NOTES

FOODS OF THE PALLID BAT, *ANTROZOUS PALLIDUS* (CHIROPTERA: VESPERTILIONIDAE), IN THE CHIHUAHUAN DESERT OF WESTERN TEXAS

PAUL A. LENHART,* VICENTE MATA-SILVA, AND JERRY D. JOHNSON

Department of Entomology, Texas A&M University, 2475 TAMU, College Station, TX 77843 (PAL)
Department of Biological Sciences, University of Texas at El Paso, El Paso, TX 79968 (VM, JDJ)
**Correspondent: palenhart@neo.tamu.edu*

ABSTRACT—Pallid bats, *Antrozous pallidus,* glean prey off the ground or from vegetation. During 27 March-19 November 2004, culled parts of prey were collected from under a night roost on Indio Mountains Research Station, Hudspeth County, Texas. Adjacent pitfall traps were monitored concurrently to determine species richness and seasonal abundance of potential prey. Prey representing 44 morphospecies from 4 classes, 13 orders, 25 families, and 34 genera were recovered and identified. Of the identified morphospecies, 29 were unrecorded previously in diet of the pallid bat. Orthopterans were the highest percentage of prey (44.1%), followed by coleopterans (26.8%), and solifugids (16.2%), but most taxa were represented by <4% of the total. Conclusions are that arthropods are the primary food source, but a wide variety of species are consumed, there is occasional predation on vertebrates (three species of lizards), there are statistical differences between amount of prey eaten and abundance of prey in the same geographic area indicating selective foraging behavior, there are seasonal dietary shifts associated with common prey items, and there is geographic variation in diet of pallid bats when compared to studies from other localities within its geographic range.

RESUMEN—Los murciélagos pálidos, *Antrozous pallidus,* recolectan presas en el suelo o en la vegetación. Del 27 de marzo al 19 de noviembre del 2004, restos de presas fueron colectados bajo un dormidero nocturno localizado en Indio Mountain Research Station, condado de Hudspeth, Texas. Trampas de caída adyacentes fueron monitoreadas al mismo tiempo para determinar la riqueza específica y la abundancia estacional de las presas potenciales. Cuarenta y cuatro morfoespecies de presas de 4 clases, 13 órdenes, 25 familias, y 34 géneros fueron recuperadas e identificadas. De éstas, 29 fueron nuevos registros para la dieta del murciélago pálido. Los ortópteros representaron el más alto porcentaje de las presas (44.1%), seguidos por coleópteros (26.8%), y solífugos (16.2%), aunque la mayoría de los taxa fue representada por <4% del total. Se concluye que los artrópodos son la principal fuente de alimento, pero una gran variedad de especies es consumida; existe una depredación ocasional de vertebrados (tres especies de lagartijas); existen diferencias significativas entre la cantidad de especies consumidas y la abundancia de presas en el área de estudio, sugiriendo una conducta de forrajeo selectiva; existen cambios estacionales en la dieta con respecto a las presas más comunes; y existe una variación geográfica en la dieta del murciélago pálido al compararla con otros estudios de otras localidades dentro de su distibución geográfica.

Diets of bats can vary greatly (Sparks and Valdez, 2003). The pallid bat, *Antrozous pallidus,* is a prime example because its diet varies geographically (Ross, 1967; Johnston and Fenton, 2001) and seasonally (Johnston and Fenton, 2001), and includes vertebrates (Engler, 1943; O'Shea and Vaughan, 1977; Bell, 1982) and plant material (Howell, 1980; Herrera et al., 1993).

Antrozous pallidus is common in arid and semi-arid regions of western North America (Orr, 1954; Hermanson and O'Shea, 1983; Adams, 2003). Its feeding behavior is of particular interest because the species feeds on terrestrial invertebrates and small vertebrates taken from the ground or from low vegetation, which often are carried to elevated feeding roosts where culled parts of prey are dropped.

The study reported herein was conducted near the headquarters of the University of Texas at El Paso Indio Mountains Research Station in extreme southeastern Hudspeth County, Texas (30°46′38″N, 105°00′58″W). The local area is composed of rocky terrain with mountainous outcrops cut by deep arroyos and alluvial fans; elevations are ca. 900-1,600 m. Vegetation is Chihuahuan Desert scrub interspaced with desert grasses of various species and Rio Grande Valley flora (J. D. Johnson, http://research.utep.edu/indio/; R. D. Worthington et al., in litt.). Sources of surface water on or near Indio Mountains Research Station are restricted to nearby Squaw Spring (ca. 3.2 km N headquarters), a few isolated ephemeral stock tanks, temporary arroyo pools, and the Rio Grande, which is located ca. 10 km SW of the headquarters. The headquarters complex of Indio Mountains Research Station includes a stone bathroom facility, the entrance of which serves as a night roost for pallid bats. As many as 83 pallid bats have been observed at the night roost, which consists of a rock wall and adjacent window screen.

We examined and classified culled parts of prey that were dropped from the night roost onto the floor at the entrance of the bathroom. On 26 occasions, during 27 March–19 November 2004, we collected culled body parts and placed them in plastic bags for later analysis. We sorted body parts from each sample into lots containing the lowest identifiable taxonomic unit (e.g., family, genus, or species). We identified taxa using stereoscopic microscopes and by comparing body parts with whole specimens in collections of the Laboratory for Environmental Biology, Centennial Museum, University of Texas at El Paso; voucher samples examined for this study also have been deposited there (UTEP 8461).

We considered separately identified taxa to be morphospecies because they were based on differences in morphological characters of culled body parts. We established numbers of each morphospecies using an estimate of the minimum number possible based on the most numerous appendage or body part found in each sample. For example, numbers of tips of chelicerae for solifugids were divided by four and numbers of cicadids were estimated by counting the number of right or left wings. Concurrently, we examined 51 pitfall traps (19-L buckets) arranged in eight transects in the vicinity of the night roost to determine species richness and seasonal abundance of potential prey items. We used a Z-test ($\alpha = 0.05$) to test for significance of differences between proportion of prey items of bats and potential sources of food in the pitfall traps. We made comparisons of taxa at the level of taxonomic order because determination to this level was possible for all samples.

We recovered 44 morphospecies of prey from the culled animal parts, five of which were identified only to genus (Table 1), one to subfamily (Melolonthinae), eight to family, and one only to order (unknown families of moths). Members of 29 species, 10 families, and 1 order (Phasmida) had not been recorded previously in the diet of pallid bats (Table 1). At the level of taxonomic order, Orthoptera was the most frequently preyed upon taxon (44.1%), followed by Coleoptera (26.8%), Solifugae (16.2%), Lepidoptera (3.5%), Phasmida (3%), and Hemiptera (2.7%); most orders were represented by <1% of the total (Table 1).

The most common species of prey was the robust toad hopper, *Phrynotettix robustus*, making up 20.1% of the total number of prey taken (87 individuals estimated). *Phrynotettix robustus* was not recorded in previous studies, so it is most likely a local replacement for ground-dwelling Jerusalem crickets, *Stenopematus*, which made up a majority of the diet of pallid bats in populations from Monterey County, California (Hatt, 1923), Marin County, California (Johnston and Fenton, 2001), Pima, Cochise, and Pinal counties, Arizona (Ross, 1967), and Brewster County, Texas (Easterla and Whitaker, 1972). Jerusalem crickets are not known from Indio Mountains Research Station (Weissman, 2001).

Prey were terrestrial forms, with the exception of nocturnal flying coleopterans (all reported families except Tenebrionidae) and lepidopterans, and members of the semi-arboreal Orthoptera, Phasmida, and Hemiptera. All were most likely taken from the ground or from shrubs where they were resting, or by being forced to the ground during flight by pallid bats, as observed by Johnston and Fenton (2001). The strong-flying sphingid moths (*Myles lineata* and *Manduca quinquimaculata*) probably were captured on the ground before flying while warming up their wing muscles by a series of rapid vibrations. We commonly observed this behavior on night walks within the study area; an activity making those moths vulnerable because pallid

TABLE 1—Prey consumed by the pallid bat (*Antrozous pallidus*) at the Indio Mountains Research Station, Hudspeth County, Texas, during 27 March-19 November 2004, based on examination of culled body parts found under a night roost. Total number of individuals for each taxon is followed by percentage in parentheses.

Taxon	Total (%)
Insecta	352 (81.3)
Coleoptera	116 (26.8)
Buprestidae	
Hippomelas caelata[a]	7 (1.6)
Carabidae	
Calosoma peregrinator[a]	11 (2.5)
Cerambycidae	
Oncideres rhodisticta	4 (0.9)
Unknown genera	16 (3.7)
Curculionidae[b]	
Unknown genus	4 (0.9)
Geotrupidae[b]	
Unknown genus	4 (0.9)
Scarabaeidae	
Tomarus	1 (0.2)
Melolonthinae	39 (9.0)
Unknown genera	4 (0.9)
Tenebrionidae	
Centrioptera texana[b]	6 (1.4)
Embophin contestum[b]	4 (0.9)
Glyptasida sardida[b]	7 (1.6)
Megasida obliterata[b]	12 (2.8)
Unknown genus	1 (0.2)
Dichyoptera	1 (0.2)
Polyphagidae[b]	
Arenivega[b]	1 (0.2)
Diptera	1 (0.2)
Oesteridae[b]	
Cuterebra[b]	1 (0.2)
Hemiptera	12 (2.7)
Coreidae	
Acanthocephala thomasi[a]	1 (0.2)
Cicadidae	
Cacama valvata[b]	9 (2.1)
Tibicen townsendii[b]	2 (0.5)
Hymenoptera	3 (0.7)
Formicidae[b]	
Aphaenogaster cockerelli (alate queen)[b]	1 (0.2)
Vespidae[b]	
Polistes[b]	2 (0.5)
Lepidoptera	15 (3.5)
Unknown families	9 (2.1)
Sphingidae	
Hyles lineata	3 (0.7)
Manduca quinquimaculata	3 (0.7)
Orthoptera	191 (44.1)
Acrididae	
Acrolophitus maculipennis[b]	1 (0.2)
Bootetix argentatus[b]	2 (0.5)
Cibolacris parviceps[b]	2 (0.5)
Mermiria texana[b]	5 (1.2)
Schistocerca nitens[a]	24 (5.5)
Trimerotropis pallidipennis[a]	5 (1.2)
Unknown genera	7 (1.6)
Gryllidae	
Gryllus	8 (1.8)
Romaleidae[b]	
Phrynotettix robustus[b]	87 (20.1)
Tettigoniidae	
Capnobotes fuliginosus	9 (2.1)
Insara elegans[b]	2 (0.5)
Pedidectes tinkhami[b]	6 (1.4)
Unknown genera	33 (7.5)
Phasmida[b]	13 (3.0)
Heteronemiidae[b]	
Diapheromera covilleae[b]	11 (2.5)
Pseudosermyle straminea[b]	2 (0.5)
Chilopoda	3 (0.7)
Scolopendramorpha[b]	3 (0.7)
Scolopendridae[b]	
Scolopendra polymorpha[b]	3 (0.7)
Arachnida	74 (17.2)
Araneae	2 (0.5)
Lycosidae	
Unknown genus	2 (0.5)
Scorpionida	2 (0.5)
Buthidae[b]	
Centruroides vittatus[b]	2 (0.5)
Solifugae	70 (16.2)
Eremobatidae	70 (16.2)
Reptilia	4 (0.9)
Squamata	4 (0.9)
Eublepharidae	
Coleonyx brevis[a]	1 (0.2)
Phrynosomatidae	
Cophosaurus texanus[b]	2 (0.5)
Urosaurus ornatus	1 (0.2)

[a] This genus was recorded as prey previously, but not the species reported herein (Hatt, 1923; Borell, 1942; Orr, 1954; Herreid, 1961; Ross, 1967; Easterla and Whitaker, 1972; O'Shea and Vaughan, 1977; Bell, 1982; Johnston and Fenton, 2001).

[b] New record of prey consumed by pallid bats.

bats predominantly locate prey based on sound rather than echolocation (Bell, 1982).

About 30 tenebrionid beetles were taken by bats during September–November. Of the 34 elytral fragments present, 22 consisted of only postero-dorsal portions of the wing cover. This

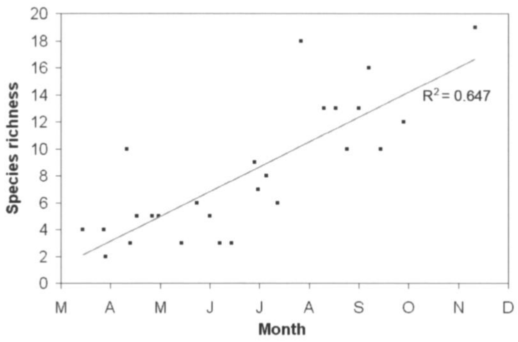

FIG. 1—Species richness of prey taken by the pallid bat (*Antrozous pallidus*) during March–November 2004 under a night roost at the Indio Mountains Research Station, Hudspeth County, Texas. The R^2-value and best-fit line of linear regression are included.

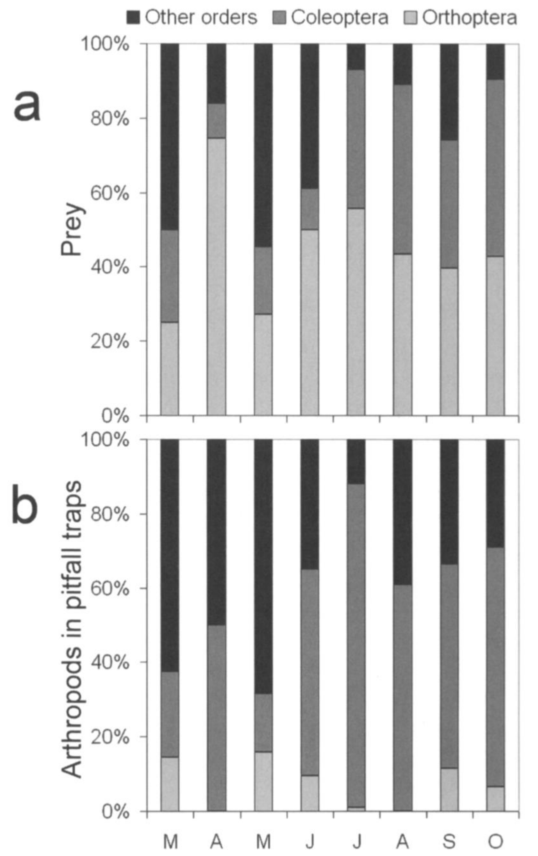

FIG. 2—a) Percentages of orders of arthropods preyed on by the pallid bat (*Antrozous pallidus*) as indicated by examining culled body parts dropped at the night roost and b) percentages of orders of arthropods captured in pitfall traps near the night roost at the Indio Mountains Research Station, Hudspeth County, Texas, during March–October 2004. Solifugids were not included in frequency analyses because of their ability to escape from pitfall traps.

indicated that *A. pallidus* can manipulate its prey efficiently enough to avoid ingesting hard and minimally nutritious chitinous pieces. This manipulation technique was observed on many occasions when bats would perch and face the wall or screen, and then make baskets with their tail membranes that collected shell fragments subsequently dropped after a second inspection for edible parts. It also is possible that *A. pallidus* has a specialized feeding procedure for tenebrionid beetles used to avoid noxious benzoquinines, similar to that exhibited by the southern grasshopper mouse *Onychomys torridus* (Eisner and Meinwald, 1966). However, this hypothesis was not supported in this study because abdominal tips were consumed in all but one culled fragment, and also by the apparent avoidance of individual *Eleodes*, a tenebrionid genus known for chemical defense (Eisner and Meinwald, 1966). *Eleodes* was common in our samples from pitfall traps.

Actual items in the diet and potential prey varied seasonally, as species richness generally increased as the year progressed when more insects reached adult stages (Fig. 1). While adult cicadas (Hemiptera) of the species *Cacama valvata* and *Tibicen townsendii* emerged during May–July, they became a major component of the diet, indicating an opportunistic shift. In addition, 88.5% of Acrididae (n = 46) and Tettigoniidae (n = 50) where taken after June, and 92.3% (n = 13) of the two species of phasmids where taken after August when most individuals had reached maturity.

The overall abundance of certain arthropods found under the night roost differed from abundances of available ground-dwelling species found during surveys using pitfall traps (Fig. 2), which implies selective foraging (also shown by Johnston and Fenton, 2001). Differences in proportion of order-level abundances between prey and pitfall collections were significant for Orthoptera (Z = −15.219, P < 0.001) and Coleoptera (Z = 7.937, P < 0.001), which are the two most abundant groups of prey sampled in the study area. Solifugids were omitted from this analysis because they easily escape pitfall traps using the suctorial organs on their pedipalps (Cushing et al., 2005).

Johnston and Fenton (2001) asserted that analysis of culled parts alone creates a significant bias toward large prey items taken to night roosts, by missing smaller prey that are consumed whole or in flight. Another potential bias, concerning frequency of prey items found under the night roost, is the difference in number of bats using the roost on a nightly basis throughout the season. This bias would tend to increase species richness of prey in general, as well as the frequency of rarer species of prey when numbers of bats were higher. However, as stated before, frequency of rarer taxa generally is low (usually <4% of total). Both situations must be taken into consideration, so our study cannot assert that it included the complete diet or that it reflected completely accurate dietary frequencies for *A. pallidus* in the study area. Yet, in only one season of sampling, examination of culled parts recorded 29 species of prey not previously reported in the literature, including 10 families and the order Phasmida (Table 1).

With respect to vertebrates in the diet of *A. pallidus*, Engler (1943) reported that individuals fed in captivity on lizards (*Plestiodon skiltonianus* and *Coleonyx variegatus*) and a Brazilian free-tailed bat (*Tadarida brasiliensis*). More recently, O'Shea and Vaughan (1977) and Bell (1982) confirmed that *A. pallidus* consumed the horned lizard (*Phrynosoma hernandesi*; cited as *P. douglassi*) and a silky pocket mouse (*Perognathus flavus*), specifically in the desert grasslands in or near the northern Sonoran Desert (Arizona and New Mexico, respectively). Johnston and Fenton (2001) reported *A. pallidus* feeding on *C. variegatus* in Death Valley National Park, California (Mojave Desert), as well. Herein, we determined that in the northern Chihuahuan Desert, *A. pallidus* foraged on three species of lizards: Texas banded gecko (*Coleonyx brevis*), greater earless lizard (*Cophosaurus texanus*), and tree lizard (*Urosaurus ornatus*). It is interesting that pallid bats locate diurnal lizards during their nighttime hunting forays, as only *C. brevis* and *C. variegatus*, of the above listed five species associated with field observations are nocturnal. However, our experience with lizards at Indio Mountains Research Station has shown that many species of diurnal lizards can be found at night on open ground, presumably absorbing from rocks and soil heat captured during daylight hours.

Despite nine reports (Hatt, 1923; Borell, 1942; Orr, 1954; Herreid, 1961; Ross, 1967; Easterla and Whitaker, 1972; O'Shea and Vaughan, 1977; Bell, 1982; Johnston and Fenton, 2001), and information presented herein, on foods of *A. pallidus* from much of its geographic range in the United States, additional investigations are needed to complete the dietary picture of this widespread species. Evidence so far indicates that *A. pallidus* is proficient in using available food resources and that it can be both a food generalist, as indicated by the breadth of taxa consumed, but also takes advantage of numerical dominance of available food resources in its ecosystem on a temporal basis (an opportunistic shift).

We thank R. D. Worthington, W. P. Mackay, S. T. Dash, and A. F. Sanborn for assistance in identification of prey. We are grateful for the help and support in the field by J. P. Hobert, D. Lin, and H. Riveroll, Jr. We also express gratitude to M. Vargas for help with a literature search and M. Shpak for statistical advice. In addition, we thank R. Lenhart, C. López-González, and the anonymous reviewers for suggested improvements to this note.

Literature Cited

Adams, R. A. 2003. Bats of the Rocky Mountain West. University Press of Colorado, Boulder.

Bell, G. P. 1982. Behavioral and ecological aspects of gleaning by a desert insectivorous bat, *Antrozous pallidus* (Chiroptera: Vespertilionidae). Behavioral Ecology and Sociobiology 10:217–223.

Borell, A. E. 1942. Feeding habit of the pallid bat. Journal of Mammalogy 23:337.

Cushing, P. E., J. O. Brookhart, H. J. Kleebe, G. Zito, and P. Payne. 2005. The suctorial organ of the Solifugae (Arachnida, Solifugae). Arthropod Structure and Development 34:397–406.

Easterla, D. A., and J. O. Whittaker, Jr. 1972. Food habits of some bats from Big Bend National Park, Texas. Journal of Mammalogy 53:887–890.

Eisner, T., and J. Meinwald. 1966. Defensive secretions of arthropods. Science 153:1341–1350.

Engler, C. H. 1943. Carnivorous activities of big brown and pallid bat. Journal of Mammalogy 24:96–97.

Hatt, R. T. 1923. Food habits of the Pacific pallid bat. Journal of Mammalogy 4:260–261.

Hermanson, J. W., and T. J. O'Shea. 1983. *Antrozous pallidus*. Mammalian Species 213:1–8.

Herreid, C. F., II. 1961. Notes on the pallid bat in Texas. Southwestern Naturalist 6:13–20.

Herrera, L. G., T. H. Fleming, and J. S. Findley. 1993. Geographic variation in carbon composition of the pallid bat, *Antrozous pallidus*, and its dietary implications. Journal of Mammalogy 74:601–606.

HOWELL, D. J. 1980. Adaptive variation in diets of desert bats has implication for the evolution of feeding strategies. Journal of Mammalogy 61:730–733.

JOHNSTON, D. S., AND M. B. FENTON. 2001. Individual and population-level variability in diets of pallid bats (*Antrozous pallidus*). Journal of Mammalogy 82: 362–373.

ORR, R. T. 1954. Natural history of the pallid bat, *Antrozous pallidus* (Le Conte). Proceedings of the California Academy of Sciences 28:165–264.

O'SHEA, T. J., AND T. A. VAUGHAN. 1977. Nocturnal and seasonal activites of the pallid bat, *Antrozous pallidus*. Journal of Mammalogy 58:269–285.

ROSS, A. 1967. Ecological aspects of the food habits of insectivorous bats. Proceedings of the Western Foundation of Vertebrate Zoology 1:205–264.

SPARKS, D. W., AND E. W. VALDEZ. 2003. Food habits of *Nyctinomops macrotis* at a maternity roost in New Mexico, as indicated by analysis of guano. Southwestern Naturalist 48:132–135.

WEISSMAN, D. B. 2001. North and Central American Jerusalem crickets (Orthoptera: Stenopelmatidae): taxonomy, distribution, life cycle, ecology and related biology of the American species. Pages 57–72 in The biology of wetas, king crickets, and their allies (L. H. Field, editor). Centre for Agricultural Bioscience International, New York.

Submitted 28 March 2008. Accepted 10 May 2009. Associate Editor was Celia López-González.

CONSUMPTION OF EGGS OF THE ENDANGERED FOUNTAIN DARTER (*ETHEOSTOMA FONTICOLA*) BY NATIVE AND NONNATIVE SNAILS

C. T. PHILLIPS,* M. L. ALEXANDER, AND R. HOWARD

United States Fish and Wildlife Service, National Fish Hatchery and Technology Center, 500 East McCarty Lane, San Marcos, TX 78666 (CTP, MLA)

H. M. Freeman Aquatic Biology Center, Department of Biology, Texas State University–San Marcos, San Marcos, TX 78666 (RH)

**Correspondent: catherine_phillips@fws.gov*

ABSTRACT—We examined the percentage of consumption of eggs of the endangered fountain darter, *Etheostoma fonticola*, by native and nonnative snails from the San Marcos River, Hays County, Texas. Although all snails consumed eggs, non-native *Marisa cornuarietis* (Prosobranchia: Ampullaridae) and native *Helisoma anceps* (Pulmonata: Planorbidae) consumed a significantly greater percentage of eggs than non-native *Tarebia granifera* and *Melanoides tuberculatus* (Prosobranchia: Thiaridae) and the native *Physella virgata* (Pulmonata: Physidae). Dramatic increases in *M. cornuarietis* in the San Marcos and Comal springs may have an adverse affect on populations of fountain darters.

RESUMEN—Comparamos los porcentajes de huevos consumidos del pececito en peligro de extinción, *Etheostoma fonticola*, por caracoles nativos y no nativos del río San Marcos, condado de Hays, Texas. Aunque todos los caracoles consumieron huevos, el caracol no nativo, *Marisa cornuarietis* (Prosobranchia: Ampullaridae), y el caracol nativo, *Heliosoma anceps* (Pulmonata: Planorbidae), consumieron porcentajes significantamente mayores que los no nativos, *Tarebia granifera* y *Melanoides tuberculatus* (Prosobranchia: Thiaridae), y el nativo, *Physella virgata* (Pulmonata: Physidae). Aumentos dramáticos de *M. cornuarietis* en los manantiales San Marcos y Comal podrían afectar adversamente las poblaciones de *E. fonticola*.

The spring-fed San Marcos and Comal rivers of central Texas are home to a rich diversity of aquatic organisms including eight species on the federal list of threatened and endangered species. Exotic species of snails also have become abundant in the springs (Bowles and Bowles, 2001) and these snails have caused a decline in communities of native gastropods (Murray, 1971; Horne et al., 1992; Cauble, 1998). Two introduced species of snails, *Terebia granifera* and *Melanoides tuberculatus* (Prosobranchia: Thiaridae) were discovered in Bexar and Comal