The effect of river drawdown on the macroinvertebrate community below Anderson Ranch Dam, South Fork Boise River, Idaho

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Introduction:

Macroinvertebrates are an important component of stream ecosystems. They promote decomposition of detritus (Wallace and Webster 1996); release nutrients during feeding, excretion, and burrowing (Covich et al. 1999); control the abundance and distribution of prey (Crowl and Covich 1994); and serve as a food source for fishes and other vertebrates (Covich et al. 1999). Macroinvertebrates are taxonomically diverse and they differ in their response to habitat conditions (Cummins and Lauff 1969). Thus, macroinvertebrates are useful predictors of water quality and they might also be useful indicators of hydrological conditions, including stream discharge patterns (Verdonschot and van den Hoorn 2010).

Stream discharge patterns have a major influence on the structure of stream ecosystems; including species diversity, community composition, channel morphology (habitat), and nutrient and energy dynamics (Jowett and Duncan 1990; Poff et al. 1997). Decreases in discharge usually cause decreased water velocity, water depth, and wetted channel width; increased sedimentation; and changes in thermal regime and water chemistry (as referenced in a comprehensive literature review by Dewson et al. 2007a). Bonada et al. (2006) reported that duration and frequency of stream drying play an important role in structuring the macroinvertebrate community. Macroinvertebrate communities in intermittent streams are known to differ from those found in permanent streams (Price et al. 2003).

Macroinvertebrate abundance is often higher near the edge of large rivers and thus these populations are particularly prone to desiccation during regulated reductions in discharge (hereafter referred to as *drawdown*) (Blinn et al. 1995). Kroger (1973) estimated a loss of approximately 3 billion macroinvertebrates (across many taxonomic groups) from a 3-km section of the Snake River below Jackson Lake following a 10-fold decrease in river flow. Downstream of Glen Canyon Dam, macroinvertebrate mass was reduced by 85% after one 12-hour summer exposure (Blinn et al. 1995). McKinney et al. (1999) also found reduced standing stocks of macroinvertebrates following drawdown of the Colorado River below Glen Canyon Dam. Slow currents resulting from low flows appeared to limit the diversity and abundance of swift-water aquatic insects below Wyman Dam, Maine (Trotzky and Gregory 1974).

The objective of this study is to examine the effect of river drawdown on the macroinvertebrate community of the South Fork Boise River, downstream of Anderson Ranch Dam, Idaho. Anderson Ranch Dam is managed to meet downstream irrigation and flood control needs and to provide for fish and wildlife (USFWS, 2005). The South Fork Boise River is considered a "blue ribbon" rainbow trout (*Oncorhynchus mykiss*) stream by the Idaho Department of Fish and Game. The South Fork Boise River below Anderson Ranch Dam typically experiences two major drawdown events during the summer months (mid-August reduction from approximately 1800 ft^3/s to 600 ft^3/s and a mid-September reduction from 600 ft^3/s to 300 ft^3/s). This study focused entirely on the mid-September 2012 drawdown which involved a ~50% reduction in flow over just a few hours on September 17th (a reduction of 100 ft^3/s at 9:00 a.m. and another reduction of 200 ft^3/s at 11:00 a.m.) (Fig.1).

Historically, most research on flow disturbance in streams has focused on floods, but climate change and the increasing human demand for water make understanding the impacts of low-flow disturbance critically important (Walters and Post 2011). Dewson et al. (2007a) indicate that the potential problems associated with low flows are well covered in the scientific literature, but that relatively few empirical studies have been undertaken to examine the effect of reduced flows on the ecology of perennial streams. This investigation is the first to document the impact of river drawdown on the macroinvertebrate community of the main-stem South Fork Boise River, a perennial river in southern Idaho. Furthermore, it is one of only a few contemporary studies (but see Blinn et al. 1995; McKinney et al. 1999) to examine the impact of river drawdown on macroinvertebrates in the western United States. More recently, investigators (Fury et al. 2006; McEwen and Butler 2010) have focused their attention on discerning the impacts of reservoir drawdown on associated reservoir biota.

Conclusions drawn from this investigation will serve as a baseline for future work to better understand the response of macroinvertebrates to river drawdown and if needed, help direct a sustainable management plan for South Fork Boise River flows. Verdenschot and van den Hoorn (2010) stress the need for more information on the relationship between flow and biota to ensure the development of proper guidelines for river management. Finally, this study provides a snapshot of the South Fork Boise River macroinvertebrate community prior to the Elk Complex fire which burned approximately 276,000 acres and led to five mudslides within the South Fork Boise River drainage during the summer of 2013 (Idaho Statesman, September 19, 2013).

Materials and Methods:

On September 11th 2012 (pre-drawdown) and September 18th 2012 (post-drawdown), I surveyed macroinvertebrates from two sites (Site 1—N 43.3737 deg., W 115.5535 deg.; Site 2—N 43.3671 deg., W 115.5525 deg.) downstream of Anderson Ranch Dam, South Fork Boise River, Idaho (Fig. 2). Elevations at Site 1 and Site 2 were 1139-m and 1145-m, respectively. Under pre-drawdown conditions (603 ft^3/s), Site 1 and Site 2 were best characterized as shallow (0.5-m depth) low slope run/riffle habitats dominated by gravel and cobble substrates (Fig. 3 and 6). Both sites were edge habitats—either near the bank of the main channel or near a main channel island bar. Following drawdown to 316 ft^3/s, the same sites consisted of small wetted areas with little to no flow (Fig. 4, 5, and 7). At each site, I generated a 5-m wide x 10-m long sampling grid. Using a random number generator, I chose sampling locations within the grid for macroinvertebrate collection. Thirty samples (15 from Site 1 and 15 from Site 2) were taken pre-drawdown and 15 samples (8 from Site 1 and 7 from Site 2) post-drawdown. Care was taken to avoid sampling the same exact location within a grid during pre and post-drawdown collection periods. Macroinvertebrates were captured using a standard 500-um mesh Surber sampler (12 inch x 12 inch frame). Samples were placed in a porcelain collection tray where macroinvertebrates were separated from the substrate. For each sample, macroinvertebrates were placed in a small plastic vial containing a solution of 70% ethanol. Later, macroinvertebrates were taken to The College of Idaho ecology research laboratory, where they were identified to the lowest practical taxonomic level (*e.g*. Order, Family), counted, and weighed (g) using a 0.001g balance.

To examine the impact of river drawdown on taxa richness, rarefaction was employed. Rarefaction is a technique for interpolating the expected number of taxa given *(n)* number of individuals and is a proven method for comparing taxa richness between sites (or time periods) of unequal sample sizes. I used a Mann-Whitney U-test to evaluate differences in median number of macroinvertebrates and median biomass of macroinvertebrates between the two time periods (pre and post-drawdown). Cluster analysis was used to measure macroinvertebrate community similarity between pre and post-drawdown. Ecologists have used cluster analysis to summarize large amounts of community and environmental data (*e.g*., Bowman et al. 2008; Winemiller et al. 2008). The un-weighted paired group method with arithmetic means approach (UPGMA) was used for hierarchical clustering (*i.e.,* dendogram construction) as outlined in Jackson et al. (2010). I used Euclidean distance on the standardized taxa abundances (percent relative abundance) as the resemblance measure. The bootstrap technique was used to assess the consistency of branching patterns in the resulting dendogram based upon a bootstrap value of 10000. Lastly, to test for differences in the relative abundance and relative biomass of specific taxa between pre and post-drawdown, I used an approach similar to Erman (1986). If a taxon's pre and post-drawdown 95% confidence interval of mean relative abundance/biomass overlapped, I concluded that there was no significant difference between sampling periods. This procedure is considered a conservative statistical approach (minimizes Type-1 error) and suitable for studies with smaller sample sizes. All statistical analyses were performed using PAST version 3.0 (Hammer 2013).

Results

One thousand seven hundred thirteen individual macroinvertebrates representing 16 macroinvertebrate taxa (*Brachycentridae*-humpless casemaker caddisflies; *Baetidae*-small minnow mayflies; *Ephemerellidae*-spiny crawler mayflies; *Chironomidae*-midges; *Perlodidae*-

perlodid stoneflies; *Pteronarcyidae*-giant stoneflies; *Annelids*-segmented worms; *Simuliidae*-black flies; *Perlidae*-common stoneflies; *Heptageniidae*-flatheaded mayflies; *Leptoceridae*-longhorned caddisflies; *Ephemeroptera*-unidentified mayfly genus; *Hydropsychidae*-netspinning caddisflies; *Leptophlebiidae*-prong-gilled mayflies; *Tipulidae*-craneflies; and *Siphlonuridae*-primitive minnow mayflies) were taken from 45 collections across the both sampling locations and time periods (pre-drawdown and post-drawdown). Macroinvertebrate richness (number of different taxa) was similar pre and post-drawdown (Fig. 8). Only four taxa present during pre-drawdown were not detected during post-drawdown. These included the flatheaded mayfly, an unidentified mayfly, common stonefly, and primitive minnow mayfly (Table 1). No taxa were found exclusively post-drawdown (Table 1).

Total number of individuals collected during the pre-drawdown phase (1541) was approximately nine-times higher than the number of individuals found post-drawdown (172). Median number of individuals collected per sample was significantly greater during pre-drawdown (median=53; mean=51; SE=3.5; range= 3-95, N=30) than post-drawdown (median=11; mean=11.5; SE=1.7; range=0-24, N=15) (U=17.5, P<0.001). Total macroinvertebrate biomass during pre-drawdown (22.4-g) was approximately three-times higher than post-drawdown biomass (8.2-g). However, median macroinvertebrate biomass per sample did not differ between river stages (pre-drawdown median macroinvertebrate biomass=0.67-g; post-drawdown median macroinvertebrate biomass=0.40-g; U=160, P=0.12).

Macroinvertebrate community structure pre and post-drawdown were distinct. Cluster analysis revealed a clear and consistent grouping pattern (based upon taxa relative abundances) among pre-drawdown and post-drawdown sites (Fig. 9). The humpless casemaker caddisflies (Brachycentrids) and small minnow mayflies (Baetids) were the two most common macroinvertebrates collected pre-drawdown, together accounting for approximately 55% by number and 44% by weight of all macroinvertebrates captured (Tables 1 and 2). The relative abundance (and relative biomass) of these two taxa significantly decreased during low flows; together representing just 5% of the post-drawdown community. Black fly and spiny-crawler mayfly numbers (and biomass) were also significantly less following drawdown (Tables 1 and 2). Post-drawdown, I also observed a significant drop in the relative biomass of netspinning caddisflies (Table 2). However, because netspinning caddisflies were rare (<2% by number and by mass) prior to drawdown, shifts in their numbers were not considered to be biologically relevant.

Chironomids were the third most common macroinvertebrate captured pre-drawdown and increased significantly post-drawdown, comprising approximately 42% of the post-drawdown community by number. By mass, Chironomids (a comparatively small macroinvertebrate) comprised approximately 22% of the post-drawdown total (Table 2). Within the Order Plecoptera (stoneflies), perlodid stoneflies were relatively common while the giant stoneflies and common stoneflies were uncommon or not detected across the two flow regimes. Other notable (but not statistically significant) shifts in macroinvertebrate relative abundances following river drawdown included increases in annelid worms, craneflies, longhorned caddisflies, and prong-gilled mayflies (Table 1). Annelid worms made up approximately 25% and longhorned caddisflies comprised 16.2% of the macroinvertebrate community by mass following drawdown (Table 2).

Discussion

Across the two study sites (low slope edge habitats), there was no change in aquatic macroinvertebrate richness following the mid-September drawdown of the South Fork Boise River. Those taxa present during pre-drawdown but absent post-drawdown were all rare (<2% relative abundance) and thus their absence may be due to sampling error (*i.e*. artifact of small sample size). Furthermore, no taxa were found exclusively post-drawdown; indicating that movement of new taxa from areas minimally impacted by drawdown to my low-flow study areas was probably a rare event. Verdonschot and van den Hoorn (2010) also reported no change in macroinvertebrate richness following flow reduction in Netherland streams while Kraft and Mandal (1984) indicated the on/off operation of a Michigan hydro-station to have little effect on downstream macroinvertebrate richness. While lowered South Fork Boise River flows did not conclusively eliminate any macroinvertebrate taxa, there were substantial shifts in abundance, biomass, and community structure.

Total invertebrate abundance and biomass declined following drawdown of the South Fork Boise River. Similarly, Englund and Malmqvist (1996) found sites in large regulated rivers to support fewer numbers of macroinvertebrates during low-flow conditions. Kinzie et al. (2006) reported lower densities of invertebrates downstream of diversions in a Hawaiian stream. Lowered flow (38-94% of August mean daily flow) also led to a decrease in total biomass of aquatic insects in Connecticut streams (Walters and Post 2011). Changes in invertebrate abundance and biomass observed in my study may be due to loss of wetted width, which occurs regularly in streams with high width to depth ratios; like the South Fork Boise River study reaches. The loss of wetted width decreases available habitat (Brasher 2003) and reduces habitat diversity (Cazaubon and Giudicelli 1999). This is particularly true for low slope edge habitats sampled in this study. Also, as flows are reduced, fine sediment cover increases (Wood and Petts 1999; James et al. 2009) and riffle and pool habitats are often compromised. Other stream habitat characteristics affected by river drawdown include temperature (Cazaubon and Giudicelli 1999; Kinzie et al. 2006), pH (Woodward et al. 2002), and food availability (Walters and Post 2011).

The alteration of stream habitat following river drawdown is thought to be a key factor driving changes in macroinvertebrate community structure in other studies (Gore et al. 2001; Dewson et al. 2007a). The pre-drawdown macroinvertebrate communities in this study clustered tightly in the dendogram plot (Fig. 9) and were associated with dominant aquatic insect groups that decreased in abundance during flow reduction. The groups that decreased in relative abundance following river drawdown were predominately humpless casemaker caddisflies (Brachycentrids), small minnow mayflies (Baetids), and black flies (Simuliids) (Table 1). Brachycentrids and black flies are collector-filterers while Baetids are predominately collector-gatherers. Walters and Post (2011) found biomass of collector-filterers and collector gatherers to decrease during low flows. The feeding mechanism of collector-filterers relies on FPOM (fine particulate organic matter) being suspended in the water column and FPOM transport in the water column is reduced during low flow (Walters and Post 2011).

As habitat conditions change during drawdown, some macroinvertebrate taxa disperse via entering the drift (James et al. 2009) or move into subsurface flow areas (hyporheic zones). Corrarino and Brusven (1983) and Dewson et al. (2007b) indicate that drift is a common behavioral response to lowered flow. Insects can move into the hyporheic zone during lowered flows in intermittent streams (Collins et al. 2007), but evidence that this occurs in perennial streams (like the South Fork Boise River) is limited (Delucchi 1989). Whether or not macroinvertebrates of the South Fork Boise River utilize the hyporheic zone as a refugium during river drawdown is unknown; but deserves research attention. The sharp decline in relative abundance of humpless casemaker caddisflies, small minnow mayflies, spiny-crawler mayflies, and black flies post-drawdown South Fork Boise River (Table 1) may be a direct reflection of the taxa's dispersal ability. Mayfly grazers have high mobility and are able to abandon unfavorable foraging patches (Poff and Ward 1992). Gore (1977) recommended using a mayfly as an indicator of optimal stream flow conditions because of its strong drift response during flow reduction. Poff and Ward (1991) and Hooper and Ottey (1998) reported increased drift of black flies, *Brachycentrus sp*. and Baetis *spp*. during low flows. Given what has been reported in the scientific literature, it is reasonable to suspect that during drawdown of the South Fork Boise River, macroinvertebrates drift to more favorable habitats. However, additional research is needed to fully understand macroinvertebrate drift response in the South Fork Boise River and whether drawdown induced changes in macroinvertebrate biomass and abundance in low slope habitats impact macroinvertebrate community structure in other South Fork Boise River habitats.

Macroinvertebrates unable to disperse to more suitable areas can suffer mortality via predation and/or competition (McIntosh et al. 2002). Lake (2003) reported predation to intensify as habitat area contracted and the rate of predator/prey encounter increased. Many macroinvertebrate predators are also more efficient at lower water velocities (Malmqvist and Sackmann 1996). However, I did not observe an increase in predatory macroinvertebrates (*i.e.*, Perlodid stoneflies) post-drawdown, suggesting that predation may not be an important driver of community changes in low slope edge habitats sampled in this study. Corti et al. (1997) and Mihuc et al. (1997) indicate vertebrates to have a great impact on macroinvertebrate community structure during reduced river flows. In this study, no fish were observed in the study area pre or post-drawdown. While bird predation of macroinvertebrates during low flows is possible, I did not observe any birds actively feeding in or around sampling sites during the study period. Future research is needed to examine if South Fork Boise River macroinvertebrates are more susceptible to bird and/or trout predation during and following drawdown.

For the two sites sampled, not all macroinvertebrates decreased in abundance following drawdown of the South Fork Boise River. Chironomids and Annelids were moderately common in the study sites prior to river drawdown but made up nearly half of the macroinvertebrate community by number and by weight (Table 1 and 2, respectively) post-drawdown. Most Annelids are obligate burrowers and increase in abundance with fine sediment (Waters, 1995), a common substrate type in low slope areas following river drawdown. Chironomids are a very diverse taxonomic group but most can be classified as burrowers with many possessing a tolerance for a wide-range of water quality conditions. The large proportion of Chironomids found post-drawdown suggests that water quality (*e.g.* night-time dissolved oxygen, pH, temperature) may be compromised in the habitats sampled. Further studies are needed to determine the impact of drawdown on the chemical and thermal properties of South Fork Boise River habitats.

Conclusion

Previous investigators have concluded that artificially reduced stream flows affect macroinvertebrate community composition. This study provides empirical support for this in that I found the abundance and biomass of macroinvertebrates to sharply decrease in low slope edge habitats following drawdown of the South Fork Boise River. But this study also challenges investigations that describe a decrease in taxa richness during low flows as I found no change in taxa richness post-drawdown. The shifts I observed in macroinvertebrate community structure within the habitat type sampled, can be explained, in part, by each taxon's feeding group, habitat preferences, and dispersal ability. It is important to note that no direct mortality of macroinvertebrates was observed in this study--suggesting that the decline in some macroinvertebrate taxa was probably the result of dispersal at the onset of flow reductions, movement into the hyporheic zone, loss to predation/competition, and/or emergence. Further study is needed to better understand which of the aforementioned factors (particularly drift) are responsible for loss of macroinvertebrate taxa from low slope habitats following river drawdown. More research is also warranted to investigate if drawdown induced macroinvertebrate community changes in low slope habitats impact macroinvertebrate abundance and biomass in other river habitat types. Finally, while Lake (2003) indicates that the decline of macroinvertebrate prey following drought can lead to declines in their predators, it is premature to suggest that decreases in macroinvertebrate abundance and biomass (as I outline in this study) are having a negative effect on rainbow trout in the South Fork Boise River. Further study is needed to determine if links exist among river drawdown, macroinvertebrate abundance/biomass, macroinvertebrate behavior, and the rainbow trout population.

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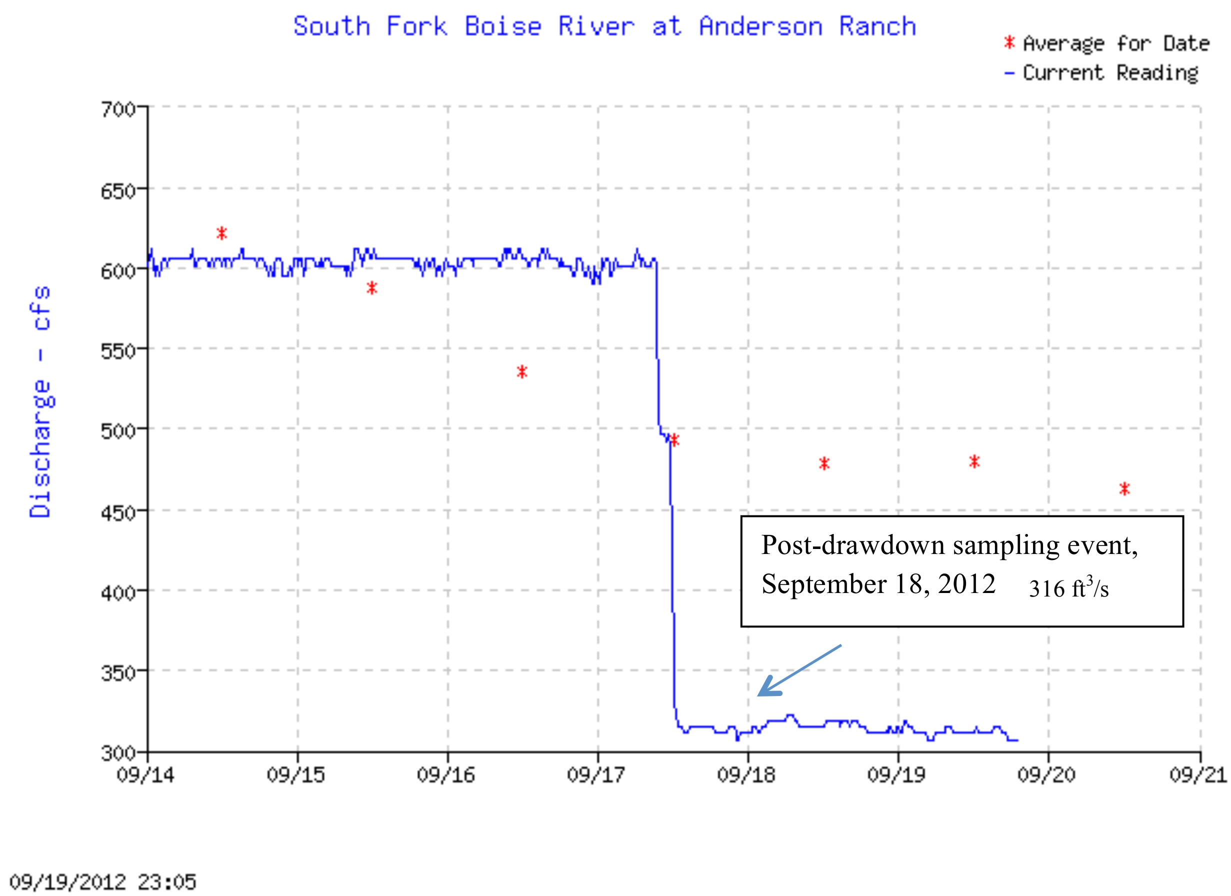
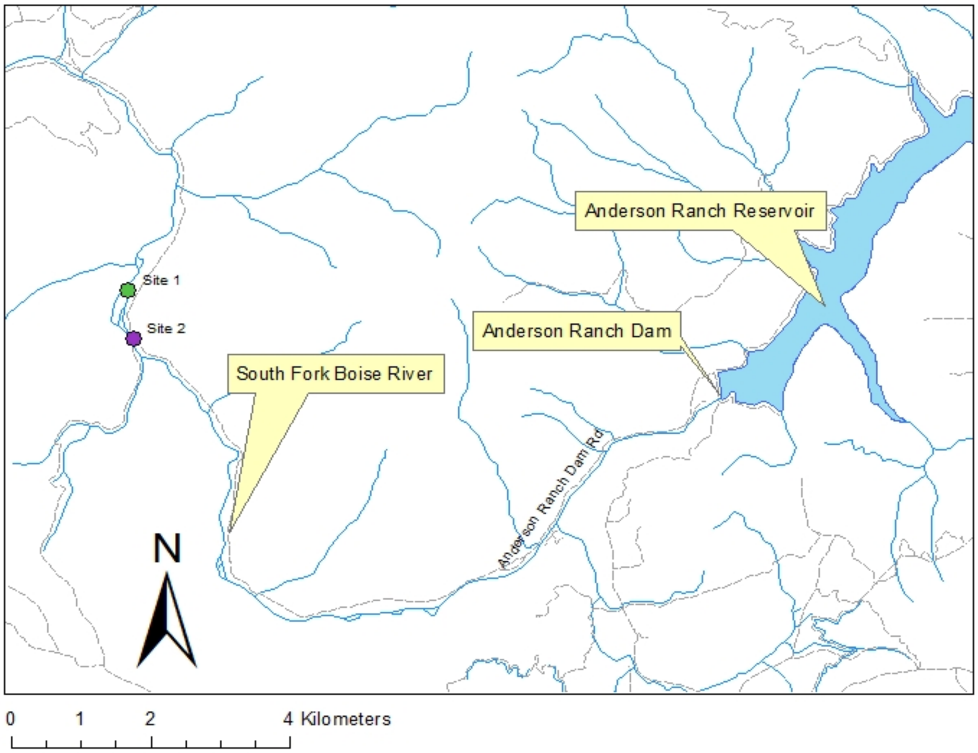


Fig. 1.—Daily mean discharge record for the South Fork Boise River at Anderson Ranch Dam for the period September 14 to September 20, 2012. Pre-drawdown sampling occurred on September 11, 2012 (discharge of 603 ft^3/sec). Graph courtesy of USGS-NWIS.



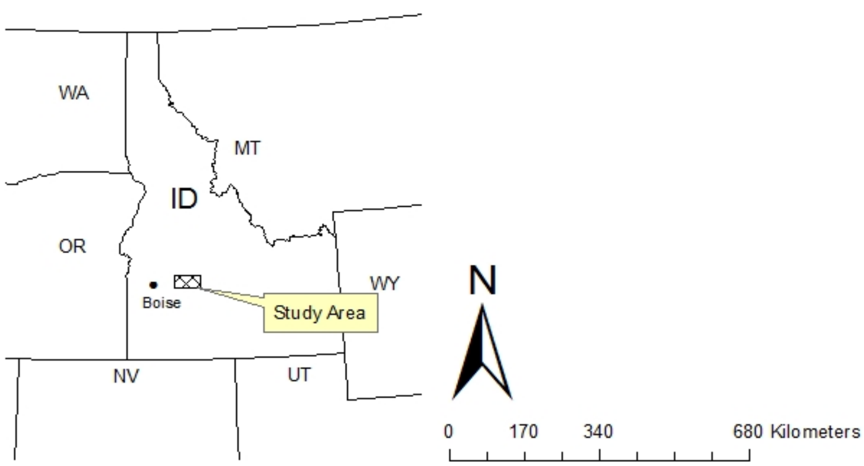


Fig.2.—Detailed map and inset map of South Fork Boise River study area, southwestern Idaho.

Fig. 3.—Near pre-drawdown river conditions (Site 1, South Fork Boise River, September 5, 2012)

Fig. 4.—Post-drawdown river conditions (Site 1, South Fork Boise River, September 18, 2012)

Fig. 5.—Post-drawdown river conditions (Site 1, South Fork Boise River, September 18, 2012).

Fig. 6.—Near pre-drawdown river conditions (Site 2, South Fork Boise River, September 5, 2012)

Fig. 7.—Post-drawdown river conditions (Site 2, South Fork Boise River, September 18, 2012)

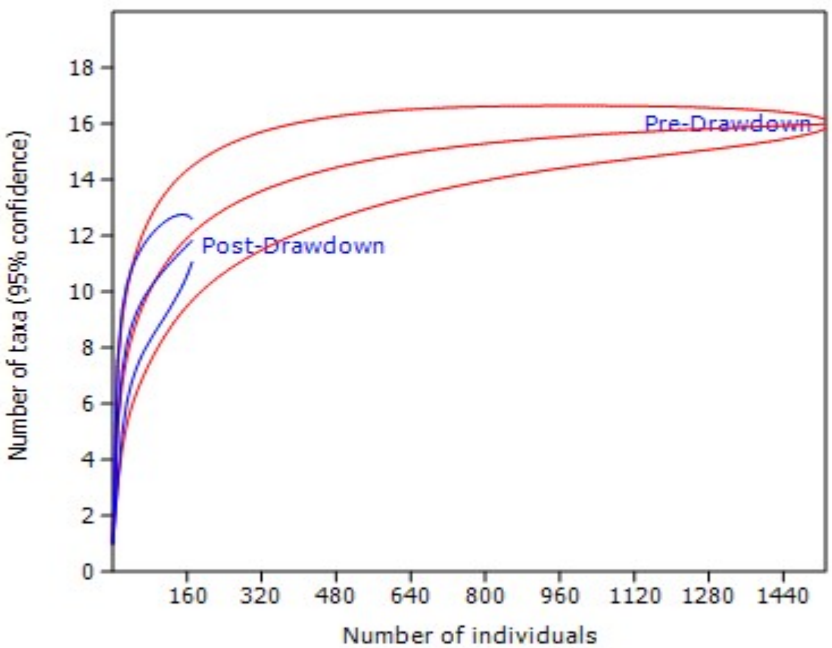


Fig. 8.—Individual rarefaction curve (with 95% confidence levels) for macroinvertebrate taxa sampled pre-drawdown (red curve, 30 samples, 1541 individual macroinvertebrates) and post-drawdown (blue curve, 15 samples, 172 individual macroinvertebrates) South Fork Boise River, Idaho.

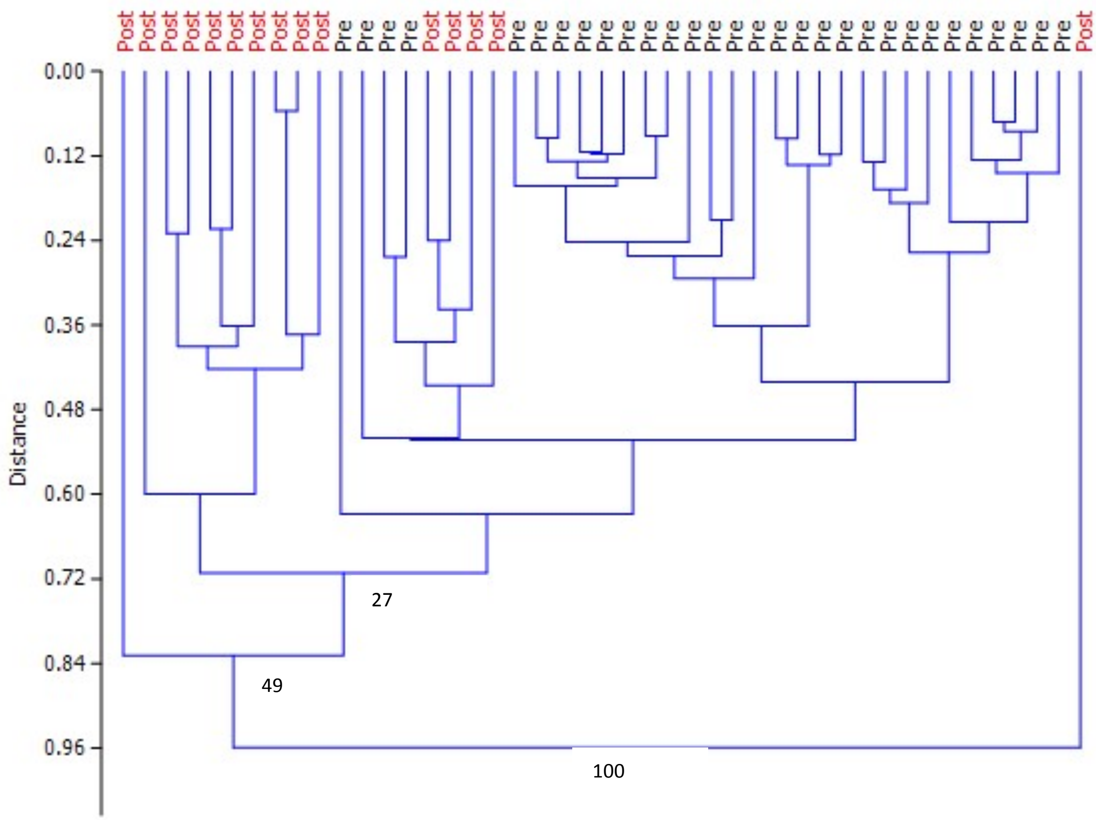


Fig. 9.—Un-weighted paired group method with arithmetic means (UPGMA) dendogram of 45 sites (30 pre-drawdown and 15 post-drawdown) sampled from two reaches of the South Fork Boise River, Idaho. The clustering was based on the Euclidean distance measure of macroinvertebrate community relative abundance data. The number at major nodes represents a bootstrapped probability (BP) estimate based upon a bootstrap value of 10000.

Table 1.—Mean relative abundance (% of total catch) of macroinvertebrate taxa from sites sampled pre-drawdown (N=30) and post-drawdown (N=15) of the South Fork Boise River, Idaho. Values in () represent the +/- 95% confidence interval (2.05 S.E. for 29 degrees of freedom and 2.15 S.E. for 14 degrees of freedom at P=0.05). *Pre-drawdown and post-drawdown relative abundances are significantly different (95% confidence intervals do not overlap).

	South Fork Boise River below Anderson Ranch Dam	
Taxonomic group	Pre-drawdown (Sept. 11, 2012)	Post-drawdown (Sept. 18, 2012)
**Brachycentridae (Trichoptera)*	30.8 (7.4)	2.5 (4.3)
**Baetidae (Ephemeroptera)*	24.8 (5.5)	2.9 (3.2)
**Chironomidae (Diptera)*	12.5 (3.1)	42.3 (13.3)
**Simuliidae (Diptera)*	8.9 (4.3)	0.3 (0.7)
**Ephemerellidae (Ephemeroptera)*	8.8 (2.3)	0.9 (1.9)
Perlodidae (Plecoptera)	6.5 (2.9)	6.8 (4.7)
Annelids (segmented worms)	1.8 (0.6)	15.0 (12.9)
Heptageniidae (Ephemeroptera)	1.3 (0.6)	0
Hydropsychidae (Trichoptera)	1.3 (0.6)	0.5 (1.1)
Ephemeroptera (unidentified genus)	1.1 (0.8)	0
Leptophlebiidae (Ephemeroptera)	0.8 (0.8)	7.3 (6.0)
Leptoceridae (Trichoptera)	0.5 (0.4)	7.8 (9.7)
Perlidae(Plecoptera)	0.3 (0.2)	0
Pteronarcyidae (Plecoptera)	0.2 (0.2)	1.8 (3.9)
Siphlonuridae (Ephemeroptera)	0.2 (0.4)	0
Tipulidae (Diptera)	0.1 (0.2)	5.0 (5.8)

Table 2.—Mean relative biomass (% of total biomass) of macroinvertebrate taxa from sites sampled pre-drawdown (N=30) and post-drawdown (N=15) of the South Fork Boise River, Idaho. Values in () represent the +/- 95% confidence interval (2.05 S.E. for 29 degrees of freedom and 2.15 S.E. for 14 degrees of freedom at P=0.05). *Pre-drawdown and post-drawdown relative biomasses are significantly different (95% confidence intervals do not overlap).

	South Fork Boise River below Anderson Ranch Dam	
Taxonomic group	Pre-drawdown (Sept. 11, 2012)	Post-drawdown (Sept. 18, 2012)
**Brachycentridae (Trichoptera)*	30.7 (7.2)	3.4 (6.2)
**Baetidae (Ephemeroptera)*	13.2 (4.3)	1.8 (2.2)
**Ephemerellidae (Ephemeroptera)*	12.4 (4.3)	0.9 (1.9)
Chironomidae	8.6 (2.7)	22.4 (14.0)
Perlodidae (Plecoptera)	6.5 (3.5)	8.3 (6.7)
Pteronarcyidae (Plecoptera)	5.8 (6.2)	4.6 (9.9)
Annelids (segmented worms)	5.5 (3.5)	25.4 (19.1)
**Simuliidae (Diptera)*	4.0 (1.6)	<0.1 (<0.1)
Perlidae(Plecoptera)	3.4 (3.7)	0
Heptageniidae (Ephemeroptera)	2.5 (1.2)	0
Leptoceridae (Trichoptera)	2.3 (1.6)	16.2 (14.4)
Ephemeroptera (unidentified genus)	2.0 (1.4)	0
**Hydropsychidae (Trichoptera)*	1.7 (1.0)	0.5 (<0.1)
Leptophlebiidae (Ephemeroptera)	0.6 (0.6)	3.5 (3.4)
Tipulidae (Diptera)	0.5 (1.0)	6.1 (8.0)
Siphlonuridae (Ephemeroptera)	0.3 (0.4)	0