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NOTES

ALGAL TAXONOMIC SURVEY OF ZION NATIONAL PARK AND CEDAR BREAKS NATIONAL MONUMENT, UTAH, AND PIPE SPRING NATIONAL MONUMENT, ARIZONA

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ABSTRACT—In an algal survey of Pipe Spring National Monument, Cedar Breaks National Monument, and Zion National Park in southern Utah and northern Arizona, 186 species were identified. Overall, diatoms were the dominant group represented by 103 species (55.4% of the reported species). Cyanobacteria and green algae included 41 species each (22.0%), and red algae had only 1 species. Only at Weeping Rock in Zion National Park were cyanobacteria and green filamentous algae dominant.

RESUMEN—En un estudio de algas en Pipe Spring National Monument, Cedar Breaks National Monument y Zion National Park en el sur de Utah y norte de Arizona, se identificaron 186 especies de algas. Sobre todo, los diatomas fueron el grupo dominante y estuvieron representados por 103 especies (55.4% de las especies registradas). Cianobacterias y algas verdes incluyeron 41 especies cada una (22.0%) y las algas rojas sólo una especie. Sólo en Weeping Rock en Zion National Park cianobacterias y algas verdes filamentosas fueron dominantes.

Pipe Spring National Monument, Cedar Breaks National Monument, and Zion National Park are located in northern Arizona and southern Utah on the Colorado Plateau. Pipe Spring National Monument is located in north-central Arizona and is surrounded by the Paiute Indian Reservation. The park encompasses 16 ha at an elevation of 2,000 m. The national monument has natural springs within a high-plain desert environment. Cedar Breaks National Monument is surrounded by Dixie National Forest and encompasses 2,491 ha at an approximate elevation of 3,333 m. The habitat in the park is comprised of spruce (*Picea*), fir (*Abies*), and aspen (*Populus*) forest and subalpine meadows. Zion National Park occupies 59,714 ha of sculptured canyons, hanging cliffs, and the North Fork of the Virgin River. The lowest elevation is 1,128 m at Coalpits Wash and the highest is 2,660 m at Horse Ranch Mountain in the Kolob Canyons section.

Studies of the algal floras of Utah and Arizona have included soils, streams, lakes (freshwater and saline), thermal springs, and terrestrial habitats (Taylor and Colton, 1928; Flowers, 1939; McCleary, 1957; Cameron, 1960; Hevly, 1961; Williams and Scott, 1962; Williams, 1964, 1972; VanLandingham, 1966, 1987; Sommerfeld et al., 1975; Stewart and Blinn, 1976; Mou-Sheng and Rushforth, 1977; Czarnecki and Blinn, 1978; Whiting et al., 1978; Lambou et al., 1979; Taylor et al., 1979; Williams et al., 1979; Czarnecki et al., 1981; Johansen et al., 1981, 1982; Rushforth and Squires, 1985; Johansen and St. Clair, 1986; Leland et al., 1986; Rushforth and Merkley, 1988; Blinn et al., 1989; Duncan and Blinn, 1989). Zion National Park has been the subject of one algal survey (Johansen et al., 1983), but Pipe Spring National Monument and Cedar Breaks National Monument have not been the subjects of published algal studies.

At Pipe Spring National Monument, samples were collected on 27 July 2001 from 2 man-made ponds and 1 natural spring. The stone ponds, built during the 1800s, were shaded, approximately 15 × 10 m in surface area, and 1 m in depth. The samples were from sediment, periphyton, and *Chara vulgaris* metaphyton.

At Cedar Breaks National Monument, samples were collected from Alpine Pond on 28 July 2001. The pond is natural and surrounded by a coniferous forest. It is oblong, approximately 0.2 ha in size, and 2 to 3 m in depth. It is recharged through precipitation, runoff, and groundwater. We collected floating algal mats, sediment, phytoplankton, metaphyton intertwined with *Chara vulgaris,* and periphyton from submerged woody plants.

In Zion National Park, samples were collected on 10 August 2001 from the North Fork of the Virgin River, Pine Creek Pool, and Weeping Rock alcove and pond. Three samples were collected from cobble at each of 11 sample locations from the Zion National Park Narrows to the Springdale Park outside the national park boundary. Pine Creek Pool is located near the switchbacks approximately halfway up from Canyon Junction and Zion-Mount Carmel Tunnel. Metaphyton were collected from the outflow stream and littoral habitats, which possibly originates outside Zion National Park. Samples were collected at the Weeping Rock alcove from the metal railing, wet wall, and below the small waterfall on limestone mounds. The Weeping Rock pond is in a natural depression below the Weeping Rock alcove. Metaphyton samples were collected from the inflow and outflow stream and from *Chara vulgaris* metaphyton.

The algal samples were preserved with M^3 (American Public Health Association, 1992). After acid washing the sediment sample, permanent slides of diatoms were made with Permount (Fischer Scientific, Hampton, New Hampshire). Semipermanent slides were made for non-diatom samples with distilled water and sealed with epoxy (Smith, 2003). Tilden (1910), Forest (1954), Desikachary (1959), Prescott (1962), Uherkovich (1966), Patrick and Reimer (1966, 1975), Whitford and Schmacher (1984), and Dillard (1989*a,* 1989*b,* 1990, 1991*a,* 1991*b,* 1993) were used to identify taxa.

The aquatic habitats in the 3 parks were unique and diverse with respect to their algal assemblages. We identified 186 algal species from the 3 parks (Table 1). Diatoms were the dominant group, represented by 103 species (55.4% of the reported species). Cyanobacteria and green algae each included 41 identified species (22.0%), and only 1 species of red algae was identified. Most species tended to be site specific, and few species were observed in all 3 locations, probably because of the diversity of habitats sampled: eutrophic desert ponds, alpine pond, desert river, wet walls, and desert stream pool.

Pipe Spring National Monument—At Pipe Spring National Monument, we identified 30 species of algae in the 2 ponds and natural spring (Table 1). Bacillariophyta had the greatest representation with 21 species (70%); Chlorophyta had 6 species (20%), and cyanobacteria had 3 species (10%).

There were 11 species (9 diatoms: *Amphora ovalis, Fragilaria acus, Gomphonema angustatum, Navicula cryptocephala, N. lanceolata, Nitzschia amphibia, N. palea, N. fonticola,* and *Synedra ulna*; 1 cyanobacterium: *Oscillatoria limnetica*; and 1 green alga: *Cladophora crispata*) that inferred eutrophic and alkaline conditions (Lowe, 1974; VanLandingham, 1982; Van Dam et al., 1994). Four of the diatom species (*A. ovalis, F. acus, G. angustatum,* and *S. ulna*) were found within the *Chara vulgaris* metaphyton. *Oscillatoria limnetica* and *Cladophora crispata* also were in the metaphyton among *Chara vulgaris* and were attached to a woody stem.

The majority of the diatoms were found in the sediment of the natural spring samples. The natural spring was not flowing, and the sediment samples came from small pools in the streambed. The lack of flow in the spring probably caused a concentration of nutrients in the sediments; thus, the diatoms in close contact with the sediments would be more indicative of eutrophic conditions. Additionally, the National Park Service feeds resident ducks at the 2 ponds for living history programs. In the previous year, it was believed the ducks caused an algal bloom in the constructed ponds.

Cedar Breaks National Monument—We identified 78 species from the Alpine Pond in Cedar Breaks National Monument (Table 1). The division Bacillariophyta had 39 species (50.0%), Chlorophyta had 20 species (25.6%), and cyanobacteria had 19 species (24.4%).

There were 9 species (1 cyanobacterium: *Microcystis aeruginosa*; and 8 diatoms: *Fragilaria pinnata, F. vaucheriae, Gomphonema intricatum, G.*

olivaceum, Nitzschia palea, Rhopalodia gibba Sellaphora pupula, and *Staurosira construens*) identified that are indicative of eutrophic and alkaline conditions (Lowe, 1974; VanLandingham, 1982). They were found in the floating cyanobacterial mats, which might have higher nutrient concentrations than the surrounding environments.

Conversely, 3 species (2 cyanobacteria: *Chroococcus limneticus* and *Nostoc paludosum*; and 1 diatom: *Staurosira construens* var. *venter*) identified from the phytoplankton are indicators of oligotrophic or mesotrophic conditions. The high numbers of *Cymbella* species identified are more characteristic of environments rich in oxygen and low in organic nitrogen (Van Dam et al., 1994). There were 4 heterocyst species (*Calothrix braunii, Nostoc linckia, N. paludosum,* and *Scytonema rivulare*), comprising 21% of the cyanobacterial species, indicative of low nitrogen concentrations. These heterocyst species were found in floating mats, periphyton, phytoplankton, and metaphyton on *Chara vulgaris.* These suggest this pond is oxygen rich, nitrogen limited, and oligotrophic, with eutrophic floating mats. It would be beneficial to analyze nutrients in both habitats.

Zion National Park—We identified 127 algal species from the Virgin River, Pine Creek Pond, and Weeping Rock alcove and pond. Diatoms dominated all samples, except from the Weeping Rock habitat. Diatoms had 78 species (61.4%), cyanobacteria and green algae both included 24 species (18.9%), and only 1 species of red algae was found.

We identified 99 algal taxa from the North Fork of the Virgin River: 66 diatoms, 18 cyanobacteria, 14 green algae, and 1 red alga (Table 1). Diatoms dominated in all of the sampled sites in terms of cell density and relative biomass (80.6% and 73.5%, respectively); cyanobacteria averaged 18.7% and 24.2%, respectively; and green and red algae averaged less than 1% for each measure. Only 13 of 55 genera comprised 95.3% of the relative abundance in the community: *Encyonopsis* (54.9%), *Achnanthidium* (11.4%), *Tolypothrix* (8.1%), *Phormidium* (6.4%), *Encyonema* (5.1%), *Nitzschia* (1.9%), *Navicula* (1.8%), *Fragilaria* (1.2%), *Gomphonema* (1.0%), *Achnanthes* (1.0%), *Dichothrix* (0.9%), *Oscillatoria* (0.8%), and *Diatoma* (0.8%). At the level of species, 14 species comprised 88.6% of the relative abundance in the community. These dominant species were represented by 10 diatoms: *Encyonopsis microcephala* (45.1%), *Achnanthidium minutissimum* (16.3%), *Encyonema lunatum* (2.0%), *Encyonema minutum* (1.9%), *Nitzschia paleacea* (1.5%), *Fragilaria vaucheriae* (1.4%), *Achnanthidium pyrenaicum* (1.2%), *Navicula radiosa* var. *tenella* (1.2%), *Nitzschia intermedia* (1.1%), and *Gomphonema olivaceum* (1.0%). The other dominant species were 4 cyanobacteria: *Tolypothrix conglutinata* (7.4%), *Phormidium tenue* (6.4%), *Oscillatoria limnetica* (1.1%), and *Dichothrix orsiniana* (1.0%).

In 2 samples from Pine Creek Pool, We identified 30 algal taxa: 23 diatoms (76.7%), 6 green algae (20.0%), and 1 cyanobacterium (3.3%) (Table 1). There were 13 diatom taxa (*Amphipleura pellucida, Diatoma vulgaris* var. *linearis, D. vulgaris* var. *grande, Fragilaria acus, Navicula lanceolata, Nitzschia palea, Opephora martyi, Rhoicosphenia curvata, Rhopalodia gibba, R. gibba* var. *ventricosa, Sellaphora bacillum, S. pupula,* and *Synedra ulna*; 56.5% of the diatom taxa) indicative of eutrophic conditions (Lowe, 1974). In Pine Creek Pool, there is concern of eutrophication. An ongoing Zion National Park study on fecal coliform did not corroborate these results for eutrophication occurring at this location. However, inorganic nutrients from fertilizers might not be seen in the fecal coliform samples but could cause eutrophication. Clean water is important because Pine Creek empties into the North Fork of the Virgin River, it is used by native wildlife, and it is a source of community drinking water and river recreation. Aquatic samples and chemistries should be assessed monthly to provide a better understanding of the stream pool dynamics.

The Weeping Rock alcove area was unique in that it was dominated by cyanobacteria. There were 5 species on the Weeping Rock metal railing and limestone mound mats. Weeping Rock pond samples included 5 diatoms and 4 green algae. *Oedogonium* ''species B'' dominated the inflowing green algal metaphyton with *Achnanthidium pyrenaicum* and *Cocconeis rugosa. Oedogonium* ''species A'' dominated the metaphyton sample attached to *Chara vulgaris* in the center of the pool. *Spirogyra* ''species A'', *Biddulphia laevis, Rhoicosphenia abbreviata,* and *Synedra ulna* also were collected from the *Chara vulgaris* metaphyton. *Biddulphia laevis* dominated the outflow brown metaphy-

TABLE 1—Cyanobacteria, Bacillariophyta, Chlorophyta, and Rhodophyta species identified from Zion National Park, Utah (NFVR = North Fork of Virgin River, PC = Pine Creek Pool, WR = Weeping Rock Alcove and Pond), Cedar Breaks National Monument, Utah (CB), and Pipe Spring National Monument, Arizona (PS).

Taxa	NFVR	PC	WR	CB	PS
CYANOBACTERIA					
Anabaena constricta Szafer[b]	X				
Aphanocapsa delicatissima W. West & G. H. Smith[b]				X	
Aphanocapsa endophytica G. M. Smith[v]				X	
Aphanocapsa rivularis (Carm.) Rabenth.[b]	X				
Aphanothece microscopica Nägeli[b]				X	
Calothrix braunii Born. & Flahault[b]				X	
Calothrix stagnalis Gomont[v]			X		
Chlorogloea fritschii Mitra[b]				X	
Chroococcus dispersus (Keissler) Lemmerm.[b]				X	
Chroococcus limneticus Lemmerm.[b]				X	
Chroococcus minor (Kütz.) Nägeli[b]	X			X	
Chroococcus minutus (Kütz) Nägeli[b]				X	
Chroococcus pallidus Nägeli[b]				X	
Chroococcus turgidus (Kütz.) Nägeli[b]	X			X	
Dactylococcopis rhaphidioides Hansg.[b]	X				
Dichothrix orsiniana (Kütz.) Born. & Flahault[b]	X				
Entophysalis cornuana Sauvineau[y]				X	
Gloeocapsa compacta Kütz.[b]				X	
Gloeocapsa livida (Carm.) Kütz.[b]	X				
Gloeothece linearis Nägeli[b]				X	
Hydrocoleum oligotrichum A. Braun in Rabenh.[v]			X		
Lyngbya major Menegh.[b]	X				
Lyngbya mesotricha Skuja[b]	X				X
Merismopedia glauca (Ehrenb.) Nägeli[b]	X				
Microcystis aeruginosa Kütz.[b]				X	
Nostoc linckia (Roth) Born. & Flahault[b]				X	
Nostoc paludosum Kütz.[b]				X	
Nostoc punctiforme var. *populorum* Geitler[b]	X				
Oscillatoria limnetica Lemmerm.[b]	X			X	X
Oscillatoria prolifica (Grev.) Gomont[b]		X			
Oscillatoria subbrevis Schmidle[b]	X				

TABLE 1—Continued.

Taxa	NFVR	PC	WR	CB	PS
Phormidium fragilis (Menegh.) Gomont[b]				X	
Phormidium tenue (Menegh.) Gomont[b]	X				X
Schizothrix friesii Gomont[b]	X				
Scytonema crispum (Agardh) Born.[w]	X				
Scytonema densum (A. Braun) Born. in Born. & Thuret[w]			X		
Scytonema hofmanni var. *calcicolum* Hansg.[w]			X		
Scytonema rivulare Borzi[b]				X	
Scytonema tolypotrichoides Kütz.[b]			X		
Synechococcus aeruginosus Nägeli[b]	X				
Tolypothrix conglutinata Borzi[b]			X		
BACILLARIOPHYTA					
Achnanthes hauckiana var. *rostrata* Schulz[t]	X				
Achnanthidium minutissimum (Kütz.) Czarn.[t]	X	X		X	X
Achnanthidium pyrenaicum (Hust.) Kobayasi[h]	X	X	X	X	X
Adlafia minuscula var. *muralis* (Grun.) L.-Bertalot[q]	X				
Amphipleura pellucida (Kütz.) Kütz.[t]	X	X			
Amphora acutiuscula Kütz.[t]				X	
Amphora ovalis Kütz.[t]				X	X
Amphora perpusilla Grun.) Grun.[t]	X				X
Biddulphia laevis Ehrenb.[y]			X		
Caloneis schumanniana (Grun.) Cleve[t]	X				
Cocconeis pediculus Ehrenb.[t]	X	X			
Cocconeis placentula Ehrenb.[t]	X			X	
Cocconeis rugosa Sov.[t]			X		
Craticula cuspidata (Kütz.) Mann[t]	X				
Cymatopleura elliptica (Balbis) W. Smith[y]	X				
Cymbella alpestris Kramm.[k]	X				
Cymbella cuspidata Kütz.[u]				X	
Cymbella cymbiformis Agardh[u]				X	
Cymbella inaequalis (Her.) Rabenh.[u]				X	
Cymbella neocistula Kramm.[k]				X	
Cymbella pusilla Grun.[u]	X				
Diatoma anceps (Her.) Kirchn.[t]	X				
Diatoma vulgaris Bory[t]	X				
Diatoma vulgaris var. *grande* (W. Smith.) Grun.[t]		X			
Diatoma vulgaris var. *linearis* Grun.[t]		X			

TABLE 1—Continued.

Taxa	NFVR	PC	WR	CB	PS
Diploneis puella (Schum.) Cleve[t]	X				
Encyonema brehmii (Hust.) Mann[j]	X				
Encyonema lunatum (Smith) V. H.[j]	X				X
Encyonema minutum (Hilse) Mann[j]	X			X	
Encyonema norvegica (Grun.) Bukht.[j]	X				
Encyonema silesiacum (Bleisch) Mann[j]	X	X		X	
Encyonema triangulum (Ehrenb.) Kütz.[j]	X				
Encyonopsis microcephala (Grun.) Kramm.[j]	X			X	
Epithemia turgida (Her.) Kütz.[u]				X	
Epithemia turgida var. *granulata* (Her.) Brun[u]				X	
Fragilaria acus (Kütz.) L.-Bertalot[o]	X	X			X
Fragilaria capucina var. *rumpens* (Kütz.) L.-Bertalot ex Bukht.[a]	X				
Fragilaria crotonensis Kitton[t]				X	
Fragilaria vaucheriae (Kütz.) Peters.[t]	X			X	
Fragilariforma virescens (Ralfs) Williams & Round[z]	X				
Gomphonema acuminatum Her.[u]				X	
Gomphonema acuminatum var. *pusilla* Grun.[u]				X	
Gomphonema angustatum (Kütz.) Rabenh.[u]					X
Gomphonema consector Hohn & Hellerm.[u]					X
Gomphonema gracile Her. emend. V. H.[u]	X				
Gomphonema intricatum Kütz.[u]				X	
Gomphonema olivaceoides Hust.[u]	X			X	X
Gomphonema parvulum (Kütz.) Kütz.[u]				X	
Gomphonema truncatum Ehrenb.[u]		X		X	
Gyrosigma acuminatum (Kütz.) Rabenh.[t]	X				
Hippodonata capitata (Ehrenb.) L.-Bertalot, Metz. & Witk.[r]	X				
Kobayasia subtilissima (Cleve) L.-Bertalot[p]	X				
Navicula upsaliensis (Grun.) Peragallo[l]	X				
Navicula arvensis Hust.[t]	X			X	X
Navicula cascadensis Soc.[t]					X
Navicula cryptocephala Kütz.[t]					X

TABLE 1—Continued.

Taxa	NFVR	PC	WR	CB	PS
Navicula cryptotenella L.-Bertalot in Kramm. & L.-Bertalot[l]	X				X
Navicula exigua Greg. ex Grun.[t]	X				
Navicula gibbosa Hust.[t]				X	
Navicula gysingensis Foged[t]	X			X	
Navicula lanceolata (Agardh) Her.[t]	X	X			X
Navicula odiosa Wallace[t]					X
Navicula paucivisitata Patr.[t]	X				
Navicula pseudoreinhardtii Patr.[t]	X				
Navicula pusilla W. Smith[t]				X	
Navicula pusilla var. *jamalinensis* Grun.[t]				X	
Navicula radiosa Kütz.[t]	X	X		X	X
Navicula tripunctata (O. F. Müll.) Bory[t]	X				
Nitzschia acicularis (Kütz.) W. Smith[y]		X			
Nitzschia amphibia Grun.[g]	X				X
Nitzschia fonticola Grun.[y]					X
Nitzschia hantzschiana Rabenh.[g]	X				
Nitzschia intermedia (Hantzsch ex. Grun.) Cleve[g]	X			X	
Nitzschia palea (Kütz.) W. Smith[y]	X	X		X	X
Nitzschia palea var. *debilis* (Kütz.) W. Smith[g]				X	
Nitzschia scalaris (Ehrenb.) W. Smith[m]	X				
Nitzschia sinuata var. *tabellaria* Grun.[g]		X			
Opephora martyi Hérib.[t]		X			
Pinnularia divergens var. *elliptica* Cleve[t]	X				
Pinnularia sp. 1[t]	X				
Pinnularia sp. 3[t]	X				
Pseudostaurosira brevistriata (Grun. in V. H.) Williams & Round[z]	X				
Reimeria sinuata (Greg.) Kociolek & Stoermer[i]	X	X			
Rhoicosphenia abbreviata (Agardh) L.-Bertalot[n]		X	X		
Rhopalodia gibba (Her.) O. Müll.[u]		X		X	
Rhopalodia gibba var. *ventricosa* (Kütz.) H. & M. Perag.[u]		X			
Rhopalodia gibberula var. *vanheurckii* O. Müll.[u]	X				
Rhopalodia musculus (Kütz.) O. Müll.[u]	X				
Sellaphora bacillum (Her.) Mann[s]	X	X			
Sellaphora pupula (Kütz.) Meresc.[s]	X	X		X	
Stauroneis smithii Grun.[t]	X				

Table 1—Continued.

Taxa	NFVR	PC	WR	CB	PS
Staurosira construens (Her.) Williams & Round[z]				X	
Staurosira construens var. *binodis* (Ehrenb.) Hamlton[z]				X	
Staurosira construens var. *venter* (Her.) Hamilton[z]	X			X	
Staurosirella leptostauron (Ehrenb.) Williams & Round[z]	X	X		X	
Staurosirella pinnata (Her.) Williams & Round[z]				X	
Surirella patela var. *neupaueri* (Pant.) Cleve[y]					X
Suirella sp. 1[y]	X				
Synedra ulna (Nitz.) Her.[t]	X	X	X	X	X
Synedra ulna var. *oxyrhynchyus* f. *mediocontracta* Hust.[t]	X				
Tryblionella hungarica (Grun.) Mann[g]	X				
CHLOROPHYTA					
Ankistrodesmus falcatus var. *stipitatus* (Chodat) Lemmerm.[c]	X				
Ankistrodesmus nannoselene Skuja[c]				X	
Bulbochaete sp. 1[d]	X				
Chara vulgaris L.[v]			X	X	X
Characium ensiforme Hermann[c]	X				
Characium limneticum Lemmerm.[c]	X				
Chlorophyta filament (10–11 × 6–7 μm) spine[e]	X				
Cladophora crispata (Roth) Kütz.[d]					X
Closterium lunula Nitzsch[e]				X	
Cosmarium angulosum Bréb.[b]					X
Cosmarium granulatum Bréb.[f]	X			X	
Cosmarium obtusatum Schmidle[f]				X	
Cosmarium obtusatum var. *beanlandii* West & West[f]				X	
Cosmarium sp. 1 (30 × 20 μm, 18)[f]	X				
Cosmarium sp. 2[f]	X				
Cosmarium undulatum Corda[f]				X	
Mougeotia sp. 1 (80 × 30 μm)[e]				X	
Oedogonium sp. A (90–100 × 50–70 μm)[d]			X		X
Oedogonium sp. B (300 × 120 μm)[d]			X		
Oedogonium sp. C (500 × 50 μm)[d]		X			

TABLE 1—Continued.

Taxa	NFVR	PC	WR	CB	PS
Oedogonium sp. 1 (15–22 × 5 µm)[d]	X				X
Oedogonium sp. 2 (30–40 × 12–15 µm)[d]	X			X	X
Oedogonium sp. 3 (60–103 × 8–12 µm)[d]	X			X	
Oedogonium sp. 4 (40–50 × 22–25 µm)[d]	X				
Oocystis lacustris Chodat[c]				X	
Oocystis solitaria Wittrock[c]				X	
Pediastrum boryanum var. *longicorne* Reinsch[c]				X	
Pediastrum duplex Meyen[c]				X	
Pediastrum integrum Nägeli[c]				X	
Pediastrum tetras (Ehrenb.) Ralfs[e]		X			
Pleurotaenium minutum var. *alpinum* (Raciborski) Gutwinski[e]				X	
Scenedesmus acuminatus (Lager.) Chodat[x]		X			
Scenedesmus acutus Meyen[x]	X				
Scenedesmus ecornis (Ralfs) Chodat[x]				X	
Scenedesmus quadricauda Turpin) Bréb.[x]				X	
Scenedesmus quadricauda var. *quadrispina* (Chodat) G. M. Smith[x]					X
Scenedesmus soli Hortobagyi[x]				X	
Scenedesmus spinosus Chodat[x]		X			
Selenastrum minutum (Nägeli) Collins[c]		X			
Spirogyra sp. A[e]			X		
Ulothrix sp. 1[d]	X				
RHODOPHYTA					
Audouinella violacea (Kütz.) Hamel[v]	X				

Principal references used to identify each taxon: [a] Bukhtiyarova, 1995; [b] Desikachary, 1959; [c] Dillard, 1989*a*; [d] Dillard, 1989*b*; [e] Dillard, 1990; [f] Dillard, 1991*a*; [g] Jarrett and King, 1989; [h] Kobayasi, 1997; [i] Kociolek and Stoermer, 1987; [j] Krammer, 1997; [k] Krammer, 2002; [l] Krammer & Lange-Bertalot, 1985; [m] Krammer & Lange-Bertalot, 1988; [n] Krammer and Lange-Bertalot, 1991; [o] Krammer & Lange-Bertalot, 2000; [p] Lange-Bertalot, 1996; [q] Lange-Bertalot, 2001; [r] Lange-Bertalot et al., 1996; [s] Mann, 1989; [t] Patrick and Reimer, 1966; [u] Patrick and Reimer, 1975; [v] Prescott, 1962; [w] Tilden, 1910; [x] Uherkovich, 1966; [y] Whitford and Shumacker, 1983; [z] Williams & Round, 1987.

ton and is an indicator of alkaline conditions (Lowe, 1974). Overall, the algal diversity was low and only represented by 2 to 3 species per sample.

The species in the algal mats from the Weeping Rock alcove tended to be terrestrial species that prefer alkaline environments (VanLandingham, 1982). All of the reported cyanobacteria genera are known to precipitate calcium carbonate as calcite (Freytet and Verrecchia, 1998). Further investigation is needed to determine if the algae depositing calcite on mounds at Weeping Rock are truly freshwater stromatolites or travertine. In Weeping Rock pond, *Chara vulgaris* was abundant and precipitated $CaCO_3$. *Chara vulgaris* also provided an excellent habitat for the attached metaphyton. *Oedogonium* ''species B'' dominated the inflow metaphyton samples, which were bright, emerald green. This could be the same species that inhabited the emerald pools on the Emerald Pool trail in Zion Canyon, but further investigation is needed.

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FIRST RECORDS OF A EURASIAN SCENTLESS PLANT BUG, *RHOPALUS TIGRINUS* (HEMIPTERA: RHOPALIDAE), FROM NEW MEXICO, TEXAS, AND UTAH

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ABSTRACT—A Eurasian scentless plant bug, *Rhopalus tigrinus,* first recorded in North America from New Jersey in 1977, has since been reported from 4 additional eastern states and 6 western states. On the basis of fieldwork and examination of museum collections, I report this crucifer-feeding insect new to New Mexico, Texas, and Utah. Despite its wide Nearctic distribution and occasional use of native Brassicaceae as hosts, the ecological, historical, and taxonomic evidence suggests that *R. tigrinus* is a nonindigenous species that has been introduced accidentally into the United States.

RESUMEN—El bicho inodoro euroasiático de plantas, *Rhopalus tigrinus,* registrado por la primera vez en Norteamárica en New Jersey en 1977, después ha sido registrado en otros 4 estados orientales y 6 estados occidentales. Basándose en trabajo de campo y examen de colecciones de museo, se registra por primera vez la presencia de este insecto, que se alimenta de cruciferae, en Nuevo México, Texas, y Utah. A pesar de su amplia distribución neártica y del uso ocasional de Brassicaceae nativo como huésped, la evidencia ecológica, histórica y taxonómica sugiere que *R. tigrinus* es una especie no nativa que ha sido introducida accidentalmente en los Estados Unidos.

The hemipteran family Rhopalidae, known as scentless plant bugs, comprises 38 species in the continental United States and Canada (Henry, 1988). *Rhopalus* (*Brachycarenus*) *tigrinus* (Schilling) is the only nonnative rhopalid in North America. The first New World records of this widespread Eurasian species were from New Jersey (Hoebeke, 1977), and it since has been reported from Maryland, Michigan, New York, and Pennsylvania in the eastern United States (Hoebeke and Wheeler, 1982; Wheeler and Hoebeke, 1988; Wheeler, 1992) and from Arizona, California, Colorado, Nebraska, Oregon, and Wyoming in the western United States (Wheeler and Hoebeke, 1999). Nymphs and adults of this multivoltine bug feed mainly on species of the crucifer genera *Capsella* and *Lepidium* in the eastern states and *Descurainia, Hirschfeldia, Lepidium,* and *Sisymbrium* in the western states (Wheeler and Hoebeke, 1988, 1999).

I here record *R. tigrinus* from New Mexico, Texas, and Utah on the basis of fieldwork and examination of undetermined material from Utah in the Monte L. Bean Life Science Museum, Brigham Young University, Provo (BYU), and the Utah State University Insect Collection, Logan (EMUS). Adults collected from 2001 through 2003 have been deposited in the National Museum of Natural History, Smithsonian Institution, Washington, D.C.

New Collection Records—NEW MEXICO: Doña Ana County, Las Cruces, 1 June 2003, A. G. Wheeler (A.G.W.), 3 adults, 1 third and 2 fifth instars, ex *Descurainia sophia* (L.) Webb. ex Prantl; Eddy County, Route 82, 6.5 km E of Loco Hills, 31 May 2003, A.G.W., 2 adults, 1 third, 1 fourth, and 1 fifth instar, ex *Lepidium montanum* Nutt. ex Torr. & A. Gray; Route 82, Loco Hills, 31 May 2003, A.G.W., 1 adult, 1 second and 1 third instar, ex *L. montanum*; Otero County, Route 82, Mountain Park, 31 May 2003, A.G.W., 1 adult, ex *Brassica nigra* (L.) Koch; Route 70, Alamogordo, 1 June 2003, A.G.W., 1 fourth and 1 fifth instar, ex *D. sophia*; Routes 70 and 82, 11.5 km E of Doña Ana County line, 1 June 2003, A.G.W., 1 second and 1 third instar, ex *L. montanum*; Quay County, Route 40, ca. 2 km W of Glenrio, 30 May 2003, A.G.W., 1 third instar, ex *D. sophia*.

TEXAS: Dallam County, Dalhart, 23 May 2001, A.G.W., 2 adults, 4 fourth and 4 fifth instars, ex *D. sophia*; Deaf Smith County, Hereford, 23 May 2001, A.G.W., 3 adults, ex *D. sophia*; Hartley County, Hartley, 23 May 2001, A.G.W., 1 adult, 4 fifth instars, ex *D. sophia*; Llano County, Ranch Road 1431, 2.3 km N of Kingsland, 1 May 2002, A.G.W., 3 adults, fourth and fifth instars, ex *Lepidium virginicum* L.; Oldham County, Vega, 23 May 2001, A.G.W., 2 adults, 2 fifth instars, ex *D. sophia*.

UTAH: Box Elder County, 21 mi NW Tremonton, 16 Aug. 1983, B.A. Haws, 1 adult (EMUS); Cache County, junction of Routes 89 and 91 and Park Avenue, Logan, 19 July 2001, A.G.W. and T. J. Henry, 1 adult, ex *Brassica*; Hyde Park, 14 July 2001, A.G.W. and T. J. Henry, 3 adults, late instars, ex *Lepidium perfoliatum* L.; Juab County, 5 mi SW Callao, 15 July 1984, Keeler and Hanson, 1 adult (EMUS); Sevier County, 15 mi E Salina, 3 May 1985, B. A. Haws, 1 adult (EMUS); Tooele County, HAFB Bombing Range, 3 Aug. 1983, C. R. Nelson, 2 adults (EMUS); Vernon Creek S of Little Valley Campground, 18 July 1984, C. R. Nelson, 1 adult (BYU); Utah County, Provo, 10 May 1984, C. R. Nelson, 1 adult (BYU).

The native *L. montanum* and Palearctic *L. perfoliatum* are new host plants for *R. tigrinus* in North America. Collections of the rhopalid from New Mexico, Texas, and Utah extend the known North American distribution of this evidently adventive species. The 1983 records from Utah predate by 1 year the earliest western United States record given by Wheeler and Hoebeke (1999). Although the widespread United States distribution might suggest this rhopalid is native to North America, it belongs to a Palearctic genus (Göllner-Scheiding, 1983). In addition, its relatively recent detection in the United States, including well-collected areas of the East, and its principal use of naturalized Eurasian crucifers as host plants, support an immigrant status in North America (Hoebeke and Wheeler, 1982; Wheeler and Hoebeke, 1999). Its unintentional introduction with imported nursery stock or other plant material has been suggested (Wheeler and Hoebeke, 1999). Whether the importation of *R. tigrinus* into North America involved a single introduction, with subsequent spread via its own dispersal and perhaps also aided by commerce, or involved multiple introductions from the Old World, is unknown.

Rhopalus tigrinus can be considered an invasive species in the sense of any species that is not native (e.g., Miller et al., 2002). The term ''invasive species'' often is reserved for nonnative species that cause economic loss or environmental damage or affect human health (Wheeler and Hoebeke, 2001). In the United States, *R. tigrinus* develops mainly on Old World crucifers found along highways, railroads, and in other ruderal sites. Like many of the other nonindigenous insects established in the continental United States (ca. 2,000 species; Pimentel et al., 2000), *R. tigrinus* remains an obscure, apparently innocuous member of our fauna.

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NOTES ON REPRODUCTION IN THE SOUTHWESTERN CAT-EYED SNAKE, *LEPTODEIRA MACULATA,* AND WESTERN CAT-EYED SNAKE, *LEPTODEIRA PUNCTATA* (SERPENTES: COLUBRIDAE), FROM MEXICO

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Abstract—The reproductive cycles of *Leptodeira maculata* and *L. punctata* were examined from museum specimens collected in Mexico. Males followed a testicular cycle in which sperm were produced in spring, summer, and autumn. Egg production in *L. maculata* occured in spring and summer. The mean of 6 egg clutches was 8.7 ± 1.5 *SD,* range = 7 to 11. The egg clutches of 10 and 11 are the maximum known from *L. maculata. Leptodeira punctata* produced eggs in spring, summer, and autumn. Mean clutch size of 9 egg clutches was 7.8 ± 1.7 *SD,* range = 6 to 11. Apparently, only part of each female population produced eggs each year. The smallest reproductively active male *L. maculata* was 280 mm snout-vent length (SVL); the smallest reproductively active female was 480 mm SVL. The smallest reproductively active male *L. punctata* was 276 mm SVL; the smallest reproductively active female was 360 mm SVL.

Resumen—Los ciclos reproductivos de *Leptodeira maculata* y *L. punctata* fueron examinados en ejemplares de museos recolectados en México. Los machos siguieron un ciclo testicular en el cual la esperma se produce en la primavera, el verano y el otoño. La producción de huevos de *L. maculata* ocurrió en la primavera y en el verano. El promedio de 6 puestas de huevos fue de 8.7 ± 1.5 *DE,* rango = 7 a 11. Las puestas de huevos de 10 y 11 son el máximo número documentado para *L. maculata. Leptodeira punctata* produjo huevos en la primavera, el verano y el otoño. El tamaño promedio de 9 puestas de huevos fue de 7.8 ± 1.7 *DE,* rango = 6 a 11. Parece que sólo una parte de cada población de hembras produjo huevos cada año. El macho de *L. maculata* más pequeño reproductivamente activo midió 280 mm de longitud hocico-cloaca (LHC); la hembra más pequeña reproductivamente activa midió 480 mm LHC. El macho de *L. punctata* más pequeño reproductivamente activo midió 276 mm LHC; la hembra más pequeña reproductivamente activa midió 360 mm LHC.

The southwestern cat-eyed snake, *Leptodeira maculata,* is known from the Mexican states of Sinaloa, Nayarit, Jalisco, Michoacán, Colima, and Guerrero; the western cat-eyed snake, *Leptodeira punctata,* is known from Sinaloa, Nayarit, and Jalisco (Flores Villela and Gerez, 1994). There is anecdotal information on clutch sizes for *L. maculata* and *L. punctata* in Duellman (1958), for *L. maculata* in Ramírez-Bautista (1994), and for *L. punctata* in Hardy and McDiarmid (1969). Duellman (1958) reviewed the taxonomy of *Leptodeira.* The purpose of this note is to provide additional information on reproduction in *L. maculata* and *L. punctata* from a histological examination of gonadal material from museum collections.

Data presented were taken from the herpetology collections of the Natural History Museum of Los Angeles County, Los Angeles (LACM), and the University of Arizona, Tucson (UAZ) (Appendix 1). Data are presented for 46 *L. maculata* (27 males, mean snout-vent length [SVL] = 384.4 mm ± 52.7 *SD,* range = 280 to 444 mm; and 19 females, mean SVL = 470.1 mm ± 82.8 *SD,* range = 317 to 630 mm); and 67 *L. punctata* (41 males SVL = 338.2 mm ± 41.1 *SD,* range = 276 to 451 mm; and 26 females, mean SVL = 391.5 mm ± 59.6 *SD,* range = 292 to 523 mm). An unpaired *t*-test was used to compare male and female body sizes for both species. A series of 6 *L. punctata* neonates from Sinaloa also was examined. *Leptodeira maculata* were collected from 1959 through 1979; *L. punctata* were collected from 1959 through 1980.

Counts were made of enlarged follicles (>8 mm length) or oviductal eggs; no histology was done on these females. The left ovary was re-

TABLE 1—Monthly distribution of conditions in seasonal ovarian cycle of *Leptodeira maculata* from Mexico. Values shown are the numbers of females exhibiting each of the 4 conditions.

Month	*n*	Inactive	Early yolk deposition	Enlarged follicles (>8 mm length)	Oviductal eggs
June	4	2	0	2	0
July	10	5	2	2*	1
August	4	1	1	2	0
December	1	1	0	0	0

* Includes 1 female with damaged ovary from which enlarged follicles could no be counted.

moved from females; the left testis, vas deferens, and part of the kidney were removed from males for histological examination. Tissues were embedded in paraffin and cut into sections at 5 μm. Slides were stained with Harris' hematoxylin followed by eosin counterstain. Testis slides were examined to determine the stage of the male cycle; ovary slides were examined for the presence of yolk deposition (=secondary vitellogenesis, sensu Aldridge, 1979). Vasa deferentia were examined for sperm. Slides of kidney sexual segments were examined for evidence of secretory activity. Some snakes were road-kills, so not all tissues were available for examination. I examined 12 ovaries, 27 testes, 20 kidneys, and 18 vasa deferentia from *L. maculata,* and 17 ovaries, 41 testes, 35 kidneys, and 16 vasa deferentia from *L. punctata.*

Testicular histology was similar to that reported by Goldberg and Parker (1975) for the colubrid snakes *Masticophis taeniatus* and *Pituophis catenifer.* In the recrudescent testis, there was renewal of spermatogenic cells characterized by spermatogonial divisions; primary and secondary spermatocytes were present. In spermiogenesis, metamorphosing spermatids and mature sperm were present. The smallest mature male *L. maculata* (spermiogenesis in progress) was 280 mm SVL; the smallest mature male *L. punctata* was 276 mm SVL.

For *L. maculata,* 1 male from January was in testicular recrudescence; all others were undergoing spermiogenesis: June (6), July (16), August (3), September (1). For *L. punctata,* all males were undergoing spermiogenesis: June (8), July (16), August (16), September (1). While there was insufficient monthly material to describe the testicular cycles of both species, the presence of males undergoing spermiogenesis in spring, summer, and autumn indicated sperm was produced over a long period. Hardy and McDiarmid (1969) collected most *L. punctata* in late June through September, although a few were collected in December, February, and April, suggesting a seasonal activity period. Vasa deferentia from 18 *L. maculata* contained sperm: June (5), July (10), August (2), September (1); kidney sexual segments from 20 *L. maculata* males were enlarged: January (1), June (4), July (11), August (3), September (1). Vasa deferentia from 16 *L. punctata* contained sperm: June (1), July (11), August (4); kidney sexual segments from 34 of 35 (97%) males were enlarged: June (6 of 7), July (14 of 14), August (13 of 13), September (1 of 1). Mating

TABLE 2—Monthly distribution of conditions in seasonal ovarian cycle of *Leptodeira punctata* from Mexico. Values shown are the number of females exhibiting each of the 4 conditions.

Month	*n*	Inactive	Early yolk deposition	Enlarged follicles (> 8 mm length)	Oviductal eggs
June	5	4	0	1	0
July	9	3	2	1	3
August	10	6	1	2	1
September	2	1	0	1	0

TABLE 3—Collection dates, snout-vent length (SVL, mm), clutch sizes (oviductal eggs* or enlarged follicles >8 mm length), states, and museum sources (Appendix 1) for 7 gravid *Leptodeira maculata* from Mexico.

Date	SVL	Clutch size	State	Source
18–20 June	533	7	Nayarit	LACM 65242
29 June	630	11	Colima	UAZ 32944
7 July	503	8	Sinaloa	LACM 103566
9 July	519	8*	Sinaloa	LACM 6913
22 July	480	4**	Nayarit	UAZ 27008
1 August	525	8	Sinaloa	LACM 6921
21 August	573	10	Sinaloa	UAZ 34703

** Incomplete clutch; right ovary was damaged.

usually coincides with enlargement of the kidney sexual segment (Saint Girons, 1982).

Female *L. maculata* were reproductively active June to August (Table 1); female *L. punctata* were reproductively active June to September (Table 2). Clutch sizes for both species are in Tables 3 and 4. The mean for 6 *L. maculata* clutches was 8.7 ± 1.5 *SD,* range = 7 to 11; the mean for 9 *L. punctata* clutches was 7.8 ± 1.7, range = 6 to 11. The smallest reproductively active *L. maculata* female (enlarged follicles >8 mm length) was 480 mm SVL. The smallest reproductively active *L. punctata* female (yolk deposition in progress) was 360 mm SVL. Six *L. punctata* neonates from Sinaloa collected 20 October were 142.3 mm SVL ± 4.0 *SD,* range = 137 to 149 mm. The length of the female reproductive season or whether females are reproductively active long enough to produce more than 1 clutch per year is not known. Female *L. maculata* were larger than male *L. maculata* ($t = 4.3$; $df = 44$; $P < 0.0001$). Female *L. punctata* were larger than male *L. punctata* ($t = 4.3$; $df = 65$; $P < 0.0001$).

Only part of the female population of both species was reproductively active (10 of 19 [53%] for *L. maculata* and 12 of 26 [46%] for *L. punctata*) suggesting not all females produce eggs in a given year. This phenomenon occurs in North American colubrid snakes from the deserts of the southwestern United States (e.g., *Masticophis flagellum,* Goldberg, 2002).

Ramírez-Bautista (1994) reported that, in Jalisco, *L. maculata* produced clutches of 6 to 9 eggs, and a gravid female collected in June produced 9 eggs in August. The clutch sizes of 10 and 11 (Table 3) are new maximum clutch sizes for *L. maculata*. Duellman (1958) reported a captive *L. maculata* deposited 5 eggs on 18 June; 2 hatched on 13 August. He also reported clutches of 5 and 7 eggs for *L. maculata* and that specimens from early August contained eggs ready to be deposited. Duellman (1958) surmised mating probably occurs at the onset of the rainy season in early June. He also reported a clutch of 6 eggs for *L. punctata* that were deposited 17 and 18 August. Clutches of

TABLE 4—Collection dates, snout-vent length (SVL, mm), clutch sizes (oviductal eggs* or enlarged follicles >8 mm length), states, and museum sources (Appendix 1) for 9 gravid *Leptodeira punctata* from Mexico.

Date	SVL	Clutch size	State	Source
15 June	468	9	Sinaloa	LACM 115811
19 July	481	8	Sinaloa	LACM 76593
22 July	422	8*	Nayarit	UAZ 27020
28 July	371	6*	Sinaloa	LACM 6962
31 July	428	9*	Sinaloa	LACM 115810
3 August	382	6*	Sinaloa	LACM 115809
6 August	393	7	Sinaloa	UAZ 41836
18 August	523	11	Sinaloa	LACM 50946
6 September	410	6	Sinaloa	LACM 6939

6 and 7 eggs were reported for *L. punctata* in Sinaloa (Hardy and McDiarmid, 1969).

Examination of additional samples of *L. maculata* and *L. punctata,* particularly from spring and autumn, will be required before the reproductive biology of these species can be further elucidated.

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Appendix 1—Specimens of *Leptodeira maculata* and *L. punctata* from Mexico examined from the Natural History Museum of Los Angeles County, Los Angeles (LACM), and the University of Arizona, Tucson (UAZ).

Leptodeira maculata: Colima: (LACM 8667, 20499, 37315, 37316); (UAZ 32944); Guerrero: (LACM 58143); Jalisco: (LACM 25918, 25919, 136949); (UAZ 27010, 27011, 41768); Nayarit: (LACM 65242, 76599, 103537, 103538, 103540, 103541, 103545, 103547, 103550–103557, 103562, 103563); (UAZ 25140, 27008, 38266); Sinaloa: (LACM 6912, 6913, 6919, 6921–6923, 7243, 58872, 103565–103567, 130094); (UAZ 34703).

Leptodeira punctata: Nayarit: (LACM 6942, 6947, 6948, 6950, 25915, 103569–103571, 103573, 103574, 103576, 103578–103581, 103583, 103584, 103586, 136950, 136951); (UAZ 27020); Sinaloa: (LACM 6924, 6925, 6927, 6930, 6931, 6933, 6935, 6937–6939, 6944, 6945, 6951–6955, 6957, 6959–6963, 31317, 50946, 50964, 51016, 58873, 58874, 76591, 76593, 103589–103592, 103594–103596, 103603, 103604, 103606, 115809–115811, 121327, 125579); (UAZ 16289, 16291, 16293, 37863, 41836, 45537).

GRAND CANYON RATTLESNAKE PREYS ON JUVENILE SPOTTED SANDPIPERS

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Abstract—On 26 August 2000, a Grand Canyon rattlesnake (*Crotalus viridis abyssus*) was observed and photographed while it swallowed a juvenile spotted sandpiper (*Actitis macularia*) on a Colorado River beach at Unkar Ruins, Grand Canyon National Park, Coconino County, Arizona.

Birds have occasionally been documented as prey of *Crotalus viridis,* but this is the first report for *C. v. abyssus* and the first record of a rattlesnake preying on a shorebird (Charadriiformes).

RESUMEN—El 26 de agosto del 2000, una víbora de cascabel del Grand Canyon (*Crotalus viridis abyssus*) fue observada y fotografiada mientras tragaba un juvenil playero alzacolita (*Actitis macularia*) en una playa del río Colorado en las ruinas de Unkar en el Parque Nacional del Grand Canyon, en el condado de Coconino, Arizona. Se ha documentado que a veces pájaros han sido presas de *Crotalus viridis,* pero éste es el primer registro por *C. v. abyssus* y el primer registro de una víbora de cascabel capturando un pájaro playero (Charadriiformes).

Rattlesnakes of the widespread *Crotalus viridis/oreganus* clade (Ashton and De Queiroz, 2001; Douglas et al., 2001) are primarily predators of lizards and small mammals, with larger snakes feeding predominately on mammals (Klauber, 1956). Passerines, probably caught incubating on ground nests, and gallinaceous birds have been reported as prey for several subspecies (Fitch and Twining, 1946; Klauber, 1956; MacArtney, 1989) but birds contributed <5% of documented prey. The Grand Canyon Rattlesnake (*C. v. abyssus*) is mostly restricted to the Colorado and Little Colorado river canyons in Arizona (Douglas et al., 2001). Analysis of fecal samples from free-ranging *C. v. abyssus* and dissection of preserved specimens documented 4 mammalian and 2 reptilian genera as prey (Reed and Douglas, 2002). Here I report the probable envenomation of 2 juvenile spotted sandpipers (*Actitis macularia*) and, thus, the first known avian prey of the Grand Canyon rattlesnake.

During late morning on 26 August 2000, I landed on a beach near Unkar Ruins (36°06′N, 111°50′W), Grand Canyon National Park, Coconino County, Arizona, and found a large (ca. 1 m snout-vent length) Grand Canyon rattlesnake with a bird in its mouth. When I approached, the snake retreated into nearby vegetation. The head of the bird was engulfed and its dorsum appeared uniformly brown. Approximately 10 m away on the bare sand, I found a limp, freshly dead juvenile spotted sandpiper, easily aged by the barred wing coverts (National Geographic Society, 1999). All flight feathers were completely grown with no sign of feather sheaths.

I approached the snake again and could clearly see the barred wing coverts on its victim and, as it continued to swallow and pull back from me, I saw the white ventrum, yellow legs, and long toes of a sandpiper, which I could easily compare with the one in hand. The snake continued to ingest its meal, and when I departed about 30 min later, the sandpiper was almost completely engulfed. The second sandpiper could not be preserved for our remaining 12 days on the river and was discarded. A voucher slide of the snake with prey has been deposited at the University of Arizona Herpetology Collection (UAZ 55758-PSV) in Tucson.

Spotted sandpipers are commonly seen along the Colorado River in the Grand Canyon (Brown et al., 1987). While rattlesnakes normally strike, release, and later retrieve mammalian prey using chemo-receptors (Chiszar et al., 1977), birds are usually held after a strike (Klauber, 1956; Hayes, 1992). In this case, the snake apparently released the first sandpiper but held the second. Shorebirds (Charadriiformes) are not mentioned as prey of any *C. viridis* subspecies, but some *C. o. abyssus* spend disproportionate time near the river (Reed and Douglas, 2002), which would logically increase chances of encounters with such birds.

R. Duncan, A. Holycross, and C. Painter provided insight into rattlesnake behavior and the herpetological literature when I started work on this manuscript. Y. Torres-Troy took the voucher slide. Logistical costs were the shared expense of the 14 trip participants, and access was authorized by a Grand Canyon National Park private boating trip permit. I thank B. Brown, N. Brown, R. Duncan, and A. Holycross for comments on a draft of this manuscript, 2 anonymous reviewers for additional improvements, and M. Chavez-Charles for translating the abstract to Spanish.

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AVIAN MORTALITY DURING FALL 2001 MIGRATION AT COMMUNICATION TOWERS ALONG THE RIO GRANDE CORRIDOR IN SOUTHERN NEW MEXICO

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ABSTRACT—Avian mortality at communication towers in the Rio Grande Valley of southern New Mexico was studied during the fall of 2001 to quantify mortality at radio towers and to identify avian species following this migratory corridor. Six radio towers of heights ranging from 265 to 805 m and distances of 150 to 18,000 m from the Rio Grande were selected. Each tower was visited twice per week for a total of 24 visits per tower. Only 6 mortalities were found: 1 migrant raptor and 5 migrant passerines. Other parts of the western United States that experience adverse weather, such as low, overcast conditions, might be more vulnerable to large numbers of avian mortalities at communication towers than we found in southern New Mexico.

RESUMEN–Se estudio la mortandad de aves en las torres de comunicación en el valle del río Grande del sur de Nuevo México durante el otoño del 2001 para cuantificar la mortandad en las torres de radio y para identificar las aves en este corredor migratorio. Se seleccionaron 6 torres con un rango de altura de 265 a 805 m y a distancias de 150 a 18,000 m del río Grande. Cada torre fue visitada 2 veces a la semana por un total de 24 visitas por cada torre. Se encontraron sólo 6 aves muertas: 1 especie de ave de rapiña migratoria y 5 de aves cantoras migratorias. Otras regiones del oeste de Estados Unidos que experimentan climas extremos, como niebla baja y densa, pueden ser más vulnerables a grandes cantidades de muertes de aves en torres de comunicación que lo que encontramos en el sur de Nuevo México.

It is estimated that 4 to 10 million birds die in the United States each year due to collisions with communication towers (Kerlinger, 2000; Manville, 2000; Shire et al., 2000). Although tower kills are well-documented phenomena, few rigorous studies have been established to examine this threat to avian populations throughout North America and other parts of the world (Kerlinger, 2000). This is an important issue in avian conservation given the large number of declining migratory bird species (Peterjohn and Sauer, 1999) and the increasing demand for communication towers in the United States and elsewhere. The presence of lights and guy wires increases the risk of mortality at towers (Cochran and Graber, 1958; Graber, 1968; Avery et al., 1976). It has been estimated that 50,000 lighted communication towers greater than 60 m in height already exist in the United States, and 5,000 new towers over 60 m are established annually (Kerlinger, 2000; Shire et al., 2000).

A number of studies have been conducted to quantify factors involved in mortality of migratory birds with respect to communication towers, including tower height, lighting, weather conditions, and possibly geographical location (Avery et al., 1976; Seets and Bohlen, 1977; Ball et al., 1995; Crawford and Engstrom, 2001). Taller towers result in higher incidences of mortalities (Kerlinger, 2000; Shire et al., 2000). Lighting on towers is an important issue and has been shown to significantly increase mortality rates (Cochran and Graber, 1958; Kerlinger, 2000; Shire et al., 2000). Crawford and Engstrom (2001) found over 90% of mortalities at a northern Florida tower were nocturnal migrants. The highest mortalities have been documented during migration on nights with low visibility; however, the cumulative effect of daily mortalities throughout the year also is considered high (Crawford and Engstrom, 2000; Larkin, 2000). The United States Fish and Wildlife Service (USFWS) has identified at least 350 avian species as being vulnerable to radio tower collisions (Shire et al., 2000). In a report prepared by the American Bird Conservancy, 52 of 230 avian species documented to have been killed at radio towers were identified as Species of Management Concern by the USFWS (Shire et al., 2000).

Although much attention has been directed at avian mortalities due to collisions with radio towers, many knowledge gaps remain (Kerlinger, 2000; Shire et al., 2000). Most studies of radio towers have been initiated after scientists or concerned citizens became aware of high mortalities at towers (Shire et al., 2000). Studies such as these often fail to produce rigorous scientific results. Long-term studies at individual towers are impressive but provide little information beyond the particular tower studied (Crawford and Engstrom, 2001).

To date, all studies of avian collisions with communication towers have focused on the eastern half of the United States; we are unaware of any reported studies for towers west of the Rocky Mountains (Shire et al., 2000; P. Kerlinger, pers. comm.). It is not known if similar rates of mortalities are found in the western United States. Differences in weather patterns with respect to geographical location might contribute to differences in vulnerability to tower collisions.

The Rio Grande Valley in New Mexico is an important migratory corridor in the western United States (Yong and Finch, 1997; Kelly et al., 1999; Kelly et al., 2000; Kelly et al., 2002). As part of a study on avian migration in New Mexico, we visited radio towers within the Rio Grande Valley during fall migration to obtain information on migrants following this corridor.

Six communication towers in southern New Mexico, ranging from 265 to 805 m in height, all with guy wires and night lighting, were searched twice per week between sunrise and 1300 h for avian mortalities from 1 August to 30 October 2001 (Table 1). Towers were chosen to represent a variety of heights and distances from the Rio Grande (150 to 18,000 m; Table 1). The area under each tower was thoroughly searched by 1 or 2 individuals. Searches averaged 45 minutes but varied with respect to habitat and terrain. Specimens were collected, brought to the lab, and identified. In addition to avian mortalities, we searched for signs of predation (tracks and scat) and scavenging beneath each tower (Crawford and Engstrom, 2001). Because we were unable to conduct each survey at sunrise, we established a schedule to ensure that towers were surveyed at different times of the morning each day. Each tower was surveyed a total of 24 times.

The number of avian mortalities found at towers was low (n = 6; Table 1), too low to assess the effects of tower heights and distances from the Rio Grande. Of the 6 specimens collected during the 3-month period, 1 was collected in August and the other 5 were collected toward the end of September; no birds were collected during the month of October. Four

TABLE 1—Communication tower height, distance of each tower from the Rio Grande, habitat type in which each tower was located, and bird species collected at each of 6 towers in southern New Mexico during autumn 2001.

Habitat type at tower	Height (m)	Distance (m)	Species
Desert grass/scrub	805	7,000	None
Desert scrub	300	200	Swainson's hawk (*Buteo swainsoni*)
Urban/industrial	265	1,500	Hammond's flycatcher (*Empidonax hammondii*)
Urban/parkland/grass	441	150	Brewer's sparrow (*Spizella breweri*)
Mesquite	357	4,000	None
Desert scrub	501	18,000	Brewer's sparrow
			Black-headed grosbeak (*Pheucticus melanocephalus*)
			Orange-crowned warbler (*Vermivora celata*)

of the mortalities were migrant passerines, 1 was a partial migrant passerine, and 1 was a migrant raptor. The timing corresponded with the major flow of migrants through the Southwest. However, the low number of mortalities did not reflect the abundance and diversity of migrants using the Rio Grande corridor (Finch, 1989; Kelly et al., 1999; Kelly et al., 2000; Kelly et al., 2002).

Crawford and Engstrom (2001) found that predators and scavengers affect the number of birds collected at a site; they report the mean number of birds collected on sites with predator control to be significantly higher than on sites without predator control (2,248 ± 950 vs. 642 ± 362, respectively). Although predators potentially could have removed avian carcasses at our sites, no difference was observed in mortalities with respect to time of day, and based on the lack of observations of tracks and scat, predation did not seem to be a problem.

The low mortalities we observed in southern New Mexico might be related to the locations of monitored towers, regional weather conditions, or differences in movement patterns of migratory birds in eastern vs. western North America. Although large numbers of migrants move through the western United States and Canada, they do not seem to move in the large pulses associated with migrants in the eastern United States and Canada (Small, 1974). Southern New Mexico typically does not experience the low visibility and fog conditions associated with increased mortality risk at towers in the eastern United States. Radio towers along migration corridors in the western United States that are more likely to experience adverse weather conditions might have higher mortality rates than observed in this study. Studies of this type on a larger geographical scale, with multiple towers of different heights and lighting need to be conducted across the western United States. A better understanding of conditions that influence collisions with communication towers will assist decisions concerning tower placement and construction in the future as the demand for these towers increases.

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