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OF FIRE, FOOD, AND FISH:
FISH PRODUCTIVITY RESPONSES TO WILDFIRE

by

Matthew Victor Schenk

A thesis

submitted in partial fulfillment

of the requirements for the degree of

Master of Science in the Department of Biological Sciences

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To the Graduate Faculty:

The members of the committee appointed to examine the thesis of Matthew Victor Schenk find it satisfactory and recommend that it be accepted.

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Animal Welfare Research Committee Approval Page

September 9, 2015

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Dear Dr. Baxter:

Thank you for your response to requests from a prior review of your application for the new study listed above. Your response was reviewed at the 9/8/2015, meeting of the Idaho State University IACUC. This is to confirm that your application is now fully approved.

You are granted permission to conduct your study as most recently described effective immediately. The study is subject to continuing review on or before 9/8/2016, unless closed before that date.

Please note that any changes to the study as approved must be promptly reported and approved. Work may not begin on a protocol until approved by the committee. Some changes may be approved by expedited review; others require full board review. Contact Tom Bailey (208-282-2179; fax 208-282-4723; email: anmlcare@isu.edu) if you have any questions or require further information.

Sincerely,

Tom Bailey
IACUC Manager

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Of Fire, Food, and Fish: Fish Productivity Responses to Wildfire

Matthew Victor Schenk

Abstract

Wildfire is a disturbance by which terrestrial effects can translate into consequences for stream ecosystems, food webs, and productivity at different trophic levels. Research regarding the effects of wildfire on fish has focused on changes in physical habitat induced by wildfire, whereas responses associated with changes in food-web interactions have received less attention. We address this by combining long-term monitoring and a short-term (1 summer), paired-stream comparison of food webs and multi-trophic level production with a spatially extensive multi-factor analysis of fish populations across 12 streams spanning gradients in fire history and riparian recovery. This enabled us to investigate the consequences of wildfire for food-web dynamics and productivity of organisms across trophic levels in wilderness streams of central Idaho. Long-term monitoring demonstrated streams compared in the short-term, paired-stream comparison exhibited similar values for chlorophyll-*a* (*chl-a*) and aquatic invertebrate biomass for 10 years preceding wildfire. In the 14 years post-fire, those trends diverged, with the stream retaining an open canopy averaging $\sim 3.2 \times$ higher *chl-a* biomass and $\sim 2.4 \times$ higher invertebrate biomass than the stream that regrew a closed canopy. During the short-term, paired-stream comparison, the stream retaining an open canopy exhibited $\sim 2.6 \times$ higher gross primary production, $\sim 3.4 \times$ higher secondary production of invertebrates, and $\sim 1.6 \times$ higher tertiary production of trout. Bioenergetic estimates of trout demand for invertebrate prey revealed trout production in the open canopy stream

required ~ 90% of the available aquatic invertebrate production, whereas in the closed canopy stream trout demand was nearly twice that of aquatic invertebrate production. In turn, diet analysis revealed that trout in the closed canopy stream consumed twice the proportion of terrestrial invertebrate biomass than did trout in the open canopy stream. Among tributaries throughout the basin, variation in biomass of salmonid fishes was best explained via a model that was generally consistent with the “bottom up” process observed in the paired streams, that included (in order of importance): area of watershed, inorganic nitrogen, invertebrate biomass, canopy cover, and proportion of the basin burned. These findings provide evidence from a wilderness setting that severe wildfire, rather than being a catastrophe for stream productivity or salmonid fishes, can be followed by resilient responses, including a pulse of productivity that may extend more than a decade depending on the trajectory of riparian vegetation recovery in the mid to long-term period following wildfire.

Key words

Wildfire, Food Webs, Trout, Production, Invertebrates, Periphyton

Introduction

Wildfire is a natural disturbance by which terrestrial effects are known to translate into consequences for stream ecosystems and the organisms that inhabit them (Resh et al. 1988, Minshall et al. 1989, Jackson et al. 2012). Although these effects vary in space and time (Gresswell 1999, Verkaik et al. 2013), the responses commonly expected for temperate, forested landscapes are based upon a presumed stable recurrence interval of wildfire, and a framework that depends upon streams and riparian areas returning to pre-fire conditions, mirroring a comparable rebound by terrestrial ecosystems (Minshall et al. 1989; 2004, Gresswell 1999, Romme et al. 2011). In the western U.S.A. increased frequency and severity of wildfire is associated with a warming climate (Westerling et al. 2006; 2011). The combination of changing climatic conditions and fire regimes is driving shifts in terrestrial vegetation and ecosystems in this region, including increasing tree mortality and decreasing tree basal area (Van Mantgem et al. 2009), low conifer seedling recruitment (Nelson & Pierce 2010), and transitions from forest to shrub-grassland (Allen & Breshears 1998). Together, these patterns call into question the equilibrium-based expectation of stream ecosystems returning to pre-fire conditions (Davis et al. 2013a), and highlight the need to understand how the character of wildfire and associated recovery of terrestrial vegetation may mediate those responses.

Previous investigations have focused on the short-term responses of ecosystems to wildfire (Spencer & Hauer 1991, Mellon et al. 2008), with fewer studies of mid to longer-term dynamics (i.e., > 2-3 yrs. post-fire; Minshall et al. 1997, Romme et al. 2011, Rugenski & Minshall 2014), or the influence of wildfire severity (Arkle et al. 2010, Malison & Baxter 2010a;b). Furthermore, past research regarding effects of wildfire on

fish populations has focused on consequences via changes in physical habitat, whereas potential responses by fish through changes in prey productivity and food-web interactions have received less attention. For example, studies have evaluated how changes in temperature and flow following fire might negatively influence populations of fishes (Rieman & Clayton 1997, Dunham et al. 2007), and Beakes et al. (2014) demonstrated that increases in temperature shortly after wildfire could have negative consequences for steelhead trout in a California, USA stream near the southern edge of this species' distribution. Generally, these studies have not investigated how changes in food resources might mediate the mid to longer-term impacts of wildfire on fish production.

In central Idaho, USA, many streams previously fringed by conifer forests have burned with high severity in the past 30 years, and rather than returning to pre-fire conditions, a large proportion of these streams have retained open canopies and elevated light inputs 5-15 years post fire (Malison & Baxter 2010b, Davis et al. 2013a). Additionally, high fluxes of adult aquatic insect emergence have been observed from streams that burned with high severity, suggesting elevated secondary production of invertebrates in those streams (Malison & Baxter 2010a). This increase in productivity has been termed the 'fire pulse,' defined as amplified productivity of aquatic primary producers and stream invertebrates extending > 5 years post-fire (Malison & Baxter 2010a, Rugenski & Minshall 2014). In turn, increases in productivity at lower trophic levels may positively affect tertiary production of salmonid fishes, which are common in these streams and are frequently limited by food (Chapman 1966, Boss & Richardson 2002, Wipfli & Baxter 2010, Collins et al. 2016), but this has not been explicitly

evaluated. Furthermore, recent observations from the region point to possible connections between dynamics of fish populations and patterns of wildfire (Copeland & Meyer 2011, Walters et al. 2013), but the mechanisms involved are not well understood.

We investigated the mid to long-term responses of fish populations and productivity to wildfire in wilderness streams of central Idaho, and evaluated the role of food resources and food-web pathways in mediating those responses. We hypothesized that the ‘fire pulse’ phenomenon is principally driven by elevated light input into streams, and leads not only to increases in primary production and invertebrate productivity, but to amplified production of fishes as well. To evaluate this overarching hypothesis, we used a combination of study designs; coupling 24 years of monitoring and a short-term comparison of food webs and fish production in a pair of streams contrasting in riparian regrowth following wildfire with a spatially extensive comparison and multi-factor analysis of fish and invertebrate biomass across a suite of streams spanning gradients in fire history and recovery patterns.

We used the long-term monitoring and the short-term, paired-stream comparison to detect patterns, provide temporal context, and analyze potential food-web mechanisms responsible for patterns in fish production following wildfire, whereas the more spatially extensive study facilitated exploration of the generality of our findings across the riverscape (*sensu* Fausch et al. 2002). Based on our overarching hypothesis and the paired stream comparison, we expected that the stream that retained an open canopy and received more light would have higher rates of net gross primary production (GPP), secondary production of invertebrates, and tertiary production of fishes. Conversely, we expected that the stream receiving less light would exhibit lower rates of production

across those three trophic levels. Additionally, we anticipated that food demand by the trout population would be more likely to exceed aquatic invertebrate production in the stream receiving less light compared to the one with more light. In turn, we expected trout in the stream receiving less light would consume greater proportions of terrestrial invertebrate prey as a subsidy. Within the context of the spatially extensive comparison, we anticipated patterns in standing crop biomass of invertebrates and fishes among streams would be associated with wildfire history and subsequent canopy cover and associated light inputs, though other habitat factors might play roles in explaining productivity patterns across this larger suite of drainages.

We expected this study to yield a range of applied benefits. First, the investigation directly evaluated responses to wildfire by a suite of threatened or endangered salmonids such as Chinook salmon (*Oncorhynchus tshawytscha*), steelhead trout (*Oncorhynchus mykiss*), cutthroat trout (*Oncorhynchus clarkii lewisi*), and bull trout (*Salvelinus confluentus*). These fish are important to the ecology, economy and culture of the Pacific Northwest, but their future is uncertain under changing climate and fire regimes (e.g., Isaak et al. 2015). Second, our study was conducted in a wilderness area, and our results quantify a natural ‘baseline’ regarding connections between fire regime, stream-riparian ecosystems, and fishes against which more actively managed landscapes can be compared. Finally, we expected this study would reveal mechanisms responsible for the trajectory of ecological change accompanying shifts in climate and fire regime in landscapes and riverscapes, providing resource managers with insights that might aid in interpreting trends in fish populations and inform integrated, adaptive management of fire, forests and fisheries.

Methods

Study design

We employed a complementary combination of three study designs to evaluate our hypothesis. The first drew on 24 years of annual monitoring of streambed biofilms (which include aquatic primary producers like algae) and invertebrate biomass in a pair of streams (Cliff Creek and Pioneer Creek, Fig. 1). The second involved a short-term (1 summer) comparison of food webs and fish production in this pair of streams, which were comparably burnt with high severity (Paysen et al. 2000) during a wildfire in 2000 designated as the Diamond Peak fire. In the years since, Cliff Creek retained an open canopy with high input of light, whereas Pioneer Creek rapidly regrew a closed canopy, and by 2014 received approximately 1/3 the light that Cliff Creek does. The third design was a spatially extensive, multi-factor comparison among reaches within 12 streams (Fig. 1) selected to encompass gradients in fire history and patterns of riparian recovery among 2nd-4th order streams. This complementary combination of study designs lent itself to improved interpretation of results, and was intended to evaluate the generality and increase the scope of inferences associated with our findings. The study was conducted during summer months for logistical reasons, but also because this period encompasses the critical growing season important for in-stream primary producers, invertebrates, and fishes in cold streams of this region (Sand-Jensen & Borum 1991, Waters 1992, Bothwell 1998, Huryin & Wallace 2000, Junker & Cross 2014).

Study Site

Research was conducted on a suite of tributaries to Big Creek, the largest tributary of the Middle Fork Salmon River, and a fifth order stream draining ~ 1,540 km² (Fig. 1).

The study area was centered on 45.13 N and 114.98 W; all sites were within the Frank Church River of No Return Wilderness, a part of the Payette National Forest in central Idaho, USA. Lithology is dominated by Cretaceous intrusive igneous rocks (mostly granitic), a suite of Proterozoic metamorphosed sediments representing the remaining bedrock, and Eocene extrusives from the Challis volcanic event (Link & Janecke, 1999, Lifton 2005, Stewart et al. 2013). Higher elevations and north-facing slopes are dominated by Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*), and Douglas-fir (*Pseudotsuga menziesii*). Sagebrush (*Artemisia* spp.) and grass communities are common in lower elevations, and on south-facing slopes. Riparian vegetation is variable in cover, but commonly dominated by gray alder (*Alnus incana*), river birch (*Betula occidentalis*), red osier dogwood (*Cornus sericea*), Rocky Mountain maple (*Acer glabrum*), willow (*Salix* spp.), thimbleberry (*Rubus parvifloris*), and mallow ninebark (*Physocarpus malvaceus*) (Jackson & Sullivan 2009).

Annual precipitation generally ranges between 38 and 50 cm in the valleys and 76 and 100 cm at higher elevations (> 1,500 m). Most of this precipitation is in the form of snow, which generally melts in the late spring producing peak discharge flows in late spring and early summer; streams generally reach base flow conditions in late summer that persist through winter (Robinson et al. 2005, Olson 2010, Davis et al. 2013b). In this region, accrual of stream bed periphyton in summer is commonly limited by N or co-limited through a combination of N+P, but may be mediated by light inputs as well (Marcarelli & Wurtsbaugh 2006, Sanderson et al. 2009).

Historical wildfire regimes for the region are highly variable in severity and frequency (Agee 1993), with a return interval ranging 13–80 years (Pierce et al. 2004,

Heyerdahl et al. 2008). The Big Creek drainage experienced wildfires in 1988, 2000, 2005, 2006, 2007, and 2008. The 2000 fire was a high severity, stand-replacing fire that burned a large portion (~ 40%) of the Big Creek watershed in 2000 (Arkle et al. 2010). Cliff and Pioneer creeks were chosen for the short-term, paired stream analysis because, though they drain watersheds of opposing aspect (Cliff is south-facing, whereas Pioneer is north-facing) they are similar in most other respects (e.g., size, locality, climate, temperature, gradient, pH, alkalinity, water hardness and wildfire history (Minshall & Rugenski 2006), and both were included in the long-term monitoring efforts. Furthermore, after severe wildfire burned both streams with comparable severity in 2000, Cliff Creek has retained a relatively open canopy while Pioneer Creek has regrown a dense overstory of deciduous shrubs. This allowed us to use them in a paired-stream framework to explore how light dynamics may affect in-stream processes like rates of primary production and production of secondary consumers. Sites used in the spatially extensive portion of the study were chosen to represent a range of 2nd-4th order stream sizes and encompass variation in wildfire history and trajectory of riparian regrowth. Moreover, they had been the subject of previous studies that documented variation in primary and secondary production (Malison et al. 2008, Davis 2015), and were accessible from a main hiking trail along Big Creek. We assessed study reaches using segment and reach-scale geomorphic classification (Frissell et al. 1986, Bisson et al. 2006), and all were 2nd to 4th order occurred within alluviated canyon segments, and were dominated by riffle-pool habitat.

Long-term monitoring

Biofilm was sampled annually from 1990 to 2014 in Cliff (open canopy) and Pioneer (closed canopy) creeks, with techniques based on methods outlined by Davis et al. (2001), and detailed in Davis et al. (2013b). Briefly, streams were sampled over a 4-5 day period between July 20th and 30th at five permanent transects located ~ 50 m apart. To calculate chl-*a* biomass, 3-5 streambed particles (stones) were randomly chosen from the nearest riffle habitat at each permanent transect, and biofilm was removed by scrubbing with nylon brushes. The composited slurry was subsampled and filtered through a pre-combusted (400°C for 30 min), pre-weighed, 47mm glass-fiber filters with 0.7-µm pores (Millipore IRL, Tullagreen, Ireland). Samples were then shielded from light and frozen for transport to the laboratory. Filters from each transect were analyzed for chl-*a* concentration using standard methods (APHA 1998, Steinman et al. 2011). Chl-*a* was extracted from filters by submergence in methanol for < 12 h, analyzed with a spectrophotometer (Genesis 5, 336001000, Thermo Fisher Scientific Ltd., Pittsburgh, PA, USA), and corrected for phaeophytin.

Benthic invertebrates were collected from riffle habitats during the same timeframe as the biofilm using a Surber sampler (0.09 m² area, 250 µm mesh size, Aquatic Research Instruments, Hope, ID, USA) at or near permanent transects (n = 5 per stream). Invertebrates were preserved in ≥ 90% ethanol and transported to the laboratory for identification. Prior to 2010, all individuals collected were identified to the lowest taxonomic level possible, usually genus or species, with the aid of 4X dissection scopes, dried at 60 °C for < 24 hr and weighed to the nearest microgram to produce dry mass (DM) estimates of biomass. Post 2010, samples were separated into large (>1 mm) and

small organisms ($> 250 \mu\text{m} < 1 \text{ mm}$) with sieves (USA Standard Testing Sieve, Fisher Scientific, Pittsburgh, PA, USA). All invertebrates $>1 \text{ mm}$ were identified, and measured to the nearest mm, and the portion containing the small organisms was subsampled until a minimum of 120 individuals was attained. Identification was to the lowest level possible, usually genus or species, with the aid of 4X dissection scopes and regional invertebrate identification keys (Adams et al. 2004, Merritt et al. 2008). Invertebrate biomass was estimated by applying published length-mass regressions to the measured individuals (Benke 1984, Gaines et al. 1992, Robinson & Minshall 1998, Benke et al. 1999, Benke & Huryn 2006, Miyasaka et al. 2008, Bellmore et al. 2012). Due to the harsh conditions associated with sample transportation, and fragility of preserved oligochaetes, individuals were often fragmented beyond recognition and therefore were excluded from our analysis.

Short-term paired-stream comparison

During summer 2014 in Cliff and Pioneer creeks, we measured rates of gross primary, invertebrate, and fish production; the diets of salmonid fishes were also quantified, and we characterized attributes of habitat that were expected to be associated with variation in productivity and food webs. With respect to the latter, widths and depths were measured with meter sticks and tapes at 3 transects $\sim 100\text{m}$ apart. Slope measurements were integrated across 10-15m of stream length using a clinometer (Suunto PM-5/360 PC clinometer, Suunto Inc. Vantaa, Finland) at the same 3 locations. Elevations and distances ($\pm 3\text{m}$) were measured with a handheld civilian GPS (Garmin Legend Hcx, Garmin International Inc. Olathe, KS, USA). Discharge was estimated using a modified version of the float method (Turnipseed & Sauer, 2010), whereby an average

of 3 replicate measures of discharge were taken at each of the 3 transects used in the other measures. Substrate heterogeneity, embeddedness, and particle sizes (B-axis) were measured via a modified version of the Wolman pebble count technique (Wolman 1954) by which we randomly selected and measured 100 particles from the benthos along the length of the 200m reach. We made monthly measurements of canopy cover at 5 transects ~ 50m apart along each study reach using a spherical densiometer (Convex Model-A spherical crown densiometer, Forest Densimeters, Bartlesville, OK, USA); four measurements of canopy cover (upstream, downstream, stream right, and stream left) were averaged at each transect. Concurrently, we estimated photosynthetically active radiation (PAR) reaching the surface of each stream by averaging 100 measurements taken ~ 1-5 cm above the water along the thalweg of the study reach using a light meter (LI-250a, LI-COR Inc. Lincoln Nebraska, USA).

We estimated GPP in Cliff and Pioneer Creeks in late summer 2014 using open-channel monitoring of diel dissolved oxygen dynamics during base flow conditions (Olson 2010, Whiting & Godsey 2016) for 11 concurrent days between July 31st and August 15th. We measured dissolved oxygen concentration dynamics and modeled whole-stream estimates of gross primary production (GPP) and reaeration flux using the single-station method (Holtgrieve et al. 2010, Dodds et al. 2013) for each stream, adjusting rates of GPP based on the measured physical characteristics of the stream (width and depth) and the environment (PAR and atmospheric pressure) to predict diel trends in oxygen (O₂). We modeled 2-5 day time periods based similarities in PAR, barometric pressure and temperature to estimate single daily values for GPP, and modeled shorter time periods (2 days) if noticeable changes in those variables in occurred

during that time. Light was collected from a single Remote Access Weather Station located between the two streams, and scaled using stream specific shading ratios from PAR measurements taken at the stream surface and outside of the riparian canopy. Detailed methodology used for developing GPP estimates can be found in Appendix A. Our aim was to make direct comparisons of production across trophic levels, which required reporting values in similar units. To accomplish this, we scaled production values across all trophic levels to the day.

Secondary production of invertebrates, in the form of dry mass (DM), was estimated by utilizing a common approach (Benke & Huryn 2006) whereby the biomass of each taxon was multiplied by taxon specific annual production to biomass values (P/B) derived from the literature, and scaled to the day for direct comparison to other trophic levels evaluated in this study. Nineteen common taxa were used in our production estimates, representing 91–96% of the invertebrate biomass. Published P/B values from the region were used when possible (Robinson & Minshall 1998, Bellmore et al. 2012); when regional values were unavailable, we applied values from outside the region (Benke 1984, Gaines et al. 1992, Benke & Huryn 2006). If P/B values for a specific taxon did not exist, we used values from closely related families, and when no literature values could be found, a value of 5 was applied (Benke & Huryn 2006; Table 1). Secondary production values were summed across taxa to determine aquatic invertebrate production. We assumed that invertebrate standing crop biomass in late summer approximated the average annual invertebrate biomass for each taxon. Although this assumption was not directly evaluated, peak emergence is usually in late-spring/early summer in the Salmon Basin (Malison and Baxter 2010a). Therefore, this snap-shot of invertebrate biomass was

likely an underestimate of the average annual biomass for many taxa, which means our overall estimates of invertebrate production were probably conservative.

We estimated fish abundance via single-pass surveys using a mask and snorkel (Li & Li 2006), conducting repeated, underwater surveys every other week between July 7th and August 20th, 2014. Studies in this region have shown that fish are more easily spotted during night as compared to day surveys (Thurow & Schill 1996); consequently, all surveys were completed between 22:00 and 2:00. A dry suit (Stream Count Drysuit, O.S. Systems Inc. Scappoose, OR, USA), associated gear (neoprene hood, gloves, and socks), and flashlight (Mini Q40 eLED Plus, Underwater Kinetics. Poway, CA, USA) aided this process. These methods precluded easily distinguishing juveniles of the two dominant trout species (*Oncorhynchus mykiss* and *Oncorhynchus clarkii lewisi*) present in these streams. Moreover, hybridization between the trout species dominating these streams made it difficult to separate species based on morphological characteristics alone (Hohenlohe et al. 2011, High, B. Idaho Dept. Fish and Game, Personal Communication 2016, Gammet, B. United States Forest Service, Personal Communication 2016). This prompted us to combine species at the genus level for the purposes of our comparisons. Lengths were estimated to the nearest 2 cm for trout ≤ 10 cm, and to 5 cm for trout ≥ 10 cm. Between population surveys, a subset of trout was captured with a handheld net, and individuals were measured to the nearest 1 mm using a ruler, and weighed to the nearest 0.1 g with a portable scale (Ohaus Scout Pro SP401, Pine Brook, NJ, USA), allowing estimation of fish biomass from the surveys using stream specific length-mass regressions. Additionally, we supplemented our sample size with the addition of a small number of trout captured in 2012 during a pilot study (Cliff Creek trout: $\log(10)$ mass (g)

= 2.8239 *log (10) length (cm) - 1.7533; $R_2 = 0.96$, $n = 105$; Pioneer Creek trout: log (10) mass (g) = 2.885 *log (10) length (cm) - 1.8502; $R_2 = 0.98$, $n = 104$; Appendix B).

Trout production was estimated by adapting a modified version of the size frequency method developed by Hynes and Coleman (1968), and described in Hayes et al. (2007). The size frequency method is used when cohort identification is not possible (e.g., in this case, because ages of fish were not known), and sums tissue losses between successive size-groups (less than 85cm, between 85 and 255 cm, and greater than 255cm) to estimate production via the following equation:

$$\hat{P} = 0.5c \left[\bar{w}_1 (\bar{N}_1 - \bar{N}_2) + \sum_{k=2}^{c-1} \bar{w}_k (\bar{N}_{k-1} - \bar{N}_{k+1}) + \bar{w}_c (\bar{N}_{c-1} - \bar{N}_c) \right]$$

Where \hat{P} = production for a particular size-class, \bar{N} = estimated mean density (arithmetic mean of estimates) for a specific length-group, \bar{w} = estimated mean weight (arithmetic mean of estimates) of individuals in a specific length-group, k = index for length groups, c = number of length-groups. Developing production estimates within a single year does not require the change in mass to be adjusted by a cohort production interval (CPI), therefore, we omitted the CPI scaler. Trout wet mass was converted to dry mass by multiplying by 0.20 (Bellmore et al. 2013).

We quantified food-web pathways sustaining production of trout, which required the collection of stomach contents to evaluate diets of individuals. Tricaine methanesulfonate (40 mg/L) was used to anesthetize fish, and non-lethal gastric lavage techniques were used to extract gut contents (Foster 1977, Strange & Kennedy 1981, Light et al. 1983). Gut contents ($n = 60$ for Cliff Creek, $n = 51$ for Pioneer Creek) were preserved in ≥ 90 % ethanol; prey items were identified and measured to the nearest 1 mm in the laboratory. Lengths of invertebrate diet items were converted to biomass via

application of published length-mass regressions (Benke et al. 1999, Sabo et al. 2002, Miyasaka et al. 2008).

Organic matter flows to trout were determined by applying the trophic basis of production (TBP) method, which estimates both the contributions of different prey to fish production, and rates of resource consumption that support measured rates of fish production (Benke & Wallace 1980, Cross et al. 2011). In addition to overall differences in composition, we were interested in potential differences in contributions to trout TBP of *r*-type taxa (Pianka 1970), because they have been shown to be important drivers of post-fire increases in invertebrate biomass in these streams (Malison & Baxter 2010b, Rugenski & Minshall 2014), and terrestrial invertebrates, which are known to be important prey subsidies to salmonid populations (Baxter et al. 2005). The relative fraction of fish production attributed to each prey type (F_i) was calculated as:

$$F_i = G_i \times AE_i \times NPE$$

Where G_i is the proportion of prey type i in fish diet, AE_i is the assimilation efficiency of prey type i , and NPE is the net production efficiency. Assimilation efficiencies of 0.75 for aquatic invertebrates, and 0.70 for terrestrial invertebrates were used for all salmonid species (Warren & Davis 1967, Brocksen & Bugge 1974, Elliot 1976). Values of net production efficiency were set at 0.125 for adult salmonids (≥ 150 mm), whereas a production efficiency of 0.250 was used for juveniles (≤ 150 mm; Donner 2011, Cross et al. 2011). Application of different net-production efficiencies for juvenile and adult fish accounted for the allometric relationship between fish consumption and growth with fish size. Estimates of total invertebrate prey demand by trout were calculated by multiplying fish production by the reciprocal of gross production efficiency (GPE), which is the

product of assimilation efficiency and net production efficiency (Waters 1988, Huryn 1996; 1998, Cross et al. 2011), and scaling values to the day for direct comparison. We did not directly estimate ecological efficiencies with this study, therefore, a GPE of 0.15 was used in calculations, which is at the low end of GPE values utilized in other studies (Waters 1988, Huryn 1996; 1998), which means (as was the case for invertebrate production) our estimates of prey demand by trout were likely conservative.

Spatially extensive comparison among streams

We surveyed fishes, invertebrates, and a range of habitat characteristics related to our working hypothesis (or that we judged might be important to explaining patterns of invertebrate and fish biomass) in reaches of 12 tributaries throughout the Big Creek watershed (Fig. 1, Table 2). Surveys took place during a 17-day window in summer 2014 (July 31st through August 16th) when streams were at base flow conditions (Olson 2010). All data were collected in a similar manner as described above, with the exception that single measures of fish biomass, invertebrate biomass, and canopy cover were conducted. When available, fish biomass estimates were generated using genus or family specific length mass regressions derived from data collected by the Idaho Fish and Game and supplemented by hook and line sampling by the authors (trout: $\text{mass (g)} = 2.933 * (\log \text{length (cm)}) - 4.847$, $R^2 = 0.99$, $n = 1969$; Appendix C). When sample size was determined to be insufficient ($n < 50$), literature derived length mass regression equations were applied (Rogers et al. 1996, Batty 2010, Collins 2016). Additionally, due to the challenges associated with conducting research in a wilderness setting, water chemistry samples used in our analysis were collected during the same summer low flow period of the previous summer (2013), and estimates of mean August water temperatures were

acquired via the United States Forest Service through the NorWest program (Parkes 2016). Water chemistry, in the form of total nitrogen (TN), total phosphorus (TP), dissolved organic carbon (DOC), phosphate (PO_4^{3-}), nitrate (NO_3^-), nitrite (NO_2^-), ammonium (NH_4^+), and silicate (SiO_4^{2-}) were collected from each stream, filtered and/or acidified in the field, and frozen or refrigerated as soon as possible after collection. All samples were analyzed by the Marine Chemistry Laboratory at the University of Washington. Total nitrogen was determined using perchloric acid digestion followed by analysis with automated colorimetry. Total phosphorus concentration was determined colorimetrically after persulfate digestion and reaction with molybdate and stannous chloride (Valderrama 1981). All other nutrients ($[\text{NO}_3^-]$, $[\text{PO}_4^{3-}]$, $[\text{NO}_2^-]$, $[\text{NH}_4^+]$ and $[\text{SiO}_4^{2-}]$) were determined following the protocols of the World Ocean Circulation Experiment Hydrographic Program using a Technicon AAI System (Knap et al. 1996). Samples for DOC analysis were acidified to pH 2 with hydrochloric acid immediately after collection; all nutrient and DOC samples were frozen until analysis on a Shimadzu TOC-Vcsh DOC analyzer (Shimadzu, Kyoto, Japan) (Knap et al. 1996). We judged that in both of these cases, our approach yielded estimates sufficient for relative comparisons among these sites. Dominant lithologies of basins were determined by referencing current geologic maps and documents produced by the Idaho Geological Survey (Shenon & Ross 1936, Lewis et al. 2012, Stewart et al. 2013).

Estimates of invertebrate biomass were determined by employing a stream-side, rapid analysis technique. Three replicates, each consisting of a composite of 3 Surber samples taken in riffle habitats, were collected at ~ 100m intervals. Each composite sample was transferred into a Caton tray (860 cm² area, 250 μm mesh size, Aquatic

Research Instruments, Hope, ID, USA), and homogenized. All large invertebrates (≥ 1 mm) were identified to the family or genus level, and measured to the nearest mm. Subsamples, consisting of a randomly chosen 36 cm² sections of the Caton tray, were extracted and used to estimate the abundance of small invertebrates ($< 250 \mu\text{m} \leq 1$ mm); subsampling continued until a minimum of 100 individuals were counted, identified, and measured. Invertebrate biomass in the form of dry mass (DM) was estimated by applying developed length-mass regressions to the measured individuals (Benke et al. 1999, Sabo et al. 2002, Miyasaka et al. 2008).

Statistical analyses

The long-term monitoring efforts produced a time series of annual means for chl-*a* and invertebrate biomass. Means for those values before and after wildfire were calculated by treating each year as a replicate ($n = 10$ prefire; $n = 14$ after fire), bootstrapping results 100,000 times (Efron 1979, Manly 1997) to generate error estimates in the form of 95% confidence intervals (CI), and non-overlapping CI's were interpreted as the basis for inferring significant differences ($p \leq 0.05$; Efron 1979). Bootstrapping was conducted with the aid of the statistical software *R* (*R* Core Development Team 2014) using the *asbio* library (Aho 2015).

Data from the paired stream comparison were analyzed using a variety of techniques. Estimates of daily GPP values were compared by bootstrapping daily values as replicates ($n = 11$ per stream) to calculate confidence intervals and evaluate potential differences between the streams; estimates of daily benthic invertebrate production were analyzed similarly, with individual Surber samples as replicates for confidence interval calculation ($n = 5$ per stream), as were estimates of daily trout production, treating each

14-day time period as a replicate ($n = 4$ per stream). Fish diet analysis was conducted via application of TBP calculations, which produced values for the proportion of production attributable to each prey item, which we directly compared between streams, and estimates of invertebrate prey demand by trout were calculated by multiplying fish production by the reciprocal of GPE. Due to the lack of replication at the stream-scale, TBP was directly compared between streams.

In each of the preceding cases, replicates in space or time employed to inform comparisons (e.g., via estimates of confidence intervals around means) were not independent in the fashion required for strict application of traditional inferential statistics. This is a challenge that faces many large-scale, or long-term, multi-trophic level studies (Carpenter 1990, Wootton 2002), such that the scope of inference associated with comparisons may be limited to the focal study system (in this case, the pair of streams themselves; Cottenie & De Meester 2003). Instead, coupling such studies with larger scale, comparative investigations can be a way forward, integrating complementary lines of evidence (Polis et al. 1998, Power et al. 1998). Indeed, evaluating the generality of our observations and increasing the potential scope of inference was the aim of our final study component, a more spatially extensive comparison.

The spatially extensive component of this study was designed to be comparative in nature, to explore possible relationships among variables, and to evaluate the generality of our findings from the paired stream scale. It was not intended to produce a predictive model of fish and invertebrate biomass patterns across the basin, nor to formally test a hypothesis. In our situation, though a sample size of 12 streams was relatively large when collected from remote wilderness streams, more replication would

have been required to provide the statistical power needed to include in models a wide range of covariates that might affect the fish and invertebrate metrics. Detecting and quantifying complex effects across trophic levels is further complicated when there are many mechanistic steps between the predictor (e.g. light input) and response (e.g. fish biomass). This combination of issues prompted us to analyze data from this study component in two stages. First, we used correlation coefficients and strategic reduction of variables to minimize the influence of covariates (Chatfield 1991; 1995, Anderson & Burnham 1999, Burnham & Anderson 2002; Figure 2, Table 3). Strong correlations existed among many of the habitat characteristics measured. For example, stream width, depth, particle size, and discharge were, not surprisingly, related to basin size (Biggs et al. 1990), and influences from bedrock geology were encompassed in measures of nutrient chemistry (Hem 1970). Subsequently, some covariates were able to be represented with a single variable that incorporated their influence. Second, we applied model selection using the information-theoretic approach, and Akaike information criterion adjusted for small sample size (AICc) to evaluate the contribution of different variables to explaining variation in invertebrate and fish biomass among streams. Model selection using AICc identifies the best approximating model, produces a weight of evidence associated with each model, and provides a method for model averaging to achieve inference based on multiple models (e.g., Benjamin et al. 2011). Model selection with AICc was executed with the statistical software *R* (*R* Core Development Team, 2014), using the *asbio* library (Aho 2015), *car* library (Fox & Weisber 2015), *leaps* library (Lumley 2009), and the *MASS* library (Venables & Ripley 2002).

Permitting

Study of protected species (Chinook salmon, steelhead, cutthroat trout, and bull trout) was conducted under permit #1990-055-00 from the National Oceanographic and Atmospheric Administration, and Idaho Department of Fish and Game permit #F-13-18-14. Implementation of non-lethal gastric lavage for collection of gut contents from fish required approved permit #732 5-4-2015 from the Institutional Animal Care and Use Committee at Idaho State University.

Results

Long-term monitoring

Long-term monitoring revealed no significant differences in chl-*a* or invertebrate biomass for the pair of streams (Cliff and Pioneer creeks) in the 10 years before the 2000 wildfire, with mean chl-*a* values of 7.57 ± 6.06 and 5.17 ± 2.42 mg/m², and mean invertebrate biomass values of 687.33 ± 211.65 and 522.70 ± 114.26 mg/m², $\pm 95\%$ CI ; respectively. Interannual variation in chl-*a* biomass (as measured by SE) before wildfire ranged 0.18 – 4.47 in Pioneer Creek, and 0.11 – 13.76 in Cliff Creek. Interannual variation in invertebrate biomass before wildfire ranged 72.58 – 343.64 in Pioneer Creek, and 30.57 – 493.78 in Cliff Creek, as indicated in Figure 3 and Appendix D.

After wildfire, the trajectories of chl-*a* and invertebrate biomass in the two streams diverged (Fig. 3, Appendix D), such that the 14-year mean for chl-*a* biomass post fire was $\sim 3.2 \times$ higher in the open canopy stream (Cliff Creek) as compared to the closed canopy (Pioneer Creek) stream (32.09 ± 14.57 and 10.09 ± 4.26 mg/m², $\pm 95\%$ CI; respectively, Fig 3, Appendix D). Invertebrate biomass followed a similar pattern; the 14-

year mean post fire was $\sim 2.5\times$ higher in the open canopy stream compared to the closed canopy stream (2159.84 ± 272.21 and 871.45 ± 155.64 mg/m², $\pm 95\%$ CI; respectively, Fig. 3, Appendix D). Interannual variation (as measured by SE) in both chl-*a* biomass and invertebrate biomass increased in range post-wildfire, with interannual variation in chl-*a* biomass after wildfire ranging 0.77 – 11.32 in Pioneer Creek, and 0.77 – 18.72 mg/m² in Cliff Creek. Interannual variation in invertebrate biomass after wildfire ranged 99.89 – 689.35 in Pioneer Creek, and 93.41 – 1015.37 mg/m² in Cliff Creek, as indicated in Figure 3 and Appendix D.

Short-term paired-stream comparison

The short-term paired-stream comparison during summer 2014 demonstrated that the open canopy stream received $\sim 2.9 \times$ more PAR than the closed canopy stream (291.7 ± 12.4 vs 101.6 ± 7.0 $\mu\text{mol}/\text{m}^2/\text{s} \pm 1\text{SE}$; Fig. 4, Appendix E), and indicated that GPP was higher in the open canopy stream, (0.944 ± 0.199 vs. 0.362 ± 0.146 g O₂/m²/day, $\pm 95\%$ CI, respectively; Fig 5 panel A, Appendix F). Similarly, the estimate of secondary production of 19 predominant taxa of invertebrates combined was $\sim 3.5 \times$ higher in the open canopy stream as compared to the closed canopy stream (0.043 ± 0.020 vs. 0.012 ± 0.004 mg/m²/ day, $\pm 95\%$ CI, respectively; Fig. 5 panel B, Table 1), and tertiary production of trout was estimated at $\sim 1.6 \times$ higher in the open canopy stream as compared to the closed canopy stream (0.029 ± 0.007 and 0.018 ± 0.002 g/m²/day, $\pm 95\%$ CI, respectively; Fig. 5 panel C, Appendix G).

Trophic basis of production

Trophic basis of production analysis revealed that, in summer, the proportion of trout production supported by terrestrially derived invertebrate prey in the open canopy

stream was half that of the closed canopy stream (mean = 15% vs. 30% respectively; Fig. 6; Appendix H). On the other hand, *r* – strategist (sensu Pianka 1970) insect taxa (*Chironomidae*, *Simulidae*, and *Baetidae*) contributed $\sim 2.4 \times$ more to trout production in the open canopy stream as compared to the closed canopy stream (30% vs 12%, respectively; Fig. 6; Appendix H). Accordingly, estimated trout population demand for invertebrate prey in the open canopy stream required $\sim 90\%$ of the available aquatic invertebrate production, whereas trout production in the closed canopy stream would have required nearly twice the aquatic invertebrate production (0.0165 vs 0.0327 mg/m²/day, $\pm 95\%$ CI, respectively; Fig. 7), a difference that was apparently bridged by heavy reliance on terrestrially-derived prey in that stream.

Spatially extensive comparison

The spatially extensive comparison among reaches using AICc model selection indicated that the model that best explained patterns in aquatic invertebrate biomass across the basin included (in order of importance): canopy cover, temperature, PO₄, and inorganic N. Model selection also produced 3 alternative models explaining patterns in invertebrate biomass that included basin area, proportion of basin burned, and time since burn, in addition to the variables found in the most parsimonious model stated above; AICc values ranged from 152.62–156.76, and Δ AICc (calculated as the difference between the highest and lowest AICc values) between the 3 other competing models ranged 0.33–4.14. The model that best explained patterns in fish biomass across the basin included (in order of importance): area of watershed, inorganic nitrogen, invertebrate biomass, canopy cover, and the proportion of the basin burned. In this case, 3 alternative models explaining patterns in fish biomass were also produced that included

temperature, time since burn, and PO_4 , in addition to the variables found in the most parsimonious model stated above; AICc values ranged from 0.09–4.86, and ΔAICc between the 3 other competing models ranged 1.28–4.77 (Appendix I).

Discussion

Our findings demonstrate that wildfire-derived alterations of basal resources and subsequently of stream-riparian food webs, likely have positive consequences for fish populations and productivity in streams retaining open canopies following wildfire, and highlight the role that the trajectory of riparian regrowth plays in mediating consequences of wildfire for aquatic ecosystems and food webs. These findings are substantiated by the results of long term monitoring, which demonstrated higher annual biomass values for streambed *chl-a* and invertebrates for up to 14 years after wildfire in a stream retaining open canopy compared to another that regained a closed canopy over this period, and through our short-term paired-stream efforts, which confirmed higher primary, secondary, and trout production in the open canopy stream. Furthermore, the results of our spatially extensive comparison were generally consistent with the “bottom up” process observed in the paired streams, indicating patterns of fish biomass across the basin were best explained by variation in light inputs and invertebrate biomass, as well as stream size, nitrogen concentrations, and wildfire history. These results are consistent with those of previous studies in the region that have demonstrated increased aquatic invertebrate biomass, adult insect emergence, and invertebrate drift export from streams retaining open canopies after severe wildfire (Malison & Baxter 2010a,b, Rugenski & Minshall 2014, Harris et al. 2015). Taken together, these findings provide evidence from a wilderness setting that severe wildfire, rather than being a catastrophe for stream

productivity or salmonid fishes, can be followed by resilient responses, including a pulse of productivity that may extend more than a decade depending on the trajectory of riparian vegetation recovery in the mid to long-term period following fire.

Our observations of an extended post-fire pulse of productivity mediated by light input and propagating to trout populations may, in part, be explained by patterns in the food-web pathways that sustain trout production. In particular, we observed higher proportions of aquatically-derived invertebrates in the diets of trout inhabiting the open canopy stream than trout in the closed canopy stream, and that trout in the closed-canopy stream relied upon the subsidy of terrestrial invertebrates to an elevated degree. Further, estimates of food demand by trout in the closed canopy stream were higher than our estimates of the production of the aquatic invertebrate prey base, implying that the trout population in that stream may be dependent on terrestrial subsidies to maintain its level of production (Fig. 6). Other studies of salmonid streams have shown the importance of terrestrial arthropod subsidies to fish population production (Nakano & Murakami 2001, Baxter et al. 2005, Wipfli & Baxter 2010), and indicated that terrestrial subsidies may be required to sustain levels of fish production observed (Allen 1951, Huryh 1996). In the present case, altered food webs appear to persist into the mid to long-term after wildfire, and provide evidence that the ‘fire pulse’, described by previous work (Malison & Baxter 2010a, Rugenski & Minshall 2014), extends well past the years immediately following severe wildfire. This is supported by the patterns evident from the long-term monitoring, but also from our short-term, paired-stream efforts, which showed $\sim 1.5\text{--}3.5 \times$ greater productivity across three trophic levels in the stream retaining an open canopy after wildfire compared to the closed canopy stream.

These findings indicate that fire severity may not be as important for predicting ecological responses by streams as is the mediation of light inputs (and perhaps other terrestrial inputs as well) by the subsequent trajectory and pattern of riparian vegetation regrowth. This is corroborated by the time series produced from our long-term monitoring efforts, which showed no difference in the observed values for periphyton chl-*a* and invertebrate biomass between the two streams before wildfire, but after wildfire burned both streams with comparable severity and one stream retained an open canopy and the other quickly regrew its canopy, these values diverged in their trajectory and magnitude. Additionally, 14 years after wildfire, the stream retaining an open canopy consistently yielded higher values for seasonal production of primary producers, invertebrates, and fish. We hypothesize that this observed divergence was principally driven by light input, which differed by more than $2.8 \times$ between the two streams. However, other variables (i.e. chemistry, hydrology, and temperature) may also affect invertebrate and fish population dynamics following fire (Rieman & Clayton 1997, Dunham et al. 2007). Therefore, the trajectory of ecological response by streams is, in part, a result of the interaction of biological and physiological characteristics of individual streams, which mediates the path of active response. Those interactions put the ecosystem's 'reaction to fire' in a broader context, such that fire severity alone may be insufficient to predict longer-term food web and ecosystem state.

We explain our observations of higher biomass and production of fish in streams retaining an open canopy into the mid to long-term after wildfire as principally driven by elevated light availability and subsequent amplified production at lower trophic levels. This increased light input is thought to directly translate into increases in the primary

production, and subsequently to increases in production of aquatic invertebrates.

Although food webs of mountain headwater streams are typically thought to be fueled by allochthonous inputs (Vannote et al. 1980, Minshall et al. 1992), increases in light have repeatedly been shown to result in increased primary production that can propagate to higher trophic levels (Wilzbach et al. 1986, Hill et al. 1995). Moreover, recent studies point to aquatic primary production contributing disproportionately to stream animal populations, owing to it generally being a higher quality food resource (Marcarelli et al. 2011, Rosi-Marshall et al. 2016). In addition, these pathways may be especially important in spring and summer when salmonids can be limited by food (Boss & Richardson 2002, Wipfli & Baxter 2010).

Patterns of structure and function of food webs are known to involve complex interactions of bottom-up and top-down regulatory processes (Power 1992, Huryn 1998, Collins et al. 2016). In the context of this system, assuming 3 dominant trophic levels, classic trophic-control theory (Hairston et al. 1960, Oksanen et al. 1981, Hunter & Price 1992) would predict that streams retaining high-light conditions and open canopies after wildfire would be likely to respond with elevated primary producer biomass, a somewhat weaker increase in invertebrate biomass (owing to top-down control by fishes), and, in turn, amplified fish biomass. The inclusion of other variables in explaining patterns of light input and invertebrate biomass may, in turn, be attributed to fish that are limiting invertebrate populations through predation, or the fact that other variables may have stronger influences on patterns of invertebrate biomass. The influences of a 4th trophic level (i.e. predatory invertebrates) or terrestrial subsidies (invertebrates) to fish could mediate the magnitude of fish predation on in-stream invertebrates (Wipfli 1997, Nakano

et al. 1999), and influence patterns of light inputs and fish population dynamics. We observed evidence for a bottom-up driven response, but that this may have been decoupled in more closed canopy streams where aquatic invertebrate demand by fish is likely intensified due to fish production being subsidized by terrestrial prey. Evaluating these possibilities will require more detailed, or perhaps experimental, future investigations of the strengths and dynamics of interactions in these stream-riparian food webs.

The mobility of fishes may have consequences for the inferences drawn regarding patterns observed at the scale of the stream reaches (100's m) within which we conducted our investigations. Most fish inhabiting the streams we studied have some migratory component to their life histories. Cutthroat, rainbow, and bull trout can all exhibit fluvial migratory patterns, spending much of their adult lives in larger-river systems (or oceans, in the case of steelhead) and using tributaries only for spawning and early rearing (Matthews & Waples 1991, Colyer et al. 2005, Hogen & Scarnecchia 2006). In these instances, those species use food resources outside of the tributary streams that were our focus, which may be subject to conditions and circumstances unrelated to the tributary, and in turn affect relationships between fish biomass/production and environmental characteristics of the tributaries (Wipfli & Baxter 2010). Despite the potentially confounding aspects of their life histories, previous research in the region has uncovered similar patterns in biomass values for fish in streams influenced by wildfire (Sestrich et al. 2011), and monitoring efforts have indicated increases in the numbers of out-migrating juvenile steelhead and Chinook salmon from basins that have experienced widespread and severe wildfire events 5–15 years previous (Copeland T. 2014. Idaho

Fish and Game, personal communication). Our findings provide a mechanistic explanation for these patterns, and also point to tributary streams as potentially important drivers of fish populations and productivity at larger scales, despite the complexity of mobile life histories exhibited by these species.

Combining long-term monitoring efforts, short-term intensive food-web investigations, and spatially extensive comparisons provided insight and scope of inference regarding effects of wildfire that would not have been possible with only one of these approaches. This underscores the power of using combinations of study designs to address complex ecological phenomena and highlights the usefulness of long term data for hypothesis development (Polis et al. 1997; 1998, Power et al. 1998). We attempted to extend the spatial scope of inference associated with our study by sampling 12 streams across the Big Creek watershed, but spatial heterogeneity at larger scales could limit the generality of our findings. The remote wilderness setting where this research was conducted provided an opportunity to measure wildfire-stream interactions without many typical influences from human management and use. For instance, the lack of roads makes fighting fire difficult in the rough terrain; it also prevents any substantial harvest or salvage logging efforts from taking place, whose impacts (e.g., Beschta et al. 2004, Lindenmayer et al. 2012) might alter the responses we report here. Those landscape characteristics and management actions narrow the scope of inference of this study, as most public lands in the western USA are managed differently. In addition, the spatially extensive portion of our work was constrained to a 16-day window in late summer, yielding a ‘snapshot’ of measurements. Moreover, our research focused on biomass and production of fish, and therefore excluded streams too small to support fish. Here we did

not investigate responses in the larger mainstem river, but other studies in this region suggest effects of wildfire may propagate downstream, delivering habitat forming sediment and wood (Benda et al. 2004) as well as pulses of invertebrate prey to fishes aggregating at confluences (Harris et al. 2015). By such means, changes like those we found may have consequences for fish populations and their habitats at scales larger than those investigated here.

Our long-term monitoring revealed not only changes in mean biomass values of streambed biofilms and invertebrates, but also, in the case of the stream retaining an open canopy after severe wildfire, increased interannual variation. Such increased interannual variability is a pattern generally expected with changing regimes of climate and hydrology (Davis et al. 2013a). These observations are consistent with long-term responses predicted for biofilms in these streams (Davis et al. 2013b). Yet, our observations also suggest those streams that rapidly regain closed canopy after wildfire may not follow this trend. This variation in trajectory and magnitude of response of streams to wildfire could create heterogeneity, and ultimately contribute to a patchwork of wildfire response trajectories that may, in turn, support stability at larger temporal and spatial scales (Turner et al. 1993, Jackson et al. 2015, Hutto et al. 2016). Previous research on Cliff and Pioneer creeks has indicated that wildfire had no negative impacts on diversity of invertebrate communities (Rugenski & Minshall, 2014). In part, this may be due to variation in the response of streams to wildfire creating refugia for species at larger spatial scales, heterogeneity that generally is important to the persistence of animals at these scales (Townsend 1989, Winemiller et al. 2010). Understanding heterogeneity in the responses of streams to wildfire, and its role as a potential driver of

stability in large, connected landscapes and riverscapes (e.g., sensu Moore et al. 2015), requires further investigation.

Organisms within this region are thought to be adapted to disturbance, including wildfire, but the mechanisms by which resistance and resilience occur are not well understood. Wildfire is a natural disturbance that has been actively managed based upon an assumption of negative effects on the landscape and its inhabitants, but a growing body of research suggests this may not hold true for fish and invertebrates in all contexts (Jackson et al. 2015). Moreover, the pulse of productivity across aquatic trophic levels that we have documented following severe wildfire (the ‘fire pulse’) may be beneficial to other organisms (e.g., terrestrial insectivores like spiders, bats and birds; Malison & Baxter 2010a, Jackson et al. 2015), influence larger scale patterns of organism distributions, and contribute to overall resilience of watershed ecosystems. Furthermore, heterogeneity in the severity, location, and timing of wildfire across the landscape could influence the long-term adaptive capacity of stream ecosystems and organisms through the provision of refugia and the formation of new habitats and conditions. Wildfire regimes are altered through management practices designed to reduce both the extent and severity of wildfire across the western USA, but such approaches may not be consistent with the emerging understanding of the ecological processes associated with severe wildfire or the long-term potential for fire and fuels management to affect the ecology of stream-riparian systems (Jackson et al. 2015, Hutto et al. 2016). Findings from our study highlight the need for spatially and temporally extensive studies to understand the large scale and long term effects of both wildfire and human attempts to manage it in landscapes.

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Figures

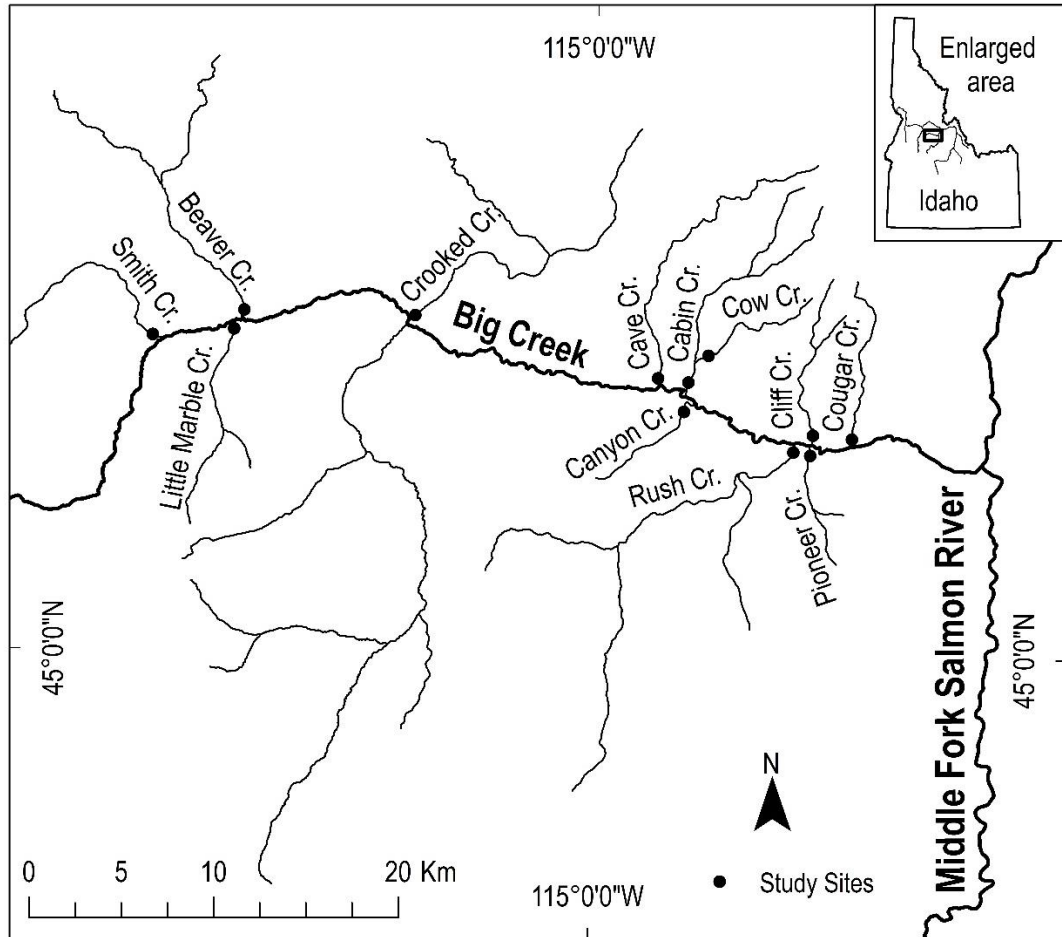


Figure 1.

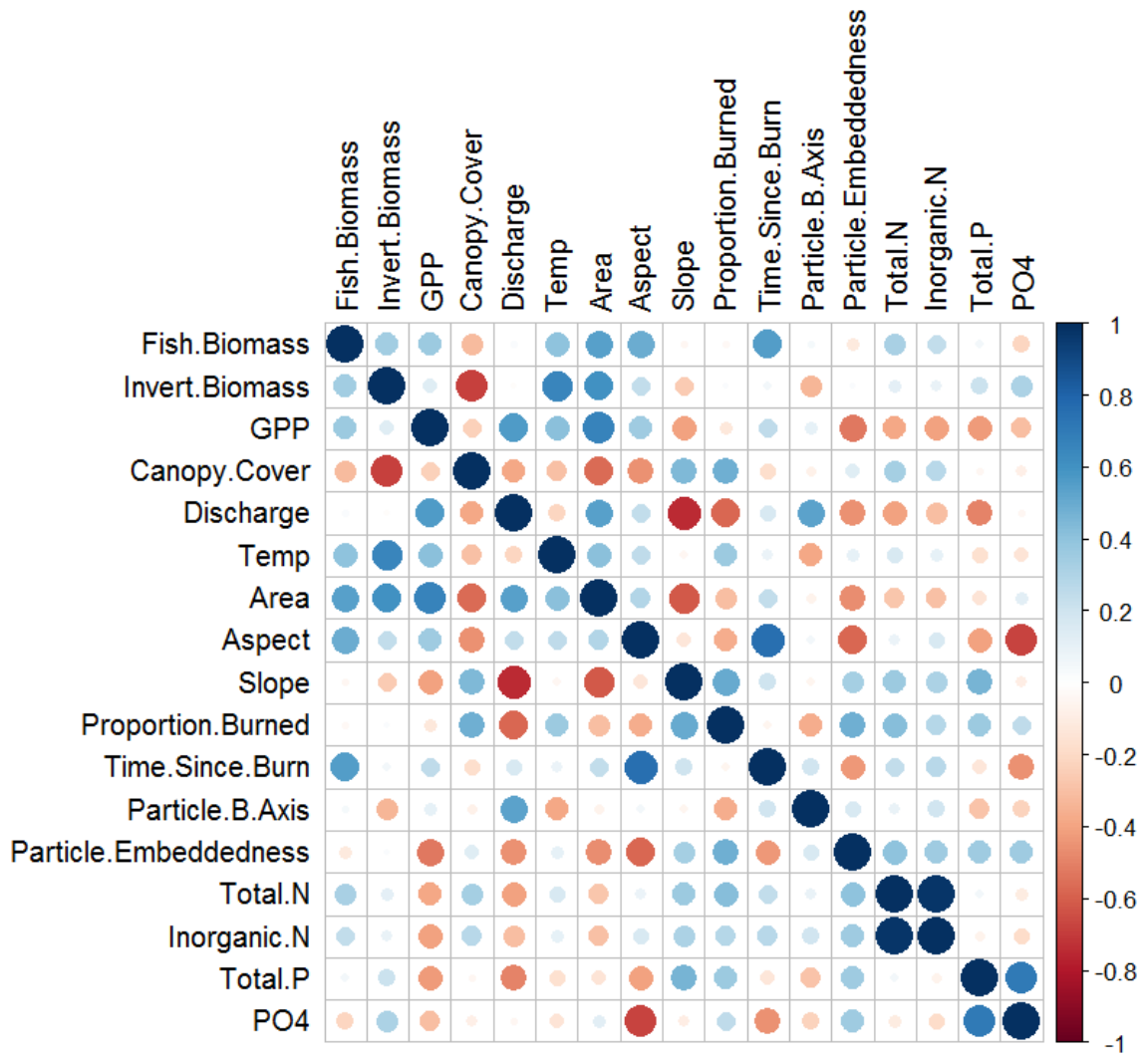


Figure 2.

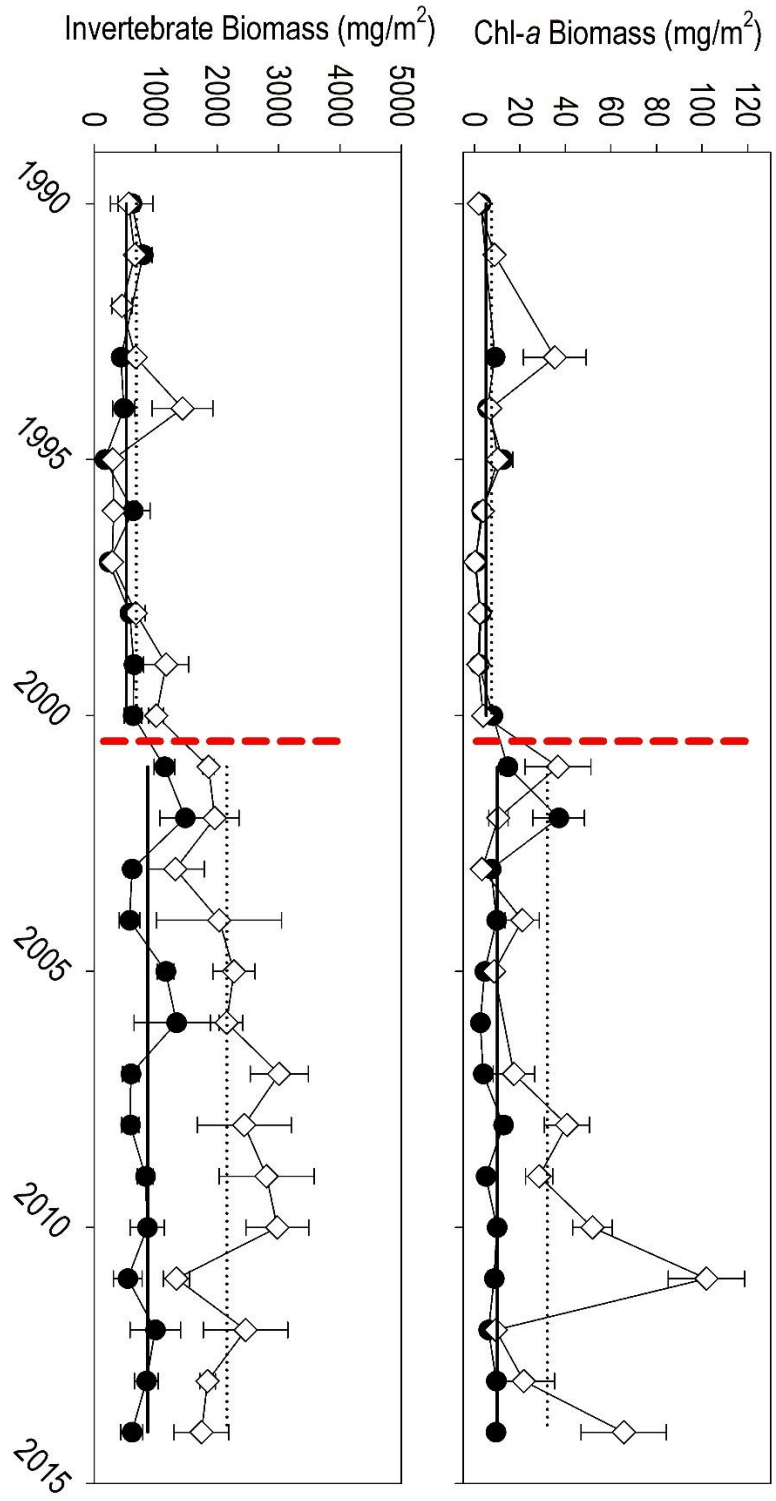


Figure 3.

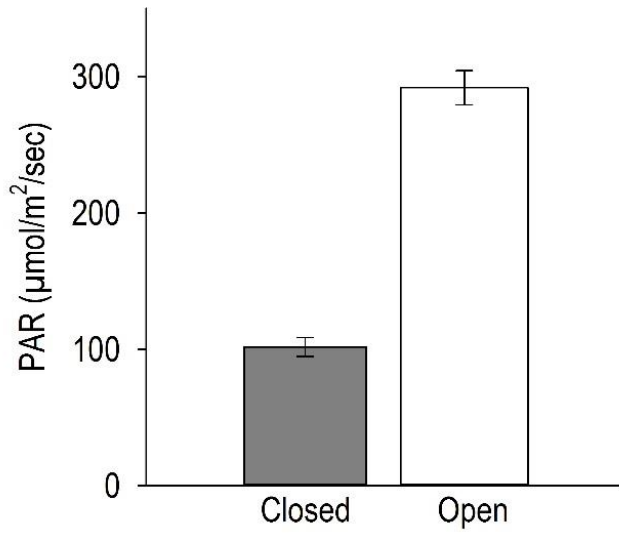


Figure 4.

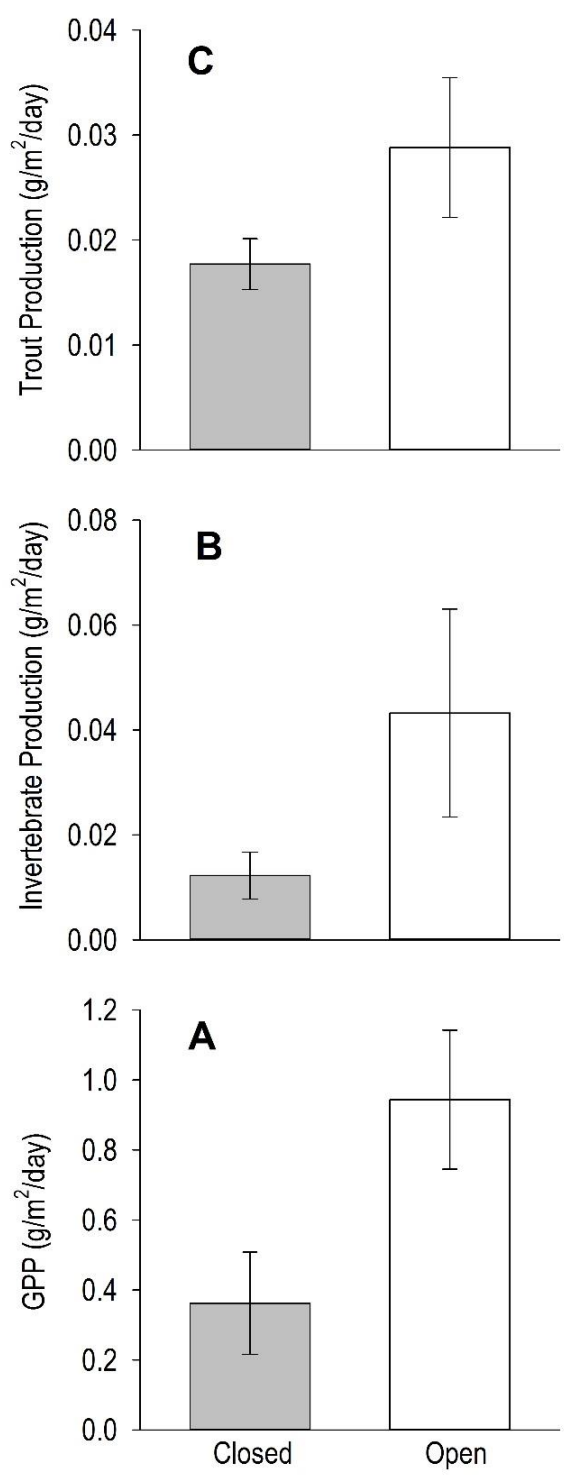


Figure 5.

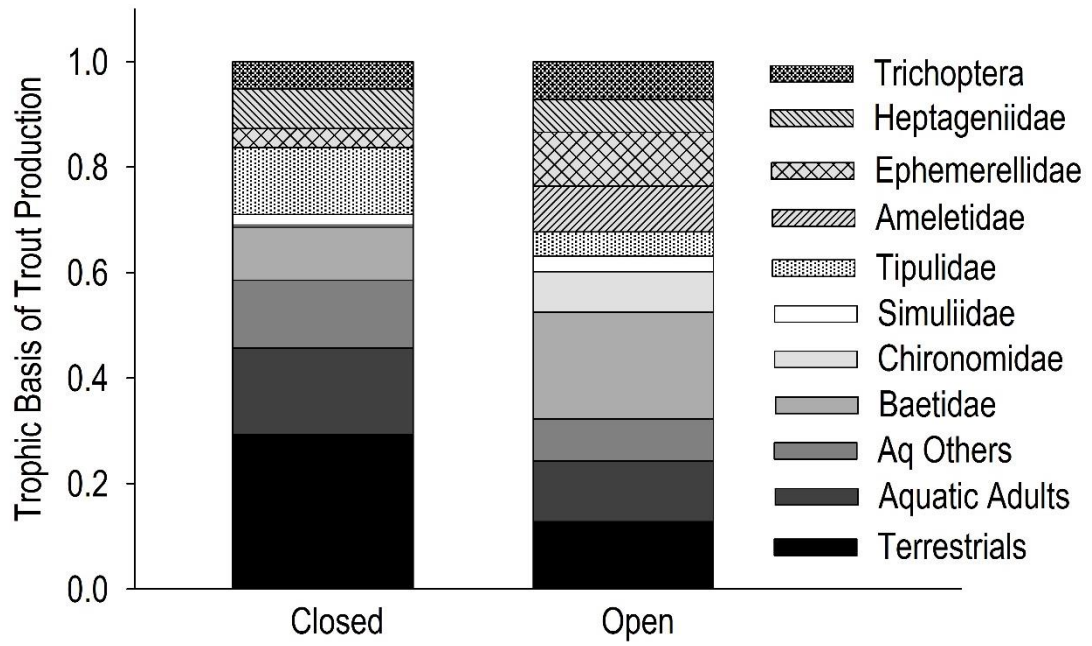


Figure 6.

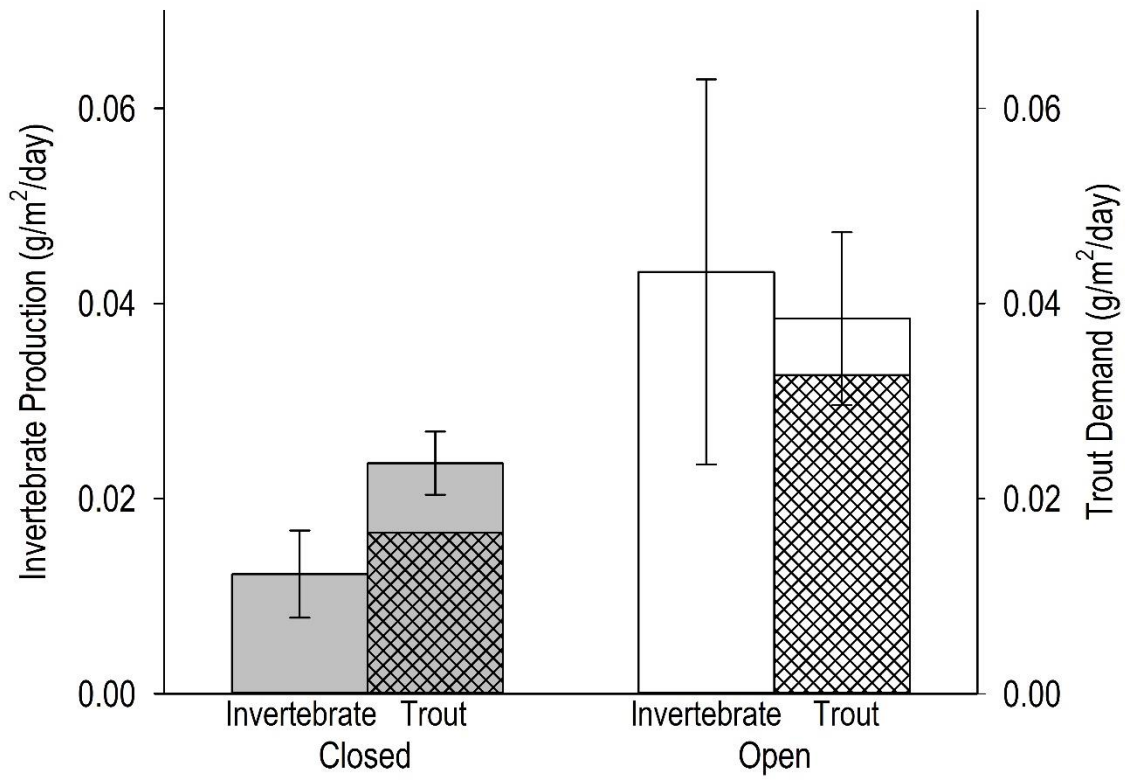


Figure 7.

Tables

Table 1.

Order	Taxa	P:B Ratio	Cliff Creek Invertebrate Biomass (mg/m ²)					Pioneer Creek Invertebrate Biomass (mg/m ²)				
			T1	T2	T3	T4	T5	T1	T2	T3	T4	T5
E	Baetis spp.	24.00	116.59	156.20	9.71	29.31	11.90	0.59	1.85	5.13	50.64	15.79
E	Ameletidae Ameletus spp.	5.00	0.00	0.00	2.94	58.40	140.22	0.00	0.00	0.00	5.51	1.47
E	<i>Drunella coloradensis</i>	6.00	172.28	388.70	2.26	13.83	526.38	0.00	4.67	0.00	46.37	44.65
E	Ephemerellidae spp.	6.00	11.44	17.83	2.26	3.98	8.42	0.00	0.00	3.77	0.00	0.46
E	<i>Serritella tibialis</i>	6.00	50.02	89.48	17.84	4.67	21.66	0.00	13.83	0.00	4.67	0.00
E	<i>Epeorus longimanus</i>	6.75	160.04	186.74	0.00	42.18	12.57	0.00	0.00	0.00	31.11	45.30
E	Heptigeneidae spp.	6.75	38.67	81.09	31.43	87.99	219.64	74.52	69.65	224.43	229.65	65.92
D	Chironomidae spp.	88.00	13.42	25.19	5.16	22.01	102.42	2.50	5.71	7.45	4.53	6.56
D	Simuliidae spp.	55.00	113.59	21.22	2.02	20.39	0.61	0.00	23.33	0.81	3.06	26.09
D	Tipulidae spp.	4.50	77.18	62.82	45.84	21.38	74.33	8.91	1.33	22.38	2.41	0.00
C	Elmidae spp.	5.90	128.39	279.85	9.75	360.40	308.80	39.67	45.55	109.79	374.59	24.17
T	Hydropsychidae spp.	7.50	377.82	493.05	0.78	0.00	0.41	0.00	240.66	0.00	0.00	0.00
T	Rhyacophilidae spp.	7.00	12.11	111.02	12.21	18.61	23.74	47.67	18.97	175.77	43.20	28.97
T	Glossosomatidae spp.	9.90	0.00	5.50	0.00	10.29	9.88	0.00	0.00	9.40	0.00	0.00
T	Unoidae spp.	9.90	0.00	0.00	0.00	6.72	17.81	0.00	0.00	0.00	0.00	1.41
P	Perlidae spp.	7.85	849.51	367.83	94.56	267.50	19.13	0.00	5.95	0.00	0.00	0.00
P	Perlodidae spp.	7.85	29.63	60.71	5.83	51.65	260.89	0.00	0.00	11.65	49.12	45.63
P	Chloroperlidae spp.	5.00	8.53	89.23	8.18	19.45	64.66	0.95	13.97	85.79	67.67	1.91
P	Nemouridae spp.	5.00	5.12	19.20	2.39	1.73	6.20	0.00	3.88	1.54	6.56	1.72

Table 2.

Stream	Fish Biomass (g/m ²)	Invert Biomass (mg/m ²)	GPP (gO ₂ /m ² /d)	Canopy Cover (%)	Discharge (m ³ /sec)	Temp (°C)	Area (km ²)	Aspect (°)	Slope (°)	Proportion watershed burned (%)	Time since burn (yr)	Particle B-axis (cm)	Embedded-ness	TN (µg/L)	Inorganic N (µg/L)	TP (µg/L)	Phosphate (µg/L)	Dominant Lithology
Beaver	2.98	1441 ± 538	2.05	55.64 ± 18.02	0.62	10.08	110642.2	169	3.0	73.58	13	21.58	0.62	108.8	8.9	10.6	1.8	Zsy
Cabin	2.12	2637 ± 353	0.77	48.71 ± 20.04	0.14	12.78	64430.3	216	3.3	98.49	5	13.61	1.8	110.0	2.5	13.4	3.2	Tgd
Canyon	2.94	3304 ± 352	0.49	28.36 ± 4.22	0.02	11.45	13093.1	186	9.0	99.85	13	11.89	1.21	142.5	37.1	29.7	2.8	Tss
Cave	2.35	2895 ± 274	1.57	57.42 ± 4.64	0.07	13.39	47092.1	194	4.8	86.41	5	9.97	0.88	123.1	6.4	12.0	0.9	Tgd
Cliff	4.05	2718 ± 727	0.39	68.64 ± 4.25	0.03	12.07	18744.0	175	7.0	97.82	13	16.75	1.46	457.9	409.5	13.3	0.8	Tgd
Cougar	3.90	0661 ± 128	1.37	80.25 ± 3.93	0.02	12.14	21410.4	165	9.3	99.16	12	13.32	1.01	158.0	34.5	15.8	0.5	Tgd
Cow	2.56	1354 ± 435	0.28	86.41 ± 1.49	0.03	8.49	16103.5	225	7.0	99.43	5	11.88	1.32	172.2	27.7	30.8	4.5	Tgd
Crooked	4.97	2178 ± 341	1.53	47.1 ± 3.08	0.18	12.34	102585.6	181	4.5	90.92	13	12.42	0.92	151.6	7.9	15.6	0.3	Zdi
Little Marble	2.49	1346 ± 174	0.69	53.04 ± 9.23	0.27	9.33	39129.2	182	2.0	33.29	10	10.59	0.32	85.6	3	9.5	1.1	Yssc
Pioneer	1.92	1121 ± 124	0.89	89.10 ± 3.31	0.07	10.77	15869.7	193	8.3	99.80	13	11.5	0.54	153.3	60.7	11.1	0.3	Yh
Rush	4.50	4620 ± 2273	1.74	25.34 ± .065	0.57	13.55	243351.5	183	3.0	53.74	13	9.59	0.3	118.6	1	17.7	2.6	Tdq
Smith	3.11	1504 ± 544	0.87	35.88 ± 7.32	0.33	9.34	52387.4	171	5.5	2.74	10	21.96	0.95	79.4	5.2	12.3	0.3	Yac

Table 3.

Potential Variables	Fish Biomass	Invert Biomass	GPP	Canopy Cover	Discharge	Temp	Area	Aspect	Slope	Proportion Burned	Time Since Burn	Particle B Axis	Embedd- edness	Total N	Inorganic N	Total P	PO4
Fish Biomass	1	0.316	0.362	-0.313	0.036	0.378	0.520	0.513	-0.051	-0.055	0.559	0.060	-0.120	0.315	0.238	0.035	-0.253
Invert Biomass	0.316	1	0.132	-0.686	-0.019	0.654	0.601	0.242	-0.258	0.027	0.054	-0.336	0.022	0.115	0.096	0.219	0.313
GPP	0.362	0.132	1	-0.235	0.569	0.417	0.667	0.358	-0.405	-0.122	0.257	0.104	-0.524	-0.383	-0.410	-0.430	-0.301
Canopy Cover	-0.313	-0.686	-0.235	1	-0.381	-0.295	-0.568	-0.460	0.447	0.487	-0.174	-0.078	0.134	0.337	0.275	-0.042	-0.090
Discharge	0.036	-0.019	0.569	-0.381	1	-0.210	0.541	0.244	-0.748	-0.578	0.165	0.536	-0.459	-0.403	-0.303	-0.491	-0.043
Temp	0.378	0.654	0.417	-0.295	-0.210	1	0.412	0.254	-0.046	0.361	0.081	-0.387	0.109	0.167	0.110	-0.162	-0.145
Area	0.520	0.601	0.667	-0.568	0.541	0.412	1	0.294	-0.611	-0.307	0.242	-0.069	-0.461	-0.271	-0.292	-0.143	0.123
Aspect	0.513	0.242	0.358	-0.460	0.244	0.254	0.294	1	-0.133	-0.366	0.757	0.052	-0.580	0.081	0.163	-0.401	-0.676
Slope	-0.051	-0.258	-0.405	0.447	-0.748	-0.046	-0.611	-0.133	1	0.502	0.203	-0.058	0.330	0.366	0.312	0.469	-0.091
Proportion Burned	-0.055	0.027	-0.122	0.487	-0.578	0.361	-0.307	-0.366	0.502	1	-0.050	-0.364	0.488	0.423	0.281	0.366	0.259
Time Since Burn	0.559	0.054	0.257	-0.174	0.165	0.081	0.242	0.757	0.203	-0.050	1	0.200	-0.436	0.241	0.278	-0.132	-0.460
Particle B Axis	0.060	-0.336	0.104	-0.078	0.536	-0.387	-0.069	0.052	-0.058	-0.364	0.200	1	0.169	0.092	0.192	-0.286	-0.222
Embedd- edness	-0.120	0.022	-0.524	0.134	-0.459	0.109	-0.461	-0.580	0.330	0.488	-0.436	0.169	1	0.410	0.357	0.353	0.358
Total N	0.315	0.115	-0.383	0.337	-0.403	0.167	-0.271	0.081	0.366	0.423	0.241	0.092	0.410	1	0.976	0.056	-0.110
Inorganic N	0.238	0.096	-0.410	0.275	-0.303	0.110	-0.292	0.163	0.312	0.281	0.278	0.192	0.357	0.976	1	-0.068	-0.189
Total P	0.035	0.219	-0.430	-0.042	-0.491	-0.162	-0.143	-0.401	0.469	0.366	-0.132	-0.286	0.353	0.056	-0.068	1	0.706
PO4	-0.253	0.313	-0.301	-0.090	-0.043	-0.145	0.123	-0.676	-0.091	0.259	-0.460	-0.222	0.358	-0.110	-0.189	0.706	1

Appendices

Appendix A.

Detailed metabolism methods. Metabolism modeling results were assessed graphically and if there was a sharp divergence in observed and predicted values during the week (i.e., a large sum of squared error) the data were broken into time periods where trends appeared to be similar. We used light with a shading ratio to scale GPP rates and made all the rates dependent on water temperature. This model employed a trial-and-error approach where three parameter estimates (CR, alpha, and reaeration) were adjusted to obtain a good match between the measured and simulated O₂ concentrations. We used the “Solver” option in Microsoft Excel (version 2007, Microsoft Corporation, Redmond, Washington) to find estimates of CR and GPP that minimized the sum of square of errors (SSE) between the observed and modeled O₂. We verified that parameter estimates of reaeration were reasonable by also calculating the daily value using the equation of Isaacs and Gaudy (1968):

$$K_a = 4.7531\left(\frac{U}{H^{1.5}}\right)1.0241^{(T-20)}$$

Where U is velocity, H is depth, and T is temperature. Although this method was developed for flumes, it is a modified version of the Churchill et al. (1962) method and is the best performing method for calculating reaeration when H , U , and T are known (Cox 2003), where the model estimates for K were within expected limits according to these calculations. The observed concentration of O₂ in the water column was compared to the modeled O₂ predicted by changing rates of CR and GPP to minimize the sum of square of

error between observed and modeled O₂ concentration. The change in O₂ concentration between each of two time periods of measurement (t₁ and t₂) was calculated as:

$$\frac{\delta O_2}{\delta t} = \frac{\delta O_{2,GPP}}{\delta t} + \frac{\delta O_{2,CR}}{\delta t} + \frac{\delta O_{2,K}}{\delta t}$$

Where O_{2,GPP} is the change in O₂ from GPP, $\delta O_{2,CR}$ is the change in O₂ from CR, $\delta O_{2,K}$ is the change in O₂ from K, and change in time (δt) is:

$$\delta t = t_1 - t_2$$

The $\delta O_{2,GPP}$ is driven by the relationship between light (PAR) and GPP, corrected for average temperature (T_{avg}) using the combined equations from Jassby and Platt (1976) for photosynthetic rate and Parkhill and Gulliver (1999) for temperature correction.

$$\delta O_{2,GPP} = P_{max} 1.036^{(T_{avg}-20)} \tanh\left(\frac{\alpha(1.036^{(T_{avg}-20)})PAR}{P_{max}(1.036^{(T_{avg}-20)})}\right) / H$$

Where P_{max} is maximum photosynthetic rate per unit area and α is the areal rate as influenced by PAR. Exploratory modeling found that the models were insensitive to initial values of P_{max} so in all models the P_{max} was set to a high value and only α was solved for. The temperature corrected CR (Parkhill & Gulliver 1999) was calculated as

$$\delta O_{2,CR} = CR(1.045^{(T_{avg}-20)}) / H$$

And the temperature corrected aeration, K, was used to calculate change in O₂ concentration by aeration for each time period

$$\delta O_{2,CR} = K(O_{2,sat} - O_2)$$

Where O_{2,sat} is the predicted dissolved oxygen concentration at 100% saturation at the water temperature during the time period.

Appendix B.

Pioneer Creek				Cliff Creek			
<i>n</i>	Date	Length (cm)	Weight (g)	<i>n</i>	Date	Length (cm)	Weight (g)
1	7/14/2014	6.6	3.3	1	7/2/2012	7.2	7.3
2	8/3/2012	6.7	3.4	2	8/20/2014	7.5	6.7
3	6/25/2012	6.8	3.1	3	7/13/2014	7.6	5.4
4	7/14/2014	6.9	4.2	4	8/8/2014	7.7	4.8
5	7/18/2012	6.9	5.0	5	6/13/2012	7.7	6.0
6	7/18/2012	6.9	5.0	6	7/2/2012	7.8	8.6
7	7/18/2012	7.0	4.0	7	7/2/2012	7.8	6.4
8	7/5/2014	7.1	3.7	8	7/19/2014	7.9	5.8
9	7/14/2014	7.3	4.4	9	7/19/2014	8.1	6.1
10	6/25/2012	7.3	4.8	10	7/6/2014	8.4	6.3
11	7/14/2014	7.4	4.8	11	7/6/2014	8.4	6.5
12	7/20/2014	7.4	4.7	12	8/8/2014	8.4	5.2
13	8/3/2012	7.6	4.5	13	7/13/2014	8.5	6.5
14	7/20/2014	7.6	5.0	14	7/13/2014	8.6	10.0
15	7/20/2014	7.7	5.0	15	7/19/2014	8.6	6.9
16	7/5/2014	7.8	5.2	16	7/6/2014	8.7	8.3
17	6/25/2014	7.9	5.4	17	8/8/2014	8.7	6.2
18	7/20/2014	7.9	5.1	18	8/20/2014	8.7	9.2
19	7/13/2012	8.0	5.7	19	7/2/2012	8.7	8.6
20	7/5/2014	8.1	5.6	20	7/2/2012	8.7	9.2
21	8/3/2012	8.2	6.2	21	8/8/2014	8.8	6.9
22	6/25/2012	8.3	5.8	22	8/1/2012	8.8	7.6
23	8/3/2012	8.3	7.1	23	7/13/2014	8.9	8.5
24	8/21/2014	8.3	6.2	24	7/13/2014	8.9	8.7
25	6/25/2014	8.4	5.5	25	7/6/2014	9.0	7.9
26	6/25/2014	8.4	6.3	26	7/2/2012	9.0	10.1
27	8/7/2014	8.7	7.9	27	7/13/2014	9.1	7.5
28	8/21/2014	8.7	7.6	28	7/2/2012	9.1	13.4
29	7/14/2014	8.8	7.4	29	7/6/2014	9.2	10.2
30	7/14/2014	8.8	7.6	30	7/19/2014	9.2	8.6
31	8/7/2014	8.8	7.3	31	6/13/2012	9.2	8.9
32	8/7/2014	8.9	8.4	32	7/6/2014	9.3	8.7
33	7/5/2014	9.3	8.1	33	7/6/2014	9.3	9.5
34	8/3/2012	9.3	8.8	34	7/13/2014	9.4	8.8
35	8/7/2014	9.3	8.8	35	7/2/2012	9.5	13.6
36	8/3/2012	9.5	8.6	36	7/6/2014	9.6	9.6
37	8/3/2012	9.5	9.5	37	7/6/2014	9.6	10.1
38	7/14/2014	9.6	9.9	38	7/13/2014	9.6	9.0
39	8/21/2014	9.6	11.1	39	7/19/2014	9.6	9.8
40	8/7/2014	9.9	9.1	40	8/8/2014	9.6	8.5

41	8/3/2012	10.2	10.8	41	6/13/2012	9.6	11.0
42	7/14/2014	10.3	11.2	42	8/8/2014	9.7	10.4
43	8/3/2012	10.3	11.5	43	7/19/2014	9.8	10.7
44	8/21/2014	10.3	13.5	44	8/20/2014	9.8	12.1
45	6/20/2014	10.5	12.0	45	7/2/2012	9.8	12.0
46	7/5/2014	10.8	13.7	46	8/1/2012	9.8	11.1
47	6/25/2012	10.8	14.0	47	7/13/2014	9.9	9.8
48	7/13/2012	10.9	13.4	48	8/1/2012	9.9	12.0
49	6/25/2014	11.0	13.4	49	8/20/2014	10.0	12.0
50	8/7/2014	11.0	12.9	50	7/6/2014	10.1	12.9
51	6/25/2012	11.0	15.0	51	8/8/2014	10.1	12.0
52	8/3/2012	11.0	14.4	52	8/1/2012	10.1	11.8
53	6/25/2014	11.2	13.2	53	6/13/2012	10.2	11.9
54	7/5/2014	11.2	14.5	54	7/6/2014	10.3	11.9
55	7/5/2014	11.3	14.0	55	8/8/2014	10.3	12.6
56	7/14/2014	11.4	15.2	56	7/6/2014	10.4	12.8
57	7/14/2014	11.4	15.3	57	7/13/2014	10.5	13.7
58	8/7/2014	11.4	14.8	58	7/19/2014	10.6	12.1
59	8/21/2014	11.4	16.1	59	8/1/2012	10.6	14.4
60	7/13/2012	11.5	17.3	60	7/19/2014	10.7	13.3
61	7/13/2012	11.5	15.7	61	8/1/2012	11.0	15.9
62	6/25/2012	11.6	16.1	62	7/13/2014	11.2	14.8
63	6/25/2012	11.6	17.2	63	7/19/2014	11.2	14.8
64	7/13/2012	11.6	18.6	64	6/13/2012	11.2	15.0
65	7/5/2014	11.6	14.5	65	7/6/2014	11.3	15.4
66	8/21/2014	11.7	17.4	66	6/13/2012	11.4	17.5
67	6/25/2012	11.9	17.9	67	8/8/2014	11.5	16.4
68	6/20/2014	12.0	17.5	68	6/21/2014	11.5	17.7
69	8/3/2012	12.0	18.0	69	8/1/2012	11.6	19.1
70	6/25/2014	12.4	19.5	70	8/8/2014	11.7	17.2
71	8/3/2012	12.4	34.2	71	8/8/2014	11.7	18.8
72	6/25/2012	12.7	23.0	72	7/19/2014	11.7	17.0
73	7/13/2012	12.8	21.5	73	8/20/2014	11.8	19.7
74	8/3/2012	12.9	22.2	74	8/20/2014	12.0	18.2
75	6/25/2012	13.0	32.2	75	6/13/2012	12.2	20.8
76	8/7/2014	13.2	26.2	76	6/13/2012	12.3	22.7
77	7/13/2012	13.2	26.2	77	7/2/2012	12.3	20.6
78	7/13/2012	13.3	26.7	78	7/2/2012	12.9	26.6
79	8/7/2014	13.4	25.1	79	7/2/2012	13.0	25.9
80	8/21/2014	13.4	26.2	80	7/6/2014	13.0	23.8
81	7/5/2014	13.5	26.5	81	6/13/2012	13.1	28.2
82	7/18/2012	13.5	11.4	82	6/13/2012	13.2	26.1
83	8/7/2014	13.9	30.3	83	7/6/2014	13.3	24.7
84	8/3/2012	13.9	28.2	84	8/1/2012	13.4	27.5
85	6/25/2012	14.0	29.8	85	6/13/2012	13.5	31.1

86	8/3/2012	14.0	30.2	86	7/13/2014	13.6	28.4
87	8/7/2014	14.3	31.6	87	8/8/2014	13.6	26.1
88	7/14/2014	14.5	32.9	88	7/2/2012	13.7	33.8
89	6/25/2012	14.5	29.7	89	8/1/2012	13.9	28.3
90	7/5/2014	14.6	31.3	90	8/1/2012	14.0	32.5
91	6/25/2012	14.6	31.4	91	8/20/2014	14.0	25.9
92	6/25/2012	15.0	34.7	92	7/19/2014	14.2	29.4
93	7/14/2014	15.2	36.0	93	8/8/2014	14.3	24.8
94	7/14/2014	15.3	40.6	94	7/6/2014	14.6	40.5
95	7/18/2012	15.3	28.9	95	6/13/2012	14.7	36.2
96	8/3/2012	15.3	38.4	96	8/8/2014	14.9	31.7
97	7/20/2014	15.6	43.2	97	7/6/2014	15.0	42.0
98	6/25/2012	15.8	35.4	98	8/20/2014	15.5	34.7
99	8/3/2012	16.3	47.7	99	8/8/2014	15.6	40.8
100	8/7/2014	16.5	46.5	100	8/1/2012	15.9	41.8
101	8/21/2014	16.7	45.2	101	7/2/2012	16.0	48.0
102	8/21/2014	17.0	50.5	102	7/13/2014	16.6	55.4
103	7/18/2012	19.5	70.1	103	6/13/2012	17.6	61.0
104	8/3/2012	20.0	91.4	104	6/13/2012	19.8	94.3
105	7/5/2014	20.3	90.3	105	7/2/2012	20.5	100.7

Appendix C.

Trout lengths (cm) and weights (g) for the spatially extensive survey

<i>n</i>	Length (cm)	Weight (g)	<i>n</i>	Length (cm)	Weight (g)	<i>n</i>	Length (cm)	Weight (g)	<i>n</i>	Length (cm)	Weight (g)
1	39.0	1.0	493	110.0	15.0	985	166.0	48.0	1477	193.0	70.0
2	41.0	1.0	494	110.0	15.0	986	166.0	42.0	1478	193.0	72.0
3	41.0	1.0	495	110.0	15.9	987	166.0	48.0	1479	193.0	72.0
4	42.0	1.0	496	110.0	15.0	988	166.0	47.0	1480	193.0	67.0
5	43.0	1.0	497	110.0	14.4	989	166.0	49.0	1481	193.0	68.0
6	43.0	1.0	498	110.0	13.5	990	166.0	46.0	1482	193.0	68.0
7	44.0	1.0	499	110.0	13.4	991	166.0	51.0	1483	193.0	74.0
8	45.0	1.0	500	110.0	12.9	992	166.0	51.0	1484	193.0	77.0
9	46.0	1.0	501	112.0	14.0	993	166.0	31.0	1485	193.0	65.0
10	46.0	1.0	502	112.0	15.0	994	166.0	41.0	1486	193.0	72.0
11	46.0	1.0	503	112.0	15.0	995	166.0	48.0	1487	193.0	72.0
12	47.0	1.0	504	112.0	15.0	996	166.0	46.0	1488	193.0	66.0
13	47.0	1.0	505	112.0	16.0	997	166.0	47.0	1489	193.0	78.0
14	47.0	1.0	506	112.0	14.0	998	166.0	47.0	1490	193.0	71.0
15	48.0	1.0	507	112.0	14.8	999	166.0	49.0	1491	193.0	72.0
16	48.0	1.0	508	112.0	14.8	1000	166.0	55.4	1492	194.0	72.0
17	48.0	1.0	509	112.0	15.0	1001	167.0	48.0	1493	194.0	62.0
18	49.0	1.0	510	112.0	13.2	1002	167.0	43.0	1494	194.0	64.0
19	49.0	1.0	511	112.0	14.5	1003	167.0	45.0	1495	194.0	78.0
20	49.0	1.0	512	113.0	15.0	1004	167.0	47.0	1496	194.0	68.0
21	50.0	1.0	513	113.0	14.0	1005	167.0	45.0	1497	194.0	72.0
22	50.0	1.0	514	113.0	14.0	1006	167.0	47.0	1498	194.0	71.0
23	50.0	1.0	515	113.0	15.4	1007	167.0	46.0	1499	194.0	74.0
24	50.0	1.0	516	113.0	14.0	1008	167.0	43.0	1500	194.0	75.0
25	50.0	1.0	517	114.0	14.0	1009	167.0	43.0	1501	194.0	77.0
26	50.0	1.0	518	114.0	17.5	1010	167.0	46.0	1502	194.0	76.0
27	50.0	1.0	519	114.0	15.2	1011	167.0	46.0	1503	194.0	78.0
28	50.0	1.0	520	114.0	15.3	1012	167.0	46.0	1504	194.0	89.0
29	50.0	1.0	521	114.0	14.8	1013	167.0	49.0	1505	194.0	71.0
30	50.0	1.0	522	114.0	16.1	1014	167.0	44.0	1506	194.0	65.0
31	50.0	1.0	523	115.0	15.0	1015	167.0	40.0	1507	194.0	71.0
32	51.0	1.0	524	115.0	18.0	1016	167.0	39.0	1508	194.0	73.0
33	51.0	1.0	525	115.0	16.4	1017	167.0	46.0	1509	194.0	76.0
34	51.0	2.0	526	115.0	17.7	1018	167.0	45.2	1510	194.0	73.0
35	51.0	1.0	527	115.0	17.3	1019	167.0	45.2	1511	194.0	76.0
36	51.0	1.0	528	115.0	15.7	1020	168.0	43.0	1512	194.0	72.0
37	52.0	1.0	529	116.0	14.0	1021	168.0	46.0	1513	194.0	76.0
38	52.0	1.0	530	116.0	18.0	1022	168.0	50.0	1514	195.0	71.0
39	52.0	1.0	531	116.0	14.5	1023	168.0	46.0	1515	195.0	64.0

40	52.0	1.0	532	116.0	19.1	1024	168.0	47.0	1516	195.0	75.0
41	52.0	1.0	533	116.0	16.1	1025	168.0	44.0	1517	195.0	76.0
42	52.0	2.0	534	116.0	17.2	1026	168.0	46.0	1518	195.0	80.0
43	52.0	2.0	535	116.0	18.6	1027	168.0	47.0	1519	195.0	71.0
44	52.0	2.0	536	117.0	16.0	1028	168.0	49.0	1520	195.0	74.0
45	52.0	2.0	537	117.0	20.0	1029	168.0	43.0	1521	195.0	69.0
46	52.0	1.0	538	117.0	18.0	1030	168.0	46.0	1522	195.0	70.1
47	53.0	2.0	539	117.0	17.0	1031	168.0	46.0	1523	195.0	79.0
48	53.0	2.0	540	117.0	17.2	1032	168.0	48.0	1524	195.0	71.0
49	53.0	2.0	541	117.0	18.8	1033	168.0	50.0	1525	195.0	72.0
50	53.0	1.0	542	117.0	17.0	1034	168.0	48.0	1526	195.0	70.0
51	53.0	1.0	543	117.0	17.4	1035	168.0	48.0	1527	195.0	76.0
52	53.0	2.0	544	118.0	16.0	1036	168.0	50.0	1528	195.0	70.1
53	53.0	2.0	545	118.0	19.7	1037	168.0	50.0	1529	196.0	71.0
54	53.0	2.0	546	119.0	18.0	1038	168.0	50.0	1530	196.0	69.0
55	53.0	2.0	547	119.0	18.0	1039	168.0	48.0	1531	196.0	74.0
56	54.0	1.0	548	119.0	18.0	1040	168.0	51.0	1532	196.0	73.0
57	54.0	2.0	549	119.0	17.9	1041	168.0	58.0	1533	196.0	84.0
58	54.0	1.0	550	120.0	20.0	1042	168.0	41.0	1534	196.0	78.0
59	54.0	2.0	551	120.0	19.0	1043	168.0	46.0	1535	196.0	78.0
60	54.0	1.0	552	120.0	21.0	1044	168.0	50.0	1536	196.0	68.0
61	54.0	2.0	553	120.0	18.2	1045	169.0	43.0	1537	196.0	67.0
62	54.0	2.0	554	120.0	18.0	1046	169.0	47.0	1538	196.0	81.0
63	54.0	2.0	555	120.0	17.5	1047	169.0	50.0	1539	196.0	76.0
64	55.0	2.0	556	121.0	18.0	1048	169.0	43.0	1540	196.0	77.0
65	55.0	2.0	557	121.0	18.0	1049	169.0	46.0	1541	197.0	75.0
66	55.0	2.0	558	122.0	19.0	1050	169.0	47.0	1542	197.0	79.0
67	55.0	2.0	559	122.0	20.8	1051	169.0	44.0	1543	197.0	78.0
68	55.0	2.0	560	123.0	20.0	1052	169.0	49.0	1544	197.0	74.0
69	55.0	2.0	561	123.0	20.0	1053	169.0	49.0	1545	197.0	77.0
70	55.0	2.0	562	123.0	22.7	1054	169.0	47.0	1546	197.0	73.0
71	55.0	2.0	563	123.0	20.6	1055	169.0	51.0	1547	197.0	98.0
72	55.0	2.0	564	124.0	19.0	1056	170.0	47.0	1548	197.0	79.0
73	56.0	2.0	565	124.0	21.0	1057	170.0	50.0	1549	197.0	75.0
74	56.0	2.0	566	124.0	23.0	1058	170.0	47.0	1550	197.0	84.0
75	56.0	2.0	567	124.0	34.2	1059	170.0	46.0	1551	197.0	77.0
76	56.0	2.0	568	124.0	19.5	1060	170.0	48.0	1552	197.0	80.0
77	56.0	2.0	569	125.0	20.0	1061	170.0	47.0	1553	197.0	70.0
78	56.0	2.0	570	125.0	19.0	1062	170.0	45.0	1554	197.0	62.0
79	56.0	2.0	571	125.0	22.0	1063	170.0	48.0	1555	197.0	75.0
80	56.0	2.0	572	126.0	22.0	1064	170.0	52.0	1556	197.0	78.0
81	56.0	2.0	573	127.0	20.0	1065	170.0	47.0	1557	197.0	72.0
82	57.0	2.0	574	127.0	21.0	1066	170.0	54.0	1558	197.0	74.0
83	57.0	2.0	575	127.0	19.0	1067	170.0	48.0	1559	197.0	86.0
84	57.0	2.0	576	127.0	23.0	1068	170.0	51.0	1560	197.0	72.0

85	57.0	2.0	577	127.0	23.0	1069	170.0	49.0	1561	197.0	76.0
86	57.0	2.0	578	128.0	21.0	1070	170.0	48.0	1562	198.0	72.0
87	57.0	2.0	579	128.0	20.0	1071	170.0	50.5	1563	198.0	74.0
88	57.0	2.0	580	128.0	22.0	1072	170.0	50.0	1564	198.0	77.0
89	57.0	2.0	581	128.0	21.5	1073	170.0	52.0	1565	198.0	69.0
90	57.0	2.0	582	129.0	24.0	1074	170.0	50.5	1566	198.0	73.0
91	57.0	3.0	583	129.0	23.0	1075	171.0	47.0	1567	198.0	84.0
92	57.0	2.0	584	129.0	27.0	1076	171.0	48.0	1568	198.0	78.0
93	58.0	2.0	585	129.0	26.6	1077	171.0	49.0	1569	198.0	89.0
94	58.0	2.0	586	129.0	22.2	1078	171.0	46.0	1570	198.0	79.0
95	58.0	2.0	587	130.0	22.0	1079	171.0	52.0	1571	198.0	94.3
96	58.0	2.0	588	130.0	24.0	1080	171.0	53.0	1572	198.0	73.0
97	58.0	2.0	589	130.0	25.0	1081	171.0	49.0	1573	198.0	81.0
98	58.0	2.0	590	130.0	25.9	1082	171.0	49.0	1574	198.0	74.0
99	58.0	2.0	591	130.0	24.0	1083	171.0	52.0	1575	198.0	82.0
100	58.0	2.0	592	130.0	23.8	1084	171.0	48.0	1576	199.0	75.0
101	58.0	2.0	593	130.0	32.2	1085	172.0	46.0	1577	199.0	78.0
102	58.0	2.0	594	131.0	24.0	1086	172.0	48.0	1578	199.0	73.0
103	59.0	2.0	595	131.0	23.0	1087	172.0	53.0	1579	199.0	70.0
104	59.0	2.0	596	131.0	21.0	1088	172.0	52.0	1580	199.0	84.0
105	59.0	2.0	597	131.0	28.2	1089	172.0	48.0	1581	199.0	81.0
106	59.0	2.0	598	132.0	22.0	1090	172.0	47.0	1582	199.0	78.0
107	59.0	2.0	599	132.0	24.0	1091	172.0	46.0	1583	199.0	81.0
108	60.0	2.0	600	132.0	22.0	1092	172.0	51.0	1584	199.0	74.0
109	60.0	2.0	601	132.0	22.0	1093	172.0	52.0	1585	200.0	78.0
110	60.0	2.0	602	132.0	22.0	1094	172.0	48.0	1586	200.0	75.0
111	60.0	3.0	603	132.0	24.0	1095	172.0	56.0	1587	200.0	76.0
112	61.0	2.0	604	132.0	26.1	1096	172.0	50.0	1588	200.0	83.0
113	61.0	2.0	605	132.0	26.2	1097	173.0	56.0	1589	200.0	77.0
114	61.0	2.0	606	132.0	26.2	1098	173.0	53.0	1590	200.0	72.0
115	61.0	3.0	607	133.0	22.0	1099	173.0	50.0	1591	200.0	81.0
116	61.0	3.0	608	133.0	22.0	1100	173.0	47.0	1592	200.0	87.0
117	62.0	2.0	609	133.0	23.0	1101	173.0	48.0	1593	200.0	83.0
118	62.0	3.0	610	133.0	24.7	1102	173.0	49.0	1594	200.0	82.0
119	63.0	3.0	611	133.0	26.7	1103	173.0	52.0	1595	200.0	84.0
120	63.0	3.0	612	134.0	26.0	1104	173.0	52.0	1596	200.0	91.4
121	63.0	2.0	613	134.0	24.0	1105	173.0	54.0	1597	200.0	80.0
122	63.0	3.0	614	134.0	27.5	1106	173.0	46.0	1598	200.0	82.0
123	63.0	2.0	615	134.0	25.1	1107	173.0	47.0	1599	200.0	84.0
124	63.0	2.0	616	134.0	26.2	1108	173.0	49.0	1600	200.0	74.0
125	63.0	3.0	617	135.0	22.0	1109	173.0	49.0	1601	200.0	72.0
126	63.0	3.0	618	135.0	24.0	1110	173.0	52.0	1602	200.0	82.0
127	63.0	3.0	619	135.0	26.0	1111	173.0	56.0	1603	200.0	76.0
128	64.0	3.0	620	135.0	22.0	1112	173.0	55.0	1604	200.0	77.0
129	64.0	2.0	621	135.0	22.0	1113	173.0	54.0	1605	200.0	80.0

130	64.0	3.0	622	135.0	23.0	1114	173.0	55.0	1606	200.0	86.0
131	64.0	3.0	623	135.0	31.1	1115	173.0	50.0	1607	200.0	91.4
132	64.0	4.0	624	135.0	26.5	1116	174.0	51.0	1608	201.0	75.0
133	64.0	3.0	625	136.0	27.0	1117	174.0	55.0	1609	201.0	91.0
134	64.0	3.0	626	136.0	23.0	1118	174.0	51.0	1610	201.0	76.0
135	64.0	3.0	627	136.0	27.0	1119	174.0	51.0	1611	201.0	85.0
136	64.0	2.0	628	136.0	28.4	1120	174.0	55.0	1612	201.0	80.0
137	65.0	3.0	629	136.0	26.1	1121	174.0	56.0	1613	201.0	85.0
138	65.0	3.0	630	137.0	27.0	1122	174.0	50.0	1614	201.0	84.0
139	65.0	3.0	631	137.0	24.0	1123	174.0	55.0	1615	201.0	76.0
140	65.0	3.0	632	137.0	26.0	1124	174.0	48.0	1616	201.0	78.0
141	65.0	3.0	633	137.0	18.0	1125	174.0	50.0	1617	201.0	76.0
142	65.0	3.0	634	137.0	33.8	1126	174.0	48.0	1618	201.0	81.0
143	65.0	3.0	635	138.0	27.0	1127	174.0	52.0	1619	202.0	79.0
144	65.0	3.0	636	138.0	24.0	1128	174.0	52.0	1620	202.0	77.0
145	65.0	3.0	637	138.0	30.0	1129	174.0	59.0	1621	202.0	78.0
146	66.0	3.0	638	138.0	27.0	1130	174.0	50.0	1622	202.0	79.0
147	66.0	3.0	639	138.0	29.0	1131	174.0	58.0	1623	202.0	83.0
148	66.0	3.0	640	138.0	28.0	1132	174.0	54.0	1624	202.0	80.0
149	66.0	4.0	641	139.0	26.0	1133	174.0	55.0	1625	202.0	79.0
150	66.0	3.0	642	139.0	26.0	1134	174.0	57.0	1626	202.0	82.0
151	66.0	4.0	643	139.0	28.0	1135	174.0	56.0	1627	202.0	85.0
152	66.0	3.3	644	139.0	31.0	1136	175.0	57.0	1628	202.0	80.0
153	67.0	4.0	645	139.0	28.0	1137	175.0	52.0	1629	202.0	83.0
154	67.0	3.0	646	139.0	28.3	1138	175.0	49.0	1630	202.0	108.0
155	67.0	3.0	647	139.0	28.2	1139	175.0	52.0	1631	203.0	92.0
156	67.0	3.0	648	139.0	30.3	1140	175.0	55.0	1632	203.0	86.0
157	67.0	3.0	649	140.0	25.0	1141	175.0	50.0	1633	203.0	82.0
158	67.0	3.0	650	140.0	26.0	1142	175.0	54.0	1634	203.0	89.0
159	67.0	3.0	651	140.0	25.0	1143	175.0	55.0	1635	203.0	98.0
160	67.0	4.0	652	140.0	26.0	1144	175.0	50.0	1636	203.0	79.0
161	67.0	3.0	653	140.0	28.0	1145	175.0	52.0	1637	203.0	90.3
162	67.0	3.0	654	140.0	27.0	1146	175.0	53.0	1638	203.0	85.0
163	67.0	3.4	655	140.0	28.0	1147	175.0	56.0	1639	204.0	89.0
164	68.0	3.0	656	140.0	29.0	1148	175.0	52.0	1640	204.0	78.0
165	68.0	3.0	657	140.0	28.0	1149	175.0	53.0	1641	204.0	87.0
166	68.0	3.0	658	140.0	32.5	1150	175.0	57.0	1642	204.0	102.0
167	68.0	5.0	659	140.0	25.9	1151	175.0	52.0	1643	204.0	76.0
168	68.0	4.0	660	140.0	29.8	1152	175.0	55.0	1644	204.0	87.0
169	68.0	3.0	661	140.0	30.2	1153	175.0	56.0	1645	204.0	89.0
170	68.0	4.0	662	141.0	28.0	1154	175.0	52.0	1646	204.0	86.0
171	68.0	3.0	663	141.0	29.0	1155	175.0	56.0	1647	205.0	80.0
172	68.0	3.1	664	141.0	29.0	1156	175.0	49.0	1648	205.0	80.0
173	69.0	4.2	665	141.0	29.0	1157	175.0	53.0	1649	205.0	84.0
174	69.0	5.0	666	141.0	27.0	1158	175.0	54.0	1650	205.0	83.0

175	70.0	3.0	667	142.0	28.0	1159	175.0	50.0	1651	205.0	76.0
176	70.0	3.0	668	142.0	28.0	1160	175.0	51.0	1652	205.0	91.0
177	70.0	4.0	669	142.0	30.0	1161	175.0	50.0	1653	205.0	82.0
178	70.0	3.0	670	142.0	30.0	1162	175.0	57.0	1654	205.0	82.0
179	70.0	4.0	671	142.0	29.0	1163	175.0	51.0	1655	205.0	84.0
180	70.0	5.0	672	142.0	32.0	1164	175.0	56.0	1656	205.0	98.0
181	70.0	4.0	673	142.0	33.0	1165	176.0	52.0	1657	205.0	81.0
182	71.0	4.0	674	142.0	28.0	1166	176.0	53.0	1658	205.0	100.7
183	71.0	3.7	675	142.0	29.4	1167	176.0	55.0	1659	205.0	80.0
184	72.0	4.0	676	143.0	29.0	1168	176.0	54.0	1660	205.0	84.0
185	72.0	4.0	677	143.0	26.0	1169	176.0	51.0	1661	205.0	91.0
186	72.0	4.0	678	143.0	27.0	1170	176.0	52.0	1662	205.0	88.0
187	72.0	4.0	679	143.0	29.0	1171	176.0	54.0	1663	205.0	88.0
188	72.0	4.0	680	143.0	24.8	1172	176.0	55.0	1664	205.0	94.0
189	72.0	4.0	681	143.0	31.6	1173	176.0	50.0	1665	205.0	97.0
190	72.0	4.0	682	144.0	27.0	1174	176.0	49.0	1666	205.0	95.0
191	72.0	4.0	683	144.0	28.0	1175	176.0	54.0	1667	205.0	88.0
192	72.0	5.0	684	144.0	29.0	1176	176.0	59.0	1668	205.0	90.0
193	72.0	4.0	685	144.0	30.0	1177	176.0	57.0	1669	206.0	76.0
194	72.0	4.0	686	144.0	28.0	1178	176.0	52.0	1670	206.0	81.0
195	72.0	4.0	687	144.0	30.0	1179	176.0	56.0	1671	206.0	90.0
196	72.0	4.0	688	144.0	33.0	1180	176.0	56.0	1672	206.0	84.0
197	72.0	4.0	689	144.0	30.0	1181	176.0	61.0	1673	207.0	84.0
198	72.0	7.3	690	144.0	35.0	1182	176.0	61.0	1674	207.0	92.0
199	73.0	4.0	691	145.0	31.0	1183	177.0	52.0	1675	207.0	80.0
200	73.0	4.0	692	145.0	29.0	1184	177.0	55.0	1676	207.0	83.0
201	73.0	4.0	693	145.0	29.0	1185	177.0	50.0	1677	208.0	91.0
202	73.0	4.0	694	145.0	30.0	1186	177.0	58.0	1678	208.0	96.0
203	73.0	3.0	695	145.0	28.0	1187	177.0	53.0	1679	208.0	90.0
204	73.0	4.4	696	145.0	29.7	1188	177.0	54.0	1680	208.0	95.0
205	73.0	4.8	697	145.0	32.9	1189	177.0	59.0	1681	208.0	89.0
206	74.0	4.0	698	146.0	32.0	1190	177.0	50.0	1682	208.0	93.0
207	74.0	4.0	699	146.0	31.0	1191	177.0	52.0	1683	209.0	85.0
208	74.0	4.0	700	146.0	28.0	1192	177.0	58.0	1684	209.0	101.0
209	74.0	4.0	701	146.0	29.0	1193	177.0	50.0	1685	209.0	106.0
210	74.0	5.0	702	146.0	31.0	1194	177.0	55.0	1686	210.0	92.0
211	74.0	4.0	703	146.0	30.0	1195	177.0	60.0	1687	210.0	90.0
212	74.0	4.0	704	146.0	31.0	1196	177.0	55.0	1688	210.0	84.0
213	74.0	5.0	705	146.0	30.0	1197	177.0	56.0	1689	210.0	86.0
214	74.0	5.0	706	146.0	33.0	1198	177.0	63.0	1690	210.0	94.0
215	74.0	4.0	707	146.0	28.0	1199	177.0	54.0	1691	210.0	87.0
216	74.0	5.0	708	146.0	31.0	1200	177.0	53.0	1692	210.0	95.0
217	74.0	4.8	709	146.0	32.0	1201	177.0	59.0	1693	210.0	87.0
218	74.0	4.7	710	146.0	32.0	1202	177.0	61.0	1694	210.0	95.0
219	75.0	5.0	711	146.0	40.5	1203	177.0	66.0	1695	210.0	84.0

220	75.0	4.0	712	146.0	31.4	1204	177.0	58.0	1696	210.0	99.0
221	75.0	5.0	713	146.0	31.3	1205	177.0	51.0	1697	211.0	89.0
222	75.0	4.0	714	147.0	30.0	1206	177.0	57.0	1698	211.0	86.0
223	75.0	4.0	715	147.0	34.0	1207	177.0	58.0	1699	211.0	97.0
224	75.0	5.0	716	147.0	34.0	1208	177.0	55.0	1700	211.0	97.0
225	75.0	4.0	717	147.0	33.0	1209	177.0	52.0	1701	211.0	93.0
226	75.0	6.7	718	147.0	30.0	1210	178.0	52.0	1702	211.0	97.0
227	76.0	6.0	719	147.0	30.0	1211	178.0	51.0	1703	212.0	92.0
228	76.0	4.0	720	147.0	36.2	1212	178.0	54.0	1704	212.0	84.0
229	76.0	5.0	721	148.0	31.0	1213	178.0	52.0	1705	212.0	100.0
230	76.0	4.0	722	148.0	36.0	1214	178.0	54.0	1706	212.0	113.0
231	76.0	4.0	723	148.0	33.0	1215	178.0	55.0	1707	212.0	104.0
232	76.0	6.0	724	149.0	32.0	1216	178.0	54.0	1708	212.0	97.0
233	76.0	5.0	725	149.0	34.0	1217	178.0	57.0	1709	213.0	90.0
234	76.0	4.0	726	149.0	33.0	1218	178.0	60.0	1710	213.0	92.0
235	76.0	5.0	727	149.0	32.0	1219	178.0	65.0	1711	213.0	94.0
236	76.0	5.0	728	149.0	32.0	1220	178.0	52.0	1712	213.0	83.0
237	76.0	5.4	729	149.0	31.0	1221	178.0	57.0	1713	213.0	104.0
238	76.0	4.5	730	149.0	33.0	1222	178.0	57.0	1714	214.0	97.0
239	77.0	5.0	731	149.0	31.7	1223	179.0	55.0	1715	214.0	97.0
240	77.0	5.0	732	150.0	31.0	1224	179.0	57.0	1716	214.0	96.0
241	77.0	5.0	733	150.0	35.0	1225	179.0	60.0	1717	215.0	90.0
242	77.0	4.0	734	150.0	30.0	1226	179.0	56.0	1718	215.0	96.0
243	77.0	6.0	735	150.0	32.0	1227	179.0	53.0	1719	215.0	110.0
244	77.0	5.0	736	150.0	33.0	1228	179.0	48.0	1720	215.0	101.0
245	77.0	5.0	737	150.0	34.0	1229	179.0	54.0	1721	215.0	111.0
246	77.0	5.0	738	150.0	38.0	1230	179.0	58.0	1722	215.0	86.0
247	77.0	5.0	739	150.0	34.0	1231	179.0	61.0	1723	215.0	91.0
248	77.0	5.0	740	150.0	35.0	1232	179.0	64.0	1724	215.0	96.0
249	77.0	5.0	741	150.0	36.0	1233	179.0	57.0	1725	215.0	115.0
250	77.0	4.8	742	150.0	40.0	1234	179.0	57.0	1726	216.0	104.0
251	77.0	6.0	743	150.0	33.0	1235	180.0	57.0	1727	216.0	92.0
252	78.0	5.0	744	150.0	42.0	1236	180.0	57.0	1728	216.0	108.0
253	78.0	5.0	745	150.0	34.7	1237	180.0	63.0	1729	216.0	101.0
254	78.0	4.0	746	151.0	32.0	1238	180.0	54.0	1730	216.0	109.0
255	78.0	5.0	747	151.0	35.0	1239	180.0	59.0	1731	216.0	96.0
256	78.0	5.0	748	151.0	37.0	1240	180.0	60.0	1732	216.0	105.0
257	78.0	3.0	749	151.0	29.0	1241	180.0	55.0	1733	216.0	109.0
258	78.0	5.0	750	151.0	33.0	1242	180.0	57.0	1734	216.0	111.0
259	78.0	6.0	751	151.0	38.0	1243	180.0	57.0	1735	217.0	99.0
260	78.0	5.2	752	151.0	36.0	1244	180.0	54.0	1736	217.0	101.0
261	78.0	8.6	753	151.0	38.0	1245	180.0	54.0	1737	218.0	105.0
262	78.0	6.4	754	151.0	37.0	1246	180.0	58.0	1738	218.0	104.0
263	79.0	5.4	755	152.0	31.0	1247	180.0	60.0	1739	218.0	102.0
264	79.0	5.1	756	152.0	35.0	1248	180.0	61.0	1740	218.0	98.0

265	79.0	5.8	757	152.0	35.0	1249	180.0	59.0	1741	218.0	110.0
266	80.0	5.0	758	152.0	32.0	1250	180.0	56.0	1742	219.0	87.0
267	80.0	6.0	759	152.0	31.0	1251	180.0	56.0	1743	220.0	103.0
268	80.0	6.0	760	152.0	32.0	1252	180.0	55.0	1744	220.0	110.0
269	80.0	5.0	761	152.0	36.0	1253	180.0	63.0	1745	220.0	114.0
270	80.0	5.0	762	152.0	36.0	1254	180.0	64.0	1746	220.0	118.0
271	80.0	5.0	763	152.0	35.0	1255	180.0	55.0	1747	220.0	104.0
272	80.0	5.0	764	152.0	38.0	1256	180.0	58.0	1748	220.0	110.0
273	80.0	6.0	765	152.0	36.0	1257	180.0	50.0	1749	220.0	110.0
274	80.0	5.7	766	152.0	38.0	1258	180.0	61.0	1750	222.0	110.0
275	81.0	6.0	767	152.0	35.0	1259	180.0	58.0	1751	222.0	110.0
276	81.0	6.0	768	152.0	36.0	1260	181.0	65.0	1752	222.0	126.0
277	81.0	5.0	769	153.0	33.0	1261	181.0	56.0	1753	223.0	103.0
278	81.0	6.0	770	153.0	33.0	1262	181.0	54.0	1754	223.0	110.0
279	81.0	6.0	771	153.0	35.0	1263	181.0	56.0	1755	223.0	131.0
280	81.0	5.6	772	153.0	33.0	1264	181.0	55.0	1756	224.0	111.0
281	81.0	6.1	773	153.0	34.0	1265	181.0	56.0	1757	224.0	116.0
282	82.0	6.0	774	153.0	36.0	1266	181.0	57.0	1758	224.0	118.0
283	82.0	6.0	775	153.0	32.0	1267	181.0	58.0	1759	224.0	106.0
284	82.0	6.0	776	153.0	35.0	1268	181.0	59.0	1760	224.0	112.0
285	82.0	6.2	777	153.0	36.0	1269	181.0	63.0	1761	225.0	105.0
286	83.0	6.0	778	153.0	37.0	1270	181.0	60.0	1762	225.0	108.0
287	83.0	6.0	779	153.0	37.0	1271	181.0	61.0	1763	225.0	115.0
288	83.0	6.0	780	153.0	38.0	1272	181.0	61.0	1764	227.0	114.0
289	83.0	6.0	781	153.0	36.0	1273	181.0	57.0	1765	227.0	121.0
290	83.0	6.0	782	153.0	28.9	1274	182.0	58.0	1766	228.0	106.0
291	83.0	5.0	783	153.0	38.4	1275	182.0	59.0	1767	228.0	116.0
292	83.0	6.0	784	153.0	40.6	1276	182.0	60.0	1768	228.0	122.0
293	83.0	6.2	785	154.0	35.0	1277	182.0	58.0	1769	228.0	108.0
294	83.0	5.8	786	154.0	36.0	1278	182.0	56.0	1770	228.0	126.0
295	83.0	7.1	787	154.0	34.0	1279	182.0	58.0	1771	229.0	123.0
296	84.0	6.0	788	154.0	39.0	1280	182.0	58.0	1772	229.0	121.0
297	84.0	6.0	789	154.0	34.0	1281	182.0	61.0	1773	231.0	129.0
298	84.0	7.0	790	154.0	37.0	1282	182.0	56.0	1774	232.0	135.0
299	84.0	7.0	791	154.0	38.0	1283	182.0	59.0	1775	232.0	120.0
300	84.0	6.3	792	154.0	35.0	1284	182.0	60.0	1776	233.0	133.0
301	84.0	6.3	793	154.0	37.0	1285	182.0	61.0	1777	233.0	137.0
302	84.0	6.5	794	155.0	38.0	1286	182.0	60.0	1778	234.0	128.0
303	84.0	5.2	795	155.0	38.0	1287	182.0	56.0	1779	234.0	115.0
304	84.0	5.5	796	155.0	36.0	1288	182.0	65.0	1780	234.0	139.0
305	85.0	7.0	797	155.0	35.0	1289	182.0	65.0	1781	235.0	112.0
306	85.0	6.0	798	155.0	35.0	1290	182.0	63.0	1782	235.0	125.0
307	85.0	7.0	799	155.0	39.0	1291	182.0	64.0	1783	237.0	123.0
308	85.0	8.0	800	155.0	35.0	1292	182.0	60.0	1784	237.0	146.0
309	85.0	6.0	801	155.0	35.0	1293	182.0	57.0	1785	238.0	140.0

310	85.0	6.0	802	155.0	39.0	1294	182.0	63.0	1786	238.0	137.0
311	85.0	6.0	803	155.0	33.0	1295	182.0	58.0	1787	238.0	137.0
312	85.0	7.0	804	155.0	37.0	1296	182.0	61.0	1788	239.0	129.0
313	85.0	6.5	805	155.0	36.0	1297	182.0	59.0	1789	240.0	124.0
314	86.0	6.0	806	155.0	35.0	1298	183.0	59.0	1790	240.0	146.0
315	86.0	7.0	807	155.0	35.0	1299	183.0	69.0	1791	240.0	144.0
316	86.0	7.0	808	155.0	38.0	1300	183.0	52.0	1792	240.0	148.0
317	86.0	7.0	809	155.0	41.0	1301	183.0	58.0	1793	240.0	133.0
318	86.0	7.0	810	155.0	42.0	1302	183.0	63.0	1794	241.0	136.0
319	86.0	6.0	811	155.0	37.0	1303	183.0	70.0	1795	241.0	140.0
320	86.0	6.0	812	155.0	44.0	1304	183.0	61.0	1796	242.0	142.0
321	86.0	6.0	813	155.0	30.0	1305	183.0	61.0	1797	242.0	161.0
322	86.0	10.0	814	155.0	34.7	1306	183.0	62.0	1798	242.0	168.0
323	86.0	6.9	815	156.0	36.0	1307	183.0	63.0	1799	245.0	140.0
324	87.0	7.0	816	156.0	37.0	1308	183.0	67.0	1800	245.0	155.0
325	87.0	7.0	817	156.0	32.0	1309	183.0	63.0	1801	245.0	160.0
326	87.0	8.0	818	156.0	34.0	1310	183.0	62.0	1802	246.0	146.0
327	87.0	8.0	819	156.0	32.0	1311	183.0	66.0	1803	246.0	147.0
328	87.0	7.0	820	156.0	38.0	1312	183.0	61.0	1804	247.0	154.0
329	87.0	7.0	821	156.0	37.0	1313	183.0	58.0	1805	247.0	158.0
330	87.0	7.9	822	156.0	36.0	1314	183.0	60.0	1806	248.0	150.0
331	87.0	7.6	823	156.0	40.0	1315	183.0	61.0	1807	248.0	149.0
332	87.0	8.3	824	156.0	39.0	1316	184.0	61.0	1808	248.0	170.0
333	87.0	6.2	825	156.0	42.0	1317	184.0	60.0	1809	248.0	149.0
334	87.0	9.2	826	156.0	58.0	1318	184.0	68.0	1810	250.0	160.0
335	87.0	8.6	827	156.0	40.8	1319	184.0	59.0	1811	252.0	166.0
336	87.0	9.2	828	156.0	43.2	1320	184.0	66.0	1812	252.0	174.0
337	88.0	7.0	829	157.0	37.0	1321	184.0	61.0	1813	252.0	168.0
338	88.0	7.0	830	157.0	35.0	1322	184.0	64.0	1814	252.0	170.0
339	88.0	8.0	831	157.0	38.0	1323	184.0	65.0	1815	252.0	161.0
340	88.0	7.0	832	157.0	40.0	1324	184.0	57.0	1816	255.0	176.0
341	88.0	7.0	833	157.0	40.0	1325	184.0	61.0	1817	255.0	160.0
342	88.0	7.6	834	157.0	37.0	1326	184.0	59.0	1818	255.0	154.0
343	88.0	7.3	835	157.0	40.0	1327	184.0	77.0	1819	258.0	180.0
344	88.0	6.9	836	157.0	40.0	1328	184.0	67.0	1820	260.0	177.0
345	88.0	7.6	837	157.0	42.0	1329	184.0	64.0	1821	260.0	181.0
346	88.0	7.4	838	157.0	42.0	1330	184.0	67.0	1822	260.0	184.0
347	89.0	7.0	839	157.0	40.0	1331	184.0	66.0	1823	261.0	192.0
348	89.0	7.0	840	157.0	36.0	1332	184.0	59.0	1824	262.0	202.0
349	89.0	8.0	841	158.0	40.0	1333	184.0	61.0	1825	264.0	194.0
350	89.0	7.0	842	158.0	40.0	1334	184.0	63.0	1826	265.0	190.0
351	89.0	8.4	843	158.0	42.0	1335	184.0	62.0	1827	265.0	199.0
352	89.0	8.5	844	158.0	37.0	1336	184.0	65.0	1828	268.0	186.0
353	89.0	8.7	845	158.0	37.0	1337	184.0	76.0	1829	268.0	209.0
354	90.0	8.0	846	158.0	37.0	1338	184.0	68.0	1830	270.0	197.0

355	90.0	8.0	847	158.0	38.0	1339	185.0	56.0	1831	270.0	198.0
356	90.0	8.0	848	158.0	39.0	1340	185.0	60.0	1832	270.0	205.0
357	90.0	8.0	849	158.0	38.0	1341	185.0	65.0	1833	270.0	231.0
358	90.0	9.0	850	158.0	41.0	1342	185.0	57.0	1834	270.0	201.0
359	90.0	8.0	851	158.0	38.0	1343	185.0	61.0	1835	270.0	196.0
360	90.0	8.0	852	158.0	41.0	1344	185.0	62.0	1836	271.0	196.0
361	90.0	7.0	853	158.0	39.0	1345	185.0	64.0	1837	272.0	222.0
362	90.0	7.9	854	158.0	38.0	1346	185.0	54.0	1838	272.0	212.0
363	90.0	10.1	855	158.0	42.0	1347	185.0	56.0	1839	272.0	202.0
364	91.0	9.0	856	158.0	38.0	1348	185.0	64.0	1840	272.0	218.0
365	91.0	9.0	857	158.0	41.0	1349	185.0	63.0	1841	272.0	207.0
366	91.0	7.5	858	158.0	41.0	1350	185.0	59.0	1842	272.0	202.0
367	91.0	13.4	859	158.0	42.0	1351	185.0	58.0	1843	272.0	189.0
368	92.0	8.0	860	158.0	50.0	1352	185.0	62.0	1844	273.0	204.0
369	92.0	8.0	861	158.0	42.0	1353	185.0	66.0	1845	274.0	214.0
370	92.0	10.2	862	158.0	35.4	1354	185.0	63.0	1846	276.0	212.0
371	92.0	8.6	863	159.0	40.0	1355	185.0	65.0	1847	278.0	231.0
372	92.0	8.9	864	159.0	43.0	1356	185.0	64.0	1848	280.0	209.0
373	93.0	8.0	865	159.0	41.0	1357	185.0	66.0	1849	280.0	212.0
374	93.0	9.0	866	159.0	40.0	1358	185.0	67.0	1850	282.0	244.0
375	93.0	10.0	867	159.0	43.0	1359	185.0	61.0	1851	282.0	205.0
376	93.0	9.0	868	159.0	32.0	1360	185.0	65.0	1852	282.0	214.0
377	93.0	9.0	869	159.0	41.8	1361	185.0	65.0	1853	283.0	233.0
378	93.0	8.8	870	160.0	42.0	1362	185.0	63.0	1854	284.0	231.0
379	93.0	8.7	871	160.0	44.0	1363	185.0	64.0	1855	284.0	222.0
380	93.0	9.5	872	160.0	33.0	1364	185.0	64.0	1856	286.0	227.0
381	93.0	8.8	873	160.0	40.0	1365	185.0	58.0	1857	286.0	236.0
382	93.0	8.1	874	160.0	37.0	1366	186.0	61.0	1858	286.0	215.0
383	94.0	9.0	875	160.0	40.0	1367	186.0	66.0	1859	287.0	134.0
384	94.0	9.0	876	160.0	39.0	1368	186.0	67.0	1860	288.0	229.0
385	94.0	9.0	877	160.0	40.0	1369	186.0	64.0	1861	288.0	236.0
386	94.0	9.0	878	160.0	42.0	1370	186.0	68.0	1862	288.0	228.0
387	94.0	9.0	879	160.0	42.0	1371	186.0	67.0	1863	290.0	239.0
388	94.0	10.0	880	160.0	43.0	1372	186.0	59.0	1864	290.0	214.0
389	94.0	8.8	881	160.0	47.0	1373	186.0	62.0	1865	290.0	239.0
390	95.0	8.0	882	160.0	44.0	1374	187.0	62.0	1866	291.0	260.0
391	95.0	9.0	883	160.0	39.0	1375	187.0	64.0	1867	292.0	169.0
392	95.0	9.0	884	160.0	44.0	1376	187.0	60.0	1868	292.0	236.0
393	95.0	9.0	885	160.0	46.0	1377	187.0	64.0	1869	292.0	241.0
394	95.0	8.0	886	160.0	48.0	1378	187.0	62.0	1870	292.0	228.0
395	95.0	9.0	887	161.0	44.0	1379	187.0	57.0	1871	292.0	230.0
396	95.0	8.0	888	161.0	41.0	1380	187.0	59.0	1872	292.0	259.0
397	95.0	10.0	889	161.0	44.0	1381	187.0	60.0	1873	293.0	257.0
398	95.0	13.6	890	161.0	41.0	1382	187.0	64.0	1874	293.0	260.0
399	95.0	8.6	891	161.0	41.0	1383	187.0	66.0	1875	293.0	280.0

400	95.0	9.5	892	161.0	45.0	1384	187.0	63.0	1876	293.0	241.0
401	96.0	9.9	893	162.0	42.0	1385	187.0	61.0	1877	294.0	250.0
402	96.0	11.1	894	162.0	44.0	1386	187.0	64.0	1878	294.0	260.0
403	96.0	9.6	895	162.0	41.0	1387	187.0	72.0	1879	294.0	245.0
404	96.0	10.1	896	162.0	42.0	1388	187.0	71.0	1880	294.0	245.0
405	96.0	9.0	897	162.0	40.0	1389	187.0	66.0	1881	294.0	250.0
406	96.0	9.8	898	162.0	44.0	1390	187.0	70.0	1882	295.0	253.0
407	96.0	8.5	899	162.0	40.0	1391	187.0	66.0	1883	295.0	280.0
408	96.0	11.0	900	162.0	42.0	1392	188.0	67.0	1884	297.0	256.0
409	97.0	11.0	901	162.0	42.0	1393	188.0	65.0	1885	298.0	257.0
410	97.0	9.0	902	162.0	39.0	1394	188.0	61.0	1886	298.0	275.0
411	97.0	10.0	903	162.0	46.0	1395	188.0	64.0	1887	299.0	235.0
412	97.0	10.4	904	162.0	43.0	1396	188.0	64.0	1888	299.0	260.0
413	98.0	12.0	905	162.0	47.0	1397	188.0	67.0	1889	299.0	277.0
414	98.0	10.0	906	162.0	44.0	1398	188.0	64.0	1890	299.0	194.0
415	98.0	10.0	907	162.0	44.0	1399	188.0	64.0	1891	300.0	273.0
416	98.0	10.0	908	162.0	45.0	1400	188.0	69.0	1892	300.0	272.0
417	98.0	11.0	909	162.0	42.0	1401	188.0	70.0	1893	300.0	272.0
418	98.0	9.0	910	162.0	45.0	1402	188.0	60.0	1894	300.0	291.0
419	98.0	10.7	911	162.0	42.0	1403	188.0	68.0	1895	300.0	255.0
420	98.0	12.1	912	162.0	44.0	1404	188.0	69.0	1896	300.0	325.0
421	98.0	12.0	913	162.0	46.0	1405	188.0	59.0	1897	300.0	271.0
422	98.0	11.1	914	162.0	42.0	1406	188.0	64.0	1898	300.0	265.0
423	99.0	10.0	915	162.0	40.0	1407	188.0	69.0	1899	300.0	270.0
424	99.0	10.0	916	163.0	42.0	1408	188.0	63.0	1900	301.0	277.0
425	99.0	11.0	917	163.0	41.0	1409	188.0	67.0	1901	301.0	297.0
426	99.0	10.0	918	163.0	40.0	1410	188.0	72.0	1902	301.0	270.0
427	99.0	9.1	919	163.0	42.0	1411	188.0	71.0	1903	302.0	284.0
428	99.0	9.8	920	163.0	51.0	1412	188.0	73.0	1904	302.0	282.0
429	99.0	12.0	921	163.0	42.0	1413	189.0	66.0	1905	302.0	282.0
430	100.0	10.0	922	163.0	38.0	1414	189.0	66.0	1906	303.0	271.0
431	100.0	11.0	923	163.0	39.0	1415	189.0	64.0	1907	303.0	280.0
432	100.0	11.0	924	163.0	42.0	1416	189.0	63.0	1908	304.0	265.0
433	100.0	12.0	925	163.0	41.0	1417	189.0	76.0	1909	304.0	273.0
434	100.0	12.0	926	163.0	40.0	1418	189.0	62.0	1910	305.0	305.0
435	100.0	14.0	927	163.0	46.0	1419	189.0	64.0	1911	305.0	286.0
436	100.0	12.0	928	163.0	43.0	1420	189.0	68.0	1912	305.0	278.0
437	101.0	11.0	929	163.0	43.0	1421	189.0	73.0	1913	305.0	292.0
438	101.0	11.0	930	163.0	45.0	1422	189.0	69.0	1914	305.0	255.0
439	101.0	11.0	931	163.0	48.0	1423	189.0	69.0	1915	305.0	239.0
440	101.0	11.0	932	163.0	37.0	1424	190.0	62.0	1916	307.0	279.0
441	101.0	11.0	933	163.0	43.0	1425	190.0	64.0	1917	308.0	285.0
442	101.0	12.9	934	163.0	47.7	1426	190.0	71.0	1918	309.0	270.0
443	101.0	12.0	935	164.0	45.0	1427	190.0	67.0	1919	310.0	301.0
444	101.0	11.8	936	164.0	44.0	1428	190.0	72.0	1920	310.0	316.0

445	102.0	11.0	937	164.0	47.0	1429	190.0	68.0	1921	310.0	246.0
446	102.0	12.0	938	164.0	50.0	1430	190.0	71.0	1922	310.0	310.0
447	102.0	12.0	939	164.0	40.0	1431	190.0	66.0	1923	311.0	298.0
448	102.0	11.9	940	164.0	41.0	1432	190.0	62.0	1924	312.0	313.0
449	102.0	10.8	941	164.0	42.0	1433	190.0	66.0	1925	312.0	327.0
450	103.0	11.0	942	164.0	41.0	1434	190.0	71.0	1926	313.0	290.0
451	103.0	12.0	943	164.0	42.0	1435	190.0	62.0	1927	313.0	302.0
452	103.0	12.0	944	164.0	41.0	1436	190.0	67.0	1928	314.0	291.0
453	103.0	10.0	945	164.0	44.0	1437	190.0	74.0	1929	314.0	273.0
454	103.0	15.0	946	164.0	44.0	1438	190.0	67.0	1930	314.0	309.0
455	103.0	10.0	947	164.0	50.0	1439	190.0	68.0	1931	315.0	290.0
456	103.0	13.5	948	164.0	44.0	1440	190.0	70.0	1932	315.0	281.0
457	103.0	11.9	949	164.0	45.0	1441	190.0	72.0	1933	315.0	307.0
458	103.0	12.6	950	164.0	44.0	1442	190.0	69.0	1934	316.0	299.0
459	103.0	11.5	951	164.0	43.0	1443	190.0	68.0	1935	317.0	226.0
460	103.0	12.1	952	164.0	46.0	1444	190.0	70.0	1936	318.0	311.0
461	103.0	11.2	953	164.0	37.0	1445	190.0	66.0	1937	318.0	328.0
462	104.0	15.0	954	165.0	42.0	1446	191.0	70.0	1938	318.0	332.0
463	104.0	11.0	955	165.0	41.0	1447	191.0	70.0	1939	318.0	319.0
464	104.0	12.0	956	165.0	42.0	1448	191.0	66.0	1940	320.0	320.0
465	104.0	11.0	957	165.0	44.0	1449	191.0	72.0	1941	320.0	288.0
466	104.0	12.0	958	165.0	42.0	1450	191.0	64.0	1942	321.0	345.0
467	104.0	12.0	959	165.0	43.0	1451	191.0	75.0	1943	324.0	340.0
468	104.0	12.0	960	165.0	44.0	1452	191.0	74.0	1944	325.0	365.0
469	104.0	12.8	961	165.0	43.0	1453	191.0	66.0	1945	325.0	358.0
470	105.0	13.0	962	165.0	45.0	1454	191.0	73.0	1946	325.0	350.0
471	105.0	11.0	963	165.0	45.0	1455	191.0	70.0	1947	326.0	342.0
472	105.0	12.0	964	165.0	44.0	1456	191.0	70.0	1948	326.0	317.0
473	105.0	14.0	965	165.0	44.0	1457	192.0	67.0	1949	327.0	354.0
474	105.0	13.7	966	165.0	43.0	1458	192.0	75.0	1950	328.0	344.0
475	105.0	12.0	967	165.0	45.0	1459	192.0	69.0	1951	329.0	255.0
476	106.0	12.0	968	165.0	39.0	1460	192.0	68.0	1952	330.0	356.0
477	106.0	14.0	969	165.0	45.0	1461	192.0	71.0	1953	330.0	350.0
478	106.0	15.0	970	165.0	46.0	1462	192.0	68.0	1954	330.0	320.0
479	106.0	12.1	971	165.0	46.0	1463	192.0	68.0	1955	331.0	358.0
480	106.0	14.4	972	165.0	47.0	1464	192.0	67.0	1956	332.0	330.0
481	107.0	13.0	973	165.0	46.0	1465	192.0	75.0	1957	333.0	343.0
482	107.0	13.0	974	165.0	43.0	1466	192.0	72.0	1958	333.0	343.0
483	107.0	14.0	975	165.0	48.0	1467	192.0	70.0	1959	335.0	356.0
484	107.0	13.3	976	165.0	48.0	1468	192.0	68.0	1960	337.0	381.0
485	108.0	14.0	977	165.0	51.0	1469	192.0	75.0	1961	337.0	369.0
486	108.0	15.0	978	165.0	40.0	1470	192.0	71.0	1962	338.0	380.0
487	108.0	14.0	979	165.0	46.5	1471	192.0	70.0	1963	339.0	375.0
488	108.0	13.7	980	165.0	41.0	1472	192.0	72.0	1964	339.0	336.0
489	109.0	15.0	981	165.0	46.5	1473	192.0	72.0	1965	340.0	390.0

490	109.0	13.4	982	166.0	44.0	1474	193.0	69.0	1966	341.0	356.0
491	110.0	15.0	983	166.0	46.0	1475	193.0	72.0	1967	342.0	389.0
492	110.0	15.0	984	166.0	46.0	1476	193.0	70.0	1968	344.0	395.0
									1969	349.0	390.0

Appendix D.

Year	Pioneer Creek (Closed Canopy)		Cliff Creek (Open Canopy)	
	Chl- <i>a</i> (mg/m ²)	Invert Biomass (mg/m ²)	Chl- <i>a</i> (mg/m ²)	Invert Biomass (mg/m ²)
1990	2.79 ± 1.39	610.40 ± 343.64	2.01 ± 1.21	562.22 ± 171.90
1991	–	796.62 ± 147.11	8.82 ± 0.56	663.89 ± 139.15
1992	–	–	–	451.99 ± 162.32
1993	9.01 ± 1.76	436.46 ± 80.62	35.33 ± 13.76	674.15 ± 62.95
1994	5.72 ± 0.82	482.00 ± 182.36	6.99 ± 1.57	1437.75 ± 493.78
1995	12.42 ± 4.47	173.35 ± 72.99	10.30 ± 1.66	300.83 ± 46.16
1996	3.13 ± 1.01	633.32 ± 275.09	3.80 ± 1.34	319.15 ± 30.57
1997	0.50 ± 0.18	238.28 ± 76.35	0.40 ± 0.11	291.05 ± 43.29
1998	2.84 ± 0.83	577.95 ± 72.58	2.38 ± 0.82	679.39 ± 151.95
1999	2.06 ± 1.00	645.56 ± 104.23	1.75 ± 1.13	1170.57 ± 366.57
2000	8.08 ± 1.29	633.08 ± 143.25	3.89 ± 0.85	1009.61 ± 122.22
2001	14.61 ± 3.07	1143.69 ± 168.55	36.70 ± 14.51	1861.73 ± 93.41
2002	37.02 ± 11.32	1477.69 ± 408.02	10.51 ± 4.20	1961.65 ± 392.56
2003	7.32 ± 2.24	615.31 ± 99.89	3.35 ± 0.77	1322.30 ± 468.41
2004	9.73 ± 2.43	575.04 ± 166.22	21.00 ± 7.49	2034.15 ± 1015.37
2005	4.51 ± 1.58	1163.86 ± 137.84	8.68 ± 1.19	2274.00 ± 345.34
2006	2.59 ± 0.92	1338.89 ± 689.35	0.00 ± 0.00	2154.61 ± 265.19
2007	3.87 ± 0.93	596.82 ± 131.88	17.39 ± 9.10	3010.52 ± 474.50
2008	12.72 ± 3.16	589.03 ± 141.45	40.64 ± 9.89	2441.62 ± 765.69
2009	5.00 ± 0.95	834.87 ± 130.04	28.42 ± 5.99	2804.07 ± 773.98
2010	9.92 ± 2.03	862.59 ± 279.56	51.84 ± 8.74	2979.38 ± 511.20
2011	8.64 ± 2.61	546.58 ± 233.09	101.87 ± 16.75	1338.82 ± 214.90
2012	6.25 ± 1.64	994.13 ± 410.89	9.43 ± 0.89	2463.36 ± 687.97
2013	9.63 ± 1.83	849.09 ± 192.78	21.71 ± 13.59	1844.89 ± 126.37
2014	9.40 ± 0.77	612.77 ± 178.02	65.62 ± 18.72	1746.62 ± 445.31

Appendix E.

Date	Transect	PAR ($\mu\text{mol}/\text{m}^2$)					
		Pioneer Creek (Closed Canopy)			Cliff Creek (Open Canopy)		
6/23/2014	T1-T2	15.37	±	0.45	248.24	±	20.68
6/23/2014	T2-T3	285.99	±	13.83	389.04	±	13.37
6/23/2014	T3-T4	253.76	±	16.49	344.91	±	15.22
6/23/2014	T4-T5	199.24	±	16.81	392.75	±	20.56
7/23/2014	T1-T2	27.72	±	2.58	294.78	±	12.00
7/23/2014	T2-T3	106.88	±	8.87	367.11	±	10.91
7/23/2014	T3-T4	118.24	±	9.97	421.02	±	13.79
7/23/2014	T4-T5	35.90	±	3.18	345.97	±	13.51
8/8/2014	T1-T2	16.59	±	0.49	104.43	±	8.08
8/8/2014	T2-T3	37.08	±	2.80	210.58	±	7.55
8/8/2014	T3-T4	50.52	±	4.13	260.60	±	8.80
8/8/2014	T4-T5	72.24	±	4.57	121.35	±	4.74

Date	Transect	Canopy Cover (%)					
		Pioneer Creek (Closed Canopy)			Cliff Creek (Open Canopy)		
6/23/2014	T1	84.00	±	1.67	54.75	±	13.7
6/23/2014	T2	93.50	±	0.92	41.00	±	10.3
6/23/2014	T3	87.25	±	2.93	89.25	±	22.3
6/23/2014	T4	92.00	±	0.65	57.75	±	14.4
6/23/2014	T5	92.50	±	0.52	91.00	±	22.8
7/23/2014	T1	88.75	±	0.43	26.50	±	10.60
7/23/2014	T2	88.00	±	3.34	32.25	±	5.26
7/23/2014	T3	89.50	±	2.63	85.00	±	1.70
7/23/2014	T4	90.50	±	0.32	66.75	±	9.62
7/23/2014	T5	55.00	±	1.95	45.25	±	8.19
8/8/2014	T1	84.75	±	2.63	69.75	±	7.00
8/8/2014	T3	82.00	±	1.24	83.50	±	1.53
8/8/2014	T5	90.00	±	0.94	44.75	±	1.63

Appendix F.

Date	Time	Pioneer Creek				Cliff Creek			
		Bar Pres (mm Hg)	Temp °C	DO (mg/L)	Light umol/m ² /s	Bar Pres (mm Hg)	Temp °C	DO (mg/L)	Light umol/m ² /s
7/31/2014	0:00	638.56	10.15	9.80	0.00	638.56	11.52	9.47	0.00
7/31/2014	1:00	638.56	9.95	9.85	0.00	638.56	11.35	9.51	0.00
7/31/2014	2:00	638.56	9.77	9.90	0.00	638.56	11.19	9.55	0.00
7/31/2014	3:00	638.56	9.60	9.94	0.00	638.56	11.03	9.59	0.00
7/31/2014	4:00	638.56	9.44	9.98	0.00	638.56	10.88	9.63	0.00
7/31/2014	5:00	638.56	9.28	10.02	0.00	638.56	10.74	9.68	0.00
7/31/2014	6:00	638.56	9.13	10.06	0.00	638.56	10.60	9.71	0.00
7/31/2014	7:00	638.56	8.99	10.10	1.26	638.56	10.48	9.75	3.74
7/31/2014	8:00	638.56	8.90	10.12	5.99	638.56	10.42	9.77	17.76
7/31/2014	9:00	638.56	8.87	10.14	43.48	638.56	10.43	9.79	128.97
7/31/2014	10:00	638.56	8.89	10.13	142.73	638.56	10.62	9.75	423.36
7/31/2014	11:00	638.56	9.11	10.07	195.35	638.56	11.12	9.62	579.43
7/31/2014	12:00	638.56	9.50	9.96	239.46	638.56	11.68	9.49	710.27
7/31/2014	13:00	638.56	10.08	9.81	272.54	638.56	12.36	9.33	808.40
7/31/2014	14:00	638.56	10.73	9.64	287.66	638.56	13.08	9.15	853.26
7/31/2014	15:00	638.56	11.26	9.52	291.76	638.56	13.61	9.02	865.41
7/31/2014	16:00	638.56	11.67	9.41	290.50	638.56	13.83	8.96	861.67
7/31/2014	17:00	638.56	11.64	9.40	149.03	638.56	13.45	9.01	442.05
7/31/2014	18:00	638.56	11.53	9.42	41.59	638.56	13.26	9.03	123.36
7/31/2014	19:00	638.56	11.48	9.44	34.97	638.56	13.01	9.09	103.74
7/31/2014	20:00	638.56	11.37	9.47	26.47	638.56	12.80	9.13	78.50
7/31/2014	21:00	638.56	11.20	9.51	7.25	638.56	12.55	9.18	21.49
7/31/2014	22:00	638.56	10.98	9.56	0.00	638.56	12.27	9.25	0.00
7/31/2014	23:00	638.56	10.76	9.62	0.00	638.56	12.01	9.31	0.00
8/1/2014	0:00	638.03	10.54	9.68	0.00	638.03	11.80	9.37	0.00
8/1/2014	1:00	638.03	10.33	9.73	0.00	638.03	11.61	9.42	0.00
8/1/2014	2:00	638.03	10.13	9.78	0.00	638.03	11.43	9.47	0.00
8/1/2014	3:00	638.03	9.96	9.82	0.00	638.03	11.28	9.50	0.00
8/1/2014	4:00	638.03	9.83	9.86	0.00	638.03	11.18	9.53	0.00
8/1/2014	5:00	638.03	9.73	9.88	0.00	638.03	11.08	9.56	0.00
8/1/2014	6:00	638.03	9.60	9.91	0.00	638.03	10.95	9.60	0.00
8/1/2014	7:00	638.03	9.47	9.96	0.95	638.03	10.84	9.63	2.80
8/1/2014	8:00	638.03	9.38	9.98	10.08	638.03	10.80	9.66	29.91
8/1/2014	9:00	638.03	9.39	9.98	25.52	638.03	10.84	9.65	75.70
8/1/2014	10:00	638.03	9.44	9.98	76.56	638.03	10.99	9.66	227.10
8/1/2014	11:00	638.03	9.68	9.91	176.44	638.03	11.38	9.55	523.36
8/1/2014	12:00	638.03	9.99	9.82	193.14	638.03	11.81	9.44	572.89
8/1/2014	13:00	638.03	10.51	9.68	260.57	638.03	12.47	9.27	772.89
8/1/2014	14:00	638.03	11.05	9.54	263.09	638.03	13.05	9.12	780.36

8/1/2014	15:00	638.03	11.10	9.54	79.08	638.03	12.96	9.11	234.58
8/1/2014	16:00	638.03	10.99	9.56	22.37	638.03	12.79	9.15	66.35
8/1/2014	17:00	638.03	10.98	9.58	48.52	638.03	12.79	9.19	143.92
8/1/2014	18:00	638.03	10.98	9.57	67.11	638.03	12.69	9.19	199.06
8/1/2014	19:00	638.03	10.98	9.56	74.67	638.03	12.57	9.20	221.49
8/1/2014	20:00	638.03	10.94	9.57	46.32	638.03	12.45	9.23	137.38
8/1/2014	21:00	638.03	10.85	9.60	16.07	638.03	12.23	9.26	47.66
8/1/2014	22:00	638.03	10.69	9.64	0.00	638.03	12.03	9.31	0.00
8/1/2014	23:00	638.03	10.50	9.69	0.00	638.03	11.84	9.36	0.00
8/2/2014	0:00	637.59	10.33	9.73	0.00	637.59	11.68	9.40	0.00
8/2/2014	1:00	637.59	10.16	9.77	0.00	637.59	11.55	9.43	0.00
8/2/2014	2:00	637.59	10.01	9.80	0.00	637.59	11.39	9.47	0.00
8/2/2014	3:00	637.59	9.84	9.85	0.00	637.59	11.23	9.52	0.00
8/2/2014	4:00	637.59	9.70	9.89	0.00	637.59	11.10	9.55	0.00
8/2/2014	5:00	637.59	9.60	9.91	0.00	637.59	11.03	9.57	0.00
8/2/2014	6:00	637.59	9.54	9.93	0.00	637.59	10.98	9.59	0.00
8/2/2014	7:00	637.59	9.48	9.96	2.84	637.59	10.95	9.62	8.41
8/2/2014	8:00	637.59	9.47	9.96	17.01	637.59	10.97	9.62	50.47
8/2/2014	9:00	637.59	9.51	9.96	34.34	637.59	11.03	9.63	101.87
8/2/2014	10:00	637.59	9.59	9.94	81.92	637.59	11.19	9.60	242.99
8/2/2014	11:00	637.59	9.73	9.89	130.76	637.59	11.42	9.52	387.84
8/2/2014	12:00	637.59	10.02	9.83	147.14	637.59	11.84	9.46	436.44
8/2/2014	13:00	637.59	10.51	9.69	251.11	637.59	12.47	9.30	744.85
8/2/2014	14:00	637.59	11.06	9.56	272.22	637.59	13.10	9.15	807.46
8/2/2014	15:00	637.59	11.53	9.45	278.53	637.59	13.58	9.02	826.16
8/2/2014	16:00	637.59	11.83	9.37	271.59	637.59	13.78	8.97	805.60
8/2/2014	17:00	637.59	11.87	9.35	154.39	637.59	13.51	9.01	457.94
8/2/2014	18:00	637.59	11.83	9.35	104.92	637.59	13.38	9.01	311.21
8/2/2014	19:00	637.59	11.73	9.37	51.36	637.59	13.10	9.07	152.33
8/2/2014	20:00	637.59	11.61	9.39	27.41	637.59	12.88	9.09	81.31
8/2/2014	21:00	637.59	11.46	9.43	6.93	637.59	12.62	9.14	20.56
8/2/2014	22:00	637.59	11.26	9.48	0.00	637.59	12.38	9.20	0.00
8/2/2014	23:00	637.59	11.05	9.54	0.00	637.59	12.10	9.28	0.00
8/3/2014	0:00	637.06	10.85	9.59	0.00	637.06	11.92	9.33	0.00
8/3/2014	1:00	637.06	10.62	9.65	0.00	637.06	11.74	9.37	0.00
8/3/2014	2:00	637.06	10.45	9.69	0.00	637.06	11.58	9.42	0.00
8/3/2014	3:00	637.06	10.29	9.73	0.00	637.06	11.43	9.45	0.00
8/3/2014	4:00	637.06	10.12	9.78	0.00	637.06	11.28	9.50	0.00
8/3/2014	5:00	637.06	9.97	9.82	0.00	637.06	11.14	9.54	0.00
8/3/2014	6:00	637.06	9.81	9.86	0.00	637.06	11.02	9.58	0.00
8/3/2014	7:00	637.06	9.76	9.88	0.63	637.06	11.02	9.58	1.87
8/3/2014	8:00	637.06	9.75	9.88	12.92	637.06	11.05	9.59	38.32
8/3/2014	9:00	637.06	9.79	9.88	26.15	637.06	11.11	9.60	77.57
8/3/2014	10:00	637.06	9.88	9.87	64.91	637.06	11.28	9.58	192.52
8/3/2014	11:00	637.06	10.02	9.83	95.47	637.06	11.45	9.53	283.17

8/3/2014	12:00	637.06	10.25	9.76	149.03	637.06	11.78	9.45	442.05
8/3/2014	13:00	637.06	10.66	9.66	211.73	637.06	12.32	9.33	628.03
8/3/2014	14:00	637.06	11.13	9.53	250.80	637.06	12.90	9.19	743.91
8/3/2014	15:00	637.06	11.53	9.44	214.88	637.06	13.16	9.12	637.37
8/3/2014	16:00	637.06	11.78	9.37	214.25	637.06	13.26	9.08	635.50
8/3/2014	17:00	637.06	11.86	9.33	145.88	637.06	13.16	9.05	432.70
8/3/2014	18:00	637.06	11.85	9.33	76.56	637.06	13.09	9.07	227.10
8/3/2014	19:00	637.06	11.78	9.35	53.56	637.06	12.87	9.10	158.88
8/3/2014	20:00	637.06	11.63	9.37	30.88	637.06	12.67	9.13	91.59
8/3/2014	21:00	637.06	11.45	9.42	8.51	637.06	12.40	9.18	25.23
8/3/2014	22:00	637.06	11.26	9.47	0.00	637.06	12.18	9.24	0.00
8/3/2014	23:00	637.06	11.08	9.52	0.00	637.06	12.01	9.29	0.00
8/9/2014	0:00	637.88	10.24	9.73	0.00	637.88	11.33	9.47	0.00
8/9/2014	1:00	637.88	10.05	9.78	0.00	637.88	11.15	9.52	0.00
8/9/2014	2:00	637.88	9.88	9.83	0.00	637.88	10.99	9.57	0.00
8/9/2014	3:00	637.88	9.71	9.87	0.00	637.88	10.84	9.60	0.00
8/9/2014	4:00	637.88	9.55	9.91	0.00	637.88	10.71	9.64	0.00
8/9/2014	5:00	637.88	9.40	9.96	0.00	637.88	10.58	9.68	0.00
8/9/2014	6:00	637.88	9.25	10.00	0.00	637.88	10.46	9.71	0.00
8/9/2014	7:00	637.88	9.11	10.03	0.63	637.88	10.35	9.75	1.87
8/9/2014	8:00	637.88	9.03	10.06	8.19	637.88	10.33	9.78	24.30
8/9/2014	9:00	637.88	9.02	10.07	29.62	637.88	10.38	9.79	87.85
8/9/2014	10:00	637.88	9.05	10.06	100.82	637.88	10.54	9.76	299.06
8/9/2014	11:00	637.88	9.22	10.02	175.81	637.88	10.99	9.66	521.49
8/9/2014	12:00	637.88	9.58	9.92	219.61	637.88	11.53	9.53	651.39
8/9/2014	13:00	637.88	10.10	9.79	247.33	637.88	12.16	9.37	733.63
8/9/2014	14:00	637.88	10.67	9.64	265.92	637.88	12.75	9.20	788.77
8/9/2014	15:00	637.88	11.11	9.54	237.57	637.88	13.24	9.11	704.66
8/9/2014	16:00	637.88	11.46	9.46	216.77	637.88	13.40	9.08	642.98
8/9/2014	17:00	637.88	11.67	9.40	205.74	637.88	13.41	9.05	610.27
8/9/2014	18:00	637.88	11.66	9.40	115.63	637.88	13.28	9.06	342.99
8/9/2014	19:00	637.88	11.57	9.42	58.92	637.88	12.96	9.12	174.76
8/9/2014	20:00	637.88	11.42	9.45	31.19	637.88	12.71	9.15	92.52
8/9/2014	21:00	637.88	11.25	9.50	9.14	637.88	12.44	9.20	27.10
8/9/2014	22:00	637.88	11.04	9.55	0.00	637.88	12.16	9.28	0.00
8/9/2014	23:00	637.88	10.80	9.61	0.00	637.88	11.91	9.34	0.00
8/10/2014	0:00	638.78	10.59	9.66	0.00	638.78	11.71	9.40	0.00
8/10/2014	1:00	638.78	10.39	9.72	0.00	638.78	11.49	9.45	0.00
8/10/2014	2:00	638.78	10.19	9.78	0.00	638.78	11.29	9.51	0.00
8/10/2014	3:00	638.78	10.00	9.83	0.00	638.78	11.11	9.56	0.00
8/10/2014	4:00	638.78	9.82	9.87	0.00	638.78	10.94	9.61	0.00
8/10/2014	5:00	638.78	9.65	9.92	0.00	638.78	10.78	9.65	0.00
8/10/2014	6:00	638.78	9.48	9.96	0.00	638.78	10.63	9.69	0.00
8/10/2014	7:00	638.78	9.32	10.01	0.32	638.78	10.50	9.74	0.93
8/10/2014	8:00	638.78	9.22	10.04	9.45	638.78	10.44	9.77	28.04

8/10/2014	9:00	638.78	9.23	10.04	30.25	638.78	10.49	9.79	89.72
8/10/2014	10:00	638.78	9.28	10.03	89.48	638.78	10.65	9.76	265.42
8/10/2014	11:00	638.78	9.45	9.98	155.02	638.78	11.03	9.67	459.81
8/10/2014	12:00	638.78	9.76	9.90	202.59	638.78	11.52	9.56	600.93
8/10/2014	13:00	638.78	10.23	9.78	238.83	638.78	12.08	9.42	708.40
8/10/2014	14:00	638.78	10.83	9.63	261.83	638.78	12.74	9.25	776.62
8/10/2014	15:00	638.78	11.28	9.52	264.35	638.78	13.22	9.12	784.10
8/10/2014	16:00	638.78	11.52	9.45	230.95	638.78	13.38	9.07	685.04
8/10/2014	17:00	638.78	11.67	9.41	209.52	638.78	13.36	9.07	621.49
8/10/2014	18:00	638.78	11.62	9.41	92.95	638.78	13.21	9.07	275.70
8/10/2014	19:00	638.78	11.50	9.43	48.21	638.78	12.83	9.14	142.99
8/10/2014	20:00	638.78	11.37	9.46	36.55	638.78	12.60	9.17	108.41
8/10/2014	21:00	638.78	11.20	9.50	7.88	638.78	12.37	9.21	23.36
8/10/2014	22:00	638.78	11.03	9.56	0.00	638.78	12.18	9.27	0.00
8/10/2014	23:00	638.78	10.89	9.59	0.00	638.78	12.01	9.31	0.00
8/11/2014	0:00	637.87	10.77	9.62	0.00	637.87	11.85	9.36	0.00
8/11/2014	1:00	637.87	10.61	9.67	0.00	637.87	11.68	9.40	0.00
8/11/2014	2:00	637.87	10.43	9.71	0.00	637.87	11.50	9.45	0.00
8/11/2014	3:00	637.87	10.26	9.76	0.00	637.87	11.33	9.49	0.00
8/11/2014	4:00	637.87	10.09	9.80	0.00	637.87	11.17	9.53	0.00
8/11/2014	5:00	637.87	9.92	9.84	0.00	637.87	11.03	9.57	0.00
8/11/2014	6:00	637.87	9.76	9.88	0.00	637.87	10.89	9.62	0.00
8/11/2014	7:00	637.87	9.62	9.92	0.32	637.87	10.77	9.66	0.93
8/11/2014	8:00	637.87	9.53	9.96	8.51	637.87	10.71	9.70	25.23
8/11/2014	9:00	637.87	9.52	9.96	28.99	637.87	10.74	9.71	85.98
8/11/2014	10:00	637.87	9.56	9.95	91.37	637.87	10.89	9.68	271.02
8/11/2014	11:00	637.87	9.71	9.91	159.43	637.87	11.28	9.59	472.89
8/11/2014	12:00	637.87	10.05	9.81	208.89	637.87	11.78	9.47	619.62
8/11/2014	13:00	637.87	10.55	9.68	249.22	637.87	12.42	9.32	739.24
8/11/2014	14:00	637.87	11.04	9.55	268.44	637.87	13.02	9.13	796.25
8/11/2014	15:00	637.87	11.44	9.46	192.51	637.87	13.30	9.09	571.02
8/11/2014	16:00	637.87	11.73	9.37	220.24	637.87	13.47	9.01	653.26
8/11/2014	17:00	637.87	11.77	9.37	63.01	637.87	13.23	9.08	186.91
8/11/2014	18:00	637.87	11.78	9.36	90.43	637.87	13.13	9.07	268.22
8/11/2014	19:00	637.87	11.77	9.36	33.40	637.87	12.99	9.09	99.06
8/11/2014	20:00	637.87	11.67	9.38	22.69	637.87	12.84	9.10	67.29
8/11/2014	21:00	637.87	11.55	9.42	2.52	637.87	12.59	9.16	7.48
8/11/2014	22:00	637.87	11.39	9.45	0.00	637.87	12.41	9.20	0.00
8/11/2014	23:00	637.87	11.20	9.50	0.00	637.87	12.18	9.25	0.00
8/12/2014	0:00	637.18	11.03	9.54	0.00	637.18	11.97	9.31	0.00
8/12/2014	1:00	637.18	10.81	9.60	0.00	637.18	11.77	9.36	0.00
8/12/2014	2:00	637.18	10.61	9.64	0.00	637.18	11.58	9.41	0.00
8/12/2014	3:00	637.18	10.45	9.69	0.00	637.18	11.45	9.44	0.00
8/12/2014	4:00	637.18	10.34	9.71	0.00	637.18	11.36	9.46	0.00
8/12/2014	5:00	637.18	10.21	9.74	0.00	637.18	11.24	9.49	0.00

8/12/2014	6:00	637.18	10.06	9.78	0.00	637.18	11.12	9.53	0.00
8/12/2014	7:00	637.18	10.00	9.81	0.63	637.18	11.11	9.54	1.87
8/12/2014	8:00	637.18	9.99	9.82	7.56	637.18	11.12	9.55	22.43
8/12/2014	9:00	637.18	10.00	9.82	6.62	637.18	11.17	9.58	19.63
8/12/2014	10:00	637.18	10.06	9.80	47.26	637.18	11.27	9.54	140.18
8/12/2014	11:00	637.18	10.17	9.77	51.04	637.18	11.41	9.54	151.40
8/12/2014	12:00	637.18	10.35	9.73	98.93	637.18	11.58	9.46	293.45
8/12/2014	13:00	637.18	10.53	9.69	34.03	637.18	11.67	9.46	100.93
8/12/2014	14:00	637.18	10.69	9.64	80.34	637.18	11.84	9.41	238.31
8/12/2014	15:00	637.18	11.01	9.56	161.95	637.18	12.42	9.29	480.37
8/12/2014	16:00	637.18	11.49	9.42	247.33	637.18	12.88	9.14	733.63
8/12/2014	17:00	637.18	11.50	9.42	36.23	637.18	12.43	9.20	107.47
8/12/2014	18:00	637.18	11.40	9.45	8.82	637.18	12.45	9.22	26.17
8/12/2014	19:00	637.18	11.33	9.46	55.77	637.18	12.37	9.23	165.42
8/12/2014	20:00	637.18	11.22	9.48	43.80	637.18	12.20	9.26	129.90
8/12/2014	21:00	637.18	11.07	9.52	7.56	637.18	12.04	9.28	22.43
8/12/2014	22:00	637.18	10.92	9.55	0.00	637.18	11.91	9.31	0.00
8/12/2014	23:00	637.18	10.79	9.58	0.00	637.18	11.79	9.34	0.00
8/13/2014	0:00	635.50	10.66	9.62	0.00	635.50	11.70	9.37	0.00
8/13/2014	1:00	635.50	10.53	9.65	0.00	635.50	11.61	9.39	0.00
8/13/2014	2:00	635.50	10.39	9.69	0.00	635.50	11.50	9.42	0.00
8/13/2014	3:00	635.50	10.25	9.72	0.00	635.50	11.39	9.45	0.00
8/13/2014	4:00	635.50	10.12	9.76	0.00	635.50	11.28	9.48	0.00
8/13/2014	5:00	635.50	10.00	9.78	0.00	635.50	11.18	9.50	0.00
8/13/2014	6:00	635.50	9.89	9.81	0.00	635.50	11.09	9.53	0.00
8/13/2014	7:00	635.50	9.81	9.83	0.63	635.50	11.02	9.55	1.87
8/13/2014	8:00	635.50	9.79	9.84	11.66	635.50	10.99	9.57	34.58
8/13/2014	9:00	635.50	9.82	9.84	22.37	635.50	10.98	9.58	66.35
8/13/2014	10:00	635.50	9.88	9.81	98.30	635.50	11.11	9.57	291.58
8/13/2014	11:00	635.50	10.02	9.77	170.14	635.50	11.51	9.48	504.67
8/13/2014	12:00	635.50	10.34	9.69	190.93	635.50	12.03	9.36	566.35
8/13/2014	13:00	635.50	10.82	9.57	243.55	635.50	12.59	9.23	722.42
8/13/2014	14:00	635.50	11.02	9.53	71.84	635.50	12.50	9.18	213.08
8/13/2014	15:00	635.50	10.96	9.57	2.84	635.50	12.35	9.27	8.41
8/13/2014	16:00	635.50	11.05	9.55	143.99	635.50	12.66	9.23	427.10
8/13/2014	17:00	635.50	11.18	9.50	184.63	635.50	12.69	9.18	547.66
8/13/2014	18:00	635.50	11.14	9.49	80.66	635.50	12.60	9.18	239.25
8/13/2014	19:00	635.50	11.05	9.51	19.22	635.50	12.41	9.20	57.01
8/13/2014	20:00	635.50	10.96	9.54	4.73	635.50	12.28	9.24	14.02
8/13/2014	21:00	635.50	10.87	9.56	2.21	635.50	12.16	9.26	6.54
8/13/2014	22:00	635.50	10.74	9.59	0.00	635.50	12.03	9.30	0.00
8/13/2014	23:00	635.50	10.61	9.63	0.00	635.50	11.93	9.32	0.00
8/14/2014	0:00	634.58	10.53	9.65	0.00	634.58	11.88	9.34	0.00
8/14/2014	1:00	634.58	10.43	9.67	0.00	634.58	11.79	9.35	0.00
8/14/2014	2:00	634.58	10.33	9.68	0.00	634.58	11.72	9.36	0.00

8/14/2014	3:00	634.58	10.26	9.70	0.00	634.58	11.64	9.39	0.00
8/14/2014	4:00	634.58	10.18	9.72	0.00	634.58	11.60	9.41	0.00
8/14/2014	5:00	634.58	10.21	9.74	0.00	634.58	11.63	9.42	0.00
8/14/2014	6:00	634.58	10.11	9.75	0.00	634.58	11.54	9.43	0.00
8/14/2014	7:00	634.58	9.98	9.79	0.00	634.58	11.46	9.46	0.00
8/14/2014	8:00	634.58	9.92	9.81	6.62	634.58	11.45	9.48	19.63
8/14/2014	9:00	634.58	9.92	9.81	26.15	634.58	11.49	9.49	77.57
8/14/2014	10:00	634.58	9.95	9.79	97.99	634.58	11.63	9.45	290.65
8/14/2014	11:00	634.58	10.07	9.77	164.47	634.58	11.99	9.38	487.84
8/14/2014	12:00	634.58	10.27	9.72	201.96	634.58	12.41	9.30	599.06
8/14/2014	13:00	634.58	10.65	9.63	210.78	634.58	12.84	9.20	625.22
8/14/2014	14:00	634.58	11.21	9.48	284.51	634.58	13.51	9.03	843.91
8/14/2014	15:00	634.58	11.49	9.41	198.18	634.58	13.70	8.97	587.84
8/14/2014	16:00	634.58	11.50	9.42	70.89	634.58	13.53	9.01	210.28
8/14/2014	17:00	634.58	11.61	9.39	143.04	634.58	13.58	8.99	424.29
8/14/2014	18:00	634.58	11.48	9.40	101.45	634.58	13.31	9.01	300.93
8/14/2014	19:00	634.58	11.31	9.44	25.84	634.58	13.02	9.07	76.63
8/14/2014	20:00	634.58	11.16	9.47	25.21	634.58	12.80	9.12	74.77
8/14/2014	21:00	634.58	10.99	9.52	3.78	634.58	12.58	9.17	11.21
8/14/2014	22:00	634.58	10.80	9.57	0.00	634.58	12.39	9.22	0.00
8/14/2014	23:00	634.58	10.63	9.61	0.00	634.58	12.22	9.26	0.00
8/15/2014	0:00	635.30	10.45	9.66	0.00	635.30	12.04	9.32	0.00
8/15/2014	1:00	635.30	10.29	9.70	0.00	635.30	11.87	9.35	0.00
8/15/2014	2:00	635.30	10.13	9.75	0.00	635.30	11.71	9.40	0.00
8/15/2014	3:00	635.30	10.01	9.77	0.00	635.30	11.61	9.42	0.00
8/15/2014	4:00	635.30	9.93	9.79	0.00	635.30	11.54	9.44	0.00
8/15/2014	5:00	635.30	9.87	9.81	0.00	635.30	11.50	9.45	0.00
8/15/2014	6:00	635.30	9.81	9.83	0.00	635.30	11.47	9.46	0.00
8/15/2014	7:00	635.30	9.75	9.84	0.00	635.30	11.39	9.48	0.00
8/15/2014	8:00	635.30	9.71	9.86	4.41	635.30	11.36	9.49	13.08
8/15/2014	9:00	635.30	9.72	9.87	8.51	635.30	11.37	9.53	25.23
8/15/2014	10:00	635.30	9.76	9.86	77.82	635.30	11.47	9.52	230.84
8/15/2014	11:00	635.30	9.83	9.84	64.28	635.30	11.58	9.48	190.65
8/15/2014	12:00	635.30	9.96	9.81	68.06	635.30	11.71	9.48	201.87
8/15/2014	13:00	635.30	10.09	9.77	78.14	635.30	11.81	9.43	231.77
8/15/2014	14:00	635.30	10.37	9.71	142.10	635.30	12.24	9.36	421.49
8/15/2014	15:00	635.30	10.75	9.61	215.83	635.30	12.67	9.23	640.18
8/15/2014	16:00	635.30	11.02	9.54	203.54	635.30	12.92	9.16	603.73
8/15/2014	17:00	635.30	11.09	9.51	90.43	635.30	12.78	9.17	268.22
8/15/2014	18:00	635.30	11.13	9.51	93.89	635.30	12.82	9.17	278.50
8/15/2014	19:00	635.30	11.12	9.50	44.11	635.30	12.63	9.19	130.84
8/15/2014	20:00	635.30	11.03	9.52	19.85	635.30	12.43	9.22	58.88
8/15/2014	21:00	635.30	10.90	9.56	2.84	635.30	12.24	9.25	8.41
8/15/2014	22:00	635.30	10.75	9.60	0.00	635.30	12.03	9.30	0.00
8/15/2014	23:00	635.30	10.57	9.65	0.00	635.30	11.82	9.36	0.00

Appendix G.

	Time Interval (2016)	Avg. Stream Area (m ²)	Trout Production (g/m ² /day)			Production (mg/m ² /day)
			Size Class (cm)	Avg. Biomass (mg)	Avg. Density (#/m ²)	
Pioneer Creek	July 5 - July 19	488.91	85	4.3422	0.0522	0.0153
			170	24.2468	0.0368	
			255	79.4370	0.0051	
	July 19 - Aug 8	488.91	85	4.7804	0.0358	0.0173
			170	19.9868	0.0501	
			255	79.4370	0.0041	
Aug 8 - Aug 21	488.91	85	3.8591	0.0409	0.0205	
		170	22.2411	0.0522		
		255	79.4370	0.0031		
Cliff Creek	July 5 - July 19	522.73	85	3.7428	0.1263	0.0226
			170	22.4892	0.0536	
			255	82.1759	0.0191	
	July 19 - Aug 8	522.73	85	4.1022	0.1014	0.0271
			170	24.9816	0.0670	
			255	79.4370	0.0134	
Aug 8 - Aug 21	522.73	85	2.6844	0.0794	0.0367	
		170	20.0479	0.1090		
		255	79.4370	0.0124		

Appendix H.

Fraction of trout production attributed to each prey item

Diet Item	Pioneer Cr.	Cliff Cr.
<i>Chironomidae spp.</i>	0.0037	0.0770
<i>Simuliidae spp.</i>	0.0200	0.0297
<i>Baetidae spp.</i>	0.1007	0.2022
Tipulidae spp.	0.1259	0.0456
Ameletidae spp.	0.0016	0.0870
Ephemerellidae spp.	0.0357	0.1018
Heptageniidae spp.	0.0753	0.0620
Trichoptera spp.	0.0514	0.0719
Aquatic Adults	0.1651	0.1152
Aquatic Others	0.1283	0.0799
Terrestrials invertebrates	0.2923	0.1276

Appendix I.

```
library(asbio)
library(car)
library(MASS)
library(leaps)
library(corrplot)
rm(list=ls())#to clear all variables
```

```
Variables<-read.csv(file.choose())
Variables_matrix<-as.matrix(Variables)
cor(Variables_matrix)
cormatrix<-cor(Variables_matrix)
corrplot(cormatrix, method="circle", tl.col="Black")
```

```
Variables<-read.csv(file.choose())# Locate and select the 'Variables_Redux.csv'
y1 <-Variables$FishBiomass
y2 <-Variables$InvertBiomass
y3 <-Variables$GPP
x1 <-Variables$CanopyCover
x2 <-Variables$Discharge
x3 <-Variables$Temp
x4 <-Variables$Area
#x5 <-Variables$Aspect
x5 <-AspectDegreesFromNorth
x6 <-Variables$Slope
x7 <-Variables$ProportionBurned
x8 <-Variables$TimeSinceBurn
x9 <-Variables$RockBAxis
x10<-Variables$Embedd
x11<-Variables$TN
x12<-Variables$InorganicN
x13<-Variables$TP
x14<-Variables$PO4
```

```
stepAIC(lm(y2~x1+x3+x4+x7+x8+x12+x14)) # y2~x1+x3+x12+x14
```

```
Invert_ValuableVariables<-
  regsubsets(y2~x1+x3+x12+x14,data=Variables,nbest=1,nvmax=11)
summary(Invert_ValuableVariables)
```

```
stepAIC(lm(y1~y2+x1+x3+x4+x7+x8+x12+x14)) #y1~y2+x1+x4+x7+x12
```

```
Fish_ValuableVariables<-
  regsubsets(y1~y2+x1+x4+x7+x12,data=Variables,nbest=1,nvmax=11)
summary(Fish_ValuableVariables)
```