FINE SEDIMENT DEPOSITION IMPACTS ON AQUATIC MACROINVERTEBRATES IN LOWER OAK CREEK, VERDE RIVER BASIN, CENTRAL ARIZONA: FINAL REPORT

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INTRODUCTION

The Oak Creek Watershed Council (OCWC), a 501c3 non-profit organization with a 25 year history of advocacy for sustainable scientific management of Oak Creek in the Middle Verde River drainage. OCWC has partnered with Dr. Larry Stevens of the Museum of Northern Arizona in Flagstaff to create a citizen science stream inventory and monitoring program. The key question that the project addresses is "What is the impact of anthropogenic fine sediment deposition on Oak Creek stream ecosystem health?" Community volunteers were given background about the relationship between stream habitat quality, aquatic invertebrate assemblage dynamics, and sampling design. Then the volunteers were trained in the use of sampling equipment and data compilation.

METHODS

Study Area

Oak Creek is a coolwater stream that occupies a 1204 km^2 basin area in Coconino and Yavapai Counties in north-central Arizona (Fig. 1). Oak Creek arises at the confluence of Sterling Spring and flows 50 km south on its course to the Verde River near Cottonwood, Arizona (Arizona Department of Environmental Quality 2010). Major perennial tributaries include Sterling Spring Creek, West Fork, Munds Canyon, Spring Creek, and other springfed tributaries, and intermittent Pumphouse Wash, Fry Canyon, and Dry Creek. Cumulatively, Oak Creek and its tributaries have a total of 1017 km of stream channel. The basin is largely owned and managed by Coconino and Prescott National Forest Service, but also has substantial private and urban lands. The drainage transitions from a steep, canyon-bound stream in the headwaters to a less geologically constrained channel in its lower reaches. Sedona is the second largest city in the Oak Creek basin, is located in the middle reaches of Oak Creek. Sedona had a population of approximately 11,220 in 2006. The Village of Oak Creek is located 15 km downstream from Sedona, and the City of Cottonwood lies at the confluence of Oak Creek and the Verde River. Ok Creek is renowned for its high diversity of aquatic life (Blinn and Ruiter 2009).

Oak Creek flow is monitored at two US Geological Survey streamflow gauging stations: Oak Creek near Sedona (09504420; since 1981) and Oak Creek near Cornville (09504500; since 1940). Additional gauge data are available from Munds Canyon Tributary near Sedona (09504400), Oak Creek at Sedona (09504430), and Oak Creek Tributary near Cornville (09504800). Gauge data show two periods of high flow: a springtime (February-April) snowmelt spate, and a summertime (July-September) period of monsoonal storms.

Two project areas were selected for sampling in the autumn 2017 first phase of the project between Soldiers and Carol Canyon Washes. The Crescent Moon/Red Rock Crossing USFS site is a US Forest Service recreational park that receives fine sediment inputs from Carol Canyon Wash and upstream development in Oak Creek. The second site at Disney Lane lies upstream

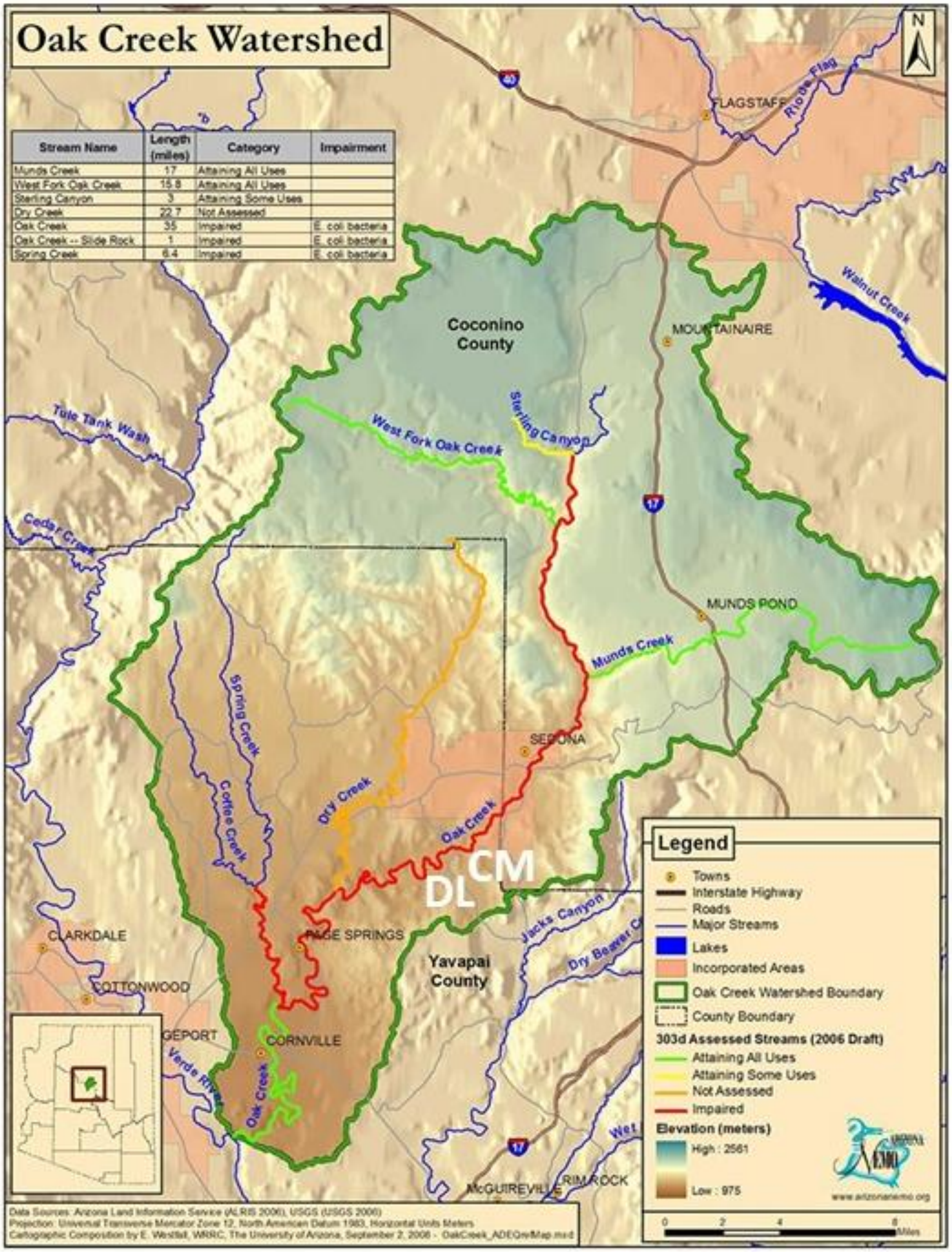

Fig 1: Map of Oak Creek drainage basin, showing sampling sites: CM – Crescent Moon Campground, DL – Disney Lane.

from the Crescent Moon Campground, upstream from the mouth of Carol Canyon Wash, and therefore potentially receiving less fine sediment input.

Field Methods and Analyses

We conducted quantitative benthic macroinvertebrates (BMI) using a team of 5-7 trained volunteers. We used a 0.31 m wide D-net and sampled pool, run, and riffle habitats at two locations (Crescent Moon Campground and Disney Lane) on two dates (November 2017 and April-May 2018). The 1 to 4 individual sampling sites in each habitat were selected randomly. Sampling was accomplished by vigorously disturbing 0.093 m^2 of streambed immediately upstream from the net for one minute, using a scrub brush. All invertebrates were transferred into a white sorting pan, and were identified to taxonomic order and enumerated in the field. Taxonomy follows Merritt et al. (2008). Voucher specimens were collected of all organisms captured and those samples area stored in the Museum of Northern Arizona invertebrate collections in Flagstaff. Field processing of individual samples required about 0.5 hr each.

An array of physical variables were measured at each site and in each habitat. Fine sediment cover was measured using a Thirsty-Mate™ Model No. 124PF hand-operated bilge pump. All fine sediment in a randomly located 0.001 m^2 sample area in the benthic sampling footprint was collected immediately prior to benthic sampling. Sediment samples were stored in individual Nalgene sample bottles and returned to the laboratory for volumetric analysis.

Field water quality variables were measured in each habitat using a YSI™ water quality probe, including water temperature, pH, and electrical conductance. In addition, alkalinity was measured using a Hach Alkalinity kit, and and dissolved oxygen concentration was measured using a ChemMets DO kit. Velocity at each sampling point was measured using timed distance on floating material.

RESULTS

Physical Conditions

The two sampling areas were generally similar in shoreline cover, both having extensive deciduous gallery riparian forest cover, dominated by *Alnus* alder, *Platanus* sycamore, *Populus fremontii* cottonwood, and mixed *Salix* willows, and understory *Carex emoryi*, non-native grasses, and various herbs and riparian shrubs. However, the Disney Lane site contained a dense stand of *Myriophyllum* water weed, which we sampled in May 2018. Current velocity within habitat types was slightly lower at Crescent Moon Campground, but water clarity was high at both sites. Average percent cover of the various channel floor substrata was strongly dominated by fine silt, sand and organic particulates in low velocity settings at both sites (Table 1; Appendix); however, the Crescent Moon Campground pool had bedrock underlying the pool and run habitats, on which fine sediment had acumulated, whereas the Disney Lane site had no bedrock exposed (Fig. 2).

Water Quality

Water quality varied only slightly among habitats and between sampling sites and dates. Water temperature varied little between sites and dates, or among habitats during sampling

Table 1: Summary of Oak Creek Watershed Council Citizen Science inventory of water quality and benthic macroinvertebrates at Crescent Moon Campground and Disney Lane 2017-2018.

Site	**Disney Lane**							**Crescent Moon**					
Date	**11/18/2017**			**5/13/2018**				**11/11/2017**			**4/29/2018**		
Habitat Type	Riffle	Run	Pool	Riffle	Run	Pool	*Myrio-phyllum*	Riffle	Run	Pool	Riffle	Run	Pool
Depth (cm)	27.3	31.7	70.8	25	50.0	95	22	6.7	40.6	67.7	28.3	55.0	60.0
Mean Velocity (m/sec)	0.7	0.2	0.3	13.0		0.00	0.00	High	0.1	0.1	0.5	0.3	0.1
Substrata - %Silt-Sand	0	68	100	0	50	55	100	0	0	75	0	0	100
% Fine Gravel	13	16	0	10	20	10	0	10	5	12.5	3	10	0
% Cobble	87	16	0	30	15	10	0	30	10	12.5	10	73	0
% Boulder	0	0	0	60	15	25	0	60	85	0	63	17	0
% Bedrock	0	0	0	0	0	0	0	0	0	0	23	0	0
Fine sediment Depth (mm)	1.5	12.8	63.3	1.0	5.2	21.0	21.0	3.7	28.0	12.7	0.6	0.8	34.1
$\log_{10}$(fine sed) (L/m^2)	0.22	1.15	1.84	0.04	0.76	1.36	1.36	0.61	1.49	1.14	-0.19	-0.04	1.58
Water Temp °C	9.9	10.5	10.6	16.7				11.1	12.0	11.7	16.4	16.4	16.5
pH	8.2	8.2	7.9	7.5	7.5	6.75	6.75	8.4	8.4	8.1	8.5	8.4	8.6
[DO] mg/L	10.2	9.9	9.8	---	---	---	---	9.6	9.4	9.4	---	---	---
Actual Cond (µS/cm)	228.2	221.8	225.4	400.5	400.5	400.5	400.5	241.5	243.3	240.4	352.7	352.7	351.8
Salinity (psu)	200	200	200	145	---	---	---	200	200	200	147	146	147
Turbidity (nphm units)	---	---	---	1.15	---	---	---	---	---	---	---	---	---
Water Clarity	high	high	low-med	high	high	high	high	high	high	high	High	High	High
Total Alkalinity (mg/L)	---	---	---	---	---	---	---	160.0	154.0	164.0	156	160.0	168
Mean Abundance/sample	73.3	42.3	33.0	261.0	100.0	37.0	216.0	45.0	48.0	53.0	64.3	19.5	24.0
Mean Species Richness	11.7	6.3	6.0	13.0	12.0	10.0	14.0	8.3	9.0	8.7	8.0	7.7	3.7
No. samples	4	3	4	1	1	1	1	2	3	3	3	3	3

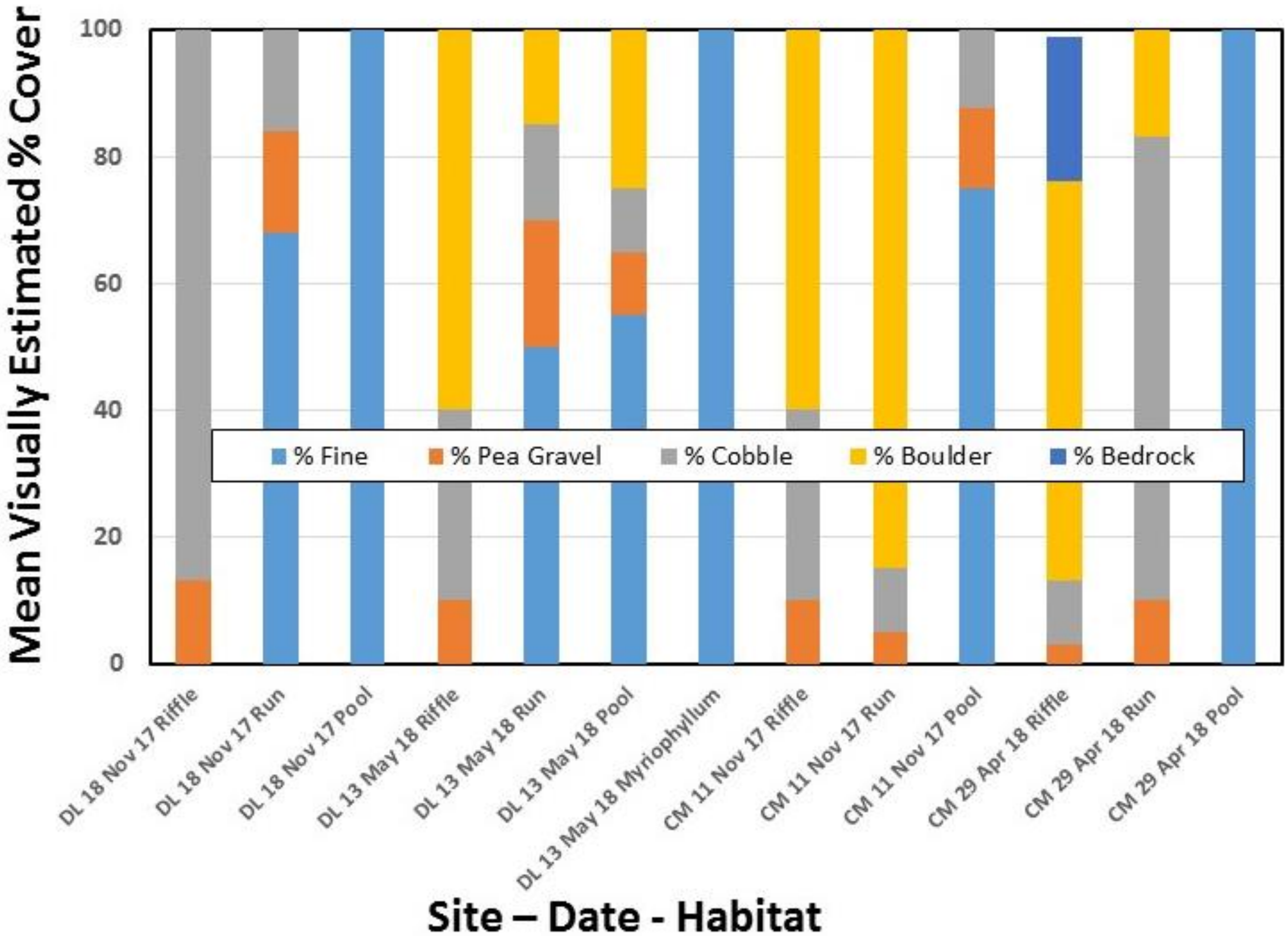

Fig. 2: Distribution of grain sizes on the channel floor at the CM (Crescent Moon Campground) and DL (Disney Lane) and sites in Oak Creek, sampled in November 2017.

bouts, ranging from 9.9 To 12.4°C in November 2017 and 16.4-16.7°C in April-May 2018 (Table 1). Water pH varied from 7.87 to 8.38 in November 2017 and more widely (6.75-8.6) in April-May 2018, often lower values in pool habitats, likely due to decomposition of organic matter there. Percent saturation of dissolved oxygen was uniformly high (nearly 100%) and dissolved oxygen concentration was likewise high (9.36-10.17 mg/L), again with slightly relatively lower values in pool habitats where microbial decomposition likely was occurring at a faster rate in the slower moving water. Specific conductance varied from 221.8 to 243.3 µS/cm in November 2017 and increased to 352.7-400.5 µS/cm in April-May after a winter of low flows. Total alkalinity was only measured at Crescent Moon, but also varied little, from 154 to 168 mg/L.

Macroinvertebrates

Benthic macroinvertebrate composition included a wide array of species density and species richness varied but broadly overlapped in relation to site and habitat relationships. In general the riffle sites had greater abundance and species richness (Figs. 3, 4); however, the small sample size resulted in only statistically non-significant differences. More sampling likely would increase the resolution of differences indicated in the present data.

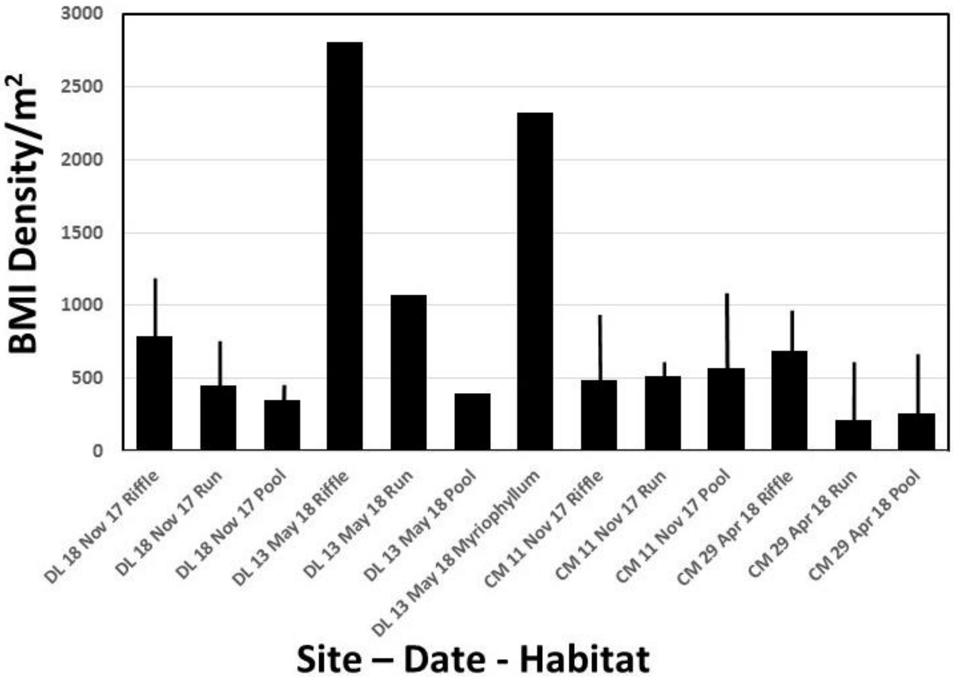

Fig. 3: Benthic macroinvertebrate density/m^2 among habitats at the CM (Crescent Moon Campground) and DL (Disney Lane) study sites in November 2017 and Apr-May 2018. Error bars are 95% confidence intervals.

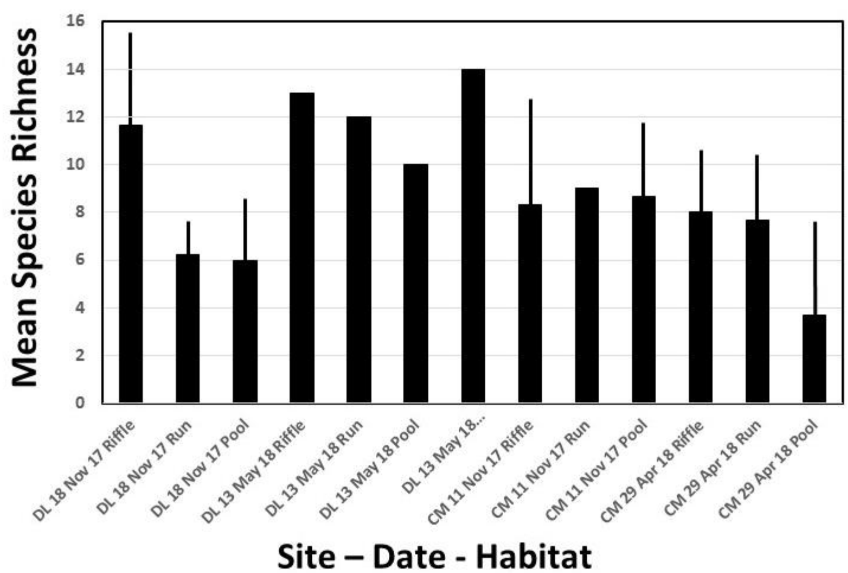

Fig. 4: Mean benthic macroinvertebrate species richness/sample among habitats at the CM (Crescent Moon Campground) and DL (Disney Lane) study sites in November 2017 and Apr-May 2018. Error bars are 95% confidence intervals. Error bars are 95% confidence intervals.

Both BMI density and species richness were negatively related to the volume of fine sediment detected in the benthic sampling (Figs. 5, 6). Again, the small sample size generated noisy relationships and low coefficient of correlation values ($R2 < 0.18$ and 0.26, respectively), and additional sampling is needed to clarify these patterns. Extensive fine sediment deposition at both study sites prevented detection of BMI assemblage differences between sites.

CONCLUSIONS

The results of this preliminary examination of fine sediment impacts on benthic macroinvertebrates in the lower middle reaches of Oak Creek provide insight into existing conditions. Fine sediment deposition was ubiquitous in lentic and low-velocity segments, and was much less evident in riffle habitats. The benthic assemblages in low velocity settings was dominated by Hyallela scud, oligochaete worms, *Chironomus* blood worm midges, and other species that indicate impaired stream ecosystem health. Riffle habitats, which are relatively rare, function as refugia for many macroinvertebrate taxa that characterize healthier stream ecosystems. Additional sampling is needed to clarify the patterns suggested by this study, and a reconnaissance of riffle distribution and biota may warrant consideration for future work.

All of the citizen scientist participants expressed keen and enthusiastic interest in the scientific aspects of the study, as well as the implications for improved stewardship. Their assistance in this effort is laudable and worthy of encouragement for development of a more robust understanding of physical and biological conditions and changes in Oak Creek.

ACKNOWLEDGEMENTS

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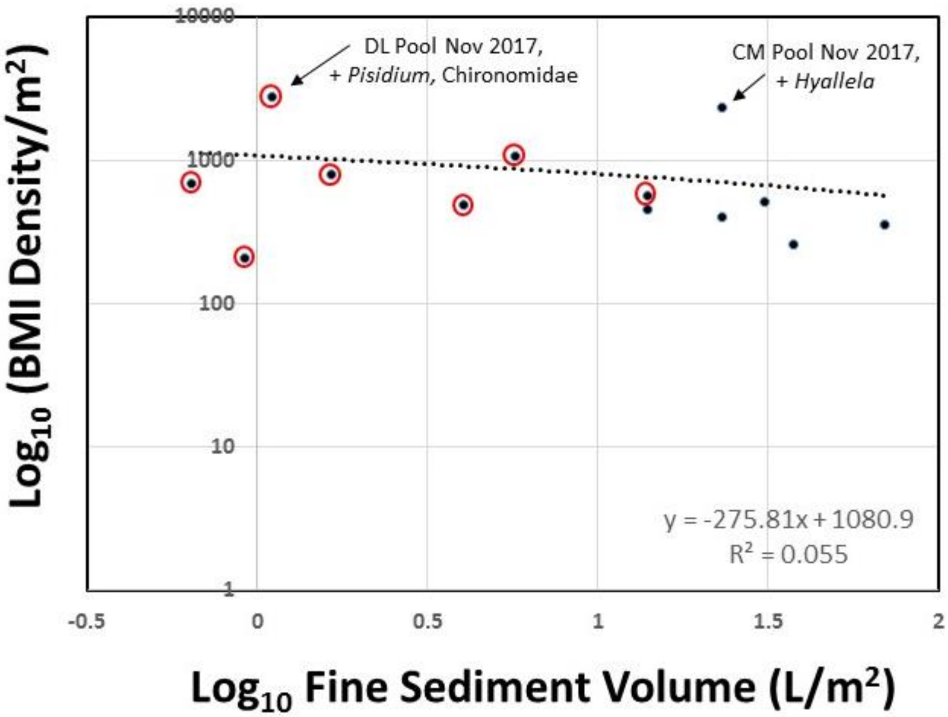

Fig. 5: Benthic macroinvertebrate density/m2 as a function of fine sediment volume at all Oak Creek habitat sampled at the Crescent Moon Campground and Disney Lane study sites in November 2017 and Apr-May 2018. Red circles indicate Disney Lane samples.

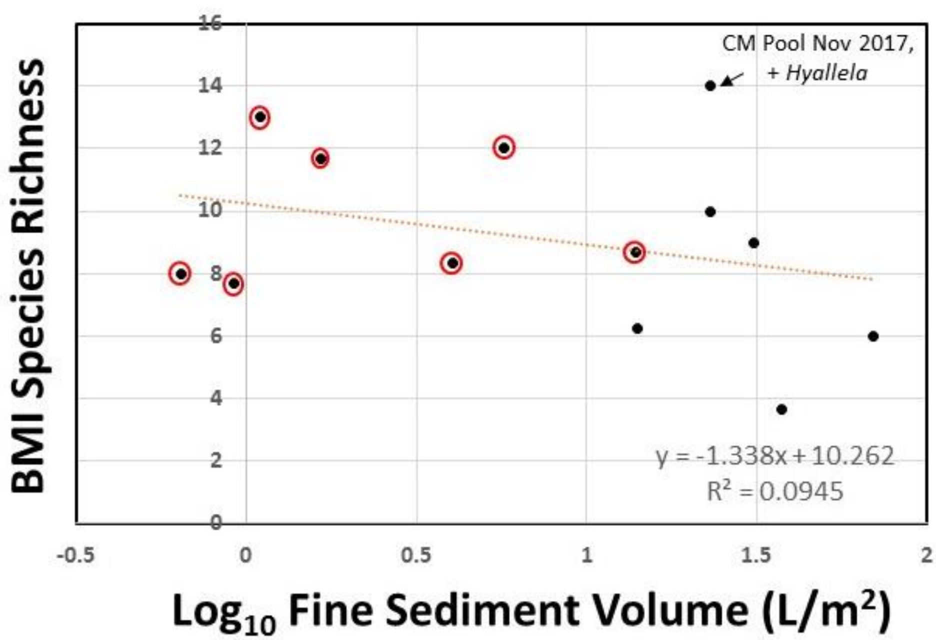

Fig. 6: Benthic macroinvertebrate species richness as a function of fine sediment volume at all Oak Creek habitat sampled at the Crescent Moon Campground and Disney Lane study sites in November 2017 and Apr-May 2018. Red circles indicate Disney Lane samples.

APPENDIX:

FIELD DATA
(Provided in electronic form in an Excel Workbook)