C (Hargreaves 1936, Kumar and Lal 1983, Waterhouse and Norris 1987).

Larva
There are four molts and five instars. Total development time for larvae is about 21 days (Kumar and Lal 1983). Larvae can be found feeding anytime on the underside or edges of leaves, but typically feed between 5 PM and 10 AM. When in danger, young larvae tend to respond by dropping to the ground, while older larvae may exhibit a characteristic aggressive posture and swaying motion (Kessing and Mau 1993). Molted skins are consumed by newly emerged larvae. Mature larvae stop feeding and construct pupal cocoons made of silk-spun leaves (Maddison 1982, Kumar and Lal 1983). When pupation occurs during unfavorably dry conditions, emergence may not be successful (Hargreaves 1936). Diapause is unknown for immature stages (CAB 2004).

Larvae typically do not attack fruit but feed preferentially on foliage of certain *Tinospora* spp., a vining plant common in rain forests belonging to the family Menispermaceae. Members of this genus serve as the larval host for several *Eudocima* spp. over broad geographic areas. Other wild hosts for larvae include plants within the family Fabaceae [see 'Host Specificity']. Migration and the ability of adults to utilize separate food sources from larvae enable this pest to extend its pool of available hosts and its period of reproduction (Fay and Halfpapp 1993b). This more effective allocation of resources allows the population to better maintain itself, even during unfavorable climatic conditions (Fay and Halfpapp 1993b). In coastal north Queensland, *E. fullonia* adults feed on lychees beginning in mid-November (Fay and Halfpapp 1993b).
Larvae are present and feed on *Tinospora* spp. (and only a few other menisperms) from November to March and then move to an alternate host (Fay and Halfpapp 1993b).

Pupa
Pupation occurs in an average of 12.5-17.8 days within a pupal cocoon that may remain in the tree or drop to the ground after drying (Hargreaves 1936, Kumar and Lal 1983, Waterhouse and Norris 1987).