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STATUS OF THE COMAL SPRINGS RIFFLE BEETLE

(Heterelmis comalensis Bosse, Tuff and Brown),

PECK's CAVE AMPHIPOD

(Stygobromus pecki Holsinger),

AND THE

COMAL SPRINGS DRYOPID BEETLE

(Stygoparnus comalensis Barr and Spangler)

FROM

CENTRAL TEXAS

SOUTHWEST TEXAS STATE UNIVERSITY

Status of the Comal Springs Riffle Beetle (Heterelmis comalensis Bosse, Tuff and Brown), Peck's Cave Amphipod (Stygobromus pecki Holsinger) and the Comal Springs Dryopid Beetle (Stygoparnus comalensis Barr and Spangler)

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SUMMARY

A status survey was conducted to determine the distributions of the Comal Springs riffle beetle, Heterelmis comalensis, Peck's cave amphipod, Stygobromus pecki, and a stygobiontic dryopid beetle, Stygoparnus comalensis at spring locations in addition to Comal Springs, New Braunfels, Texas. Benthic invertebrate collections were made during spring and summer of 1991 at San Antonio Springs and Salado Springs in Bexar County, San Marcos Springs, Sink Springs and Fern Bank Springs in Hays County and Hueco Springs and Comal Springs in Comal County.

Heterelmis comalensis Bosse, Tuff and Brown

Adult beetles of Heterelmis comalensis were only collected from orifice three at Comal Springs; no specimens were discovered at orifice openings 1 and 2, which had ceased flowing during the summer of 1990. A large number of larvae of the genus Heterelmis also were collected at spring orifice 3 and are likely to be immature stages of Heterelmis comalensis. Taxonomic identification to species are not possible on the basis of characteristics of larval stages of most members of the family Elmidae. A larval specimen of the genus Heterelmis also was collected from the San Marcos River. Heterelmis vulnerata is the only species of this genus believed to occur in the headwaters of the San Marcos River (Bosse, Tuff and Brown 1988).

Stygobromus pecki Holsinger

Mature specimens of Stygobromus pecki were collected only from orifice openings 1 and 3 at Comal Springs and two immature specimens of Stygobromus from opening 2. At all others springs, the common and widespread Hyallela azteca was the only species of amphipod discovered.

Stygoparnus comalensis Barr and Spangler

No specimens of Stygoparnus comalensis were collected from any of the spring systems that were sampled.

Although no specimens of Stygoparnus comalensis and only a few specimens (only from Comal Springs) of Stygobromus pecki were collected, these data do not necessarily mean that the distribution of each species is restricted to Comal Springs or that the population size of either species is rare. These species are stygobiontic and are adapted to conditions, food resources and interactions with other species characteristic of a subterranean world without light. I am unaware of studies or methods available to explore the extent of this habitat or determine the distribution and abundance of its species. The only insight

we obtain on this unique community is through openings to the surface world in the form of springs or wells. It is not surprising that few to no individuals of the stygobiontic species were discovered in this study since the quantitative and qualitative sampling methods are largely designed to collect the benthic fauna of surface-running waters and stygobiontic individuals might be suspected to suffer high mortality because they lack the ability to exploit the resources of lighted surface waters and escape predators. Barr and Spangler (1992) suggested that S. comalensis might have a highly restricted distribution since it was only collected from one of the three spring orifices which lie close to each other. To improve estimates of relative population size and distribution of the stygobiontic species, I recommend that drift nets be positioned as close as possible to spring orifices and held in position over a 24 hour period. This may prove to be a more effective sampling technique than benthic samples that limit the surface area which can be covered because of sorting time constraints. Drift net sampling allows large volumes of water, which may contain floating or swimming amphipods or dryopid beetles emerging from the aquifer, to pass through the net.

That Heterelmis comalensis was collected only from Comal Springs during this study supports the conclusions of others (e.g. Bosse et al. 1988) that this species is apparently endemic to Comal Springs.

The major threats to the species are loss of habitat due to overdrafting of the Edwards Aquifer and other anthropogenic threats such as pollution, development and recreation.

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STATUS SUMMARY

Taxon:	Heterelmis comalensis (Bosse,Tuff and Brown)
Common Name:	Comal Springs Riffle Beetle
Family:	Elmidae
Order:	Coleoptera
County and State Where Taxon Occurs	Comal County, Texas
Current International Status	None
Current Federal Status	Category 2 (U.S. Fish and Wildlife Service 1991)
Current State Status:	None

STATUS SUMMARY

Taxon:	Stygobromus pecki (Holsinger)
Common Name:	Peck's Cave Amphipod
Family:	Crangonyctidae
Order:	Amphipoda
County and State Where Taxon Occurs	Comal County, Texas
Current International Status	None
Current Federal Status	Category 2 (U.S. Fish and Wildlife Service 1991)
Current State Status:	None

STATUS SUMMARY

Taxon:	Stygoparnus comalensis (Barr and Spangler)
Common Name:	Comal Springs Dryopid Beetle
Family:	Dryopidae
Order:	Coleoptera
County and State Where Taxon Occurs	Comal County, Texas
Current International Status	None
Current Federal Status	Pending
Current State Status:	None

INTRODUCTION AND BACKGROUND

Classification and Nomenclature

Scientific Name:	Heterelmis comalensis (Bosse et al.)
Original Description	Bosse, L.S., D.W. Tuff and H.P. Brown. 1988. A new species of Heterelmis from Texas (Coleoptera:Elmidae). Southwestern Naturalist 33:199-203.
Type Specimen:	An adult male collected by L.S. Bosse on 9 April 1976 at Landa Park Springs (spring orifice/run #2) in New Braunfels, Comal County, Texas. Holotype on deposit with U.S. National Museum of Natural History.
Synonyms:	None
Common Names:	Comal Springs Riffle Beetle
Family:	Elmidae

Description

The first known specimen was collected from Comal Springs #2 orifice and run on 9 April 1976 by L.S.Bosse. Subsequent collections of the species have been made from Comal Springs #2 and #3 orifices and runs by C.B. Barr (California State University-Sacramento) on 11 and 19 September 1987 and 2 May 1988. Barr, during these collecting trips, found no specimens of the species from other spring orifices nor from Hueco Springs and San Marcos Springs. Dr. Harley Brown also has collected specimens of Heterelmis comalensis from Comal Springs in March of 1977 and in April 1988.

As adults, members of the family Elmidae, the riffle beetles, are small (less than 5mm, smaller than Dryopidae), long-legged and somewhat elongate beetles. Antennae are threadlike but occasionally slightly clubbed at the end. The paired tarsal claws are long. The larvae are rounded in cross section, elongate overall with a ventral caudal flap that covers a chamber containing hooks and gills.

Heterelmis comalensis are small (1.7-2.1mm length, about 1mm diameter) with moderately convex wings slightly wider than the prothorax. The shiny cuticle is covered with fine, golden colored hairs, although the color of the beetle ranges from brownish yellow to dark brown. Heterelmis comalensis is believed to have evolved from an isolated population of Heterelmis glabra (Bosse et al. 1988) hence they share many morphological characteristics, including genitalia indistinguishable from one another. They are distinguished from one another in that H. comalensis is smaller, more slender and much lighter in color than H. glabra. The distribution of H. glabra in Texas is largely restricted to the Big Bend region (Bosse et al. 1988).

Present Legal Status

International: None

Federal: Heterelmis comalensis is identified as a Category 2 animal in the Fish and Wildlife Service's Notice of Review (U.S. Fish and Wildlife Service 1991). This category "comprises taxa for which information now in possession of the Service indicates that proposing to list as Endangered or Threatened is possibly appropriate, but for which substantive data are not currently available to biologically support a proposed rule. Further biological research and field study may be needed to ascertain the status of the taxa in this category, and it is likely that some of the taxa will not warrant listing."

State: Texas provides no listing or protection of invertebrate species.

Natural History

Members of the genus Heterelmis are largely neotropical in distribution (13 of 16with species scattered throughout South and Central America northward into the mountains of the western United States. Heterelmis comalensis is apparently the only species (of 13) in the genus with such a highly restricted distribution.

Elmids are common inhabitants of running waters, yet what little is known of their natural history, ecology and trophic interactions is based on studies of just a few of the more than 100 described species (Tavares and William 1990). Larvae undergo 6-8 instars, requiring anywhere from 6 months to 3 years to complete a life cycle from egg to adult. Growth and development times are temperature dependent, being faster at higher temperatures. Mature larvae crawl out of the water to construct terrestrial pupal chambers in moist soils, under rocks or in decaying wood. After emergence, adults undergo a short flight period, after which they reenter the water and are incapable of further aerial activity. Reproductive activities occur after the flight period.

Elmids have been described as small sturdy beetles and are capable of burrowing deep into the bottom substrates (depths to 70cm, Williams and Hynes 1974). Although primarily inhabitants of flowing waters, Brown (1973) showed that adult and larval elmids of the genera Macronychus and Stenelmis have a longevity of several years and can survive under environmental extremes (low dissolved oxygen, high temperature etc.) similar to those occuring in ponds and pools. It is possible that H. comalensis shares adaptive traits with its congeners, such as the ability to burrow and tolerate environmental stress; if so, this may explain how H. comalensis was able to survive the drought of the 1950's, particularly 1956, when apparently Comal Springs ceased flowing for up to six months.

Classification and Nomenclature

Scientific Name: Stygobromus pecki (Holsinger)

Original Description: Holsinger, J.R. 1967. Systematics speciation and distribution of the subterranean amphipod genus Stygonectes (Gammaridae). United States National Museum Bulletin 259:176pp.

Type Specimen: An adult female (males are unknown) was collected by James Reddell on 18 May 1988 from one of the large spring orifices (# not given) in Landa Park, New Braunfels, Comal County,Texas. Holotype on deposit with U.S. Museum of Natural History.

Synonyms:

Common Names: Peck's Cave Amphipod

Family: Crangonyctidae

Taxon History:

Stygobromus is composed of previously described genera (Apocrangonyx, Stygonectes and Synpleonia) that have been synonymized under a single name (Holsinger 1977). Holsinger (1978) suggests that it might not be a completely natural group and should be divided into smaller groups to reflect patterns of morphological divergence and sexual dimorphisms.

Description

Stygobromus pecki is a crustacean belonging to the order Amphipoda, family Crangonyctidae. Members of this order are characterized by having five pairs of legs, two pair of antennae and a laterally flattened body. The family Crangonyctidae is differentiated from other families in the order by possession of a two segmented flagellum (appendage) on the first antenna and the rear margin of the telson (last body segment) not deeply cleft to the base of the segment. The genus Stygobromus is distinguished from other genera in the family by the absence of eyes; all species of this genus are primarily subterranean. Stygobromus dejectus is the most closely related species to Stygobromus pecki. The two species can be most easily differentiated from each other in that S. pecki is larger (up to 10.5mm) than S. dejectus (up to 8.25mm) and S. pecki has a proportionately larger first antennae. Other morphological differences of a more specialized nature are described in Holsinger (1967).

Present Legal Status

International: None

Federal: Stygobromus pecki is identified as a Category 2 animal in the Fish and Wildlife Service's Notice of Review (U.S. Fish and Wildlife Service 1991). This category "comprises taxa for which information now in possession of the Service indicates that proposing to list as Endangered or Threatened is possibly appropriate, but for which substantive data are not currently available to biologically support a proposed rule. Further biological research and field study may be needed to ascertain the status of the taxa in this category, and it is likely that some of the taxa will not warrant listing."

State: Texas provides no listing or protection of invertebrate species.

Natural History

Although collected in the springrun outside the orifices at Comal Springs, the primary habitat of Stygobromus pecki is subterranean and associated with the underground waters of the Edward's aquifer. Virtually nothing is known about the life history, trophic relations and other aspects of the biology and ecology of this species of stygobiontic (eyeless, underground/cave-water-inhabiting) amphipods. However, sufficient information on other species of amphipods has accumulated, together with the unique characteristics of a subterranean existence, to warrant speculation and generalization.

As a group, amphipods are recognized as being characteristic of cold, relatively constant temperature habitats and lack a resistant stage in the life cycle capable of resisting dessication. Lack of a resistant stage limits their dispersal into other habitats by passive dispersal such as on bird feet, mammal fur, wind etc. Their abilities for active dispersal by swimming are also limited and they cannot migrate upstream against strong currents. This restricts spread of amphipods throughout river drainage networks. Most amphipods avoid bright light and are mainly associated with bottom materials such as rocks, interstitial crevices, detritus etc. Since Stygobromus pecki is subterranean its primary source of food most likely consists of dead organic matter produced by plants and animals that live aboveground that is transported to the aquifer via recharge streams.

Most amphipods have annual life cycles, completing growth, development and maturation within a single year. However, some troglobitic species are reported to require up to six years to mature (Culver 1982). With few exceptions, female amphipods reproduce only once during an annual life cycle. Compared to warm-water amphipods, amphipods of cold, spring type habitats exhibit longer life cycles, reduced fecundity and absence of seasonality in life cycles (i.e. they have overlapping generations, Thorp and Covich 1991). These characteristics probably apply to Stygobromus pecki.

Amphipods generally are good indicators of water quality because they require high concentrations of oxygen. When vertebrate and invertebrate predators are absent and food resources abundant, amphipods can reach high densities, numbering thousands of individuals per square meter. They are important components of ecosystems and play a critical role in detrital food chains as well as being an important food resource to higher trophic levels.

Classification and Nomenclature

Scientific Name: Stygoparnus comalensis (Barr and Spangler)

Original Description: Barr, C.B. and P.J. Spangler. 1992. A new genus and species of stygobiontic dryopid beetle, Stygoparnus comalensis (Coleoptera: Dryopidae) from Comal Springs, Texas. Proceeding of the Biological Society of Washington 105:40-54.

Type Specimen: An adult male was collected by C.B. Barr on 2 May 1988 from Comal Springs orifice number 2 in Landa Park, New Braunfels, Comal County, Texas. Holotype is deposited in the National Museum of Natural History, Smithsonian Institution, Washington, D.C.

Synonyms: None

Common Names: Comal Springs dryopid beetle

Family: Dryopidae

Description

The first known specimens were collected from Comal Springs in 1987 by Dr. Harley Brown, Professor Emeritus (University of Oklahoma); however the holotype was based on collections made 2 May 1988 by C.B. Barr (California State University-Sacramento). Other specimens have since been collected by Dr. W.D. Shepard (California State University-Sacramento) on 6 June 1988. Dr. Paul Spangler (National Museum of Natural History) collected at Comal Springs during May 1991 and did not encounter specimens of Stygoparnus comalensis. Intensive collecting at Comal Springs at each of the three major springhead orifices during the present study also resulted in no specimens of this species.

As adults, members of the family Dryopidae, the long-toed water beetles, are so named on the basis of tarsal segment five being at least as long as the basal five tarsal segments. The beetles are somewhat elongate and possess an eight to eleven segmented antennae with segments 4-11 expanded laterally. As larvae, they are cylindrical and elongate and look similar to larval riffle beetles (Elmidae) but lack filamentous gills in caudal chamber.

Stygoparnus comalensis represents a new species as well as new genus in the family Dryopidae. It is believed to be most closely related to the genus Helichus since they share a number of morphological features. However, Stygoparnus can be easily distinguished from Helichus and all other described dryopid genera on the basis of its vestigial eyes and possession of an eight segmented antennae. At present, Stygoparnus comalensis is the only described species of the genus.

Present Legal Status

International:	None.
Federal:	Sygoparnus comalensis status is pending
State:	State provides no listing or protection for invertebrates.

Natural History

Stygoparnus comalensis represents the first and only known stygobiontic species of the family Dryopidae in the world. Although the species was collected aboveground in the springrun just downstream from the spring orifice, its primary habitat is clearly subterranean as evidenced by eyelessness and light pigmentation of the adults. The areal extent of its underground distribution is not clear. The fact that it was collected from only a single spring orifice (Comal 2) close to two others (Comal 1&3) indicates the possibility its distribution is limited to an underground cavern in the vicinity of where flows from Comal 2 emerge (Barr and Spangler 1992).

Little is known about the feeding ecology or demographic characteristics of Stygoparnus comalensis or other members of the Dryopidae upon which to base discussions of their importance as ecosystem components.

Little is known about many features of the life history of species in the family Dryopidae. However, two known biological characteristics for most species in the family are significant in that certain habitat modifications could eliminate the population of Stygoparnus comalensis from its presently restricted distribution associated with the Comal Spring Orifice

2. The first feature regards the strict reliance of adult beetles on atmospheric oxygen for respiration. Adult elmid and dryopid beetles capture a bubble of air (plastron) on their undersides, which is held in place when submerged underwater by a dense layer of specialized hairs. The bubble behaves as a "physical gill" with oxygen for respiration diffusing from the water into the bubble and carbon dioxide diffusing out. For the trapped air bubble to function effectively as a gill requires the water to be rich in oxygen. Consequently, changes in water quality that lower oxygen levels may be detrimental to this species. This feature also needs to be considered in the evaluation and design of any type of spring augmentation plan.

The second biological feature of note concerns the distribution and habitats of adult and larval beetles. Larval forms of Stygoparnus comalensis are thought to be terrestrial and presumed to be associated with soil, roots and debris lining the ceiling of the subterranean orifices (Barr and Spangler 1992). Thus, habitat alterations that affect or separate either the larval or adult habitats could have profound negative consequences for the species.

Study Sites

Historical flow and elevational data for all springs were obtained from Brune (1981).

Comal County

Comal Springs, the largest spring system in Texas, consists of 29 springs that emerge from Cretaceous Edwards and other associated limestones into man-made Landa Lake. The four major spring orifices are referred to as Comal Springs 1, 2, 3 and 4 from highest to lowest elevation (after Barr and Spangler 1992). This system is located within the city of New Braunfels and rests at an elevation of 190 meters above mean sea level (msl). Its annual average flow is about 318 cubic feet per second (cfs) and a maximum combined discharge of 530 cfs occurred on October 16, 1973, although drought conditions in the middle 1950s caused Comal Springs to stop flowing. The temperature of spring water ranges between 23.1 ^{o}C and 23.9 ^{o}C. Orifice and spring-run # 1 was sampled on 30 May 1991 and the temperature was 23.8 ^{o}C with a dissolved oxygen of 5.7 milligrams per liter. Orifices and spring-runs 2 and 3 were sampled 3 June 1991.

Hueco Springs consists of two main groups of springs and surges from Edwards limestone. It is located seven kilometers north of New Braunfels near the confluence of Elm Creek and the Guadalupe River on private property. The recharge area is relatively small and nearby as evidenced by marked changes in turbidity, temperature, and discharge fluctuations shortly after rain events. The southeast springs is at an elevation of around 200m asl and begins flowing when the northwest springs reach 25 cfs. The average annual combined discharge has been 39 cfs and the maximum recorded discharge was 131 cfs on January 21, 1968. Hueco Springs went dry from 1928 to 1929 and from 1955 to 1956. Hueco Springs were sampled 5 August 1991 and the water temperature was 21.3 ^{o}C with a dissolved oxygen of 5.5 milligrams per liter

Hays County

San Marcos Springs consists of about 200 springs and arises from three large fissures along the San Marcos Springs Fault from Edwards and associated limestones in the city limits of San Marcos, Texas. The spring openings are located at the bottom of Spring Lake, a man-made lake on the property of Aquarena Springs Resort. Elevation of this system is 175m asl. The average annual discharge is 159 cfs. The maximum recorded high was 316 cfs on June 12, 1975; the low was recorded on August 15, 1956 at 46 cfs. The recharge zone is quite extensive and is recharged when several creeks and the Guadalupe and Blanco Rivers cross the Balcones fault line. Several federally threatened or endangered species, including the fountain darter, the San Marcos salamander, and Texas wild rice, are endemic to this system. The San Marcos gambusia, thought by some to now be extinct, occurred here as well. San Marcos Springs were sampled 1 February 1991. The site was a series of cascading riffles located adjacent to Clear Springs Apartments. Water temperature was 21 ^{o}C with a dissolved oxygen reading 6.9 milligrams per liter.

Sink Springs are located on private property 3 miles northeast of San Marcos. The two springs issue from Edwards limestone along a fault crossing Sink Creek. On October 14, 1937, the discharge was 2 cfs. The springs were sampled 13 August 1991 and the water temperature was 23.1 ^{o}C with a dissolved oxygen of 5.2 milligrams per liter.

Fern Bank Springs, also known as Little Arkansas Springs, issue from the Hidden Valley Fault where it crosses the Blanco River. It is located 4.8 miles east of Wimberley on private property. The five springs emerge from the side of a tall bluff and cascade down about 60 feet off the bluff. The flow on May 31, 1975 was 5 cfs while on May 1, 1971 only 0.3 cfs poured out. The springs were sampled 13 August 1991 and the water temperature was 22.4 ^{o}C with a dissolved oxygen of 5.9 milligrams per liter.

Bexar County

San Antonio Springs are located north of East Hildebrand Avenue on the property of Incarnate Word College in San Antonio. There are over 100 springs resting at an elevation of 205m asl, but the largest, Blue Hole, rests at 204m asl. Blue Hole rises from a deep hole. The springs went dry during the drought period of the 1950s. In 1977, the springs flowed at a discharge greater than 141 cfs. Due to the fluctuations in water level of the Edwards Aquifer, the discharge is quite erratic and tends to be declining. Recharge of these springs relies on rainfall in the watersheds of the Frio, Sabinal, and Medina Rivers and Hondo and Leon Creeks. Water in these streams reach the aquifer through the Balcones fault zone. All of the historical springs were dry when we sampled 21 August 1991. Instead, we went across the street from Incarnate Word College to Brackenridge Park. There, just inside the park beneath the overpass near the headquarters of the Parks and Recreation Department is a well-head pump. We sampled at the pipe outflow. There was cobble where flow was high but otherwise the predominant substrate was mostly a silt-clay muck. Vegetation present was Ludwigia repens and Nuphar. Temperature was 24.5 ^{o}C and dissolved oxygen was 6.3 milligram per liter.

San Pedro Springs, at an elevation of 202m msl, are located in San Pedro Park in San Antonio. The flow of the four springs is erratic and declining and relies on the same source of water as San Antonio Springs. Flows ceased during the 1950s but almost reached 18 cfs during 1976. The springs were dry when we sampled 21 August 1991.

Salado Springs are in San Antonio just northwest of the crossing of Austin Highway and Salado Creek. The springs flow from terrace gravels but are backed up by a dam. Dry during the 1950s, the seven springs discharged 1.2 cfs in 1970 but declined to 0.05 cfs five years later. The springs were sampled 21 August 1991 and the water temperature was 22 ^{o}C with a dissolved oxygen of 6.2 milligrams per liter.

Methods

Benthic macroinvertebrate samples were collected at specified sites in the summer of 1991 using both quantitative and qualitative techniques. Quantitative samples were obtained with a Hess sampler from riffles or runs at each site in areas where depth did not exceed 35 centimeters (14 inches). The sampler is ineffective due to backwash at depths greater than this and prevented us from sampling several sites with this sampler. The Hess sampler has a diameter of 33 cm (13 inches) and incorporated a Nitex net with a mesh size of 243 microns. To procure a sample, the Hess sampler was buried into the substrate to a depth of 3 - 7cm (1.2-2.8 inches) depending on the predominant substrate composition (sand, cobble, etc.) Immediately after implantation, large rocks were removed and hand washed to remove attached organisms, which were then carried by the current into the net. The remaining substrate within the cylinder was then disturbed to dislodge free-living organisms that inhabitat finer substrates. The contents of the net were concentrated into a 200 micron mesh detachable sock and then transferred to permanent collection containers. Four quantitative samples were taken at each site in close proximity to the spring orifice. Each Hess sample requires about 15 minutes to collect and process.

Qualitative samples were obtained using a dip net and handpicking representative microhabitats (dead logs, large rocks, leaf accumulations etc.). Qualitative sampling at each spring or orifice lasted for an hour. Specimens were preserved in 80% ethanol in the field and transported to the lab for sorting, identification, and enumeration. Specimens were keyed to the lowest taxon possible and stored in numbered vials with 80% ethanol. Taxonomic resolution was limited in many cases if larvae were in the early stages of their life cycles; at this time many morphological features used in their identification are incompletely developed. Taxonomic keys used in identifications were by Merritt and Cummins (1984) for insects, Pennak (1989) for non-insects, and Thorp and Covich (1991) for both insects and non-insects.

Where substrate, flow, depth, and spring size permitted, four quantitative samples were taken at each site in addition to thorough qualitative sampling such as submerged detritus accumulations, macrophytes and branches. The qualitative samples were combined across habitats. Quantitative sampling was conducted at Comal Springs 1, 2 and 3 and Hueco Springs; all other springs were sampled qualitatively.

Results and Discussion

Total number of taxa found in the springs were highly variable ranging from a low of seven taxa for Sink Springs to a high of 35 taxa for Comal Springs # 1 (Appendices 1 - 5). For some springs, (San Marcos, Hueco, Comal Springs # 1) gastropods were significant contributors to taxonomic richness. A general feature of springs with a well developed gastropod composition is that they have fairly open canopies. This allows solar radiation and the growth of macrophytes and periphyton upon which snails can graze.

Macroinvertebrate densities were highest in Comal Springs # 1 (4364 individuals per square meter, intermediate in Comal Springs # 3 and Hueco Springs (2820 and 2774 individuals per square meter) and lowest in Comal Springs # 2 (930 individuals per square meter). Larval water pennies, <u>Psephenus</u> <u>texanus</u>, were the numerical dominant at all four springs making up 24% to 40% of all individuals. At Comal Springs # 1 <u>Microcylloepus</u> sp. was codominant (24%) with <u>P</u>. <u>Texanus</u>. Chironomids were also a significant component of the fauna at these four spring runs. The beetles are classified as grazers meaning they obtain their food principally by scraping attached biofilms off the surfaces of rocks. Chironomids are classified as collector gatherers and their principal food consists of decaying fine particulate organic matter.

General Assessment

Although no specimens of Stygoparnus comalensis and only a few specimens (only from Comal Springs) of Stygobromus pecki were collected, these data do not necessarily mean that the distribution of each species is restricted to Comal Springs or that the population size of either species is rare. These species are stygobiontic and are adapted to conditions, food resources and interactions with other species characteristic of a subterranean world without light. I am unaware of studies or methods available to explore the extent of this habitat or determine the distribution and abundance of its species. The only insight we obtain on this unique community is through openings to the surface world in the form of springs or wells. It is not surprising that few to no individuals of the stygobiontic species were discovered in this study since the quantitative and qualitative sampling methods are largely designed to collect the benthic fauna of surface-running waters and stygobiontic individuals might be suspected to suffer high mortality because they lack the ability to exploit the resources of lighted surface waters and escape predators. Barr (1992) suggested that S. comalensis might have a highly restricted distribution since it was only collected from one of the three spring orifices which lie close to each other. To improve estimates of relative population size and distribution of the stygobiontic species, I recommend that drift nets be positioned as close as possible to spring orifices and held in position over a 24 hour period. This may prove to be a more effective sampling technique than benthic samples, that limit the surface area that can be covered because of sorting time constraints. Drift net sampling allows large volumes of water, which may contain floating or swimming amphipods or dryopid beetles emerging from the aquifer to pass through the net.

That Heterelmis comalensis was collected only from Comal Springs during this study supports the conclusions of others (e.g. Bosse et al. 1988) that this species is apparently endemic to Comal Springs.

Threat Assessment

Present and potential threats to populations and habitats

There do not appear to be significant threats associated with predation, disease or other biological components of the habitats to populations of the Comal Springs riffle beetle, Peck's cave amphipod or the Comal Springs dryopid beetle. However, little is known on the biology, community structure or food web interactions for any of the species. Scientific collecting does not appear to be frequent or intensive enough to pose much of a problem. All species are small and inconspicuous and would not attract interest as components of aquarium communities. Further, the Parks and Recreation Department of the City of New Braunfels does not allow public access (wading) to the spring orifices and runs and requires permission from the city to collect on city property. San Pedro and San Antonio springs when flowing are subject to recreational impacts. Hueco and Sink springs are relatively protected since they are on private property. Fern Bank Springs, even though on private property, may be sensitive to recreational impact. The springs are small and run a short distance before falling into the Blanco River. A lot of campers use the area and frequently visit the springs.

Present and potential threats to habitat

The most significant threats to endemic invertebrates at Comal Springs are related to elimination or modification of habitat as a result of anthropogenic disturbances. The most immediate threat is declining levels and the ever increasing likelihood of cessation of springflow due to overdrafting of groundwater associated with human activities. A number of other springs (San Antonio, San Pedro) at elevations higher than Comal Springs, once issued from major natural discharge points of the Edward's Aquifer now cease to flow or do so intermittently. The Edward's Aquifer and the springs that issue from the aquifer are the sole source of water for the 1.5 million people of the region. the Texas Legislature recently passed legislation (Senate Bill 1477) to regulate pumping from the aquifer. A key feature of this bill is that total annual usage permitted to be pumped is 450,000 acre feet (this amount is equal to current average withdrawals) over the next 15 years and then 400,000 acre feet from then on. While this bill is a step in the right direction, it still might not be able to gaurantee spring flows during even a mild drought. For example, minimum recharge to the aquifer has been as little as 43.7 thousand acre feet in 1956. Even now, pumping for agricultural and lawn watering can cause the aquifer to drop more than foot a day measured in well J-17 in San Antonio. Even with aquifer levels at historic highs, it would require little time without rain for the aquifer to drop to 619 feet and for Comal Springs to begin to go dry. Although Bill 1477 calls for a critical period management plan to be in effect when aquifer levels are low, the adequacy of the plan cannot be evaluated at this time since it has not been formulated. Projected water usage associated with human population growth predicted for the region indicates demands on the aquifer will increase (Texas Water Development Board1990). Expectations are that by the year 2000, continuous flow from Comal Springs is unlikely. Late spring and summer are seasons with the greatest probability for cessation of springflow. During these periods, recharge from rainfall is low and withdrawal for irrigation by agriculture and landscape watering is high. When levels of the Edward's Aquifer drop below about 619 feet mean sea level (J-17 reference well, San Antonio), Comal Springs will cease flowing. During the summer of 1990, the aquifer level dropped below the lip of the orifices of Comal Springs 1 & 2 and the spring runs dried up. Too little is known to determine levels of threat posed by spring flow cessation on the subterranean species. However, H. comalensis as adults may be able to survive periods of no spring flow by burrowing down into the coarse cobble substrate. The period of time this may work as a survival strategy will depend on the depth of the substrate in relation to the duration of no spring flows. The primary substrate at each of the spring runs is limestone bedrock which is covered by a relatively thin (5-15 cm) layer of cobble, gravel and finer sediments.

Declining springflows also may impact species through indirect effects. With declining flows, water depths decrease and the turnover time for Landa Lake is increased, which means the water has a longer residence time. This allows for greater solar insolation and consequently warmer water temperatures. There is an inverse relationship between water temperature and its ability to hold oxygen; as temperature rises oxygen concentration decreases. In contrast, invertebrates exhibit a positive relationship between temperature and rate of metabolism; as temperature rises oxygen consumption increases. Thus, declining flows could cause physiological stress to invertebrates in that as water temperature increases oxygen concentration decreases at a time when invertebrate metabolic demands for oxygen are increasing. This effect will be more pronounced in the more lentic (static) than lotic (flowing) habitats of the Comal Springs ecosystem.

A second threat to the habitat is the potential for pollution since Comal Springs and its associated terrestrial watershed are located in the urban environment of New Braunfels, Texas. At present, this does not appear to be a major problem based on recent water quality analyses conducted by the Edwards Aquifer Research and Data Center. However, the possibility for increased flooding, erosion and silt deposition with increased urbanization and population growth within the vicinities of the springs should be monitored. Also, as springflow declines, the effects of point and non-point source pollution increase proportionately since the dilution factor is decreasing.

Exotic species also may pose a threat to the habitat. Recently, the exotic giant rams-horn snail, Marisa cornuarietis rapidly increased in number and is markedly altering habitats and communities by consuming vast quantities of vegetation in Landa Lake below the largest spring orifices. At present, since all three endemic invertebrate species are primarily limited to the spring runs and orifices, the giant rams-horn snail poses no threat. It has yet to show evidence of migrating upstream against a fast current. However, as spring flows decline with depletion of the aquifer, invasion by this exotic into biological communities associated with the spring orifices and runs seems likely.

Conservation Recommendations

The Comal Springs riffle beetle (Heterelmis comalensis), Peck's Cave amphipod (Stygobromus pecki) and the Comal Springs dryopid beetle (Stygoparnus comalensis) all depend on the biological communities of which they are a part. Although little is known about the structure, function and key interactions that occur in these communities, it is clear that there is a strong reliance on springflow to maintain the biological intregrity of these communities. As such, the conservation and protection of species is best achieved by ensuring adequate springflows.
Since the species appear to have a rather limited distribution and are restricted to the spring orifices and spring runs, I recommend that future development and construction in the surrounding watershed adjacent to and upstream from the spring orifices be curtailed to minimize the impacts of anthropogenic disturbances (sedimentation, chemical spills, pesticide runoff, other pollutants) to the species.

Literature Cited

~~Anonymous.~~ 1990. Water for Texas:Today and Tomorrow. Report by Texas Water Development Board DocumentNo. GP-5-1.

Barr, C.B. and P.J. Spangler. 1992. A new genus and species of stygobiontic dryopid beetle Stygoparnus comalensis (Coleoptera: Dryopidae) from Comal Springs, Texas. Proceedings of the Biological Society of Washington 105:40-54.

Bosse, L.S., D. W. Tuff and H.P. Brown. 1988. A new species of *Heterelmis* from Texas (Coleoptera: Elmidae). The Southwestern Naturalist 33:199-203.

Brown, H.P. 1973. Survival records for elmid beetles, with notes on laboratory rearing of various dryopids (Coleoptera). Entomological News 84:278-284.

Tavares, A.F. and D.D. Williams. 1990. Life histories, diet and niche overlap of three sympatric species of Elmidae (Coleoptera) in a temperate stream. Canadian Entomologist 122:563-577.

Brune, G. 1981. Springs of Texas-Volume I. Branch-Smith Inc. Fort Worth, Texas.

Culver, D.C. 1982. Cave life. Harvard University Press, Cambridge.

Holsinger, J.R. 1967. Systematics, speciation and distribution of the subterranean amphipod genus Stygonectes (Gammaridae). U.S. National Museum Bulletin 259:1-176.

Holsinger, J.R. 1977. A review of the systematics of the Holarctic amphipod family Cragonyctidae. Crustaceana Supplement 4:244-281.

Holsinger, J.R. 1978. Systematics of the subterranean amphipod genus Stygobromus (Crangonyctidae) Part II: Species of the eastern United States. Smithsonian Contributuions to Zoology 266:1-144.

Merritt, R.W., and K.W. Cummins (eds.). 1984. An introduction to the aquatic insects of North America, 2nd edition Kendall/Hunt,. Iowa. 722 pp.

Pennak, R.W.. 1989. Fresh-water invertebrates of the United States, 3rd edition. John Wiley & Sons, Inc., New York. 628 pp.

Thorp, James H. and Alan Covich (eds.). 1991. Ecology and classification of North American freshwater invertebrates. Academic Press, Inc., New York. 874 pp.

U.S. Fish and Wildlife Service. 1991. Endangered and threatened wildlife and plants. 50 CFR 17.11 and 17.12, 37pp.

Williams, D.D. and H.B.N. Hynes. 1973. The occurence of benthos deep in the substratum of a stream. Freshwater Biology 4:233-246.

Appendix 1: Coleopterans found at spring sites.
Mean number of organisms/m2 and standard deviation are reported for quantitative (n=4) samples.
X indicates specimens were collected but not enumerated.

TAXA		Stage	**Comal Springs** Site 1	Site 2	**Comal Springs** Hand-picked	Site 3	Hand-picked
			5/30/91	6/3/91	6/3/91	5/30/91	6/3/91
Order Coleoptera							
Psephenidae	*Psephenus sp.*	larval	1037.3 (955.06)	376.5 (254.8)	1	1117.6 (1478.8)	
	Psephenus texanus	adult	7.06 (15.78)		4	3.9 (6.8)	2
Elmidae	*Microcylloepus sp.*	larval	1027.5 (993.2)	3.9 (6.8)		454.9 (391.7)	
	Microcylloepus sp.	adult				117.7 (20.4)	
	Microcylloepus pusillus	adult	68.6 (104.5)			19.6 (24.5)	
	Heterelmis sp.	larval				70.6 (93.4)	
	Heterelmis comalensis	adult				7.8 (6.8)	
Hydrophilidae	Undetermined	larval			1		

continued

Appendix 1. (continued)

TAXA		Stage	Hueco Springs Quantitative	Hueco Springs Qual	Fern Bank Springs	San Marcos Springs	San Antonio Springs	Salado Creek Springs
			8/5/91	8/5/91	8/13/91	5/30/91	8/21/91	8/21/91
Order Coleoptera								
Psephenidae	*Psephenus sp.*	larval	855.9 (1108.4)		15			
	Psephenus texanus	adult				X		
Elmidae	*Microcylloepus sp.*	larval	138.2 (119.0)	9	1		3	
	Stenelmis sp.	larval					1	1
	Stenelmis crenata (?)	adult						2
	Phanocerus clavicornis	adult				X		
	Macrelmis sp.	larval				X		
	Macrelmis texanus	adult				X		
	Hexacylloepus ferrugineous	adult				X		
	Ancyronyx sp.	larval				X		
	Heterelmis sp.	larval				X		

Appendix 2. Amphipods collected during survey of Comal Springs. Mean number of organisms/m2 and standard deviation reported for quantitative samples (n=4).

TAXA	**Site 1**	**Site 2 (Hand-picked)**	**Site 3**
Amphipoda			
Hyallela azteca	3.9 (6.1)		168.6 (262.1)
Stygobromus pecki	17.6 (33.1)		3.9 (6.8)
Stygobromus sp.		2	35.3 (42.4)

Appendix 3. Invertebrates collected from Comal and Hueco Springs (Comal Co.).
Mean number of organisms/m2 and standard deviation reported for quantitative (n=4) samples.
HP = Hand-picked

		Comal Springs						**Hueco Springs**		
		SITE 1		SITE 2		SITE 3		Quantitative		Qual
Class Insecta	**Taxa**	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Order Ephemeroptera										
Baetidae	*Baetis*	11.8	19.7	23.5	40.8	3.9	6.8	19.6	14.8	1
	Baetodes	5.9	14.4							
	Dactylobaetis			1	(HP)			3.9	5.9	
Caenidae	*Caenis*					58.8	82.4			
Tricorythidae	*Leptohyphes*	304.5	33.6							
	Tricorythodes	80.4	108.4							
Order Odonata										
Corduliidae	*Neurocordulia*	2.4	4.7							
Gomphidae	*Phyllogomphoides*					7.8	13.6			
Libellulidae	*Macrothemis*			7.8	13.6	3.9	6.8	3.9	5.9	
Coenagrionidae	*Argia*	5.9	14.4	74.5	71.9					
Order Hemiptera										
Corixidae	Adult stage							3.9	5.9	
Gerridae	*Gerris*			3.9	6.8					
Naucoridae	*Limnocoris*					3.5	7.1	3.5	5.9	
Veliidae	*Rhagovelia*					11.8	20.0			
Order Trichoptera										
Helicopsychidae	*Helicopsyche*	3.9	9.6					31.4	19.2	1
Hydrobiosidae	*Atopsyche*							43.1	64.7	
Hydroptilidae	*Hydroptila*	2.0	4.8					62.7	79.2	9
	Leucotrichia	313.7	525.2	31.4	44.5	215.7	190.2	98.0	147.1	
	Unidentifiable *	245.1	351.2							
	Ochrotrichia	7.8	19.2					27.5	41.2	
	Stactobiella	2.0	4.8							
Unidentifiable *		3.9	9.6	7.8	13.6			11.8	17.6	
Order Lepidoptera										
Pyralidae	*Petrophila*	251.0	283.9			94.1	51.3	47.1	41.9	2
	Unidentifiable*			3.9	6.8					
Order Diptera										
Chironomidae	larvae	743.1	596.9	215.7	106.1	298.0	396.8	909.8	296.2	76
	pupae	33.3	21.6							
Ceratopogonidae				3.9	6.8	15.7	27.2	11.8	11.3	1

Appendix 3. (continued)

Non-Insects	Taxa	Comal Springs SITE 1 Mean	SD	SITE 2 Mean	SD	SITE 3 Mean	SD	Hueco Springs Quantitative Mean	SD	Qual
Gastropoda										
Ancylidae	*Ferrissia*	15.7	38.4	7.8	13.6					
Hydrobiidae	*Pyrygophorus (?)*	2.0	4.8	19.6	6.8			94.1	19.2	25
	Cincinnatia	2.0	4.8							
Physidae	*Physa virgata*	5.9	6.4					2.9	5.9	
Planorbidae	*Biomphalaria*							5.9	11.8	
	Unknown**	2.0	4.8					17.6	22.5	
Pleuroceridae	*Elimia comalensis*	19.6	48.0			3.9	6.8			
Thiaridae	*Thiara granifera*	13.7	33.6							
	Thiara tuberculata	19.6	21.9	15.7	18.0	11.8	20.4			
Unknown**		2.0	4.8			3.9	6.8	2.9	5.9	
Platyhelminthes										
Turbellaria		15.7	25.4			35.3	61.1	3.9	5.9	
Nematoda		3.9	6.1							
Annelida										
Oligochaeta		49.0	76.8	39.2	18.0	31.4	54.3	66.7	66.8	1
Crustacea										
Amphipoda	*Hyallela azteca*	See Appendix 2 for Comal Springs						82.4	123.5	134
Copepoda				7.8	6.8	11.8	20.4			
Decapoda										
Cambaridae				3.9	6.8			3.9	5.9	3
Isopoda				43.1	74.7			211.8	158.9	15
Ostracoda										1
Hydracarina		33.3	18.8	7.8	6.8	7.8	13.6	7.8	11.8	

*Early instar larvae are unidentifiable because sufficient morphological development has not occurred.

**Unable to identify to higher taxa because no bodies were present in the shells. No match found for shells in keys.

Appendix 4. Invertebrates collected from San Marcos, Fern Bank, and Sink Hole Springs (Hays Co.). Collections were made using a dipnet. X indicates specimens were collected but not enumerated.

Class Insecta	**Taxa**	**San Marcos Springs**	**Fern Bank Springs**	**Sink Hole Springs**
Order Ephemeroptera				
Baetidae	*Baetis*	X	4	1
	Baetodes	X		
Caenidae	*Caenis*			1
Heptageniidae	*Stenonema*		3	
Tricorythidae	*Tricorythodes*	X		
	Leptohyphes	X		
Order Odonata				
Libellulidae	*Pachydiplax*			4
	Telebasis			3
	Brachmesia	X		
	Plathemis	X		
Lestidae	*Archilestes*		5	
Order Hemiptera				
Gerridae	*Gerris*		2	
	Metrobates	X		
Naucoridae	*Ambrysus*	X	5	
	Pelocoris			1
	Cryphocricos	X		
	Theobates	X		
Saldidae				1
Veliidae	*Microvelia*		2	
	Husseyella	X		
	Rhagovelia		12	
Order Trichoptera				
Calamoceratidae	*Phylloicus*		9	
Helicopsychidae	*Helicopsyche*	X		
Philopotamidae	*Chimarra*	X		
Order Lepidoptera				
Pyralidae	*Petrophila*	X		

Appendix 4. (continued)

Class Insecta	**Taxa**	**San Marcos Springs**	**Fern Bank Springs**	**Sink Hole Springs**
Order Lepidoptera	*Paraponyx*	X		
Order Diptera				
Chironomidae		X	1	3
Simuliidae	*Simulium*	X		
Tipulidae	*Holorusia*		1	
Non-Insects				
Gastopoda				
Ancylidae	*Ferrissia*			2
	Gundulachia radiata	X		
Physidae	*Physa virgata*	X	6	8
Planorbidae	*Biomphalaria*		9	12
	Gyralus parvus	X		
Thiaridae	*Thiara granifera*	X		
	Thiara tuberculata	X		
Hydrobiidae	*Pyrogophorous coronatus*	X		
	Cincinnatia comalensis	X		
Ampulariidae	*Marisa cornuarietis*	X		
Pleuroceridae	*Elimia comalensis*	X		
Pelecypoda				
Corbiculidae	*Corbicula fuminea*			
Platyhelminthes				
Turbellaria		X	12	1
Nematomorpha			1	
Annelida				
Oligochaeta		X	1	
Hirudinea				2

Appendix 4. (continued)

	Taxa	San Marcos Springs	Fern Bank Springs	Sink Hole Springs
Crustacea				
Amphipoda	*Hyallela azteca*	X	17	1
Decapoda				
Cambaridae		X	1	
	Palaemonetes			
Ostracoda		X		
Hydracarina		X	2	

Appendix 5. Invertebrates collected from San Antonio and Salado Creek Springs (Bexar Co.). Collections were made using a dipnet.

Class Insecta	**Taxa**	**San Antonio Springs**	**Salado Creek Springs**
Order Ephemeroptera			
Baetidae	*Baetis*		2
Caenidae	*Caenis*		2
Tricorythidae	*Tricorythodes*		6
Order Odonata			
Calopterygidae	*Hetaerina*		1
Coenagrionidae	*Argia*	7	1
	Enallagma	1	
Order Hemiptera			
Nepidae	*Ranatra*		1
Veliidae	*Rhagovelia*		8
Order Trichoptera			
Hydropsychidae	*Potamyia*		1
Hydroptilidae	*Hydroptila*	1	
Unidentifiable*			1
Order Coleoptera			
Elmidae	*Neoelmis*		
Psephenidae			
Order Diptera			
Chironomidae	larvae	15	11
Non-Insects			
Gastropoda			
Ancylidae	*Ferrissia*	1	
Lymnaeidae	*Pseudosuccinea columella*		1
Physidae	*Physa virgata*	6	1
Thiaridae	*Thiara granifera*	18	14
	Thiara tuberculata	4	
Unknown**		6	
Pelecypoda			
Corbiculidae	*Corbicula fuminea*		3

Appendix 5. (continued)

Taxa		San Antonio Springs	Salado Creek Springs
Sphaeriidae	*Eupera*		7
Platyhelminthes			
Turbellaria		4	3
Annelida			
Oligochaeta		5	1
Hirudinea			2
Crustacea			
Amphipoda	*Hyallela azteca*	11	1

*Early instar larvae are unidentifiable because sufficient morphological development has not occurred.

**Unable to identify to familial level because no bodies were present in the shells. No match found for shells in keys.