FINAL REPORT

SURVEY FOR TWO EDWARDS AQUIFER INVERTEBRATES:

COMAL SPRINGS DRYOPID BEETLE
STYGOPARNUS COMALENSIS BARR AND SPANGLER
(COLEOPTERA: DRYOPIDAE)

AND

PECK'S CAVE AMPHIPOD
STYGOBROMUS PECKI HOLSINGER
(AMPHIPODA: CRANGONYCTIDAE)

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September 2, 1993

Prepared for

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SUMMARY

Stygoparnus comalensis (Coleoptera: Dryopidae) and Stygobromus pecki (Amphipoda: Crangonyctidae) are two subterranean aquatic (stygobiontic) invertebrates which inhabit the Edwards Aquifer. They have been known only from their type locality at Comal Springs in New Braunfels, Texas. In August 1992 I conducted a field survey to examine the geographic distribution of these species in Edwards Aquifer springs. Nine groups of springs where the target species were considered most likely to occur were studied in Bexar, Comal, and Hays counties. The project was timed to take advantage of unusually high spring flows in the area and included springs which had been dry for years.

All of the major spring orifices at each of the sites were manually (kick) sampled. Drift netting was implemented at six sites, but was not feasible at three. The use of drift nets to collect these stygobionts was highly successful and is recommended for future studies. Drift netting provided nearly all of the new locality information and a majority of the specimens.

New locality records extending the ranges of the Comal Springs dryopid beetle and Peck's cave amphipod indicate that they are more widespread in the aquifer than previously believed. The Comal Springs dryopid beetle was collected at Fern Bank

(Little Arkansas) Springs in the Recharge Zone of the aquifer about 20 miles northeast of New Braunfels. Peck's cave amphipod was taken at Hueco Springs in the Artesian Zone about four miles north of New Braunfels. At Comal Springs the beetle occurs in three of the four major spring runs (Comal 2, 3, 4) and was uncommon during the survey. The amphipod occurs in all four runs and was common in all but one. Both species were collected in low volume springs and seeps as well as high volume springs, and their presence in springs does not seem to be dependant on a high volume of discharge. Very little is known about their life histories.

In addition to the field survey, I examined museum collections at three institutions and sent written inquiries to four others in search of specimens and data. The aquatic invertebrate collection at the Edwards Aquifer Research and Data Center in San Marcos contained material taken from well sampling projects in addition to specimens from surface waters. No specimens of the target species were found in any of the collections.

Stygoparnus comalensis and Stygobromus pecki are part of one of the most diverse subterranean aquatic ecosystems in the world. Factors that affect the quality and quantity of the water in the Edwards Aquifer are of prime importance for the stygobiontic fauna as well as for inhabitants of the springs.

INTRODUCTION

A field survey was conducted in August 1992 to examine the geographic distribution in Edwards Aquifer springs of two subterranean aquatic invertebrates. The Comal Springs dryopid beetle, Stygoparnus comalensis Barr and Spangler, and Peck's cave amphipod, Stygobromus pecki Holsinger, were previously known only from Comal Springs in New Braunfels, Texas. Peck's cave amphipod is a candidate for the Federal Threatened and Endangered Species List, and the Comal Springs dryopid beetle is included in a petition for listing.

Stygobionts are defined as "free-living taxa which: (a) are exclusively found, or almost so, in all their developmental stages in one or more subterranean aquatic habitats, and (b) which display adaptations generally to be seen as characteristic of subterranean aquatic animals" (Botosaneanu 1986). The terms "troglobitic" or "hypogean" are used by some researchers instead of "stygobiontic," and all three will be used interchangeably in this report.

The Edwards Aquifer is one of the most diverse subterranean aquatic ecosystems in the world in terms of richness of troglobitic species (Longley 1981, 1986). Forty-three species and/or subspecies of stygobiontic animals have been described from the Artesian Zone, including the species targeted by this survey (Hershler and Longley 1986, Barr and Spangler 1992).

Stygoparnus comalensis is the world's first known stygobiontic member of the family Dryopidae. The beetle was first collected and recognized as new in 1987. Paul Spangler and I described it in March 1992 from 53 adult and six larval specimens taken from Comal Springs (Barr and Spangler 1992). Prior to this survey it had only been found in the spring orifices and run of Comal 2 despite collection efforts at Comal, Hueco, and San Marcos springs by several researchers. Table 1 summarizes the data and disposition of all known specimens collected prior to this survey. The frequency of collection of the Comal Springs dryopid beetle in Comal 2 has been quite variable, ranging from 0-22 specimens collected on each of seven different dates in 1987 and 1988.

John Holsinger first described *Stygobromus pecki* as *Stygonectes pecki* in 1967 from two Comal Springs specimens collected in 1964 and 1965 (Holsinger 1967); in 1977 he transferred the species to the genus *Stygobromus* (Holsinger 1977). It is a member of the *S. flagellatus* group composed of four rare species inhabiting the groundwater of Comal, Hays, and Kendall counties. Table 2 summarizes the data and disposition of all known specimens collected prior to this survey. According to Holsinger (Old Dominion University, Norfolk, Virginia; pers. comm. 1992), the amphipod had been previously collected only from Comal 1 and Comal 3 spring groups at Comal Springs. The species was named in the Proposed Rules of November 21, 1991, as a Category 2 candidate for Federal listing (*Federal Register*

Table 1. Collection data and disposition of Stygoparnus comalensis specimens collected at Comal Springs prior to this survey; all belong to the type series.

DATE COLLECTED	COLLECTOR	NUMBER OF SPECIMENS	REPOSITORY* (NUMBER OF SPECIMENS)
25 April 1987	H.P.Brown	3	AMNH(1),CBB(1),OMNH(1)
1 August 1987	C.B.Barr	2	NMNH(2)
23 April 1988	H.P.Brown	7	BMNH(1),CBB(2),NMNH(1),OMNH(3)
28 April 1988	C.B.Barr	7	BMNH(1),CBB(3),NMNH(3)
2 May 1988	C.B.Barr	12	AMNH(1),CAS(1),CBB(3), LSUC(1),NMNH(5),TAMU(1)
6 June 1988	W.D.Shepard	22	CAS(1),CBB(2),CNCI(2),LSUC(1), MNHN(1),NMNH(1),TAMU(1),WDS(13)

* AMNH = American Museum of Natural History, New York, NY
BMNH = Natural History Museum (formerly British Museum), London, England
CAS = California Academy of Sciences, San Francisco, CA
CBB = Cheryl B. Barr Research Collection, Sacramento, CA
CNCI = Canadian National Collection, Ottawa, Canada
LSUC = Louisiana State University Collection, Baton Rouge, LA
NMNH = National Museum of Natural History, Washington, D.C.
MNHN = Museum National d'Histoire Naturelle, Paris, France
OMNH = Oklahoma Museum of Natural History, Norman, OK
TAMU = Texas A & M University, College Station, TX
WDS = William D. Shepard Research Collection, Sacramento, CA

Table 2. Collection data and disposition of _Stygobromus pecki_ specimens collected at Comal Springs prior to this survey (Holsinger pers. comm.).

DATE COLLECTED	COLLECTOR	NUMBER OF SPECIMENS*	REPOSITORY**
18 June 1964	S.B.Peck	1F	USNM (paratype)
18 May 1965	J.R.Reddell	1F	USNM (holotype)
10 May 1977	H.Karnei J.R.Holsinger G.Longley	2F	JRH
19 May 1977	H.Karnei	9F,2M,5J	JRH
15 July 1981	M.Brzozowski	1M,2J	JRH
31 Dec. 1984	S.J.Harden	1J	JRH
5 Jan. 1985	S.J.Harden	1J	JRH
4 Jan. 1987	S.J.Harden C.F.Lindblom	1F,1M,3J	JRH
3 June 1991	P.J.Spangler	1F,1M	JRH

* F = female(s) M = male(s) J = juvenile(s)

** JRH = John R. Holsinger Research Collection, Norfolk, VA
USNM = U.S. National Museum (National Museum of Natural History), Washington, D.C.

56:58835).

The natural flow of Comal Springs, the type locality and only known habitat for the Comal Springs dryopid beetle and Peck's cave amphipod, is predicted to permanently cease within 30 years due to increasing groundwater withdrawals (Klemt et al. 1979). Comal Springs is hydrologically isolated from sources of local recharge, and unlike San Marcos and Hueco springs, cannot be aided by recharge devices (Rothermel and Ogden 1987).

On June 14, 1992, the water level in the Edwards Aquifer reached 703.31 ft. (San Antonio reference well, J-17), the highest ever recorded since monitoring began in 1932. This was caused by unusual amounts of rainfall in the recharge zone during the winter of 1991-92 and spring of 1992. Springs that were dry for years began to flow, and others experienced record discharges. By the time the survey began, the aquifer level had dropped about 11.5 ft. from the June high. Aquifer levels continued to fall slowly (from 691.85 ft. to 691.54 ft.) during the survey period from August 7-21, 1992.

A study similar to this one was conducted from May to August 1991 by Dr. Thomas L. Arsuffi (Department of Biology-Aquatic Station, Southwest Texas State University, San Marcos). At the time of his work, aquifer levels (ranging from 668.43 ft. in May to 640.54 ft. in August) and resultant spring flows were low.

MATERIALS AND METHODS

Field Survey

Survey Area:

The nine springs surveyed for the Comal Springs dryopid beetle and Peck's cave amphipod are located in Bexar, Comal, and Hays counties (Fig. 1). Selection criteria included one or more of the following: (1) Location within the Artesian (Reservoir) Zone of the San Antonio (Sub)Region of the Edwards (Balcones Fault Zone) Aquifer; (2) Edwards and associated limestones as the water-bearing formation; (3) reasonably close geographic proximity to Comal Springs. The following springs thought most likely to harbor the target species were chosen: Bexar County - San Antonio Springs, San Pedro Springs; Comal County - Altgelt Springs, Buffalo Springs, Comal Springs, Gruene Springs, Hueco Springs; Hays County - Fern Bank (Little Arkansas) Springs, San Marcos Springs, Sink Springs. Of these, two were not sampled. Access to Buffalo Springs was denied by the landowner, therefore it is excluded from this report. Altgelt Springs was visited, but samples were not obtained because of its size and depth. A description and discussion are included, however.

Most of the springs are actually complexes, or groups of

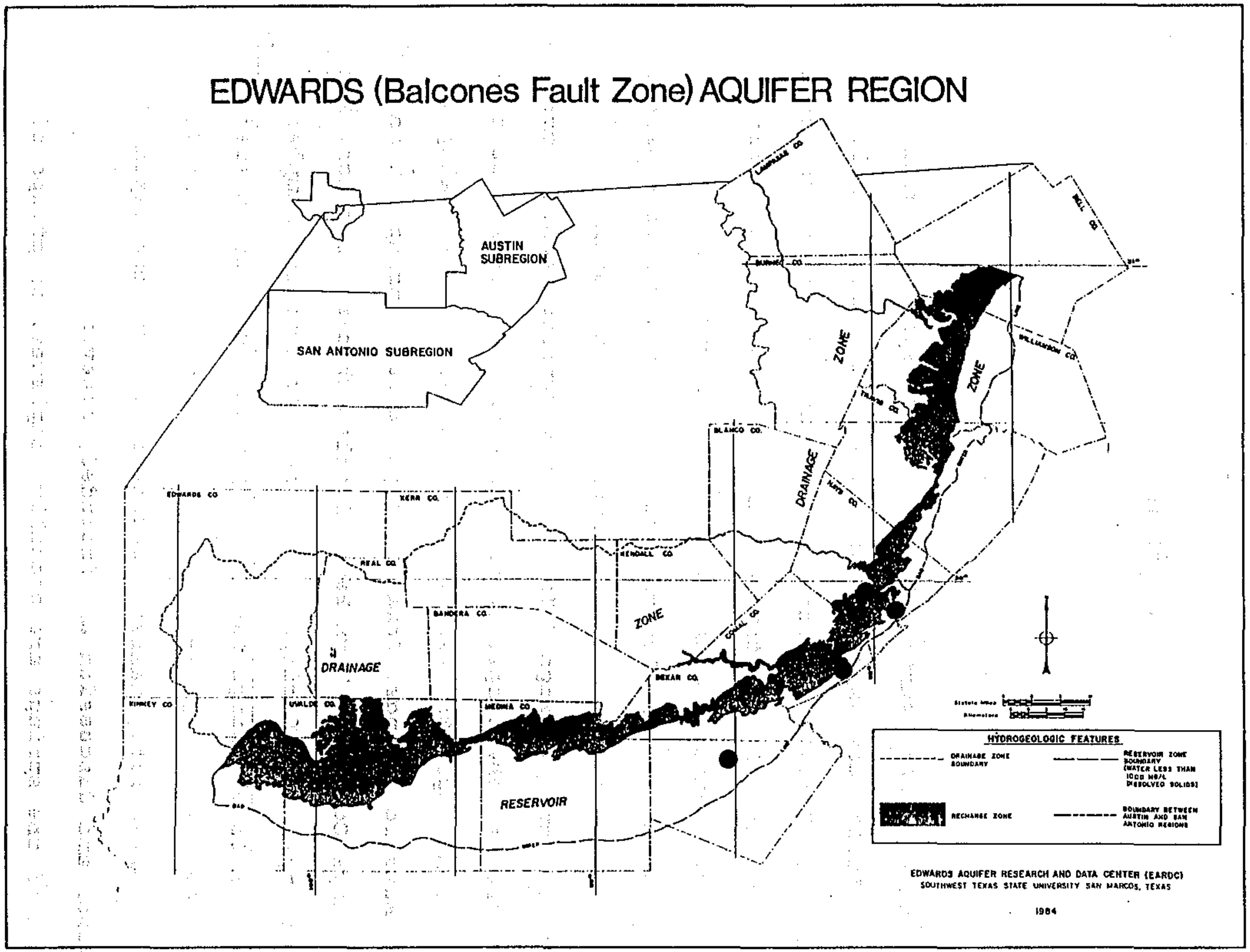

Figure 1. Distribution of springs surveyed in Bexar, Comal, and Hays counties, Texas.

springs, with multiple outlets (orifices). When this was the case, an effort was made to sample all of the major ones. Nearly all of the spring outlets were free-flowing and minimally altered. Exceptions were an old artesian well at Hueco Springs, and a PVC pipe groundwater drain at San Antonio Springs. Gruene Springs is used as a domestic water source.

The above springs were surveyed from August 7-21, 1992; a total of 13 days were spent in the field.

Techniques and Equipment:

At each spring outlet examined, sampling was conducted close to the orifice or, if possible, inside. In most cases, two types of samples were obtained from each. Manual, or active, sampling involved disturbing the substrate by hand or foot and catching the dislodged debris and organisms, carried by the flow, in a net. This technique is often termed "kick netting." A standard D-frame aquatic net (Ward's) was typically used, but occasionally a fine mesh aquarium net (opening 0.15 m x 0.20 m, length 0.47 m) was substituted at very small outlets with low flow. Netted material was briefly examined for visible organisms, which were picked out and preserved in vials of 70% ethanol. The remaining debris, minus larger sticks, stones, leaves, etc., was preserved with alcohol in half-pint jars for later examination in the laboratory.

Spring discharge was passively sampled over a period of time using drift nets at six of the sites. The nets were left in place for a minimum of 48 hours. Drift nets (Kahl Scientific Instrument Corp.) measuring 0.30 m x 0.45 m, with a mesh size of 363 microns and a plexiglass collection bottle, were utilized at large volume outlets. Standard aerial and aquatic insect net bags were used as improvised drift nets on low flow springs and seeps, as well as pipe outlets; these will be termed "net bags" or "bag-type nets." The mesh on these was sufficiently small to capture the target species. Material trapped in the drift nets was likewise preserved with alcohol in half-pint jars for later examination.

Physical measurements taken at the springs included: (1) size of the sampled orifice and other pertinent features, measured with a metric tape and reported in meters (m); (2) depth of water at the orifice, using a metric tape equipped with lead weights and reported in meters (m); (3) water velocity at the orifice, measured with a Marsh-McBirney Model 201 Portable Water Current Meter in feet/second (f/s); (4) water temperature, taken with a hand-held field thermometer recording in degrees Celsius (°C).

Data from each of the orifices sampled were recorded on a field survey form, and generally included locality, date, water clarity and temperature, size of outlet, depth and velocity of water at outlet, substrate composition, presence/absence of aquatic vegetation and leaf litter, collecting method(s), and time invested. Usually a crude map was drawn at each of the sites to illustrate the location of sampled orifices. Brune's (1981) maps were used at two springs, and maps from the Edwards Aquifer Research and Data Center (EARDC) were used at three others (Ogden et al. 1985a,b). Photographs were taken at each site.

Specimen Examination

Over 40 jars of preserved debris samples from both manual and drift netting were examined in the laboratory using a dissecting microscope. Recovered specimens were combined with those removed in the field, and stored in one dram vials of 70% ethanol. Each vial was provided with permanent, printed locality data labels.

The taxonomic complexity of hypogean (stygobiontic) amphipods necessitated that they all be sent to an expert in the group. Eighteen vials from five spring sites were sent to Dr. John R. Holsinger (Old Dominion University, Norfolk, Virginia), the author of the genus and species, for identification of Stygobromus pecki. Specimens of Stygoparnus comalensis were identified by me. Holsinger and I will retain the specimens for further study and as vouchers for this project. Other invertebrates collected incidently during this study were, or will be, distributed to researchers in their respective taxa.

Institutional Collections

Dr. John R. Holsinger furnished information on the collection data and deposition of all *Stygobromus pecki* specimens he has examined (Table 2), and I have reported that of *Stygoparnus comalensis* (Table 1).

In August 1992 I examined aquatic invertebrate collections maintained by the Edwards Aquifer Research and Data Center (EARDC) at Southwest Texas State University in San Marcos, and the Texas Memorial Museum (TMM) at the University of Texas in Austin, for additional records of the target species.

Written inquiries about the target species, accompanied by a reprint describing *Stygoparnus comalensis*, were sent in September 1992 to the following institutions which maintain collections: Texas A & M University (Entomology and Biology departments), Texas Tech University (Department of Agronomy, Horticulture and Entomology), and the Dallas Natural History Museum (Invertebrate Department). It was not necessary to contact the National Museum of Natural History (NMNH) in Washington, D.C., because Holsinger and I are aware of its holdings in our respective research areas. In addition, the coauthor of the Comal Springs dryopid beetle is a curator of Coleoptera at the NMNH.

RESULTS

Survey Sites

Table 3 summarizes information about the survey sites and collection of the target species. Details of the study are presented in the following accounts of the individual springs.

<u>Bexar</u> <u>County</u>:

San Antonio Springs

San Antonio Springs are located in San Antonio at an elevation of about 205 m (673 ft.), with most of the major outlets on the campus of the Incarnate Word College. The discharge from this large complex of springs forms the headwaters of the San Antonio River. Flowing from Edwards and associated limestones through faults in Austin chalk, they are recharged from rivers and streams to the west (i.e., the Frio, Sabinal and Medina rivers, Hondo and Leon creeks) (Brune 1981).

The springs have periodically ceased flowing since records have been kept (1897-1899, 1949-50, 1952-57, 1970-72), primarily as a result of groundwater pumping in the San Antonio area (Brune 1975, 1981). After having been dry since May 1988, they had

Table 3. Summarization of data from survey sites, 7-24 August 1992. (NA = data not available)

COUNTY	SPRING	ELEVATION (ft)	SOURCE[1]	DISCHARGE (cfs) MEAN	DISCHARGE (cfs) MIN/MAX YEAR	SAMPLING EFFORT (hrs)	TARGET SPP. SP[3]	TARGET SPP. SC[4]
Bexar	San Antonio	673	EAL	NA	0/212 1990/1920			
	Blue Hole					73.25[2]		
	PVC pipe					217.00[2]		
	footbridge					0.75		
	group m					0.75		
	group n					1.00		
	Patterson					0.50		
Bexar	San Pedro	663	EAL	NA	0/30 1991/1936			
	4c-d					1.00		
	4f					2.50		
	4h-i					0.50		
	bridge					0.75		
Comal	Comal	623	EAL	300	0/666 1956/1992			
	Comal 1					203.25[2]	78	
	Comal 2					7.00	62	3A,5L
	Comal 3					102.25[2]	130	4L
	Comal 4					99.00[2]	1	1A
Comal	Gruene	650	NA	NA	.52/3.8 1978/1936	121.50[2]		

Table 3, con't. Summarization of data from survey sites, 7-21 August 1992. (NA = data not available)

COUNTY	SPRING	ELEVATION (ft)	SOURCE[1]	DISCHARGE (cfs) MEAN	DISCHARGE (cfs) MIN/MAX YEAR	SAMPLING EFFORT (hrs)	TARGET SPP. SP[3]	TARGET SPP. SC[4]
Comal	Hueco		EAL	38.8	0/135 1984/1992			
	Hueco I	652				52.00[2]	1	
	Hueco II	658				49.25[2]		
Hays	Fern Bank	770	EAL	NA	.32/4.9 1978/1975	137.25[2]		1A,12L
Hays	San Marcos	574	EAL	161	46/451 1956/1992			
	Inn					109.00[2]		
	W shore					215.25[2]		
	Bert Brown					0.50		
Hays	Sink	600	EL	NA	1.77 1937	1.75		

[1] EAL = Edwards & associated limestones; EL = Edwards limestone
[2] includes drift netting
[3] SP = number of *Stygobromus pecki* collected
[4] SC = number of *Stygoparnus comalensis* collected; A = adult(s), L = larva(e)

minimal discharge from April to December 1991, then their flow increased markedly in January 1992 in response to high water levels in the aquifer (D. Brown, U.S. Geological Survey, San Antonio; pers. comm. 1993). As a result, numerous new springs popped up in "inappropriate" spots. One of these was a new soccer and track field which was extensively damaged when the pre-existing drainage system was overwhelmed. The U.S. Geological Survey, which monitors the springs on an irregular basis, reported the flow to be 180 cfs (5098 lps) on July 6 and 162 cfs (4588 lps) on August 20, 1992, around the time of this survey (D. Brown, pers. comm. 1993); the 180 cfs discharge was the largest in recent years. The maximum recorded discharge from San Antonio Springs was 212 cfs (6004 lps) in 1920 (Brune 1975).

During the survey six groups of outlets were sampled, five of which were on the college campus. Drift nets were installed on two of these. The well at nearby Brackenridge Zoo was not sampled. It was netted in 1977 or 1978 by Dr. Glenn Longley of the EARDC in San Marcos (pers. comm. 1993).

The main spring is Blue Hole, or Head of the River. It is enclosed in an octagonal rock and concrete well-like structure 2.6 m in diameter and 1.7 m deep. The clear water, issuing from a small cave in the bedrock of the west wall, was 3.6 m deep when measured. Manual samples were obtained from just outside the mouth of the cave because the large volume of flow prevented entry. The bottom substrate consisted of clay, silt, cobble, and bedrock, along with some wood and leaf litter. Ideally, it would have been preferable to set a drift net at the mouth of the cave, but that was impossible due to the strong current and depth of the spring. Instead, a drift net was placed near ground level in the outlet channel, which was 0.75 m wide and 0.65 m deep. Snails, clams, crayfish, and larval chironomid flies (Chironomidae) and caddisflies (Hydropsychidae: <u>Smicridea fasciatella</u>) were collected. Longley (EARDC) attempted to drift net the flow from the Blue Hole in 1977 or 1978 without success (pers. comm. 1993).

Adjacent to the sidewalk just east of Blue Hole there is a 3-inch PVC pipe groundwater drain. Its artesian outflow formed a small rivulet with a substrate of clay, silt, sand, and gravel. A net bag tied over the end of the pipe trapped hypogean amphipods (Crangonyctidae: <u>Stygobromus</u> <u>russelli</u>), isopods, snails, fly larvae, a mesoveliid bug (Mesoveliidae: <u>Mesovelia</u> sp.), a dytiscid beetle (Dytiscidae: <u>Hydrovatus</u> <u>pustulatus</u> <u>compressus</u>), and a larval hydrophilid beetle (Hydrophilidae: <u>Hydrobius</u> sp.?). The net was checked and re-set after a period of 70.5 hours.

A small spring arising beneath a footbridge over the San Antonio River to the south of the swimming pool was manually sampled. The combined flow from several small outlets was about 1.5 m wide and less than 0.1 m deep, and formed a short run of about 2 m to the river. The substrate was clay, sand, gravel, and cobble. Caddisfly (Hydroptilidae: <u>Stactobiella</u> sp.) and fly larvae, and empty snail shells were present.

Table 4. Sampling effort and technique, water temperature, and water velocity at San Antonio Springs, Bexar County, Texas.

ORIFICE	DATE	EFFORT (HRS) Manual	EFFORT (HRS) Drift	WATER TEMPERATURE (°C)	WATER VELOCITY (f/s)
Blue Hole	9-VIII	2.75	70.50	24	1.0
PVC pipe	9-VIII	0.50	216.50	-	n.m.[1]
footbridge	9-VIII	0.75	-	-	n.m.[1]
group m	9-VIII	0.75	-	-	-
group n	9-VIII	1.00	-	-	-
Patterson	18-VIII	0.50	-	-	0.1-0.2

[1]Not measurable due to low flow

Groups "m" and "n" (Brune 1981) were in a swampy area of numerous seeps and small springs, drained by two channels emptying into the San Antonio River due west of the Blue Hole. Sampling was difficult because the springs and seeps were mostly small and scattered, and the overlying substrate very silty. Manual samples were taken from small deposits of gravel within five orifices in the underlying clay substrate. The single orifice sampled in group "m" was oval-shaped, about 0.5 m wide and 0.75 m deep. A similar one in group "n" was 0.45 m wide, 0.4 m deep, and was situated beneath a clay ledge. Three others in the latter group emerged in a pool about 1.5 m in diameter, and each measured less than 0.3 m across. Only empty snail shells were collected.

The last group of outlets sampled was located in the backyard of a private residence on Patterson Avenue. The landowner (pers. comm. 1992) believes them to be the true headwaters of the San Antonio River because they are the farthest upstream. These springs are ephemeral, but at the time of the survey their discharge and that of others nearby formed a rushing stream which passed beneath the street as it flowed southwestward to join with that from groups "o" and "p" (Brune 1981). At the site several small springs emerged at the base of a low ridge. The largest of the four outlets that were sampled was less than 0.3 m deep and wide. Together they formed a small run, paralleling the ridge, which was only about 0.15 m deep. The substrate was composed of clay, sand, gravel, and small cobbles. Surprisingly, the manual collections yielded hypogean (Crangonyctidae: Stygobromus russelli) and epigean (surface-dwelling) amphipods, isopods, snails, and caddisfly (Hydroptilidae: Stactobiella sp.) and fly larvae.

San Pedro Springs

Also in San Antonio, San Pedro Springs are located in city-owned San Pedro Park, the second oldest public park in the country. The springs, at an elevation of about 202 m (663 ft.), flow from Edwards and associated limestones along a fault bounded by Austin chalk on the southeast and Pecan Gap chalk on the northwest. Recharge is from streams up to 100 km (62 mi.) to the west. As with San Antonio Springs, San Pedro Springs have ceased regular flow due to heavy pumping from the aquifer. They were totally dry during water years 1948-50, 1952-57, 1963, and 1971 (Brune 1975, 1981). More recently, after being dry most of the time since June 1988, they began to flow again in January or February 1992 when heavy rains resulted in record aquifer levels. The largest recorded spring discharge in recent years, 21.7 cfs (614.5 lps), occurred on December 22, 1992 (D. Brown, pers. comm. 1993). The maximum recorded discharge was 30 cfs (850 lps) in 1936 (Brune 1975).

Four groups of springs were examined during this survey. Only manual samples were taken; drift netting was not feasible due to very heavy public use of the park and lack of security. Children, and even a few adults, were swimming and wading in the springs despite a sign prohibiting the activity.

Two groups of orifices "4c-4d" and "4e-4f" (Brune 1981) emerged from the base of a low limestone ridge into two man-made pools bounded by concrete. The water exited the pools into a common channel from whence it was diverted into underground drains. The easternmost pool was 8.2 m long, 4.9 m wide at the dam, and up to 1 m deep. Orifices "4c-4d" (Brune 1981) consisted of a series of holes and cracks in the north bank at a depth of 0.7 m, none of which is very large. The substrate was composed of silt, sand, gravel, and some cobbles. The westernmost pool was 6.6 m long, 5.7 m wide at the dam, and 1.6 m deep at the deepest point. Outlet "4e" was not found; only one orifice corresponding in location to "4f" (Brune 1981) was noted. The water emerged from a small vertical cave opening about 1 m in diameter at the bottom of the pool under 1.2 m of water. The horizontal depth of the cave into the rock was not determined, but it begins to narrow immediately. Samples were taken from up to 1 m inside the orifice from a substrate of gravel, cobble, and bedrock. Because of interference from children jumping into the water from the rock wall above the orifice, sampling was repeated on a subsequent visit. Contrary to Brune (1981), orifice "4f" appeared to be the major outlet in terms of discharge rather than "4d.".

The flow from another group of small springs, "4g-4i" (Brune 1981) just southwest of the main springs, formed a little pond. Rooted aquatic macrophytes were present and the substrate was very silty. There was no apparent drain and, as a result, surplus water had flooded the grassy area between the pond and the nearby swimming pool. Only one small spring outlet adjacent to the sidewalk was discernible in the vicinity of "4h-4i," flowing at a depth of 0.4 m.

Brune's orifice "4j" was not found; the ditch held only low flow seeps and stagnant water. However, adjacent to the park bridge southwest of the main spring complex, there were two small outlets in a shallow, rock-margined pool which drained into a concrete-walled ditch. The pool had a bottom of silt, sand, and gravel. These springs, called "bridge" in Table 5, were not shown on Brune's (1981) map.

Table 5. Sampling effort and technique, water temperature, and water velocity at San Pedro Springs, Bexar County, Texas.

ORIFICE	DATE	EFFORT (HRS) Manual	EFFORT (HRS) Drift	WATER TEMPERATURE (°C)	WATER VELOCITY (f/s)
4c-d	12-VIII	1.00		24	0.4
4f	12-VIII	1.50		24	1.5
	18-VIII	1.00			
4h-i	12-VIII	0.50		24	0.6
bridge	18-VIII	0.75		24	n.m.[1]

[1]Not measurable due to low flow

Neither the target species nor any other stygobionts were found at the surveyed orifices of San Pedro Springs. Specimens taken from the samples included snails, clams, oligochaetes, a dytiscid beetle (Dytiscidae: *Liodessus affinis*), veliid bugs (Veliidae: *Microvelia* sp., *Rhagovelia* sp.), and the immature stages of chironomid flies (Chironomidae), caddisflies (Hydroptilidae: *Stactobiella* sp.), and mayflies.

Comal County:

Altgelt Springs

Altgelt Springs, at an elevation of about 192 m (630 ft.), are on undeveloped private property southwest of the intersection of Loop 337 and Wald Road in southwest New Braunfels. According to George et al. (1952), their source is believed to be Austin chalk, although the water rises through an opening in Taylor marl. Brune (1981) stated that they emerge from a reversible, or resurgence, sinkhole in Austin chalk. On December 4, 1936, the sinkhole was reported to be 18 m deep, with water flowing at 3.1 lps (0.11 cfs) at a depth of 14 m; on November 18, 1978, the discharge was 1.6 lps (0.06 cfs) (Brune 1981). A 1956 Texas Board of Water Engineers report (Pettit and George) gave the average flow as 50 gpm (3.2 lps/0.11 cfs). The water was formerly used for irrigation.

The sinkhole is situated in a wooded, overgrown area, and resembles a typical pond except for its unusually circular shape. The location of the spring orifice(s) was not apparent since no evidence of flow could be seen at the pond surface. This was undoubtedly due to its considerable depth. Although the sinkhole was full of water, flow was barely discernible in the shallow outlet channel on the southeast side, indicating low spring discharge. The clay bottom of the pond drops off sharply outward from the shore; the water was measured to be 1.1 m deep about 1 m out from the bank. It is inhabited by fish.

I visited the site on August 15 and 16, but was unable to obtain samples because the size and depth of the sinkhole would have necessitated specialized equipment and training.

Comal Springs

Comal Springs, the largest complex of springs in Texas and the Southwest, are located in New Braunfels in city-owned Landa Park and adjacent private and city property at an elevation of about 190 m (623 ft.). Four main spring groups (Comal 1-4, all on city property) emerge from Edwards and associated limestones at the Comal Springs fault along a 1402 m (4600 ft.) stretch of the Balcones Escarpment (Rothermel and Ogden 1987). The springs fill Landa Lake and are the source of the Comal River. The springs, spring runs, and lake are the home of several rare, range-restricted organisms.

Comal Springs water is derived from a deep flow, phreatic conduit system. Although faulting has hydrologically isolated the springs from any large sources of local recharge, major storms temporarily contribute a small but significant recharge component (Rothermel and Ogden 1987). The principal recharge area lies as much as 100 km (~62 mi.) to the west (Brune 1981), and the water migrates to depths over 150 m (2000 ft.) below the surface before re-emerging at the springs (Ogden et al. 1986).

As a consequence of this deep circulation, the water is never turbid and is free from bacterial contamination when it emerges from the spring openings. According to Pearson et al. (1975), most of the water has been in the aquifer system for over 20 years, and only a small portion is less than 10 years old. Hydrological evidence suggests that the immediate source of all of the springs is the same waters beneath the southeast fault block in Landa Park (Rothermel and Ogden 1987).

Klemt et al. (1979) predicted that the natural flow of Comal Springs will cease permanently before the year 2020 if groundwater pumpage continues at projected rates. It is not possible to enhance the flow of these springs with recharge dams (Rothermel and Ogden 1987). Their mean historic flow has been approximately 300 cfs (8496 lps), but this average is steadily decreasing (Ogden et al. 1986). In recent years some of the springs have ceased flowing during droughts. The only time they all were dry was from June 13 to November 3, 1956, when the aquifer levels reached a record low after seven years of drought (Brune 1975, 1981). During the summer of 1984 the springs came within one foot of drying (Rothermel and Ogden 1987), and in the summer of 1990 several orifices ceased flowing for one to three weeks (Arsuffi, pers. comm. 1993; Whatley, Director, Landa Park, New Braunfels, pers. comm. 1993). The minimum total discharge from the springs in 1990, 46 cfs (1303 lps), was recorded on June 29 (Stephens, U.S. Geological Survey, San Antonio; pers. comm. 1993).

During the survey period from August 7-21 the spring flow was well above average, ranging from 458 cfs (12,971 lps) to 468 cfs (13,254 lps). The all-time maximum recorded discharge of the springs, 666 cfs (18,861 lps), occurred on December 22, 1991 (Stephens, pers. comm. 1993).

The Comal 1 spring group (spring "j," Brune 1981) is located at the northwest corner of Landa Park on the west side of California Boulevard, and has the second largest discharge of the four spring groups (Ogden et al. 1985a,b). At the highest elevation, it is the first to stop flowing when the total discharge of the springs falls to about 100 cfs (2832 lps) (Whatley, pers. comm. 1993). The main orifice was a shallow limestone cave about 0.6 m in diameter, with water 0.15 m deep. The flow of this and two adjacent outlets formed a short, swift (3.2-4.4 f/s) run emptying into the main spring run. Two other large orifices were present at the head of the main run, one beneath the rock and concrete wall, and the other under 0.45 m of water on the bottom. A substantial cluster of smaller outlets was located just downstream at the base of the west bank of the run. The substrate in the various orifices was bedrock, cobble, gravel, and to a lesser extent, sand.

All of the above outlets and numerous smaller ones at the head of the run were manually sampled. In addition, drift nets were installed on the exit channel from the cave and on the large bottom orifice. The latter net became packed with sand and gravel carried up from the bottom by the flow. Stygobromus pecki was taken in both manual and drift samples, with the greatest number (70) coming from the cave orifice; only four were from the bottom outlet. The species had been previously collected in Comal 1 (Holsinger, pers. comm. 1992). Stygoparnus comalensis was not found here during this survey, nor during pre-survey sampling efforts. Other organisms present were snails, crayfish, elmid beetles (Elmidae: Heterelmis comalensis, Microcylloepus sp.), water penny beetles (Psephenidae: Psephenus texanus), hypogean dytiscid beetles (Dytiscidae: undescribed), veliid bugs (Veliidae: Rhagovelia sp.), and the immature stages of flies, moths, mayflies, and caddisflies (Helicopsychidae: Helicopsyche sp.; Hydroptilidae: Leucotrichia sarita, Ochrotrichia nigritta, Stactobiella sp.).

Comal 2 (spring "k," Brune 1981) is slightly northeast of Comal 1 on the east side of California Boulevard. Numerous low volume springs discharge from the base of rock and concrete retaining walls along the lower channel of ephemeral Panther Creek. Outlets were evident, mostly along the west bank, from the head of the run downstream to just above the stone arch bridge, a total distance of about 36.6 m (120 ft.). The largest of these were at the head of the run, which is 2.5 m wide, and along the west wall in the upper part of the run. The water issued from cracks in and between rocks in orifices mostly less than 1 m wide, and was very shallow, about 0.2 m deep, in the upper run. The run progressively deepened downstream, but remained less than a meter deep. Below the stone arch bridge the run is impounded to form a children's wading pool just before it merges with that of Comal 1. Gravel, cobbles, and boulders compose the substrate.

Table 6. Sampling effort and technique, water temperature, and water velocity at Comal Springs, Comal County, Texas.

ORIFICE	DATE	EFFORT (HRS) Manual	Drift	WATER TEMPERATURE (°C)	WATER VELOCITY (f/s)
Comal 1	7-VIII	3.25	-	23	3.2-4.4
	10-VIII	-	100.00[1]	-	-
Comal 2	7-VIII	2.50	-	23	0.1-0.4
	16-VIII	3.00	-	-	-
	21-VIII	1.50	-	-	-
Comal 3	7-VIII	1.75	-	-	-
upper	7-VIII	-	-	23	0.4
bank	7-VIII	-	-	23	1.8
	10-VIII	-	100.50	-	-
Comal 4	10-VIII	2.00	-	-	-
right			97.00	23	0.5-0.6
left			-	23	0.4

[1]For each of 2 nets

All of the visible spring outlets at Comal 2 were manually sampled on three separate occasions. All were situated in roughly the upper three-quarters of the run above the bridge.

Drift netting was not attempted because children frequently wade in the run and the likelihood of disturbance was great. Comal 2 is the type locality of Stygoparnus comalensis, and prior to this study it was known only from this run. The beetle was collected on each of the three sampling dates, but in low numbers: one adult and two larvae were collected on both August 7 and August 16, and one adult and one larvae on August 21, for a total of three adults and five larvae. In contrast, Stygobromus pecki was common each of the three dates (13, 36, and 13 specimens). Twice as many individuals were collected in the upper quarter than the middle half of the run on August 16 when samples from different sections of the run were kept separate. This may be a result of the fact that most of the larger orifices are in the upper quarter. A single specimen of recently-described Mexiweckelia hardeni Holsinger (1992) (Hadziidae), a rare hypogean amphipod, was also collected. Other fauna present included isopods, ostracods, snails, oligochaetes, elmid beetles (Elmidae: Heterelmis comalensis, Microcylloepus sp.), water penny beetles (Psephenidae: Psephenus texanus), a dytiscid beetle (Dytiscidae: Hydroporus rufilabris), veliid bugs (Veliidae: Rhagovelia sp.), and immature stages of flies, moths, mayflies, caddisflies (Helicopsychidae: Helicopsyche sp.), and dragonflies.

Comal 3 (spring "1," Brune 1981) arises about 152 m (500 ft.) northeast of Comal 2 along the base of the fault escarpment, and is the largest of the four spring groups in terms of discharge (Ogden et al. 1985a,b). It is composed of many springs ranging from moderately large outlets to small seeps, most of which are at the head of the run or along a 140 m (460 ft.) stretch of the escarpment almost to Landa Lake. The orifices and run have a substrate of gravel, cobble, boulders, and bedrock.

All of the major, and many minor, spring outlets along the entire length of the run were manually sampled. The uppermost of these, at the head of the run under 0.45 m of water, was 0.9 m wide (upper, Table 6). A drift net was set at the orifice with the largest discharge which was located beneath the escarpment bank near the head of the run (bank, Table 6). The opening was on the bottom under water 0.65 m deep, and measured about 1 m in diameter; the water velocity was 1.8 f/s. Four larval Stygoparnus were captured in the drift sample. Numerous specimens of Stygobromus pecki were taken in both drift (80 specimens) and manual samples (ca. 50 specimens). Peck's cave amphipod was previously known to occur in Comal 3 (Holsinger, pers. comm. 1992), but the Comal Springs dryopid beetle was not. Also collected were a rare hypogean amphipod (Sebidae: Seborgia relicta), epigean amphipods, isopods, ostracods, snails, oligochaetes, elmid beetles (Elmidae: Heterelmis comalensis, Microcylloepus sp.), water penny beetles (Psephenidae: Psephenus texanus), hypogean dytiscid beetles (Dytiscidae: undescribed), veliid bugs (Veliidae: Rhagovelia sp.), a water strider (Gerridae), and the immature stages of flies, moths, mayflies, caddisflies (Helicopsychidae: Helichopsyche sp.; Hydroptilidae:

Stactobiella sp.), and dragonflies.

Comal 4 (spring "a," Brune 1981) is located at the end of the northeast arm of Landa Lake, just upstream from the mouth of macrophyte-choked Blieders Creek. The site is adjacent to, and owned by, the New Braunfels Utility and is near the municipal water wells. The two main outlets emerged at either side of the base of a concrete wall at the head of the 3.7 m wide channel. Both were rather low volume springs. The larger of the two, on the right (facing the wall), was about 1 m wide and under 0.45 m of water; the one on the left was 0.4 m wide and 0.35 m under water. The run, like that of the other spring groups, is confined by rock and concrete walls, but unlike them, had little discernible flow. Nonetheless, the water was clear and not stagnant. The substrate consisted of sand, gravel, cobbles, and concrete, and was much more sandy than the other three runs.

A drift net on the larger, right-hand orifice captured one adult Stygoparnus comalensis and one specimen of Stygobromus pecki, neither of which has been previously reported from Comal 4. Manual and drift sampling also yielded other hypogean amphipods (Crangonyctidae: Stygobromus russelli; Hadziidae: Mexiweckelia hardeni), epigean amphipods, isopods, ostracods, prawns, crayfish, snails, clams, oligochaetes, elmid beetles (Elmidae: Microcylloepus sp.), water penny beetle larvae (Psephenidae: Psephenus sp.), dytiscid beetles (Dytiscidae: Neoclypeodytes discretus, Neoclypeodytes sp.), veliid bugs

(Veliidae: Rhagovelia sp.), water striders (Gerridae), marsh treaders (Hydrometridae), and the immature stages of flies, moths, mayflies, and caddisflies (Helicopsychidae: Helicopsyche sp.; Hydroptilidae: Hydroptila sp., Leucotrichia nigritta, Ochrotrichia sarita).

Gruene Springs

Gruene Springs are a collection of small springs and seeps flowing from a high bluff of terrace gravel or alluvium on the east bank of the Guadalupe River at an elevation of about 198 m (650 ft.). I could find no information indicating which geologic formation is the source of the springs. They are on private property in northeastern New Braunfels between Gruene Road and the river, near the historic village of Gruene. The flow was reported to be 3.8 lps (0.13 cfs) on December 30, 1936; 1.6 lps (0.06 cfs) on September 29, 1943; and 0.52 lps (0.02 cfs) on November 18, 1978 (Brune 1981). The springs serve as the water supply for a nearby residence. Brune may have named the springs himself, because the landowner had never heard them called Gruene Springs until seeing the name in Brune's book, Springs of Texas.

The main spring outlet(s) are confined within a closed concrete cistern covered by an old wooden shed. The water presently does not accumulate in the cistern, but exits through a large crack in the base and flows into the first of two open water collection boxes which is 1.2 m long and 1 m wide. From this tank some of the water is pumped to the top of the bluff for household use. Excess water enters the larger second box (1.2 m long x 1.9 m wide), then spills down the hillside depositing travertine along its flow. Old travertine deposits on the bluff nearby indicate the former presence of now-extinct spring outlets.

Table 7. Sampling effort and technique, water temperature, and water velocity at Gruene Springs, Comal County, Texas.

ORIFICE	DATE	EFFORT (HRS) Manual	EFFORT (HRS) Drift	WATER TEMPERATURE (°C)	WATER VELOCITY (f/s)
Gruene	16-VIII	2.50	119.00	21	n.m.[1]

[1]Not measurable due to low flow

Gruene Springs were sampled manually just inside the base of the cistern, and with a bag-type drift net where the water exited the structure. At this point the flow was just 5 cm wide and only a couple of centimeters deep. With input from other nearby seeps, it widened to 38 cm at the point where it entered the first collection box. The substrate inside the cistern consisted of clay, gravel, and travertine. Samples yielded elmid beetle

(Elmidae: Stenelmis sp.) and water penny larvae (Psephenidae: Psephenus sp.), fly larvae, a veliid bug (Veliidae: Rhagovelia sp.), epigean amphipods, snails, and oligochaetes, but neither of the target species. Other seeps located in a steep-walled ravine to the north were manually sampled, but were unproductive. These had extremely low flow.

Hueco Springs

Hueco Springs, sometimes spelled Huaco or Waco, are located on private property along River Road about 7 km (4 mi.) north of New Braunfels. Two main groups of springs issue from alluvial gravel on the floodplain of the Guadalupe River. They emerge at the Hueco Springs fault and their source is Edwards and associated limestones (Rothermel and Ogden 1987). Hueco I (or Hueco A) is in an undeveloped, brushy, wooded area just west of River Road at an elevation of 198.7 m (652 ft.). Hueco II (or Hueco B) is between River Road and the river at an elevation of 200.6 m (658 ft.) on the grounds of a private campground called Camp Hueco Springs. The discharge from both groups of springs independently flows into the Guadalupe River.

Hydrologically, the Hueco Springs system consists of a phreatic base flow component of older, more distant recharge, and a shallow, rapid flow, storm recharge (vadose) component. The flow of the springs could be enhanced by the construction of recharge dams at the headwaters of creeks like Elm and Blieders (Rothermel and Ogden 1987). This is in contrast to the Comal Springs system which has a minimal local recharge component and cannot be supplemented by recharge dams.

Hueco I, the larger group, normally is perennial but often stops flowing during droughts (Ogden et al. 1986). Hueco II is intermittent, ceasing to flow during the dry portions of most years (D. Brown, pers. comm. 1993). The springs stopped flowing for a few months in 1984 (Rothermel and Ogden 1987), but Hueco I did not go dry during the drought of 1989-1991 (landowner, pers. comm. 1992; D. Brown, pers. comm. 1993). The maximum recorded discharge from the springs was 135 cfs (3823 lps) on March 11, 1992 (D. Brown, pers. comm. 1993); the average annual discharge has been 1100 lps (38.8 cfs) (Brune 1981). The individual flows of Hueco I and II are currently monitored about six times a year by the U.S. Geological Survey (D. Brown, pers. comm. 1993).

Hueco I is a cluster of a few large and many small springs. At the time of the survey their combined flow formed a slightly turbid run, 5.4 m wide and about 0.5 m deep, with a swift current. A few days later (August 11, 1992), the U.S. Geological Survey measured their discharge at 48.2 cfs (1365 lps) (D. Brown, pers. comm. 1993). The greatest flow came from an underwater fissure on the bottom near the head of the run; the orifice was 1.2 m wide (bottom, Table 8). The uppermost outlet at the head of the channel (upper, Table 8) was less than 1 m wide and only about 0.2 m deep. The substrate consisted of sand, gravel, and cobbles.

Table 8. Sampling effort and technique, water temperature, and water velocity at Hueco Springs, Comal County, Texas.

ORIFICE	DATE	EFFORT (HRS) Manual	Drift	WATER TEMPERATURE (°C)	WATER VELOCITY (f/s)
Hueco I	8-VIII	4.00			
upper			-	21.5	0.2
bottom			48.00	21.5	1.2
Hueco II	8-VIII				
pool		1.25		21.5	0.1
pipe		-	48.00	-	-

Manual sampling included all visible springs and seeps at the head of the run. Elmid (Elmidae: Microcylloepus sp.) and water penny (Psephenidae: Psephenus texanus) beetles, epigean amphipods, crayfish, and snails were collected. A drift net set over the large bottom fissure yielded one specimen of Stygobromus pecki, which represents a new locality record and range extension for the species. Other invertebrates in the drift included isopods, epibenthic copepods (Acanthocyclops vernalis, Mesocyclops edax, Skistodiaptomus sp.), snails, clams, oligochaetes, and the larvae of caddisflies (Hydroptilidae: Hydroptila sp.), moths, and flies.

Hueco II consisted of three main and several smaller sand-boil springs arising in the bottom of a pool about 6 m in diameter and 0.7 m deep. On August 11, 1992, its discharge was 42.5 cfs (1204 lps) (D. Brown, pers. comm. 1993). The slightly turbid water exited through two channels, one flowing north, the other east. The bottom substrate consisted of sand and gravel.

Manual sampling in the pool was totally unproductive. Due to heavy use of the campground and the popularity of the pool for soaking and wading, drift netting was not implemented. However, the overflow from an old artesian well adjacent to the northern run was sampled by placing a drift net bag over an exit pipe. This was also unproductive. The well, not currently in use, flows when there has been much rain (landowner, pers. comm. 1992).

Hays County:

Fern Bank Springs

Fern Bank Springs, called Little Arkansas by the local people, emerge at an elevation of about 235 m (770 ft.) on the south bank of the Blanco River approximately 8 km (5 mi.) east of Wimberley. A number of low volume springs and seeps, they flow from Edwards and associated limestones near the base of a vertical bluff where the Hidden Valley fault crosses the Blanco River (Brune 1981). Travertine deposits are present in the orifices and along the downhill course of the water. Several of the rivulets merge before cascading off a high bank into the river. According to their owner (pers. comm. 1992), the springs are perennial and their discharge is temporarily increased by rainstorms. Recorded discharge was 140 lps (4.9 cfs) on May 31, 1975, and 9.1 lps (0.3 cfs) on May 1, 1978 (Brune 1981). Although the area is privately owned and developed as a campground, the springs themselves have been minimally altered. The rare, range-restricted Fern Bank salamander, *Eurycea neotenes pterophila*, occurs in the springs and seeps.

The uppermost orifice was inside a small cave, entrance diameter about 2.5 m, in the base of the bluff. A pool of water inside the cave was formerly tapped for drinking water (landowner, pers. comm. 1992), and the intake box and pipes running westward across the hill are still in place. Although water from the pool could not be seen exiting the cave, subsurface flow was undoubtedly present. An attempt to manually sample the pool was not productive.

The flow of a few small outlets was captured by a pair of open stone and concrete water collection boxes (maximum length 10.1 m x maximum width 3.15 m) which were the most noticeable "improvement" of the springs. At the time water was not being diverted from the spring boxes for domestic or other uses. When the lower box is full of water, as it was during this survey, it overflows onto the ground. The orifices feeding the boxes were sampled manually and the largest, at the upper box, was also sampled with a bag-type drift net (box, Table 9).

Table 9. Sampling effort and technique, water temperature, and water velocity at Fern Bank (Little Arkansas) Springs, Hays County, Texas.

ORIFICE	DATE	EFFORT (HRS) Manual	EFFORT (HRS) Drift	WATER TEMPERATURE (°C)	WATER VELOCITY (f/s)
outlets	11-VIII	5.75		21	n.m.[1]
cave			-		
box			65.75		
hill 1			-		
hill 2			-		
hill 3			65.75		

[1]Not measurable due to low flow

Three other small orifices located on the hillside to the east were also examined (hill 1-3, Table 9). Each had a diameter of between 0.30 to 0.35 m and a water depth of less than 0.1 m; the substrate of each was composed of gravel, small cobbles, bedrock, and travertine. All were manually sampled and drift nets were placed at two of them (hill 1 & 3). One of the nets (hill 1), an inexpensive bag-type, was stolen during the survey period. Fortunately the second net (hill 3) and the one at the upper box were undisturbed.

One adult and 12 larval <u>Stygoparnus comalensis</u> were taken by drift net at the easternmost orifice (hill 3). This is a new locality record and significant range extension for the Comal Springs dryopid beetle, previously known only from Comal Springs. The number of larvae collected was twice the cumulative total previously collected at Comal Springs prior to this survey. A number of hypogean amphipods, <u>Stygobromus russelli</u> (Crangonyctidae), were collected both in manual and drift samples. The following organisms were also taken: epigean amphipods, isopods, snails, oligochaetes, planarians, elmid beetles (Elmidae: <u>Heterelmis</u> sp. near <u>vulnerata</u>, <u>Microcylloepus</u> sp., <u>Stenelmis</u> sp.), water penny beetles (Psephenidae: <u>Psephenus texanus</u>), veliid bugs (Veliidae: <u>Rhagovelia</u> sp.), mesoveliid bugs (Mesoveliidae: <u>Mesovelia</u> sp.), naucorid bugs (Naucoridae: <u>Ambrysus</u> sp.), and the larvae of soldier flies (Stratiomyidae), moths, and caddisflies (Calamoceratidae: <u>Phylloicus ornatus</u>; Ecnomidae: <u>Austrotinodes</u> n. sp.; Hydroptilidae: <u>Stactobiella</u> sp.;

Polycentropodidae: Polycentropus sp.). The new Austrotinodes is being described by David E. Bowles, a Trichoptera specialist working for the Texas Parks and Wildlife Department's Resource Protection Division (formerly at the Armstrong Laboratory at Brooks Air Force Base, Texas).

San Marcos Springs

San Marcos Springs, in the city of San Marcos, are the second largest spring system in Texas with an average annual discharge of 4300 lps (152 cfs) (Brune 1981) to 4500 lps (161 cfs) (Ogden et al. 1986). They were impounded in the 1840's to run a mill (Boyd 1989), forming Spring Lake with a surface elevation of 175 m (574 ft.) (Ogden et al. 1986). The area is now a resort park and tourist attraction called Aquarena Springs. The springs and upper San Marcos River are home to several rare and Federally listed organisms.

The springs emerge from Edwards and associated limestones along the San Marcos Springs fault where an impervious layer of Austin chalk and Taylor marl forces the water to the surface (Brune 1981). The six major and numerous minor orifices are now at the bottom of the lake under up to 12 m (40 ft.) of water. According to Ogden et al. (1986), two separate flow regimes contribute water to the springs. "Older" groundwater moves northward from the San Antonio Region and emerges only from the

southern orifices. The "younger" component, emerging from the northern orifices, is local recharge from the Blanco River and Sink Creek. The two components appear to be separated from one another by a fault-controlled pressure boundary.

The maximum recorded discharge from San Marcos Springs was 451 cfs (12,772 lps) from March 12-15, 1992 (Stephens, pers. comm. 1993); the record low was 1300 lps (46 cfs) on August 15, 1956 (Brune 1981). During the drought of 1984 the discharge dropped to 60 cfs (1700 lps) (Ogden et al. 1986). The springs were flowing at a rate of 283 cfs (8015 lps), nearly twice the average discharge, on August 26, 1992, shortly after sampling for this project was completed (Stephens, pers. comm. 1993).

During this survey all of the obvious spring outlets along the margin of Spring Lake were sampled. These were in three groups situated along the western shore of the northwest arm of the lake. In addition, one very small spring located near Sink Creek, just northeast of the northeast arm of the lake, was examined. The larger, high volume orifices in the lake bottom were not sampled. One of these, Pipe (Diversion, Divergent, Installation) Spring, was flow netted by the EARDC for extended periods of time in past years. Neither of the target species were collected during their study (see Institutional Collections).

A group of springs arise directly in front of the Aquarena Springs Inn near the end of the northwest arm of the lake. Four

of the five outlets sampled emerged from beneath a concrete walkway and stairs at water depths of 0.1-0.8 m; one of them was furnished with an outflow trench. The fifth orifice was under 1.4 m of water about 1.5 m from shore. At all, the substrate was sand, gravel, cobbles, and bedrock.

Two drift nets were set, one over a rock-rimmed upwelling by the stairs, and the other in the sidewalk trench. The fauna was quite diverse and included several species of hypogean amphipods (Crangonyctidae: Stygobromus flagellatus, S. russelli; Hadziidae: Texiweckelia texensis, Texiweckeliopsis insolita; Sebidae: Seborgia relicta), all of which had been previously collected from either San Marcos Springs or the artesian well at nearby Southwest Texas State University. Epigean amphipods (Hyalellidae: Hyalella azteca), isopods, prawns, epibenthic copepods (Macrocyclops albidus, Megacyclops latipes, Orthocyclops modestus), ostracods, snails, oligochaetes, elmid beetles (Elmidae: Heterelmis sp. larvae, Microcylloepus sp. adult and larvae), water penny beetle larvae (Psephenidae: Psephenus sp.), a dryopid beetle (Dryopidae: Helichus suturalis), and the immature stages of flies, moths, mayflies, and caddisflies (Helicopsychidae: Helicopsyche sp.; Polycentropodidae: Polycentropus sp.) were also collected.

Two groups of small, low volume springs and seeps along the lakeshore southwest of the Aquarena Springs Inn were also surveyed. The park personnel were unaware of their presence, and it is possible that they are intermittent. One group was located across the lake from the Underwater Theater and repair boathouse; the other was to the southwest, directly across from fountains near the mouth of the northwest arm of the lake. Each stretched 10-15 m along the shore at the base of a steep bluff, and emerged directly into the lake from small orifices extending as deep as 0.5 m under the bank. The water depth was less than 0.5 m at the outlets, with a substrate of sand, gravel, silt, and a few cobbles.

Besides manual sampling, four drift nets (two large and two small) were set at the larger outlets. The nature of the fauna was much more epigean than that from the springs by the Inn, perhaps exclusively so. Collections included epigean amphipods (Hyalellidae: Hyalella azteca), isopods, crayfish, epibenthic copepods (Eucyclops agilis, E. elegans, Macrocyclops albidus), ostracods, snails, oligochaetes, planarians, elmid beetles (Elmidae: Heterelmis comalensis, Microcylloepus sp., Stenelmis sp. larvae), water penny beetle larvae (Psephenidae: Psephenus sp.), water scorpions (Nepidae: Ranatra sp.), veliid bugs (Veliidae: Rhagovelia sp.), and the immature stages of naucorid bugs (Naucoridae), flies, dragonflies, moths, mayflies, and caddisflies (Hydroptilidae: Hydroptila hamata). Due to their proximity to one another and the similarity of their faunas, the data and samples from these two groups of springs were combined.

The last site was a very small spring in a roadside ditch, located on the northeast side of Bert Brown Road near the San

Marcos Treatment Center and Aquarena Springs Golf Course. According to Aquarena Springs Attractions Manager David Edwards (pers. comm. 1992), it is one of several small springs that have popped up this year in response to the wet weather and high aquifer levels. The small orifice was 0.15 m in diameter and the water was less than 0.1 m deep; it created a run 0.5 m long before entering water in the ditch. The substrate was silt, mud, sand, and gravel. Manual sampling resulted only in epigean organisms such as amphipods, ostracods, snails, clams, a dytiscid beetle (Dytiscidae: Hydroporus sp.), and dragonfly nymphs.

Table 10. Sampling effort and technique, water temperature, and water velocity at San Marcos Springs, Hays County, Texas.

ORIFICE	DATE	EFFORT (HRS) Manual	EFFORT (HRS) Drift	WATER TEMPERATURE (°C)	WATER VELOCITY (f/s)
Inn	13-VIII	1.00	-	20.5	1.1-1.4
	18-VIII	-	54.00[1]	-	-
W shore	13-VIII	3.25	-	20.5	n.m.[3]
	18-VIII	-	53.00[2]		
Bert Brown	16-VIII	0.50	-	-	n.m.[3]

[1]For each of two nets
[2]For each of four nets
[3]Not measurable due to low flow

Sink Springs

Sink Springs are located in northeast San Marcos near the end of Spring Road (Hays Co. Rd. 141), only about 1.1 km (0.7 mi.) northeast of San Marcos Springs. They emerge from Edwards limestone where the San Marcos Springs fault crosses Sink Creek at an elevation of about 183 m (600 ft.). The flow from the springs was reported to be 50 lps (1.8 cfs) on October 4, 1937 (Brune 1981). The water fills a small pond covered with duckweed (Lemna sp.), and with enough discharge, flows into the bed of Sink Creek which enters the northeast arm of Spring Lake. The privately-owned spring is in a wooded area, and is undeveloped except for an old pumphouse. The water is not currently being utilized by people.

Table 11. Sampling effort and technique, water temperature, and water velocity at Sink Springs, Hays County, Texas.

ORIFICE	DATE	EFFORT (HRS)		WATER TEMPERATURE (°C)	WATER VELOCITY (f/s)
		Manual	Drift		
Sink	13-VIII	1.75		26	n.m.[1]

[1]Not measurable due to low flow

According to the landowners (pers. comm. 1992), the unusually large discharge from the springs earlier this year temporarily washed away most of the duckweed. Although there may have been subsurface flow, at the time of this survey there was no evident outflow from the pond, nor could any current be detected at the water surface.

The general location of the main orifice was indicated by the landowners, but was difficult to pinpoint. Manual samples were obtained from a substrate of clay, silt, and cobble at a depth of 1.1 m, and contained epigean amphipods, snails, clams, and dragonfly nymphs. According to Glenn Longley of the Edwards Aquifer Research and Data Center (pers. comm. 1993), his graduate student dove there with scuba gear earlier in the year (1992). She reported that at that time the spring outlet was about 15 ft. (4.6 m) underwater and had a diameter of a couple of feet.

Surveys of Wells

Stygoparnus comalensis and *Stygobromus pecki* are not known to have been collected from either artesian or pumped wells. Although this project did not focus on wells, such studies have been conducted by the Edwards Aquifer Research and Data Center (EARDC) (Hershler and Longley 1986, Holsinger and Longley 1980, Longley 1981). During their studies 22 Edwards Aquifer wells were periodically sampled from 1976 to 1981, and 14 of them yielded stygobiontic organisms. I spoke to Dr. Longley and examined the EARDC collection in order to determine if the Comal Springs dryopid beetle or Peck's cave amphipod had been collected from the sampled wells, but found neither (see Institutional Collections, below).

An artesian well at Hueco Springs and an artesian groundwater drain at San Antonio Springs that were incidently sampled during this survey did not yield the target species.

Institutional Collections

Neither the Edwards Aquifer Research and Data Center (EARDC) at Southwest Texas State University nor the Texas Memorial Museum at University of Texas (TMM), which I visited during the study, had specimens of the Comal Springs dryopid beetle or Peck's cave amphipod.

The EARDC had a large collection of both identified and unidentified specimens. The identified amphipods, many of which were from well sampling studies (Hershler and Longley 1986, Holsinger and Longley 1980, Longley 1981), had been determined by Dr. John R. Holsinger. I borrowed and sent to Holsinger 58 vials of unidentified amphipods from springs and wells in Bexar, Comal, and Hays counties. The majority of these were from Pipe Spring, one of the San Marcos Springs at the bottom of Spring Lake, which was extensively sampled in the past. Because Holsinger had already examined many amphipods from the site, he felt that it was unnecessary to identify this material (pers. comm. 1992). He found no specimens of Stygobromus pecki in the vials he elected to examine. The TMM had no unidentified hypogean amphipods.

Of the four institutions or departments that were sent written inquiries about their collections, three responded: the Department of Entomology at Texas A & M University in College Station (Edward G. Riley), the Department of Biology also at Texas A & M (Merrill H. Sweet), and the Invertebrate Department at the Dallas Museum of Natural History (Gail R. Manning). Manning sent me a dryopid beetle which turned out to be a common epigean species. Apparently none of the above collections has specimens of the target species. No reply was received from Dr. Leland Chandler of the Department of Agronomy, Horticulture and Entomology at Texas Tech University in Lubbock.

Both Holsinger and I work closely with the National Museum of Natural History (NMNH) in Washington, D.C., and are familiar with its holdings in our research areas. The types of Stygobromus pecki, and many other species described by Holsinger, were deposited in the NMNH (Holsinger 1967). The only specimens of Stygoparnus comalensis at the museum are the type series deposited subsequent to publication of the description (Barr and Spangler 1992).

The repositories and data of all known specimens of Stygoparnus comalensis collected prior to this survey are given in Table 1, and those of Stygobromus pecki are given in Table 2 (see Introduction).

DISCUSSION

Target Species

It is not possible to infer the subterranean geographic distributions of stygobiontic organisms from their presence in a few springs. However, new locality records extending the known ranges of the Comal Springs dryopid beetle and Peck's cave amphipod evidence that the species are more widespread than previously believed.

Very little is known about the life histories of either the Comal Springs dryopid beetle or Peck's cave amphipod. Because they are adapted for a hypogean existence (i.e., blind, unpigmented, fragile) they are presumably ill-suited for life in surface waters. But nothing is really known about their survivability in the springs or how their epigean versus hypogean (above ground versus subterranean) longevity compares. Another unanswered question is whether individuals that have emerged via springs have the instinct and the ability to re-enter the aquifer.

The use of drift nets to collect these stygobiontic invertebrates was highly successful and is recommended for future studies. A comparison of collection success using manual (kick) and drift netting techniques showed that drift netting yielded nearly all of the new locality information. Although both of the target species were sometimes manually collected, they would have been missed at all but one of the new sites (Comal 2, amphipod) if drift nets had not been employed. In all cases where Stygobromus pecki was collected both manually and by drift net, more specimens were taken by the latter method.

Stygoparnus comalensis:

Previously known only from the spring orifices and run of Comal 2, the Comal Springs dryopid beetle was found to inhabit three of the four major outlets of Comal Springs. More surprising is its presence at Fern Bank (Little Arkansas) Springs some 32 km (20 mi.) to the northeast. The two spring complexes flow from different pools of the San Antonio (Sub)Region of the Edwards (Balcones Fault Zone) Aquifer: Comal Springs from the San Antonio Pool, and Fern Bank (Little Arkansas) Springs from the San Marcos Pool (Longley 1981, map p. 124). The pools are connected when piezometric levels (aquifer levels) are high and, conversely, are separated during severe droughts (Longley 1981). Comal Springs is in the Artesian (Reservoir) Zone of the aquifer, while Fern Bank Springs is in the Recharge Zone.

Obviously the beetle has a much wider distribution than previously thought, and it is reasonable to assume that with further sampling it may be found at other spring localities.

Many low volume springs have been inadequately sampled, if at all, for stygobionts. The cryptic coloration and behavior of the Comal Springs dryopid beetle may also contribute to its elusiveness and rarity in collections.

During this survey a total of four adult and nine larval beetles were collected at Comal Springs. At Comal 2 three adults and five larvae were manually collected. Four larvae were taken from Comal 3 and one adult from Comal 4, all in drift net samples. At Fern Bank (Little Arkansas) Springs, all 12 larvae and one adult beetle were taken from a drift net at a small spring. This is twice the total number of larvae previously collected at Comal Springs, upon which the larval description was based (Barr and Spangler 1992).

Limited data from Comal Springs suggest that there are fluctuations in the numbers of individuals present in the springs at any given time. Evidence for this is wide variability in my collection success rates, 0-17 adults, on seven different dates (including pre-survey data) at Comal 2. Adult beetles were more scarce in August 1992 than they had been during three of the four pre-survey dates, when a total of 26 adults and four larvae were collected. During this study only three adults and five larvae were taken during a total of seven field hours accrued on three separate dates. The reason, or reasons, for this scarcity is not known. The previous drought and resultant lack of spring flow may have curtailed the size of the epigean population by causing mortality at the springheads and in the runs. Conversely, the record spring flows of 1991-1992 could have dislodged beetles from the substrate, washing them downstream away from the springheads.

Although conclusions cannot be drawn using such a small amount of data, I explored the possibility that the volume of spring flow and aquifer level may affect the likelihood of finding the beetle. During the three collection dates in 1987 and 1988 the flow from Comal Springs ranged from 311 to 384 cfs, and the water level in the aquifer from 663.89 to 686.89 feet (San Antonio reference well, J-17); in 1992 the flow was 458 to 468 cfs, and aquifer level 691.54 to 691.85 feet. When placed on a line graph which also included three collections by two other collectors, the trend was fewer specimens collected as spring flow and aquifer level increased. A potential flaw in this reasoning, besides the small sample size, is that the beetles could have emerged from the aquifer and survived in the springs for an unknown period of time prior to collection.

Comparison of the sites where <u>Stygoparnus comalensis</u> was collected during this survey shows that the beetle was taken at low volume springs and seeps (Comal 2, Comal 4, Fern Bank Springs), as well as a high volume outlet (Comal 3). Because most of the specimens were taken in low volume springs and seeps, its presence or likelihood of collection does not seem to be dependent on a high volume of spring discharge.

Details of the life history of this beetle, including the microhabitat of the larva, are unknown. The presence of larvae in the spring flow, as evidenced by their capture in drift nets, is very puzzling in light of the fact that dryopid larvae (and pupae) are thought to be terrestrial (Ulrich 1986). Because of the requirements of the immature stages, it is possible that the distribution of adults in the aquifer is restricted to the vicinity of spring openings.

Stygobromus pecki:

The known range of Stygobromus pecki now includes Hueco Springs about 7 km (4 mi.) to the north of the type locality at Comal Springs. Holsinger is of the opinion that the species may be restricted to a small range in Comal County (pers. comm. 1993). The presence of the subterranean amphipod at Hueco Springs is interesting because the springs have a mixed phreatic-vadose flow system, whereas Comal Springs have minimal local recharge (Rothermel and Ogden 1987). The single specimen was collected at Hueco I in a drift net set for a 48 hour period. It could not have been a contaminant from Comal Springs, or elsewhere, because it was caught in the first net placed during the study.

Peck's cave amphipod was present at Comal Springs in all four of the major spring groups sampled, and was abundant in all but Comal 4. A total of 271 specimens were collected, most in four drift nets which were set for four days each. Seventy-eight specimens were taken at Comal 1: 70 of these were from a drift net at the cave outlet, four were from a large bottom outlet, and four were manually collected. At Comal 2, 62 specimens were manually collected on three separate dates. The amphipod was much more common in the upper quarter of the run than further downstream. The largest series, 130 individuals, was taken from Comal 3: 50 of these were collected by hand, the other 80 by drift net. Just one specimen was collected from the drift net set at Comal 4. A total of only 32 specimens had been collected prior to this survey, and the amphipod was not known to occur at either Comal 2 or Comal 4 (Holsinger, pers. comm. 1992, 1993).

Other species of hypogean amphipods were collected at three of the survey sites: San Antonio Springs, Fern Bank (Little Arkansas) Springs, and San Marcos Springs. Most of these were *Stygobromus russelli* (Holsinger), the most widely distributed troglobitic species in Texas (Holsinger and Longley 1980). A few specimens of uncommon or rare species were taken at Comal Springs in addition to *Stygobromus pecki*; these are discussed in the next section.

Other Rare or Uncommon Invertebrates

During the survey several epigean (surface-dwelling) and hypogean species were collected which are presently undescribed, which had previously been known only from type localities, or which represent significant geographic range extensions.

Coleoptera (Insecta):

Most exciting was the discovery of an unknown genus and species of stygobiontic bidessine dytiscid beetle at Comal Springs. Eleven adult specimens were collected from Comal 1, 3, and 4, all in drift nets. The new taxon is being described by Dr. Paul Spangler at the National Museum of Natural History in Washington, D.C. The only other troglobitic dytiscid beetle known from the aquifer is *Haideoporus texanus* (Hydroporinae) from an artesian well in San Marcos (Longley and Spangler 1977, Young and Longley 1976).

Heterelmis comalensis (Elmidae), described from Comal Springs by Bosse et al. (1988), was added to the U.S. Fish and Wildlife Service's list of candidates for Federal listing in the Proposed Rules of November 21, 1991 (*Federal Register* 56:58826). I am now reporting San Marcos Springs as a second locality for the species. A single male specimen taken along the margin of Spring Lake keys to H. comalensis using the keys in Brown (1976) and Bosse et al. (1988), and has been verified by Dr. Harley Brown (University of Oklahoma, Norman; pers. comm. 1993).

At Comal Springs a total of 59 adult specimens were collected in Landa Park during the survey. Previously known only from a single run (Comal 2), this epigean species is now known to occur in all of the major runs except Comal 4. The beetle was common in Comal 2 and 3, and rare in the sampled upper section of Comal 1. In Comal 2, it was collected twice as often in the upper quarter of the run than in the middle half; it was not found in the lower quarter.

Trichoptera (Insecta):

Fern Bank (Little Arkansas) Springs yielded a pupal specimen of a new species of Austrotinodes (Ecnomidae) currently being described by Dr. David Bowles, a Trichoptera specialist at the Texas Parks and Wildlife Department's Resource Protection Division (formerly at the Armstrong Laboratory at Brooks Air Force Base, Texas). Fern Bank Springs is the second locality recorded for the new species, which is the only known representative of its family in the United States. The pupa of the species was unknown until collection of this specimen (Bowles, pers. comm. 1992).

<u>Amphipoda</u> <u>(Crustacea)</u>:

In addition to <u>Stygobromus pecki</u>, two very rare species of subterranean amphipods were taken at Comal Springs. Eight specimens of <u>Mexiweckelia hardeni</u> (Hadziidae), a species just described from Medina County by Holsinger (1992), were collected from Comal 2 and Comal 4. This is the second known locality for the species, as well as the second known locality for the genus outside of Mexico. Comal 3 yielded three specimens of <u>Seborgia relicta</u> (Sebidae), a minute species described from the artesian well in San Marcos (Holsinger and Longley 1980). Another specimen, from Hueco Springs (Group A or Hueco I), was among those from the EARDC collection identified by Holsinger (pers. comm. 1993). He recently reported a second locality for the species (Medina Co., Hondo Creek hyporheic) (Holsinger 1992), therefore Comal and Hueco springs are the third and fourth known localities.

Factors Affecting the Comal Springs Dryopid Beetle and Peck's Cave Amphipod

The present or threatened destruction, modification, or curtailment of its habitat or range:

The Edwards Aquifer supports a unique ecosystem of subterranean and spring-dwelling organisms. Because the Comal Springs dryopid beetle and Peck's cave amphipod are stygobiontic inhabitants of the aquifer, factors affecting the quantity and quality of the groundwater are of primary concern. Public and private demands on the aquifer as a water source now exceed the amount of recharge. As a result, the flows of Comal and Hueco springs (and San Marcos Springs) are increasingly threatened and are predicted to permanently cease within the next thirty years.

Lowering the Edwards Aquifer to the extent that spring flow ceases is an obvious threat to spring-inhabiting organisms, and a potential threat to groundwater inhabitants. The Comal Springs dryopid beetle and Peck's cave amphipod have survived past droughts when flow to the springs has ceased for short periods of time, but because almost nothing is known about their life histories, the effect of extended spring drying and low aquifer levels on their survival cannot be predicted. Although the extent and depth of their subterranean distributions are not known, it is reasonable to expect that populations of the species may be stranded and extirpated by receding groundwater. Stygoparnus comalensis could be even more negatively impacted if adults are restricted to the vicinity of spring openings because of the terrestrial requirements of the immature stages.

Pollution of the rivers and streams that recharge the aquifer would eventually result in groundwater and spring contamination. The extent of the damage to hypogean and epigean aquatic ecosystems would depend on the circumstances and severity of the pollution. Furthermore, any activities causing reduction of the dissolved oxygen in the aquifer could have a disastrous effect on the aquatic organisms relying on it for respiration.

In addition to the general threats discussed above, specific hazards exist at Comal Springs in Landa Park. The runs of Comal Springs 1 and 2 parallel a busy street where they may be vulnerable to a catastrophic chemical spill due to a vehicular accident. At the present time Comal Spring 2 is somewhat negatively impacted by the wading, swimming, and bathing activities of park visitors. Although the lower end of the run is impounded to form a children's wading pool, a sign on the stone arch bridge upstream prohibits wading in the upper run. This sign is routinely ignored and apparently not enforced by park personnel.

Over-utilization for commercial, recreational, scientific, or educational purposes:

The target species are unlikely to be over-utilized. They have no commercial or applied value. Dryopid beetles are not popular with amateur insect collectors because of their small size and lack of colorfulness, and are not likely to be collected inadvertently. Amphipods are not usually the target of amateur collectors. Both species could occasionally be taken by students preparing collections for biology classes, but this would be unlikely. They are of scientific interest only to a small number of researchers who work on the taxonomy and systematics of the groups to which they belong.

Diseases or predation:

No diseases are known, but predation may be a factor. Because the species targeted by this study are adapted for a hypogean existence (i.e., blind, unpigmented, fragile) and are presumably ill-suited for life in surface waters, they may be particularly susceptible to predation. Nonetheless, their ability to survive outside of the aquifer may be quite limited regardless of the presence or absence of predators. At Comal Springs, and probably also Hueco Springs, the target species co-occur with fish, crayfish, frogs, and salamanders. Salamanders inhabit Fern Bank Springs along with the Comal Springs dryopid beetle. I do not know whether these potential predators are native species, introduced species, or both.

The inadequacy of existing regulatory mechanisms:

Neither species is afforded any specific protection at the Federal or state level at this time. Peck's cave amphipod is a Category 2 Candidate for the Federal Threatened and Endangered Species List, i.e., there have been insufficient data for listing. At present there is no regulatory agency which has the power to prevent abuse of the Edwards Aquifer by the various factions which claim rights to it. The state of Texas, however, is now in the process of creating a board to oversee use of the aquifer.

Other natural or manmade factors affecting their continued existence:

All perceived threats are addressed under the previous categories.

ACKNOWLEDGMENTS

I especially thank Dr. Thomas Arsuffi and the Aquatic Station - Department of Biology, Southwest Texas State University, San Marcos, for loan of their drift nets and other equipment used during this survey. Dr. Glenn Longley of the Edwards Research and Data Center in San Marcos is likewise acknowledged for providing information and for loaning amphipod specimens. Data on the Edwards Aquifer and spring flows were furnished by Bobby Bader, Christopher Sutton, and Gayle Kipp of the Edwards Underground Water District in San Antonio, and Dean Stephens and David Brown at the San Antonio Sub-District Office of the U.S. Geological Survey.

David Whatley, Director of Landa Park in New Braunfels, went out of his way to make my work at Comal Springs easier. I am also grateful to Gene Sueltenfuss and staff at Aquarena Springs in San Marcos, and Bill Mulcahy and staff at Incarnate Word College in San Antonio, for giving me personalized tours and access to their respective facilities and springs.

I am particularly indebted to Dr. John Holsinger at Old Dominion University, Norfolk, Virginia. Without his amphipod identifications this project could not have been completed. And special thanks to Dr. Paul Spangler and Dr. Janet Reid (National Museum of Natural History, Washington, D.C.), Dr. Harley Brown (University of Oklahoma, Norman), and Dr. David Bowles (Texas

Parks and Wildlife, Austin), for their respective identifications of Dytiscidae (Coleoptera), Copepoda, Elmidae (Coleoptera), and Trichoptera collected during the survey.

Thanks to Bob Simpson of the U.S. Fish and Wildlife Service in Austin whose help exceeded that for which he was obligated. Lastly, my appreciation to Dr. William Shepard, a fellow aquatic biologist who also happens to be my husband, for time he spent in the laboratory sorting field samples.

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