

INTRODUCTION TO
THE BEHAVIORAL ECOLOGY OF THE PROTECTION OF
NATIVE FLORAS AND FAUNAS

COMMERCIAL IMPORTATION INTO FLORIDA OF
INVERTEBRATE ANIMALS AS BIOLOGICAL
CONTROL AGENTS

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ABSTRACT

A survey of commercial producers and sellers of biological control agents revealed 49 species of invertebrate animals imported into Florida. Of these, 48 were imported for augmentative biological control of pests, and one for educational purposes. There were 3 species of nematodes, 1 mollusc, 8 mites, and 37 insects. More than half (25) of them were not known to occur in Florida at the time of importation, and some of them might be capable of establishing populations in Florida and might serve as classical biological control agents. Targets were mainly pest insects in the orders Homoptera (41%), Diptera (19%), Lepidoptera (15%) and Thysanoptera (11%). The targets were on or in perennial plants, annual plants, greenhouses, pasture- and turfgrasses, stored products, and feces of domesticated vertebrates. Some targets of commercially-imported biological control agents had been targets of classical biological control research. Some agents ("common") were imported frequently and by several producers, but others ("uncommon") were imported perhaps only once or twice. More targets previously recorded as targets of classical biological control agents were associated with "uncommon" commercially-imported agents than with "common" ones; more of the "common" agents than the "uncommon" ones were released into multiple habitats.

Key Words: Florida, biological control, commercial producers, introduced species, integrated pest management.

RESUMEN

Una encuesta a productores y vendedores comerciales de agentes de control biológico reveló 49 especies de animales invertebrados importadas a Florida. De estas, 48 fueron importadas para control aumentativo biológico de plagas, una con fines educativos. Hubieron 3 especies de nemátodos, 1 molusco, 8 ácaros y 37 insectos. Antes de su importación no se conocía de la existencia en Florida de más de la mitad (25) de ellos, y algunas podrían ser capaces de establecer poblaciones en Florida y servir como agentes de control biológico clásico. Los objetos de control fueron principalmente insectos de los órdenes Homoptera (41%), Diptera (19%), Lepidoptera (15%) y Thysanoptera (11%). Estos objetos de control fueron localizados sobre o dentro de plantas perennes, plantas anuales, en invernaderos, pastos ornamentales y potreros, en productos almacenados y excrementos de animales vertebrados domésticos. Algunos insectos sujetos a control por agentes importados comercialmente, habían sido objetos de investigación de control biológico clásico. Algunos agentes ("comunes") eran importados frecuentemente por varios productores, mientras que otros ("no comunes") se importaban quizás solo una o

dos veces. De los insectos previamente registrados como objetos de agentes de control biológico clásico, estuvieron más asociados a agentes importados comercialmente "no comunes" que a agentes "comunes"; de los agentes en habitats multiples, más fueron del tipo "comunes" que de los "no comunes."

The theme of our symposium is behavioral ecology of the protection of native floras and faunas. This encompasses the behavioral response of native organisms to all sorts of human encroachments, as well as use of behavior of these organisms to protect them. We could have included the behavioral response of native organisms to the use of chemical pesticides, but we did not. At the opposite extreme, we have included the study of how knowledge of behavior of butterflies may be used to protect them. We discuss the subject area further toward the end of this paper.

This introduction continues a theme of the behavioral ecology of biological control, a subject that we began to explore two years ago. In that paper (Frank & McCoy 1992), we asked what are the immigrant insects whose existence has been documented in Florida within the last 20 years, how they arrived in Florida, and what are their likely effects. A year ago (Frank & McCoy 1993), we documented what insects have been introduced to Florida, and discovered that almost all the introduced species were brought to Florida as classical biological control agents of pest insects, most of which, in turn, were of exotic origin. With this paper, we document the invertebrate animals that have been imported into Florida and released for commercial purposes, as augmentative or inundative biological control agents [this is a topic that we excluded from the discussion last year (Frank & McCoy 1993)]. We continue to use our definition (Frank & McCoy 1990) of the word **introduced**. In our view, organisms that arrived by their own volition by flying, walking, swimming, or hitchhiking (stowaways) in cargoes, are **immigrants**. Only those brought here deliberately by humans are introduced. Taken together, these immigrant and introduced organisms are adventive.

METHODS AND MATERIALS

A newsletter called **The IPM Practitioner** publishes periodically a list of names and addresses of companies that sell biological control agents. We devised a questionnaire to mail to all listed companies that we thought might sell insect biological control agents to buyers in Florida. We asked these companies what insect biological control agents they had sold to purchasers in Florida, what were the target pests, and how many individual insects of each species were sold annually within the last 5 years to purchasers in Florida.

Thirty nine companies (see ACKNOWLEDGMENTS) replied, but some did not. Some did not do so because they had gone out of business, others did not do so because they had moved without forwarding addresses, and some presumably did not choose to do so. Therefore, we asked the Division of Plant Industry (DPI) of the Florida Department of Agriculture and Consumer Services, for a list of permits issued to such companies for the importation into Florida of insect biological control agents. This not only gave us information on introduced organisms, but gave us names of additional companies. Florida law in Florida Statutes (1991), applied in Florida Administrative Code (1993), now requires that anyone shipping biological control agents into Florida obtain a permit to do so. Companies whose names appeared on the list of permits issued were contacted by mail if we had not already received information from them.

RESULTS

Targets

Table 1 contains 31 reported targets (27 insects) of imported biological control agents. Many (13) of these targets were listed previously as targets of introduced biological control agents (Frank & McCoy 1993). Well-represented insect orders are Homoptera (41%), Diptera (19%), Lepidoptera (15%), and Thysanoptera (11%). Diptera are better

TABLE 1. REPORTED TARGETS OF THE IMPORTED BIOLOGICAL CONTROL AGENTS, IN FLORIDA OR ELSEWHERE. THOSE NOT KNOWN TO OCCUR IN FLORIDA ARE ANNOTATED. ALMOST ALL THE SPECIES THAT DO OCCUR IN FLORIDA ARE IMMIGRANTS. THIS LIST IS TO SOME EXTENT AN EXPANSION OF INCOMPLETE INFORMATION.

<i>Acarus siro</i> L. (Acarina: Acaridae) - flour mite.
<i>Amyelois transitella</i> (Walker) (Lepidoptera: Pyralidae) - navel orangeworm.
<i>Aonidiella aurantii</i> (Maskell) (Homoptera: Diaspididae) - California red scale.
<i>Aphis gossypii</i> Glover (Homoptera: Aphididae) - cotton aphid.
<i>Aspidiotus nerii</i> Bouche (Homoptera: Diaspididae) - oleander scale.
<i>Bemisia tabaci</i> Gennadius (Hemiptera: Aleyrodidae) - sweetpotato whitefly.
<i>Blissus</i> spp. (Heteroptera: Lygaeidae) - chinch bugs.
<i>Bradysia</i> spp. (Diptera: Sciaridae) - fungus gnats.
<i>Coccus hesperidum</i> L. (Homoptera: Coccidae) - brown soft scale.
<i>Carpocapsa pomonella</i> (L.) (Lepidoptera: Olethreutidae) - codling moth.
<i>Diaprepes abbreviatus</i> (L.) (Coleoptera: Curculionidae) - the "common" names are West Indian sugarcane rootstock weevil, citrus root weevil, Apopka weevil, and Apopka bug.
<i>Epilachna varivestis</i> Mulsant (Coleoptera: Coccinellidae) - Mexican bean beetle.
<i>Frankliniella occidentalis</i> (Pergande) (Thysanoptera: Thripidae) - western flower thrips.
<i>Haematobia irritans</i> (L.) (Diptera: Muscidae) - horn fly.
<i>Heliothrips haemorrhoidalis</i> (Bouché) (Thysanoptera: Thripidae) - greenhouse thrips.
<i>Helix aspersa</i> Müller (Pulmonata: Helicidae) - brown garden snail, native to Europe, immigrant into California and other parts of the USA, twice eradicated from Florida (Dekle 1969); not known at present to occur in Florida (L. A. Stange pers. comm.).
<i>Liriomyza</i> spp. (Diptera: Agromyzidae) - <i>Liriomyza</i> leafminers.
<i>Musca domestica</i> L. (Diptera: Muscidae) - house fly.
<i>Myzus persicae</i> (Sulzer) (Homoptera: Aphididae) - green peach aphid.
<i>Planococcus citri</i> (Risso) (Homoptera: Pseudococcidae) - citrus mealybug.
<i>Plutella xylostella</i> (L.) (Lepidoptera: Yponomeutidae) - diamondback moth.
<i>Pseudococcus longispinus</i> (Targioni-Tozzetti) (Homoptera: Pseudococcidae) - long-tailed mealybug.
<i>Saissetia neglecta</i> DeLotto (Homoptera: Coccidae) - Caribbean black scale.
<i>Saissetia oleae</i> (Bernard) (Homoptera: Coccidae) - black scale.
<i>Scapteriscus</i> spp. (Orthoptera: Gryllotalpidae) - <i>Scapteriscus</i> mole crickets.
<i>Sitotroga cerealella</i> (Olivier) (Lepidoptera: Gelechiidae) - Angoumois grain moth.
<i>Stomoxys calcitrans</i> (L.) (Diptera: Muscidae) - stable fly.
<i>Tetranychus cinnabarinus</i> Boisduval (Acarina: Tetranychidae) - no generally-accepted common name.
<i>Tetranychus urticae</i> Koch (Acarina: Tetranychidae) - two-spotted mite.
<i>Thrips tabaci</i> Lindeman (Thysanoptera: Thripidae) - onion thrips.
<i>Trialeurodes vaporariorum</i> (Westwood) (Homoptera: Aleyrodidae) - greenhouse whitefly.

represented as targets of commercially-imported biological control agents than as targets of classical biological control agents.

Even though our questionnaire asked only for information on insect biological control agents, some companies chose to send us information on nematodes, mites, and molluscs. Because so few species of insects were listed, we decided to include this additional information when it was provided, even though it may be incomplete. At the same time, our list of target organisms was expanded because of this additional range of organisms. To avoid repetition in later text, we listed target organisms and their classification and common names in Table 1.

Arthropod targets of imported biological control agents include tetranychid mites (especially *Tetranychus urticae*), thrips (especially *Frankliniella occidentalis*), whiteflies (*Bemisia tabaci* and *Trialeurodes vaporariorum*), aphids (especially *Myzus persicae*), mealybugs (*Planococcus citri* and *Pseudococcus longispinus*), soft scale insects (*Coccus hesperidum*), armored scale insects (*Aspidiotus nerii*), diamondback moth (*Plutella xylostella*), *Liriomyza* leafminers (*Liriomyza* spp.), fungus gnats (*Bradysia* spp.), and muscoid flies (*Musca domestica*, *Stomoxys calcitrans* and *Haematobia irritans*).

Biological Control Agents

Table 2 contains the information we sought about biological control agents sold in Florida. For each species listed we give a brief account of origin, distribution, and host/prey relations from the literature. For each, after the words IMPORTED VS, we give the intended target as it appeared on forms returned by suppliers and in the DPI records. We have arranged this information in order of precise (specific identification of target), through more general (family or superfamily of target), to very imprecise

TABLE 2. INVERTEBRATE BIOLOGICAL CONTROL AGENTS IMPORTED INTO FLORIDA SINCE 1982 BY COMMERCIAL ORGANIZATIONS.

RHABDITIDA: STEINERNEMATIDAE

Steinernema feltiae (Filipjev): this entomopathogenic nematode is believed to be native to Europe, but occurs also in Australia and New Zealand (Poinar 1990); IMPORTED VS *Scapteriscus* spp.

Steinernema carpocapsae (Weiser): this entomopathogenic nematode is widely distributed in Europe, North America, Australia and New Zealand, its origin obscure (Poinar 1990); IMPORTED VS *Diaprepes abbreviatus*.

Steinernema scapterisci Nguyen & Smart: this entomopathogenic nematode is native to South America and was released in Florida as a classical biological control agent (Parkman et al. 1993) after laboratory screening showed a high level of host-specificity to *Scapteriscus* mole crickets (Nguyen & Smart 1991); IMPORTED VS *Scapteriscus* spp.

PULMONATA: SUBULINIDAE

Rumina decollata (L.): native to the Mediterranean region of Europe and northern Africa, this species was introduced into California for biological control of *Helix aspersa*, which it achieved with some success as a non-specialist predator, though it proved to be a minor plant pest (Auffenberg & Stange 1986); IMPORTED VS *Helix aspersa*.

ACARINA: LAELAPIDAE

Hypoaspis miles (Berlese): this species was described from Europe; we have not discovered published evidence of its feeding habits or that it might be a useful biological control agent; IMPORTED VS *Bradysia* spp.

Hypoaspis sp.: we have not discovered published evidence of feeding habits of "*Hypoaspis* sp." or that it might be a useful biological control agent; however, an undescribed species, mentioned as *Geolaelaps* [nr. *aculeifer* (Canestrini)] was found in potting soil in British Columbia (Canada) and was there shown experimentally using inoculative introductions in a greenhouse to be able as a predator to suppress populations of *Bradysia* sp. and of *Frankliniella occidentalis* (Gillespie & Quiring 1990); these are pests in Florida greenhouses, too; *Geolaelaps* sp. (with no documentation that it is the same as was investigated in British Columbia) was IMPORTED VS "insects"; *Hypoaspis* sp. was IMPORTED VS "invertebrates."

ACARINA: PHYTOSEIIDAE

Galendromus occidentalis (Nesbitt): native to Canada and the northern USA (Moraes et al. 1986), this predacious mite has been used successfully to control *Tetranychus urticae* by inoculative introductions into apple orchards in the northwestern USA (Croft & Mcrae 1992); IMPORTED VS *Tetranychus urticae*, or not given.

Mesoseiulus longipes (Evans): native to Africa (Moraes et al. 1986); IMPORTED VS *Tetranychus urticae*, *Trialetrodes vaporariorum*, or not given.

Neoseiulus barkeri Hughes: perhaps native to Europe (Moraes et al. 1986); is a predator of thrips and has controlled *Thrips tabaci* when released inoculatively, several times per season, into Danish greenhouses (Hansen 1988); IMPORTED VS *Frankliniella occidentalis*, *Thrips tabaci*, *Acarus siro*, "broadmites," and "thrips."

Neoseiulus californicus (McGregor): native to California (Moraes et al. 1986); IMPORTED VS *Tetranychus urticae*, or not given.

Neoseiulus cucumeris (Oudemans): native to Europe (Moraes et al. 1986); is a predator of thrips and has controlled *Thrips tabaci* and *Frankliniella occidentalis* when released inoculatively into Canadian greenhouses (Gillespie 1989); IMPORTED VS *Acarus siro* L. (flour mite), *Tetranychus urticae*, *Frankliniella occidentalis*, "mites," "thrips," and "biocontrol in greenhouses."

Phytoseiulus persimilis Athias-Henriot: native to Africa, and introduced into California (Moraes et al. 1986); IMPORTED VS *Tetranychus cinnabarinus*, *T. urticae*, "phytophagous mites," "spider mites," "spider mites in greenhouse," "vegetable pests," or not given.

COLEOPTERA: COCCINELLIDAE

Cryptolaemus montrouzieri Mulsant: native to Australia, introduced into California in 1891, and is a predator of Coccidae and Pseudococcidae; introduced into Florida from California in 1930 against *Planococcus citri*, and established in the center and south (Gordon 1985, Frank & McCoy 1993); IMPORTED VS *Planococcus* sp., "mealybug on cucumber" and "mealybug."

Delphastus pusillus (LeConte): native to the southern USA and widely distributed in the center and north of Florida; is a predator of Aleyrodidae and to some extent of Coccidae (Gordon 1985); IMPORTED VS *Bemisia tabaci*, and "insects."

Hippodamia convergens Guérin-Méneville: native to the USA and occurring throughout Florida, this species is a predator of Aphididae (Gordon 1985); IMPORTED VS "aphids" or "various," or not given.

Rhyzobius lophanthae (Blaisdell): native to Australia, introduced into California in 1892, and now widely distributed in the southern tier of states across the USA including Florida, this species is a predator of Coccidae, Pseudococcidae, and Diaspididae (Gordon 1985); IMPORTED VS *Aspidiotus nerii*, and "scale insects."

COLEOPTERA: HISTERIDAE

Carcinops sp.: there are at least 16 species in America north of Mexico, and 4 of them occur in Florida, including *C. pumilio* (Erichson) and *C. troglodytes* (Paykull) (M. C. Thomas pers. comm.); adults and larvae of *Carcinops* are predacious, especially on muscid fly larvae in dung and carrion, with interspecific variation in habitat preferences; only *C. pumilio* (which occurs in temperate climates) and *C. troglodytes* (which occurs in tropical climates) include poultry manure in their habitat range (Geden 1990); *C. pumilio* shows potential as a biological control

TABLE 2. (Continued)

agent of muscid fly larvae in poultry houses under certain circumstances (Geden 1990); the effect of *C. troglodytes* on the muscid fauna of poultry dung has not been studied, but it may be better adapted for existence in Florida, or at least southern Florida; IMPORTED VS "insects and mites in greenhouses."

DIPTERA: CECIDOMYIIDAE

Aphidoletes aphidimyza (Rondani): Holarctic, its origin obscure, but at least for many decades has inhabited North America, including Florida, though it is not abundant in the southeastern USA (R. Gagné, pers. comm.); it "has been used as a predator with good results for the control of aphids in many northern climates [but] success obtained with it in Florida has been limited to the cooler months of the year" (Osborne & Oetting 1990); IMPORTED VS *Myzus persicae*, *Aphis gossypii*, "aphids," "biocontrol in greenhouses," "plant pests," and "insects."

HEMIPTERA: ANTHOCORIDAE

Orius insidiosus (Say): native to North America, including Florida, and is known to prey on thrips and mites (Clausen 1940; Herring 1966); IMPORTED VS "vegetable pests," and as "general predator."

Orius tristicolor (White): native to the western parts of North America, excluding Florida (Herring 1966); thrips are preferred prey items, but it will feed on plant materials to maintain itself when prey is scarce (Salas-Aguilar & Ehler 1977); IMPORTED VS "insects," "vegetable pests," "plant pests," "biocontrol in greenhouses," or not given.

HEMIPTERA: PENTATOMIDAE

Podisus maculiventris Say: native to North America, including Florida, and is a predator of larvae of Lepidoptera and of Chrysomelidae (Clausen 1940; Richman & Mead 1980); IMPORTED VS *Epilachna varivestis*.

HYMENOPTERA: APHELINIDAE

Aphytis melinus DeBach: native to India and Pakistan, introduced into California in 1956-1957 as a parasitoid of *Aonidiella aurantii* and became established (Laing & Hamai 1976); there seem to be no records of existence of *A. melinus* in Florida, nor of attempts to introduce it as a classical biological control agent, nor is this surprising, because its host (*A. aurantii*) is not at all common (H. W. Browning, pers. comm.); IMPORTED VS "scale," and "pest management in groves."

Encarsia formosa Gahan: cosmopolitan, its origin obscure, but at least for many decades has inhabited North America including Florida; it is best-known as a parasitoid of *Trialeurodes vaporariorum*, but it also attacks *Bemisia tabaci* (Gordh 1979; Osborne & Oetting 1990; Frank & McCoy 1993); release of this species in greenhouses has achieved effective control of *T. vaporariorum* in several countries, though the methods used are critical to success (Hussey & Scopes 1985; Osborne & Oetting 1990); IMPORTED VS *Trialeurodes vaporariorum*, *Tetranychus urticae*, "vegetable pests," "whiteflies," and "insects."

Eretmocerus mundus Mercet: native to the Mediterranean region of southern Europe, northern Africa, and western Asia (it has also been reported from Illinois), it is a parasitoid of *Bemisia tabaci*, though it has been reported from a few other whitefly species (Lopez-Avila 1986); was imported from Israel and Sudan to Florida in 1990-1991 for classical biological control purposes (Frank & McCoy 1993) and progeny of the material from Sudan subsequently was released in Dade, Hillsborough, Marion, Orange, Palm Beach and Volusia counties, without evidence yet of permanent establishment (R. Nguyen, pers. comm.); IMPORTED VS *Bemisia tabaci*.

HYMENOPTERA: APHIDIDAE

Aphidius matricariae Haliday: a Holarctic species which is a parasitoid of several aphid species (Marsh 1979); attempts were made in the 1950s to establish populations

of it in Florida, apparently without success (Frank & McCoy 1993); IMPORTED VS *Myzus persicae*, or not given.

Lysiphlebus testaceipes (Cresson): widespread in temperate North America (including Florida) and South America, and is a parasitoid of several species of aphids (Marsh 1979); IMPORTED VS "vegetable pests," and "insects and mites in greenhouses."

HYMENOPTERA: BETHYLIDAE

Goniozus legneri Gordh: native to South America, introduced into California in 1979, and became established, for control of *Amyelois transitella* (Legner & Warkentin 1988); there are no records of *G. legneri* being imported into Florida for classical biological control purposes (Frank & McCoy 1993); IMPORTED VS "insects and mites in greenhouses."

HYMENOPTERA: BRACONIDAE

Cotesia plutellae (Kurdjumov): native to Europe, introduced to several countries around the world, and established successfully, for control of *Plutella xylostella*; an insecticide-tolerant strain was introduced to Florida from Malaysia in 1990, but its establishment has not yet been announced (Jansson & Pena 1990); IMPORTED VS *Plutella xylostella*.

Dacnusa sibirica Telenga: native to the Palearctic region, and used in European greenhouses for seasonal inoculative releases for control of *Liriomyza* leafminers (Minkenberg 1992); IMPORTED VS *Liriomyza* spp. leafminers, "leafminers," "insects," "vegetable pests," "thrips" and "broad mites."

HYMENOPTERA: EULOPHIDAE

Diglyphus isaea (Walker): native to the Palearctic region, invades European greenhouses and plays a part in suppression of *Liriomyza* leafminer populations (Minkenberg 1992); IMPORTED VS *Liriomyza* spp. leafminers, "leafminers", and "vegetable pests."

Thripobius semiluteus Bouček: native to the Old World tropics, this species was discovered in the New World (Brazil) for the first time in 1988, and specimens were taken to California for study as a potential biological control agent of *Heliothrips haemorrhoidalis* (LaSalle & McMurtry 1989); IMPORTED VS *Heliothrips haemorrhoidalis*.

HYMENOPTERA: ENCYRTIDAE

Anagyrus fusciventris (Girault): native to the Pacific and known as a parasitoid of *Pseudococcus longispinus*, this species was imported from Hawaii into California and thence into Bermuda (Bartlett 1978; Gordh 1979); IMPORTED VS "mealybugs."

Anagyrus pseudococci (Girault): native to the Mediterranean region of southern Europe and northern Africa, but imported from South America to California in 1953 and established, it attacks several species of *Planococcus* and *Pseudococcus* including *Planococcus citri* (Bartlett & Lloyd 1958; Bartlett 1978b); IMPORTED VS "mealybugs."

Leptomastidea abnormis (Girault): possibly native to the Mediterranean region of southern Europe and northern Africa, with no record of introduction to North America, it nevertheless has been present in Florida for many decades, presumably as an immigrant, and is known primarily as a natural enemy of *Planococcus citri*, though it attacks some other mealybugs (Bartlett 1978b); IMPORTED VS "mealybugs."

Leptomastix dactylopii Howard: native to Brazil and the West Indies, and perhaps also to southern Florida, certainly has been present in Florida for many decades, and is more or less a specific natural enemy of *Planococcus citri*, though it will attack other species of *Planococcus* and *Pseudococcus* in the laboratory (Bartlett 1978b); IMPORTED VS *Planococcus citri*, "mealybug on cucumber," and "mealybugs."

Microterys flavus (Howard): native to eastern North America including Florida, its recorded hosts belong to several genera (*Coccus*, *Lecanium*, *Pulvinaria*, and *Saissetia*) of scale insects (Gordh 1979); IMPORTED VS *Coccus hesperidum*.

TABLE 2. (Continued)

Metaphycus helvolus (Compere): native to South Africa, imported to California as a natural enemy of *Saissetia oleae* and established there in 1937, its recorded hosts belong to several genera (*Coccus*, *Lecanium*, *Parasaissetia*, and *Saissetia*) of scale insects (Bartlett 1978a); it was imported into Florida in 1971 against *Saissetia neglecta*, under the mistaken belief that this pest was *S. oleae*, but there is no evidence that it became established (McCoy 1985; Frank & McCoy 1993); IMPORTED VS "mealybugs," and "scale".

Tachinaephagus zealandicus Ashmead: native to Australia and New Zealand, this species was introduced into California in 1967-1968 as a biological control agent of dung-inhabiting fly larvae, and material of it was shipped also to Virginia (Legner 1978); it is a parasitoid of fly pupae (Gordh 1979); it has been reported from Florida (Butler et al. 1981); material of this species from Mauritius, perhaps with a genetic composition differing from that of feral Florida stock, was imported to Florida for study in 1975 and 1989 but was not released (Frank & McCoy 1993); IMPORTED VS "insects and mites in greenhouses."

HYMENOPTERA: PTEROMALIDAE

Muscidifurax zaraptor Kogan & Legner: native to the southwestern USA (California, New Mexico, Arizona, and Utah) and recorded as a parasitoid of pupae of muscid flies including *Musca domestica* and *Stomoxys calcitrans* (Burks 1979a); there are no records of *M. zaraptor* being imported for classical biological control purposes (Frank & McCoy 1993); IMPORTED VS *Musca domestica*, and "insects and mites in greenhouses."

Nasonia vitripennis (Walker): cosmopolitan, its origin obscure, but at least for many decades inhabiting North America including Florida, is a parasitoid of pupae of calliphorid and muscid flies including *Musca domestica* (Burks 1979a); material of this species from France, Zimbabwe, and Brazil, perhaps with a genetic composition differing from that of feral Florida stock, was imported to Florida for study in 1986-1987 but was not released (Frank & McCoy 1993); IMPORTED VS *Musca domestica*.

Spalangia endei Walker: cosmopolitan, its origin obscure, but at least for many decades inhabiting North America including Florida, is a parasitoid of pupae of calliphorid and muscid flies including *Musca domestica*, *Stomoxys calcitrans*, and *Haematobia irritans* (Burks 1979a); material of this species from Thailand, Mauritius, France, Hungary, India, Australia, and Brazil, perhaps with a genetic composition differing from that of feral Florida stock, was imported to Florida for study in 1984, 1986-1987, and 1989, but was not released (Frank & McCoy 1993); IMPORTED VS *Musca domestica*.

Spalangia nigroaenea Curtis: cosmopolitan, its origin obscure, but at least for many decades inhabiting North America including the eastern USA south to Virginia, is a parasitoid of pupae of muscid flies including *Musca domestica* and *Stomoxys calcitrans* (Burks 1979a); it was reported to occur also in Florida by Morgan & Patterson (1975); material of this species from Zimbabwe, perhaps with a genetic composition differing from that of feral stock, was imported to Florida for study in 1986 but was not released (Frank & McCoy 1993); IMPORTED VS *Musca domestica*.

Sphegigaster sp.: there are 2 species in America north of Mexico, one of which is native to the northern USA (Michigan and Montana), and the other was introduced from England into British Columbia in the mid-1930s; the introduced species [*S. flavigaster* (Walker)] is a parasitoid of leafminers of the genus *Phytomyza*, but the host of the other one is not recorded (Burks 1979a); an unidentified species is a parasitoid of *Musca domestica*, and material of it was introduced from South Africa to California in 1967-1968, apparently without success (Legner 1978); there are no records of any *Sphegigaster* sp. being imported to Florida for classical biological control purposes (Frank & McCoy 1993); IMPORTED VS "insects and mites in greenhouses."

HYMENOPTERA: TRICHOGRAMMATIDAE

Trichogramma minutum Riley: native to southern Canada and the USA except for most southern and southwestern areas, and is a parasitoid of eggs of many species of Lepidoptera and other orders in arboreal habitats (Burks 1979b); IMPORTED VS *Sitotroga cerealella*.

Trichogramma pretiosum Riley: native to southern Canada and the USA except for most southern and southwestern areas, and is a parasitoid of eggs of many species of Lepidoptera and other orders on herbaceous vegetation (Burks 1979b); was imported to Florida from Texas in 1971 and reportedly became established (Martin et al. 1976; Frank & McCoy 1993); IMPORTED VS *Sitotroga cerealella*.

MANTODEA: MANTIDAE

Tenodera aridifolia Stoll: native to Asia, its arrival and liberation at Mt. Airy, Pennsylvania, about 1896, were due to actions by a nurseryman (Blatchley 1920); we presume that it hitchhiked in plant material and thus is an immigrant rather than that the nurseryman introduced it [see Frank & McCoy (1990) for explanation of terms **immigrant** and **introduced**]; it is now distributed widely in the northeastern USA and southeastern Canada (Nickle 1987) but is not established in Florida (M. C. Thomas, pers. comm.); females are flightless, and populations have limited powers of dispersal without the effect of commercial movement of plants and commercial sales of the mantid itself (Hurd & Eisenberg 1984); sold to purchasers in Florida by one commercial organization for "educational purposes" without implication that it will succeed in controlling pest insects.

NEUROPTERA: CHRYSOPIDAE

Chrysoperla carnea (Stephens): native to the Holarctic region, but is rare or absent in the extreme south of Florida (Tauber & Tauber 1983); its rarity in Florida led to introductions into Florida from India in the 1950s against *Myzus persicae*, and other aphids, but the lacewing remained rare or absent where it was introduced, and the introductions were viewed as failures (Frank & McCoy 1993); has a broad host range including Tetranychidae, Aphididae and other Homoptera, Thysanoptera, eggs and larvae of Lepidoptera, and even eggs of Coccinellidae (Balduf 1939); IMPORTED VS "aphids," "insects," and "insects and mites in greenhouses" or not given.

Chrysoperla rufilabris (Burmeister): native to eastern North America including Florida, is more abundant in Florida than is *C. carnea*, is better adapted for the humid conditions of the southeastern USA, and better adapted for use in irrigated crops and in greenhouses than is *C. carnea* (Tauber & Tauber 1983); has a broad range of prey including Tetranychidae, Aphididae, *Blissus*, and eggs of *Carpocapsa* (Balduf 1939); IMPORTED VS "aphids," or not given.

(e.g., "vegetable pests"). It appears that some importers are reluctant to provide precise information.

Naturalization Status. There are 3 levels of status for "naturalization" of the imported biological control agents. First, some of them are native to Florida. Second, some of them which are thought not to be native, were known to occur in Florida at the time of importation. Third, some were not known to occur in Florida. This third group is of especial interest, because it is conceivable that some of them may become established in Florida as a result of the commercial importations. We have attempted in Table 2 (and the Discussion) to distinguish among these levels. Nine of the biological control agents are native to Florida, another nine are naturalized, and five are either native or naturalized. Of the total 48 agents imported, more than half (25), therefore, were not known to occur in Florida at the time of importation.

Habitats. We recognize six groups of habitats into which imported biological control agents have been released. These are perennial plants, annual plants, greenhouses, stored products, grasses (pasture and turf), and vertebrate feces. The distribution of imported biological control agents among habitats is unlike that of their targets (Fig. 1). Specifically, relatively more biological control agents were released into greenhouses than might be expected from the relative number of targets in that habitat, and relatively fewer into perennial plant habitats. This may have been because of the high value of greenhouse-grown plants, the relative inability of the agents to disperse beyond the greenhouse, or a combination of these and other factors.

Greenhouses are mentioned specifically in several places in Table 2. Biological control in greenhouses has received much attention in Europe, somewhat less in Canada and a few states in the USA, and is now receiving attention in Florida. In some ways, biological control in greenhouses resembles classical biological control, because pests in them are in a confining environment which is (in the ecological sense) an island. Some of the pests may only be able to thrive in greenhouses, because the surrounding environment may be inhospitable. Introduction of appropriate natural enemies in appropriate numbers and with appropriate timing into the greenhouse may control the pests during the growth of a crop. One release of agents may suffice to control some pests. Populations of pest and natural enemy alike may die when crop residues are removed or when soil is heat- or steam-sterilized. The ecosystem is then reset only at planting of the next crop, when already-infested seedling plants are used, or when pests invade from outside.

Annual field crops (most field crops) provide another habitat in which biological control is used commercially. Annual ornamental plants are comparable from the ecosystem viewpoint. These habitats are more readily invaded by pests and native natural enemies alike than are greenhouses, and are more subject to the vagaries of climate.

Perennial plants in groves and orchards are a venue of commercial biological control releases. Experience in biological control suggests that these habitats are the ones more

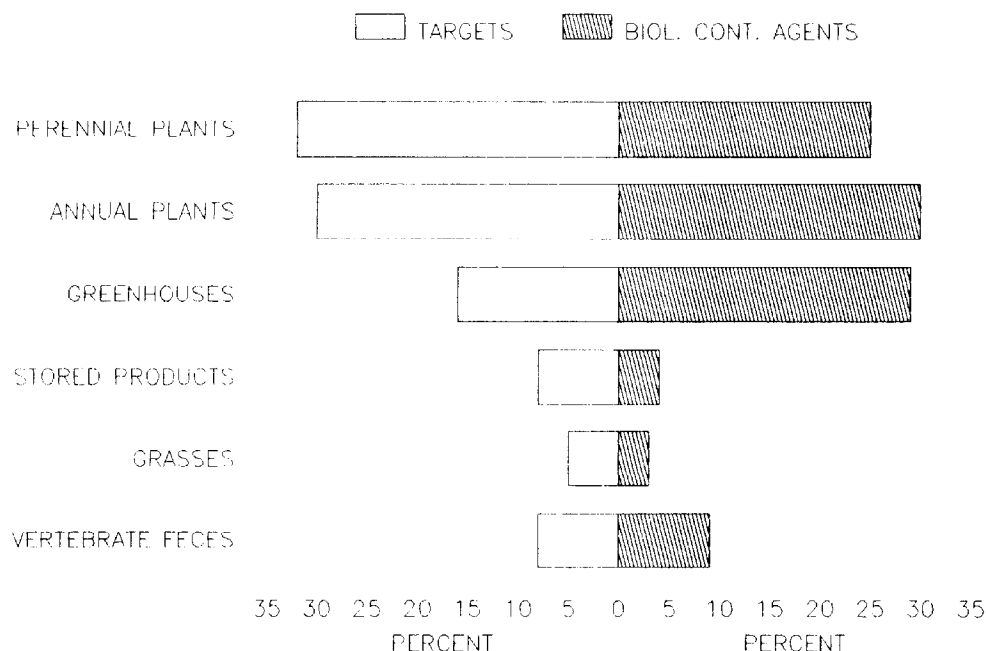


Fig. 1. Relative numbers of targets and imported biological control agents in the 6 habitat types.

TABLE 3. ALTERNATIVE NAMES USED IN THE DOCUMENTATION AND LITERATURE WHICH WAS CONSULTED FOR BIOLOGICAL CONTROL AGENTS LISTED IN TABLE 2. AT LEFT ARE SYNONYMS OR TYPOGRAPHICAL ERRORS FOR NAMES AT RIGHT

<i>Amblyseius californicus</i>	see <i>Neoseiulus californicus</i>
<i>Amblyseius cucumeris</i>	see <i>Neoseiulus cucumeris</i>
<i>Amblyseius mackenziei</i>	see <i>Neoseiulus barkeri</i>
<i>Anagyrus fusiventris</i>	see <i>Anagyrus fusciventris</i>
<i>Aphidius colemani</i> Viereck	see <i>Aphidius matricariae</i>
<i>Geolaelaps</i> sp.	see <i>Hypoaspis</i> sp.
<i>Lindorus lophanthae</i>	see <i>Rhyzobius lophanthae</i>
<i>Metaseiulus occidentalis</i>	see <i>Galendromus occidentalis</i>
<i>Neoseiulus barkeri</i>	see <i>Neoseiulus barkeri</i>
<i>Neoseiulus mckenziei</i>	see <i>Neoseiulus barkeri</i>
<i>Paratenodera sinensis</i>	see <i>Tenodera aridifolia</i>
<i>Phytoseiulus longipes</i>	see <i>Mesoseiulus longipes</i>
<i>Steinernema bibionis</i>	see <i>Steinernema feltiae</i>
<i>Tenodera aridifolia</i>	see <i>Tenodera aridifolia</i>
<i>Tenodera aridifolia</i>	see <i>Tenodera aridifolia</i>
<i>Tenodera aridifolia sinensis</i>	see <i>Tenodera aridifolia</i>
<i>Tenodera sinensis</i>	see <i>Tenodera aridifolia</i>
<i>Thripobius semilutens</i>	see <i>Thripobius semiluteus</i>

amenable to classical biological control, but not necessarily to augmentative biological control.

Use of classical biological control agents against pests of stored products was reviewed by Brower (1990). Storage bins and greenhouses are alike in confining the commodity that is protected, and in forming a barrier to ingress and egress of pests and their natural enemies.

Chemical control of pests has, until recently, been the norm in turfgrass in Florida, but attitudes are changing rapidly. Pasture grasses are now treated relatively little with chemicals because the few chemicals registered for such uses are generally too costly to use routinely.

Poultry houses, stables and dairies provide habitats for muscoid flies whose population control depends in part on physical management of wastes and regulation provided by native natural enemies. Augmentative release of biological control agents can provide additional suppression of the pests.

Patterns

We ranked the biological control agents simultaneously by number of companies importing them into Florida, and number of individuals reported. We then multiplied the rankings together to pool them, and divided the agents into two equally sized groups, "common" agents and "uncommon" agents. We employed only two groups because the data are incomplete and of variable quality; we assume, therefore, that our sample of the data is unbiased. We then asked whether the number of species in any of six categories of targets was distributed disproportionately between the two groups. The categories were: (1) targets, (2) agents, (3) native and naturalized biological control agents, (4) agents released into more than one habitat, (5) agents released into each of the six habitats, and (6) targets of major economic concern (i.e., targets whose effects are estimated to be \$2 million or more annually). Targets of major economic effect were

determined from information provided by Hamer (1985), Schuster (1992), comments by J. E. Funderburk, and our experience.

More targets recorded previously as targets of introduced biological control agents were associated with "uncommon" imported agents than with "common" ones (G test, $G = 9.9$, $P < 0.05$), and more of the "common" agents than the "uncommon" ones were released into multiple habitats ($G = 5.9$, $P < 0.05$). No other disproportionate distributions were detected. The first relationship may indicate that importers focus on supplying biological control agents aimed at targets that are different from those of governmental introduction programs. The second relationship may indicate that importers focus on biological control agents that can be employed in a wide array of circumstances. On the other hand, it may simply indicate that the most useful agents also are the ones that can adapt best to varying environmental conditions.

DISCUSSION

Naturalization Status

The 3 levels of naturalization status of imported organisms are discussed below in light of their possible environmental and economic effects.

Natural Enemies Native to Florida. The ladybird beetles *Delphastus pusillus* and *Hippodamia convergens* are typical of this group. The action of commerce is to release appropriate numbers of them where they may reduce numbers of pest whitefly or aphid species. This action is unequivocally preferable environmentally to the use of chemical pesticides that will kill non-target organisms and perhaps cause other side-effects. Economically, the action is more complex. It is beneficial when its cost is exceeded by the cost (i.e., losses to the grower) of taking no action. Nevertheless, the grower must endeavor to release the appropriate number of agents at the appropriate time(s) to maximize his economic returns. The questions about numbers and time(s) can be answered only by experimentation. Even if a natural enemy provides the best suppression of the pest that it can under any circumstances, the grower still may not make a profit on the crop because the level of suppression was inadequate. The grower under these circumstances has no option but to use other methods of pest control, whether they be additive methods of biological control (several biological control agents), or of a combination of biological and other methods (IPM), or of strict chemical control.

Natural Enemies Naturalized in Florida. The ladybird beetles *Cryptolaemus montrouzieri* and *Rhyzobius lophanthae* are typical of this group. Both were introduced from Australia into North America during the last century as biological control agents, and both are now established in Florida. The action of commerce is to release appropriate numbers of them where they may reduce numbers of a pest mealybug or soft scale insect. This action is unequivocally preferable environmentally to the use of chemical pesticides that will kill non-target organisms and perhaps cause other side-effects. Economically, the action is identical to that of releasing numbers of a native natural enemy.

At an extreme, however, is the decollate snail (*Rumina decollata*) which is established only in very restricted areas of Florida is a generalist predator of other snails and will eat plant materials. Its further dissemination in Florida has not been documented to be beneficial, and it may conceivably be harmful [see Protection of the Native Fauna and Flora].

Natural Enemies Not Yet Established in Florida. Several of the biological control agents being imported into Florida have, to our knowledge, not been introduced for classical biological control purposes. Typical of this group are *Dacnusa sibirica* and *Diglyphus isaea*. It is conceivable that some of them might establish populations and

become useful classical biological control agents. The action of commerce is to release appropriate numbers of them where they may reduce numbers of *Liriomyza* leafminers. This action is unequivocally preferable environmentally to the use of chemical pesticides that will kill non-target organisms and perhaps cause other side-effects. Economically, the action is identical to that of releasing numbers of a native natural enemy.

At an extreme, however, is the "Chinese mantis" (*Tenodera aridifolia*), which is sold in Florida for educational purposes. It is unlikely to have any beneficial effect in Florida's environment because studies elsewhere do not suggest it would make an effective biological control agent (Hurd & Eisenberg 1984).

Protection of the Native Fauna and Flora

There is a range of host-specificity among the imported organisms. At one extreme, some of them are specialized to a target species, but at the other, some are generalists, feeding on a range of organisms not necessarily related to the target. One of the latter is the snail *Rumina decollata*. It is not native to Florida, but has small populations established at 3 localities. The original reason for its importation to California was to combat brown garden snail, a pest of exotic origin. But brown garden snail does not occur in Florida, and we do not understand why *Rumina decollata*, its predator, should have been imported. We think rather that its importation was inadvisable in that it is known to be a minor plant pest, and that it might attack native non-pest molluscs. It can be argued that the species already occurs in Florida so should not be barred from additional entry, but its wider dissemination by commerce for no apparently useful reason is questionable.

Importation of the mantid *Tenodera aridifolia* also is questionable. A native of Asia, it is established in the northeastern USA, but is unable to spread rapidly because females are wingless. Thus, such spread of its population as occurs beyond a few meters is mainly by movement of plants and by commercial sales of *T. aridifolia*. This mantid is not known to be established in Florida and perhaps could not become established in Florida if it is physiologically adapted to more temperate regions. It might be argued that the importation of an insect for educational purposes is harmless, especially if it cannot survive outdoors in Florida, and also if it has little effect as a predator. The counter-argument would state that it might be able to survive outdoors, and might threaten some component of the native fauna, perhaps as a competitor of native mantids. Direct and indirect, but unintended, effects of introduced and imported organisms, including biological control agents, are always a potential risk (Howarth 1991, Simberloff 1992).

Selection of Biological Control Agents. So far as we have determined, there are no Florida-based producers of biological control agents: all agents are being produced elsewhere and imported into Florida. Many of these biological control agents are effective elsewhere according to the literature, but there is little literature on their effectiveness in Florida. Many of the biological control agents are native to temperate climates, and some of them apparently are not well-adapted physiologically to existence in Florida. An example of this is the export to Florida of *Chrysoperla carnea*, when *C. rufilabris* seems better adapted to existence in Florida.

Perhaps natural enemies native to Florida would be superior to some of the natural enemies currently being imported. Producers in northern and western North America, or Europe, may not be aware of the potential of some of these natural enemies native to Florida, and may not have access to stock of them. An example is the predacious mite *Galendromus helveolus* (Chant). This mite, native to Florida, is an effective predator of tetranychid mites, including *Tetranychus urticae* (Caceres & Childers 1991). Yet, we are not aware of any commercial producer even listing *G. helveolus* for sale,

let alone exporting it to Florida. Perhaps it is time for commercial production of biological control agents to begin in Florida.

Commercial Production of Biological Control Agents

Advantages of Commercial Production. The Division of Plant Industry (DPI) releases a very limited range of biological control agents for the public benefit, but these are all classical (inoculative) biological control agents. These releases are based upon perceived need, and are not experimental. The Agricultural Research Service of the Department of Agriculture (USDA-ARS) is involved in releases of classical biological control agents for the public benefit in Florida, but also is involved to a limited extent in releasing augmentative (or inundative) biological control agents, for experimental purposes. The principal releaser of classical biological control agents for experimental purposes is the Institute of Food & Agricultural Sciences (IFAS) of the University of Florida, and it also is involved in experimental trials of augmentative biological control agents. These three organizations do not sell biological control agents to growers for augmentative or inundative purposes.

The governmental organizations in Florida that release classical biological control agents as needed (as contrasted with releases for experimental purposes) are DPI and the Animal and Plant Health Inspection Service of the Department of Agriculture (USDA-APHIS). Such releases are for further dissemination of established natural enemies. Mosquito control districts (which are funded by a combination of state and local taxes) release predacious mosquito larvae and fishes only against pest mosquitoes. No governmental organization sells augmentative and inundative biological control agents to commercial agricultural, horticultural, and livestock producers, or for control of mosquitoes or aquatic weeds. Commercial producers of (augmentative and inundative) biological control agents therefore offer unique services which governments do not duplicate.

What the Customer Needs to Know. The would-be purchaser of a biological control agent needs considerable information before making a purchase, including:

- the correct identity of the pest -
- the current size of the pest population -
- whether effective natural enemies already are present and in adequate numbers -
- what is the damage the pest will cause if left untreated -
- are there effective natural enemies for use against this pest (on this crop) at this time of year in Florida and what are they -
- how many natural enemies are needed, when should they be applied, are they available and at what cost -
- will use of the natural enemy be cost-effective -
- will use of the natural enemy be compatible with other operations being conducted in the same place (crop, etc.), and are there more cost-effective methods than biological control?

This is more information than the would-be purchaser of a chemical pesticide requires (though some uses of chemicals are quite sophisticated), and only part of it can be supplied by a producer of biological control agents at a distant location. If the customer cannot obtain all the necessary information unaided, then he/she will have to contract pest control (or pest control advice) or a scouting service.

Responsibilities of the Producer. The subjects of correct identification of natural enemies, quality control in mass-production, guidelines for use provided to purchasers by producers, and professionalism of the producers, were discussed by Hoy et al. (1991). We have nothing to add beyond emphasizing that the producer of biological control

agents should not be expected to answer all the questions that a customer may need to know about the customer's particular circumstances, **unless** that producer offers a scouting service which will visit the customer's location.

Responsibilities of DPI. In our interpretation, the purpose of statute 581.083 (Florida Statutes 1991) is to protect plants in agriculture and horticulture by (among other things) preventing the movement into Florida of pests of plants, biological control agents, and arthropods, except under permit of the Division of Plant Industry. Arthropods are mentioned specifically, so all seem to be included, whether or not they are pests of plants or are biological control agents. Nematodes and molluscs are not mentioned by name, so presumably are included only if they are pests of plants, or are biological control agents, or will "directly or indirectly affect plant life." Chapter 5B-57 (Florida Administrative Code 1993) specifically excludes Crustacea from Arthropoda and, in our interpretation, broadens agriculture and horticulture to "the environment."

The law does not specifically address the encouragement of biological control vs. other means of pest control, although we believe that it should do so explicitly, and although unwritten administrative policy in DPI is to do so. The law does not discuss its own demise if federal laws should be written to replace it and laws of other states. If many states had their own laws on importation, the burden of paperwork on biological control producers would become overwhelming, and the replacement of state laws by a single, federal, set of laws would be an attractive proposition. We think that existing Florida laws are reasonable, and that they imply a willingness to admit biological control agents to be imported to Florida by commercial organizations.

Administration of the laws is currently being made more efficient. Response to applications for importation permits is now being made by facsimile transmission (FAX), together with a condensed explanation of Florida laws. Records are now being compiled into a computerized database, so that permits for individual species, once granted, may be reissued very rapidly. We think that the Arthropod and Arthropod Pathogen Introduction Committee (which reviews importation requests) could readily compile a computerized list of all approved biological agents, current and foreseen, even in advance of a request having been made; this would allow rapid action on new applications. The committee could review catalogs of biological control agents offered for sale by commercial companies to decide which items would and would not be permitted for admission to Florida. Companies selling living organisms (which may die within a few days) may need a very rapid response to an application for importation permit. At the same time, any company selling biological control agents in Florida should be willing to send a small sample of organisms to DPI for verification of identification.

Effectiveness. The question of effectiveness of biological control agents is not part of Florida law. It does the customer no good to buy biological control agents which cannot be effective under his circumstances. It does the customer no good to buy potentially-effective biological control agents if he/she lacks the knowledge to release them to best effect (too few, too many, wrong timing, or other incorrect strategy). The customer, by costly trial and error, may learn the necessary release strategies. Alternatively, the customer may hire a scouting company with the necessary knowledge. No body of knowledge exists to provide information to the customer on all biological control agents which may conceivably be imported legally. In Florida, the onus to provide such information falls not upon DPI, but mainly upon the Cooperative Extension Service (CES) of the University of Florida. Although the CES can now provide some information, this is woefully inadequate, because the necessary experimentation has been done for few biological control agents. The basic reason that the research has not been done is because of lack of funds to support experimentation. Traditionally, manufacturers of chemical pesticides **have** provided funds for field trials of their products, so the CES has knowledge on use of chemicals. Growers' organizations or producers' organizations can fund the necessary studies on biological control agents if they are so inclined; it is

unlikely that public funds will be provided for such studies while public funds are in such short supply that funding even for schools, roads, prisons and welfare, is deemed inadequate in Florida. The senior author will be pleased to answer questions from growers' organizations or producers' organizations about research possibilities.

THIS SYMPOSIUM

We have pointed out that large numbers of insect species arrived in Florida as **immigrants**, and that some of these became pests (Frank & McCoy 1992). We have also pointed out that considerable numbers of insect species were **introduced** for classical biological control of pests (Frank & McCoy 1993). The introduction to this symposium focuses on commercial importations of biological control agents, and completes our review of **introduced** biological control agents. The theme of the symposium is the relationship between biological control and the preservation of native floras and faunas. We are aware that certain segments of the public view "**introduced**" insects as being detrimental to the environment, but we think in the first part that these people confuse those that are **immigrant** with those that are **introduced**, and in the second that they have no clear concept of the benefits of biological control. In our view, the key to this understanding is in the behavioral ecology of the biological control agents and of their targets. We hope that this symposium and the two that preceded it will provide biologists with a background of information on **adventive** insects in Florida. With this background, we may in future be able to examine how introductions of plants and animals (vertebrates as well as invertebrates) for agricultural, horticultural, educational, and trivial purposes, have altered ecosystems.

Exotic plants and animals invade native ecosystems, attacking individual species, or affecting whole communities through crowding, or alteration of ecosystem properties such as soil chemistry or fire frequency. Control of exotic species in native ecosystems over large areas by chemical or mechanical means is costly and potentially damaging to other components of the ecosystems. Roy Van Driesche explains how classical biological control can be used to suppress these exotic species, and he gives examples in the control of weeds and of invertebrate and vertebrate animal pests.

Strawberries are a high-value crop in Florida. Their main arthropod pest is *Tetranychus urticae*, which is most often controlled by use of chemical acaricides. Gordon Decou explains that the pest mites often come with seedling plants from the nursery, and that chemical control can be difficult due to plant density or resistance of the mites to chemical acaricides. However, he has demonstrated that the pest mites can be controlled effectively by the use of the predacious mite *Phytoseiulus persimilis*, when appropriate release strategies are used. He uses these strategies in commercial strawberry production to the economic advantage of growers and himself.

Caribbean fruit fly, *Anastrepha suspensa* (Loew), is an immigrant pest in Florida. It attacks tropical soft fruits and, to some extent, citrus. Several classical biological control agents have been introduced to Florida against it, but their combined effect still is inadequate. Their limitations seem to be due to their inability to track periodic increases in populations of the fly, to the influence of oviposition-detererring markers, and to microclimate. John Sivinski (manuscript not submitted) has demonstrated experimentally that augmentative releases of a braconid parasitoid substantially lowered fruit fly populations.

The number of species of rare and endangered vertebrate animals is vastly less than that of invertebrates. Nevertheless, almost all funds for conservation are awarded to vertebrate animals. There are at least two reasons for this, though their limits are blurred. First is the general public's lack of awareness of invertebrate animals unless they bite, sting, or otherwise cause damage. Second is an anthropocentric scale of values in which invertebrates (insects are a prime example) are for the most part viewed

as being pests. Tonya Van Hook sees this situation as a challenge in environmental education.

Butterflies are the prime example of insects which are appreciated by the general public. This appreciation is because of the visual beauty of the adult stage, no matter that the larval and perhaps pupal stages, when noticed, may be viewed as repugnant. Jacqueline Miller discusses behavior of adult butterflies, some of which can be explained in terms of predator avoidance. Differences in behavior of adults from mainland and insular populations accentuate her account. These kinds of behaviors by adults must be considered in designing refugia for rare and endangered butterflies.

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CLASSICAL BIOLOGICAL CONTROL OF ENVIRONMENTAL PESTS

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ABSTRACT

Exotic species commonly invade areas of conservation concern. Such species may threaten native species or ecosystems, either attacking individual species, or changing ecosystem characteristics in ways that make them less suitable for the continued existence of one or more native species. Among the potential effects of exotic species are crowding, changes in water table levels, fire frequency or intensity, altered soil fertility or chemistry, and altered levels of predation or disease. Chemical, mechanical and biological methods each may be used to control exotic species in some cases. Chemical and mechanical methods are difficult to apply to large areas and must be repeated periodically to prevent pest resurgence. Classical biological control often has high initial costs but is permanent in nature and self propagating, such that large areas can be treated economically. Risks of biological control are minimal if agents are appropriately screened to determine host range prior to introduction and if introductions are conducted using appropriate quarantine procedures. Biological control is a useful approach for control of a variety of kinds of environmental pests that threaten the conservation of native species and ecosystems, including exotic plants, herbivorous and predacious arthropods, other invertebrates, and in some instance vertebrates.

Key Words: Biocontrol, nature conservation, exotic species.