

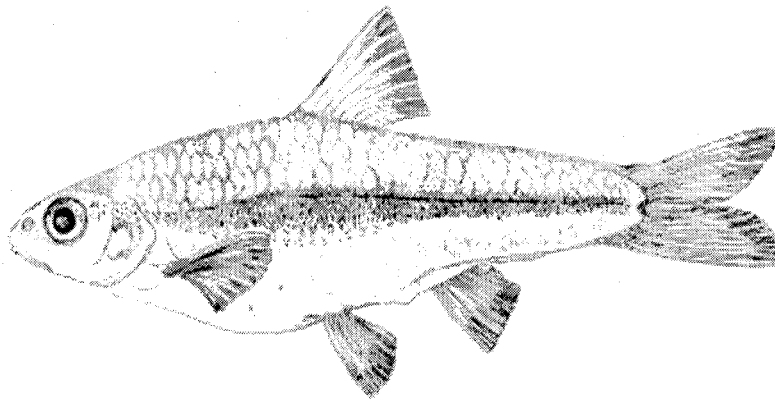
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GAMMARID AMPHIPODS OF NORTHERN CHIHUAHUAN DESERT SPRING SYSTEMS: AN IMPERILED FAUNA

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ABSTRACT

Gammarid amphipods of the *Gammarus pecos* complex Cole, 1985 are restricted to euryhaline desert spring systems in the Pecos River Valley of New Mexico and Texas. Within the past 35 years, complete loss and diminution of spring flows, exacerbated by regional drought conditions and local groundwater withdrawals, are implicated in the extirpation of 2 isolated populations of *G. desperatus* in New Mexico, and the dramatic decline of the *Gammarus* sp. form "C" from the Phantom Lake Spring system in Texas. The distribution and abundance of gammarid amphipods

was determined from benthic samples collected in May 2001 from 7 sites in the study area. Gammarid densities were highest in shallow, low velocity habitats with aqueous silts. Three new gammarid populations were documented from 2 springs in Reeves County, Texas, and 1 site in Eddy County, New Mexico. This study illustrates the need for comparative morphological and biochemical genetic studies of the *G. pecos* complex to clarify outstanding taxonomic relationships within this group.

INTRODUCTION

Members of the *Gammarus pecos* complex Cole, 1985 represent endemic species geographically isolated in euryhaline desert spring systems of the Pecos River Valley of New Mexico and Texas. These freshwater amphipods are likely derived from a widespread progenitor marine amphipod that was isolated inland during recession of the Late Cretaceous epicontinental sea (ca. 66 mya) (Bousfield, 1958; Holsinger, 1976). Speciation within this complex likely occurred as a result of local adaptive variation in response to ecological constraints imposed by diverse aquatic environments on amphipod populations further isolated during progressive climatological changes that ensued in the late Pleistocene to early Holocene. Such models of island and vicariant biogeography are proposed for a diversity of invertebrate taxa within arid ecosystems of southwestern North America (e.g., Peracarida crustaceans [freshwater isopods, see Bowman, 1981; hyalellid amphipods, see Thomas et al., 1994]; prosobranch snails, see Hershler et al., 1999; pulmonate land snails, see Bequaert and Miller, 1973, Metcalf and Smartt, 1997).

Based on percent similarities in Mann-Whitney U tests for 20 morphological traits from 7 populations of gammarid amphipods, Cole (1985) identified the *G. pecos* complex as a group of morphologically similar species that are endemic to Chihuahuan Desert spring systems of the Pecos River Valley in southeastern New Mexico and western Texas. Morphological character combinations unique to this group include: non-calceolate antennae with spine(s) on the first peduncular article of the antennule; mandibular palps bearing C-setae; setiferous coxal plates I-IV; and narrow oostegites (brood plates). Currently this complex is understood to consist of 3 described species (Cole and Bousfield, 1970; Cole, 1976, 1981), 2 populations representing undescribed species, and 2 morphotypes of undetermined taxonomic affinity (see Cole, 1985).

Cole (1985) emphasized numerous unresolved taxonomic relationships within this complex based on marked intra- and inter-population variation of morphological characters and body sizes among West Texas gammarids.

Formulation of effective conservation measures or intensive ecological assessments would be premature until outstanding taxonomic affinities of the *G. pecos* complex have been clarified. Morphological assessment of the *G. pecos* complex, considered in combination with ongoing genetic studies, can fill a critical gap in our current knowledge of these endemic taxa: "Which species or significant population segments merit conservation management?" Resource agencies charged with protection and stewardship of these amphipods have no baseline data from which to assess conservation status and threats, or to prescribe management options for this group.

Amphipods are vital links in aquatic food webs and play critical roles in nutrient processing of aquatic ecosystems (Gee, 1988; Pennak, 1989). Due to their acute sensitivity to aquatic conditions (Covich and Thorpe, 1991), gammarid amphipods can be considered ecological indicators of ecosystem health (Lackey, 1995) and integrity (Callicott, 1994). The current rate of imperilment of amphipods of the *G. pecos* complex is alarming and provides testimony to the deterioration of aquatic conditions of the Pecos River Basin of New Mexico and Texas.

No gammarids were observed during preliminary status surveys of Phantom Lake Spring and its canal system in March and June 2000, which suggested that *Gammarus hyalelloides* Cole, 1976 and the undescribed

Gammarus sp. form "C" were possibly extirpated from this aquatic system. Although the location of Cole's (1985) *Gammarus* sp. form "M" population could not be reconciled from locality descriptors while in the field, the ample evidence of spring head drying and defunct irrigation canal systems observed in the general vicinity of Phantom Lake Spring suggested that this gammarid morphotype may be extirpated as well. These preliminary findings prompted this study.

Specific causes for the suspected extirpation of *Gammarus* sp. form "C" from the aquatic environs of Phantom Lake Spring appeared directly related to reduced spring discharge. Diminution of Phantom Lake Spring discharge has been attributed to depletion of the Toyah Basin Aquifer from groundwater withdrawals under ongoing regional drought conditions (Ashworth et al., 1997; Schuster, 1997; Sharp et al., 1999; Allan, 2000). Similar factors were largely responsible for the extirpation of 2 isolated populations of *Gammarus desperatus* Cole, 1981 in New Mexico (Cole, 1981, 1985).

We present preliminary findings from a macroinvertebrate survey to document the current status of gammarid amphipods from desert spring systems in the Pecos River Valley of New Mexico and Texas. This study illustrates the need for comparative morphological and biochemical genetic studies of the *G. pecos* complex.

STUDY AREA AND METHODS

The distribution and abundance of gammarid amphipods was determined from benthic samples collected in May 2001 from 7 sites in the study area of southeastern New Mexico and West Texas (Figure 1). Amphipod densities were determined from 3 random benthic collections per site using a stainless steel mesh sampler (sample area = 80 cm²). Benthos were preserved in 95% ethanol for enumeration by taxa in the lab. Habitat parameters measured at each sample site included water depth (± 1 cm; metric topset rod), velocity (cm/sec; Marsh-McBirney Flowmate®), and substrata following the general scheme of Cummins' (1962) index of dominant grain size as clay, silt, sand, gravel, and mixed. Vegetation, including submerged macrophyte beds and detrital plant debris, was included

as a "substrate" category since amphipods of this complex typically frequent this cover type. Physicochemical data (i.e., water temperature [°C], pH, dissolved oxygen [DO; mg/l, % saturation], salinity [ppt], specific conductance [μ S/cm] and total dissolved solids [TDS; ppt]) presented herein were compiled from published accounts and agency reports due to equipment failure in the field.

Live *Gammarus* for ongoing morphological and biochemical genetic studies were collected with a dip net by sweeping submerged macrophyte beds, by sieving aqueous silt, or from the underside of coarse substrata by washing into a tray. To quantify genetic and morphological variation within a gammarid population,

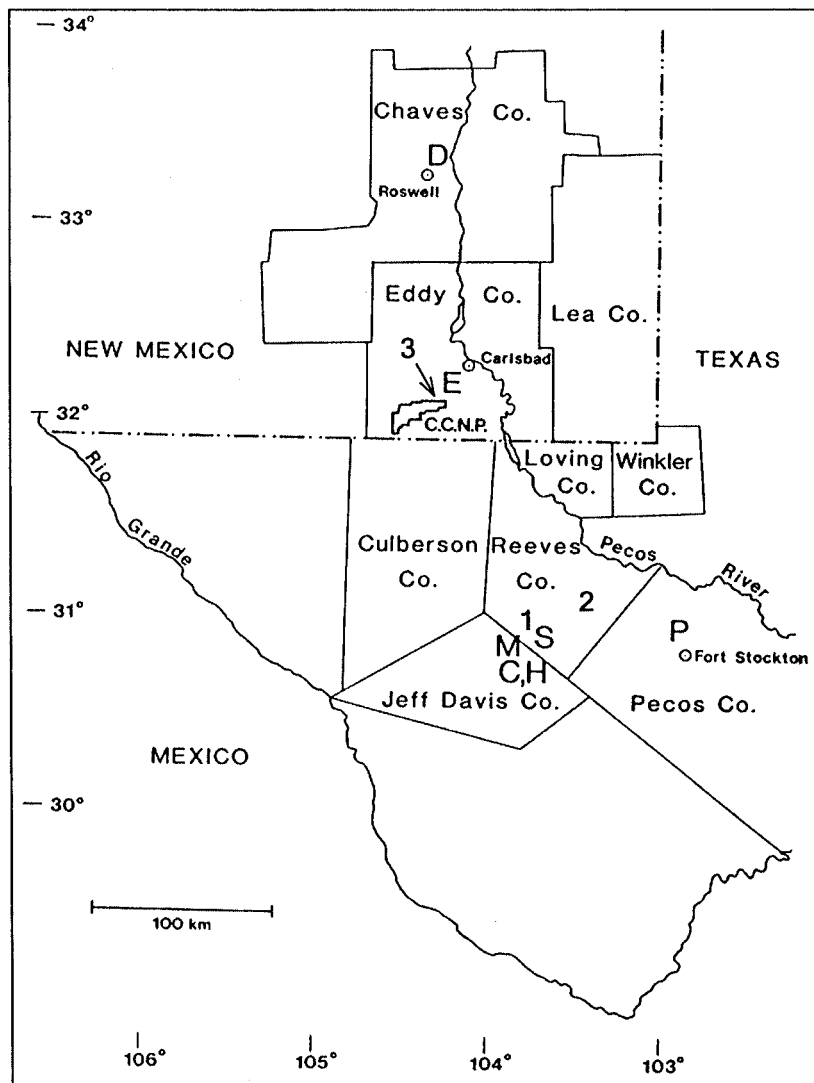


Figure 1. Historic and current distribution of gammarid amphipods of the *Gammarus pecos* complex Cole, 1985 in the Pecos River Valley of New Mexico and Texas. Population designations from modified map per Cole (1985.): "D", *G. desperatus*, Roswell, Chaves Co., NM (extant at Bitter Lake National Wildlife Refuge, extirpated from Lander Springbrook and North Spring); "E", *Gammarus* sp., "in Carlsbad" or "in Carlsbad Caverns National Park", Eddy Co., NM; "P", *Gammarus pecos*, Diamond Y Spring, Pecos Co., TX; "S", *Gammarus* sp., San Solomon Spring, Toyahvale, Reeves Co., TX; "H", *Gammarus hyalelloides*, Phantom Lake Spring, Jeff Davis Co., TX; "C", *Gammarus* sp., Phantom Lake Spring canal system, Jeff Davis Co., TX; "M", *Gammarus* sp., "3.5 miles west of Toyahvale" or "350 m north of Phantom Lake Spring", Jeff Davis Co., TX. Numeric population designations: 1, *Gammarus* sp., Giffin Spring, Toyahvale, Reeves Co., TX; 2, *Gammarus* sp., East Sandia Spring, Reeves Co., TX (0.5 mi. east of Brogado, TX, and 0.3 mi. south of state route 17); 3, *Gammarus* sp., Sitting Bull Spring, Eddy Co., NM.

representative voucher material was collected from diverse habitat types employing subsampling in large spring systems (e.g., Diamond Y Preserve, San Solomon Spring) or from populations with geographically isolated populations (i.e., Bitter Lake National Wildlife Refuge). This sampling protocol yielded adequate voucher material for intra- and interspecific

genetic and morphological studies from multiple subsamples for 7 gammarid populations. At least 50 amphipods from each collecting locality were frozen in liquid nitrogen immediately upon collection for genetic study. Specimens retained for morphological analysis (N = 50 amphipods/locality) were preserved in 95% ethanol.

RESULTS

Our survey documented 3 previously undetected gammarid populations from Giffin and East Sandia springs, Texas, and Sitting Bull Spring, New Mexico, that morphologically are referable to the *G. pecos* complex (Cole, 1981, 1985). It remains unclear to us whether the Sitting Bull Spring gammarid population is referable to Cole's (1985) *Gammarus* sp. form "E", or may actually represent a previously undocumented population, as Cole listed two possible localities for the latter taxon: "A third unnamed population occurs [or once occurred] in Carlsbad Cavern National Park, or the town of Carlsbad..." Notwithstanding, preliminary analysis indicates that the Sitting Bull Spring population appears morphologically distinct from the nearest gammarid populations in New Mexico (*G. desperatus*) and Texas (*G. pecos*). Morphological studies are ongoing to describe the Sitting Bull Spring gammarid, and to compare within- and among-population variation of morphological characters in this species complex.

No gammarids were observed in Phantom Lake Spring or in the downstream canal system during the May 2001 inventory. All lateral canals in the immediate area were either dry or dysfunctional; this further confirmed our March and June 2000 observations that *Gammarus hyalelloides* and the morphotype *Gammarus* "C" were in all likelihood extirpated from the Phantom Lake Spring system. However, sampling during a visit in November 2001 by Lang and Berg revealed *G. hyalelloides* from the cave mouth pool, where intensive surveys in March and June 2000, and May 2001, failed to yield even the slightest evidence of an extant gammarid population. We also found live *G. hyalelloides* in hypogean habitats at 3-4 meters inside the cave's entrance during the November 2001 survey.

Table 1 presents amphipod densities (\pm SE) and flow conditions (depth and velocity; \pm SE) measured at sample sites. Physicochemical parameters compiled from published records and agency reports (Table 2) show highly variable chemical environments with ionic concentrations of these fresh to moderately saline desert spring systems determined largely by the underlying karst stratigraphy.

Amphipod densities were highest in the Diamond Y Draw spring system (Euphrasia Spring, *Gammarus pecos*, = 8,042 amphipods/m²) where mean water depths and velocities measured at 3 sites ranged from 0.06-0.16 m and 0.03-0.06 m/sec., respectively. The gammarid population in the upper rheocrene of Sitting Bull Spring was the least dense with 125 amphipods/m². Low flow conditions in the main canal of San Solomon Spring (velocity = 0; depth = 0.09 m \pm 0.02 SE) likely account for the high mean density of *Gammarus* sp. form "S" (6,833 amphipods/m²) during seasonal draw down for swimming pool maintenance at Balmorhea State Park. Mean density of *G. desperatus* (575 amphipods/m²) from Sago Spring is considered lower than expected since this estimate was derived from artificial tile samples (Lang, unpublished data).

Hyaellid amphipods are referred to herein as *Hyaella* sp. since ongoing taxonomic research continues to identify genetically and morphologically distinct populations once considered as a single ubiquitous species, *Hyaella (Hyaella) azteca*, in the southwest United States (see references in Baldinger et al., 2000; Duan et al., 2000). *Hyaella* occurred syntopically with *Gammarus* sp. at East Sandia (1,083 *Hyaella* sp./m²) and Euphrasia (125 *Hyaella* sp./m²) springs (Table 1). Densities of *Hyaella* sp. were high-

Table 1. Mean density of hyalellid and gammarid amphipods (no./m²) and mean water depth (m) and mean velocity (m/sec.) measured at benthic sample sites (N = 36 grabs) in desert spring systems of the Pecos River valley of New Mexico and Texas, May 2001.

| Taxon | Site | Amphipod Subsample | Amphipod Density ($\bar{X} \pm SE$) | Water Depth ($\bar{X} \pm SE$) | Water Velocity ($\bar{X} \pm SE$) |
|------------------------------|---------------------|-----------------------|---------------------------------------|----------------------------------|-------------------------------------|
| Texas | | | | | |
| <i>Gammarus hyalelloides</i> | Phantom Lake Spring | spring head pool | 0 | 0.40 ± 0.04 | no measurable flow |
| <i>Gammarus</i> sp. form "C" | Phantom Lake Spring | lateral canal | 0 | dry | - |
| <i>Gammarus</i> sp. form "S" | San Solomon Spring | swimming pool | 0 | 0.18 ± 0.04 | no measurable flow |
| <i>Gammarus</i> sp. form "S" | San Solomon Spring | main canal | 6833 ± 5416 | 0.09 ± 0.02 | no measurable flow |
| <i>Gammarus</i> sp. form "S" | San Solomon Spring | ciénega outflow | - | - | - |
| <i>Gammarus</i> sp. | Giffin Spring | spring head pool | 0 | 0.26 ± 0.06 | no measurable flow |
| <i>Gammarus</i> sp. | Giffin Spring | rheocrene | 1167 ± 730 | 0.19 ± 0.09 | 0.12 ± 0.04 |
| <i>Gammarus</i> sp. | East Sandia Spring | rheocrene | 4625 ± 804 | 0.10 ± 0.03 | 0.14 ± 0.08 |
| <i>Hyalella</i> sp. | " " | " " | 1083 ± 1083 | " " | " " |
| <i>Gammarus pecos</i> | Diamond Y Draw | rheocrene near source | 2208 ± 1585 | 0.16 ± 0.04 | 0.03 ± 0.02 |
| <i>Gammarus pecos</i> | Diamond Y Draw | Euphrasia Spring | 8042 ± 7229 | 0.06 ± 0.00 | 0.06 ± 0.03 |
| <i>Hyalella</i> sp. | " " | " " | 125 ± 72 | " " | " " |
| <i>Gammarus pecos</i> | Diamond Y Draw | John's Pool | 2708 ± 1381 | 0.09 ± 0.02 | 0.04 ± 0.01 |
| New Mexico | | | | | |
| <i>Gammarus</i> sp. | Sitting Bull Spring | lower rheocrene | 4542 ± 2361 | 0.09 ± 0.01 | 0.09 ± 0.02 |
| <i>Gammarus</i> sp. | Sitting Bull Spring | upper rheocrene | 125 ± 72 | 0.12 ± 0.03 | 0.02 ± 0.01 |
| <i>Hyalella</i> sp. | " " | " " | 3167 ± 1601 | " " | " " |
| <i>Gammarus desperatus</i> * | Bitter Creek | Lost River pool | 4250 ± 683 | 0.16 ± 0.04 | 0.12 ± 0.03 |
| <i>Gammarus desperatus</i> * | Bitter Creek | Sago Spring head | 575 | 0.18 ± 0.04 | 0.08 ± 0.06 |
| <i>Gammarus desperatus</i> * | Bitter Creek | Sago Spring run | 3750 ± 735 | 0.07 ± 0.06 | 0.18 ± 0.05 |
| <i>Gammarus desperatus</i> | Bitter Creek | Unit 6 | 167 ± 110 | 0.11 ± 0.02 | 0.16 ± 0.04 |

*Density estimates derived from previous study (Lang, unpubl. data).

Table 2. Physicochemical data for desert spring systems in the Permian Basin where gammarid amphipods of the *Gammarus pecos* complex Cole, 1985 occur in New Mexico and Texas.

| Site | Temperature °C | pH units | Specific Conductance $\mu S/cm$ | Salinity ppt | TDS mg/l | DO % saturation | DO mg/l |
|---|----------------|----------|---------------------------------|--------------|----------|-----------------|----------|
| Lander Springbrook, Chaves Co., NM ^{1,2} | 18–22 | 7.1–7.2 | — | 4.4–5.7 | — | — | — |
| North Spring, Chaves Co., NM ² | 19.0–20.5 | 7.2 | 17,600 | 5.7 | — | — | — |
| BLNWR, Bitter Creek, Chaves Co., NM | 7.6–25.2 | 6.9–8.7 | 8044–10,538 | 4.9–5.3 | 5.5–6.7 | 8.0–191.1 | 0.8–15.9 |
| BLNWR, Sago Spring, Chaves Co., NM | 16.0–21.5 | 7.0–7.3 | 6500–8100 | 4.3–5.1 | 5.1–5.8 | 10.0–185.0 | 2.5–14.8 |
| BLNWR, Unit 6, Chaves Co., NM | 22.8 | 7.3 | 5367 | 2.9 | 3.5 | 70.2 | 7.4 |
| Sitting Bull Spring, Eddy Co., NM | 14.0–18.5 | — | — | — | — | — | — |
| Diamond Y Draw (Sta. 2), Pecos Co., TX ³ | 20.6 | 7.1 | — | 3.6 | — | — | 6.7 |
| East Sandia Spring, Reeves Co., TX ³ | 19.8 | 7.2 | — | 2.2 | — | — | 8.2 |
| Giffin Spring, Reeves Co., TX | 15.5–17.5 | — | — | — | — | — | — |
| San Solomon Spring, Reeves Co., TX | 25.0 | 7.2 | — | 1.8 | — | — | 1.9 |
| PLS, Jeff Davis Co., TX ³ | 24.7 | 6.9 | — | 1.9 | — | — | 1.9 |
| PLS, below weir (Sta. 1), Jeff Davis Co., TX ³ | 19.1 | 6.5 | — | 4.2 | — | — | 8.8 |

¹ Noel (1954); ² Cole (1981); ³ Hubbs (2001)

BLNWR = Bitter Lake National Wildlife Refuge; PLS = Phantom Lake Spring

est (3,167 amphipods/m²) at the upstream sample site in Sitting Bull Spring. There was no evidence of geographic overlap between these amphipod genera at the downstream site in this system. We note similar distributional patterns of amphipods at Bitter Lake National Wildlife Refuge (BLNWR) where *G. desperatus* shows affinities for shallow lotic habitats near thermally stable spring sources, while *Hyaella* occurs in more lentic eurythermal waters and deep aqueous silts.

The abundance of amphipod taxa was variable across the spectrum of substrate types sampled (N = 36 benthic grabs) throughout the study area (Figure 2). Sampling inefficiency likely accounts for the high outlying densities of *Gammarus* spp. in clay (22,500

amphipods/m²) and gravel (18,280 amphipods/m²) substrata since sample effort in these indurate substrate types was limited to a single benthic grab. Small sample size (N = 3) may likewise explain the high density of *Gammarus* (3,667 amphipods/m²) found in sand. Non-indurate substrata afforded by loosely compacted, aqueous silts (N = 16 grabs) and vegetation (i.e., macrophyte beds, detritus; N = 7 grabs) were inhabited by both amphipod genera, but to a lesser degree than mixed substrates (N = 8 grabs) where *Hyaella* (1,078 amphipods/m²) and *Gammarus* (2,406 amphipods/m²) were abundant. Gammarid amphipods were particularly abundant beneath large stones in lotic habitats that were difficult to sample by our quantitative methods.

DISCUSSION

All desert spring systems surveyed in this study occur within an area once overlain by Permian seas (Hills, 1942) where the underlying geology of these karst lands consists of dissolute evaporite rock (White et al., 1995; Martinez et al., 1998). Several basins in

the lower Pecos River Valley are described in the study area, namely the Roswell Artesian Basin of New Mexico, the Toyah Basin of West Texas (Hill, 1900), and the Delaware Basin in both states (Lang, 1937). Gammarid populations of this complex occur in

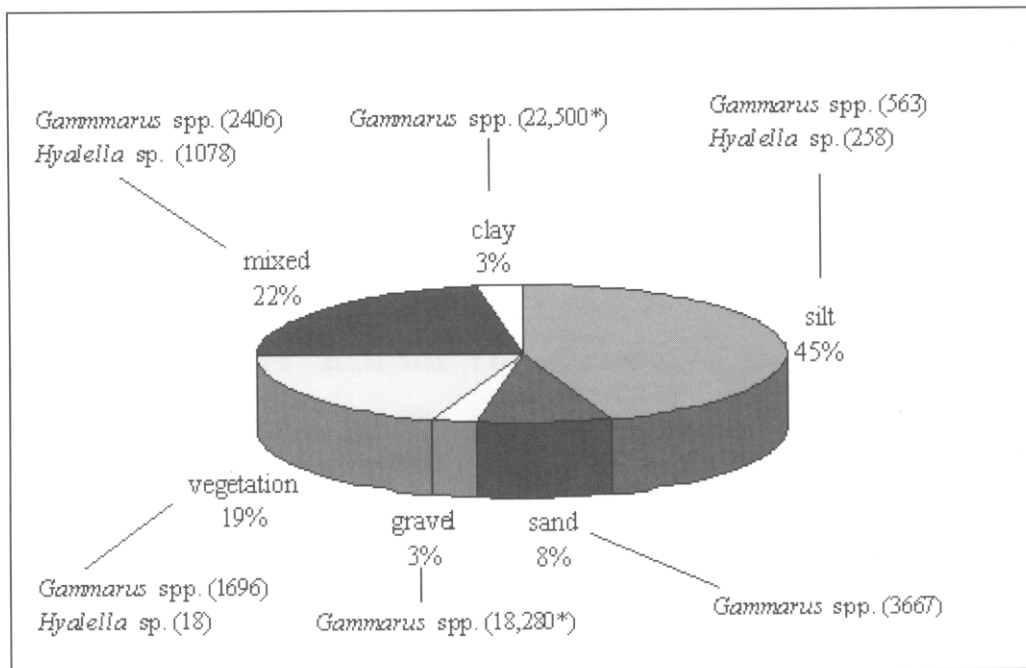


Figure 2. Mean density of Amphipoda (#/m²) by percentage substrate types sampled (n=36 benthic grabs) in desert spring systems surveyed in the Pecos River Valley of New Mexico and Texas, May 2001. (*Denotes sample bias from a single benthic grab.)

sulfatochloride, carbonate-rich spring systems of variable salinities and alkalinities over small spatial scales that Cole (1985) considered “fresh-to-miohaline” (Table 2). There are numerous reports that such spatial diversity of hydrochemical habitats and lithological features in karst basins of the eastern United States and Central Europe leads to habitat segregation, migration barriers, and geographical differences in genetic and morphological variation among gammarid amphipods in discrete, highly-structured habitats (Gooch and Hetrick, 1979; Foeckler and Schrimpf, 1985; Gooch, 1989, 1990; Sarbu et al., 1993). Similar physical and ecological constraints may be responsible for speciation within the *G. pecos* complex.

Within the past 35 years, diminution or complete loss of spring flow, exacerbated by regional drought conditions and local groundwater withdrawals, is implicated in the extirpation of 2 isolated populations of gammarid amphipods in New Mexico (*G. desperatus* from Lander Springbrook and North Spring [Cole, 1981, 1985]), and *Gammarus* sp. form “C” from the seasonally dewatered and impoverished aquatic conditions of the Phantom Lake Spring canal system in Texas (Allan, 2000). Gammarid amphipods in the Phantom Lake Spring canal were previously documented in 1995 (Winemiller and Anderson, 1997).

The enigmatic recurrence of *G. hyalelloides* at Phantom Lake Spring pool in November 2001, where repeated survey effort from March 2000 to May 2001 implied that the species was possibly extirpated, may be attributed to a number of factors. Preliminary survey effort focused on epigeal habitats at the spring head pool since access to hypogean waters was limited. However, recent scuba surveys did not document gammarid amphipods from hypogean habitats deep within the Phantom Lake Spring cave system where several aquatic troglobites (i.e., the isopods, *Lirceolus cocytus* [Lewis, 2001] and *Cirolanides texasensis*, and an undescribed cave-adapted amphipod) are reported (J. Krejca, University of Texas at Austin, pers. comm.). Aquatic surveys may have simply over-looked shallow lotic habitats near the cave's entrance that interface between epigeal waters and deeper hypogean habitats. Similar cave streams are colonized by *Gammarus minimus* in highly structured karst areas of the eastern United States (Holsinger and Culver, 1970; Gooch and Hetrick, 1979). Secondly, it

is possible that under diminished spring flows and impoverished aquatic conditions of Phantom Lake Spring (Allan, 2000), that *G. hyalelloides* was either at very low densities or actually extirpated from epigeal habitats during the period March 2000 to May 2001. Efforts to sustain the endangered fish community in Phantom Lake Spring through installation of a pumping system commenced in June 2000 with construction of a sand-bag dam in the cave mouth to maintain adequate surface water elevation in the spring pool. The pump was activated in May 2001 and began cycling water from the cave to the spring pool. Such conservation practices may have serendipitously prevented the extirpation of *G. hyalelloides* at Phantom Lake Spring by replenishing the epigeal pool population with individuals of a hypogean source population of *G. hyalelloides* from inside the cave.

The March 2000 Sandhill Fire at BLNWR has resulted in demonstrable effects on abiotic conditions (e.g., depressed dissolved oxygen levels [0.7 mg/l], increased temperature, spikes in salinity and pH) of Bitter Creek, which harbors 1 of 3 known *G. desperatus* populations on BLNWR (Lang 2001). Preliminary findings implicate increased levels of post-fire polycyclic aromatic hydrocarbons as a possible adverse short-term effect on localized populations of *G. desperatus* in Bitter Creek. All described amphipods of this complex are considered Federal species of concern. *Gammarus desperatus* is the only species that has formal protection as a state Endangered species (NMGF Regulation 657); and has been recently proposed for Federal listing as endangered under the Endangered Species Act (67 Federal Register 6459-6479).

Although direct causes responsible for the extirpation of gammarid amphipods from North Spring and the seasonal disappearance from the Phantom Lake Spring system remain undetermined, altered hydrologic conditions of regional groundwater aquifers affecting these desert springs are implicated. Reduced flow regimes can significantly alter the physicochemical balance of a lotic ecosystem (Hynes, 1970), resulting in an altered hydrologic regime, disruption of complex ecological relationships, and adverse consequences for aquatic fauna of desert spring ecosystems (Bowles and Arsuffi, 1993; Mehlhop and Vaughn, 1994; Hubbs, 1995, 2000, 2001).

Local adaptive variation (genetic and morphological) of gammarid amphipods is reported from diverse aquatic ecosystems in response to local environmental conditions and regional geohydrology (Gooch and Hetrick, 1979; Gooch, 1989, 1990). In some instances morphological differentiation in hyalellid and gammarid amphipods has been attributed to genetic differentiation (Kane et al., 1992; Sarbu et al., 1993; Müller et al., 1999; Duan et al., 2000). Physiologically stressful conditions, frequently caused by anthropogenic activities, can select for certain genotypes in hyalellid and gammarid amphipods (Guttman, 1994; Duan et al., 1997; Hogg et al., 1998, 1999). Such selection can result in highly localized populations consisting of stenotropic demes acutely adapted to a narrow range of abiotic conditions (e.g., physicochemical gradients) and hydrologic regimes. Under extreme environmental stress isolated amphipod populations may lack sufficient genetic diversity to cope with stochastic fluctuations in the aquatic environment and are susceptible to extirpation events.

From a conservation perspective, genotypic variability provides populations with genetic plasticity to cope with environmental perturbations. Amphipod species with low genotypic variation and marked morphological differentiation are usually highly adapted to specific natural habitat conditions (e.g., *G. pecos* complex), but may be less capable of surviving long-term environmental change (Foeckler and Schrimpf, 1985; Duan et al., 1997; Hogg et al., 1998, 1999). Evolutionary consequences must be considered in the evaluation of natural or anthropogenic environmental stressors in order to direct conservation efforts that focus on not only a typological approach for species protection, but also consider important population segments as significant evolutionary units that likewise merit preservation (Rojas, 1992; Nee and May, 1997).

Cole (1985) documented marked overlap in body size and morphological characters between geographi-

cally proximate gammarid populations "M", "S" and "C" of West Texas. The numerous unresolved taxonomic affinities within the *G. pecos* complex highlight the need for phylogenetic assessment of this group focusing on comparative morphological and biochemical genetic studies. Recent genetic studies of hyalellid amphipods (Guttman, 1994; Duan et al., 1997; Thomas et al., 1994; Hogg et al., 1998; McPeck and Wellborn, 1998) indicated that lack of phylogenetic research has impeded studies of *Hyaella* comparative biology, biogeography, and evolution (Duan et al., 2000).

Morphological discrimination of amphipod species requires analysis of whole animal morphology, proportional metrics of diagnostic character combinations and structural meristics of sexually mature males and females to distinguish cryptic species (Holsinger, 1967, 1976; Müller et al., 1999). We are currently engaged in such studies, and limit our comparison of characters examined from new gammarid populations discovered during this survey (i.e., Giffin, East Sandia, and Sitting Bull springs) with traits diagnostic for the complex (see Cole, 1985). Biochemical genetic analyses using allozyme electrophoresis to compare within- and among-population variation are ongoing. While preliminary results of these genetic studies indicates significant within-population variation with 75% of the populations showing heterozygote deficiencies (Gervasio, unpubl. data), ongoing analyses will characterize the partitioning of genetic variation across spatial scales.

Once taxonomic boundaries of this complex are identified, resource agencies and private land stewards will have a solid baseline for evaluating broad-scale environmental trends and assessment of threats due to environmental degradation in the Pecos River Valley of New Mexico and Texas. These data are essential for stewardship of aquatic resources in the Chihuahuan Desert ecoregion.

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