

Full Length Research Paper

Parasitism of *Cuterebra* (Diptera: Oestridae) on rodents of islands of the Gulf of California, Mexico

Arnaud, G.^{1*}, Rodríguez-Moreno, A.², Cordero-Tapia, A.¹ and Sandoval, S.¹

¹Centro de Investigaciones Biológicas del Noroeste, Av. Instituto Politécnico Nacional 195, Col. Playa Palo de Santa Rita Sur, La Paz, Baja California Sur, México 23096.

²Instituto de Biología, Universidad Nacional Autónoma de México.

Received 29 March, 2016; Accepted 26 July, 2016

The genus, *Cuterebra* is an obligate dermal parasite of New World mammals that can cause problems with rodent reproduction. 2812 rodents of nine species from nine Gulf of California Islands were sampled for the presence of *Cuterebra* sp. Only two species of rodents were parasitized by *Cuterebra* sp. on two islands (Montserrat and Danzante): the canyon mouse, *Peromyscus caniceps* (n = 261) with a prevalence of 17.97% and the white-footed woodrat, *Neotoma bryanti* (n = 4) with a prevalence of 7.5%. The presence of a single parasite per individual was common (\bar{x} = 78.5%). Since *P. caniceps* is listed by the Mexican government as a conservation at risk species, the parasitism of *Cuterebra* sp. represents a potential risk to the viability of this endemic rodent population. This is the first record of *Cuterebra* sp. as parasite of rodents in the Gulf of California Islands, and *P. caniceps* represents a new host record.

Key words: Bot fly, *Peromyscus caniceps*, *Neotoma bryanti*, Monserrat Island.

INTRODUCTION

In the Gulf of California, there are more than 150 islands, 19 of which have native rodents (Lawlor et al., 2002). Over 30 species are represented, of which 16 are endemic (Alvarez-Castañeda and Patton, 1999). Many species are considered by the Mexican government to be rare, threatened and endangered (SEMARNAT, 2010). Small mammals such as members of the Muridae and Cricetidae families often occur in large numbers and play an important role in maintaining ecosystems (Dickman,

1999). On islands, these populations are vulnerable to predation, habitat modifications, and parasites that cause disease.

Little is known about parasites affecting rodents of these islands. Parasite proliferation in these species could cause dramatic effects on population size, possibly even extermination. The genus *Cuterebra* includes obligate dermal parasites of New World mammals, especially rodents and lagomorphs (Sabrosky, 1986;

*Corresponding author. E-mail: garnaud04@cibnor.mx.

Pape, 2001). Bot flies can cause parasitic castration preventing the development of the testicles in sub-adult males (Payne and Cosgrove, 1966; Tim and Cook, 1979; Cheng, 1986), which is particularly serious for endemic species of restricted distribution. The *Cuterebra* sp. females do not directly oviposit eggs onto the host. Instead, the females place the eggs on soil near rodent burrows. These eggs then become attached to the rodents when they walk over the site (Catts, 1982; Baird, 1997). Hatching is stimulated by body heat and enter the host through openings (mouth, nose, eyes or anus) (Hunter and Webster, 1973; Gringrich, 1981; Catts, 1982; Slansky, 2006). When the maggots complete their development in the host, the larvae exit through the skin and continue the pupal stage in the soil (Catts, 1982; Wood, 1987).

This is the first record on parasitism of *Cuterebra* sp. in rodent populations in the Gulf of California Islands, which is part of a Natural Protected Area called Islands of Gulf of California where some human activities, such as tourism and fishing camps are permitted.

MATERIALS AND METHODS

Nine islands of the Gulf of California were surveyed from 2000 to 2010 (Figure 1). These islands are uninhabited, arid with sarcocaulous vegetation (Shreve, 1951). Trapping rodents with Sherman traps was performed in three localities per island with 50-66 traps. Transects of 50 Sherman traps with 10 m intervals between traps and one hectare grid with 66 traps were established.

Trapping was performed for two or three consecutive nights. Seven islands (El Muerto, Tortuga, Coronados, Danzante, Monserrat, Santa Catalina, and San Francisco) were surveyed four times a year (May, August, October and December), and two (Santa Cruz and Espiritu Santo), twice (June and September) a year. Each animal captured was examined, recording age, sex and presence or absence of larvae and their number. They were subsequently released to the same site.

Statistical analyzes as nonparametric tests (Xi-square) were applied to see if there was a relationship between parasitized mice and sex, either by month, year, or sampling site. ANOVA tests were also applied to compare the two sampling sites in Monserrat Island, as this test is a generalization of contrast equality of averages for two independent samples. Statistical analysis was performed in Matlab R2011a software.

RESULTS

A total of 2812 rodents were caught, representing nine species. *Peromyscus caniceps* was the most abundant with 1452 individuals (51.9% of total). Only two species of rodent were parasitized by *Cuterebra* sp. on two islands (Monserrat and Danzante): the canyon mouse, *P. caniceps* (n = 261), and the white-footed woodrat, *Neotoma bryanti* (n = 4). No warbles were found on rodents from Muerto Island, *P. maniculatus* (n = 40);

Tortuga Island, *P. dickey* (n = 30); Coronados Island, *Chaetodipus spinatus* (n = 450) and *P. pseudocrinitus* (n = 417); Danzante Island, *C. spinatus* (n = 50) and *N. bryanti* (n = 37); Monserrat Island, *P. caniceps* (n = 1191); Santa Catalina Island, *Peromyscus slevini* (n = 40); Santa Cruz Island, *Peromyscus sejugis* (n = 150); San Francisco Island, *C. spinatus* (n = 50) and *N. bryanti* (n = 25) and Espiritu Santo Island, *C. spinatus* (n = 30), *P. eremicus* (n = 30) and *N. bryanti* (n = 3).

Peromyscus caniceps, Monserrat Island

A total of 1452 specimens of canyon mouse were captured from 2001-2003 trapping, of which 261 were parasitized (adults and sub-adults) with a prevalence of 17.97%. Bot fly larvae were found to parasitize from May to November. The number of rodents varied throughout the year at the two trapping sites (rocky and scrub plain habitats), with a maximum of 170 individuals (August 2002), and minimum of 36 individuals (October 2003) (Table 1).

In the rocky plain habitat from Monserrat Island, 797 canyon mice were caught, of which 149 were parasitized with a prevalence of 18.69%; 80 were females with a prevalence of 10.03% and 69 were male with a prevalence of 8.65%. In the scrub plain habitat, 655 rodents were captured, of which 112 were parasitized with a prevalence of 17.09%; 68 were male with a prevalence of 10.38%, and 44 were females with a prevalence of 6.71% (Figure 2).

In both habitats, the presence of a single parasite per individual was common (79 and 78% of the infected mice in the scrub plain and rocky plain, respectively), followed by the presence of two parasites (15% in scrub plain and 13% in rocky plain). In the rocky plain, 1% of the captured mice were parasitized by five parasites per individual. The number of infected mice was analyzed and uninfected in females and males per month, year, and sampling site applying Xi-square test. The difference was not statistically significant; there was no relationship between sex and infected mice or by month, year, or sampling site.

Applying ANOVA test, per site and population showed no differences (Figure 3). Finally, the paired t-test was evaluated, and differences were obtained between females parasitized in rocky plains ($t = 2.09$; $p = 0.05$). Female rodents were mainly infected in the region of the base of the tail or in a single site on the back with a very small proportion having the parasite present in the inguinal region, causing displacement of the vagina disabling the copula. In the males, bot fly larvae were most frequently found in the inguinal region, followed by the dorsum and base of the tail.

Table 1. Number and prevalence percentage of parasitized rodents by *Cuterebra* sp. in relation to sex in rocky and shrub plains, in Monserrat Island.

Sampling	Rocky plains				
	No. caught	No. parasitized	Prevalence (%)	Males parasitized	Females parasitized
May 2001	165	27	16.36	12	15
Aug 2001	82	0	0	0	0
Dec 2001	68	34	50	13	21
May 2002	61	21	36.36	13	8
Aug 2002	170	0	0	0	0
Dec 2002	55	20	36.36	7	13
May 2003	111	32	28.82	14	18
Oct 2003	25	0	0	0	0
Dec 2003	60	15	25	10	5
Totals	797	149	18.69	69	80

	Shrub plains				
	No. caught	No. parasitized	Prevalence (%)	Males parasitized	Females parasitized
May 2001	99	15	15.15	10	5
Aug 2001	82	0	0	0	0
Dec 2001	59	21	35.59	15	6
May 2002	57	21	36.84	18	3
Aug 2002	135	0	0	0	0
Dec 2002	61	11	18.03	5	6
May 2003	77	33	42.85	14	19
Oct 2003	36	0	0	0	0
Dec 2003	49	11	22.44	6	5
Totals	655	112	17.09	68	44

Neotoma bryanti latirostra (*N. lepida latirostra*), Danzante Island

Forty adult woodrats were captured in 2001, of which 3 were found to be parasitized by bot flies, showing a prevalence of 7.5%. A single larvae of *Cuterebra* infected adult woodrats in March (1 male and 1 female) and November (1 female); the bot flies were located in the abdominal region. Parasitized hosts were collected only from two canyons on the island, and these woodrats were found to be living in colony densities of 0.13 and 0.34 ind/ha. Although, *C. spinatus soersus* was also captured in abundant numbers on Danzante Island, none were parasitized by *Cuterebra* sp. larvae.

DISCUSSION

This study reports the first record of *Cuterebra* sp. Larvae in *P. caniceps*. The bot fly on *N. lepida* had been reported

(Verts and Carraway, 2002) but not from an island of the Gulf of California. The presence of bot flies in rodents from Monserrat and Danzante islands, which are separated by 20 km, were during two different infestation periods (wet and dry season). Whole year presence of these parasites has been reported in other rodent species such as *P. leucopus* (Sillman, 1956; Wecker, 1962; Layne, 1963; Cramer and Cameron, 2006), *P. difficilis* (Galindo-Leal, 1997), and *Proechimys semispinosus* (Adler et al, 2003). Another case was found only in the wet season in five rodent species from Panamá (Bermudez et al., 2010).

The prevalence of parasitism on *P. caniceps* is in contrasts with other studies from New Mexico and Canada where 3.1% on *P. truei* and 1% on *P. leucopus* (Wilson et al., 1997) while 2.3% infestation on *P. maniculatus* (Bowman, 2000) were found. Nevertheless, infestation levels can vary from 0 to 82% on different species of *Peromyscus* (Burt, 1940; Wecker, 1962; Brown, 1965; Timm and Cook, 1979; Kollar, 1995;

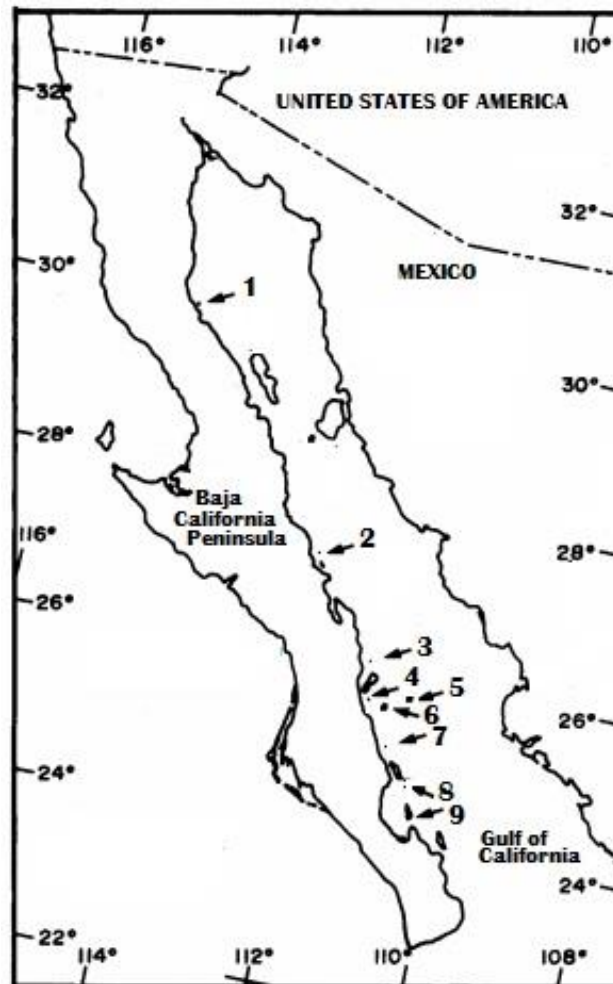


Figure 1. Gulf of California islands where rodents were sampled. 1- Muerto Island, 2- Tortuga Island, 3- Coronados Island, 4- Danzante Island, 5- Santa Catalina Island, 6- Monserrat Island, 7- Santa Cruz Island, 8- San Francisco Island and 9- Espiritu Santo Island.

Galindo-Leal, 1997; Barko, 2003; Hayes et al., 2015).

Parasitism prevalence in rocky and shrub habitats of the Montserrat Island (18.69 and 17.09%) may relate to the high density of rodents, environmental differences in relation to other regions, as well as differences in the density of fly larvae present on the island. The statistics analysis showed no differences in different seasons. The presence of the parasite and its interaction with male mice were not found. But in females, differences were found, giving a greater number of records to the rocky plain ecosystem. That zoonosis problem is low because there was no difference in general between animals that were parasitized and non-parasitized, only in the case of females in rocky plains.

The 7.5% prevalence of *Cuterebra* on *N. bryanti* from Danzante Island was lower than 18% reported from Utah on *N. lepida* (Stones and Hayward, 1968). Any difference between parasitism among sexes, has been reported (Dalmat, 1943; Test and Test, 1943; Wecker, 1962; Scholten, 1965; Childs and Cosgrove, 1966; Dunaway et al., 1967; Miller and Getz, 1969; Galindo-Leal, 1997), although other studies have found differences in relation to sex (Sealander, 1961; Goertz, 1966; Whitaker, 1968; Timm and Cook, 1979; Catts, 1982). Moreover, Barko (2003) reported a significant difference between sexes in one year in Illinois, but in the following year these differences were not observed. Timm and Cook (1979) suggested *Cuterebra* sp. larvae do not discriminate

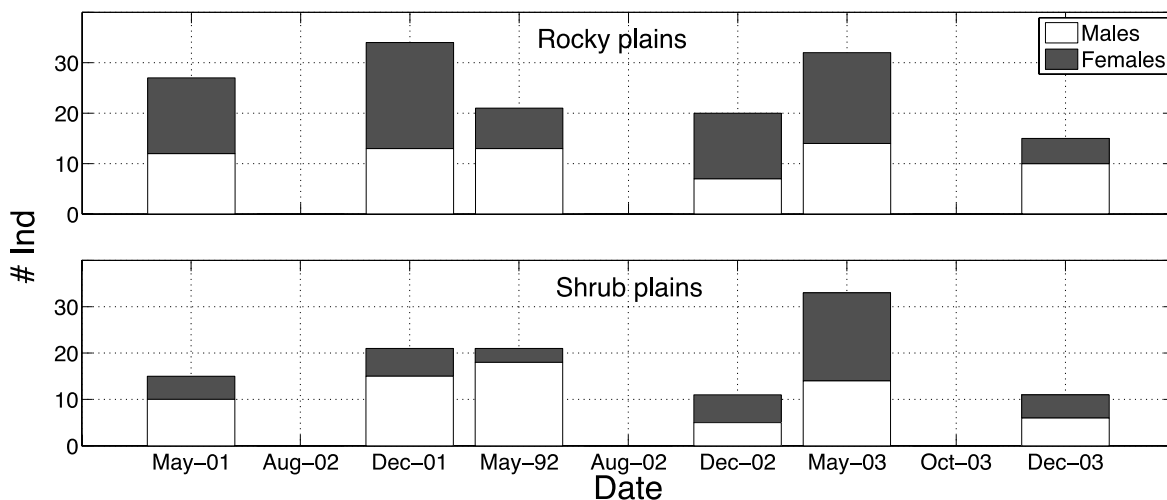


Figure 2. Number of *Peromyscus caniceps* parasitized or non-parasitized in relation to sex in rocky and shrub plains in Monserrat Island.

between host sex but simply parasitize the first mouse they encounter. It is possible that incidence of infection is the result of rodent displacements; thus having a greater opportunity for them to have contact with fly larvae (Stickel, 1968).

In the present study, it was found that the inguinal region of *P. caniceps* was the location where larvae caused the greatest injury to the host. In this region, larvae displaced the testicles and even caused castration by disabling the copula temporarily or permanently. These results are similar to what has been reported previously by Cheng (1986), who found that larva can cause death of the host.

Since *P. caniceps* is listed as a species with a conservation at risk by the Mexican government (category special protection) (SEMARNAT, 2010), the parasitism of *Cuterebra* sp. in the canyon mouse represents a potential risk to the viability of this rodent population. These effects will differ and depend, presumably, on the dwell time of the parasite, the period in which it appears, as well as of other existing endogenous and exogenous factors that occur during and after the infection period. Under conditions of environmental stress (droughts, food shortage) where the habitat cannot maintain a numerous populations of rodents, parasitism can be dangerous. Therefore, the presence of this parasite is a risk for *P. caniceps* on Montserrat Island.

CONCLUSIONS

This is the first record of *Cuterebra* as parasite of rodents

in the Gulf of California islands where *P. caniceps* represents a new host record. This study results indicated that parasitism by *Cuterebra* was independent of *P. caniceps* and *N. bryanti* density. It is possible that environmental factors and meteorological conditions of the islands were responsible for the lack of correlation between density and *Cuterebra* parasitism.

RECOMENDATIONS

The parasitism of *Cuterebra* represents a potential risk to the viability of *P. caniceps* because it is an endemic species. Thus, it is recommended to monitor this species to see if the prevalence of *Cuterebra* remains low. Further research is needed throughout the other islands in the Gulf of California to expand on the effects of weather and host populations on *Cuterebra* population dynamics.

Conflicts of interest

The authors declare that they have no conflicts of interest.

ACKNOWLEDGEMENTS

The authors thank Fondo Mexicano para la Conservación de la Naturaleza for providing financial support to carry out this study (A1-99/012 project); Parque Nacional Bahía de Loreto for their logistical support; and Diana Dorantes for the revision of the document in English.

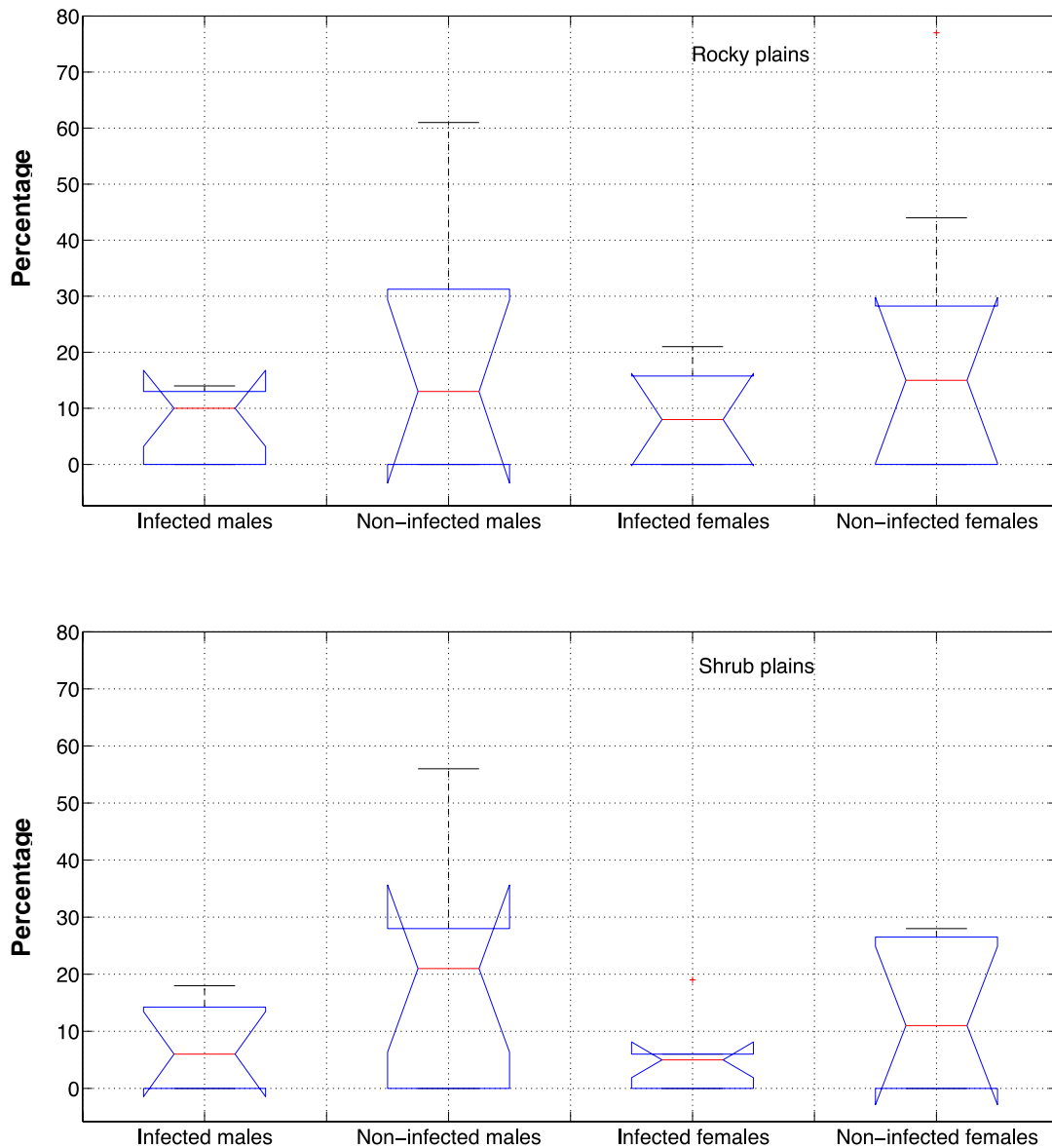


Figure 3. ANOVA test for the rocky and shrub plains habitats in Monserrat Island.

REFERENCES

Alvarez-Castañeda ST, Patton JL (1999). Mamíferos del Noroeste de México. Centro de Investigaciones Biológicas del Noroeste. México. 583p.

Adler G, Shannon D, Carbajal A (2003). Bots (Diptera: Oestridae) infesting a Neotropical forest rodents *Proechimys semispinosus* (Rodentia: Echimyidae) in Panama. *J. Parasitol.* 89:693-697.

Baird C (1977). Bionomics of *Cuterebra austeni* (Diptera: Cuterebridae) and its association with *Neotoma albigula* (Rodentia: Cricetidae) in the southwestern United States. *J. Med. Ent.* 34:690-695.

Barko VA (2003). Bot fly (*Cuterebra* sp) parasitism of White-footed mice (*Peromyscus leucopus*) in southern Illinois. *Trans. Ill. State Acad. Sci.* 96(2):99-105.

Bermudez SE, González P, Ávila M, Miranda R, Armién A, Armién B (2010). Parasitism of *Cuterebra* sp. (Diptera: Oestridae) on rodents of Central Panama. *Rev. Mex. Biol.* 81:57-60.

Brown LN (1965). Botfly parasitism in the brush mouse and whit-footed mouse in the Ozarks. *J. Parasitol.* 51:302-304.

Bowman J (2000). Forest components associated with parasitism of small mammals by botflies (*Cuterebra*). *Mammalia* 64:243-247.

Burt WH (1940). Territorial behavior and populations of some small mammals in southern Michigan. *Miscellaneous Publications Museum of Zoology, University of Michigan*, no. 45, University of Michigan press. pp. 1-58.

Catts EP (1982). Biology of New World bot flies: Cuterebridae. *Ann. Rev. Entomol.* 27:313-338.

Cheng CT (1986). *General Parasitology. Second Edition. Medical*

- University of South Carolina Charleston. Acad. Press Coll. Div. United States of America.
- Childs HE, Cosgrove GE (1966). A study of pathological conditions in wild rodents in radioactive areas. *Am. Midland Natur.* 76:309-324.
- Cramer MJ, Cameron GN (2006). Effects of Bot fly (*Cuterebra fontinella*) parasitism on a population of white-footed mice (*Peromyscus leucopus*). *J. Mamm.* 87(6):1103-1111.
- Dalmat HT (1943). A contribution to the knowledge of the rodent warble flies (Cuterebridae). *J. Parasitol.* 29:311-318.
- Dickman CR (1999). Rodent-ecosystem relationships: a review. In: Singleton GR, Hinds L, Leirs H, Zhang Z (eds). *Ecologically Based Rodent Management*. Australian Centre for International Agricultural Research, Canberra. pp. 113-133.
- Dunaway PB, Payne JA, Lewis LL, Story JD (1967). Incidence and effects of *Cuterebra* in *Peromyscus*. *J. Mamm.* 48(1):38-51.
- Galindo-Leal C (1997). Infestation of Rock Mice (*Peromyscus difficilis*) by bot flies: Ecological consequences of differences between sexes. *J. Mamm.* 78(3):900-907.
- Getz LL (1970). Bot fly infestations in *Microtus pennsylvanicus* in southern Wisconsin. *Am. Midland. Nat.* 84:187-197.
- Goertz JW (1966). Incidence of warbles in some Oklahoma rodents. *Am. Midland Nat.* 75:242-245.
- Gingrich R (1981). Migratory kinetics of *Cuterebra fontinella* (Diptera: Cuterebridae) in the with-footed mouse, *Peromyscus leucopus*. *J. Parasitol.* 67:398-402.
- Hayes SJ, Holzmüller EJ, Nielsen CK (2015). Bot fly (Cuterebrid) prevalence and intensity in Southern Illinois *Peromyscus* species and comparison to the literature. *Trans. Ill. State Acad. Sci.* 108:1-3.
- Hunter D, Webster JM (1973). Determination of the migratory route of botfly larvae, *Cuterebra grisea* (Diptera: Cuterebridae) in deer mice. *J. Parasitol.* 3:311-316.
- Kollar T (1995). Factors affecting distribution of Botflies (Diptera: Oestroidea) on islands in Lake Barkley, Kentucky and Tennessee. *J. Entomol. Sci.* 30:513-518.
- Lawlor TE, Hafner DJ, Stapp P, Riddle BR, Alvarez-Castañeda ST (2002). The Mammals. In: Case TJ, Cody ML, Ezcurra E (eds.), *A new Island Biogeography of the Sea Cortés*. Oxford University Press. pp. 326-361.
- Layne JN (1963). A study of the parasites of the Florida mouse, *Peromyscus floridanus* in relation to host and environmental factors. *Tulane Stud. Zool.* 11:1-27.
- Miller DH, Getz LL (1969). Botfly Infections in a population of *Peromyscus leucopus*. *J. Mamm.* 50(2):277-283.
- Pape T (2001). Phylogeny of Oestridae (Insecta: Diptera). *Syst. Entomol.* 26:133-171.
- Payne JA, Cosgrove GE (1966). Tissue change following *Cuterebra* infestation in rodents. *Am. Midland Nat.* 75:205-213.
- Sabrosky CW (1986). North American Species of *Cuterebra*, the rabbit and rodent bot flies (Diptera: Cuterebridae). *Entomological Society of America. Thomas S. Found. Monog. Coll. Park. MD.* 240p.
- Scholten TH (1965). The morphology, life history and host-parasite relations of *Cuterebra angustifrons* Dalmat. Ph.D. dissertation, U. West. Ontario, London, Ontario, Canada.
- SEMARNAT (2010). Secretaría de Medio Ambiente y Recursos Naturales. Norma Oficial Mexicana NOM-059- SEMARNAT-2010. Especies nativas de México de flora y fauna silvestres-Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio-Lista de especies en riesgo. *Diario Oficial de la Federación (DOF)*, Seg. Secc.
- Sealander JA (1961). Hematological values in deer mice in relation to bot-fly infection. *J. Mamm.* 42:47-60.
- Sillman EJ (1956). Further laboratory and field observations on the ecology of some Ontario Cuterebridae (Diptera), in particular, *Cuterebra angustifrons*. *Ann. Rep. Entomol. Soc. Ont.* 87:28-30.
- Shreve F (1951). The vegetation of the Sonoran Desert. *Carnegie Institution of Washington*. pp. 1-1192.
- Slansky F (2006). *Cuterebra* Bot fly (Diptera: Oestroidea) and their host indigenous host and potential host in Florida. *Flor. Entomol.* 89:150-152.
- Stickel LF (1968). Home range and travels. In: *Biology of Peromyscus (Rodentia)* (King JA, ed.). Special Pub. Am. Soc. Mamm. 2:1-593.
- Stones RC, Hayward L (1968). Natural history of the desert woodrat, *Neotoma lepida*. *Am. Midland Nat.* 80(2):458-476.
- Test FH, Test AR (1943). Incidence of dipteran parasites in population of small mammals. *J. Mamm.* 24:506-508.
- Timm RM, Cook EF (1979). The effect of bot fly larvae on reproduction in white-footed mice, *Peromyscus leucopus*. *Am. Midland. Nat.* 101:211-217.
- Verts BJ, Carraway LN (2002). *Neotoma lepida*. *Mamm. Sp.* 699:1-12.
- Wecker SC (1962). The effects of Bot Fly parasitism on a local population of the White-footed mouse. *Ecology* 43(3):561-565.
- Whitaker JO Jr. (1968). Parasites. pp. 254-311. In: King J. A. (ed.). *Biology of Peromyscus (Rodentia)*. Special Pub. Am. Soc. Mamm. 2:1-593.
- Wilson W, Hnida J, Duszynski D (1997). Parasites of mammals on the Sevilleta National Refuge, Socorro, New Mexico: *Cuterebra austeni* and *C. neomexicana* (Diptera: Oestridae) from *Neotoma* and *Peromyscus* (Rodenti: Muridae), 1991-1994. *J. Med. Entomol.* 34:359-367.
- Wood DM (1987). Oestridae. In: McAlpine JF (eds). *Manual of Nearctic Diptera*. (2):1147-1158. Ottawa.