

PRECINCTIVE INSECT SPECIES IN FLORIDA

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ABSTRACT

The number of insect species now occurring in Florida is estimated at about 12,500. Statements from specialists in 28 insect taxa (at the level of family or higher), representing some 40% of the fauna, suggest that about 12% of the total fauna (13% of the indigenous fauna, with range 0-43% among taxa) is precinctive. Immigrants form less than 8% of the total fauna. Only 42 (0.3%) species are known to have been introduced deliberately, for purposes of biological control. The proportions of immigrants and of precinctive species are far lower than in the Hawaiian insect fauna, but the proportion of immigrants exceeds that of the fauna of the contiguous United States as a whole.

Key Words: Adventive species, indigenous species, precinctive species, immigrant species, diversity.

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RESUMEN

Se estima que el número de especies de insectos existentes en la Florida es cercano a 12500. Opiniones de especialistas en 28 grupos de insectos (a nivel de familia o superior) que representan un 40% de la fauna, sugieren que cerca de 12% de la fauna total (13% de la fauna indígena, con intervalo 0-43% entre grupos) es precinictiva. Los inmigrantes constituyen menos del 8% de la fauna total. Solo 42 (0.3%) especies han sido introducidas intencionalmente, con fines de control biológico. Las proporciones de especies inmigrantes y precinictivas son mucho menores que en la fauna de insectos de Hawaii, pero la proporción de inmigrantes excede la de la fauna de los Estados Unidos contiguos como un total.

Many generalizations about the diversity of insects have been drawn from the European fauna, especially the fauna of the British Isles. This has been possible because of virtually complete checklists published, for example, by the Royal Entomological Society. Checklists are available for other locations, as well, such as Hawaii. A second (revised) edition of a computerized checklist of the arthropod fauna reported from Hawaii in the literature has just been published (Nishida 1994). Even though it is stated to be incomplete and may contain errors, it documents some striking facts. For example [using our terminology (Frank & McCoy 1990) rather than Nishida's (1994) terms], it gives the number of **indigenous** insect species as 5,059 (4,980 **precinictive** and 79 **indigenous but not precinictive**), and the number of **adventive** species as 2,549 (2,137 **immigrant** and 412 **introduced**). These proportions are so different from our conception of the Florida insect fauna that we thought it useful to compare the faunas of Florida and Hawaii.

Because we shall use precise terminology (Frank & McCoy 1990) to make comparisons between faunas, it is important that we reiterate what the terms mean. The six categories into which we shall place insects are **indigenous**, **precinictive**,¹ **indigenous but not precinictive**, **adventive**, **immigrant**, and **introduced**. The six categories are delimited as follows.

Indigenous: native

- A. **Precinictive:** native to and restricted to the area specified (the usage follows Sharp 1900)
- B. **Indigenous but not precinictive:** native to the area specified and elsewhere

Adventive (= non-indigenous): not native; arrived from elsewhere

- C. **Immigrant:** not native to the area specified and arrived there by means other than purposeful introduction, such as flight, walking, swimming, rafting, phoresy, hitchhiking in cargoes, and as aerial plankton (the usage follows Sailer 1978, although he neither provided a definition nor used the term consistently)
- D. **Introduced:** not native to the area specified and arrived there by means of purposeful introduction (the usage follows Zimmerman 1948)

There is no checklist of the insect fauna of Florida, although works including all known species of Ephemeroptera, Odonata, Blattodea, Isoptera, Orthoptera and Lep-

¹Later in this paper we use the noun preciniction (the state of being restricted to a specified area) which was used in English in 1730 (OED 1971). It bears the same relationship to precinictive as endemism bears to the adjective endemic.

diptera, and partial checklists of one, or a few related families in other orders, have been published. Therefore, we estimated the total number of insect species now occurring in Florida and, using this total number as a basis, we estimated the numbers of **immigrant** species, **precinctive** species, and **indigenous but not precinctive** species (number of **introduced** species was known). With these estimates in hand, we could then compare the insect faunas of Florida and Hawaii.

THE TOTAL NUMBER OF INSECT SPECIES IN FLORIDA

Several ways exist to estimate the total number of insects in Florida. One could, for example, use the combined knowledge of expert taxonomists (e.g., Gaston 1991), or extrapolate from extensive field collections (e.g., Stork 1988, Hodkinson & Casson 1991), or extrapolate from ratios of numbers of insect species to numbers of plant species (e.g., Hodkinson & Casson 1991, Gaston 1992). We have chosen yet another way, to extrapolate from a particularly well-known group, the beetles (see Erwin 1982, 1988; Stork 1988). Although there is no checklist of the insect fauna of Florida, Michael C. Thomas is constructing a computerized catalog of Florida Coleoptera. This catalog will include all species documented in the literature and all species represented in the Florida State Collection of Arthropods, with entries corrected in consultation with specialist taxonomists. Thomas informs us that the number of species names listed is now over 4,000, and he expects the total to reach 5,000 when documentation is complete. Given that beetles comprise 40% of all insect species (Borror et al. 1976), and assuming that the composition (proportions among orders) of the insect fauna of Florida is not especially divergent from other faunas, then the total number of insect species now occurring in Florida should be about $(5,000 \times 100/40 =) 12,500$.

THE NUMBERS OF IMMIGRANT AND INTRODUCED INSECT SPECIES IN FLORIDA

We documented 271 **immigrant** insect species as newly recorded in the literature from 1971 to 1991 (Frank & McCoy 1992). We have not surveyed the older literature to the same purpose, but will attempt to extrapolate. We adopted the anthropocentric concept that species occurring in Florida before Columbus' first voyage are indigenous. Immigrant species probably did arrive (as stowaways) with early Spanish colonists, but we believe that the number of species immigrating has increased very much in recent decades (see Frank & McCoy 1993). We attribute this recent increase to the arrival of insects (as stowaways) in the cargoes, especially cargoes of plants, that have been shipped to Florida in ever-increasing numbers. Although dozens of immigrant species were known as pests in the 19th century, the number is now in the hundreds. Based on our documentation of recent immigrations, we would place the number of **immigrant** species now present in Florida at about 1,000; the estimate derived from statements of specialist taxonomists (see below) is about 950.

We also documented 42 **introduced** insect species as established in Florida (Frank & McCoy 1993). Many more species have been brought to Florida deliberately (Frank & McCoy 1993, 1994), and 151 of these have been released for biological control purposes.

THE NUMBER OF PRECINCTIVE INSECT SPECIES IN FLORIDA

Determining which taxa are precinctive is an undertaking fraught with uncertainties, and it is worth spending some time to understand clearly what it means to be precinctive. Precinctive taxa often are of great interest simply because they are

unique (Australian marsupials or the "Teesdale Rarities," for instance) or because they may tell us something interesting about biogeographic processes or for numerous other reasons. Perhaps the most interesting question to be asked about precinctive taxa is: What creates them? We may proceed to answer this question by looking for areas with large numbers of precinctive taxa and then inferring a cause based upon which particular areas are singled out. Like all conclusions generated in this fashion, the "cause" decided upon may not be totally convincing. A classic example may be found in patterns of precinctive taxa on isolated oceanic islands (Briggs 1966, 1969; McDowell 1968, 1970; McCoy & Heck 1987). It seems clear that precinctive taxa are produced by precisely the same biotic and abiotic constraints that circumscribe ranges in general. Indeed, it should be apparent that there is nothing unusual about precinctive taxa per se; every taxon is precinctive to some geographical area. Precinctive taxa typically become useful and interesting when they are confined to relatively-small areas, especially if those areas harbor large numbers of them. In such cases, one quite naturally assumes that restriction of many species to small areas is improbable and, consequently, that very powerful biotic or abiotic range limitations have been at work. Rotondo et al. (1981), for example, illustrate the role of island integration in promoting high numbers of precinctive taxa on some Pacific islands, especially the Hawaiian Islands. So, how does one determine when a certain level of precinction in an area is improbable? For example, is the 10%-level of precinction thought to be present among marine invertebrates in the northern Gulf of Mexico (Hedgpeth 1953, McCoy & Bell 1985) truly unusual? We suppose that to find out, one could divide the eastern coast of the Western Hemisphere into segments, each equal the length of the northern Gulf of Mexico, assign species to them in a weighted random fashion, and compute resulting levels of precinction. Such a procedure would be overkill, though, for it is almost always relative levels of precinction that are deemed out of the ordinary. In the Gulf of Mexico, it is true that levels of precinction are low in most places, so an area with a level of 10% stands out. It would not stand out if, say, 8% precinction were the rule everywhere else in the Gulf. One could probably argue, therefore, that any changes in precinction, even small ones, deserve investigation. The roles of various limiting factors in circumscribing ranges may be understood further by such investigations. One should keep in mind, however, that the identification of areas of unusual levels of precinction is a subjective and relative process. The criterion employed usually will be consensus. Failure to acknowledge these facts about how precinction is recognized may lead to some unusual exercises in logic. Consider, for example, a hypothetical case of three adjacent areas divided by arbitrary boundaries. Suppose that researchers have identified areas "A" and "C" as possessing relatively many precinctive species, and have produced some geological explanation for their isolation. By consensus, then, "A" and "C" are touted as unusually rich areas of precinction, and the other area, "B," is forgotten. This scenario might be appropriate if, say, "A" and "C" each had 6 precinctive species and "B" only 2. It might not be appropriate, however, if "A" and "C" each had 10 precinctive species and "B" none. One might feel compelled in the second case to single out "B" as an unusually poor area of precinction, and try instead to explain this "phenomenon." Of course, the explanation produced is likely to be the reciprocal of one that would be produced for relatively-high levels of precinction in "A" and "C." Because of inherent subjectivity and relativity, the entire process of identifying unusual levels of precinction is dangerously prone to circularity (see, for example, Guillory 1979). Bearing these caveats in mind, we shall attempt to provide some estimates of the number of insect taxa precinctive to Florida.

We felt estimates of the numbers of precinctive species could be achieved best by asking a large number of specialists with knowledge of the Florida fauna at the family

level (or a higher level) to prepare a statement for publication (cf. Muller et al. 1989). Each statement would be published under the name of the specialist who prepared it, and would give the total number of **indigenous** species, subdivided into the two sub-categories (**precinctive**, and **indigenous but not precinctive**), as recorded in the literature. Subspecies would not be considered. Species present at the time of Columbus would be considered **indigenous**. Indigenous species reported only from Florida (not from neighboring states, nor from the West Indies, nor from other regions) would be considered **precinctive**. Obviously, this determination requires substantial judgment by the specialists. Species believed to be indigenous to the Greater Antilles or to the southeastern USA, that also occur in Florida, would be considered **indigenous but not precinctive**. The specialists' statements would not only allow an overall estimate of the proportion of **precinctive** species, but would allow examination of variation from taxon to taxon. We contacted colleagues who study a broad cross-section of the fauna, and it was their interests that selected the taxa included, so we felt that there is no biological bias in selection of taxa. Their statements included about 40% of the estimated 12,500 species of Florida insects, and allowed the compilation shown in Table 1.

Mayflies (Ephemeroptera)

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Florida has a mayfly fauna of relatively low diversity. Of the 71 species known in the state, 23 are indigenous, 10 of which are **precinctive** and 13 are not precinctive. The precinctive species include 3 of Baetidae [*Baetisalachua* (Berner), *Callibaetis floridanus* Banks, and *C. pretiosus* Banks], 3 of Metretopodidae [*Siphoplecton brunneum* Berner, *S. fuscum* Berner, and *S. simile* Berner], one of Heptageniidae [*Stenacron floridense* (Lewis)], one of Ephemeridae [*Hexagenia orlando* Traver], and 2 of Caenidae [*Brachycercus maculatus* Berner and *B. nasutus* Soldan]. There is no evidence to suggest any mayfly dispersal from the West Indies to Florida, and the mayfly faunas of the two areas show no phyletic relationships.

Dragonflies and damselflies (Odonata)

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An estimated 144 species of Odonata were indigenous to Florida at the time of European discovery. Of these, 104 are dragonflies (Anisoptera) and 40 are damselflies (Zygoptera). Of the 144 indigenous Odonata, 5 (4 Anisoptera, 1 Zygoptera) are **precinctive**. There are now 12 established species of **immigrant** Odonata, one of them [*Crocothemis servilia* (Drury)] from Asia, 3 [*Celithemis elisa* (Hagen), *Enallagma basidens* Calvert and *E. civile* Hagen] from North America, and 8 from the neotropics. No species of Odonata has been **introduced** (deliberately) to Florida. Additionally, 7 species have been found as vagrants, without breeding populations. More than a third (163 species) of the North American odonate fauna has now been found in Florida. This information was extracted from a publication by S. W. Dunkle (1992. Distribution of dragonflies and damselflies in Florida. Bull. American Odonatology 1(2): 29-50).

TABLE 1. VARIATION AMONG TAXA IN PROPORTION OF PRECINCTIVE SPECIES AND NUMBER OF IMMIGRANT SPECIES.

Taxon	Indigenous	Precinctive		Immigrant
EPHEMEROPTERA	23	10	(43%)	48
ODONATA	144	5	(4%)	12
BLATTODEA	25	1	(4%)	15
ISOPTERA	14	3	(21%)	3
ORTHOPTERA	232	41	(18%)	10
HEMIPTERA				
Lygaeidae	105	10	(10%)	10
Miridae	175	36	(21%)	10
HOMOPTERA				
Fulgoroidea	214	34	(16%)	6
Coccidae	14	3	(21%)	30
NEUROPTERA	85	1	(1%)	0
COLEOPTERA				
Carabidae	365	40	(11%)	3
Staphylinidae	328	74	(23%)	15
Scarabaeidae	275	45	(16%)	17
Lampyridae	49	20	(41%)	1
Nitidulidae	51	3	(6%)	6
flat bark beetles ¹	38	0	(0%)	18
Bruchidae	30	0	(0%)	14
Curculionidae ²	526	115	(22%)	45
LEPIDOPTERA				
Tortricidae	239	26	(11%)	9
Sesiidae	41	2	(5%)	0
Geometridae	244	33	(14%)	5
butterflies ³	199	0	(0%)	1
DIPTERA				
Culicidae	74	1	(1%)	4
Tabanidae	99	3	(3%)	0
Tephritidae	52	4	(8%)	2
HYMENOPTERA				
Ichneumonidae	340	20	(6%)	5
Aphelinidae	30	3	(10%)	1

¹Silvanidae+Passandridae+Laemophloeidae²excluding Brentidae+Antrhribidae+Scolytidae+Platypodidae³Papilionoidea+Hesperioidea

TABLE 1. VARIATION AMONG TAXA IN PROPORTION OF PRECINCTIVE SPECIES AND NUMBER OF IMMIGRANT SPECIES.

Taxon	Indigenous	Precinctive	Immigrant
Formicidae	149	14 (11%)	52
TOTAL (THIS SAMPLE)	4,160	547 (13%)	342
TOTAL (WHOLE FAUNA)	11,512	1,514 (13%)	946

¹Silvanidae+Passandridae+Laemophloeidae

²excluding Brentidae+Anthribidae+Scolytidae+Platypodidae

³Papilionoidea+Hesperioidea

Cockroaches (Blattodea)

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The cockroach fauna of Florida has recently been cataloged and is taxonomically diverse compared to that of other U.S. states. There are 25 indigenous species in 17 genera and 4 families. One species, *Arenivaga floridensis* Caudell, is **precinctive**. It is the only species of this genus in the eastern USA, and is a remnant of a larger, xeric-adapted biota that was abundant during the last glacial period. There are 24 cockroach species **indigenous but not precinctive**. The range of 8 extends to the West Indies, whereas the range of 9 extends to the U.S. mainland outside Florida. An additional 3 species range from Florida to the U.S. mainland and into Central America, and 2 species range from the West Indies into Florida and to the U.S. mainland outside Florida. The range of the final 2 species is from the West Indies into Florida and into Central America. The Florida fauna also includes 15 **immigrant** species that arrived from the Old World. The major pest species of cockroaches are all immigrants.

Termites (Isoptera)

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The termite fauna of Florida, although taxonomically diverse, is a well-studied group. Fourteen indigenous species from 8 genera and 3 families are represented. Three species, *Calcaritermes nearcticus* Snyder, *Neotermes luykxi* Nickle & Collins, and *Amitermes floridensis* Scheffrahn et al. are **precinctive**. Of the remaining 11 indigenous species, six are also recorded from the West Indies or Neotropical mainland, three occur on the U.S. mainland outside Florida, and two occur both on the U.S. mainland and offshore. Based on extensive recent collections in the West Indies, it is unlikely that species now thought to be precinctive to Florida will be found elsewhere in the future. The Florida fauna also includes 3 **immigrant** species.

Grasshoppers and crickets (Orthoptera)

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Except for an eneopterine cricket, probably from Taiwan, recently established in south Florida, these figures are from S. B. Peck, T. J. Walker & J. L. Capinera (1992). Distributional review of the Orthoptera of Florida. Florida Entomol. 75: 329-342). There are 242 species of Orthoptera known to occur in Florida. Of these, 232 are indigenous, 191 are **indigenous but not precinctive**, 41 are **precinctive**, and 10 are

post-Columbian **immigrants**. For the 87 species of Caelifera, the numbers are 87, 70, 17, and 0, and for the 155 Ensifera, they are 145, 121, 24, and 10.

Seed bugs (Hemiptera: Lygaeidae)

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There are 115 species of Lygaeidae known to occur in Florida. Ten species are known only from Florida, and 95 more are likewise considered indigenous. Ten species are considered recent **immigrants** based on habitat distribution and the probability of their being collected by general collectors. Thus, of the 115 known Florida species, 105 are known from outside of Florida.

Plant bugs (Hemiptera: Miridae)

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The Floridian mirid fauna consists of 175 indigenous (= native) species, including 36 (21%) that are **precinctive**. These figures are based on the most recent catalog of the group, by T. J. Henry & A. G. Wheeler (1988. Family Miridae Hahn 1833 (= Capsidae Burmeister 1835). The plant bugs, p. 251-507 *in* T. J. Henry and R. C. Froeschner [eds.]. Catalog of the Heteroptera, or True Bugs, of Canada and the Continental United States. E. J. Brill; Leiden). The total number of mirids recorded from Florida increases to 185 with the addition of 10 species that we consider to be **immigrant**.

Planthoppers (Homoptera: Fulgoroidea)

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In 7 of the 11 families of Fulgoroidea found in the U.S. (except Delphacidae, Derbidae, Flatidae, and Tropiduchidae), most species occur in the western U.S. In one family, Tropiduchidae, all 3 species known from the U.S. occur in Florida; one is **precinctive**, one indigenous with extensions to nearby states and Cuba, and one indigenous to Florida, Cuba, and Hispaniola. However, many species in the Greater Antilles were identified before genitalia were used for identification, and some records are suspect. Species from the Lesser Antilles are better known and, except for Delphacidae, at least 90% are precinctive to one island. Species that were described from the Greater Antilles have been discovered in Florida during the last 50 years, but their date of arrival cannot be pinpointed. Thirty-four (16%) of 214 indigenous Florida species of Fulgoroidea are precinctive. There are 6 **immigrants**, including 3 pantropical pests of corn and sugarcane which arrived in this century.

Soft scales (Homoptera: Coccidae)

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Fourteen species of the soft scale family Coccidae are indigenous to Florida. Of these 14 species, only 3 are **precinctive**, and the other 11 are **indigenous but not precinctive**. Thirty **immigrant** species of soft scales are reported from Florida.

Lacewings, antlions, and relatives (Neuroptera)

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There are 85 species of Neuroptera (including Megaloptera) indigenous to Florida. Only one species, *Mantispa floridana* Banks, is **precinctive** to Florida. There are no adventive species. At least 4 species remain to be described.

Ground beetles (Coleoptera: Carabidae)

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Florida has 365 indigenous species of ground beetles. Of these, 40 are **precinctive**, while 325 are **indigenous but not precinctive**. There are 3 **immigrant** species.

Rove beetles (Coleoptera: Staphylinidae, *sensu stricto*)

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The traditional concept of Staphylinidae is used here, to include Micropeplinae (no species yet reported from Florida), but exclude Scaphidiidae [-inae], Dasyceridae [-inae], and Pselaphidae [-inae]. There are 328 indigenous species of Staphylinidae in Florida, including 74 **precinctive** species and 254 **indigenous but not precinctive** species. In addition, 15 **adventive** species are established in Florida, all of which are **immigrants** (none of them was **introduced**). At very least a quarter of the staphylinid fauna is yet unrecorded: its eventual recording will increase the totals in the various categories. The proportion of precinctive species may be reduced by modern reports of the staphylinid fauna of Alabama, Georgia, and the Greater Antilles.

Scarab beetles (Coleoptera: Scarabaeidae)

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Two volumes (of 3) in the series "The Scarab Beetles of Florida" have been published by R. E. Woodruff (1973. Part I. Arthropods of Florida and Neighboring Land Areas, Vol. 8) and by R. E. Woodruff & B. M. Beck (1989. Part II. Arthropods of Florida and Neighboring Land Areas, Vol. 13), and the family is better known than most. There are 292 species recorded from Florida of which 17 are **immigrant**, thus 275 are indigenous and of these 45 are **precinctive**!

Fireflies (Coleoptera: Lampyridae)

James E. Lloyd, Entomology & Nematology Department, University of Florida,
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There have been 49 indigenous species of fireflies in 8 genera reported to occur in Florida, with 20 of these in 6 genera being **precinctive**. This tally includes 11 species for which I and others (whom I have supplied with living fireflies for research) have used informal designations (e.g., *Photuris* sp. "B", *Photinus* "slow-pulse" *consimilis*).

These numbers bear only quaint relationship to Florida fireflies in nature. Misidentifications of cabinet specimens account for a few names in the literature, these being made before the magnitude of the sibling species problem was appreciated. Some

species known to occur in Florida are not counted because they have never been mentioned in the literature, and some that certainly are here for they are known from localities nearby to the north, but cannot now be counted. One species appears to be a repeated **immigrant** from Central America, and may occasionally survive a year or so before disappearing. The most realistic estimate (not prediction) that I can give, these problems considered, is that there are 57 indigenous species in 11 genera in Florida, of which 17 species in 6 genera are precinctive. But, what bearing do such presumptively good species have to real, that is, actual (isolation of gene pools) diversity as it exists in nature? Systematists have multiple species concepts and dissatisfaction with all of them, and I am confident that an interplanetary visitor would avoid taking sides in this, and probably not do any counting, for scientific not sociable reasons. A species count for Florida fireflies is at once myth, theory, and reality.

Sap beetles (Coleoptera: Nitidulidae)

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There are 51 indigenous species of Nitidulidae in Florida including one species of Cybocephalinae, a group sometimes given family status. Only 3 species are **precinctive** and 48 are **indigenous but not precinctive**. Six species are, or are presumed to be, adventive (**immigrants**).

Flat bark beetles (Coleoptera: Laemophloeidae, Silvanidae, Passandridae)

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Of the 56 species of flat bark beetles recorded from Florida by M. C. Thomas (1993. The Flat Bark Beetles of Florida (Coleoptera: Silvanidae, Passandridae, Laemophloeidae). Arthropods of Florida & Neighboring Land Areas, Vol. 15), a total of 38 species (Silvanidae, 10; Passandridae, 2; Laemophloeidae, 26) can be considered indigenous. The other 18 are **immigrant** species. There are no **precinctive** species of flat bark beetles in Florida. Of the indigenous species, the major part of the distributions of 30 species is to the north of Florida; the distributions of the remaining 8 species are primarily Neotropical.

Seed beetles (Coleoptera: Bruchidae)

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Of the 44 species of Bruchidae now recorded from Florida, 30 are indigenous, including 23 which are part of the eastern U.S. fauna, 2 which are Circumcaribbean, and 5 common to the West Indies and Florida. There are no **precinctive** species. Of the 14 **immigrant** species, 4 are cosmopolitan "tramp" species in stored legume seeds, 3 are South American, and 7 are Central American. No species was **introduced** (deliberately).

Weevils (Coleoptera: Curculionidae, *sensu lato*)

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There are 526 indigenous species of Curculionidae in Florida. The number of **precinctive** species of Curculionidae is 115 and the number of **indigenous but not pre-**

cinctive species is 411. Among these species of indigenous Florida weevils there are 46 which have distributions in the West Indies and 35 which have distributions which include Mexico and/or Central America. It is evident from recent collections, which reduced the number of species that were previously thought to be precinctive in Florida but are now known to be in the Greater Antilles and other West Indian islands as well, that the number of precinctive species will be reduced with further collecting. In addition, 50 **adventive** species are established in Florida; 5 of these were **introduced** (deliberately) for biological control of weeds, and 45 are **immigrants**.

Leaf-rolling moths (Lepidoptera: Tortricidae)

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In Florida are reported to occur 239 indigenous species of Tortricidae, of which 26 (11%) are **precinctive**. In addition, there are 9 **immigrant** species.

Clear-winged moths (Lepidoptera: Sesiidae)

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Historically, the clearwing moths (family Sesiidae) have been rather difficult to collect, because adults mimic wasps, fly very fast, are rather inconspicuous, and are only emergent for a short period of time. The development of scent attractants (pheromones) within the last two decades has caused tremendous numbers of clearwing moths (mainly males) to be collected, representing many species. The total number of species of Sesiidae indigenous to Florida is 41 as documented by L. N. Brown & R. F. Mizell (1993. The clearwing borers of Florida (Lepidoptera: Sesiidae). *Tropical Lepidoptera* 4 (suppl. 4): 1-21), in which no **immigrant** species are recorded. Only two species are known only from Florida. This is not too surprising because the sesiids clearly colonized Florida from areas to the north and west.

Measuringworms (Lepidoptera: Geometridae)

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In Florida are reported to occur 244 indigenous species of Geometridae, of which 33 (14%) are **precinctive**. In addition, there are 5 **immigrant** species.

Butterflies (Lepidoptera: Papilionoidea, Hesperioidea)

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The butterfly fauna of Florida is composed of a mixture of temperate species extending into the peninsula from the north and west, and tropical species invading from the south. There are 199 indigenous species of butterflies in Florida, including 120 Papilionoidea (10 Papilionidae, 24 Pieridae, 40 Nymphalidae, 8 Satyridae, 3 Danaidae, 1 Libytheidae, 33 Lycaenidae, and 1 Riodinidae) and 79 Hesperioidea (3 Megathymidae and 76 Hesperiiidae). These totals include no **precinctive** species, and 199 **indigenous but not precinctive** species. One species, *Pieris rapae* L., is an **immigrant**.

Mosquitoes (Diptera: Culicidae)

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In Florida, the family Culicidae contains 12 genera and 74 indigenous species. The genera and number of species for each are: *Aedes* (18), *Anopheles* (18), *Coquillettidia* (1), *Culex* (14), *Culiseta* (2), *Deinocerites* (1), *Mansonia* (2), *Orthopodomyia* (2), *Psorophora* (10), *Toxorhynchites* (1), *Uranotaenia* (2), and *Wyeomyia* (3). Only one species, *Anopheles quadrimaculatus* sibling species C₁, is **precinctive** to Florida, and additional research may extend its range to southern Georgia. The other 73 species have distributions outside Florida. There also are 4 **immigrant** species.

Horseflies and deerflies (Diptera: Tabanidae)

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Ninety-nine species of Tabanidae were listed by C. M. Jones & D. W. Anthony (1964. The Tabanidae (Diptera) of Florida. USDA-ARS Tech. Bull. 1295) as occurring in Florida. Of the species listed in that bulletin (which now needs revision), 3 are **precinctive** and none are adventive.

Fruit flies (Diptera: Tephritidae)

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Florida is home to 52 species of indigenous tephritid flies based on published records, which are easily retrievable from R. H. Foote, F. L. Blanc & A. L. Norrbom (1993. Handbook of the Fruit Flies (Diptera: Tephritidae) of America North of Mexico. Comstock; Ithaca, New York). Of these, only 4 species are **precinctive** and the remaining 48 are **indigenous but not precinctive**. Further collecting in Georgia would almost surely reveal the presence of one of the Florida precinctive species; further collecting in the Caribbean would potentially reveal the presence of one or two of the others. An additional 6 immigrant fruit fly species have been recorded from Florida, but only two (Caribbean fruit fly and papaya fruit fly) have successfully colonized. The other 4 immigrant species either have been eradicated (e.g., Mediterranean fruit fly) or never successfully established.

Ichneumon wasps (Hymenoptera: Ichneumonidae)

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In 1979, 185 species of Ichneumonidae were reported from Florida by K. V. Krombein, P. D. Hurd & D. R. Smith, eds. (1979. A Catalog of Hymenoptera in America North of Mexico. Smithsonian Institution Press; Washington, DC, 3 vols). Another 160+ species were reported in several revisionary works of G. H. Heinrich, H. K. Townes, C. E. Dasch and V. K. Gupta during 1976-1992. Only about 20 of them are **precinctive** and 4-5 are adventive (**immigrants**). Several additional species were discovered during surveys in 1982-1986, and my estimate of species occurring in Florida is about 500-600. In the groups studied so far, about 30 new species have been identified but not yet described. It is difficult to say whether these new species are **precinctive**, and the likelihood is that most have a wider distribution, mainly in adjoining states. Several species occurring in Florida also occur in Central America.

Aphelinids (Hymenoptera: Aphelinidae)

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Worldwide, the family Aphelinidae contains about 1,120 species in 40 genera. About 42 species in 11 genera are reported from Florida. Of these 42, at least 11 were introduced as biological control agents for homopterous pests, and there is one **immigrant**, leaving perhaps 30 indigenous species. Of these 30, only 3 are reported to occur only in Florida. Most aphelinid species are closely associated with aphid, scale insect, or whitefly host species, many of which have hitchhiked around the world in ships, and later in planes, since the time of Columbus. Knowledge of North American aphelinids is very poor. Knowledge of Florida species has expanded recently because of surveys of parasitoids of *Bemisia tabaci* (Gennadius) and of diaspine scales, but much remains to be done, and an accurate estimate of the number of species is impossible.

Ants (Hymenoptera: Formicidae)

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There are 149 indigenous species of ants known from Florida (74.2% of the entire fauna). This figure is based on 11 years of survey work, and is not expected to change by more than 10 species. This number includes 14 apparently **precinctive** species, and 135 **indigenous but not precinctive species**. The remaining 52 species (25.8% of the fauna) are **immigrants**. The most secure precinctives are a group of 5 species found in xeric uplands in the central peninsula. Eight apparent precinctives might occur to the north of Florida, and one might be West Indian. Relative to Florida, the other intensively studied southeastern state (North Carolina) has a similar number of indigenous species (145), but these are a larger percent of the fauna (97.0%), and there is only one precinctive species.

DISCUSSION

Our estimate of the total number of insect species in Florida is made roughly, but should be approximately correct. The proportions of species in the subcategory **introduced** should be accurate. The proportions in the other 3 subcategories, **precinctive**, **indigenous but not precinctive**, **immigrant**, are based on the sample shown in Table 1 and should be approximately correct: we have no reason to think the sample is badly biased. We hope that anyone with better methods for deriving estimates will challenge us and publish them. Overall, we estimate that precinctive species are about 13% of the indigenous insect species, and about 12% of the total insect species, in Florida (Table 2). If the estimate of 12,500 insect species in Florida is accepted, and knowing that 42 introduced species have become established, then the proportions and numbers in the other subcategories must be approximately as in Table 2.

The differences between the entomofaunal compositions of Florida and Hawaii are striking (Table 2). Almost all (98.4%) of the Hawaiian indigenous fauna is precinctive, whereas only about 13% of the indigenous Florida fauna is precinctive. At least part of the explanation for this difference is the extreme isolation of Hawaii, but other abiotic and biotic attributes of the Hawaiian environment also may have contributed (see Mooney & Drake 1986). A much greater proportion (33.5%) of the Hawaiian fauna than of the Florida fauna (7.9%) also is adventive, despite the greater isolation of Hawaii. This difference, because it is calculated as a proportion, is accentuated by the relatively smaller size of the indigenous Hawaiian fauna. Nevertheless, Hawaii has a

TABLE 2. A COMPARISON OF THE INSECT FAUNAS OF FLORIDA AND HAWAII.

	Florida		Hawaii ¹	
	Number	Percent	Number	Percent
Indigenous species	11,512⁵	92.1⁴	5,059	66.5
Precinctive species	1,514 ⁵	12.1 ⁴	4,980	65.5
Indigenous but not precinctive species	9,998 ⁵	80.0 ⁴	79	1.0
Adventive species	988⁵	7.9⁴	2,549	33.5
Immigrant species	946 ⁵	7.6 ⁴	2,137	28.1
Introduced species	42	0.3 ³	412	5.4
Total species	12,500²	100	7,608	100

¹The numbers for Hawaii are based on number of species now recorded (from Nishida 1994). ²estimates of the total number existing, and ³consequences of these estimates. It is not necessarily true that more species occur in Florida than in Hawaii. ⁴estimates derived from Table 1, and ⁵consequences of these estimates.

much greater burden of immigrant species (at least 2,137 vs. about 946). The ratio of immigrant to indigenous species in Florida, based on our estimates, is about 1:12, while in Hawaii the ratio is about 1: 2.5 (Table 2). The immigrants to Hawaii are likely, even more so than immigrants to Florida, to be mainly stowaways in cargoes, because the barrier of distance precludes much aerial dispersal and rafting. This is not to say that aerial dispersal and rafting did not occur: they must have been the methods used by the insects ancestral to the present indigenous population (350-400 species; US Congress 1993). We assume that most of the insects introduced into Hawaii were introduced for purposes of biological control, as is true of Florida. Their number in Hawaii is exaggerated by including (apparently) all the species released, whereas we include for Florida only those species known to have become established. The high percentages of adventive species in Hawaii (33.5%) and Florida (7.9%) are strikingly greater than the 1.7% estimated for the contiguous states of the USA (Sailer 1978), and likely for most of those states individually (US Congress 1993).

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