

**Evaluating Recovery of Stream Invertebrate Communities Following
Removal of Introduced Trout in Kings Canyon National Park:
Baseline Biological Stream Surveys**

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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. 2003). 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 have 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 will also include removals from several lake outlet streams, and this provides 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, will provide data permitting assessment of the potential for restoration. This report documents the pre-removal baseline conditions of 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, while the other two were deeper streams with higher discharge volume, and located on side channels, exiting and returning to larger streams. The former pair are a fishless control and a trout-removal treatment, and the latter pair another trout-removal treatment and a trout-control (no removal to be done). These pairs, having contrasting habitat features, will form the basis for comparisons. The two larger streams were similar

in taxonomic composition and had higher diversity than the two smaller outlet streams. Invertebrate taxa that are expected to be most vulnerable to trout presence (*Ameletus*, *Paraleptophlebia*, *Doroneuria*, *Parapsyche*, *Apatania*, Corixid water boatmen, Dytiscid diving beetles, and flatworms), as suggested by earlier studies, were present in low numbers in the streams from which trout will be removed. There is thus the potential for a rapid numerical response to fish removal in these streams. Response to fish removal is likely to be easier to detect in the larger treatment stream than the smaller treatment stream because few vulnerable taxa were present even in the small fishless target, suggesting a limited scope for change in the small streams. However, the fishless stream had the least amount of algae present, as observed in previous studies, and among filter-feeding black flies, *Prosimulium* (mostly *travisi*) and *Stegopterna mutata* complex were abundant, but were rare or absent in the trout streams. Conversely, *Simulium (tuberosum)* was common to abundant in the small 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*. The two years of post-trout removal studies to come will reveal how the black fly populations and other vulnerable invertebrates respond to the absence of fish, and whether restoration of historical ecological values to trout-stocked streams is possible in this setting.

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 (25% of species in the Sierra are endemic) and caddisflies (19% endemic species), representing a significant national 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 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. 2003). 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. In the SEKI mountain yellow-legged frog restoration project, introduced trout are currently being removed from several lakes and stream segments in two restoration areas. The stream invertebrate communities were not sampled before fish removal, preventing evaluation of community response to restoration. However, beginning in 2005, SEKI will begin removing introduced trout from two lakes and

adjacent streams in a new restoration area, providing an opportunity to evaluate the effect of trout removal on the recovery of stream invertebrate communities. Conducting two seasons of both pre-treatment and post-treatment invertebrate sampling will allow SEKI to evaluate the recovery rate 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 completed in SEKI with minimal samples 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 are to: 1) evaluate the potential for recovery of streams after the removal of introduced trout; 2) evaluate differences in the structure and diversity of benthic invertebrate communities between fishless and fish-stocked paired-watershed streams in SEKI; 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 will accomplish the following work: 1) conduct two seasons of both pre-treatment and post-treatment invertebrate sampling in four SEKI streams in the Bubbs Creek sub-basin of the South Fork of the Kings River; and 2) use a BACI statistical design (before-after, control-impact) or multiple paired comparisons tests, in which two treated streams (fish removed) are compared with one control untreated streams (fish not removed), and one fishless target stream (to establish the potential scope for recovery), before and after the treatment period to assess changes in the diversity and functional organization of the benthic invertebrate community.

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. All study streams were matched for similarity according to order, channel size, location, watershed area, elevation, length, gradient, aspect, and riparian canopy. We examined stream community structure and a variety of physical and chemical factors in each study stream.

A representative 75 meter reach length was selected in each of the study streams for survey during the summer months over a two year pre-treatment period. Benthic invertebrate samples were taken using a D-frame kick net (250 micron mesh, 0.09 square meter area) in 3 riffle (3 composited kick samples from each riffle) and 3 pool habitats (1 collection from each pool) from within each reach. Samples were preserved in 80% ethanol with Rose Bengal added as stain. All specimens in larval form were identified to genus (species where possible) and samples archived (oligochaetes and ostracods were not further identified). 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.

The algae and organic matter measures permit quantification of invertebrate food resources. Algal biomass was determined by scraping periphyton from rocks, then subsampling for chlorophyll analysis and taxonomic composition. 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 in each study reach were determined along a series of cross-stream transects (depth, substrate size, current velocity, bank cover, riparian canopy). Water quality measures included temperature, pH, alkalinity, conductivity, dissolved oxygen, silica, and turbidity.

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 many but not all trout-containing streams relative to native fishless streams (Herbst et al. 2003). These changes suggest that trout can reduce vulnerable native taxa and alter the structure and function of high Sierra streams. The pre-trout removal studies reported here will establish the composition of the existing benthic biota, and potential scope for biological response in high elevation lake outlet streams.

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 1-3). This may explain declines in the quantity of retained FPOM and CPOM (all sites except Outlet 10477) in 2004 (Figures 4 and 5). Periphyton biomass, as indicated by chlorophyll *a* measurements, increased in 2003-2004 at all sites except Outlet 10477 (Figure 6).

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 will have fish removed while 11007 is fishless, and Outlet 10487 will have fish removed while Outlet Vidette will retain its exotic trout population.

The fishless target stream, Outlet 11007, conforms to expectations from the results of studies in Yosemite in terms of having lower chlorophyll *a* density than all the other streams (presently containing trout). This pattern is also consistent in the fishless target site having the lowest percent cover by visible macroalgae, which may be explained by the absence of predatory pressure on invertebrate grazers by fish.

During the period of the baseline study, from the four subject streams, over 30,000 individual invertebrate specimens were counted and identified, comprising 126 distinct taxa. Relative to pairing with the most similar fish-containing outlet stream, the invertebrate community of the fishless target was consistent with previous results in Yosemite - there was somewhat higher overall diversity (53 vs. 50 total taxa, 8 vs. 6 vulnerable taxa, and mean diversity higher in riffles, and higher or even in pools, Figure 7a and 7b), and several vulnerable taxa were rare in the fish-containing stream (i.e. Triclad flatworms, mobile swimmers in the form of some diving beetles and water boatmen). The two larger streams were similar in taxonomic composition and had higher diversity than the two smaller outlet streams (Figure 7). Taxa that are expected to be most vulnerable to trout presence (*Ameletus*, *Paraleptophlebia*, *Doroneuria*, *Parapsyche*, *Apatania*, Corixid water boatmen, Dytiscid diving beetles, and flatworms), as suggested by the Yosemite studies, were found at low percentages in the streams from which trout will be removed (Table 2). Thus, there is the potential for a rapid numerical response to fish removal in these streams. Response to fish removal is likely to be easier to detect in the larger treatment stream (Outlet 10487) than the smaller stream (Outlet 10477) because few vulnerable taxa were present even in the small fishless target (Outlet 11007), suggesting a limited scope for change in the small streams. One interesting pattern was observed, however, among filter-feeding black flies that showed *Prosimulium* (mostly *travisi*) and *Stegopterna mutata* complex were abundant in the fishless stream Outlet 11007, but were rare or absent in the trout streams. Conversely, *Simulium (tuberosum)*

was common to abundant in the paired Outlet 10477, but rare in the fishless stream (Figure 8). There may be something about the biology of the former taxa that would make them more vulnerable to trout predation compared to *Simulium*. 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 two years of post-trout removal studies ahead will reveal how the black fly populations respond to the absence of fish, with a large potential scope for this response.

Overall densities were between 3 and 12 thousand per-square-meter in all streams except pools in the Outlet Vidette, where densities were in the 15 to 40 thousand range and in Outlet 10477, where pool densities were less than 1,000 per square meter in 2004 (Figure 9a and 9b). Though population densities are often 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.

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 is consistently greater in riffles than pools, and the larger streams support higher diversity, with more of the variety represented by mayflies, stoneflies and caddisflies (Figures 7a and 7b). One finding of interesting note in 2004 was the collection of tardigrades, or

water bears (genus *Hypsibius*), found 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.

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. 2003) 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. If the post-removal follow-up studies fail to show recovery within two years, it may also be necessary to re-visit the treatment sites after a longer period to assess the potential for a slower recovery response than anticipated.

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Table 1: Summary of physical habitat measurements in 2003 and 2004.

		Outlet Vidette below Upper Lakes		Outlet 10487 Treatment		Outlet 11007 Fishless Target		Outlet 10477 Treatment	
Latitude		36° 44.393'		36° 43.338'		36° 43.152'		36° 43.928'	
Longitude		118° 24.567'		118° 20.846'		118° 21.129'		118° 23.188'	
Elevation (m)		3,200		3,430		3,500		3,420	
Slope		5.2%		4.4%		8.7%		6.6%	
Sinuosity		1.31		1.24		1.08		1.07	
Aspect		20° (NNE)		330° (NNW)		0° (N)		45° (NE)	
Date		7/23/03	7/6/04	7/22/03	7/8/04	7/21/03	7/9/04	7/20/03	7/7/04
Width (cm)	Mean	225	253	217	269	169	326	235	249
	S.D.	84	80	92	112	96	122	137	159
Depth (cm)	Mean	7	14	8	10	4	6	6	8
	S.D.	4	19	6	8	2	3	5	6
Maximum Depth (cm)		23	122	46	50	10	16	26	27
Velocity (cm s⁻¹)	Mean	23	29	14	17	4	10	5	4
	S.D.	23	26	14	18	8	13	11	10
Discharge (cfs)	Mean	1.0	4.7	0.9	1.2	0.1	0.7	0.3	0.3
	S.D.	0.3	4.1	0.5	0.7	0.2	0.3	0.4	0.6
	Non-Zero Mean	1.0	4.1	0.9	1.2	0.2	0.7	0.4	0.5
	S.D.	0.3	4.0	0.5	0.6	0.2	0.3	0.4	0.7
	Mode (10% bins)	1.0	4.1	0.8	1.1	0.1	0.6	0.1	0.2
Reach Composition	Riffle	96%	100%	76%	85%	83%	86%	68%	79%
	Pool	4%	0%	21%	11%	11%	7%	13%	13%
Percent Riparian Cover		39%	35%	39%	30%	4%	20%	11%	24%
Herbaceous Cover Score (1-5)		5	5	5	5	4	5	3	3
Woody Cover Score (1-5)		3	3	4	3	2	1	4	2
Bank Condition	Stable	100%	100%	100%	100%	100%	100%	100%	100%
	Eroded	0%	0%	0%	0%	0%	0%	0%	0%
	Open	0%	0%	0%	0%	0%	0%	0%	0%
Bank Cover	Herbaceous	70%	77%	43%	43%	53%	40%	23%	7%
	Woody Bush	17%	17%	27%	27%	3%	7%	17%	10%
	Tree	0%	0%	0%	0%	0%	0%	0%	0%
	Armored	13%	7%	30%	30%	43%	53%	60%	83%
Bank Angle	Shallow (<30°)	0%	0%	10%	0%	20%	3%	3%	7%
	Moderate (30-90°)	50%	20%	40%	37%	73%	70%	87%	83%
	Undercut (>90°)	50%	80%	50%	63%	7%	27%	10%	10%

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.

Table 1 (continued): Summary of physical habitat measurements in 2003 and 2004.

		Outlet Vidette below Upper Lakes		Outlet 10487 Treatment		Outlet 11007 Fishless Target		Outlet 10477 Treatment	
		07/23/03	07/06/04	07/22/03	07/08/04	07/21/03	07/09/04	07/20/03	07/07/04
Substrate Particle Size Distribution	Fines (0.01-0.25 mm)	1%	1%	0%	8%	0%	0%	3%	0%
	Sand (0.25-2 mm)	0%	0%	0%	0%	0%	1%	0%	0%
	Gravel (2-16 mm)	7%	5%	7%	13%	11%	5%	4%	0%
	Pebble (16-64 mm)	16%	24%	41%	28%	16%	16%	14%	8%
	Cobble (64-256 mm)	48%	47%	20%	25%	43%	40%	29%	40%
	Boulder (>256 mm)	28%	23%	32%	25%	31%	37%	51%	52%
D ₅₀ Substrate Particle Size (mm)		168	144	83	69	169	195	256	256
Percent Cobble Embeddedness	Mean	0%	9%	0%	9%	0%	1%	0%	6%
	Cobbles with Zero %	100%	88%	100%	72%	100%	96%	100%	92%
Substrate Cover	Algae	24%	15%	21%	8%	16%	11%	61%	21%
	Macrophyte	0%	0%	0%	0%	0%	0%	0%	0%
	Leaf	1%	1%	0%	0%	0%	0%	16%	7%
	Wood	4%	3%	0%	0%	0%	0%	4%	3%
	Roots	3%	3%	8%	4%	0%	0%	1%	1%
	Detritus	3%	4%	4%	8%	17%	7%	13%	4%
	Moss	1%	7%	17%	0%	0%	0%	0%	0%
Temperature (°C)		14.5	12.0	13.0	12.6	15.5	12.1	13.6	14.1
pH		6.09	6.39	6.20	6.36	5.56	6.10	5.00	5.93
Conductivity (uS)		16.5	17.6	19.5	19.5	13.9	13.3	5.8	6.3
DO (mg l ⁻¹)		7.0	8.0	6.6	7.5	6.4	8.0	6.4	8.0
Alkalinity (mg l ⁻¹ HCO ₃)		24	20	28	22	28	22	20	23
Turbidity (ntu)		0.31	0.17	0.11	0.04	0.27	0.10	0.21	0.09
Silica (mg l ⁻¹)		5	5	7	1	4	3	5	3
FPOM (g m ⁻²)	Mean	3.2	2.5	5.8	1.6	13.5	1.4	2.8	1.2
	S.D.	1.0	1.3	6.4	1.0	9.1	0.4	3.2	0.9
CPOM (g m ⁻²)	Mean	122	103	156	88	90	61	78	85
	S.D.	47	19	219	64	53	26	16	17
Chlorophyll a (ug cm ⁻²)	Mean	0.9	3.7	1.0	1.3	0.2	0.8	5.2	1.3
	S.D.	0.2	4.5	0.3	0.8	0.1	0.3	0.8	0.6

Notes: D₅₀ substrate particle size is an estimate of the median particle size, based on the cumulative 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 and 2004 (riffle and pool habitat samples combined)

Class	Order	Family (or sub-)	Genus & species (some)	Outlet 10477	Outlet 11007	Outlet 10487	Outlet Vidette	
Insecta	Ephemeroptera	Baetidae	Baetis	0.0059	0.0182	0.0249	0.0095	
			Dipheter			0.0069	0.0046	
		Ameletidae	Ameletus**	0.0011		0.0004	0.0147	
		Heptageniidae	Cinygmula		0.0001		0.0060	
			Epeorus			0.0005		
		Leptophlebiidae	Paraleptophlebia**		0.0010	0.0189	0.0203	
		Ephemereilidae	Drunella spinifera				0.0001	
			Serratella			0.0008	0.0003	
		Plecoptera	Rhyacophila baumanni**			0.0007	0.0070	
		Perlidae	Isoperla			0.0001		
		Chloroperlidae	Sweltsa			0.0003	0.0031	
			Suwallia		0.0001		0.0003	
		Nemouridae	Soyedina				0.0001	
			Zapada			0.0014	0.0038	
	Trichoptera	Rhyacophilidae	Rhyacophila alberta group	0.0034		0.0006	0.0007	
			Rhyacophila acropedes group			0.0003	0.0005	
			Rhyacophila betterni group			0.0014	0.0003	
			Rhyacophila sibirica group				0.0002	
			Rhyacophila verrula group			0.0001	0.0002	
		Arctopsychidae	Parapsyche almota**			0.0001		
			Parapsyche elsis**			0.0003	0.0003	
		Apataniidae	Apatania**				0.0085	
		Limnephilidae	Desmona	0.0015	0.0007			
			Chyranda centralis				0.0001	
		Psychoglypha	0.0008		0.0001	0.0020		
	Megaloptera	Sialidae	Sialis		0.0002	0.0009	0.0002	
	Hemiptera	Corixidae	Cenocorixa**	0.0002				
			Arctocorisa sutilis**		0.0002			
	Coleoptera	Dytiscidae	Graptocorixa californica**			0.0001		
			Agabus**	0.0005	0.0041			
			Hydroporus	0.0002	0.0039			
			Sanfilippodytes	0.0046	0.0037	0.0005		
			Oreodytes	0.0008				
		Elmidae	Heterolimnius			0.0266		
		Hydraenidae	Hydraena vandykei			0.0001		
		Diptera	Tipulidae	Dicranota	0.0002	0.0008	0.0003	0.0003
			Limonia			0.0004		
			Ormosia (Rhypholophus)			0.0001		
		Dolichopus		0.0001				
		Empididae	Clinocera		0.0005			
		Chelifera		0.0001	0.0025		0.0001	
		Culicidae	Culiseta incidens	0.0002	0.0001		0.0009	
		Ceratopogonidae	Bezzia-Palpomylia			0.0006	0.0035	
			Culicoides				0.0001	
			Monohelea		0.0002			
			Atrichopogon		0.0001			
		Simuliidae	Forcipomyia				0.0001	
			Simulium (tuberosum)	0.0889	0.0005	0.0541	0.0002	
			Prosimulium frohnei		0.0005			
			Prosimulium travisi		0.0359		0.0001	
			Metacnephia	0.0002	0.0002			
			Stegopterna mutata complex	0.0057	0.0372			
		Muscidae	Limnophora	0.0042	0.0138	0.0004	0.0007	
		Chironomidae	Parochlus kiefferi	0.0113	0.0189		0.0009	
			Diametinae	Diamesa	0.0337		0.0005	0.0038
			Pagastia			0.0139	0.0057	
			Pseudodiamesa	0.0051	0.0446		0.0080	
		Prodiamesinae	Monodiamesa				0.0006	
		Tanytopodinae	Thienemannimyia group	0.0031		0.0863	0.0003	
			Ablabesmyia	0.0002				
			Apsectrotanypus				0.0005	
			Larsia		0.0001			
			Helopelopia	0.0026		0.0767		
			Krenopelopia	0.0013				
			Trissopelopia				0.0045	
			Zavrelimyia	0.0086		0.0104	0.0202	
		Orthocladinae	Brillia				0.0019	
			Corynoneura	0.0344	0.0234	0.0052	0.0120	
			Cricotopus-Orthocladus	0.0240	0.0997	0.1069	0.0524	
			Diplociadus	0.0003	0.0007	0.0010		
			Eukiefferiella brehmi group	0.0002		0.0010	0.0021	
			Eukiefferiella claripennis group	0.0085	0.0085	0.0036	0.0013	
			Eukiefferiella devonica group			0.0012		
			Eukiefferiella gracel group	0.0002		0.0058	0.0007	
			Eukiefferiella rectangularis group		0.0384			
			Eukiefferiella similis group	0.0003		0.0152	0.0001	
			Heterotrissocladus marcidus group			0.0039		
			Heleniella	0.0018	0.0013	0.0039	0.0003	
			Limnophyes	0.0256			0.0008	
			Nanocladus parvulus group	0.0003	0.0001		0.0007	
			Orthocladus cf. rivulorum				0.0384	
			Paralimnophyes	0.0003				
			Parametriocnemus		0.0005		0.0023	
			Paraphaenocladus	0.0010	0.0019		0.0014	
			Parorthocladus		0.0038	0.0005	0.0042	
			Psectrocladius limbatellus group	0.0011				
			Psectrocladius sordidellus group			0.0001		
			Rheocricotopus			0.0001	0.0068	
			Synorthocladus				0.0014	
			Thienemanniella fusca				0.0003	
			Thienemanniella cf. xena	0.1082	0.0004		0.0113	
			Tveteria bavarica group	0.0008	0.0364	0.0187	0.0081	
		Chironominae	Apedilum		0.0001			
			Lithotanytarsus			0.0001		
			Micropsectra	0.2847	0.4618	0.1006	0.1722	
			Paratanytarsus			0.0004		
			Phaenopsectra	0.0051	0.0042	0.0021		
			Polypedilum aviceps			0.0005	0.0009	
			Polypedilum laetum			0.0003		
			Polypedilum tritum			0.0039		
	Rheotanytarsus		0.0002					
	Stempellinella					0.4058		
		Tanytarsus			0.0785			
	undetermined	undetermined ostracodes		0.0030	0.0004	0.0077		
	tardigrades	Hypsibiidae	0.0051	0.0001				
		Sphaeriidae			0.0034	0.0096		
	Tricladida	Dugesidae	0.0002	0.0023	0.0013	0.0129		
	undetermined	undetermined oligochaetes	0.0095	0.0658	0.0825	0.0222		
	Arachnida	Lebertidae	0.0002		0.0009	0.0039		
		Estelloxus				0.0002		
	Arrenuridae	Arrenurus	0.0016					
	Aturidae	Aturus			0.0009	0.0086		
		Brachypoda	0.0020		0.0004	0.0001		
		Ljania				0.0027		
		Atractides				0.0014		
		Hygrobates				0.0009		
		Feltria			0.0017	0.0019		
		Sperchon (some cf. crassipalpis)			0.0001	0.0304		
		Testudacarus			0.0001	0.0014		
		Wandesia				0.0002		
		Mucronothrus	0.3333	0.0297	0.2132	0.0262		
		Hydrozetes	0.0003	0.0005	0.0006	0.0009		
		Cheiroseius	0.0005	0.0004		0.0001		
		cf. Soldanellonyx			0.0098	0.0036		
		SUM count	6129	8363	7721	8618		
		total taxa all samples	50	53	67	83		
		vulnerable all samples	6	8	7	6		
		% vulnerable	0.73	1.22	2.54	6.37		

Figure 1: Discharge in 2003 and 2004 (error bar is 1 S.D.).

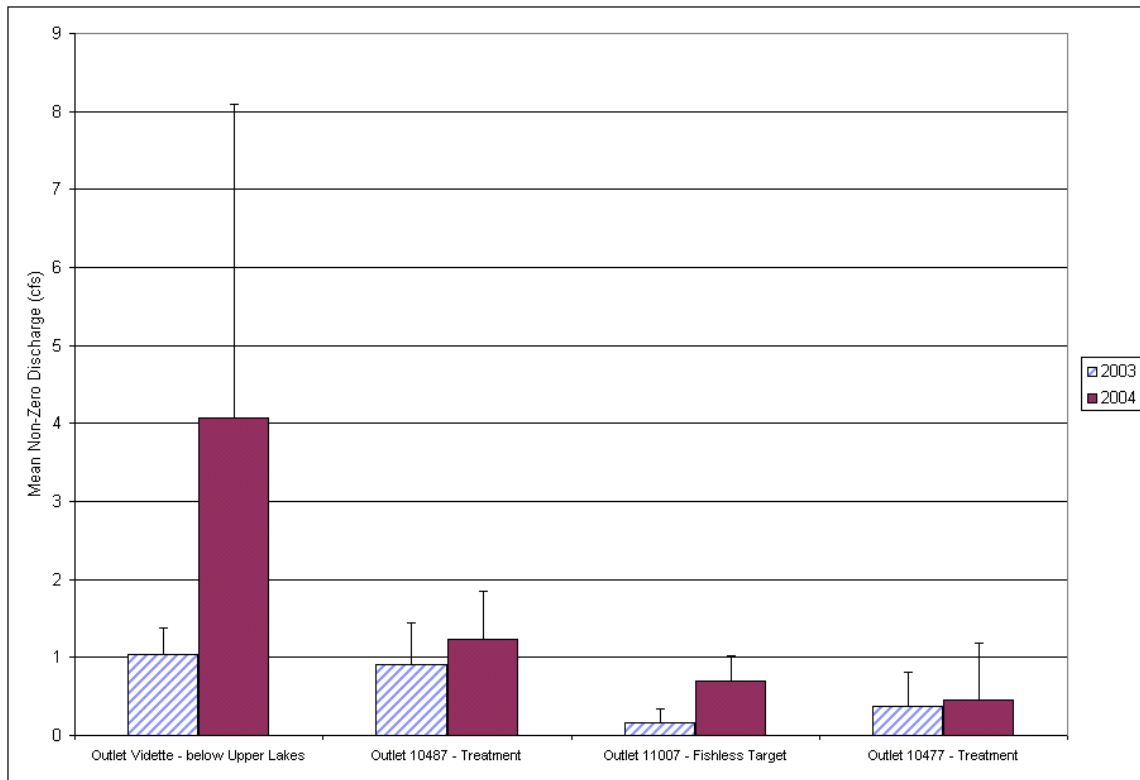


Figure 2: Mean width in 2003 and 2004 (error bar is 1 S.D.).

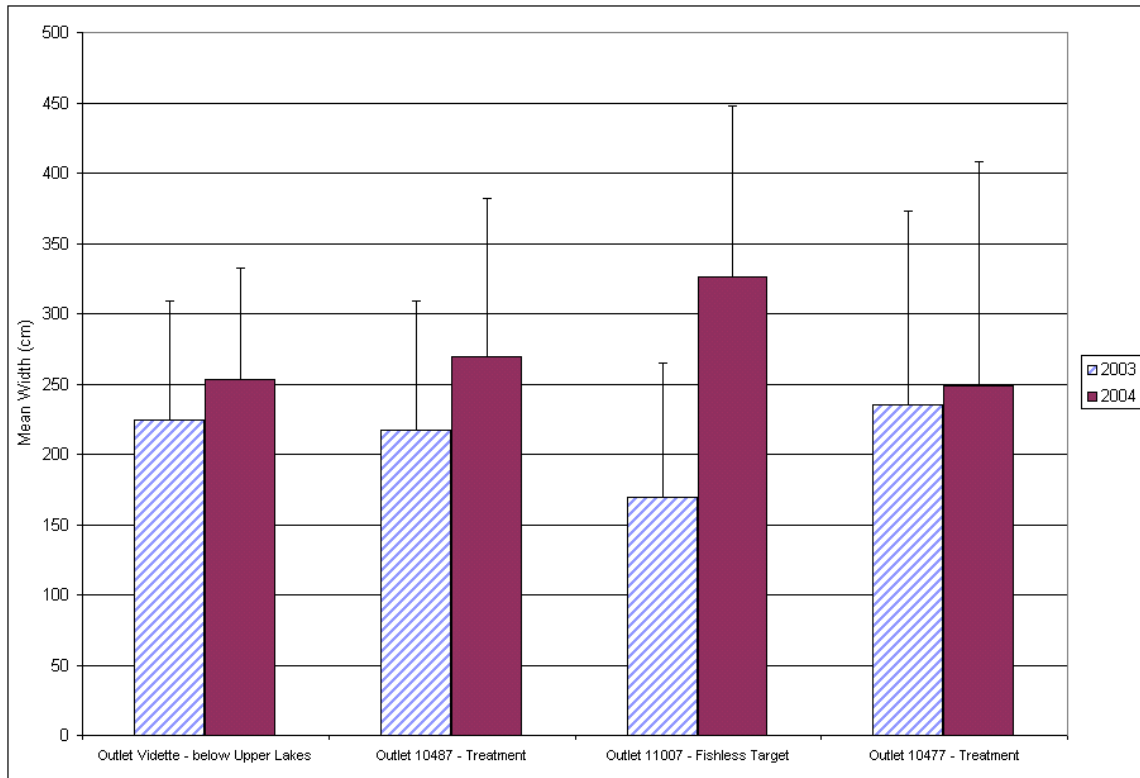


Figure 3: Mean depth in 2003 and 2004 (error bar is 1 S.D.).

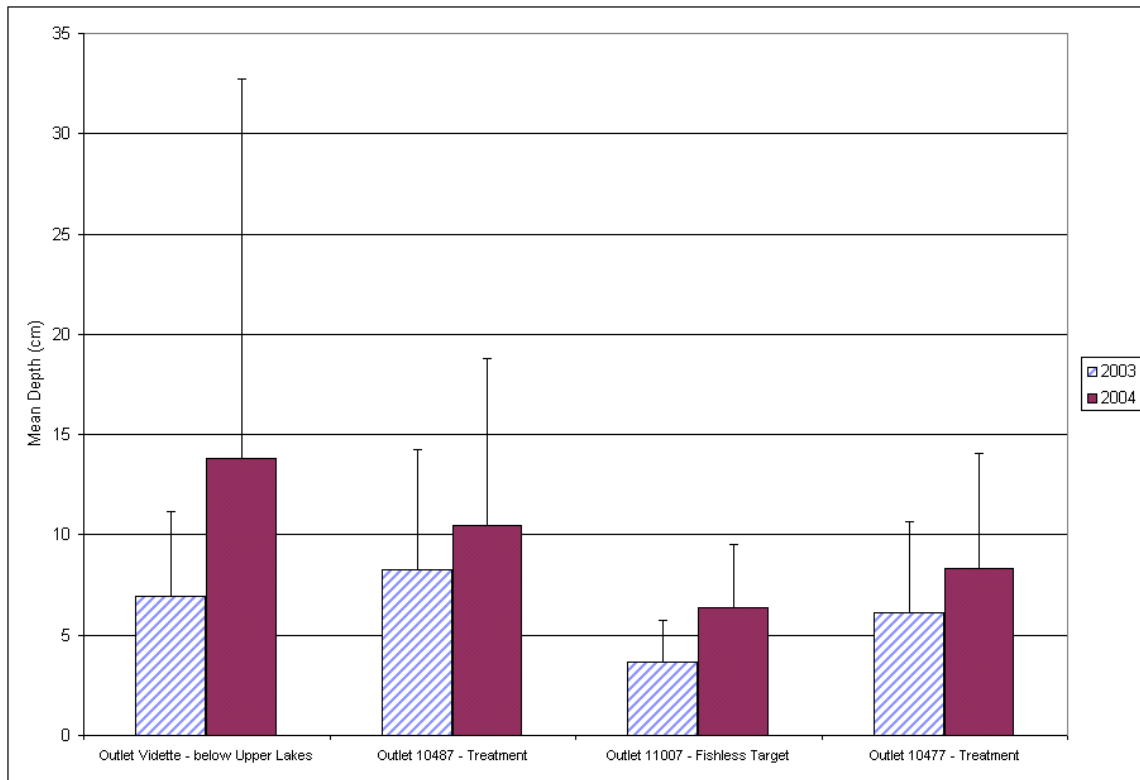


Figure 4: Mean FPOM in 2003 and 2004 (error bar is 1 S.D.).

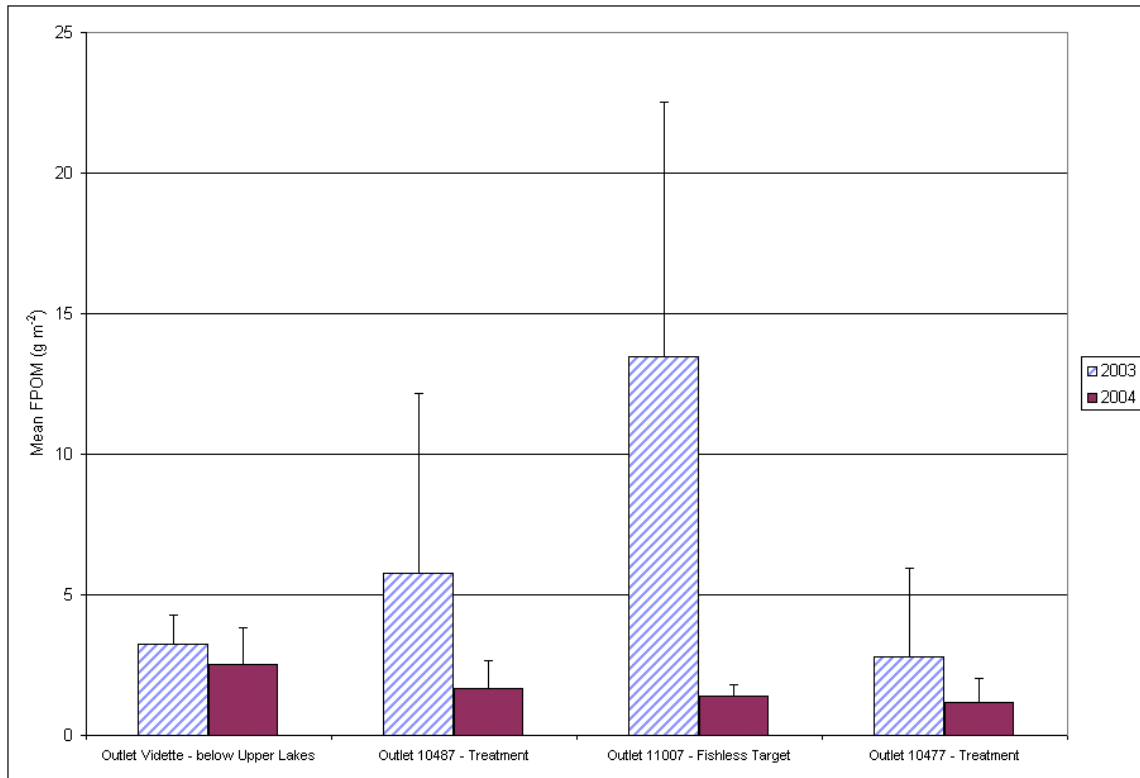


Figure 5: Mean CPOM in 2003 and 2004 (error bar is 1 S.D.).

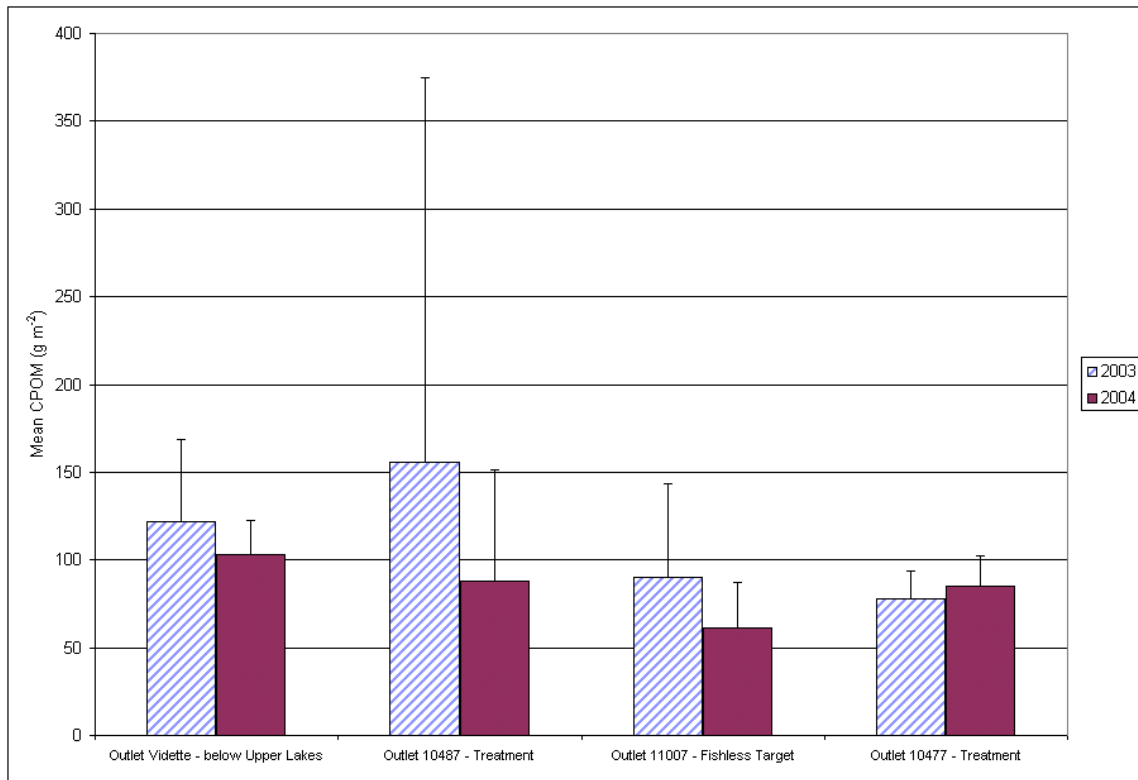
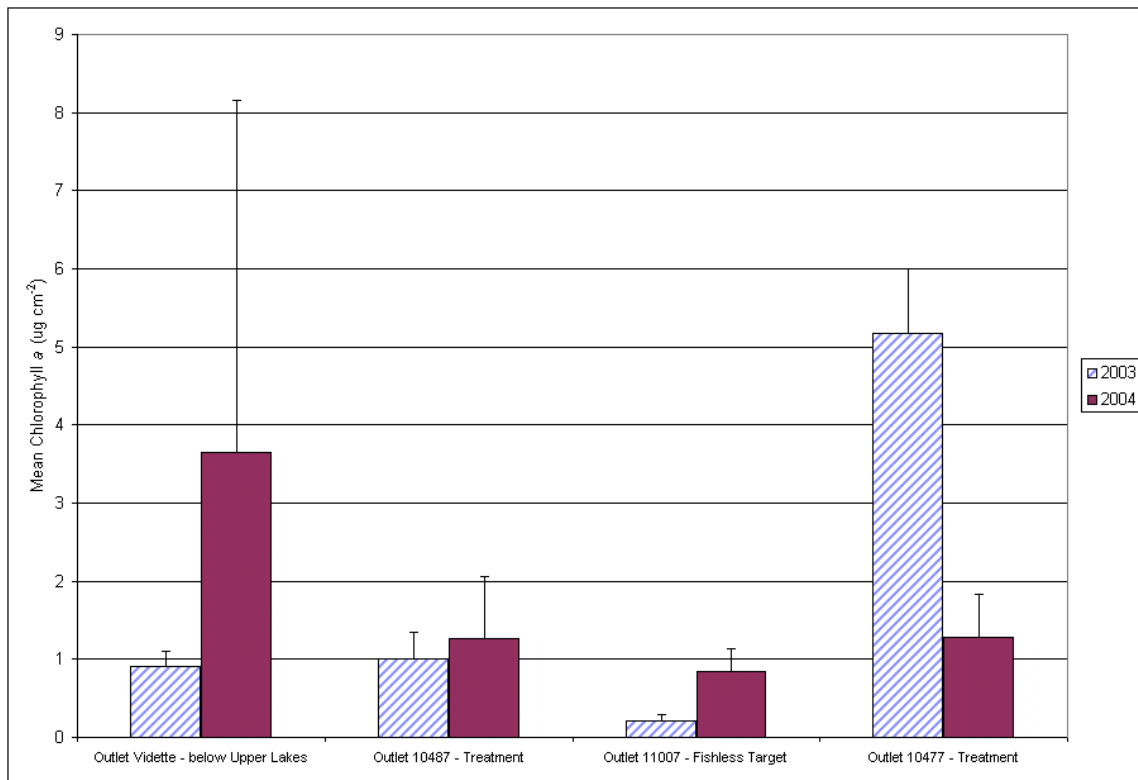


Figure 6: Mean Chlorophyll *a* in 2003 and 2004 (error bar is 1 S.D.).



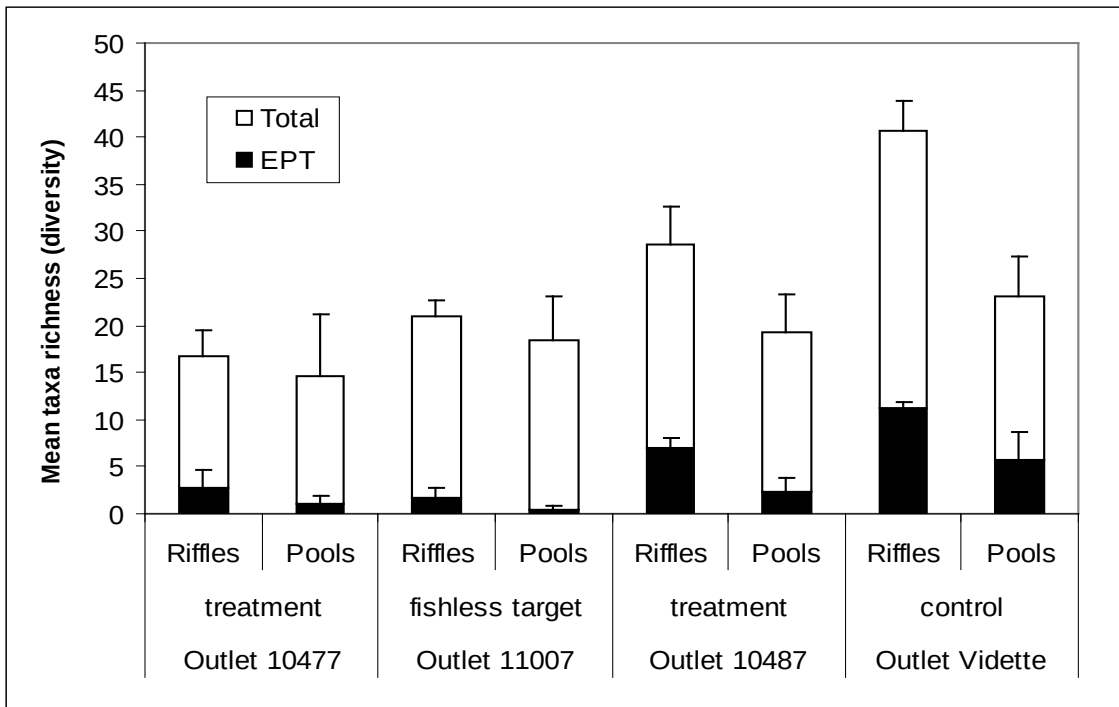


Figure 7a. Mean richness of all taxa and of EPT taxa collected in **2003** samples from 3 replicates each of riffle and pool habitats (diversity measure, standard deviations shown).

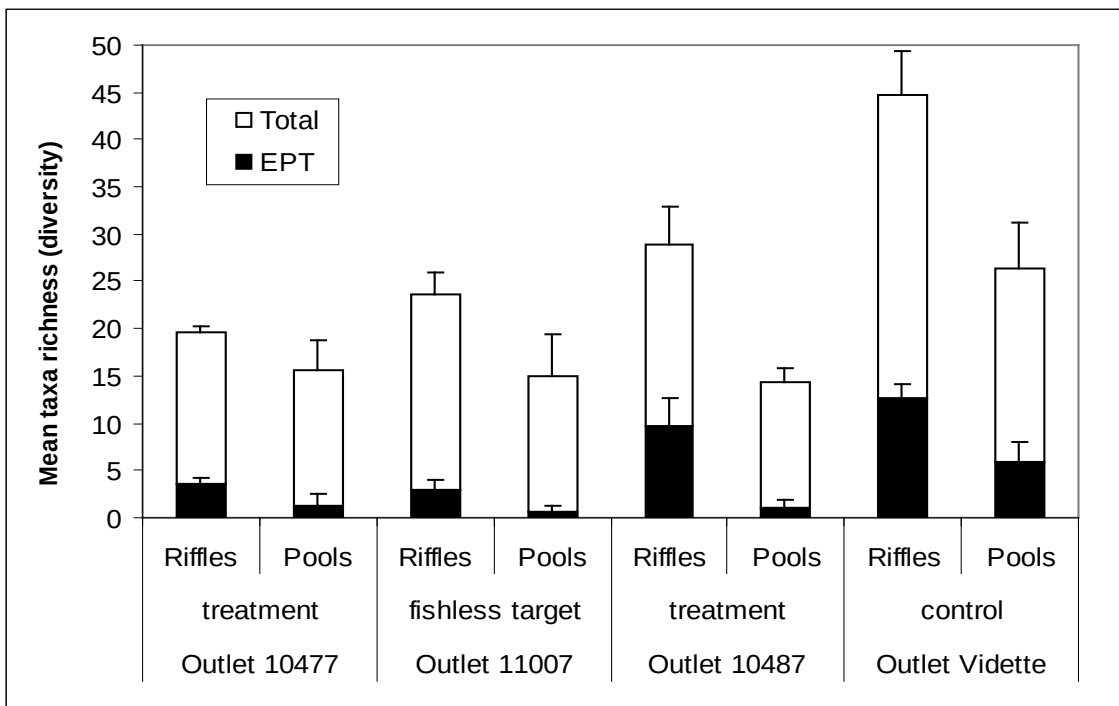


Figure 7b. Mean richness of all taxa and of EPT taxa collected in **2004** samples from 3 replicates each of riffle and pool habitats (diversity measure, standard deviations shown).

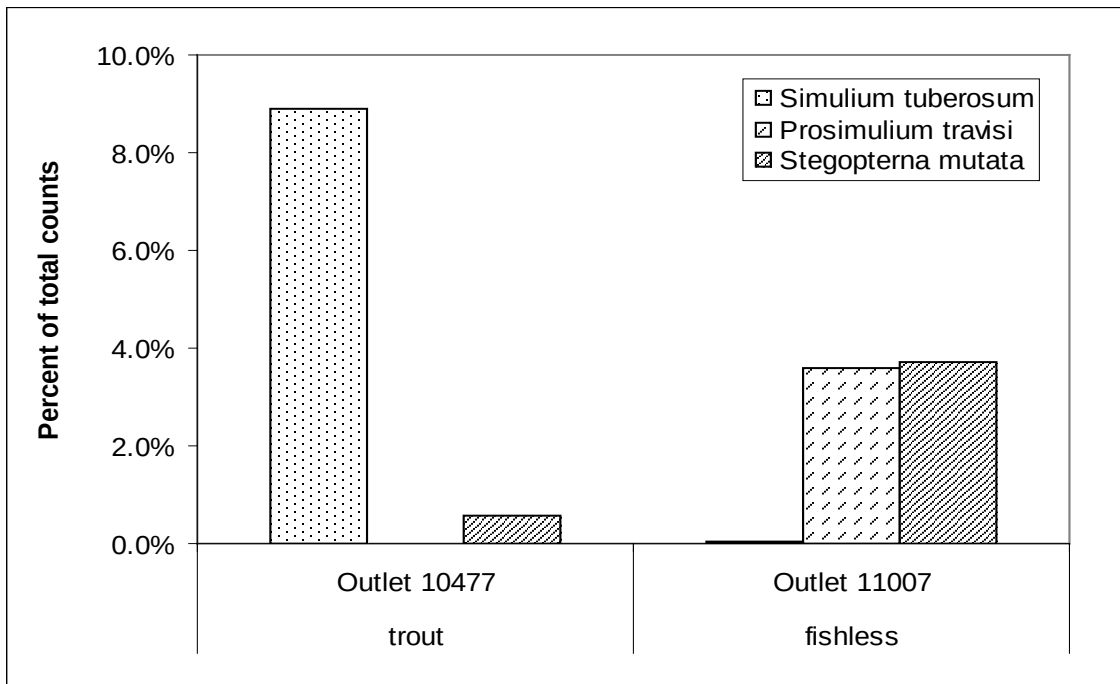


Figure 8. Relative abundance (percent) of different black fly (Simuliidae) taxa combined over both years of baseline monitoring, contrasting the fishless and trout-containing populations in the small lake outlet streams.

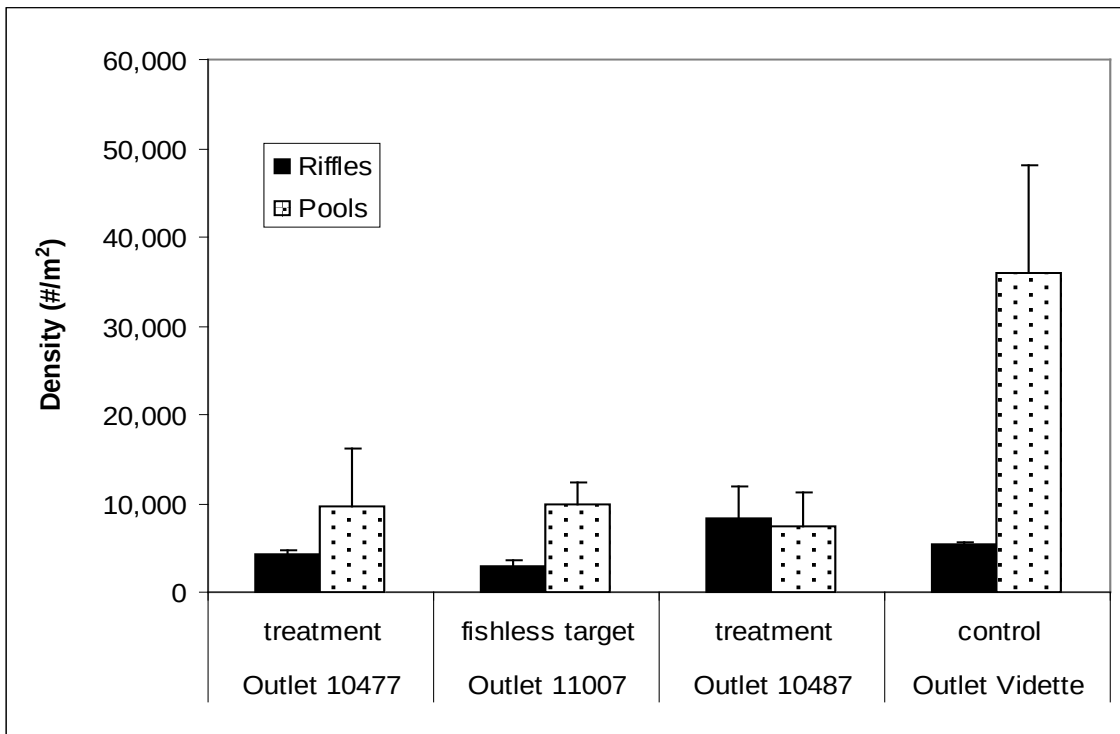


Figure 9a. Mean density of all invertebrates collected from riffle and pool habitats in **2003** (with standard deviation shown in error bars).

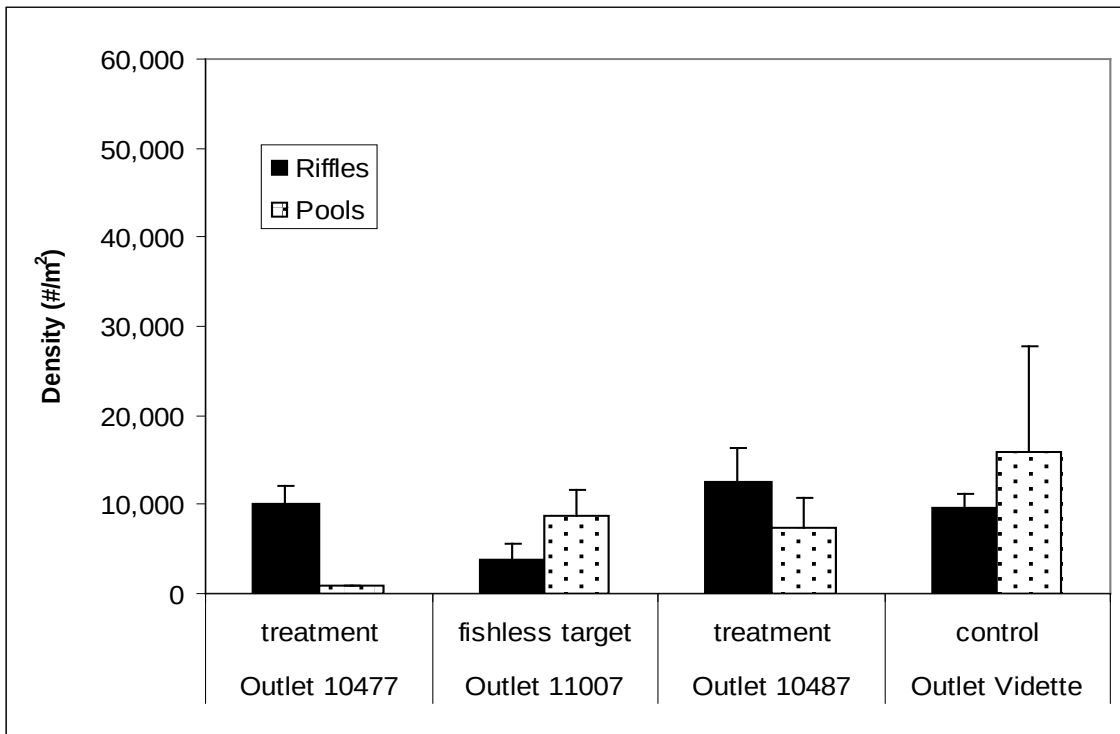


Figure 9b. Mean density of all invertebrates collected from riffle and pool habitats in **2004** (with standard deviation shown in error bars).