CADDISFLY (TRICHOPTERA) ASSEMBLAGES ALONG MAJOR RIVER DRAINAGES IN ARIZONA

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ABSTRACT.—Seventy-two caddisfly species in 36 genera and 15 families were collected along the Little Colorado, Verde, Gila, and Colorado rivers in Arizona. Brachycentrids, hydropsychids, limnephilids, and uenoids made up nearly 50% of the assemblage in forested sites above 2200 m. Hydropsychids, hydroptilids, and leptocerids made up 75% of the assemblage in grassland watersheds between 2200 and 1000 m, and 80% at sites below 1000 m in desert watersheds. Species richness averaged 16 at sites above 2200 m elevation, 7 between 2200 and 1000 m, and 3 below 1000 m. H' diversity was typically >3 at sites above 2200 m and <2.5 below 2200 m. Each river had distinct faunas likely due to isolation of drainages across semiarid landscapes. Low Sørensen similarity values were measured for caddisfly assemblages in the highly regulated Colorado River and the other 3 rivers. Only 17 species were collected at 14 sites along 700 km of the Colorado River. Indicator caddisfly species are provided for altered and less disturbed drainages. We added 7 species not previously reported in Arizona for a total of 154 caddisfly species in the state. We provide a baseline of caddisfly indicators for monitoring changes in ecosystem health during the predicted long-term drought and population expansion in southwestern USA.

Key words: *Trichoptera, Colorado River, Gila River, Little Colorado River, Verde River, elevation, semiarid landscapes, species richness, indicator species.*

Arizona has a number of streams that flow from subalpine coniferous forests to arid deserts. These streams flow through 4 major river drainages including the Little Colorado (LCR), Verde, Gila, and Colorado rivers. Watersheds as well as physicochemical conditions and biota change dramatically in stream channels along elevation gradients (Blinn and Poff 2005). Yet few invertebrates have been cataloged along these drainages.

Previous reports on caddisfly distribution in Arizona have been largely restricted to localized areas, including Oak Creek in north central Arizona (May 1972, Parrott 1975, Scott 1982, Dehoney and Gaud 1983, Moulton et al. 1994, Blinn and Ruiter 2009) and the White Mountains in eastern Arizona (Houghton 2001). Spindler (1996) correlated caddisfly genera in the Little Colorado, Verde, and Gila rivers with ecoregions. Finally, Blinn and Ruiter (2006) compared 104 caddisfly species to channel conditions at 93 sites in 49 streams throughout Arizona, but species composition was not reported at each site.

Blinn and Ruiter (2006) reported low channel embeddedness ($\leq 5\%$) at sites on the LCR

above 2200 m and high channel embeddedness ($\geq 70\%$) for rivers below 2200 m due to heavy agriculture and grazing on the watersheds (Table 1). Watersheds above 2200 m were typically forested, while those below 2200 m were mostly semiarid grassland and desert. Riparian vegetation changed from willow-alder in the upper sites to cottonwood-sycamore at moderate elevations to mesquite and the invasive saltcedar at lower elevations (Blinn and Poff 2005).

In this study, we collected caddisfly species at sites along the Little Colorado, Verde, Gila, and Colorado rivers in Arizona and compared species assemblages with elevation, watershed, and stream-channel conditions. The information in this report provides a baseline for monitoring changes in ecosystem health during the predicted long-term drought and population expansion in southwestern USA (Seager et al. 2007).

STUDY SITES

Thirty-three sites were grouped into 3 elevation ranges based on watershed. Watersheds >2200 m were primarily forested; those

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TABLE 1. Stream site locations, percent channel embeddedness (% EMBED), percent canopy cover, and elevation (m) along the Little Colorado, Verde, Gila, and Colorado rivers, Arizona. Information was taken from Blinn and Ruitter (2006) except for Access Rd LCR, Winslow LCR, Cameron LCR, Gila River Grapevine, and several Colorado River sites (K1, K84, K140, K198, BP, and PD).

No.	Site	Location	% EMBED	% Canopy	Elevation (m)
Little Colorado River					
1	Upper East Fork (EF)	109°29'W, 33°56'N	10	10	2797
2	Sheeps Crossing West Fork (SC)	109°27'W, 33°58'N	5	90	2757
3	Greer East Fork (GE)	109°27'W, 33°60'N	5	90	2600
4	Greer West Fork (GW)	109°28'W, 33°60'N	5	90	2541
5	Greer (GR)	109°27'W, 34°00'N	10	75	2539
6	South Fork (SF)	109°25'W, 34°05'N	30	70	2290
7	Eagar LCR (EA)	109°19'W, 34°07'N	85	10	2114
8	Springerville LCR (SP)	109°18'W, 34°09'N	95	10	2042
9	Access Rd LCR (TE)	109°21'W, 34°17'N	90	10	1850
10	Holbrook (HO)	110°40'W, 34°85'N	100	0	1524
11	Winslow LCR (WI)	110°42'W, 35°15'N	100	0	1500
12	Cameron LCR (CA)	111°34'W, 35°55'N	100	0	1212
13	Grand Canyon confluence (GC)	111°47'W, 36°14'N	90	20	830
Verde River					
14	Upper Verde River Paulden (UP)	112°26'W, 39°52'N	35	75	1275
15	Tuzigoot Bridge Verde River (TB)	111°51'W, 34°33'N	85	10	1010
16	Camp Verde (CV)	111°51'W, 34°33'N	90	20	959
Gila River					
17	Gila River Grapevine, NM (GV)	108°12'W, 33°11'N	45	60	1707
18	Gila River Duncan (DU)	109°06'W, 32°44'N	85	20	1118
19	Gila River Yuma (YU)	109°25'W, 32°46'N	95	5	45
Colorado River					
20	River kilometer 0 (K1)	111°36'W, 36°52'N	95	5	947
21	River kilometer 15 (K15)	111°39'W, 36°46'N	95	5	930
22	River kilometer 50 (K50)	111°46'W, 36°41'N	95	5	871
23	River kilometer 62 (K62)	111°50'W, 36°29'N	95	5	850
24	River kilometer 84 (K84)	111°53'W, 36°17'N	95	5	835
25	River kilometer 140 (K140)	112°06'W, 36°06'N	95	5	734
26	River kilometer 198 (K198)	112°16'W, 36°07'N	95	5	629
27	River kilometer 290 (K290)	113°06'W, 36°12'N	95	5	535
28	River kilometer 309 (K309)	113°20'W, 36°04'N	95	5	475
29	River kilometer 346 (K346)	113°10'W, 35°53'N	95	5	412
30	River kilometer 402 (K402)	113°40'W, 35°51'N	95	5	400
31	Bullhead, AZ Park (BP)	114°35'W, 35°07'N	95	5	230
32	Lake Havasu Marina (LH)	114°21'W, 34°29'N	95	5	224
33	3.5 km below Parker Dam (PD)	114°11'W, 34°15'N	95	5	129

between 2200 and 1000 m were agricultural (i.e., ranching areas), and those <1000 m were desert (Fig. 1). Feeder systems of the LCR originate at about 3400 m in the White Mountains of eastern Arizona and join the Colorado River some 650 km downstream in the Colorado Plateau shrublands at an elevation of 830 m (Ricketts et al. 1999). The Gila River originates in the Black Range on the western slope of the Continental Divide in New Mexico at 3100 m, crosses into Arizona at 1325 m, and travels through the Chihuahuan and Sonoran deserts for nearly 1050 km to join the Colorado River at an elevation of about 40 m. Midsections of the LCR and Gila rivers are intermittent due to irrigation and regulation

by dams, respectively (Blinn and Poff 2005). The Verde River originates in the Arizona mountain forests in western Arizona at an elevation of 1325 m and joins the Gila River near Phoenix, Arizona, at 340 m on the northern edge of the Sonoran Desert. Finally, the Colorado River in Arizona begins near the Utah–Arizona border at 947 m and has highly regulated flows from 5 mainstem dams as it meanders for over 900 km through the Mohave and Sonoran deserts before emptying into the Gulf of California at >50 m elevation (Blinn and Poff 2005). Collection sites along the LCR ranged from 830 m to 2797 m, while sites in the other 3 rivers were all <2200 m (Table 1).

Fig. 1. Map of 33 collection sites for caddisflies at 3 elevation ranges along the Little Colorado, Verde, Gila, and Colorado rivers in Arizona during 2000–2004.

METHODS

Caddisfly larvae and pupae were hand-picked from submerged vegetation, rocks, and woody debris for approximately 30 minutes during each site visit. Adult caddisflies were collected with a vertical, 30-cm, 8-watt, portable, ultraviolet light over a 19-L white plastic bucket between early May and early September in the years 2000 to 2004. Light traps were placed near the stream site 1 hour after sunset and retrieved after 3–4 hours. All

collections were placed in 70% ethanol and sorted in the laboratory. Species abundance was determined as the percentage of captured adults within an elevation range and ranked as rare (<2%), common (2%–20%), or abundant (>20%; Table 2). A diversity index (H') was calculated for caddisfly assemblages at each site (Shannon and Weaver 1949). A Sørensen similarity index (SI; Sørensen 1948) was used to compare paired caddisfly assemblages among the 4 river systems. Specimens are in the collections of D.E. Ruiter.

RESULTS

Seventy-two caddisfly species in 36 genera and 15 families were represented in the 3010 specimens collected in the 4 river systems (Table 2). Fifty-five species were collected in the LCR, 17 in the Verde River, 15 in the Colorado River, and 13 in the Gila River.

Distinct assemblages were found at each elevation range. Caddisfly assemblages above 2200 m included 48 species in 31 genera and 15 families (Table 2). These sites were located only in the upper LCR (Fig. 1, Table 2). Brachycentrids, hydropsychids, limnephilids, and uenoids made up nearly 50% of the caddisfly assemblage. Limnephilids were most diverse but never abundant at any site. Dominant species included *Brachycentrus americanus*, *B. occidentalis*, *Ceratopsyche oslari*, *C. venada*, *Gumaga griseola*, *Hydroptila arctica*, *Ithytrichia mexicana*, *Lepidostoma unicolor*, *Oligophlebodes minutus*, *Polycentropus arizonensis*, and *P. gertschi*.

Twenty-eight species in 17 genera and 8 families were collected at sites between 2200 and 1000 m (Table 2). These sites were located on the lower Little Colorado and upper Gila and Verde rivers (Fig. 1, Table 2). Hydropsychids, hydroptilids, and leptocerids made up

75% of the caddisfly assemblage at this elevation range. Dominant species included *Cheumatopsyche enonis*, *Hydropsyche auricolor*, *Hydropsyche occidentalis*, *Hydroptila arctica*, *Smicridea dispar*, and *S. signata*.

Sites within desert watersheds below 1000 m included 25 species in 16 genera and 7 families. These sites were located on the lower Gila and Verde rivers and the Colorado River (Fig. 2, Table 2). Hydropsychids, hydroptilids, and leptocerids made up 80% of the caddisfly assemblage with *Hydroptila ajax*, *H. arctica*, *Ochrotrichia logana*, *Oxyethira arizona*, and *Smicridea fasciatella* being the dominant species.

Species richness averaged 16 ($s_{\bar{x}} = 1.5$, $n = 6$) at sites above 2200 m, 7 ($s_{\bar{x}} = 1.4$, $n = 10$) between 2200 and 1000 m, and 3 ($s_{\bar{x}} = 0.6$, $n = 17$) below 1000 m. H' diversity also declined with decreasing elevation. Values were >3.0 at sites above 2200 m, from 2.5 to 0.2 between 2200 and 1000 m, and from 1.0 to 0.5 below 1000 m.

Caddisfly assemblages were different in each of the 4 river systems. Sørensen similarity index (SI) values ranged from 0.28 to 0.03 for paired-river comparisons. Less than 35% of the species in the Colorado, Gila, and Verde rivers were found in the LCR system, and $<33\%$ of the species were common in the Verde

TABLE 2. Location (LOCA), emergence period (EMER), and abundance (ABUN) of caddisfly species along elevational ranges in the Little Colorado, Verde, Gila, and Colorado rivers, Arizona, during 2000–2004. Species without emergence data were collected as larvae or pupae. R = rare ($<2\%$); C = common (2–20%); A = abundant ($>20\%$). GPS locations and acronyms are provided in Table 1. Grapevine (GV) collections were made by O.S. Flint. Sites along the Verde, Gila and Colorado rivers were typically visited once, while sites on the Little Colorado River were visited multiple times.

	Little Colorado River			Verde River	Gila River	Colorado River
Species	LOCA	EMER	ABUN			
>2200 m elevation				No Data		
APATANIIDAE						
<i>Apatania arizona</i>	SC, GW					
BRACHYCENTRIDAE						
<i>Brachycentrus americanus</i>	GE, SC, GW, GR	2 Jul–30 Aug	C			
<i>B. occidentalis</i>	EF, SC, GW, GR	25 Jul–30 Aug	C			
<i>Micrasema</i> sp.	GE, SF		R			
GLOSSOSOMATIDAE						
<i>Agapetus boulderensis</i>	GW, GR, SF	23 Jul	R			
<i>Culoptila moselyi</i>	GE, GR SF	5 May–22 Jun	R			
<i>Glossosoma ventrale</i>	GW		R			
HELICOPSYCHIDAE						
<i>Helicopsyche borealis</i>	GE, GR, SF	21 Jun–3 Jul	R			
<i>H. mexicana</i>	SF		R			

TABLE 2. CONTINUED.

	Little Colorado River					
Species	LOCA	EMER	ABUN	Verde River	Gila River	Colorado River
>2200 m elevation				No Data		
HYDROBIOSIDAE						
<i>Atopsyche sperryi</i>	GE, SC, GR , SF	4 Jul–14 Aug	R			
<i>A. tripunctata</i>	GW					
HYDROPSYCHIDAE						
<i>Ceratopsyche cockerelli</i>	SF	19 Jun	R			
<i>C. oslari</i>	GE, SC, GW, SF	5 May–21 Jul	A			
<i>C. venada</i>	GE, SC, GW, GR, SF	8 Jun–26 Jul	C			
<i>Cheumatopsyche arizonensis</i>	SF	19 Jun	A			
<i>C. gelita</i>	SF	19 Jun	A			
<i>Hydropsyche</i> sp.	EF, GE, GW, GR					
<i>H. occidentalis</i>	SF	8 Jun–21 Jul	A			
HYDROPTILIDAE						
<i>Hydroptila arctia</i>	GE, GW, GR, SF	5 May–4 Jul	C			
<i>H. hamata</i>	SC	2 Jul	R			
<i>Ithytrichia mexicana</i>	GE, SF	9 Jun–4 Jul	C			
<i>Neotrichia</i> sp.	GE	1 Jul	R			
<i>Ochrotrichia dactylophora</i>	SF	8–21 Jun	R			
<i>O. lometa</i>	GE, SF	19 Jun–4 Jul	R			
<i>O. stylata</i>	SF	19 Jun	R			
LEPIDOSTOMATIDAE						
<i>Lepidostoma unicolor</i>	EF, SC, GE	2 Jul–26 Aug	C			
LEPTOCERIDAE						
<i>Ocetis disjuncta</i>	EF, GE, GR, SF	8 Jun–4 Jul	R			
<i>Ylodes reuteri</i>	SF	19 Jun	R			
LIMNEPHILIDAE						
<i>Amphicosmoecus canax</i>	SC, GR	8 Oct	R			
<i>Anabolia bimaculata</i>	SC, GR	19 Jun–6 Oct	R			
<i>Clistoronia maculata</i>	EF, GW	19 Jun–1 Jul	R			
<i>Crenophylax sperryi</i>	SC	20 Jun–2 Jul	R			
<i>Hesperophylax magnus</i>	GE, SC, GR	5 May–14 Aug	R			
<i>H. occidentalis</i>	GE, SC, GR	5 May–14 Aug	R			
<i>Limnephilus diversus</i>	GR	26 Jul	R			
<i>L. granti</i>	GW	8 Jun	R			
<i>L. lithus</i>	GR	3 Jul	R			
<i>Onocosmoecus unicolor</i>	SC	30 Aug	R			
<i>Psychoglypha schuhi</i>	SC, GR	1 Jul	R			
<i>P. subborealis</i>	SC	6 Oct	R			
PHILOPOTAMIDAE						
<i>Chimarra</i> sp.	GE		R			
<i>C. utahensis</i>	SF	21 Jul	R			
POLYCENTROPODIDAE						
<i>Polycentropus arizonensis</i>	GE, GR, SF	5 May–25 Jul	C		No Data	
<i>P. gertschi</i>	GE, GR, SF	4 Jul–1Sept	C			
RHYACOPHILIDAE						
<i>Rhyacophila angelita</i>	SC	30 Aug	R			
<i>R. coloradensis</i>	GW, SF	1–4 Sept	R			
SERICOSTOMATIDAE						
<i>Gumaga griseola</i>	EF, GE	1–4 Jul	C			
<i>G. nigricula</i>	EF		R			
UENOIDAE						
<i>Oligophlebodes minutus</i>	EF, GE, SC, GW, GR	5 May–20 Jun	C			
<i>O. sigma</i>	SC, GW		R			
2200–1000 m elevation						
APATANIIDAE						
<i>A. arizona</i>	HO	26 Jun	R			

Table 2. Continued.

Species	Little Colorado River			Verde River			Gila River		
	LOCA	EMER	ABUN	LOCA	EMER	ABUN	LOCA	EMER	ABUN
2200–1000 m elevation									No Data
GLOSSOMATIDAE									
<i>Protophila erotica</i>				TB	30 Jun	C			
HELICOPSCHIDAE				UP	30 Jun	R			
<i>H. borealis</i>									
HYDROPSCHIDAE									
<i>C. arizonensis</i>	EA	22 Jun–1 Jul	C	TB	30 Jun	R	GV, DU	26 Jul, 19 Apr	C
<i>Cheumatopsyche enonis</i>	EA, SP	8 Jun–1 Jul	C						
<i>C. gelita</i>	EA	22 Jun	R						
<i>Cheumatopsyche pinula</i>				TB	30 Jun	A	GV	26 Jul	R
<i>Hydropsyche</i> sp.	WI, CA		R	UP					
<i>H. auricolor</i>				TB, UP	30 Jun, 24 Aug	A	GV, DU	19 Apr, 26 Jul	C
<i>H. occidentalis</i>	EA, SP	8 Jun	A	TB	30 Jun	R	GV	26 Jul	R
<i>Smicridea dispar</i>				TB	30 Jun	C	DU	19 Apr	C
<i>S. signata</i>				TB	30 Jun	A	GV, DU	19 Apr, 26 Jul	C
HYDROPTILIDAE									
<i>Hydroptila ajax</i>				TB, UP	30 Jun, 24 Aug	R			
<i>H. arcia</i>	EA, TE	8 Jun–1 Jul	C						
<i>H. hamata</i>	TE	21 Jun	R	TB	30 Jun	R			
<i>Magatrichia acuna</i>	TE	21 Jun	R						
<i>Neotrichia</i> sp.	EA	1 Jul		UP	24 Aug	R			
<i>Ochrotrichia</i> sp.									
<i>O. dactylophora</i>	EA	8 Jun–1 Jul	R						
<i>O. stylata</i>	EA, TE	21 Jun	R	TB	30 Jun	R			
<i>O. tarsalis</i>	TE	21 Jun	R	UP					
<i>Oxyethira</i> sp.	EA	1 Jul	R	UP	24 Aug	R			
<i>O. dualis</i>				UP	24 Aug	A			
<i>O. pallida</i>							GV	26 Jul	R
<i>Zamotrichia notosa</i>									
LEPTOCERIDAE									
<i>Nectopsyche</i> sp.	TE	21 Jun	R						
<i>N. intervena</i>									
<i>Oecetis avara</i>	TE	21 Jun	R				GV	26 Jul	R
<i>O. disjuncta</i>	TE	21 Jun	R				GV, DU	26 Jul, 19 Apr	R
<i>Y. reuteri</i>	EA	1 Jul	R				GV	26 Jul	R
LYNCEPHILIDAE									
<i>L. lithus</i>	EA, SP	9 Jun–1 Jul	R						
SERICOSTOMATIDAE									
<i>Gumaga griseola</i>							GV	26 Jul	R

Table 2. Continued.

Species	Little Colorado River			Verde River			Gila River			Colorado River		
	LOCA	EMER	ABUN	LOCA	EMER	ABUN	LOCA	EMER	ABUN	LOCA	EMER	ABUN
<1000 m elevation												
GLOSSOSOMATIDAE												
<i>Caloptilia cantha</i>												
<i>P. erotica</i>				CV	17 Jul	R				PD	2 Aug	R
HELICOPSYCHIDAE												
<i>H. borealis</i>				CV	17 Jul	R						
HYDROPSYCHIDAE												
<i>Ceratopsyche oslari</i>	GC	11 Sep	R							K1, K15, K50, K140, K309	7 Apr–11 Jul	R
<i>C. arizonensis</i>												
<i>C. pinula</i>				CV	17 Jul	R						
<i>Hydropsyche</i> sp.				CV	17 Jul	R						
<i>Smicridea fasciatella</i>												
<i>S. signata</i>	GC			CV	17 Jul	A		YU	9 May	R	8 Aug	A
HYDROPTILIDAE												
<i>Hydroptila</i> sp.				CV	17 Jul	A				BP	5 Apr	R
<i>H. ajax</i>												
<i>H. arcita</i>	GC	11 Sep	R	CV	17 Jul					K84, K140, K290, K309, K346, K402	11 Jun–30 Jul	C
<i>Hydroptila icona</i>								YU	9 May	A		
<i>M. ayana</i>				CV	17 Jul	R						
<i>Neotrichia</i> sp.				CV	17 Jul	R				LH	12 Jul	R
<i>N. olorina</i>										PD	8 Aug	R
<i>O. dactylophora</i>										K290	16 Jun	R
<i>Ochrotrichia logana</i>										K84, K290, K309	16 Jun–23 Jul	C
<i>O. lometa</i>												
<i>O. stylata</i>	GC	11 Sep	A							K290	16 Jun	A
<i>O. tarsalis</i>				CV	17 Jul	R						
<i>Oxyethira</i> sp.												
<i>O. arizona</i>										K84		
LEPTOCERIDAE										LH, PD	12 Jul–8 Aug	A
<i>Nectopsyche dorsalis</i>												
<i>Oecetis inconspicua</i>										PD	8 Aug	R
PHILOPOTAMIDAE								YU	9 May	R	8 Aug	R
<i>Chimarra ridleyi</i>												
<i>C. utahensis</i>										K290	15 May	R
POLYCENTROPIDAE										K140, K309	11 Jun–4 Jul	R
<i>Polycentropus halidus</i>										K198, K346	8 May–30 Aug	R

and Gila rivers at comparable elevations. SI values were especially low (≤ 0.14) between the Colorado River and the other 3 rivers.

DISCUSSION

Caddisfly assemblages in channels changed dramatically along elevation gradients and land-use variations in the Colorado, Gila, Little Colorado, and Verde rivers in Arizona. Seventy-two species were collected along these changing watersheds, including over half of the species currently reported from the state. Nine additional species have been reported in these 4 drainages. These include *Hydroptila rono* and *Ochrotrichia ildria* in the south fork and *Lepidostoma ormeum* in the west fork of the LCR reported by Houghton (2001), *Limnephilus abbreviatus* and *Limnephilus spinatus* in the LCR drainage reported by Ruiter (1996), and *Hydroptila icona*, *Oecetis avara*, *Polycentropus arizonensis*, and *Smicridea arizonensis* in the Verde River reported by Moulton et al. (1994).

Caddisfly assemblages at elevations >2200 m were most diverse with 70% of the species collected at these sites. There was also a decrease in H' diversity from >3 at sites >2200 m to 0.5 at elevations <1000 m. Wilhm (1970) suggested macroinvertebrate assemblages with $H' > 3$ were associated with unpolluted waters while those with $H' < 0.5$ were in polluted or disturbed waters.

Species of *Agapetus*, *Amphicosmoecus*, *Anabolia*, *Atopsyche*, *Clistorina*, *Crenophyllax*, *Hesperophyllax*, *Lepidostoma*, *Micrasema*, *Oligophlebodes*, *Onocosmoecus*, *Psychoglypha*, and *Rhyacophila* were not collected below 2200 m, and *Mayatrichia*, *Nectopsyche*, *Oxyethira*, *Protophila*, *Smicridea*, and *Zumatrichia* were not collected above 2200 m. However, Blinn and Ruiter (2009) recently reported *Hesperophyllax magnus*, *Lepidostoma aporna* and *Lepidostoma knulli* below 2200 m in upper Oak Creek, Arizona.

Changes from mesic to semiarid conditions along elevation gradients likely played a role in the dramatic decrease in species richness, but intense agriculture, ranching, and river regulation were mainly responsible for these declines (Blinn and Poff 2005). Blinn and Ruiter (2006) reported that channel embeddedness averaged 10% ($s_{\bar{x}} = 4.6$, $n = 22$) at >2200 m, 37.8% ($s_{\bar{x}} = 4.1$, $n = 49$) at elevations

between 2200 and 1000 m, and 82.7% ($s_{\bar{x}} = 4.5$, $n = 22$) at elevations <1000 m. The limited sample frequency at lower-elevation sites, in part due to ephemeral conditions, likely reduced the overall number of species collected. Additional sampling is recommended for this region.

Channels below 1000 m were highly regulated, especially those in the Colorado and Gila rivers (Blinn and Poff 2005). Species richness at these sites was 5-times lower than it was at sites in unregulated channels >2200 m. Water diversions along the lower LCR at elevations between 2200 and 1000 m likely caused similar reductions in species richness. Only 1 caddisfly species was collected at each site with intermittent flows along the lower LCR. However, sites in the lowest 21 km of the LCR, near the Grand Canyon confluence, are fed by waters from Blue Springs (Blinn and Poff 2005). These waters have high specific conductance (>3 mS) but still provide habitat for *Helicopsyche borealis*, *Hydropsyche* sp., *H. arctia*, and *Ochrotrichia lometa*.

Table 3 provides a list of indicator caddisfly species in altered (highly disturbed) and less disturbed stream channels at high and low elevations in Arizona. The list is based on information from Blinn and Ruiter (2006) and from this study and includes a combined total of 104 stream sites throughout Arizona. High channel embeddedness was used as the criterion for disturbed sites; it is caused by altered landscapes and reduced canopy and often-times occurs concomitantly with high nutrients (Laws 2000). Species in less disturbed channels at high and mid-elevations were distinctly different with only *Atopsyche sperryi* and *H. magnus* common in the 2 upper-elevation ranges. No species were provided in the less disturbed category <1000 m due to excessive agriculture, channelization, invasion of exotic riparian vegetation, water diversion, and regulation (Blinn and Poff 2005).

Hydroptila arctia was the only species common in highly disturbed sites at all 3 elevation ranges (Table 3), while *Cheumatopsyche arizonensis* and *Cheumatopsyche pinula* were in the 2 upper ranges. This observation suggests that these species have a wide tolerance for environmental disturbance. The caddisfly assemblage in the highly disturbed channels at sites <1000 m is mainly associated with the highly regulated Colorado River since only 2 other sites (Camp

TABLE 3. Caddisfly assemblages in Arizona rivers in less disturbed and highly disturbed channels at high (>2200 m), mid (1000–2200 m), and low (<1000 m) elevations. Channel embeddedness is <10% in less disturbed river channels and >30% in highly disturbed channels.

Disturbance level and elevation	Species
Less disturbed >2200 m	<i>Agapetus boulderensis</i> <i>Amphicosmoecus canax</i> <i>Anabolia bimaculata</i> <i>Atopsyche sperryi</i> <i>Brachycentrus americanus</i> <i>B. occidentalis</i> <i>Clistorina maculata</i> <i>Crenophylax sperryi</i> <i>Gumaga griseola</i> <i>Hesperophylax magnus</i> <i>H. occidentalis</i> <i>Oligophledodes minutus</i> <i>Polycentropus arizonica</i>
Less disturbed 1000–2200 m	<i>Atopsyche sperryi</i> <i>Gumaga griseola</i> <i>Hesperophylax magnus</i> <i>Hydropsyche occidentalis</i> <i>Lepidostoma knulli</i> <i>Polycentropus arizonica</i> <i>Timodes provo</i>
Highly disturbed >2200 m	<i>Cheumatopsyche arizonensis</i> <i>C. pinula</i> <i>Helicopsyche borealis</i> <i>Hydropsyche occidentalis</i> <i>Hydroptila arctia</i> <i>H. hamata</i> <i>Limnephilus lithus</i> <i>Ochrotrichia dactylophora</i> <i>Psychoglypha subborealis</i>
Highly disturbed 1000–2200 m	<i>C. arizonensis</i> <i>C. pinula</i> <i>Chimarra utahensis</i> <i>Hydroptila ajax</i> <i>H. arctia</i> <i>Marilia flexuosa</i> <i>Ochrotrichia stylata</i> <i>Polycentropus halidus</i> <i>Smicridea dispar</i>
Highly disturbed <1000 m	<i>H. arctia</i> <i>Hydroptila icona</i> <i>Ochrotrichia inconspicua</i> <i>O. logana</i> <i>Oxyethira arizona</i> <i>Neotrichia olorina</i> <i>Smicridea fasciatella</i>

Verde River and the Gila River near Yuma) were sampled at elevations <1000 m. *Ceratopsyche osleri* also occurred throughout the regulated Colorado River but at a low abundance.

A nonmetric multidimensional ordination of Arizona caddisflies by Blinn and Ruiter (2005) also showed species listed in the less disturbed category of Table 3 to be closely associated with dense riparian canopies, low water temperature, low specific conductance, and low channel embeddedness, while those in the highly disturbed category were closely associated with reduced canopies, high water temperature, high specific conductance, and high channel embeddedness. Generally, Barbour et al. (1999) reported similar regional tolerances for species listed in each category.

The indicator assemblages in Table 3 may be applicable in adjacent western semiarid regions. Ward et al. (2002) found similar species assemblages in major river basins in Colorado. Barbour et al. (1999) also reported similar tolerances to water quality for these species in other regions of the United States.

Recent collections in Arizona have yielded 7 additional species records for the state. These include *Neotrichia okopa* in the Salt River, *Phylloicus mexicanus* in the south fork of Cave Creek (Chiricahua Mountains), *Helicopsyche probolata* in the north fork of the White River, and *Hesperophylax consimilis* in Upper West Fork in the White Mountains—all part of the Gila River drainage. In addition, *Neotrichia olorina* was collected below Parker Dam in the Colorado River. Also, Ruiter (2007) described *Neotrichia blinni* and *N. sandyae* from the LCR and Gila River watersheds, respectively. These reports combined update the lists in Blinn and Ruiter (2005, 2006, 2009) to a total of 154 caddisfly species reported from Arizona.

We provide a baseline of indicator caddisfly species for monitoring changes in ecosystem health along major drainages in Arizona during the predicted long-term drought and population expansion in southwestern USA (Seager et al. 2007). Some areas were not sampled due to difficult access, including the “sky islands” in the southeastern part of the state. Aquatic habitats associated with these isolated sky islands are somewhat protected from anthropogenic activities and are clearly distinct from the surrounding desert and semi-desert grasslands (Ricketts et al. 1999). Therefore, investigations on these habitats as well as on those in ephemeral streams may provide further insight into caddisfly assemblages in southwestern USA.

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