Evaluating Recovery of Stream Invertebrate Communities Following Removal of Introduced Trout in Kings Canyon National Park:
Baseline Biological Stream Surveys and Contrasts After Fish Removal

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Executive Summary

Streams of the high elevation Sierra Nevada contain a diverse variety of aquatic life forms but were naturally fishless above waterfall barriers to fish migration. After more than a century of the stocking of exotic trout into streams of the Sierra, these fishless streams have become a rarity (Moyle et al. 1996), restricted mostly to small and remote headwater drainages. The presence of these dominant aquatic predators has been shown to significantly reduce the abundance of many native invertebrates, especially Sierra Nevada endemics that have no evolutionary history of exposure to fish predation (Herbst et al. 2009). In addition, contrasted with paired fishless drainages, trout-stocked streams have on average twice the biomass and cover of algae on rock surfaces, and a disproportionately increased density of small midge inhabitants, suggesting that the energetic and food web relations of affected streams, as well as the species composition, have been substantially altered. The extent of impact to the native aquatic invertebrate fauna of the Sierra Nevada and natural ecological function of high elevation streams is uncertain, but there is a need to evaluate whether restoration is possible.

Removal of introduced trout from lakes in Sequoia & Kings Canyon National Parks has been underway for several years in an attempt to recover populations of the mountain yellow-legged frog (*Rana muscosa*). Work in the upper portions of the Bubbs Creek drainage include removals from several lake outlet streams, providing an opportunity to also examine recovery of stream community structure and function. Surveys of outlet streams before and after removals, and in control streams with and without introduced trout, provided data permitting assessment of the potential for restoration. This report documents two years of pre-removal baseline conditions and two years of post-removal changes in four 75-meter length study streams with respect to physical and chemical habitat conditions, algae biomass, organic matter, and invertebrate densities and diversity. Two of the stream study reaches were shallow rocky channels with little riparian cover and low discharge, and the other two were deeper streams with higher discharge volume, both of which were side channels, exiting and returning to larger streams. Comparing these pairs of similar habitat type formed the basis for data analysis. The rock-channel stream pair was a fishless control and a trout-removal treatment, and the side-channel pair was another trout-removal treatment and a trout-control (no removals of trout done). The two larger side channel streams were similar in taxonomic composition and had higher diversity than the two smaller rocky outlet streams. Invertebrate taxa that were expected to be most vulnerable to trout presence (*Ameletus*, *Paraleptophlebia*, *Doroneuria*, *Parapsyche*, *Apatania*, corixid water boatmen, dytiscid diving beetles, and flatworms), as suggested by studies in Yosemite National Park (Herbst et al. 2008), were initially present in low numbers or absent in the streams from which trout were to be removed. There was thus the potential for numerical increase or appearance as a response to fish removal in these streams. Although there were few vulnerable taxa present in the small fishless target stream, this stream had an abundance of the alpine filter-feeding black flies, *Prosimulium* (mostly *travisi*) and *Stegopterna mutata* complex, which were rare or absent in the trout streams. Conversely, *Simulium* (*tuberosum*) was common to abundant in the small pre-treatment stream, but rare in the matched fishless stream. The black flies *Prosimulium travisi* and *Stegopterna mutata* populations have restricted distributions to mountain alpine zones (Peterson and Kondratieff 1994), and are likely to have evolved in high elevation lake outlets in the absence of fish predation and so may be vulnerable because they have had no evolutionary history of exposure. Common *Simulium* by contrast have a broad geographic/elevation distribution and may possess traits enabling coexistence with trout. The larvae of *Prosimulium* and *Stegopterna* may also be vulnerable because they are typically larger at maturity and develop more slowly compared to *Simulium*. In the initial year of post-removal monitoring in 2011 in the smaller outlet stream (10477), after six years of trout absence (removals reported effective in the first year of electrofishing in 2005), the alpine black fly populations appeared in large numbers, and density of the trout-vulnerable mayfly *Ameletus* increased by about 100 times the pre-removal level (and these persisted even with the channel drying to intermittent pools in the second post-removal year). The side-channel fish removal stream (10487) by contrast showed less response compared to either the pre-removal state or the paired fish-bearing control stream, possibly because of incomplete trout removal. Constriction of available habitat during the drought conditions of 2012 resulted in large density increases where streams still flowed, but even though drying of surface flow occurred in the small treatment stream Outlet 10477, *Ameletus* still persisted in remnant pools.

Introduction

The Sierra Nevada Ecosystem Project identified aquatic and riparian systems as the most altered and impaired habitats of the Sierra Nevada. Sequoia-Kings Canyon National Park (SEKI) has hundreds of miles of high-elevation streams, including several Wild and Scenic Rivers that are designated (Middle and South Forks of the Kings Rivers; North Fork of the Kern River) or determined eligible and suitable and are awaiting Congressional designation (South Fork of the San Joaquin River; North, Marble, Middle, East, and South Forks of the Kaweah River). These habitats harbor high proportions of endemic species in insect groups such as the stoneflies and caddisflies, representing a significant biodiversity resource. Fishless stream environments may be critical habitat for large and vulnerable insects, and for endemic aquatic invertebrates that evolved in high elevation streams without exposure to predatory fish. Invertebrate communities of streams are often composed of dozens of species with diverse roles in food webs. They are also primary prey of trout, which were introduced to the High Sierra beginning in the 1860's. Recent research in Yosemite compared physical, chemical, and biological parameters of 21 fishless stream segments with adjacent matched streams containing trout. Results showed that fishless streams contained a significantly greater diversity and abundance of certain large and/or endemic invertebrate fauna than found in matched trout streams, while trout streams contained more algae biomass and small midge flies than fishless streams (Herbst et al. 2009). These data suggest that introduced trout cause significant changes in the biological structure and function of high-elevation streams, and thus native resources are vulnerable to direct and indirect effects of trout predation.

Removing introduced trout from high-elevation lakes has been shown to reverse their effects on native faunal assemblages (Knapp et al. 2001); however, we do not know if removing trout from high-elevation streams will reverse their effect on native invertebrate communities. Beginning in 2005, SEKI began removing introduced trout from two lakes and adjacent streams in a restoration area of the Bubbs Creek headwaters, providing an opportunity to evaluate the effect of trout removal on the recovery of stream invertebrate communities. The strategy of this project has been to conduct two seasons of both pre-fish removal and post-fish removal invertebrate sampling to obtain data to evaluate potential recovery of native biodiversity in high-elevation streams.

Additionally, although fish removals in SEKI are currently planned only for areas with adjacent threatened frog populations, if invertebrate recovery is observed in stream areas, it will underscore the need to include these habitats in park-wide restoration planning. Further, the proposed work will facilitate 1) the development of criteria for identifying aquatic diversity management areas for conserving native biodiversity, 2) the establishment of baseline biological indicators for monitoring the progress and success of projects designed to restore stream biodiversity, and 3) the extension of biogeographic coverage of undescribed invertebrate distribution patterns in Sierra Nevada streams.

Despite their diversity, key ecological roles, and potential for application in environmental assessments, aquatic invertebrates are the most poorly known of all faunal groups in the Sierra Nevada (Erman 1996). Data for stream invertebrates are especially incomplete, with most collection records coming from intensively studied locales or taxonomic groups. Park managers and scientists recognize the need for a baseline invertebrate inventory, and the Sierra Nevada Network identified obtaining invertebrate species presence and distribution information as a critical need to help monitor ecosystem health and preserve biodiversity (USDI 2001). However, only a fraction of invertebrate inventory work has been undertaken in SEKI with few collections identified to species. The data collected in this study will contribute not only to a monitoring design for evaluating ecological effects of trout removal, but also to documenting unknown headwater stream communities of SEKI.

The objectives of this project were to: 1) evaluate the potential for recovery of streams after the removal of introduced trout; 2) evaluate between-year differences in the structure and diversity of benthic invertebrate communities among different headwater streams; and 3) use the resulting recovery and inventory information to consider the inclusion of high-elevation stream habitats in park-wide planning to restore native biodiversity.

The project design accomplished the following work: 1) conduct two seasons of both pre-removal and post-removal invertebrate sampling in four SEKI streams in the Bubbs Creek sub-basin of the South Fork of the Kings River; and 2) use a paired-stream design in which two treated streams (fish removed) are compared with either one untreated fish-bearing stream (fish-control: fish not removed), or one fishless stream (fishless-control), to establish the potential scope for recovery; and before and after the fish removal period to assess changes in the diversity and functional organization of the benthic invertebrate community within streams.

Methods

The selection of study streams for this research is based on sites identified for restoration of mountain yellow-legged frogs and an inventory of high-elevation lakes and adjacent streams in SEKI. Study streams were matched for similarity according to order, channel size, location, watershed area, elevation, length, gradient, aspect, and riparian canopy (Figure 1, map of site locations). Stream surveys consisted of sampling benthic macroinvertebrates and a variety of physical and chemical factors at each study site.

A representative 75 meter reach length was selected for survey in each of the study streams over a two year pre-removal period, and over a two-year post-removal period (with 6 intervening years during which trout removals were taking place). Benthic invertebrate collections were taken using a D-frame kick net (250 micron mesh, 30 cm wide, 0.09 square meter area) in 3 riffles combined as one sample (3 30x30 cm area samples from each riffle) and 3 pools combined as another collection (1 30x30 cm area from each pool) from within each reach. Samples were preserved in 80% ethanol with Rose Bengal added as stain. All specimens (mostly larval forms) were identified to genus or species level (oligochaetes and ostracods were not further identified) and these samples archived in the SNARL museum. To aid in identification, additional collections of mature specimens of all invertebrates were obtained from a variety of stream habitats, and any adult aquatic insects were taken from the bank margins at each site (not included in quantitative counts).

Algae and organic matter measures permit quantification of invertebrate food resources. Algal biomass was determined by scraping periphyton from rocks, then subsampling for chlorophyll extraction and taxonomic composition. Chlorophyll *a* was determined by extraction of frozen filters in 95% ethanol and reading in a fluorometer relative to standards. Organic matter was quantified from D-net samples taken from riffles, with the coarse particulate fraction (CPOM) retained on a 1 mm sieve, and the fine fraction (FPOM) representing organic matter passing through the 1 mm sieve but being retained on a 250 micron sieve. Wet weight of CPOM was determined on site, and FPOM was determined from formalin-preserved samples that were dried, weighed and ashed in a muffle furnace to calculate the ash-free dry mass (AFDM).

Physical habitat conditions along each study reach were determined at 5-meter intervals on 15 cross-stream transects at 5 equal-spaced point each (depth, substrate size, current velocity, bank cover, riparian canopy). Water quality measures included temperature, pH, alkalinity, conductivity, dissolved oxygen, silica, and turbidity.

Ordination plots were created in PC Ord v6. using non-metric multi-dimensional scaling (NMS) and Sorensen (Bray-Curtis) distance measures. All taxonomic density values were log transformed and rare taxa excluded by including only taxa present in at least two site/date visits with relative abundance >1% of the community total.

Results and Discussion

Studies of the effects of trout introductions in Yosemite showed that endemic invertebrate taxa and a substantial portion of common benthic fauna were reduced in most trout-containing streams relative to native fishless streams (Herbst et al. 2009). These changes suggest that trout can reduce vulnerable native taxa and alter the structure and function of High Sierra streams. Invertebrate diversity, predators, and algae-grazers were reduced in the presence of trout, and algae abundance increased presumably because of removal of algae-eating invertebrates. The pre-trout removal studies reported here established the composition of the existing benthic biota, and potential scope for biological response in high elevation lake outlet streams.

Pre-Removal Contrasts:

Initial pre-fish removal sampling from 2003 and 2004 showed that all study streams had cobble-boulder/bedrock dominated substrate composition, were about 2 meters wide, with stable banks, slightly acid pH, low conductivity, and low alkalinity (little buffer capacity). During late-season low-flow periods, when the upstream lakes are not overflowing, the smaller channels may become intermittent, though sub-surface (hyporheic) flows probably continue beneath the porous stream bed substrates.

There were few substantial differences in physical habitat parameters between 2003 and 2004 (Table 1). At the time of sample collection, discharge was greater in each stream in 2004, with concomitant increases in mean depth and width (Figures 2-4). This may explain declines in the quantity of retained FPOM and CPOM (all sites except Outlet 10477) in 2004 (Figures 5 and 6). Periphyton biomass, as indicated by chlorophyll *a* measurements, increased in 2003-2004 at all sites except Outlet 10477 (Figure 7).

Diversity and community composition within the stream sites was similar in both years of the baseline period, suggesting there is stability within sites that forms a sound basis for contrasts with the post-trout removal communities. The number of taxa was consistently greater in riffles than pools, and the larger streams support higher diversity, with more of the variety represented by mayflies, stoneflies and caddisflies (Figure 8).

Outlet streams 10477 and 11007 are both shallow rocky channels with little riparian cover and low discharge, while Outlet stream 10487 and Outlet Vidette are higher discharge volume, deeper streams that are both side channels, exiting and returning to larger streams. For these reasons, it is most appropriate to compare the biological communities of these streams as matched pairs. Outlet 10477 is a fish removal treatment while 11007 is fishless, and Outlet 10487 is fish removal while Outlet Vidette will retain its exotic trout population.

The two larger streams were similar in taxonomic composition as were the two smaller streams (Table 2) with the larger streams having higher diversity (Figure 8). The fishless-control stream, Outlet 11007, conformed to expectations from the results of studies in Yosemite in terms of having lower chlorophyll *a* density than all the other streams (containing pre-removal trout). This pattern is also consistent in the lower cover of visible macroalgae in the fishless stream which may be due to the absence of predation on invertebrate grazers.

Paired with Outlet 10477 prior to fish removal, the invertebrate community of the fishless-control (Outlet 11007) was consistent with previous results in Yosemite, having somewhat higher overall diversity (53 vs. 47 total taxa), more vulnerable taxa present (6 vs. 3), and mean diversity higher in riffles, and higher or even in pools (Figure 8). Two of the vulnerable taxa present in the fish bearing Outlet 10477, the predacious diving beetle *Agabus* and the flatworm Turbellaria, were more rare in the presence of fish compared to the fishless control (3 vs. 34/m^2 and 1 vs. 19/m^2 respectively). The other vulnerable taxon present in Outlet 10477, *Ameletus*, was not found in the fishless Outlet

11007. Alpine black flies species of the genera *Prosimulium* and *Stegopterna* were found almost exclusively in Outlet 11007 in pre-treatment samples (Figure 9a). Compared to the broadly distributed genus *Simulium*, these alpine black flies, with more restricted distributions to high elevation streams that are often fishless, may also be vulnerable to trout predation.

Another interesting life form, found only in 2004, was the appearance of tardigrades, or water bears (genus *Hypsibius*), in the smaller streams where flows were low and probably dry periodically. These minute creatures (a few millimeters at most) are able to live in an anhydrobiotic or desiccated state of no metabolic activity for prolonged periods, and are thereby adapted to life in intermittent streams and freezing conditions. With renewed wet conditions, these resistant invertebrates are able to rehydrate, convert cell protectant organic molecules of glycerol and trehalose to energy, and resume life.

During the entire study period, over 48,000 individual invertebrate specimens were counted and identified from the four subject streams, comprising162 distinct taxa (Table 2). Overall densities were between 5,000 and 21,000 per-square-meter in all streams in 2003 and 2004 and between 3,000 and 91,000 in 2011 and 2012 (Figure 10). Though population densities are sometimes useful indicators of ecological response, these total density figures are often variable and difficult to interpret because they are a composite of many interacting organisms. In 2012, where flows persisted in the two side-channel streams, densities were much higher than any other year as available habitat became constricted and benthic organisms were concentrated.

Post-Removal Contrasts (2011-2012)

In the southern Sierra Nevada, April 1st Snow Water Equivalency in the winter of 2002-03 was 63% of normal and in 2003-04 was 72% of normal. These drier, low flow conditions contrast with the wet 2010-11 winter at 161% of normal and the very dry 2011-12 winter at 37% of normal. This was reflected in observations of higher average velocity and discharge in 2011 compared to the 2003 and 2004 surveys. In contrast, 2012 had lower average velocity and discharge compared to 2003 and 2004 for two streams (Outlet 10487 and Outlet Vidette) and drying of outlet streams 10477 and 11007 to small remnant pools (Figure 2). There does not appear to be a clear consistent response of water chemistry, CPOM, or FPOM to fish removal (Table 1, Figures 5-6). Following fish removal treatment, Chlorophyll *a* was lower in both the treatment sites, but was also lower in the fish control site (Figure 7).

Of particular interest was the finding of substantial changes in the invertebrates present in treatment stream Outlet 10477. Lake 10477 and its outlet proved to be easy for fish removal and were deemed 100% effective in just the first year of treatments (D.Boiano, personal communication). This lake and outlet would therefore have had a full 6 years of recolonization time available. One prediction was that the alpine black flies *Prosimulium* and *Stegopterna* found only in the paired fishless stream might colonize Outlet 10477 after fish removal. As predicted, *Prosimulium* appeared in both treatment streams after the removal of trout and *Stegopterna* densities also increased (Figure 9). Further, *Simulium* densities decreased in the absence of trout perhaps as a function of competition with *Prosimulium* and *Stegopterna* now relieved of fish predation pressure. The black flies *Prosimulium travisi* and *Stegopterna mutata* populations are known as inhabitants of mountain alpine zones (Peterson and Kondratieff 1994), and are likely to have evolved in high elevation lake outlets in the absence of fish predation and so may be vulnerable because they have had no evolutionary history of exposure. Common *Simulium* by contrast have a broad geographic/elevation distribution and may possess traits enabling coexistence with trout even where the predator has only recently been introduced. The larvae of *Prosimulium* and *Stegopterna* may also be vulnerable because they are typically larger at maturity compared to *Simulium*. If these mountain black flies are restricted to high elevation habitats, consumption and elimination by trout predators may limit the opportunity for recovery because of the rarity of fishless sources for re-colonization. If these taxa require longer to develop they may not be able to escape predation by rapid growth and emergence (*Simulium* usually has rapid growth and dispersal ability). Perhaps suspended food resources of the feeder lakes also become depleted by the presence of fish.

The studies in Yosemite found that one of the most trout-vulnerable taxa was the mayfly *Ameletus* (Herbst et al. 2009). Indeed, studies of lake-dwelling *Ameletus* in Sierra lakes have also shown them to be extremely susceptible to trout predation (Knapp et al. 2001). We found that after the removal of trout, the density of *Ameletus* increased in both treatment streams (8 to 1034/m^2 in outlet 10477 and from 3 to 200/m^2 in outlet 10487; Figures 11 and 12). While both streams showed an increase in *Ameletus*, the increase in outlet 10487 is similar to that seen in the Outlet Vidette and may be attributable to the concentrating effect of low flows in 2012 (Figure 11). At this point it remains unclear why the fishless control did not have a population of *Ameletus*.

Another invertebrate shown to be far more abundant in fishless than trout-stocked streams of Yosemite are flatworms (class Turbellaria; genus and species designations unknown for this taxonomically problematic group). In side-channel Outlet 10487, the pre-removal average density of Turbellaria was about 10/m^2 and increased to over 600/m^2 post-removal. Even though densities of flatworms also increased in the Outlet Vidette fish-bearing control from 120 to about 1,000/m^2, the 60-fold increase in the Outlet 10487 appears to be more than low-flow concentration because the increase also occurred in 2011 under high flows (from 10/m^2 to 130/m^2 increase in that year). Fish removals from Outlet 10487 were never found to be entirely effective as some numbers of trout continued to be found each year (D.Boiano, personal communication). Apparently the downstream barrier, reconstructed in an attempt to make it more effective in excluding downstream fish, did not prevent some upstream movement of trout. This may have impeded recovery of other vulnerable benthic invertebrates.

In the small streams Outlet 10477 and 11007, the drought conditions produced by the dry winter of 2011-2012 resulted in early drying of these channels, such that sampling during the late July survey period for this study came only from small isolated remnant pools. Even so, these pools revealed that in the 10477 trout-removal streams, the large mayfly *Ameletus* still persisted, comprising a substantial fraction of the community (Table 3), along with a fauna of invertebrates dominated by chironomid midges. In addition, another sensitive mayfly, *Callibaetis*, known to be depleted by trout in lakes (Knapp et al 2001), was also found in these remnant pools. Despite the severe conditions brought on by drought and drying of the surface channel, benthic invertebrate recovery persists following trout removal. Although these streams were both small rocky channels, the remnant pool communities were quite different in composition, with relatively few shared taxa. This supports other data showing that between-habitat or beta-diversity, even for intermittent channels, can be quite high in mountain alpine headwater streams (Finn et al. 2011).

Overall community changes can be expressed as an NMS ordination plot (Figure 13) and this shows that in 3 of the streams the most dramatic departure in community composition occurred in 2011 when high flows occurred in all study streams. Only in the 10487 fish removal stream was there little change in the community. This result emphasizes that it is important to examine responses of individual taxa that have traits or histories that make them most susceptible to the effects of introduced trout.

Monitoring Recommendations

To establish the extent to which historically fishless streams of the mid-to-high elevation Sierra Nevada have been altered by trout introduction, an inventory of the distribution of fishless streams should be conducted throughout the system of National Parks in the Sierra as has been completed for lakes. This was identified as a research priority with high sensitivity for detecting impact in the Vital Signs Workshop, hosted by the National Park Service in Yosemite in 2002 (NPS 2003). The paired watershed studies done in Yosemite (Herbst et al. 2009) suggested that not all streams were impacted by trout, but did not determine what made streams more or less vulnerable to changes in species composition and trophic function. Further monitoring of trout impacts should therefore contrast streams with varied potential for affecting the strength of the trophic cascade produced by predation, such as the availability of habitat refugia, resource productivity, quality and the efficiency of its consumption (Borer et al. 2005), and external stressors on fish survival. Additional case histories of trout removals from other streams would also provide a means of validation and testing the applicability of management in different settings. The rapid responses detected in post-removal monitoring for some vulnerable and alpine-stream invertebrates suggests that re-colonization by sensitive montane species can recover biodiversity that had been lost due to the impacts of introduced trout.

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Table 1: Summary of physical habitat measurements

		Outlet 10477 Fish Removal			Outlet 11007 Fishless Control			Outlet 10487 Fish Removal				Outlet Vidette Fish Control			
Latitude		36° 43.928'			36° 43.152'			36° 43.338'				36° 44.393'			
Longitude		118° 23.188'			118° 21.129'			118° 20.846'				118° 24.567'			
Elevation (m)		3,420			3,500			3,430				3,200			
Slope		6.6%			8.7%			4.4%				5.2%			
Sinuosity		1.07			1.08			1.24				1.31			
Aspect		45° (NE)			0° (N)			33° (NNW)				20° (NNE)			
Date		07/20/03	07/07/04	07/27/11	07/21/03	07/09/04	07/26/11	07/22/03	07/08/04	07/26/11	07/19/12	07/23/03	07/06/04	07/27/11	07/20/12
Width (cm)	**Mean**	235	249	514	169	326	442	217	269	271	259	225	253	240	193
	S.D.	137	159	261	96	122	131	92	112	136	104	84	80	73	62
Depth (cm)	**Mean**	6	8	9	4	6	9	8	10	14	8	7	14	14	7
	S.D.	5	6	4	2	3	4	6	8	6	4	4	19	5	3
Maximum Depth (cm)		26	27	22	10	16	24	46	50	32	18	23	122	30	19
Average Habitat Area (Avg Width x Depth)		1435	2072	4722	616	2072	4184	1791	2820	3907	2072	1552	3491	3379	1351
Velocity (cm s^{-1})	**Mean**	5	4	36	4	10	46	14	17	36	11	23	29	55	18
	S.D.	11	10	31	8	13	31	14	18	24	14	23	26	32	17
Discharge (cfs)	**Mean**	0.3	0.3	5.6	0.1	0.7	6.5	0.9	1.2	4.3	0.6	1.0	4.7	6.4	0.9
	S.D.	0.4	0.6	3.5	0.2	0.3	2.5	0.5	0.7	1.4	0.3	0.3	4.1	1.0	0.5
	Non-Zero Mean	0.4	0.5	5.6	0.2	0.7	6.5	0.9	1.2	4.3	0.6	1.0	4.1	6.4	0.9
	S.D.	0.4	0.7	3.5	0.2	0.3	2.5	0.5	0.6	1.4	0.3	0.3	4.0	1.0	0.5
	Mode (10% bins)	0.1	0.2	1.2	0.1	0.6	0.7	0.8	1.1	0.5	0.6	1.0	4.1	0.4	0.8
Reach Composition	**Riffle**	68%	79%	68%	83%	86%	89%	76%	85%	89%	72%	96%	100%	100%	93%
	Pool	13%	13%	13%	11%	7%	7%	21%	11%	7%	12%	4%	0%	0%	4%
Percent Riparian Cover		11%	24%	22%	4%	20%	9%	39%	30%	8%	14%	39%	35%	24%	33%
Herbaceous Cover Score (1-5)		3	3	3	4	5	5	5	5	5	5	5	5	5	5
Woody Cover Score (1-5)		4	2	3	2	1	2	4	3	2	2	3	3	3	3
Bank Condition	**Stable**	100%	100%	100%	100%	100%	100%	100%	100%	100%	93%	100%	100%	100%	97%
	Eroded	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Open	0%	0%	0%	0%	0%	0%	0%	0%	0%	7%	0%	0%	0%	3%
Bank Cover	**Herbaceous**	23%	7%	17%	53%	40%	37%	43%	43%	57%	57%	70%	77%	73%	70%
	Woody Bush	17%	10%	20%	3%	7%	17%	27%	27%	20%	27%	17%	17%	23%	23%
	Tree	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Armored	60%	83%	63%	43%	53%	47%	30%	30%	23%	13%	13%	7%	3%	7%
Bank Angle	**Shallow** (<30°)	3%	7%	17%	20%	3%	17%	10%	0%	7%	0%	0%	0%	0%	3%
	Moderate (30-90°)	87%	83%	77%	73%	70%	70%	40%	37%	23%	17%	50%	20%	27%	30%
	Undercut (>90°)	10%	10%	7%	7%	27%	13%	50%	63%	70%	83%	50%	80%	73%	67%

Notes: Discharge is calculated from paired depth and velocity measurements. Percent riparian cover is based on densiometer measurements within the stream channel. Herbaceous and woody cover scores are based on a visual assessment of riparian area vegetative cover types, with a score of 1 indicating sparse (<25%) and 5 indicating dense (>75%) cover.

		Outlet 10477 **Fish Removal**			**Outlet 11007** **Fishless Control**			**Outlet 10487** **Fish Removal**				**Outlet Vidette** **Fish Control**			
Latitude		36° 43.928'			36° 43.152'			36° 43.338'				36° 44.393'			
Longitude		118° 23.188'			118° 21.129'			118° 20.846'				118° 24.567'			
Elevation (m)		3,420			3,500			3,430				3,200			
Slope		6.6%			8.7%			4.4%				5.2%			
Sinuosity		1.07			1.08			1.24				1.31			
Aspect		45° (NE)			0° (N)			33° (NNW)				20° (NNE)			
Date		07/20/03	07/07/04	07/27/11	07/21/03	07/09/04	07/26/11	07/22/03	07/08/04	07/26/11	07/19/12	07/23/03	07/06/04	07/27/11	07/20/12
Width (cm)	**Mean**	235	249	514	169	326	442	217	269	271	259	225	253	240	193
	S.D.	137	159	261	96	122	131	92	112	136	104	84	80	73	62
Depth (cm)	**Mean**	6	8	9	4	6	9	8	10	14	8	7	14	14	7
	S.D.	5	6	4	2	3	4	6	8	6	4	4	19	5	3
Maximum Depth (cm)		26	27	22	10	16	24	46	50	32	18	23	122	30	19
Average Habitat Area (Avg Width x Depth)		1435	2072	4722	616	2072	4184	1791	2820	3907	2072	1552	3491	3379	1351
Velocity (cm s^{-1})	**Mean**	5	4	36	4	10	46	14	17	36	11	23	29	55	18
	S.D.	11	10	31	8	13	31	14	18	24	14	23	26	32	17
Discharge (cfs)	**Mean**	0.3	0.3	5.6	0.1	0.7	6.5	0.9	1.2	4.3	0.6	1.0	4.7	6.4	0.9
	S.D.	0.4	0.6	3.5	0.2	0.3	2.5	0.5	0.7	1.4	0.3	0.3	4.1	1.0	0.5
	Non-Zero Mean	0.4	0.5	5.6	0.2	0.7	6.5	0.9	1.2	4.3	0.6	1.0	4.1	6.4	0.9
	S.D.	0.4	0.7	3.5	0.2	0.3	2.5	0.5	0.6	1.4	0.3	0.3	4.0	1.0	0.5
	Mode (10% bins)	0.1	0.2	1.2	0.1	0.6	0.7	0.8	1.1	0.5	0.6	1.0	4.1	0.4	0.8
Reach Composition	**Riffle**	68%	79%	68%	83%	86%	89%	76%	85%	89%	72%	96%	100%	100%	93%
	Pool	13%	13%	13%	11%	7%	7%	21%	11%	7%	12%	4%	0%	0%	4%
Percent Riparian Cover		11%	24%	22%	4%	20%	9%	39%	30%	8%	14%	39%	35%	24%	33%
Herbaceous Cover Score (1-5)		3	3	3	4	5	5	5	5	5	5	5	5	5	5
Woody Cover Score (1-5)		4	2	3	2	1	2	4	3	2	2	3	3	3	3
Bank Condition	**Stable**	100%	100%	100%	100%	100%	100%	100%	100%	100%	93%	100%	100%	100%	97%
	Eroded	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Open	0%	0%	0%	0%	0%	0%	0%	0%	0%	7%	0%	0%	0%	3%
Bank Cover	**Herbaceous**	23%	7%	17%	53%	40%	37%	43%	43%	57%	57%	70%	77%	73%	70%
	Woody Bush	17%	10%	20%	3%	7%	17%	27%	27%	20%	27%	17%	17%	23%	23%
	Tree	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Armored	60%	83%	63%	43%	53%	47%	30%	30%	23%	13%	13%	7%	3%	7%
Bank Angle	**Shallow** (<30°)	3%	7%	17%	20%	3%	17%	10%	0%	7%	0%	0%	0%	0%	3%
	Moderate (30-90°)	87%	83%	77%	73%	70%	70%	40%	37%	23%	17%	50%	20%	27%	30%
	Undercut (>90°)	10%	10%	7%	7%	27%	13%	50%	63%	70%	83%	50%	80%	73%	67%

Notes: Discharge is calculated from paired depth and velocity measurements. Percent riparian cover is based on densiometer measurements within the stream channel. Herbaceous and woody cover scores are based on a visual assessment of riparian area vegetative cover types, with a score of 1 indicating sparse (<25%) and 5 indicating dense (>75%) cover.

		Outlet 10477 **Fish Removal**			**Outlet 11007** **Fishless Control**			**Outlet 10487** **Fish Removal**				**Outlet Vidette** **Fish Control**			
		07/20/03	07/07/04	07/27/11	07/21/03	07/09/04	07/26/11	07/22/03	07/08/04	07/26/11	07/19/12	07/23/03	07/06/04	07/27/11	07/20/12
Substrate Particle Size Distribution	**Fines** (0.01-0.25 mm)	3%	0%	1%	0%	0%	0%	0%	8%	0%	0%	1%	1%	1%	1%
	Sand (0.25-2 mm)	0%	0%	0%	0%	1%	0%	0%	0%	1%	0%	0%	0%	0%	1%
	Gravel (2-16 mm)	4%	0%	0%	11%	5%	4%	7%	13%	15%	11%	7%	5%	1%	5%
	Pebble (16-64 mm)	14%	8%	13%	16%	16%	35%	41%	28%	32%	48%	16%	24%	37%	47%
	Cobble (64-256 mm)	29%	40%	64%	43%	40%	48%	20%	25%	40%	25%	48%	47%	44%	33%
	Boulder (>256 mm)	51%	52%	21%	31%	37%	13%	32%	25%	12%	8%	28%	23%	16%	3%
D_{50} Substrate Particle Size (mm)		256	256	145	169	195	105	83	69	72	50	168	144	74	72
Percent Cobble Embeddedness	**Mean**	0%	6%	0%	0%	1%	8%	0%	9%	12%	18%	0%	9%	8%	11%
	Cobbles with Zero %	100%	92%	100%	100%	96%	80%	100%	72%	72%	52%	100%	88%	76%	76%
Substrate Cover	**Algae**	61%	21%	11%	16%	11%	9%	21%	8%	15%	45%	24%	15%	8%	8%
	Macrophyte	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Leaf	16%	7%	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%	0%	0%
	Wood	4%	3%	4%	0%	0%	0%	0%	0%	0%	0%	4%	3%	8%	3%
	Roots	1%	1%	0%	0%	0%	0%	8%	4%	0%	0%	3%	3%	0%	1%
	Detritus	13%	4%	0%	17%	7%	0%	4%	8%	0%	0%	3%	4%	0%	0%
	Moss	0%	0%	0%	0%	0%	0%	17%	0%	7%	8%	1%	7%	4%	8%
Temperature (^{o}C)		13.6	14.1	12.2	15.5	12.1	11.6	13.0	12.6	8.7	11.5	14.5	12.0	9.3	13.1
pH		5.00	5.93	5.49	5.56	6.10	5.91	6.20	6.36	6.47	7.68	6.09	6.39	6.47	7.38
Conductivity (uS)		5.8	6.3	6.0	13.9	13.3	9.2	19.5	19.5	15.1	22.0	16.5	17.6	13.0	17.3
DO (mg l^{-1})		6.4	8.0	-	6.4	8.0	-	6.6	7.5	-	-	7.0	8.0	-	-
Alkalinity (mg l^{-1} HCO_3)		20	23	16	28	22	18	28	22	20	16	24	20	20	16
Turbidity (ntu)		0.21	0.09	-	0.27	0.10	-	0.11	0.04	-	-	0.31	0.17	-	-
Silica (mg l^{-1})		5	3	3	4	3	1	7	1	2	9	5	5	14	4
FPOM (g m^{-2})	**Mean**	2.8	1.2	1.3	13.5	1.4	5.1	5.8	1.6	1.9	1.9	3.2	2.5	0.6	5.3
	S.D.	3.2	0.9	0.9	9.1	0.4	1.8	6.4	1.0	1.3	1.5	1.0	1.3	0.4	1.5
CPOM (g m^{-2})	**Mean**	78	85	123	90	61	117.3	156	88	60	127	122	103	57	193
	S.D.	16	17	87	53	26	39	219	64	24	57	47	19	29	62
Chlorophyll *a* (ug cm^{-2})	**Mean**	5.2	1.3	0.4	0.2	0.8	0.1	1.0	1.3	0.2	0.3	0.9	3.7	0.2	0.1
	S.D.	0.8	0.6	0.3	0.1	0.3	0.0	0.3	0.8	0.1	0.2	0.2	4.5	0.1	0.0

Notes: D_{50} substrate particle size is an estimate of the median particle size, based on the cummulative distribution. Mean fine particulate organic matter (FPOM), coarse particulate organic matter (CPOM), and chlorophyll *a* values are calculated from three replicate samples from each reach. CPOM (>1 mm, wet weight) is measured in the field. FPOM (<1 mm, ash free dry mass) and chlorophyll *a* (quantity of periphyton removed from cobble) are measured in the laboratory following collection and preservation in the field.

Table 2: Taxa lists for 2003-2004 and 2011-2012 (riffle / pool habitat samples combined). Trout-vunerable taxa denoted by **

					Outlet 10477	Outlet 11007	Outlet 10487	Outlet Vidette
Phylum	**Class**	**Order**	**Family** (or sub-)	**Genus & species** (some)	Treatment	Fishless Control	Treatment	Fish Control
Arthropoda	Insecta	Ephemeroptera	Baetidae	*Baetis*	**X**	**X**	**X**	**X**
				Callibaetis	**X**			
				Diphetor			**X**	**X**
			Ameletidae	*Ameletus***	**X**		**X**	**X**
			Heptageniidae	*Cinygmula*		**X**		**X**
				Epeorus			**X**	**X**
				Cinygma				**X**
			Leptophlebiidae	*Paraleptophlebia***		**X**	**X**	**X**
			Ephemerellidae	*Drunella flavilinea*			**X**	**X**
				Drunella coloradensis			**X**	
				Drunella spinifera				**X**
				Ephemerella tibialis			**X**	
				Serratella			**X**	**X**
		Plecoptera	Perlidae	*Doroneuria baumanni***			**X**	**X**
			Peltoperlidae	*Yoraperla*				**X**
			Perlodidae	*Isoperla*			**X**	
			Chloroperlidae	*Sweltsa*			**X**	**X**
				Suwallia		**X**		**X**
				Haploperla			**X**	
			Nemouridae	*Soyedina*				**X**
				Zapada			**X**	**X**
		Trichoptera	Rhyacophilidae	*Rhyacophila alberta group*	**X**	**X**	**X**	**X**
				Rhyacophila acropedes group			**X**	**X**
				Rhyacophila brunnea		**X**		**X**
				Rhyacophila betteni group			**X**	**X**
				Rhyacophila rotunda			**X**	
				Rhyacophila sibirica group				**X**
				Rhyacophila verrula group			**X**	**X**
			Arctopsychidae	*Parapsyche elsis***			**X**	**X**

Table 2. Cont.					Outlet 10477	Outlet 11007	Outlet 10487	Outlet Vidette
Phylum	**Class**	**Order**	**Family** (or sub-)	**Genus & species** (some)	Treatment	Fishless Control	Treatment	Fish Control
Arthropoda	Insecta	Trichoptera	Apataniidae	*Apatania***				**X**
			Limnephilidae	*Desmona*	**X**	**X**		
				Chyranda centralis				**X**
				Psychoglypha	**X**	**X**	**X**	**X**
				Dicosmoecus		**X**	**X**	**X**
				Ecclisomyia		**X**		**X**
			Brachycentridae	*Micrasema*				**X**
			Hydroptilidae	*Agraylea*			**X**	
		Megaloptera	Sialidae	*Sialis*	**X**			
		Hemiptera	Corixidae	*Cenocorixa***		**X**		
				*Arctocorisa sutilis***		**X**		
				*Graptocorixa californica***		**X**		
		Coleoptera	Dytiscidae	*Agabus***	**X**	**X**		
				Hydroporus		**X**		
				Sanfilippodytes	**X**	**X**	**X**	
				Oreodytes	**X**			
		Coleoptera	Elmidae	*Heterlimnius*			**X**	
		Diptera	Tipulidae	*Dicranota*	**X**	**X**	**X**	**X**
				Limonia		**X**		
				Monophilus	**X**			
				Ormosia (Rhypholophus)		**X**		
				Pedicia	**X**			
				Antocha				**X**
			Dolichopodidae	*Dolichopus*		**X**		
			Empididae	*Clinocera*		**X**	**X**	**X**
				Chelifera		**X**	**X**	**X**
				Neoplasta	**X**		**X**	**X**
			Culicidae	*Culiseta incidens*		**X**		
			Ceratopogonidae	*Bezzia-Palpomyia*			**X**	**X**
			Ceratopogonidae	*Stilobezzia*		**X**	**X**	

Table 2. Cont.					Outlet 10477	Outlet 11007	Outlet 10487	Outlet Vidette
Phylum	**Class**	**Order**	**Family** (or sub-)	**Genus & species** (some)	Treatment	Fishless Control	Treatment	Fish Control
Arthropoda	Insecta	Diptera	Ceratopogonidae	*Ceratopogon*		**X**		
				Culicoides				**X**
				Monohelea		**X**		
				Atrichopogon		**X**		
			Simuliidae	*Simulium (tuberosum)*	**X**	**X**	**X**	**X**
				Prosimulium	**X**		**X**	
				Prosimulium frohnei		**X**		
				Prosimulium travisi	**X**	**X**	**X**	
				Metacnephia		**X**		
				Stegopterna mutata complex	**X**	**X**		
			Sciaridae	*Sciara*		**X**		
			Muscidae	*Limnophora*	**X**	**X**	**X**	**X**
				Muscidae		**X**		
			Dixidae	*Dixa*				**X**
		Chironomidae	Podonominae	*Parochlus kiefferi*	**X**	**X**		**X**
				Boreochlus sinuaticornis			**X**	
			Diamesinae	*Diamesa*	**X**	**X**	**X**	**X**
				Pagastia	**X**	**X**	**X**	**X**
				Pseudodiamesa	**X**	**X**	**X**	**X**
			Prodiamesinae	*Monodiamesa*			**X**	**X**
			Tanypodinae	*Thienemannimyia group*	**X**	**X**	**X**	**X**
				Ablabesmyia	**X**	**X**		
				Apsectrotanypus			**X**	**X**
				Larsia		**X**		
				Psectrotanypus		**X**		
				Helopelopia	**X**		**X**	
				Krenopelopia	**X**		**X**	
				Trissopelopia				**X**
				Zavrelimyia	**X**	**X**	**X**	**X**
			Orthocladinae	*Acricotopus*			**X**	

Table 2. Cont.					Outlet 10477	Outlet 11007	Outlet 10487	Outlet Vidette
Phylum	**Class**	**Order**	**Family** (or sub-)	**Genus & species** (some)	Treatment	Fishless Control	Treatment	Fish Control
Arthropoda	Insecta	Chironomidae	Orthocladinae	*Brillia*			**X**	**X**
				Corynoneura	**X**	**X**	**X**	**X**
				Cricotopus-Nostococladius			**X**	
				Cricotopus-Orthocladius	**X**	**X**	**X**	**X**
				Diplocladius	**X**	**X**	**X**	
				Doithrix				**X**
				Eukiefferiella brehmi group	**X**		**X**	**X**
				Eukiefferiella claripennis group	**X**	**X**	**X**	**X**
				Eukiefferiella devonica group		**X**	**X**	
				Eukiefferiella gracei group	**X**		**X**	**X**
				Eukiefferiella rectangularis group		**X**	**X**	**X**
				Eukiefferiella similis group				**X**
				Heterotrissocladius marcidus group	**X**	**X**	**X**	**X**
				Heleniella		**X**	**X**	**X**
				Hydrobaenus	**X**	**X**	**X**	**X**
				Krenosmittia	**X**	**X**		
				Limnophyes	**X**	**X**		**X**
				Nanocladius parvulus group	**X**	**X**	**X**	**X**
				Orthocladius cf. rivulorum				**X**
				Parachaetocladius		**X**	**X**	
				Paralimnophyes	**X**			
				Parametriocnemus		**X**	**X**	**X**
				Paraphaenocladius	**X**	**X**	**X**	**X**
				Parasmittia				**X**
				Parorthocladius		**X**	**X**	**X**
				Psectrocladius limbatellus group	**X**			
				Psectrocladius sordidellus group		**X**	**X**	
				Rheocricotopus		**X**	**X**	**X**
				Smittia				**X**
				Symposiocladius			**X**	

Table 2. Cont.					Outlet 10477	Outlet 11007	Outlet 10487	Outlet Vidette
Phylum	**Class**	**Order**	**Family** (or sub-)	**Genus & species** (some)	Treatment	Fishless Control	Treatment	Fish Control
Arthropoda	Insecta	Chironomidae	Orthocladinae	*Synorthocladius*	**X**		**X**	**X**
				Thienemanniella fusca				**X**
				Thienemanniella cf. xena		**X**	**X**	**X**
				Tvetenia bavarica group	**X**	**X**	**X**	**X**
			Chironominae	*Apedilum*	**X**	**X**		
				Cladotanytarsus		**X**		
				Lithotanytarsus			**X**	
				Micropsectra	**X**	**X**	**X**	**X**
				Paracladopelma		**X**		
				Paratanytarsus		**X**	**X**	
				Phaenopsectra	**X**	**X**	**X**	
				Polypedilum aviceps			**X**	**X**
				Polypedilum laetum	**X**	**X**	**X**	
				Polypedilum tritum			**X**	
				Rheotanytarsus	**X**		**X**	
				Stempellina	**X**			
				Stempellinella			**X**	**X**
				Tanytarsus	**X**	**X**	**X**	
Crustacea	Ostracoda	undetermined	undetermined	*undetermined ostracodes*	**X**	**X**	**X**	**X**
Tardigrada		tardigrades	Hypsibiidae	*Hypsibius*	**X**	**X**		
Molluska	Bivalvia		Sphaeriidae	*Pisidium*			**X**	**X**
Platyhelminthes	Turbellaria			*Turbellaria undet.***	**X**	**X**	**X**	**X**
Annelida	Oligochaeta	undetermined	undetermined	*undetermined oligochaetes*	**X**	**X**	**X**	**X**
Chelicerata	Arachnida	Actinedida	Halacaridae	*Halacaridae*	**X**	**X**	**X**	**X**
		Hydrachnidia	Lebertiidae	*Lebertia*	**X**	**X**	**X**	**X**
				Estelloxus				**X**
			Arrenuridae	*Arrenurus*	**X**			
			Ascidae	*Cheiroseius*	**X**	**X**	**X**	**X**
			Aturidae	*Aturus*		**X**	**X**	**X**
				Brachypoda	**X**		**X**	**X**

Table 2. Cont.					Outlet 10477	Outlet 11007	Outlet 10487	Outlet Vidette
Phylum	**Class**	**Order**	**Family** (or sub-)	**Genus & species** (some)	Treatment	Fishless Control	Treatment	Fish Control
Chelicerata	Arachnida	Hydrachnidia	Aturidae	*Ljania*			**X**	**X**
			Hygrobatidae	*Atractides*			**X**	**X**
				Hygrobates				**X**
			Feltriidae	*Feltria*		**X**	**X**	**X**
			Sperchontidae	*Sperchon (some cf. crassipalpis)*		**X**	**X**	**X**
			Stygothrombidiidae	*Stygothrombium*			**X**	**X**
			Torrenticolidae	*Testudacarus*		**X**	**X**	**X**
				Torrenticola			**X**	**X**
			Hydryphantidae	*Wandesia*				**X**
			Anisitsiellidae	*Utaxatax*			**X**	
		Oribatida	Malaconothridae	*Trimalaconothrus*	**X**	**X**	**X**	**X**
			Hydrozetidae	*Hydrozetes / Limnozetes*	**X**	**X**	**X**	**X**
				Hydrozetes aquaticus			**X**	
			Trhypochthoniidae	*Trhypochthoniellus*			**X**	

Table 3. Taxa list and relative abundance from combined remnant pool collections (5-10 samples each) taken in 2012 from the smaller study streams, Outlets 10477 and 11007. These pools could not be quantitatively samples as they could be accessed only with small nets from bottom-areas that could not be measured (relative abundance is the fraction of total individuals counted from combined samples for >300 specimens each).

Table 3. Relative percent abundance of taxa collected from remnant pools at two sites with no surface flow in 2012.					Relative Abundance (%)	
					Outlet 11007	Outlet 10477
Phylum	Class	Order	Family (or sub-)	Genus & species (some)	fishless target	treatment
Arthropoda	Insecta	Ephemeroptera	Baetidae	*Baetis*	3.5	
				*Callibaetis***		1.2
			Ameletidae	*Ameletus***		15.3
			Heptageniidae	*Cinygmula*	0.7	
		Plecoptera	Perlodidae	*Isoperla*	0.7	
		Trichoptera	Limnephilidae	*Desmona*	2.1	0.9
		Coleoptera	Ditiscidae	*Sanfilippodytes*		0.3
				Oreodytes		1.2
		Diptera	Tipulidae	*Dicranota*	0.7	
			Empididae	*Clinocera*	0.3	
			Chironomidae	*Pseudodiamesa*		1.5
				Zavrelimyia	2.8	
				Acricotopus		23.6
				Corynoneura	5.9	14.2
				Cricotopus-Orthocladius	21.3	0.6
				Hydrobaenus	1.4	
				Psectrocladius sordidellus group	33.1	
				Rheocricotopus	0.7	
				Micropsectra	13.2	35.7
				Phaenopsectra	5.2	4.1
				Polypedilum laetum	0.7	
				Rheotanytarsus	0.7	
Crustacea	Ostracoda	undetermined	undetermined	*undetermined ostracodes*	0.7	
Platyhelminthes	Turbellaria			Turbellaria undet.**		0.3
Annelida	Oligochaeta	undetermined	undetermined	*undetermined oligochaetes*	3.1	0.9
Chelicerata	Arachnida	Oribatida	Malaconothridae	*Trimalaconothrus*	3.1	0.3

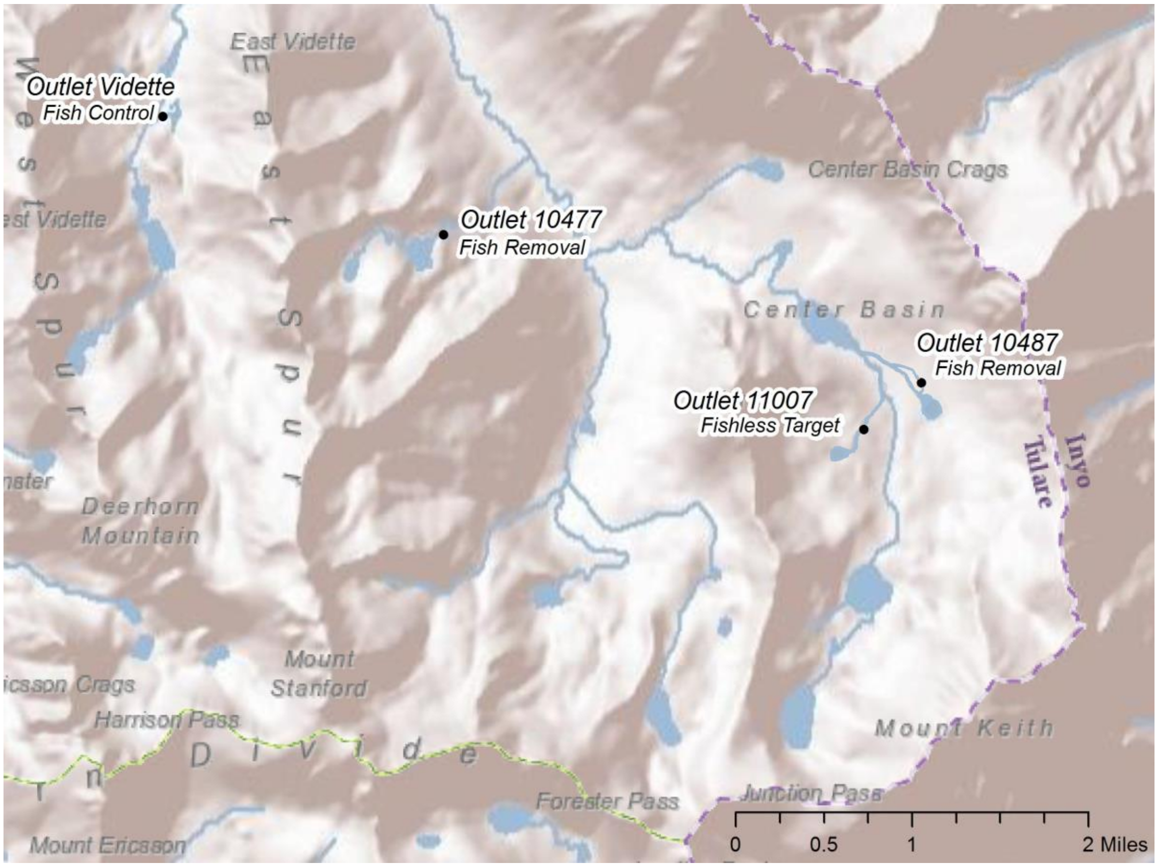

Figure 1. Map showing the 4 study streams contrasted before and after trout removals.

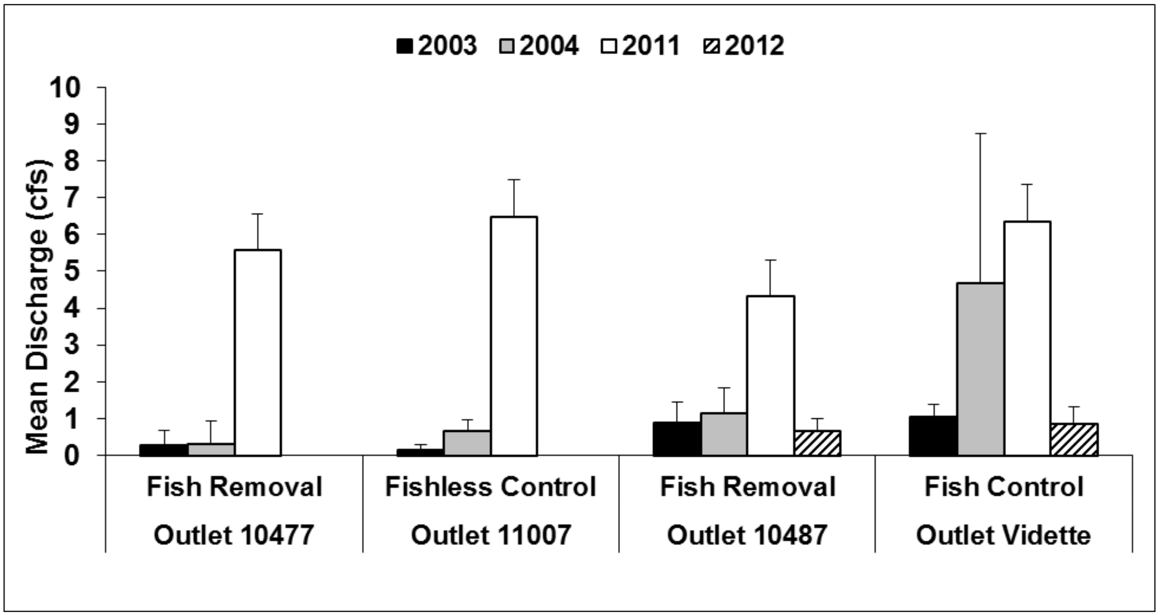

Figure 2: Mean Discharge (error bar is 1 S.D.). No discharge in 2012 in 10477 & 11007 at the time of sampling as these had dried down to remnant pools (also for Figures 3-7).

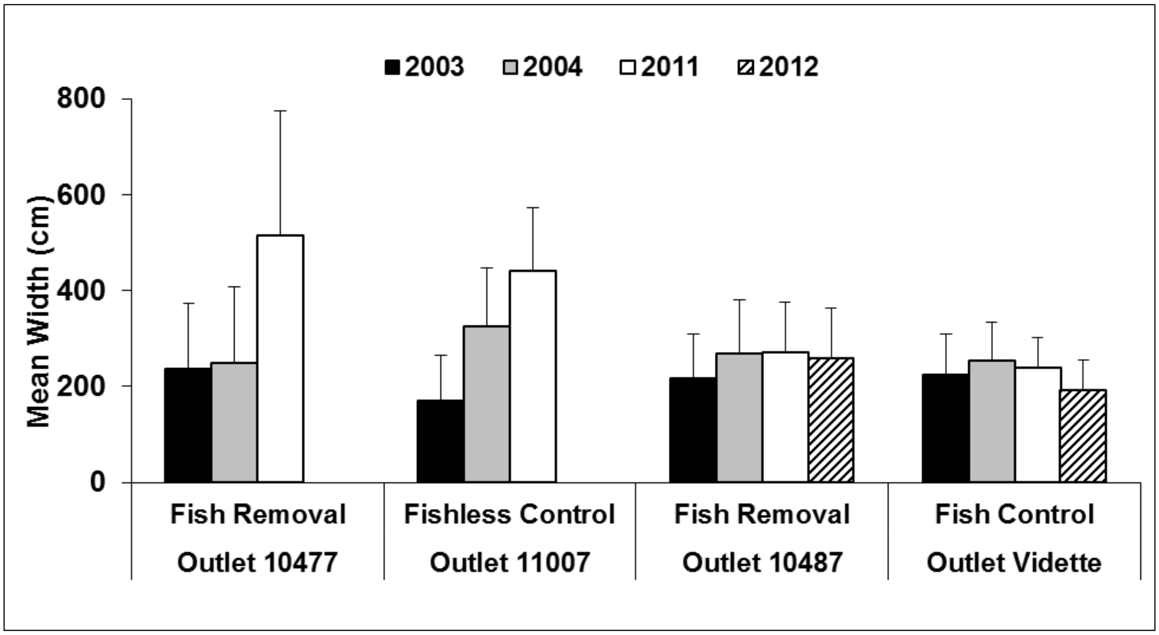

Figure 3: Mean Width (error bar is 1 S.D.).

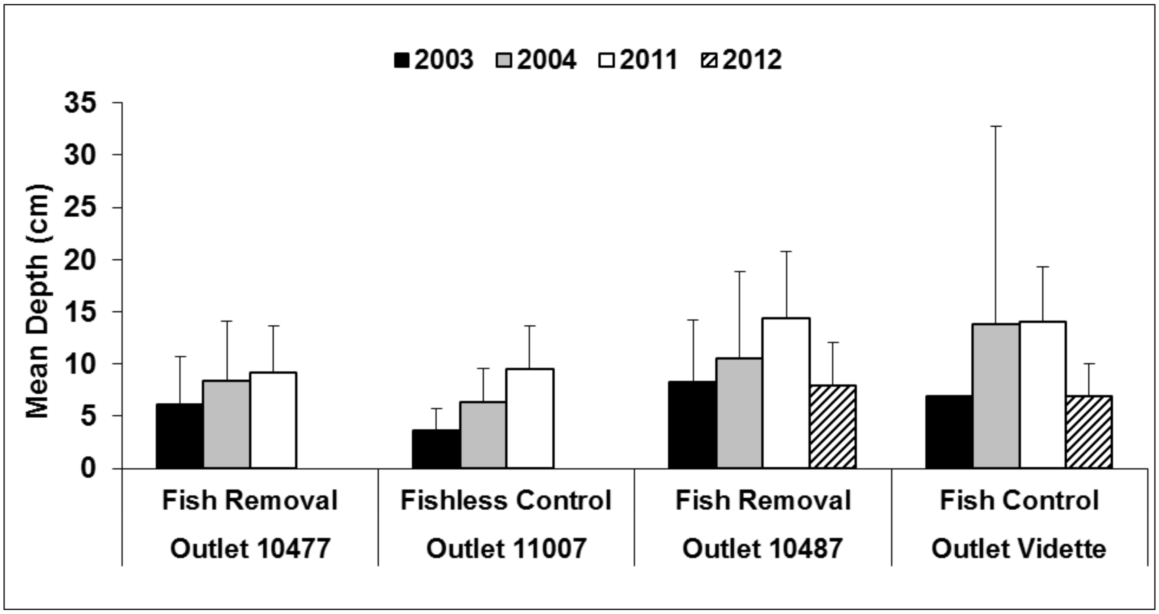

Figure 4: Mean depth (error bar is 1 S.D.).

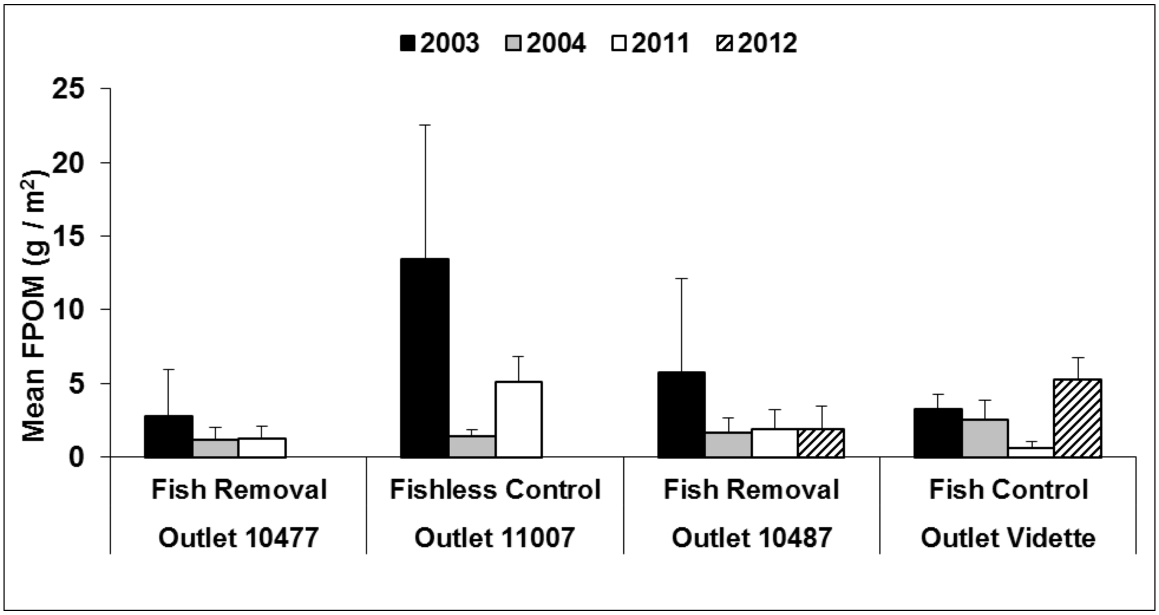

Figure 5: Mean FPOM (error bar is 1 S.D.).

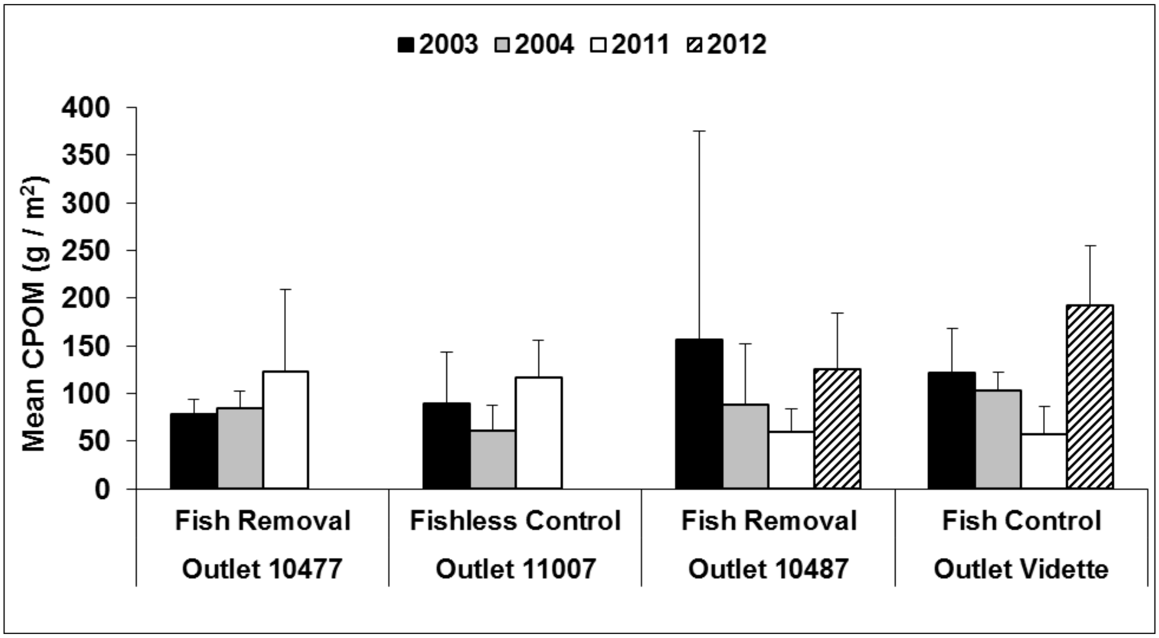

Figure 6: Mean CPOM (error bar is 1 S.D.).

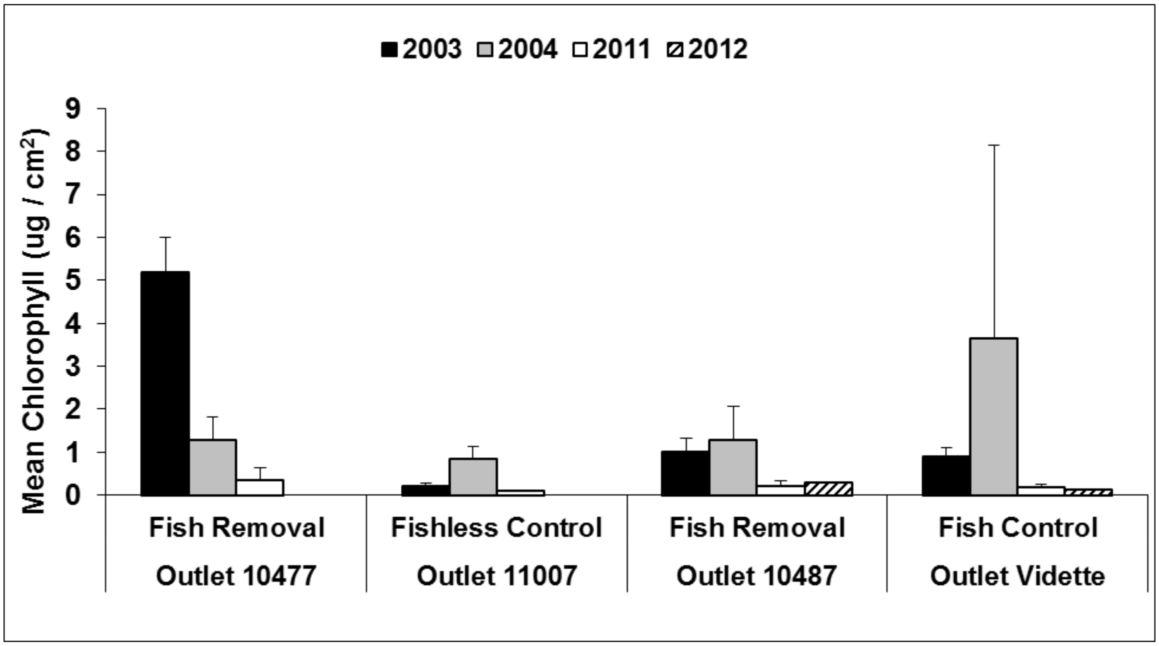

Figure 7: Mean Chlorophyll *a* (error bar is 1 S.D.).

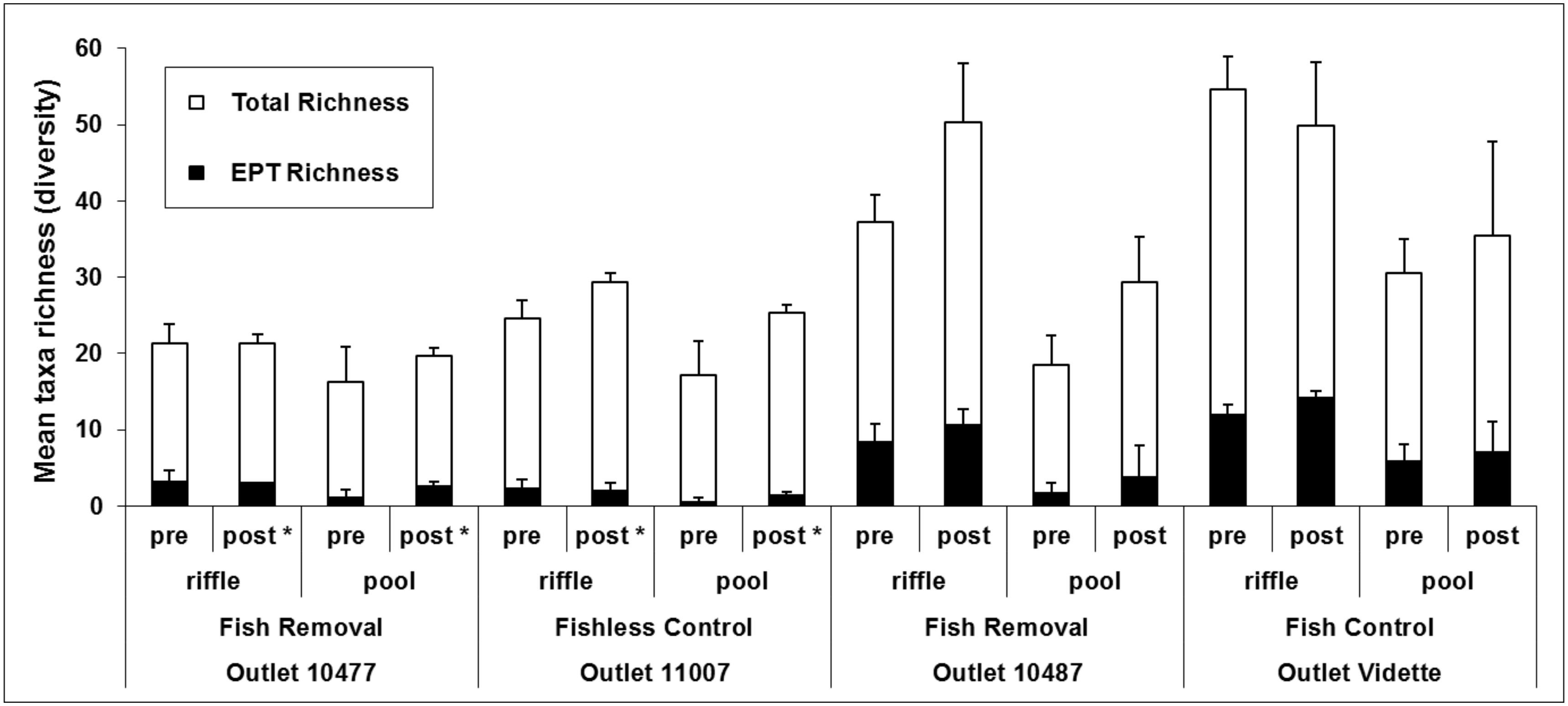

Figure 8. Mean (+ 1 SD) taxonomic richness of all taxa and of EPT taxa for samples collected during pre-fish removal (2003 and 2004) and post-fish removal (2011 and 2012). Mean and SD based on three spatial replicates each of riffle and pool habitats over two sample years, n=6. Note: bars labeled post* indicate mean values from 2011 only (n=3), no samples collected when sites surface flow dry in 2012. Relative abundance data for taxa collected in remnant pools of 2012 reported in Table 3.

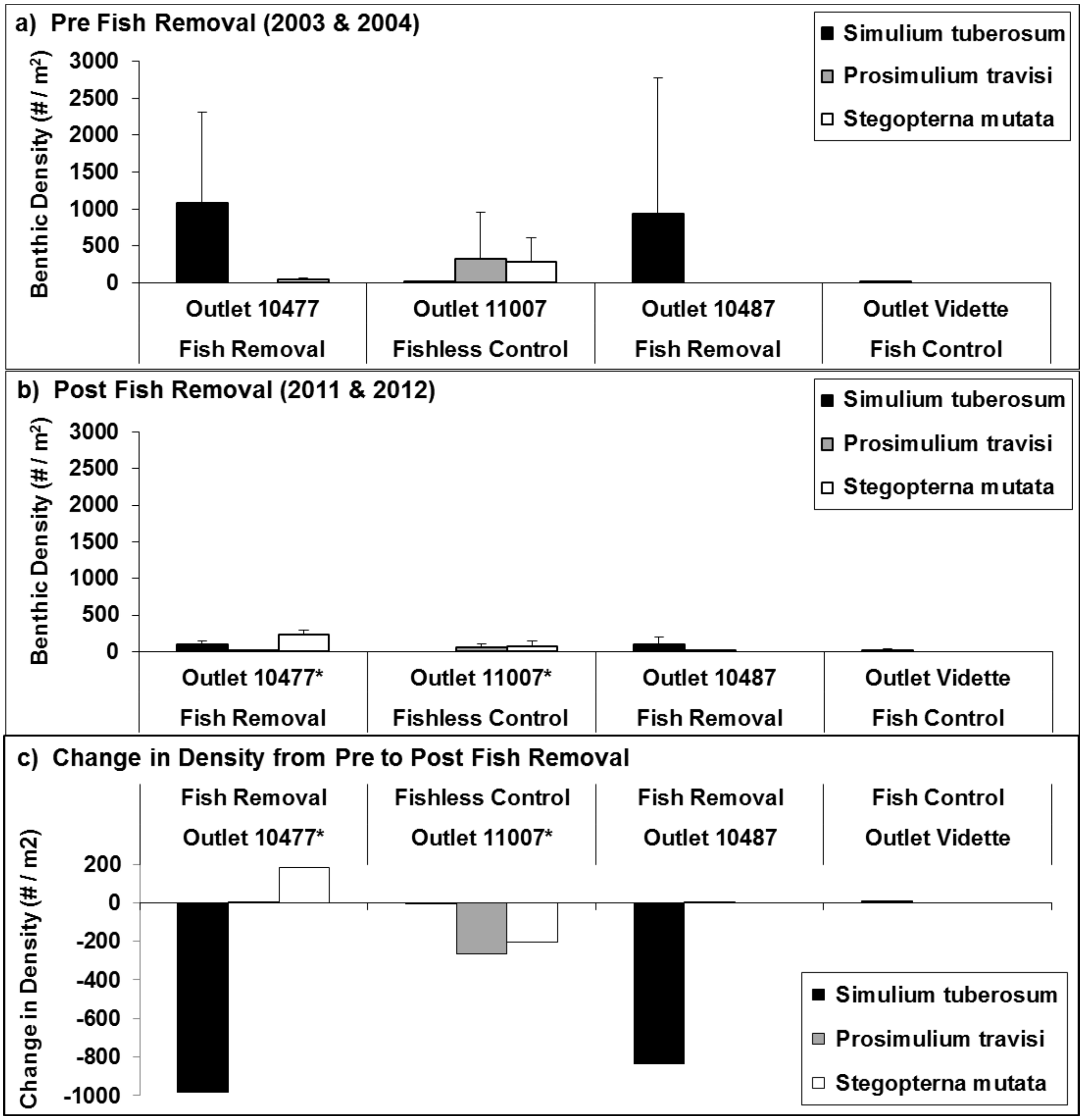

Figure 9. Mean (+ 1 SD) benthic density of three Simulidae taxa for riffle samples collected during a) pre-fish removal (2003 and 2004) and b) post-fish removal (2011 and 2012) with c) representing the difference in density between those years. Mean and SD based on three spatial replicates of riffles over two sample years (n=6). Note: sites labeled with * indicate mean post fish removal values from 2011 only (n=3), no samples collected when dry in 2012 for those sites (but see Table 3).

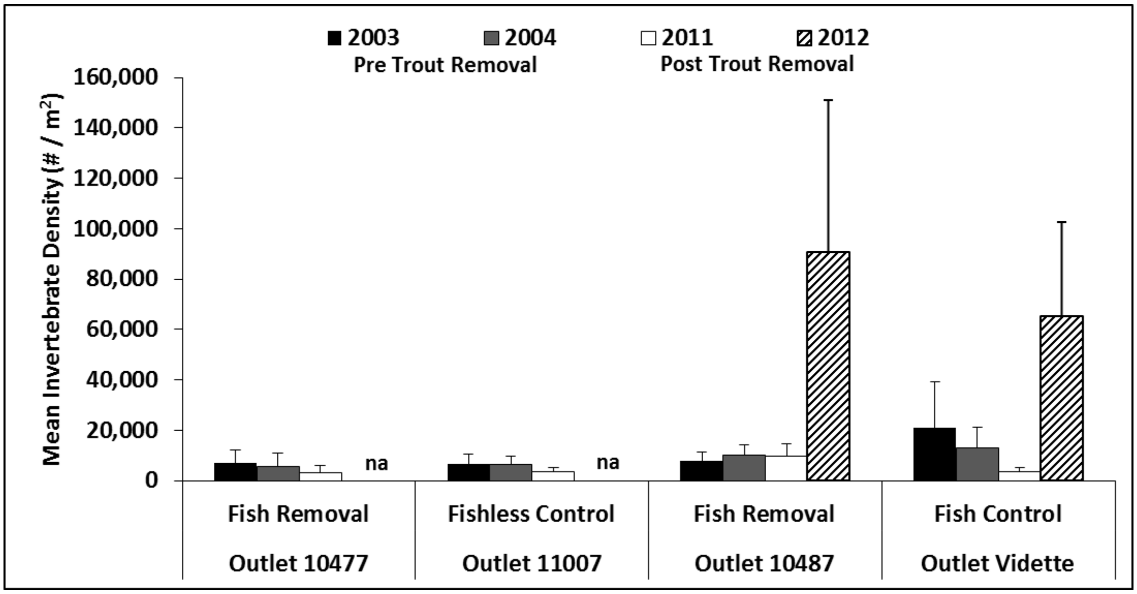

Figure 10. Mean (+ 1 SD) density of all invertebrates collected in 2003, 2004, 2011, and 2012 from each of four sites. Mean and SD based on 3 spatial replicates each of riffles and pools combined (n=6). Note: na indicates no samples collected when dry in 2012 (but see Table 3).

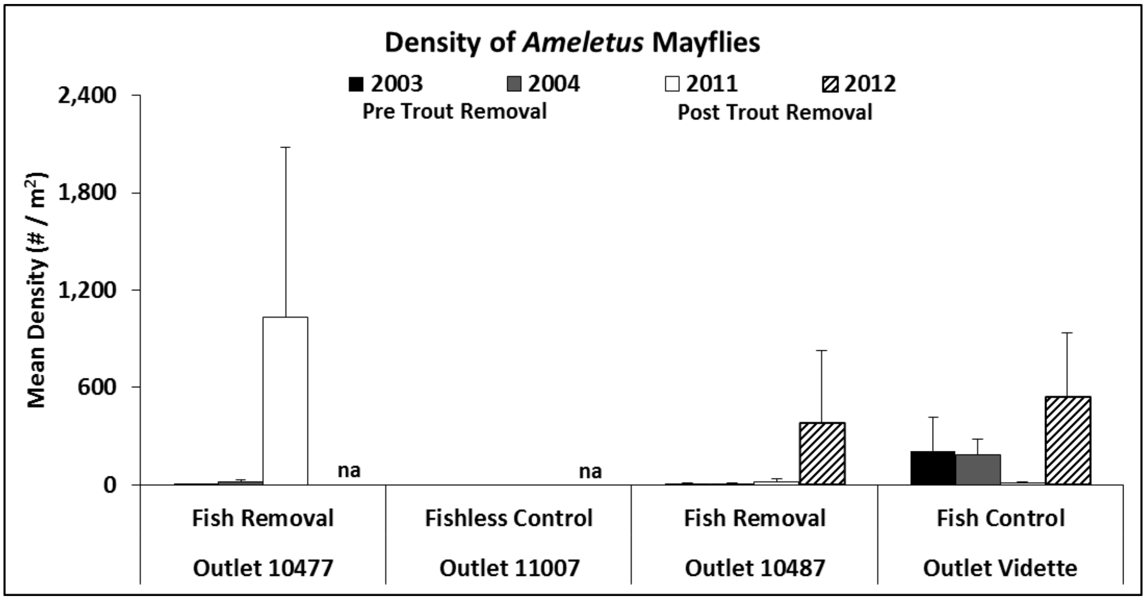

Figure 11. Mean (+ 1 SD) density of *Ameletus* collected in 2003, 2004, 2011, and 2012 from each of four sites. Mean and SD based on 3 spatial replicates each of riffles and pools combined (n=6). Note: na indicates no samples collected when dry in 2012 (but see Table 3).

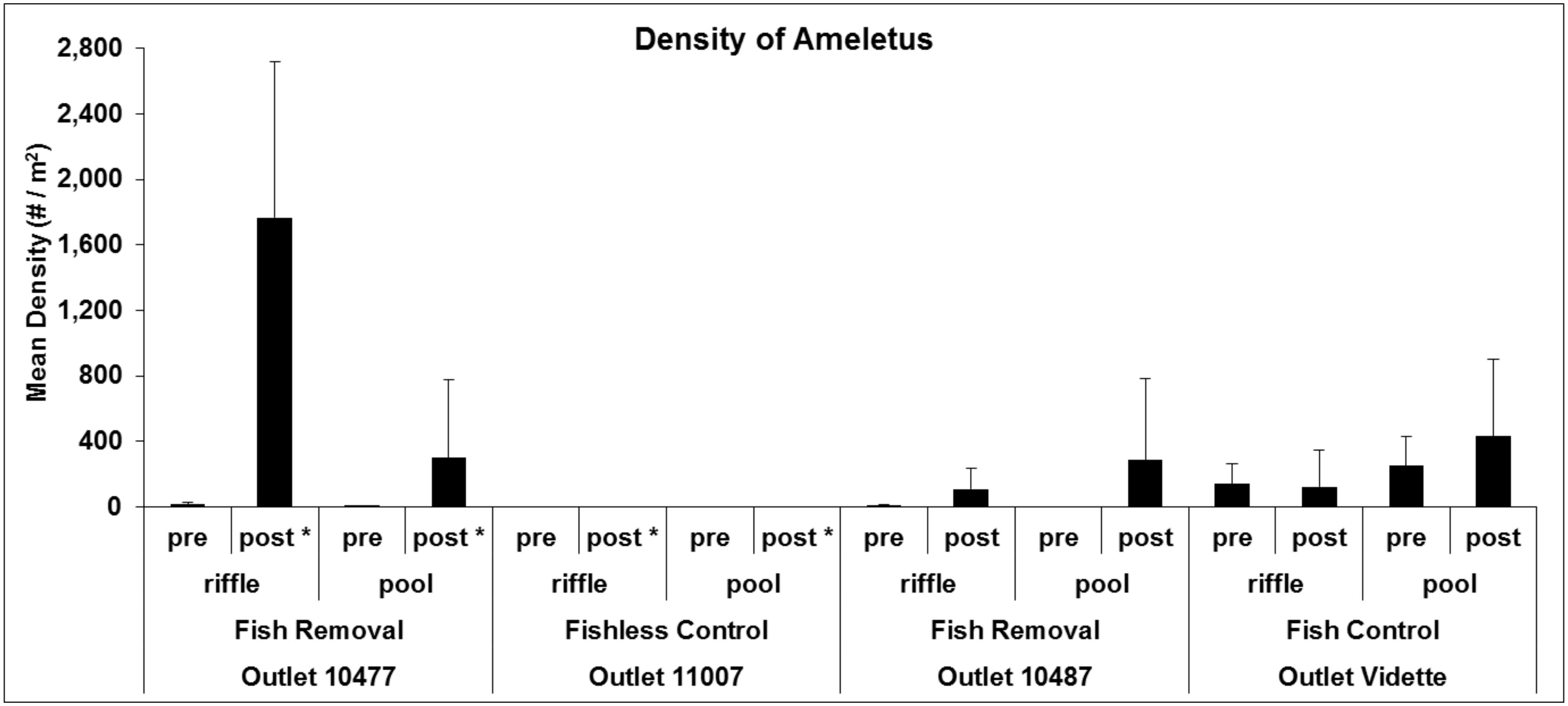

Figure 12. Mean (+ 1 SD) benthic density of *Ameletus* mayflies during pre-removal (2003-2004) and post-removal (2011-2012) of trout in four small lake outlet streams. Mean and SD based on three spatial replicates each of riffles and pools over two sample years (n=6). Note: bars labeled post* indicate mean values from 2011 only (n=3), no quantitative samples collected in 2012 for those sites (see Table 3 for relative abundances by taxa).

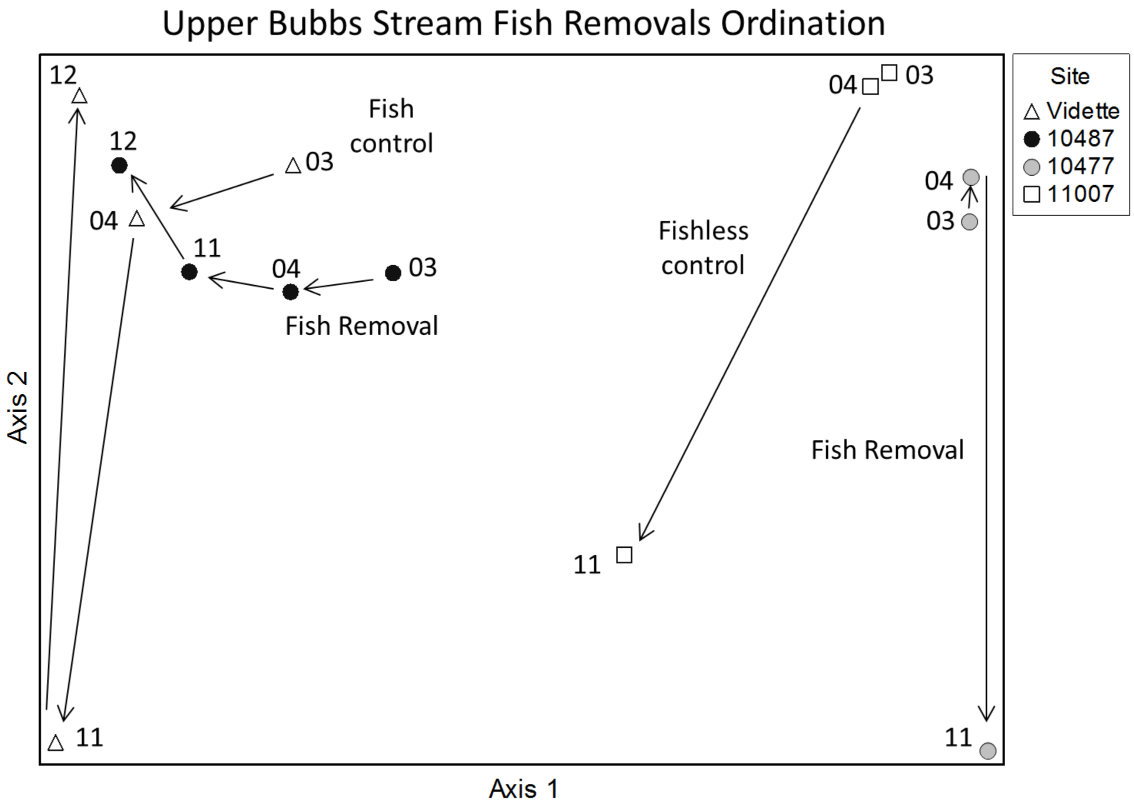

Figure 13. Community composition ordination for fish removal and control sites within Sequoia Kings National Park. Numbers refer to year (e.g., 2003 = 03, etc). Fish removals occurred in 2005-2010. Only one year of "post removal" data was collected for outlet 10477 and outlet 11007 because these small streams were dry in 2012. This analysis was based on 48 of the 162 total taxa collected, including just those present in more than 2 site-collection dates and comprised more than 1% abundance (i.e. rare taxa were removed from the analysis). The ordination shown has a 2-dimensional solution and stress = 9.5; the indicator taxa most responsible for the shift to low values on axis 2 in 2011 were the small mites *Cheiroseius* and Halacaridae and the midges *Limnophyes* and *Diamesa*. Larger stream sample-dates group on the left, and smaller streams group on the right.