Euphytica (2006) 148: 165–183
DOI: 10.1007/s10681-006-5950-8

A pest risk assessment for *Copitarsia* spp., Insects associated with importation of commodities into the United States

Robert C. Venette[1,3,*] & Juli R. Gould[2]
[1]*Department of Entomology and Midwest Ecological Risk Assessment Center, University of Minnesota, 1980 Folwell Avenue, 219 Hodson Hall, St. Paul, MN 55108, USA;* [2]*Survey Detection and Eradication Laboratory, USDA-APHIS, Building 1398, OTIS Air National Guard Base, Cape Cod, MA 02542-5008, USA;* [3]*Current address: USDA Forest Service, 1561 Lindig Street, St. Paul, MN 55108, USA*
*(*author for correspondance: e-mails: venet001@umn.edu; rvenette@fs.fed.us)*

Key words: Copitarsia, exotic species, international trade, pathway analysis, phytosanitary security, risk assessment

Summary

Eggs and larvae of *Copitarsia* spp. (Lepidoptera: Noctuidae) are frequently intercepted on fresh commodities arriving in the United States from Mexico, Central America, and South America. *Copitarsia* spp. are not known to occur in the US and, thus, are considered actionable pests by the US Department of Agriculture, Animal and Plant Health Inspection Service (USDA, APHIS). Whenever the genus is detected in imported goods, shipments must be disinfested, destroyed, or returned to the country of origin. Inspections and interdictions might be unnecessary if *Copitarsia* spp. were unlikely to establish in the US or if consequences of *Copitarsia* establishment were trivial. Consequently, we prepared a qualitative pest risk assessment to characterize the degree of risk posed by the genus to US agricultural and natural ecosystems. Published literature was consulted to describe the biology and ecology of the genus. Trade statistics and interception records were summarized to identify pathways of introduction. With this information, experts assigned risk ratings to each of eleven elements identified by USDA, APHIS that pertained to the likelihood or consequence of exotic-pest establishment. The likelihood of *Copitarsia* spp. becoming established in the US was considered high, but confidence in this assessment was low. Similarly, consequences of *Copitarsia* establishment were rated high, but confidence in this assessment was moderate. Overall, the assessment revealed that *Copitarsia* pose a high degree of risk to the US and phytosanitary measures to exclude the pest seem warranted. However, additional research is needed to address critical data gaps and refine assessments of risk for individual species within the genus.

Introduction

The potential impact of exotic arthropods on natural and agricultural ecosystems is now widely recognized. More than 2000 species of non-indigenous arthropods occur in the US (OTA, 1993). Of these species, approximately 1000 are pests of crops and roughly 120 are serious pests of forests (Pimentel et al., 2000). Non-indigenous pests typically cause US$ 500 million in control costs and US$ 16 billion in losses and damage per year (Pimentel et al., 2000). Alien species are also considered a general threat to species diversity and ecosystem processes (Kiritani, 1999; Mack et al., 2000). For example, in a recent review, Reitz and Trumble (2002) found that 78% of the cases of competitive displacement of established arthropods involved the introduction of an exotic species. Safeguarding the US from the establishment of non-indigenous pests is now considered a vital component of ensuring an inexpensive food supply and preserving natural resources (National Plant Board, 1999).

The US Department of Agriculture, Animal and Plant Health Inspection Service (USDA, APHIS) plays a pivotal role in the exclusion of exotic pests from the

US, particularly pests of plants and animals that are transported through commerce and travel (Mack et al., 2002). However, the task of excluding exotic pests is especially daunting when one considers the number of species that USDA, APHIS is attempting to keep out of the country. APHIS has reported $n = 609{,}303$ interceptions of $n = 4{,}222$ taxa of insects from 1985 to 2001 (USDA, Port Information Network [PIN] database), and insects only represent 60–65% of all interceptions (Mack et al., 2002). Not all of these taxa are likely to pose the same degree of economic or environmental risk. In this context, risk is defined as the probability of an exotic pest becoming established weighted by the consequences of pest establishment (Mack et al., 2002; Orr et al., 1993). By understanding the risks associated with particular species, APHIS can more efficiently utilize limited resources to exclude pests that pose the greatest threat to the US (National Plant Board, 1999). Risk assessment can provide a valuable tool to evaluate which pests are most threatening.

Noctuid moths in the genus *Copitarsia* are frequently intercepted at US border ports on produce and cut flowers from Mexico, Central America, and South America (Hunter & Elliott, 1995; Hunter & Simmons, 1995). During an inspection, APHIS officers typically encounter the genus as eggs or larvae. *Copitarsia* spp. are considered quarantine pests because members of the genus are not known to occur in the US and are of potential economic significance (FAO, 2002). If *Copitarsia* spp. are found in a shipment, the commodity must be treated, destroyed, or returned to the country of origin (USDA APHIS, 1999). Inspection and interdiction would be unnecessary if *Copitarsia* spp. were unlikely to become established in the US or cause significant economic or ecological damage. Although risks associated with *Copitarsia* spp. have been addressed in documents related to international trade (Cave & Redmond, 1997a,b; USDA, APHIS, 1997), the risks posed by the genus have not been assessed in depth.

The objectives of this study were to: (a) analyze trade and interception records to identify pathways for introduction of *Copitarsia* spp.; (b) describe pertinent aspects of the ecology of *Copitarsia* spp. to evaluate the likelihood of the genus becoming established in the US and causing adverse economic or environmental impacts; and, (c) identify critical data gaps about *Copitarsia* spp. that could substantially impact the risk assessment. This study was not intended to evaluate the relative risks associated with each pathway by which *Copitarsia* spp could arrive in the United States. This paper does provide a case study for qualitative risk assessments that are intended to characterize risk sufficiently to inform a decision-making process (Mack et al., 2002). Qualitative approaches to pest risk assessment are particularly useful when biological information about a pest is itself qualitative. The principles upon which this risk assessment is built apply not only to non-indigenous arthropods but also to exotic vertebrates, pathogens, and plants.

Description of the genus

Taxonomy

Copitarsia spp. occur within the subfamily Cuculliinae (Lepidoptera: Noctuidae). Systematics and nomenclature within this genus are particularly problematic (Poole, 1989). Over time, the genus has included from six to eleven species, depending on which taxonomic authority is consulted (Castillo & Angulo, 1991; Hampson, 1906; Köhler, 1959; Poole, 1989). Currently-described species include: *C. anguloi* Castillo and Angulo, *C. basilinea* Köhler, *C. clavata* (Köhler), *C. editae* Angulo and Jana-Saenz, *C. humilis* (Blanchard), *C. incommoda* (Walker) (=*C. consueta* Walker), *C. naenoides* (Butler), *C. paraturbata* Castillo and Angulo, *C. patagonica* Hampson, *C. purilinea* (Mabille), and *C. decolora* (Guenée) (=*C. turbata* (Herrich-Schäffer)). Of these only *C. humilis*, *C. incommoda*, *C. naenoides*, and *C. decolora* have been reported as pests in the literature. Recently, the validity of the eleven names has come into question; moreover, because *Copitarsia* spp. have not been examined with modern phylogenetic techniques, these names may represent geographic variants of one or two species (R. Simmons, personal communication).

Our assessment focuses on the genus as a whole, rather than an individual species. Since taxonomy within the genus *Copitarsia* is poor, pest reports or biological studies cannot be assigned reliably to any one species. Adult *Copitarsia* spp. have few external characteristics to distinguish them from other noctuid moths and can only be identified with confidence by genitalia dissections. Simmons and Pogue (2004) provide morphological descriptions for representatives of the genus. At times, members of *Copitarsia* have been confused with the genera *Agrotis*, *Euxoa*, *Polia*, and *Orthosia*, presenting the possibility that undescribed species of *Copitarsia* are currently misnamed within these genera (Gould et al., 2000). *Copitarsia* larvae can be distinguished from other genera based on external characteristics. For example, *Copitarsia* larvae have dark bars at the base of the two medial setae, white dorsal setae, misaligned head setae (dorsal ventrally), and two dark triangles on posterior abdominal segments (Riley, 1998). Because rearing studies are limited, identification of species from larval specimens is not yet possible (R Simmons, personal communication).

Bionomics

Copitarsia spp. can be found along the western edge of South and Central America from the southern tip of Argentina through central Mexico (Figure 1). *Copitarsia* spp. have been reported in the literature from all countries south of the United States except Belize, Brazil, El Salvador, French Guiana, Honduras, Nicaragua, Panama, Paraguay, Suriname, Uruguay, and the islands of the Caribbean. Nevertheless, the genus has been intercepted by USDA, APHIS on commodities shipped from several countries known to have *Copitarsia* spp. and from Belize, Brazil, Dominican Republic, El Salvador, Haiti, Honduras, Jamaica, Nicaragua, Panama, St. Lucia and Trinidad and Tobago (Table 1; USDA, PIN). The true origin of these commodities is not known. However, such information suggests that the range of *Copitarsia* extends from central Mexico to southern South America and may include several Caribbean nations. Populations of the genus have not been reported in the United States.

Copitarsia spp. begin life as eggs, deposited singly (Lopez-Avila, 1996a) or in egg masses (Velasquez, 1988), depending on species. A single female may produce between 570 and 1640 eggs, depending on the quality of the environment and host (Arce de Hamity & Neder de Roman, 1992; Larrain S., 1996; Rojas & Cibrian-Tovar, 1994; Velasquez, 1988). Larvae complete five to six instars during development (Arce de Hamity & Neder de Roman, 1993;Lopez-Avila, 1996a)

Figure 1. Distribution of *Copitarsia* spp. in the Americas. Circles and municipalities are depicted in gray. Hatch marks designate reported origins of commodities infested with *Copitarsia* spp.

Table 1. Country of origin of commodities in which *Copitarsia* spp. were intercepted by USDA, APHIS

Origin	Interceptions
Colombia	4054
Mexico	2166
Ecuador	524
Guatemala	241
Chile	195
Costa Rica	91
Peru	74
Venezuela	30
Dominican Republic	11
Unknown	9
Honduras	8
Jamaica	5
The Netherlands	5
Bolivia	4
Panama	4
El Salvador	3
Argentina	2
Brazil	2
Belize	1
Haiti	1
Japan	1
Nicaragua	1
St. Lucia	1
Trinidad and Tobago	1

and reach a length of ≈2–4 cm (Arce de Hamity & Neder de Roman, 1993). Later-instars are typically green but can also be black or gray (Arce de Hamity & Neder de Roman, 1993; Lopez-Avila, 1996a). Development time from egg to adult depends on many factors including temperature, humidity, and host. Reported larval development times vary from approximately 43 days at 24.5 °C on lettuce (*Lactuca sativa* L.) to 82.5 days at 20.4 °C on artificial diet (Arce de Hamity & Neder de Roman, 1992; Lopez-Avila, 1996a; Velasquez Z., 1988). Larvae generally feed externally on leaves, stems, and fruits of host plants but will occasionally bore into thicker non-woody tissues (J.R.G., personal observation). Pupation occurs in the soil. Diapause has not been reported for any members of the genus. In general, *Copitarsia* spp. appear to have two to four generations per year (Arce de Hamity & Neder de Roman, 1992; Artigas & Angulo, 1973; Liberman Cruz, 1986), although Hichins and Mendoza (1976) report only one generation per year for *C. humilis* on alfalfa (*Medicago sativa* L.) in Chile.

Larvae of *Copitarsia* spp. are polyphagous. Thirty nine crop plants are listed as hosts in the published literature (Table 2), and the genus has been found at US ports of entry on several additional plant species not reported in the literature (Table 3). Collectively, these plants represent more than 19 families. Most of the crops listed as hosts of *Coptarsia* spp. are also commonly grown in the US. Within its current range, *Copitarsia* spp. cause damage by reducing yields or marketability of crops (Arce de Hamity & Neder de Roman, 1992; Artigas & Angulo, 1973; Arestegui, 1976; Cortes et al., 1972; Lamborot et al., 1999; Larrain, 1984, 1996; Liberman Cruz, 1986; Lopez-Avila, 1996a; Machuca et al., 1990; Monge et al., 1984; Quiroga et al., 1989; Sanchez & Aldana, 1985; Sanchez & Maita-Franco, 1987; Velasquez, 1988; Vimos et al., 1998). Information on the extent of damage is scarce, but *Copitarsia* spp. have been reported to reduce marketability of artichoke heads by 24% (Larrain, 1984) to 54% (Machuca et al., 1990). *Copitarsia* spp. may reduce quinoa yields by 80–90% if no pesticides are applied (Liberman Cruz, 1986).

A large number of natural enemies attack *Copitarsia* spp. Members of the genus are susceptible to microbial pathogens such as *Bacillus thuringiensis*, *Beauveria bassiana*, and *Entomophthora sphaerosperma* (Aruta et al., 1974; Lopez-Avila, 1996a). Larvae of the genus are parasitized by at least 13 taxa of tachinid parasitoids, such as *Archytas scutellatus*, *Incamyia chilensis*, *Prosopochaeta setosa*, and *Winthemia* spp. (Alcala, 1978; Cortes, 1976; Lamborot et al., 1995; Leyva & Sanchez, 1993; Sanchez & Maita-Franco, 1987). Eggs and larvae are attacked by another 11 parasitoid taxa in Aphelinidae (e.g., *Encarsia portreri*), Braconidae (e.g., *Apanteles* spp.), Ichneumonidae (e.g., *Netelia gerlingi*, *Thymebatis* spp) and Trichogrammatidae (e.g., *Trichogramma minutum*) (Lamborot et al., 1995; Leyva & Sanchez, 1993; Loo & Aguilera, 1983; Lopez-Avila, 1996a; Machuca et al., 1989; Porter, 1980; Sanchez & Maita-Franco, 1987). Collectively, natural enemies may suppress populations of *Copitarsia* spp., as outbreaks of the pest have been associated with changes in agricultural practices, particularly the use of pesticides (Artigas & Angulo, 1973; Cortes, 1976; Cortes et al., 1972; Liberman Cruz, 1986; Machuca et al., 1989; Monge et al., 1984).

Table 2. Commercial horticultural or agronomic crops which are suitable host plants for *Copitarsia* spp. insects

Family/Scientific name	Spanish (English) common name	Reference(s)
Actinidiaceae		
Actinidia chinensis	Kiwi (Kiwi)	(Larrain, S., 1996)
Anacardiaceae		
Pistacia spp.	Pistacho (Pistacio)	(Larrain, S., 1996)
Apiaceae		
Coriandrum sativum	Cilantro (Coriander)	(Riley, 1998)
Daucus carota subsp. *sativus*	Zanahoria (Carrot)	(Neder de Roman & Arce de Hamity, 1991; Arce de Hamity & Neder de Roman, 1992)
Asteraceae		
Calendula spp.	Maravilla (Calendula)	(Larrain, S., 1996)
Cynara scolymus	Alcachofa (Artichoke)	(Larrain, S., 1984; Machuca, L. et al., 1988, 1989, 1990, Castillo & Angulo, 1991; Larrain, S. & Araya, C., 1994; Larrain, S., 1996)
Helianthus annuus	Girasol (Sunflower)	(Angulo Weigert, 1975b)
Lactuca spp.	lechuga (lettuce)	(Neder de Roman & Arce de Hamity, 1991; Arce de Hamity & Neder de Roman, 1992)
Basellaceae		
Ullucus tuberosus	Melloco, Olluco, Ulluma, Chuguas (Ulluco)	(Vimos, N. et al., 1998)
Brassicaceae		
Brassica napus	Raps (Rapeseed)	(Artigas & Angulo, 1973; Castillo & Angulo, 1991; Larrain; S., 1996)
Brassica oleracea	Repollo (Cabbage)	(Carrillo, S., 1971; Aruta et al., 1974; Monge, V. et al., 1984; Grez, 1992; Rojas et al., 1993; Larrain S., 1996; Castrejon G. et al., 1998)
Brassica oleracea botrytis	coliflor (cauliflower)	(Rojas et al., 1993; Castrejon G. et al., 1998)
Brassica oleraceae	broccoli (broccoli)	(Rojas et al., 1993; Castrejon G. et al., 1998)
Buxaceae		
Simmondsia californica	jojoba (jojoba)	(Quiroga et al., 1989; Castillo & Angulo, 1991; Larrain S., 1996)
Caryophyllaceae		
Dianthus caryophyllus	clavel (carnation)	(Castillo & Angulo, 1991)
Chenopodiaceae		
Beta vulgaris	remolacha, betabel (beet)	(Angulo & Weigert, 1975; Castillo & Angulo, 1991; Neder de Roman & Arce de Hamity, 1991; Arce de Hamity & Neder de Roman, 1992; Rojas et al., 1993; Larrain S., 1996)
Beta vulgaris ssp. cicla	acelga (chard)	(Rojas et al., 1993, Lamborot et al., 1995)
Chenopodium quinoa	quinoa, quinua (quinoa)	(Angulo & Weigert, 1975; Liberman Cruz, 1986; Castillo & Angulo, 1991; Lamborot et al., 1999)
Spinacia oleracea	espinaca (spinach)	(Castillo & Angulo, 1991; Rojas et al., 1993)
Fabaceae		
Vicia faba	habas (broad or lima bean)	(Gomez T., 1972; Neder de Roman & Arce de Hamity, 1991; Arce de Hamity & Neder de Roman, 1992; Lamborot et al., 1995)
Cicer arietinum	garbanzo (chick pea)	(Larrain S., 1996)
Medicago saliva	alfalfa (alfalfa)	(Hichins O. & Rabinovich, 1974; Angulo & Weigert, 1975; Cortes, 1976; Hichins O. & Mendoza M., 1976; Porter, 1980; Castillo & Angulo, 1991; Arce de Hamity & Neder de Roman, 1992; 1993, Rojas et al., 1993; Apablaza & Stevenson, 1995; Larrain S., 1996)
Pisum spp.	arverjas, chicaro (peas)	(Rojas et al., 1993; Lamborot et al., 1995)
Trifolium pratense	trébol (clover)	(Castillo & Angulo, 1991)
Iridaceae		
Gladiolus spp.	galdiolo (gladiolus)	(Riley, 1998)

(*Continued on next page*)

Table 2. (*Continued*)

Family/scientific name	Spanish (English) common name	Reference(s)
Lamiaceae		
Lolium multiflorium	Ballica (Ryegrass)	(Angulo & Weigert, 1975; Castillo & Angulo, 1991)
Rosmarinus officinalis	Romerito (Rosemary)	(Rojas et al., 1993)
Liliaceae		
Allium cepa	Cebolla (Onion)	(Quiroz, E., 1977; Castillo & Angulo, 1991; Lamborot, et al., 1995; Larrain, S., 1996; Lopez-Avila, 1996b; Castrejon, G. et al., 1998)
Allium sativum	Ajo (Garlic)	(Larrain, S., 1996; Lopez-Avila, 1996b)
Asparagus officinalis	Espárragos (Asparagus)	(Castillo & Angulo, 1991; Larrain, S., 1996)
Linum usitatissimum	Lino (Flax)	(Wille, T., 1943; Angulo & Weigert, 1975; Castillo & Angulo, 1991)
Poaceae		
Triticum aestivum	Trigo (Wheat)	(Larrain S., 1996)
Zea mays	Maíz (Corn or Maize)	(Castillo & Angulo, 1991; Olivares & Angulo, 1995; Larrain, S., 1996)
Polygonaceae		
Polygonum segetum	Malezas (Field Smartweed)	(Zenner de Polenia, 1990; Castillo & Angulo, 1991)
Rosaceae		
Fragaria chiloensis	Frutilla (Strawberry)	(Castillo & Angulo, 1991; Larrain, S., 1996)
Malus sp.	Manzana (Apple)	(Larrain S., 1996)
Rubus idaeus	Frambuesa (Raspberry)	(Castillo & Angulo, 1991; Larrain, S., 1996)
Solanaceae		
Capsicum sp.	Pimiento Verde (Bell Pepper)	(Riley, 1998)
Lycopersicon esculentum	Tomate (Tomato)	(Lamborot, et al., 1995; Larrain, S., 1996)
Nicotiana tabacum	Tobacco (Tobacco)	(Angulo & Weigert, 1975; Castillo & Angulo, 1991; Larrain S., 1996)
Physalis pubescens	Tomatillo (Husk Tomato)	(Riley, 1998)
Solanum melongena	Berenjena (Eggplant)	(Lamborot, et al., 1995)
Solanum tuberosum	Papa (Potato)	(Munro, 1968; Angulo & Weigert, 1975; Arestegui P., 1976; Loo P. & Aguilera P., 1983; Sanchez V. & Maita-Franco, 1987; Zenner de Polenia, 1990; Castillo & Angulo, 1991; Arce de Hamity & Neder de Roman, 1992; Leyva O. & Sanchez V., 1993; Rojas et al., 1993; Olivares & Angulo, 1995; Larrain, S., 1996; Lopez-Avila, 1996a)
Vitaceae		
Vitis spp., *Vitis vinifera*	uva, vid (Grape)	(Castillo & Angulo, 1991; Larrain, S., 1996)

Materials and methods

Pathways of introduction

The Port Information Network database, maintained by USDA, APHIS, Plant Protection and Quarantine (PPQ) was queried for interceptions of all *Copitarsia* spp. between January 1985 and April 2000. Four taxa were identified: *Copitarsia* sp., *C. consueta, C. incommoda*, and *C. turbata*. The port of entry, interception date, reported host, method of conveyance (i.e., mail, cargo, etc.), and country of origin were noted from each interception record. Information for the four taxa was combined for analysis. Since interception reports are not based on random sampling nor are sampling procedures identical from port to port, traditional parametric statistics (e.g., *t*-tests and ANOVA) are not appropriate. Therefore, data were not analyzed statistically.

Risk assessment

The pest risk assessment for *Copitarsia* spp. followed the general framework developed by Orr et al. (1993), which has been further discussed and analyzed by Mack et al. (2002). Standard, operational guidelines developed by APHIS for commodity risk assessments

Table 3. The top 90% of "host" plants reported for interceptions of *Copitarsia* spp. at the border by USDA, APHIS

Host	Common name	Number intercepted
Limonium sp.	Sea Lavender	1998
Alstroemeria sp.	Lily of the Incas	1822
Brassica sp.	Cole crops	638
Dianthus sp.	Pinks	432
Coriandrum sp.	Coriander/cilantro	332
Chrysanthemum sp.	Chrysanthemum	223
Pisum sp.	Pea	171
Asparagus sp.	Asparagus	166
Gladiolus sp.	Gladiola	143
Chenopodium sp.	Quinoa	136
Gypsophila sp.	Baby's breath	117
Aster sp.	Aster	113
Lactuca sp.	Lettuce	92
Unidentified plant		80
Physalis sp.	Husk tomato	78
Rosa sp.	Rose	57
Rosmarinus sp.	Rosemary	47
Capsicum sp.	Pepper	46
Rubus sp.	Blackberry	40
Helianthus sp.	Sunflower	39

(USDA, 1997, 2000) were used to produce a qualitative assessment of pest risk. Although USDA continues to refine these guidelines, at the moment, they remain a standard approach to evaluate pest risk. The current paper is not meant to reinvent the process but simply to use the current guidelines and introduce the concepts of uncertainty and variability. The guidelines address the consequences and likelihood of pest introduction (i.e., successful invasion). Five risk elements (i.e., climate/host interaction, host range, dispersal potential, economic damage, and environmental damage) address the consequences of pest establishment. Six risk elements (i.e., quantity of potential hosts imported annually, likelihood of surviving post-harvest treatment, likelihood of surviving shipment to US, likelihood of not being detected at port of entry, likelihood of arriving in a suitable habitat, and likelihood of finding a host) address the probability of successful pest invasion. Each risk element is given a ranking of high (3 points), medium (2 points) or low (1 point) based upon established criteria (USDA, 2000). The sum of all risk ratings characterizes the overall degree of risk.

In preparation for the assessment, we assembled an extensive bibliography on the bionomic characteristics of *Copitarsia* spp. Information sources included published literature, web pages, Internet databases, APHIS databases, CD-ROM databases, internal APHIS reports, and APHIS port manuals. Information in Spanish was translated to English by translation software (SYSTRAN Professional, SYSTRAN Software, Inc., La Jolla, CA) and manually checked for accuracy.

In an attempt to predict the potential distribution of *Coptarsia* spp. in the US, we used a geographic information system (ArcView 3.2, ESRI, Redlands, California, USA) to determine which biomes (i.e., habitat types) may support populations of the genus in its native range. We presumed those biomes would provide climatically suitable habitat for *Copitarsia* if they occurred in the US. We first generated a map of the known worldwide geographic distribution of the genus (based on reports from the literature; Figure 1). This map was then placed over a map of the worldwide distribution of biomes, as defined by the World Wildlife Fund (Olson et al., 2001). A list was made of the biomes that occurred within each respective country or municipality where *Copitarsia* spp. were reported.

We recognized that *Copitarsia* spp. may not exist in all biomes within a country. In most cases, distribution records provided little guidance (i.e., the presence of *Copitarsia* was simply reported for an entire country or state). Using all biomes within a country as a basis for prediction is likely to overestimate the potential distribution of the genus. As a result, we attempted to select the minimum number of biomes that could account for the global distribution of *Copitarsia*. If only one biome were reported for a state (for example) from which *Copitarsia* was also reported, this biome must be suitable for members of the genus. All countries or municipalities that contained *Copitarsia* and just one biome were identified, and a list of these biomes was prepared (i.e., the "short list"). We then cross-referenced the short list with biomes reported in each remaining country/municipality (i.e., locations with multiple biomes). Countries/municipalities with at least one biome on the short list were assumed to be accounted for and no additional biomes were selected from these areas. We then examined those locations with biomes which did not appear on the short list. From these locations only, we added the biome to the short list that occurred in the greatest number of countries/municipalities. In the event that two or more biomes occurred with equal frequency, the biome that was reported most frequently from the entire geographic distribution of *Copitarsia* was added to the short list. The process of adding additional biomes to the short list continued until at least one biome was noted from each location with *Copitarsia*. The short list of biomes was evaluated for their occurrence in the US.

A document that summarized results from the analysis of *Copitarsia* interceptions, the climate matching exercise, and queries of information sources was distributed to an expert panel of 15 scientists for review. This document constitutes the first 47 pages of the report by Gould et al. (2000). Panel members were chosen for their expertise in Lepidoptera biology or pest risk assessment. Five panel members were employed by academic institutions and ten members were employed by regulatory agencies. After reviewing copies of the document, each panelist was mailed a survey for his or her evaluation of the eleven elements that contribute to pest risk. Risk ratings were based on the information provided and the assessor's previous experience. Because the risk assessment is based on the genus as a whole, we asked reviewers to assume that if one species of *Copitarsia* satisfied the criterion, the entire genus satisfied the criterion. All panelists responded to our request but did not necessarily answer all questions.

In addition, for each element, we asked for an indication of the level of confidence in the assessment, again high, medium, or low. Confidence levels were assigned based upon the following criteria: high, data were adequate AND analyses were appropriate to draw a conclusion; medium, data were available, but insufficient OR analyses were questionable; or low, no data were available OR analyses were incorrect. Assigning a high risk rating with a low degree of confidence, for example, was acceptable as was a low risk rating with a high degree of confidence.

Results and discussion

Pathways of introduction

From 1985 to April 2000, $n = 7434$ interceptions of *Copitarsia* spp. were reported from 38 ports of entry into the US. Only three records were found where specimens were identified to the species level. Interceptions were most commonly reported from Miami (Table 4). Reports from Miami, Florida, were seven times greater than the second most commonly reporting port, Laredo, Texas. Interceptions of *Copitarsia* from ports along the US/Mexico border were greatest from Laredo and Hidalgo, Texas. Notably, Nogales, Arizona and San Diego, California, which receive a significant volume of agricultural commodities from Mexico, reported few interceptions of *Copitarsia* (Table 4). Among all interception records, *Copitarsia* were most commonly reported from permit cargo (92.8%), baggage (3.2%), general cargo (2.7 %), and ship stores (1.1%). Mail, ship quarters, ship holds, and miscellaneous pathways collectively accounted for less than 1% of all interceptions.

Copitarsia-infested goods/commodities were reported from 23 countries (Table 1). Nearly twice as many reports were based on commodities from Colombia as compared to Mexico. Colombia, Mexico, Ecuador, Guatemala, Chile, and Costa Rica accounted for more than 95% of all interception records (Table 1). Reported interceptions of *Copitarsia* spp. from the Netherlands and Japan may not reflect the true origin(s) of these commodities. The proportion of insects arriving from each country remained relatively constant throughout the year (data not shown). Approximately 150 genera of plants were indicated in reports of *Copitarsia* interceptions. Genera accounting for the top 90% of interceptions are reported in Table 2. The majority (∼60%) of reported interceptions were from ornamentals and cut flowers.

Risk assessment

Element #1 – climate/host

This risk element attempts to describe the geographic area that might be impacted by a pest. For this element, a non-indigenous organism in a new habitat is expected to behave as it would in its native range if acceptable host plants are available and climate is conducive to survival and reproduction (USDA, 1997, 2000). APHIS guidelines assign risk ratings based on the number of US plant hardiness zones (Cathey, 1990) that a species is expected to occupy. A high rating is assigned if the pest has the potential to become established in four or more hardiness zones; medium, if the pest is expected to establish in two or three plant hardiness zones; or low, if the pest is expected to establish in a single plant hardiness zone. One hardiness zone is $<19\%$ of the area of the contiguous US; 2–3 zones represent 19–39% of the area of the contiguous US, and four or more zones are $>39\%$ of the area of the contiguous US (R. Venette, unpublished data).

A simple climate matching exercise suggests that *Copitarsia* spp. may survive in biomes characterized as montane grasslands; temperate coniferous forests;

Table 4. Interceptions of *Copitarsia* spp. reported from US ports of entry by USDA, APHIS and percentage of interceptions at each port associated with different pathways

Port	*Copitarsia* interceptions	% Observed in Baggage	General cargo	Permit cargo	Misc.	Stores	Quarters
Miami Florida	4,617	2.0	1.9	95.4	0.1	–	0.2
Laredo Texas	656	18.4	2.0	79.5	–	–	–
Hidalgo Texas	589	4.6	1.7	93.1	0.6	–	–
San Juan Puerto Rico	252	5.4	0.6	93.4	–	0.6	–
Dallas Texas	247	9.0	–	90.3	–	0.7	–
Chile 2J	191	1.5	–	98.5	–	–	–
Brownsville Texas	172	16.9	9.4	78.7	1.1	–	–
Houston Texas	171	9.2	5.9	71.1	–	13.8	–
JFK Airport New York	118	–	56.0	44.0	–	–	–
Des Plaines Illinois	62	10.5	89.5	–	–	–	–
Los Angeles California	46	11.1	6.7	82.2	–	–	–
Fort Lauderdale Florida	45	–	2.9	91.2	–	5.9	–
New Orleans Louisiana	43	–	–	26.2	–	73.8	–
Chicago Illinois	38	15.2	–	81.8	–	–	3.0
El Paso Texas	34	44.8	–	55.2	–	–	–
San Antonio Texas	34	3.2	3.2	90.3	–	3.2	–
Atlanta Georgia	19	16.7	22.2	61.1	–	–	–
Tampa Florida	18	–	–	92.3	–	7.7	–
Roma Texas	14	10.0	–	90.0	–	–	–
Elizabeth New Jersey	13	30.8	15.4	53.8	–	–	–
Pharr Texas	9	–	–	100.0	–	–	–
Jacksonville Forida	8	–	–	–	–	87.5	12.5
Port Arthur Texas	8	–	–	–	14.3	85.7	–
Progreso Texas	5	20.0	–	80.0	–	–	–
Nogales Arizona	4	25.0	–	50.0	25.0	–	–
Savannah Georgia	4	–	–	25.0	–	75.0	–
Others (12 ports)	17	11.8	11.8	52.9	–	23.5	–
Total	7,434	5.8	5.0	85.2	0.2	2.1	0.1

temperate grasslands, savannas, and shrub lands; desert and xeric shrub lands; tropical and subtropical dry broadleaf forests; and tropical and subtropical moist broadleaf forests. Montane grasslands and tropical and subtropical dry broadleaf forests do not occur in the US. Because of its broad host range, the potential distribution of *Copitarsia* is unlikely to be constrained by host availability. As a result, *Copitarsia* spp. may have the potential to become established in 70% of the contiguous US (Figure 2).

The majority of survey respondents felt it was likely for this genus to survive in four or more plant hardiness zones and rated the element high; however, there was no consensus among panel members (Figure 3A). The majority of respondents also felt that data were insufficient or analyses were questionable and, as a result, only had a moderate degree of confidence in their assessment of this element. Again, no consensus was apparent (Figure 3B). We believe that further research is necessary on the response of *Copitarsia* populations to temperature and soil moisture to better predict the range of *Copitarsia* spp. in the United States. Such biological data would increase confidence in the ranking for this element. Two of three previous commodity risk

Figure 2. Possible distribution (*gray*) of *Copitarsia* spp. in the US based on simple climate matching.

assessments that addressed *Copitarsia consueta* also gave this element a high rating (Table 5).

Element #2 – host range

This risk element accounts for the diversity of domestic plants that could be affected by a pest. The element is rated high if a pest attacks multiple plant species within multiple plant families; medium, if it attacks multiple species within a singe plant family; and low, if it attacks a single species or multiple species within a single genus. In addition to the 39 species of host plants reported in the literature, *Copitarsia* spp. have been intercepted on more than 100 other plant genera arriving in the US. Reports do not indicate whether *Copitarsia* spp. were actively feeding on these additional genera or were simply hitchhiking. Nevertheless, most of the crops reported as hosts of *Copitarsia* are grown in the US (Texas Agricultural Statistics Service, 1999).

All respondents felt that *Copitarsia* spp. could attack multiple species within multiple plant families and assigned a high risk rating in this category (Figure 3A), which is consistent with previous risk assessments (Table 5). The majority of respondents also felt that adequate data were available and analyses were appropriate to draw a conclusion (Figure 3B). Respondents generally had high confidence in their assessment of this element.

Element #3 – dispersal potential

This risk element pertains to the rate at which a new pest will achieve its maximum range in the US. Assessors consider pest movement and reproductive potential when evaluating this element. A high rating is assigned if a pest has the potential to move >10 km/year and reproduce rapidly (e.g., many generations per year, many offspring per generation, or a high innate capacity for population increase). A medium rating is assigned, if a pest has only one of these characteristics. A low rating is assigned if none of these attributes applies.

Several *Copitarsia* species are highly fecund. *Copitarsia consueta* and *C. turbata* produce approximately 1500 eggs per female (Arce de Hamity & Neder de Roman, 1992; Larrain, 1996; Rojas & Cibrian-Tovar, 1994; Velasquez, 1988). These two species also have three to four generations per year (Arce de Hamity & Neder de Roman, 1992; Artigas & Angulo, 1973; Liberman Cruz, 1986). No information has been published about the dispersal characteristics of *Copitarsia* spp. However, other noctuid species

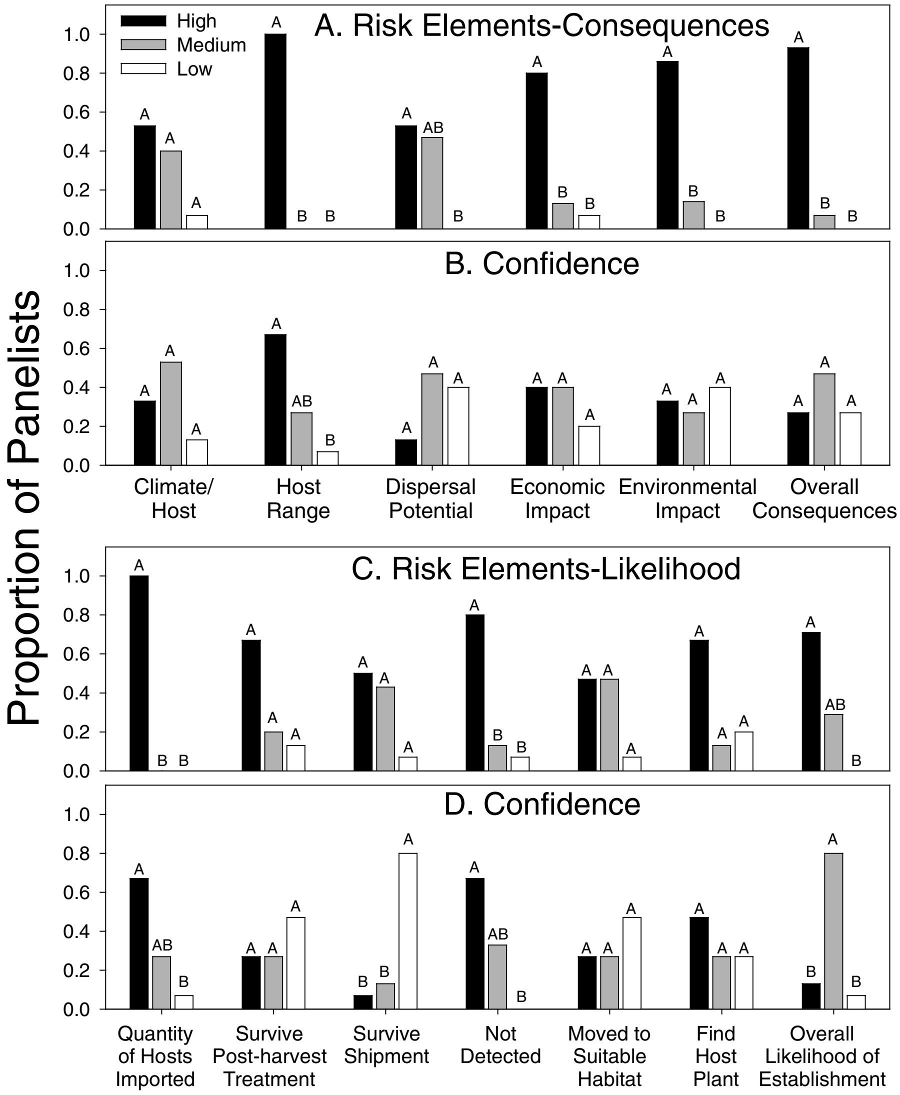

Figure 3. Proportion of an expert panel ($n = 15$) assigning a high, medium, or low rating to characterize: (A) risk elements describing the consequences of *Copitarsia* establishment; (B) the panel's level of confidence in those ratings; (C) risk elements describing the likelihood of *Copitarsia* establishment; and (D) the panel's level of confidence in those ratings. For each cluster of three bars, bars with the same letter are not significantly different ($P > 0.05$) as determined by overlap of 95% confidence intervals.

disperse as adults over immense distances (Hendricks et al., 1973; Rose et al., 1985; Showers et al., 1989; Westbrook et al., 1995).

The majority of respondents gave this risk element a medium/high rating (Figure 3A), but there was little agreement about the sufficiency of data to reach a conclusion (Figure 3B). Additional research on the dispersal potential of members of the genus would refine evaluation of this element. Two of three previous risk assessments also classified this risk element as high (Table 5).

Element #4 – economic impact

Assessors consider three types of economic impacts when evaluating this risk element. Economic impacts can occur if a pest lowers yield of the host, lowers value of the host, or causes the loss of markets (USDA, 1997, 2000). A high rating is given to this risk element if a pest could cause all three impacts; medium, if two impacts could occur; and low, if only one impact could occur.

In its native range, *Copitarsia* spp. have lowered yields, lowered the value of the commodity,

Table 5. Previous qualitative assessments of the likelihood and consequences of *Copitarsia* establishment in the US based on 11 risk elements

Element	*Brassica* from Mexico[a]	*Brassica* from Central America[b]	*Pisum* from Mexico[c]
Climate/host	High	High	Medium
Host range	High	High	High
Dispersal potential	High	High	Medium
Economic impact	High	High	Medium
Environmental impact	Medium	Medium	High
Overall consequences of establishment	*High*	*High*	*High*
Quantity imported annually	Medium	Medium	Low
Likelihood survive post-harvest treatment	High	High	Medium
Likelihood survive shipment	High	High	High
Likelihood not detected	High	Medium	Low
Likelihood moved to suitable habitat	High	High	Medium
Likelihood find suitable host	High	High	Medium
Overall likelihood of establishment	*High*	*High*	*Medium*
Overall degree of risk via this pathway	High	High	Medium

Note: Additional details about each risk element and associated criteria for high, medium, or low ratings are provided in the text.
[a](Cave & Redmond, 1997b).
[b](Cave & Redmond, 1997a).
[c](USDA APHIS, 1997).

and affected export markets (see 'Bionomics' section above). For many of the commodities attacked, *Copitarsia* directly damages the part of the plant that is harvested and consumed. Hunter and Elliott (1995) consider the potential economic impact of *Copitarsia* spp. to be significant in Texas. In addition, the US exports at least seven crops (asparagus, berries, broccoli, cabbage, cauliflower, and lettuce), valued at US$ 457 million in 1999 (USDA Economic Research Service, 1999), that could harbor *Copitarsia* eggs or larvae. The presence of *Copitarsia* spp. could affect access to local markets through domestic quarantine; *Copitarsia* spp. are not noted as quarantine pests by plant protection organizations outside the US (EPPO, 2000).

The majority of respondents felt that all three impacts were likely in the US (Figure 3A), as did two of three previous risk assessments (Table 5). The overall confidence in this assessment was considered medium/high, but again no consensus was apparent (Figure 3B).

Element #5 – environmental impact

APHIS lists five potential impacts for consideration: direct environmental impacts, direct impacts on endangered or threatened species, indirect impacts on endangered or threatened species, initiation of disruptive control programs (pesticides), and release of non-indigenous biological control agents (USDA, 1997, 2000). A high rating is warranted if two or more of the criteria apply; medium, if one criterion applies; or low, if none of the criteria apply.

If established in the US, *Copitarsia* spp. would have the potential to damage the environment directly, through feeding on native plants, or indirectly by stimulating pest control. Nearly 700 plants native to the US belong to genera known to be attacked by *Copitarsia* larvae (USDA NRCS, 1999). The U.S. Fish and Wildlife Service lists seven of these native species as threatened or endangered (USDA NRCS, 1999). Munz's onion (*Allium munzii*), showy Indian clover (*Trifolium amoenum*), and Monterey clover (*T. trichocalyx*) are endangered and occur in California. Running buffalo clover (*T. stoloniferum*) is also endangered and occurs in Arkansas, Illinois, Indiana, Kansas, Kentucky, Missouri, Ohio, and West Virginia. Eggert's sunflower (*Helianthus eggertii*) and the Pecos sunflower (*H. paradoxus*) are threatened. Eggerts sunflower occurs in Alabama, Kentucky and Tennessee, whereas the Pecos sunflower occurs in New Mexico and Texas. Unfortunately, reports of *Copitarsia* spp. feeding on non-crop plants generally list the host as a "weed", except for field smartweed (*Polygonum segetum*), without providing taxonomic identification (Castillo & Angulo, 1991; Zenner de Polenia, 1990).

Indirect environmental damage could be caused if pesticides applied to control *Copitarsia* leave the treated field, either as drift or in contaminated water, and affect other species in the ecosystem. APHIS also considers the potential release of natural enemies through a biological control program to constitute a risk to native organisms (USDA, 1997, 2000). Many natural enemies have been reported attacking *Copitarsia* in its native range and would be potential agents for a biological control program. These natural enemies include: pathogens, predators and parasitoids (see 'Bionomics' above). Any pest with the potential to reduce yields or reduce the marketability of a crop is likely to stimulate biological or chemical control efforts.

In contrast to two of three previous risk assessments (Table 5), the majority of respondents assigned a high rating to this element (Figure 3A). However, the panel was equally divided in their level of confidence in this assessment (Figure 3B). Evaluation of this element was complicated by the fact that the need for chemical/biological control depends on the value and use of a commodity. Furthermore, many crops in the US are already subject to intense pest control regimens. These control programs may effectively lower numbers of *Copitarsia* spp. below economic thresholds. As a result, *Copitarsia* spp. may not stimulate new pest control activities, but the effects of current pest management programs on this genus are not known.

Element # 6a – quantity of commodity imported
The likelihood of introducing a foreign pest generally increases as the quantity of imported host plants increases. APHIS estimates the volume of imported commodities in terms of the number standard shipping containers (12.2 m × 2.59 m × 2.44 m), a unit of measure readily understood by importers/exporters, that are expected to arrive in the US annually (USDA, 1997, 2000). If >100 shipping containers are imported each year, the element is assessed as high; 10–100 containers, medium; <10 containers, low. APHIS guidelines about the quantity of a commodity imported refer to one specific commodity from one country imported into the entire US. Our pest based risk assessment concerns a genus that is found on many commodities from many countries of origin, and we included all possible shipments for assessing the risk element.

A query of the APHIS Plant Quarantine database (PQ-280) indicated that from October 1993 to December 1999, six billion metric tons of fruits, vegetables, herbs, ornamentals, and cut flowers potentially harboring *Copitarsia* were imported in 814,278 shipments into the US from Western Hemisphere countries. All respondents felt that a high rating for this element was justified given the total volume of all the commodities on which *Copitarsia* could enter (Figure 3C). A high rating would be appropriate even for certain, individual commodities from specific countries entering a single port (data not shown). The majority of respondents were highly/moderately confident in the assessment (Figure 3D). Certain commodities from specific countries may not meet the standard for a high rating, which would explain why previous APHIS risk assessments assigned ratings of low or medium to this risk element (Table 5).

Pest opportunity

Collectively, the remaining five elements describe the likelihood of a pest remaining associated with a commodity, arriving as a viable individual in a suitable environment, and locating a suitable host plant. For each element, a rating of high is given if the probability of the event is >10%; medium, 0.1–10%, and low, <0.1% (USDA, 2000). Each risk element is evaluated independently of the preceding elements in this section.

Element #6b – likelihood of surviving post-harvest treatment
For this element, post-harvest treatment refers to any manipulation, handling or treatment of the commodity including culling, washing, fumigation with pesticides, and cold storage. If no post-harvest treatment occurs, APHIS recommends assigning this element a high rating (USDA, 1997, 2000). We did not find any indication that commodities were treated prior to export specifically to reduce the number of *Copitarsia*. As part of the processing of certain commodities, obviously-damaged plants are removed prior to shipment. However, the commodity receives no additional treatment to destroy any pests that may have been missed. Because no data were available, the panel was divided in their ranking of this element (Figure 3C) and in their level of confidence in this assessment (Figure 3D). Two of three previous risk assessments ranked this element as high (Table 5).

Risk Element #6c – likelihood of surviving shipment
This element estimates the probability that pests will survive the conditions experienced under standard shipping conditions, or under conditions specifically designed to provide phytosanitary control (e.g., cold treatment in refrigerated containers). We know that *Copitarsia* larvae survive shipment because only live larvae are reported in the APHIS PIN database. Between January 1985 and April 2000, 7434 interceptions of commodities containing live *Copitarsia* were reported. Over 90% of these interceptions were in cargo, with the remainder of the interceptions from baggage, mail, stores, quarters, and holds. We do not know the percentage of all *Copitarsia* larvae that survive shipment or whether intercepted larvae were healthy. The majority of the panel ranked this element as medium/high, but no obvious consensus was achieved (Figure 3C). The panel expressed a strong lack of confidence in their assessments (Figure 3D). To adequately assess this element, we would need to know the

number of larvae associated with a commodity at the time a shipment was ready to leave its country of origin. A detailed study of shipping conditions and their effects on the viability of *Copitarsia* larvae is an important area for future study.

Risk element #6d – likelihood of avoiding detection

All plant and animal products imported into the US are subject to physical inspection by APHIS PPQ officers at ports of entry. The likelihood of detecting a pest when it is present in a shipment is a function of how noticeable a pest is (which is related to pest size, color, and behavior), the size of the shipment, the degree of infestation, and the amount of sampling effort. When assessors evaluate this risk element, typical sampling procedures are assumed to apply. PPQ officers use one of two sampling strategies before releasing cargo. The first strategy is recommended under agricultural quarantine inspection monitoring (AQIM), often called hypergeometric sampling. The term "hypergeometric" refers to a special statistical distribution that describes the probability of detecting 1, 2, or more pests (considered successes) after inspecting a certain number of units (boxes, trays, etc.), when the total number of pests in the shipment is known (or is assumed) and the total shipment size is relatively small. The sampling strategy recommended under AQIM is designed to detect pests (assuming a 10% infestation level) with 95% confidence (USDA, 1998). Less than 1% of all shipments entering the U.S. are currently inspected following AQIM guidelines. Typically, cargo is inspected following a 2% guideline (i.e., 2% of the shipment is inspected for the presence of pests). Ideally, the 2% sample should be drawn at random from a shipment, but tailgate inspections (i.e., inspection of units in a shipment that are easily accessible) remain common.

We conducted an analysis to determine the probability of releasing cargo for entry into the U.S. when AQIM guidelines or the 2% rule were followed (Venette et al., 2002). We assumed that all shipments were 10% infested. Because the number of samples collected (N) under the 2% rule is small relative to the shipment size, we applied binomial statistics. From binomial statistics, it can be shown that the probability of observing 1 or more pests, $P[X > 0]$, is $P[X > 0] = 1-(1-p)^N$. In this analysis, $p = 0.10$. We conducted a further analysis to look at the infestation rate needed to detect >1 pest with 95% confidence. If the probability of detection is set at 95% (0.95) and the number of samples is known (e.g. 2% of the shipment), we can rearrange the equation to solve for p. In this case, p is the level of infestation that would be necessary in order to detect the pest with 95% confidence when 2% of the shipment is sampled.

Samples collected following AQIM guidelines maintain a 95% probability of detecting pests at an infestation level of 10%, regardless of the size of the shipment (USDA, 1998; Venette et al., 2002). When a constant 2% of the shipment is sampled, pests in small shipments are not likely to be detected. For example, in shipments with 300 potential sampling units (e.g., boxes of produces), the probability of finding at least one pest is 0.469. The goal of detecting pests with 95% confidence is only achieved when the shipment size is large (i.e. $>\approx$1,500 boxes) and $\geq$30 boxes are inspected (Venette et al., 2002). As the shipment size (and the number of boxes inspected) declines, the level of infestation must be high to be 95% certain that pests will be detected (Figure 4). As the infestation level declines, the chances of selecting an infested box also decline (Venette et al., 2002). When the 2% rule is followed in shipments smaller than 500 boxes, PPQ officers are not likely to detect *Copitarsia* with 95% confidence unless $>$25% of the commodity is infested (Figure 4).

Because most sampling conducted by APHIS-PPQ follows the 2% rule, the majority of respondents felt that the probability of *Copitarsia* spp. not being detected when it was present in commodity shipments was high (Figure 3C). The majority of respondents also felt that adequate data were available and appropriately analyzed to reach a conclusion (Figure 3D). Previous risk assessments were divided on this issue with rankings for this element ranging from low to high (Table 5).

Element #6e – likelihood of arriving in a suitable climate

APHIS recognizes that not all final destinations will have a climate suitable for pest survival. This risk element considers the geographic locations of likely markets and the proportion of a commodity that is likely to move to locations that are suitable for pest survival. Without any additional information, we assume that *Copitarsia*-infested products are distributed into different biomes in the US in direct proportion to the number of people who live in those areas and would presumably purchase produce for consumption. In risk element #1, we identified temperate coniferous forests; temperate grasslands, savannas, and shrub lands; desert and xeric shrub lands; and tropical and subtropical moist broadleaf forests as biomes that occur in the US and could be suitable for *Copitarsia* establishment.

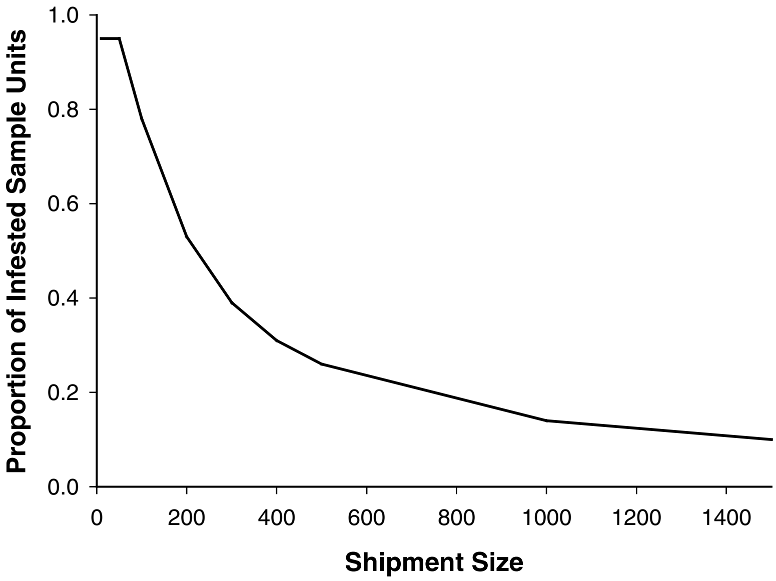

Figure 4. Proportion of sample units that must be infested to have 95% confidence of finding at least one pest when sampling 2% of a shipment.

Approximately, 39.2% of the US population lives in these zones (R. Venette, unpublished data). *Copitarsia* also must survive domestic shipment.

Respondents were divided in their assessment of the fraction of viable larvae that would be transported to a climatically suitable habitat (Figure 3C). Correspondingly, respondents were divided in their level of confidence in these decisions (Figure 3D). No research has been conducted to formally define the probability of pests surviving the environmental conditions encountered during shipment or the final processing of the commodity.

Element #6f – likelihood of finding suitable host

This element considers whether suitable host plants would be available to support pest populations and whether a pest has the potential to detect and move to those hosts. *Copitarsia* spp. can feed on >39 crops. An additional ≈700 native plant species in the United States belong in genera fed upon by *Copitarsia*. Potential host plants can be found in almost every county in the United States (Texas Agricultural Statistics Service, 1999). The likelihood of finding a suitable host is also related to the dispersal capability of an individual. The dispersal potential for larvae or adults is not known. As a result, the panel did not agree on the likelihood of *Copitarsia* spp. finding a suitable host nor did they concur about their level of confidence in the assessment (Figure 3C,D).

Additional research is needed on the ability of C*opitarsia* spp. to survive during the transport process from harvest to market. Moreover, it may be useful to consider the ultimate fate of an imported commodity, whether it is consumed (e.g., fresh fruits and vegetables) or not (e.g., cut flowers and ornamentals). In this assessment, we did not ask panelists to distinguish the relative risks associated with each commodity or pathway. Yet, if we had, the fate of the commodity would only affect responses to Element #6f. As a result, we conducted a sensitivity analysis on this risk element by setting the response of each panelist to low (i.e., host material and associated insects most likely to be consumed), then to high (i.e., host material put into the environment), and examined changes in the likelihood of establishment and the overall degree of risk.

Overall assessment of risk

Despite some variation in responses to individual risk elements, the panel agreed, though not unanimously, that *Copitarsia* spp. posed an overall high degree of risk. Summary assessments of risk were determined based on the sum of original scores provided by each respondent and criteria developed by USDA (USDA, 2000). Likewise summary assessments of confidence were evaluated by summing individual confidence scores; this analysis of confidence is not part of USDA guidelines (USDA, 2000). In total, the panel felt that the consequences of *Copitarsia* establishment would be high (Figure 3A), but there was no consensus in the confidence of this conclusion (Figure 3B). Three previous risk assessments also concluded that the consequences of *Copitarsia* establishment would be high (Table 5). The panel also felt that the likelihood of establishment was high to moderate (Figure 3C), but confidence in this conclusion was only moderate (Figure 3D). Previous risk assessments found that the likelihood of establishment was high to moderate (Table 5).

Overall 85% of the panel judged the joint consequences and likelihood of *Copitarsia* establishment to be high; 15% judged the risk to be medium; 20% of the panel was highly confident with the data and analysis, 60% was moderately confident, and 20% had low confidence. For individual risk elements, our panel of experts rarely concurred about their level of confidence in their assessments. This lack of confidence reflects a general lack of information about the genus; however, we note that far more is known about this genus than many other exotic pests. Two of three previous risk assessments also concluded that *Copitarsia* posed high risk (Table 5).

Our sensitivity analysis showed that the overall degree of risk when all responses to risk element #6f were set to low did not differ significantly from the outcome when all responses for this element were set to high. In the former case, the modified scores of 77% of respondents indicated high risk and 23% indicated medium risk. In the latter case, the modified scores of 85% of respondents indicated high risk and 15% showed moderate risk. As would be expected, the estimated overall degree of risk was less sensitive than the estimated likelihood of establishment to changes in scores assigned to element #6f. When this element was set to low, the sum of modified scores of 57% of respondents indicated a high likelihood of establishment, 36% indicated medium likelihood, and 7% indicated low likelihood. When the score was raised to high, 86% indicated a high likelihood of establishment and 14% indicated a medium likelihood. These changes were not statistically significant ($P > 0.05$), but the lack of significance is not surprising given the small size of the panel. Nevertheless, this analysis suggests that the fate of the commodity does not dictate the degree of risk posed by a pest, at least as measured using a standard protocol (USDA, 2000; Mack et al., 2002).

A recent review of the APHIS PPQ safeguarding system reports that "...a major obstacle to the evolution of the APHIS pest risk analysis process has been, and remains, the lack of reliable data. In the absence of robust data, APHIS relies on a process that analyzes potential pest introductions based largely on highly subjective and uncharacterized expert judgment in the assessment of risk values" (National Plant Board, 1999, p. 9). There will always be gaps in the data available about potentially invasive organisms, and risk assessments will need to be based on incomplete data. We agree with Gray et al. (1998) that the risk assessment process must include measures of variability and uncertainty and clearly document information sources. We have attempted to follow these golden rules. In developing a risk assessment for the genus *Copitarsia*, we chose to formally describe the variability and uncertainty in risk ratings by quantifying the ratings of a group of experts. We have also provided statistical and phenomenological models to help inform the risk rating process. As a result, this assessment moves beyond a strictly qualitative approach to a hybrid of qualitative and quantitative methods to evaluate risks associated with non-indigenous species.

If *Copitarsia* spp. are high-risk pests and members of the genus are frequently intercepted at U.S. ports of entry, suggesting potentially high levels of infestation given typical sampling protocols, why has not the genus already established in the United States? We consider four responses to this question. First, because this evaluation focuses on an entire genus, it may overestimate the risk associated with an individual species. For example, if species *X* were oligotrophic within one plant family (warranting a medium risk rating for risk element #2) and species *Y* were oligotrophic within a separate family, the genus would receive a high risk rating for this element. Thus, it is conceivable that individual species of *Copitarsia* may pose less risk than we and other risk assessments have described. Addressing the biological and pathway-related research questions outlined above, and improving taxonomy and systematics within the genus, would allow us to more accurately characterize risks associated with a particular species. Second, the framework that we used (USDA, 2000) incompletely addresses the invasion process. Specifically, the framework does not address the fate of a pest population after viable individuals find a host plant in an area climatically suitable for survival. Allee effects, resident antagonists, and a potential absence of mutualists further lower the probability of invasion and are exceptionally difficult to characterize *a priori* (Crawley, 1989). Third, the scores for risk elements are additive rather than multiplicative, which tends to overestimate the likelihood of pest invasion (Mack et al., 2002). If four of the five elements describing invasion potential were high, but one element was incredibly unlikely, the overall probability that the pest would establish would be low, but this probability would be characterized as high using this ranking system. In a qualitative pest risk assessment framework for aquatic species, Orr (2003) suggests that the lowest rating assigned in the assessment of the likelihood of pest establishment be used to characterize the overall likelihood of establishment. Finally, we cannot exclude the possibility that *Copitarsia* has in fact successfully established in the United States. Currently, there are no pheromone lures to aid in detection programs, nor are there routine, systematic surveys for this pest. Further, the difficulty of distinguishing *Copitarsia* in the field increases the possibility of confusing this potential new insect with other endemic/naturalized noctuid pests.

This risk assessment provides a blueprint for future research that should be used to validate/refute elements of the assessment. Risk assessment should be a dynamic process with the risk assessment identifying needed research, and the research results contributing to a re-evaluation of risk. In fact, the authors are currently pursuing research to validate this risk assessment for *Copitarsia* spp.

Acknowledgments

We would like to thank L. Thompson, R. Simmons, F. Muñoz-Quesada for technical assistance. We appreciate the constructive comments of D. Andow and S. Naranjo on earlier versions of this manuscript.

References

Alcala, C.P., 1978. Tachinidos parasitos de *Copitarsia turbata* en el Valle del Mantaro. Rev Peru Entomol 21: 126.

Angulo, A.O. & G.T. Weigert, 1975. Mimetismo y homocromismo larval en noctuidos Chilenos (Lepidoptera: Noctuidae). Bol Soc Biol Concep 49.

Apablaza, J.U. & T.R. Stevenson, 1995. Fluctuaciones poblacionales de áfidos y de otros artropódos en el follaje de alfalfa cultivada en la Region Metropolitana. Cienciabe Investigacion (Chile) 22: 115–121.

Arce de Hamity, M.G. & L.E. Neder de Roman, 1992. Aspectos bioecologicos de *Copitarsia turbata* (Herrich-Schaffer) (Leipdoptera: Noctuidae) importantes en la determinacion del dano economico en cultivos de *Lactuca sativa* L. de la Quebrada de Humahuaca, Jujuy, Argentina. Rev Soc Entomol Arg 50: 73–87.

Arce de Hamity, M.G. & L.E. Neder de Roman, 1993. Morfologia de los estados inmaduros y aspectos etologicos de *Copitarsia turbata* (Herrich-Schaffer) (Lepidoptera: Noctuidae). Neotrop 39: 29–33.

Arestegui, P.A., 1976. Plagas de la papa en Andahuaylas, Apurimac. Rev Peru Entomol 19: 97–98.

Artigas, J.N. & A.O. Angulo, 1973. *Copitarsia consueta* (Walker), biologia e importancia economica en el cultivo de raps (Lepidoptera, Noctuidae). Bol Soc Biol Concep 46: 199–216.

Aruta, M.C., R. Carillo, L. & S.M. Gonzalez, 1974. Determinacion para Chile de hongos entomopatogenos del genero *Entomophthora*. Agro Sur 2: 62–70.

Carrillo, S.J.L., 1971. Pruebas de thuricide (*Bacillus thuringiensis*) para combatir gusanos de la Colen Chapingo. Mex Agric Tecnic Mex 3: 58–60.

Castillo, E.E. & A.O. Angulo, 1991. Contribution to the knowledge of the genus *Copitarsia* Hampson 1906 (Lepidoptera, Glossata, Cucullinae). Guy Zool 55: 227–246.

Castrejon, G.J.R., T.L. Cibrian, J. Valdes & M.L. Camino, 1998. Morfologia, distribucion y cuantificacion de los sensulos antenales en adultes de *Copitarsia consueta*. Fol Entomol Mex 103: 63–73.

Cathey, H.M., 1990. USDA plant hardiness zone map, Miscellaneous Publication No. 1475. U.S. National Arboretum, Agricultural Research Service, U.S. Department of Agriculture, Washington, DC. http://www.usna.usda.gov/Hardzone/ushzmap.html.

Cave, G.L. & L. Redmond, 1997a. Importation of *Brassica* spp. from Costa Rica, El Salvador, Honduras, and Nicaragua into the United States. US Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine. http://www.aphis.usda.gov/ppq/pra/.

Cave, G.L. & L. Redmond, 1997b. Importation of Chinese cabbage (*Brassica pekinensis*), kohlrabi (*B. oleracea* var *gongylodes*) and pak-choi (*B. chinensis*) from Mexico into the United States. US Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine. http://www.aphis.usda.gov/ppq/pra/.

Cortes, R.P., A.P. Aguilera, C.H. Vargas, Q.N. Hichins, L.E. Campos & W.J. Pacheco, 1972. Las "cuncunillas" (Noctuidae) de la alfalfa en Lluta y Camarones, Arica-Chile.- un problema bio-ecologico de control. Rev Peru Entomol 15: 253–266.

Cortes, R., 1976. Multi-control of cutworms and armyworms (Noctuidae) in alfalfa in the desert valleys of Lluta and Camarones, Arica., Proc. Tall Timbers Conf. Ecological Animal Control by Habitat Management. pp. 79–85. Tallahassee, Tall Timbers Research Station.

Crawley, M.J., 1989. Chance and timing in biological invasions. In: J.A. Drake, H.A. Mooney, F. di Castri, R.H. Groves, F.J. Kruger, M. Rejmánek & M. Williamson (Eds.), Biological Invasions: A Global Perspective, pp. 407–423. John Wiley and Sons, New York.

FAO, 2002. Glossary of phytosanitary terms. Food and Agriculture Organization of the United Nations. http://193.43.36.94/servlet/CDSServlet?status=Mj1vcmcuZm FvLndhaWNlbnQu Y2RzLm9mLk1haW5QYWdlJjQ9MTMzOTkmNz1lbiY2MT0q JjY1PWtvcw==.

Gomez, J.T., 1972. Moscas minadoras en el cultivo de la haba (*Vicia faba* L.) en la Sierra Central del Peru. Congr Lati Am Entomol 15: 239–243.

Gould, J., R. Venette, J. Davidson & P. Kingsley, 2000. A pest risk assessment for *Copitarsia* species: A case study in support of a risk-based resource allocation model. US Department of Agriculture, Animal and Plant Health Inspection Service, Phoenix.

Gray, G.M., J.C. Allen, D.E. Burmaster, S.H. Gage, J.K. Hammitt, S. Kaplan, R.L. Keeney, J.G. Morse, D.W. North, J.P. Nyrop, A.

Stahevitch & R. Williams, 1998. Principles for conduct of pest risk analyses: Report of an expert workshop. Risk Anal 18: 773–780.

Grez, A.A., 1992. Requeza de especies de insectos herbivoros y tamano de parche de vegetacion huesped: Una contrastacion experimental. Rev Chile Hist Nat 65: 115–120.

Hampson, G.F., 1906. Noctuidae. Catalogue of the Lepidoptera Phalaenae in the British Museum. Trustees of the British Museum, London.

Hendricks, D.E., H.M. Graham & J.R. Raulston, 1973. Dispersal of sterile tobacco budworms from release points in northeastern Mexico and southern Texas. Environ Entomol 2: 1085–1088.

Hichins, N.O. & M.R. Mendoza, 1976. Algunas observaciones sobre habitos y costumbres de estadios larvarios de noctudios asociados a la alfalfa en Lluta y Camarones (Lepidoptera: Noctuidae). Idesia 4: 163–169.

Hichins, N.O. & J.E. Rabinovich, 1974. Fluctuaciones de la poblacion de larvas de cinco especies de Noctuidos de importancia economica asociadas a la alfalfa en el Valle de Lluta. Idesia 3: 35–79.

Hunter, L.A. & R.P. Elliott, 1995. An evaluation of frequently intercepted pests at Dallas with regards to economic impact and potential pathway surveys. Texas Agricultural Extension Service, Texas A&M University System, College Station.

Hunter, L.A. & G.D. Simmons, 1995. A summary of frequently intercepted pests at Texas ports of entry. Texas Agricultural Extension Service, Texas A&M University System, College Station.

Kiritani, K., 1999. Formation of exotic insect fauna in Japan. In: E. Yano, K. Matsuo, M. Shiyomi & D.A. Andow (Eds.), Biological invasion of ecosystem by pests and beneficial organisms, pp. 49–65. National Institute of Agro-Environmental Sciences, Tsukuba, Japan.

Köhler, P., 1959. Noctuidarum miscellanea I. (Lep. Het.). Rev Soc Entomol Arg 20: 9–15.

Lamborot, L., P. Arretz, M.A. Guerrero & J.E. Araya, 1995. Parasitismo de huevos y larvas de *Copitarsia turbata* (Herrich y Schaffer) (Lepidoptera: Noctuidae) en cultivos horticolas en la Region Metropolitana. Acta Entomol Chile 19: 129–133.

Lamborot, L., M.A. Guerrero & J.E. Araya, 1999. Lepidopteros asociados al cultivo de la quinoa (*Chenopodium quinoa* Willdenow) en la zona central de Chile. Bol San Veg Plagas 25: 203–207.

Larrain, P.S., 1984. Plagas de la alcachofa. Invest Prog Agropec La Platina 25: 19–22.

Larrain, P.S., 1996. Biologia de *Copitarsia turbata* (Lep. Noctuidae) bajo ambiente controlado. Agric Tecnic 56: 220–223.

Larrain, P.S. & C.J.E. Araya, 1994. Prospeccion y control quimico de plagas de la alcachofa en la region Metropolitana. Invest Agric (Chile) 14: 35–41.

Leyva, C.O. & V.G. Sanchez, 1993. Ocurrencia estacional de las principales plagas del cultivo de papa en Cajamarca. In: F. Quevedo I. & R. Arroyo V. (Eds.), Resumen de investigaciones apoyadas por FUNDEAGRO (Fundacion para el Desarrollo del Agro) 1988–1992., pp. 91–92. Proyecto Transformacion de la Tecnologia Agropecuaria, Lima, Peru. Fondo para el Aumento de Oportunidades de Investigacion, Fundacion para el Desarrollo del Agro, Lima.

Liberman Cruz, M., 1986. Impacto ambiental del uso actual de la tierra en el Altipiano sur de Bolivia: Con enfasis en el cultivo de *Chenopodium quinoa* Willd. Riv Agric Subtrop Trop 80: 509–538.

Loo, E.P. & P.A. Aguilera, 1983. Multiplicacion experimental de *Trichogramma brasiliensis* (Ashm.) (Hymenoptera: Trichogrammatidae) en la IV Region de Chile. Idesia 7: 45–52.

Lopez-Avila, A., 1996a. Insectos plagas del cultivo de la papa en Colombia y su manejo. In: Anon. (Ed.), Papas Colombianas con el mejor entorno ambiental, pp. 146–148,150–154. Comunicaciones y Asociados Ltda, Santafe de Bogota, Colombia.

Lopez-Avila, A., 1996b. Plagas del ajo y las cebollas. In: Anon. (Ed.), El cultivo del ajo y las cebollas en Colombia, pp. 61–71. Corporacion Colombiana de Investigacion Agropecuaria, Instituto Colombiano Agropecuario, Santafe de Bogota, Colombia.

Machuca, J.R., P. Arretz & J. Araya, 1989. A new Ichneumonid wasp for Chile. Acta Entomol Chile 15: 269–270.

Machuca, J.L., C.J.E. Araya, V.P. Arretz & S.P. Larrain, 1990. Evaluation of chemical and cultural control for noctuid larvae in Chilean artichokes produced for foreign markets. Crop Protec 9: 115–118.

Machuca, L.J.R., V.P. Arretz & C.J.E. Araya, 1988. Parasitismo de noctuidos en cultivos de alcachofas en la Region Metropolitana: Identificacion y observaciones preliminares de los parasitos. Rev Chile Entomol 16: 83–87.

Mack, R.N., S.C.H. Barrett, P.L. deFur, W.L. MacDonald, L.V. Madden, D.S. Marshall, D.G. McCullough, P.B. McEvoy, J.P. Nyrop, S.E.H. Reichard, K.J. Rice & S.A. Tolin, 2002. Predicting invasions of nonidigenous plants and plant pests. National Academy of Sciences, Washington, DC.

Mack, R.N., D. Simberloff, W.M. Lonsdale, H. Evans, M. Clout & F.A. Bazzaz, 2000. Biotic invasions: Causes, epidemiology, global consequences, and control. Ecol Appl 10: 689–710.

Monge, V.L.A., G.J. Vera, G.S. Infante & S.J.L. Carrillo, 1984. Efecto de las practicas cultureales sobre las poblaciones de insectos y dano causado al cultivo del repollo (*Brassica oleraceae* var. *capitata*). Centro de Entomologia y Acarologia 57: 109–126.

Munro, J.A., 1968. Insects affecting potatoes in Bolivia. J Econ Entomol 61: 882.

National Plant Board, 1999. Safeguarding American plant resources: A stakeholder review of the APHIS-PPQ safeguarding system. US Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine, Riverdale, MD.

Neder de Roman, L.E. & M.G. Arce de Hamity, 1991. *Meteorus chilensis* Porter (Hymenoptera: Braconidae) enemigo natural de *Copitarsia turbata* (Herrich-Schaffer) (Lepidoptera: Noctuidae) en zonas de la Quebrada de Humahuaca, Jujuy. Neotrop 37: 137–144.

Olivares, T.S. & A.O. Angulo, 1995. El organo timpanico en la clasificacion de Lepidoptera: Noctuidae. Bol Entomol Venez 11: 155–183.

Olson, D.M., E. Dinerstein, E.D. Wikramanayakw, N.D. Burgess, G.V.N. Powell, E.C. Underwood, J.A. D'Amico, I. Itoua, H.E. Strand, J.C. Morrison, C.J. Loucks, T.F. Allnutt, T.H. Ricketts, Y. Kura, J.F. Lamoreux, W.W. Wettengel, P. Hedao & K.R. Kassem, 2001. Terrestrial ecoregions of the world: a new map of life on Earth. BioScience 51: 933–938.

Orr, R., 2003. Generic nonindigenous aquatic organisms risk analysis review process. In: G.M. Ruiz & J.M. Carlton (Eds.), Invasive species: vectors and management strategies, pp. 415–438. Island Press, London.

Orr, R.L., S.D. Cohen & R.L. Griffin, 1993. Generic nonindigenous pest risk assessment process (for estimating pest risk associated with the introduction of nonindigenous organisms). U.S. Department of Agriculture, Animal and Plant Health Inspection Service (Internal report), Riverdale, MD.

OTA, 1993. Harmful non-indigenous species in the United States. U.S. Government Printing Office, Washington, DC.

Pimentel, D., L. Lach, R. Zuniga & D. Morrison, 2000. Environmental and economic costs of nonindigenous species in the United States. BioScience 50: 53–65.

Poole, R.W., 1989. Lepidopterum Catalogus, fascilce 118: Noctuidae, part 1. E. J. Brill, Leiden.

Porter, C.C., 1980. Joppini (Hymenoptera: Ichneumonidae) of Tarapaca. Flor Entomol 63: 226–243.

Quiroga, P., V.P. Arretz & C.J. Araya, 1989. Chewing insects on jojoba, *Simmondsia chinensis* (Link) Schneider, in the north-central and central regions of Chile, and characterization of damage. FAO Plant Prot Bull 37: 121–125.

Quiroz, E.C., 1977. Plagas de la cebolla. Investig Prog Agric 9: 43–46.

Reitz, S.R. & J.R. Trumble, 2002. Competitive displacement among insects and arachnids. Ann Rev Entomol 47: 435–465.

Riley, D.R., 1998. Identification key for *Copitarsia*, *Spodoptera exigua*, and *Peridorma saucia*. US Department of Agriculture, Animal and Plant Health Inspection Service (Internal report), Pharr, TX.

Rojas, J.C. & J. Cibrian-Tovar, 1994. Reproductive behavior of *Copitarsia consueta* (Walker) (Lepidoptera: Noctuidae): Mating frequency, effect of age of mating, and influence of delayed mating on fecundity and egg fertility. Pan-Pacific Entomol 70: 276–283.

Rojas, J.C., J. Cibrian-Tovar, J. Valdez-Carrazco & R. Nieto-Hernandez, 1993. Analisis de la conducta de cortejo de *Copitarsia consueta* y aislamiento de la feromona. Agrocienc Prot Veget 4: 23–39.

Rose, D.J.W., W.W. Page, C.F. Dewhurst, J.R. Riley, D.R. Reynolds, D.E. Pedgley & M.R. Tucker, 1985. Downwind migration of the African armyworm moth, *Spodoptera exempta*, sutdies by mark-and-capture and by radar. Ecol Entomol 10: 299–313.

Sanchez, V.G.A. & M.R. Aldana, 1985. Algunas plagas de la papa en el Valle Mantaro, durante 1982–1983. Rev Peru Entomol 28: 49–52.

Sanchez, V.G.A. & F. Maita-Franco, 1987. *Copitarsia turbata* (Lep.: Noctuidae) en papa del Valle Mantaro durante 1983–1984. Rev Peru Entomol 30: 111–112.

Showers, W.B., R.B. Smelser, A.J. Keaster, F. Whitford, J.F. Robinson, J.D. Lopez & S.E. Taylor, 1989. Recapture of marked black cutworm (Lepidoptera: Noctuidae) males after long-range transport. Environ Entomol 18: 447–458.

Simmons, R.B. & M.G. Pogue, 2004. Redescription of two, often confused Noctuid pests, *Copitarsia decolora* and *C. incommoda* (Lepidoptera: Noctuidae: Cucullinae). Ann Entomol Soc Am 97: 1159–1164.

Texas Agricultural Statistics Service, 1999. County estimates. Texas Agricultural Statistics Service.

USDA, 1997. Guidelines for plant pest risk analysis of imported commodities, ver 4.0. US Department of Agriculture, Animal and Plant Health Inspection Service, Riverdale, MD.

USDA, 1998. Agriculture quarantine inspection monitoring (AQIM) handbook. US Department of Agriculture, Animal and Plant Health Inspection Service, Washington, D.C.

USDA, 2000. Guidelines for pathway-initiated pest risk assessments. US Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine. http://www.aphis.usda.gov/ppq/pra/.

USDA APHIS, 1997. Importation of leaves and stems of peas, *Pisum sativum* from Mexico into the United States. US Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine. http://www.aphis.usda.gov/ppq/pra/.

USDA APHIS, 1999. Plant import: Nonpropagative manuals. US Department of Agriculture, Animal and Plant Health Inspection Service, Riverdale, MD.

USDA Economic Research Service, 1999. Foreign agricultural trade of the United States: United States agricultural imports. US Department of Agriculture. http://www.ers.usda.gov/db/FATUS.

USDA NRCS, 1999. The PLANTS database. National Plant Data Center, Baton Rouge, LA. http://plants.usda.gov.

Velasquez, Z.L.D., 1988. Ciclo biologico de *Copitarsia turbata* (Lep.: Noctuidae) sobre cebolla, en Arequipa. Rev Peru Entomol 30: 108–110.

Venette, R.C., R.D. Moon & W.D. Hutchison, 2002. Strategies and statistics of sampling for rare individuals. Ann Rev Entomol 47: 143–174. 0

Vimos, N.C., C.C. Nieto & M.M. Rivera, 1998. El Melloco: Caracteristicas, tecnicas de cultivo y potencial en Ecuador. http://www.idrc.ca/library/document/096951/index_s.html.

Westbrook, J.K., J.R. Raulston, W.W. Wolf, S.D. Pair, R.S. Eyster & P.D. Lingren, 1995. Field observations and simulations of atmospheric transport of noctuids from northeastern Mexico and the south-central U.S. Southwest Entomol 18 (Suppl.): 25–44.

Wille, T.J.E., 1943. Entomolgia agricola del Peru. In: Anon. (Ed.), Manual para entomologos, ingenieros agronomos, agricultures y estudiantes de agricultura., pp. 334–348. Editado por la Estacion Experimental Agricola de La Molina, Lima.

Zenner de Polenia, I., 1990. Research and management strategies for potato insect pests in Colombia. In: S.K. Hahn & F.E. Caveness (Eds.), Proc. Integrated pest management for tropical root and tuber crops; workshop on the global status of and prospects for integrated pest management of root and tuper crops in the tropics. pp. 139–148. International Institute of Tropical Agriculture. Ibadan, Nigeria.