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CUTEREBRA BOT FLIES (DIPTERA: OESTRIDAE) AND THEIR INDIGENOUS HOSTS AND POTENTIAL HOSTS IN FLORIDA

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ABSTRACT

Typical mammal hosts (indigenous rodents and lagomorphs), geographic distributions and phenologies of the five species of *Cuterebra* bot flies occurring in Florida are described. This coverage includes a reevaluation of some previously reported host records and presentation of unpublished data on larval infestations and captures of adult *Cuterebra* in Florida. In addition, indigenous species of Florida rodents for which there appear to be no in-state reports of larval infestation are listed (both native species of lagomorphs in Florida are hosts of *Cuterebra* within the state). Many gaps in our knowledge of the biology of these flies in Florida are identified, but based on available information, it appears that Florida is not exceptional when compared with certain other areas of North America in *Cuterebra* species diversity or the species of native rodents that apparently are not used as larval hosts. The geographic affinities of the Florida *Cuterebra* are Nearctic. Four of the species (*C. americana* (Fabricius), *C. buccata* (Fabricius), *C. emasculator* Fitch and *C. fontinella* Clark) have broad ranges in North America, whereas *C. cuniculi* (Clark) appears to be restricted to southern Georgia and Florida.

Key Words: lagomorph, parasite, phenology, rodent, species diversity

RESUMEN

Se describen los hospederos mamíferos típicos (roedores y lagomorfos indígenas), la distribución geográfica y la fenología para cinco especies de tórsalo (moscas del género *Cuterebra*) que ocurren en la Florida. Algunos de los pasados informes de los hospederos son re-evaluados y se presentan datos no publicados sobre las infestaciones de larvas y adultos de *Cuterebra* recolectados en Florida. Se presenta una lista de las especies de roedores indígenas de Florida las cuales aparentemente no tienen un registro de infestación de estas larvas dentro del estado (ambas de las especies nativas de lagomorfos en Florida son hospederos de *Cuterebra*). Muchas incognites en nuestro conocimiento de la biología de estas mosca en Florida estan identificadas, pero basadas sobre la información disponible, parece que Florida no es excepcional cuando se compara con ciertas otras áreas de America del Norte en cuanto de la diversidad de especies de *Cuterebra* o las especies de roedores nativos que aparentemente no son usados como hospederos de las larvas. Las afinidades geográficas de las moscas *Cuterebra* de Florida son Nearcticas. Las especies *C. americana* (Fabricius), *C. buccata* (Fabricius), *C. emasculator* Fitch y *C. fontinella* Clark tienen un rango geográfico amplio en America del Norte mientras que *C. cuniculi* (Clark) aparentemente es restringida en el sur de Georgia y Florida.

Cuterebra bot flies (Diptera: Oestridae; often listed as Cuterebridae) (e.g., Sabrosky 1986; Alcock & Kemp 2004; Burns et al. 2005) are obligate parasites of many native (indigenous) rodents (mice, rats, tree squirrels, etc.) and lagomorphs (rabbits, hares, etc.) in the Americas (Sabrosky 1986). Larvae (bots) of these dipterans are subcutaneous parasites that live in encapsulated pockets known as warbles. Depending on the species of *Cuterebra* and its host, the larvae develop for four to six weeks, ingesting body fluid and excreting and respiring through a hole (the warble pore) they create in the host's skin (Catts 1982; Slansky & Kenyon 2003). In addition to species they typically parasitize, these insects occasionally infest 'atypical' hosts, especially non-native (= non-indigenous or adventive; Frank & McCoy 1995) rodents and lagomorphs and non-rodent/ non-lagomorph mammals (including humans) (Sabrosky 1986; Baird et al. 1989; Glass et al. 1998; Harris et al. 2000; Suedmeyer et al. 2000; Safdar et al. 2003; F. S., unpublished data).

Most of the 30+ species of *Cuterebra* are temperate zone species, with flies in other cuterebrine genera (*Dermatobia*, *Metacuterebra*, *Alouattamyia*, *Rogenhofera* and *Pseudogametes*) occurring in subtropical and tropical climates (Catts 1982; Sabrosky 1986; Guimaraes 1989; Colwell & Milton 1998; Bergallo et al. 2000; note, however, that Pape (2001) suggested that the latter three genera likely should be included in *Cuterebra*). Based on morphological features of the adults and on larval hosts, Sabrosky (1986) divided *Cuterebra* into four 'groups', defined by a species within

the group: the rodent-infesting '*americana*' and '*fontinella*' groups, and the lagomorph-infesting '*buccata*' and '*cuniculi*' groups.

Diverse biogeographic patterns are exhibited by various taxa of Florida's indigenous entomofauna and other biota; these may include precinctive species, either depauperate or high species diversity, declining diversity from north to south (e.g., peninsula effect), and affinities to different geographic regions (e.g., Frank 1986; Peck 1989; Choate 1990; Deyrup 1990; Frank & McCoy 1995). In this paper I address various components of the biogeography of *Cuterebra* in Florida, a topic that has previously not been investigated. I review literature relevant to the presence in the state of flies in this genus and of their indigenous mammal hosts. This coverage includes a reevaluation of some previously reported host records as well as presentation of unpublished data on larval infestations and captures of adult *Cuterebra* in Florida. In addition, I list the indigenous rodents occurring in the state for which there appear to be no in-state reports of *Cuterebra* larval infestation (both native lagomorph species are hosts for larvae of these flies in Florida). Finally, I discuss the diversity and geographic affinities of these flies in Florida and address the question of whether there are an exceptional number of vacant niches (potential host species) for *Cuterebra* species in the state.

Materials and Methods

Published literature was reviewed to determine which species of *Cuterebra* and other cuterebrines occur in Florida, as well as their typical hosts, ranges, and phenologies. Unless indicated otherwise, information before 1986 was obtained from Sabrosky (1986), who not only compiled and synthesized most of the published information available at that time on *Cuterebra* but also reported numerous unpublished records resulting from his examination of specimens from many private and museum collections. Information on mammal species in Florida was obtained from the American Society of Mammalogists (undated), the Florida Fish and Wildlife Conservation Commission (2004a,b) and Brown (1997a,b), unless cited otherwise. Nomenclature follows that of the International Taxonomic Information Service (ITIS 2004).

Results

Cuterebra in Florida

Five species of *Cuterebra* occur in Florida: *C. americana* (Fabricius), *C. buccata* (Fabricius), *C. cuniculi* (Clark), *C. emasculator* Fitch, and *C. fontinella* Clark. There apparently are no verified published records for flies of other *Cuterebra* species or in other cuterebrine genera occurring naturally in Florida. Worth (1950a) listed "*Dermatobia*-like" larvae removed from roof (or black) rats, *Rattus rattus* (L.) (a non-indigenous, atypical host species), captured in Hillsborough Co., but this appears to be a misidentification of second instar *Cuterebra* larvae, as done previously (Townsend 1892). In subsequent reports (Worth 1950b,c) in which he thanked a *Cuterebra* taxonomist, C. W. Sabrosky, for identifying the larvae, Worth no longer mentioned *Dermatobia*. Below I discuss the typical hosts, ranges and phenologies in Florida for these five species.

C. americana

Typical Hosts. There apparently is only one main typical host species for larvae of *C. americana,* the eastern wood rat *Neotoma floridana* (Ord), which ranges throughout the northern two thirds of peninsular Florida and the Panhandle (there is also an isolated population on Key Largo). There appear to be only two published infestation reports for this host in Florida. Without any additional information, Johnson (1930) stated that he "obtained *Cuterebra* larvae from the large wood rat" (presumably *N. floridana*) in the state, and Worth (1950b) reported capturing *Cuterebra*-infested individuals of this species in Hillsborough county.

Distribution. County records for captures of adult *C. americana* in Florida include Alachua, Citrus, Duval, Hillsborough, Lake, Orange, Pasco, and Sarasota. If Worth's (1950a,b) reports of infested *R. rattus* captured in Dade Co. involved *C. americana*, as suspected by Sabrosky (1986), then this species would appear to occur throughout peninsular Florida. However, in Worth's papers the larvae were not described and no mention was made of obtaining adults for definitive species identification even though Sabrosky (1986) stated that Worth "reared" these specimens (in fact, Worth thanks Sabrosky for identifying the larvae only to the level of *Cuterebra* sp.). In addition, the typical host (*N. floridana*) of this species apparently does not occur in Dade Co. Finally, larvae of at least one other Florida *Cuterebra* species (*C. buccata*) have been recorded infesting *Rattus* species as atypical hosts. Taken together, these caveats would appear to call into question the presence of *C. americana* in Dade Co. Because this species has been reported from Georgia and Louisiana (as well as from several other states from eastern Colorado to Virginia and southward), it likely also occurs throughout the Florida Panhandle.

Phenology. Sabrosky (1986) provided no dates for adult captures or host infestations. An adult female *C. americana* was collected in Alachua Co. on 7-X-1992 (P. M. Choate, Dept. Entomology & Nematology, University of Florida, personal communication). Worth (1950b) captured *R. rattus* in-

fested with *Cuterebra* (possibly *C. americana*; but see above) in Dade Co. in January and *Cuterebra*-infested *R. rattus* and *N. floridana* in Hillsborough Co. in late February through early March (these were the only times that trapping was done; see also Worth 1950c). Because the data are so limited, the phenology of this species in Florida is uncertain, but it appears to be univoltine outside the state (Goertz 1966).

C. buccata

Typical Hosts. Larvae of this species typically infest eastern cottontails, *Sylvilagus floridanus* (J. A. Allen), and probably also individuals of other *Sylvilagus* species. Both *S. floridanus* and the marsh rabbit *S. palustris* (Bachman) are widespread in Florida, but the presence in the state of the swamp rabbit *S. aquaticus* (Bachman), which might occur in the extreme western Panhandle, is uncertain. There appear to be no definitive records of infestation of rabbits of either of these species by larvae of *C. buccata* in Florida. However, Worth (1950a,b) reported that individuals of *S. palustris* were commonly infested with larvae of *Cuterebra* (Sabrosky (1986) does not mention these records). Although these larvae were not identified to species, they probably were either *C. buccata* or *C. cuniculi* (see below), the only *Cuterebra* species in Florida known to use rabbits as their typical hosts.

Distribution. This is a very widespread species, reported from all states east of the western mountain states except Maine, Vermont and Rhode Island. According to Sabrosky (1986), supposed records of this species from St. Johns and Collier counties (Johnson 1895, 1913) in Florida presumably involved another species (*C. fontinella*; see below). *Cuterebra*-infested *S. palustris* collected in Hillsborough Co. (Worth 1950a,b) may have involved this species, and/or possibly *C. cuniculi* (see below). Sabrosky (1986) considered as valid the claim of Knipling & Bruce (1937) that a larva of this species was removed from a cow in September in Sumter Co. However, the involvement of *C. buccata* (or indeed any species of *Cuterebra*) in this infestation is questionable for a variety of reasons: (1) the larva was a second instar, and no species identification key for this stage of the *Cuterebra* lifecycle was then (nor is now) available; (2) the authors provide no information on the characteristics used to identify this larva either as a species of *Cuterebra* or as *C. buccata* in particular; (3) a cow is a very unusual atypical host for *Cuterebra* larvae, and I am aware of no other reports documenting cattle as hosts; and (4) cattle are subject to parasitization by larvae of cattle warble flies (two species of *Hypoderma*), both of which occur in Florida (Glick 1976). Larvae of these insects typically form warbles on the backs of these animals, which was the site of the supposed *Cuterebra* larva. Thus, although a *Cuterebra* larva may have infested a cow, as stated by Knipling & Bruce (1937), I consider this conclusion highly unlikely.

Phenology. There apparently are no definitive phenological records for this species in Florida, although *C. buccata* larvae may have infested the *S. palustris* trapped by Worth (1950a,b) in late February to early March (the only time that trapping was done). Thus, the phenology of this species in the state cannot presently be determined, but elsewhere it appears to be at least bivoltine.

C. cuniculi

Typical Hosts. The typical hosts for *C. cuniculi* are *S. floridanus* and *S. palustris,* with infestation records for both hosts in the state.

Distribution and Phenology. *Cuterebra cuniculi* is very restricted in distribution, apparently occurring only in Florida and southern Georgia. County and date records for this species in Florida (adults, unless indicated otherwise) include Alachua (May and December), Broward (August), Collier (April), Dade (May), Hamilton (October), Highlands (May and December), Indian River (a larva from *S. palustris* in June; the adult emerged in October), Orange (May), Palm Beach (May and December; also, a larva from an unspecified host in October with the adult emerging in November; and another adult in November from a larva (no date) infesting *S. palustris*), Polk (March), St. Johns (April) and St. Lucie (a larva from *S. floridanus* in December; the adult emerged in February). Worth's (1950a,b) records of *Cuterebra*-infested *S. palustris* trapped in Hillsborough Co. during late February through early March (the only time that trapping was done) likely would have involved this species and/or *C. buccata*. Apparently, there are no records for this species from counties in the Panhandle. From the records listed above, it is likely that this species occurs at least throughout the peninsular part of the state and that it has two or more generations during the year. Based on very limited data, it appears to be bivoltine in Georgia.

C. emasculator

Typical Hosts. The typical hosts for this species include tree squirrels (*Sciurus* sp.), and eastern chipmunks, *Tamias striatus* (L.). There are Florida infestation records for eastern gray squirrels, *S. carolinensis* Gmelin, and fox squirrels, *S. niger* L., both of which are widespread throughout the state. In contrast, *T. striatus* is restricted to the northern portions of a few counties in the Panhandle (Escambia, Holmes, Okaloosa, Santa Rosa, and Walton) (Gore, 1990), and there appear to be no published *Cuterebra*-infestation records for individuals of this species in Florida. Southern flying squirrels, *Glaucomys volans* (L.), which are

widely distributed in Florida, have rarely been reported to be parasitized by *Cuterebra* larvae (presumably *C. emasculator)* in the state or elsewhere, suggesting that *G. volans* is an atypical host species for *Cuterebra* larvae.

Distribution. *Cuterebra emasculator* is widely distributed throughout eastern North America from just west of the Mississippi River to the Atlantic coast. Published records for Florida include Alachua (Sabrosky 1986; Forrester 1992; Slansky & Kenyon 2000; 2002) and Columbia (Coyner 1994; Coyner et al. 1996) counties, although the latter record may not have involved *C. emasculator.* A recent study has extended the known range of this species to over 40 additional counties throughout the northern and central regions of the state (including the Panhandle) (F. S., unpublished data). Apparently, *C. emasculator* is rare in or absent from the southern counties despite the presence of potential host squirrels.

Phenology. Sabrosky (1986) does not provide phenological data for this species in Florida, but infested squirrels typically are observed in the state from July through October (Slansky & Kenyon 2000; 2002; 2003; F. S., unpublished data). Coyner's (1994; Coyner et al. 1996) report of finding one individual of *S. niger* (out of 123 examined fox squirrels) with a larva presumed to be *C. emasculator* on 21-II-1991 is exceptional. Because no information was given that the larva was definitively identified to species, the possibility exists that it was of a different species such as *C. cuniculi*, which, unlike *C. emasculator*, appears to have a winter generation. *Cuterebra emasculator* appears to be univoltine in Florida and throughout its geographic range (Bennett 1972a,b; F. S., unpublished data).

C. fontinella

Typical Hosts. The main typical hosts for *C. fontinella* apparently are the white-footed mouse *Peromyscus leucopus* (Rafinesque) and the cotton mouse *Peromyscus gossypinus* (LeConte) (records in Sabrosky (1986) and Durden (1995)). However, adults of this species have been reared from a variety of other indigenous rodents, including the deer mouse *Peromyscus maniculatus* (Wagner) (mice of this species apparently are the main typical hosts for a closely related species, *Cuterebra grisea* Coquillett), the golden mouse *Ochrotomys nuttalli* (Harlan), the northern grasshopper mouse *Onychomys leucogaster* (Wied-Neuwied), the Mexican spiny pocket mouse *Liomys irroratus* (Gray), the woodland jumping mouse *Napaeozapus insignis* (Miller), the meadow vole *Microtus pennsylvanicus* (Ord), and the yellow-pine chipmunk *Tamias amoenus* J. A. Allen (records in Sabrosky (1986); also, Clark & Durden (2002) for *O. nuttalli*). Of these, only *P. gossypinus*, *O. nuttalli,* and a subspecies of *M. pennsylvanicus* occur in Florida. *Cuterebra*-infested individuals of *P. gossypinus*, which occurs statewide, and *O. nuttalli*, which is found in the northern half of peninsular Florida and the Panhandle, have been captured in the state (Pearson 1954; Layne 1963; Bigler & Jenkins 1975). In addition, Layne (1963) trapped *Cuterebra*-infested Florida mice, *Peromyscus* (= *Podomys*) *floridana* (Chapman), which occur only in Florida (the central portion of the peninsula). It is likely that the mice in the latter three studies were parasitized by *C. fontinella*. If so, then *O. nuttalli*, *P. gossypinus,* and *P. floridana* would apparently constitute the typical hosts for this *Cuterebra* species in the state.

Distribution. *Cuterebra fontinella* is a very widespread species, occurring throughout most of the continental US (except Alaska), southern Canada, and northeastern Mexico. Sabrosky (1986) provides a distribution map for this species, including several records for Florida. Because of the small size of this map and the large symbols used to mark collection locations, identification of the counties involved is somewhat tenuous, but these appear to be Alachua, Broward, Citrus, Collier, Columbia, Dade, Hillsborough, Lee, Manatee, Monroe, Orange, Pinellas, Sarasota, St. Lucie, Union, and Volusia. Pearson's (1954) infestation records are for Levy Co., and Bigler & Jenkins (1975) performed their study in Monroe Co. Layne (1963) did extensive trapping throughout the northern half of the state (Alachua, Clay, Gilchrist, Levy, Putnam and St. Johns counties) and some in Highlands Co. Individual county records were not presented in the latter study but apparently *Cuterebra*-infested mice were found in each of these counties. According to Sabrosky (1986), Johnson (1895) originally thought a fly captured in St. Johns Co. was *C. buccata* but he later correctly identified it as *C. fontinella* (Johnson 1913). However, in the latter publication he provided a separate record for *C. buccata* from Collier Co., but Sabrosky (1986) indicated that Johnson more likely was again dealing with *C. fontinella*. Apparently, there are no published records for this species from the Panhandle.

Phenology. Sabrosky (1986) provided no phenological data for *C. fontinella* in Florida. An adult female *C. fontinella* was captured in Alachua Co. on 19-IV-2003 (P. M. Choate, Dept. Entomology & Nematology, University of Florida, personal communication). Pearson (1954) reported trapping *Cuterebra*-infested *P. gossypinus* in all months of the year except February and March, with almost half of these records in June; he did not report capture dates for the *Cuterebra*-infested *P. nuttalli* he trapped. Bigler & Jenkins (1975) also captured *Cuterebra*-infested *P. gossypinus* during most months of the year; no trapping was done in December, but parasitized mice were caught in every other month except October, with peaks in the prevalence of infestation in January and June. Layne (1963) found *Cuterebra*-

infested *P. floridana* in all quarters of the year. If these latter three studies involved *C. fontinella* (as is likely), then this species probably has two or more generations per year in Florida. It appears to be at least bivoltine in other southeastern states (Durden 1995, Georgia; Clark & Durden 2002, Mississippi) and elsewhere (e.g., Goertz 1966; Wolf & Batzli 2001, Illinois).

Indigenous Rodents not Known to be Parasitized by *Cuterebra* Larvae in Florida

Several species of indigenous rodents occur in Florida for which no published records of parasitization by *Cuterebra* larvae in this state apparently exist. These are listed below, along with published reports and a few unpublished records of *Cuterebra* infestation (or indication of the apparent lack thereof) from elsewhere in the ranges of these, and in some cases closely related, taxa.

Castoridae and Aplodontidae. American beavers, *Castor canadensis* Kuhl, occur in the Panhandle and northern third of peninsular Florida. Apparently, there are no published *Cuterebra*-infestation records for this species in any part of its range in North America. Sabrosky (1986) listed only two records of mountain beavers, *Aplodontia rufa* (Rafinesque) (note that this species belongs to a different family (Aplodontidae) than *C. canadensis*), parasitized by *Cuterebra* larvae (Oregon and Washington). These limited records suggest that no *Cuterebra* species uses beavers of either of these two species as typical hosts.

Geomyidae. The southeastern pocket gopher *Geomys pinetis* Rafinesque is the only member of this family in Florida. It is found in the Panhandle and the northern half to two thirds of the Florida peninsula. One individual of this species captured by Worth (1950a; probably in Hillsborough Co.) was not parasitized by *Cuterebra* larvae. Sampling of *G. pinetis* in Alachua Co. for an entire year and in Alabama, Florida and Georgia primarily from December through February (totaling over 150 individuals trapped) yielded no specimens obviously infested with *Cuterebra* larvae (P. E. Skelley, FDACS/DPI, Gainesville, FL, personal communication). In the western US, the northern pocket gopher *Thomomys talpoides* (Richardson) is the typical host of *Cuterebra polita* Coquillett (a member of the '*americana*' group). There appear to be no *Cuterebra*-infestation records for the several other species of *Geomys* and *Thomomys* in North America.

Muridae. A number of indigenous murid rodents occur in Florida for which no published *Cuterebra*-infestation records in the state appear to be available. The marsh rice rat *Oryzomys palustris palustris* (Harlan) has a statewide distribution in Florida. There is also a subspecies, the silver rice rat *O. p. natator* Chapman (sometimes listed as the invalid *O. argentatus* Spitzer and Lazell), which is apparently limited to some of the Lower Keys. There appear to be no *Cuterebra*-infestation records for any members of this genus in North America; none are listed in Sabrosky (1986) and no infested individuals were captured by Worth (1950a), Pearson (1954), Durden (1995), or Clark & Durden (2002). However, parasitization of another member of this genus, *O. russatus* (Wagner), by *Metacuterebra apicalis* (Guerin-Meneville) in South America has been well documented (Bergallo et al. 2000; Bossi et al. 2002; both Brazil). The hispid cotton rat *Sigmodon hispidus* Say and Ord is distributed statewide in Florida. Goertz (1966) reported that individuals of this species were very rarely parasitized by an unknown species of *Cuterebra* (possibly *C. americana*) in Oklahoma, whereas no such infestations were found in Florida (Worth 1950a; Pearson 1954; Bigler & Jenkins 1975) or elsewhere in North America (Clark & Kaufman 1990, Kansas; Boggs et al. 1991, Oklahoma; Clark & Durden 2002). Disney (1968) reported infestation of *Sigmodon* sp. cotton rats in Honduras by larvae of *Cuterebra* (= *Metacuterebra*) *flaviventris* (Bau).

Two species of *Peromyscus* mice occur in Florida, and *Cuterebra*-infested individuals of one of these, *P. gossypinus*, have been captured in the state. However, the other species, *P. polionotus* (Wagner), which is comprised of several subspecies (beach mouse, oldfield mouse, etc.) variously distributed in Florida, is apparently lacking in *Cuterebra*-infestation records. Another indigenous mouse species in Florida, the eastern harvest mouse *Reithrodontomys humulis* (Audubon and Bachman), occurs throughout the northern two thirds of the peninsula and in the Panhandle. Little or no parasitization of *Reithrodontomys* mice has been reported from elsewhere in North America (Goertz 1966; Hensley 1976, Virginia; Sabrosky 1986; Clark & Kaufman 1990; Boggs et al. 1991; Clark & Durden 2002), which suggests that members of this genus may serve only occasionally as atypical hosts for *Cuterebra* larvae.

Two species of *Microtus* voles occur in Florida: the pine (or woodland) vole *M. pinetorum* (LeConte), found in the central part of the northern one third of the peninsula, and a rare subspecies of the meadow vole *M. pennsylvanicus*, namely the Florida saltmarsh vole *M. p. dukecampbelli* Woods, Post & Kilpatrick, which inhabits saltmarshes in the Cedar Key area (Levy Co.). There are several records from outside Florida of individuals of *M. pennsylvanicus* and other *Microtus* voles parasitized by larvae of various *Cuterebra* species (Clough 1965, Wisconsin; Maurer & Skaley 1968, New York, North Dakota and Pennsylvania; Getz 1970, Wisconsin; Hensley 1976, *M. pennsylvanicus* but not *M. pinetorum*; Boonstra et al. 1980, British Columbia, Canada), as well as reports of *Cuterebra*-infested *Clethrionomys* voles (Sabrosky 1986, Manitoba and Quebec, Canada; Bowman 2000, New Brunswick, Can-

ada), which do not occur in Florida. However, none of the *Microtus* voles captured by Sillman (1955, Ontario, Canada), Goertz (1966), Shoemaker & Joy (1967, West Virginia), Hensley (1976, *M. pinetorum*), Clark & Kaufman (1990), Boggs et al. (1991), Bowman (2000), or Clark & Durden (2002), nor any of the *Clethrionomys* individuals trapped by Maurer & Skaley (1968) or Hensley (1976), were infested with *Cuterebra* larvae.

Round-tailed muskrats, *Neofiber alleni* True, are distributed throughout much of peninsular Florida, with some isolated populations in the Panhandle. Sabrosky (1986) provided records of infestation of an individual of this species (location not given) and of the muskrat *Ondatra zibethicus* (L.) (Michigan). These limited records suggest that no *Cuterebra* species uses these muskrat species as typical hosts.

Sciuridae. There are few reports of flying squirrels (*Glaucomys* species) parasitized by *Cuterebra* larvae. Apparently, the only published North American record is for an individual of *G. volans* in Alachua Co., Florida (Forrester 1992), and I am aware of a few such cases from other eastern states (F. S., unpublished data). Because of the rarity of these records, it is likely that *Glaucomys* species are atypical hosts of *Cuterebra* (presumably *C. emasculator*). *Tamias striatus*, which is restricted in Florida to the northern portions of certain counties in the Panhandle, is a frequent host of *C. emasculator* outside the state, especially in the northern portion of its range.

Discussion

From the above coverage, it is evident that there are many gaps in our knowledge, specific to Florida, of the biology of the *Cuterebra* species occurring in the state. The most complete data on host species, county distribution, and phenology within Florida are available for *C. cuniculi* and *C. emasculator.* However, if the studies of Pearson (1954), Layne (1963), and Bigler & Jenkins 1975) involved *C. fontinella* (as is likely), then aspects of the biology of this species in Florida also are reasonably well understood. The least amount of information is available for *C. americana* and *C. buccata*.

Obviously, more studies are required to provide the information needed to better understand the biology of these five *Cuterebra* species in Florida. The mammals that serve as typical and atypical hosts for these species within the state need to be determined, or in some cases better documented. In addition, the distributions and phenologies of these species within the state need to be established for some of the species or better delineated for the others. A key limitation in the research required to achieve these goals involves the difficulty of determining *Cuterebra* species when only larval specimens are available. Generally, the larvae of these flies cannot be identified to species based on their external features; instead, they usually need to be reared to the adult stage, for which definitive morphologically-based descriptions are available (Sabrosky 1986). However, obtaining adults from larvae can be problematic; second and early third instars removed from their hosts are unable to pupate, and although more mature third stadium larvae can pupate, they may enter pupal diapause, which can delay obtaining adults by several months (e.g., Bennett 1972a;b). In addition, there can be substantial mortality of diapausing pupae (F. S., unpublished data). The problem of species identification of the larvae will be overcome as comparative DNA sequences become available for more species of *Cuterebra* (Otranto et al. 2003; Noel et al. 2004; F. S., unpublished data). At a broader level, third stadium *Cuterebra* larvae can be separated into species that typically parasitize rodents and those that infest lagomorphs, based on certain features of their cuticular ornamentation (Knipling & Brody 1940; Baird & Graham 1973).

Limitations in our knowledge prevent a meaningful biogeographic analysis of the in-state distribution of the Florida species of *Cuterebra* (Deyrup 1990). However, it is possible to address some broader patterns for these flies in Florida. Although the biogeography of the genus has not been studied quantitatively (e.g., species/area relationships), the number of *Cuterebra* species (five) occurring in Florida appears comparable to that in certain other states of similar area (Illinois and Washington; species distributions from Sabrosky (1986)). In addition, Florida is inhabited by members of all four of the *Cuterebra* groups. The state contains each of the species chosen by Sabrosky (1986) to name these groups, as well as *C. emasculator*, which is in the '*fontinella*' group. Thus, Florida does not appear to be either depauperate or unusually rich in its total number of *Cuterebra* species or in representatives of Sabrosky's (1986) four *Cuterebra* groups. However, before definitive conclusions can be reached regarding *Cuterebra* species diversity within Florida, the effects of habitat heterogeneity, host species diversity, historical influences, and other relevant biogeographic factors must be investigated for the entire genus.

Regional affinities of the indigenous entomofauna of Florida are diverse. In many cases these reflect relationships to taxa in other areas of the southeastern US, but for some groups there are affinities to taxa in southwestern North America or in the Caribbean region (Frank 1986; Peck 1989; Choate 1990; Deyrup 1990). The five species of *Cuterebra* occurring in Florida are all Nearctic temperate zone species with eastern distributions, but three (*C. americana*, *C. buccata,* and *C. fontinella*) range very broadly into western North America. In contrast, *C. emasculator* is found from just west of the Mississippi River eastward to the Atlantic Ocean, and *C. cuniculi* is the

most narrowly distributed, apparently occurring only in southern Georgia and in Florida (Sabrosky 1986). Only one other species, *Cuterebra abdominalis* Swenk, a member of the '*cuniculi*' group, is present in the southeastern US. Although ranging broadly from the Midwest to the Atlantic coast, this species apparently does not occur in Florida. Thus, there are no precinctive species of *Cuterebra* in Florida (although *C. cuniculi* comes close to being in this category) and there appear to be no Caribbean ties for the Florida species of this genus. In addition, Neotropical species in other cuterebrine genera are absent from Florida, despite the subtropical climate in the southern part of the state (Henry et al. 1994).

There appear to be several vacant niches for *Cuterebra* species in Florida, in terms of the presence of indigenous rodent species that apparently seldom if ever serve as hosts for flies in this genus. It appears that 11 of the 17 (65%) native rodent species within Florida fall into this 'vacant niche' category (note that for these numbers, the various subspecies are not considered separately): *C. canadensis, G. pinetis*, *G. volans, M. pennsylvanicus*, *M. pinetorum*, *N. alleni*, *O. palustris*, *P. polionotus*, *R. humulis*, *S. hispidus,* and *T. striatus*. None of these species are restricted to Florida (although some of the subspecies are), and most of them appear to show little or no infestation by *Cuterebra* larvae outside the state as well. Of these species, apparently only *M. pennsylvanicus* and *T. striatus* are typical hosts of *Cuterebra* larvae outside Florida. It is likely that further study will demonstrate that individuals of both of these species serve as hosts for *Cuterebra* larvae within Florida because species that typically parasitize these rodents elsewhere (*C. fontinella* and *C. emasculator*, respectively) are present in the state. Thus, although additional research on host use within Florida, as well as comparative studies of other areas of North America, are required before a definitive conclusion can be reached, Florida does not appear to be exceptional in its apparently unutilized, potential host species among its indigenous rodents. Indeed, apparently the only unique aspect of the association between *Cuterebra* species and their typical host species in Florida is the parasitization of individuals of the Florida mouse (*P. floridana*), which apparently occurs only in the state, by larvae of an unidentified species of *Cuterebra* (Layne 1963; probably *C. fontinella*).

In conclusion, there are many unanswered questions about *Cuterebra*/ host species associations in Florida and elsewhere. In addition to the need to better understand these flies' biology, such as their typical and atypical host species, geographic ranges, and phenologies. Questions such as what factors determine the suitability of rodents and lagomorphs to serve as hosts, both between and within these orders, as well as in comparison with mammals in other orders, and what are the effects of larval infestation on the performance of individual hosts and host species population dynamics, remain to be answered. For example, in Florida there are several 'at-risk' (endangered, threatened, or of special concern) species and subspecies of rodents and a lagomorph (Florida Fish and Wildlife Conservation Commission 2004b) that might be affected by *Cuterebra* larval infestation, but even the most basic data on prevalence and intensity of parasitization within these populations are apparently lacking; similar situations occur in certain other states as well (Slansky & Kenyon 2003). Throughout North America, domestic felines with outdoor access can become infested with *Cuterebra* larvae (F. S., unpublished manuscript). Unlike with most other hosts, such occurrences can be fatal to the cats (Glass et al. 1998), and yet information as basic as which species of *Cuterebra* are involved in these cases is not available. Thus, it would seem that additional research on *Cuterebra* and host associations both within and outside Florida is well justified.

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