Survival and dispersal of hatchery-raised rainbow trout (*Onchorynchus mykiss*) in a river basin undergoing urbanization

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Summary

Changes in land and water use associated with the conversion of rural lands to urban are pervasive problems for freshwater fauna in North America. Urban development can increase stream temperatures through increased impervious surfaces, alterations of riparian vegetation, and increased water use. We evaluated the effect of increasing urbanization on water temperatures and rainbow trout *Onchorynchus mykiss* survival for a popular coldwater fishery in the Chattahoochee River, near Atlanta Georgia. We estimated monthly survival, dispersal, and angler harvest reporting rates of stocked trout in two study reaches from March-October 2006 using multistrata tag-recovery models. The best-fitting models indicated that the monthly survival of stocked trout was negatively related to the total number of 15 minute intervals that temperatures exceeded 20^{o}C and angler effort. We estimate trout survival was more sensitive to increased water temperatures than angler effort. Dispersal rates from a warmer downstream to a cooler upstream reach were 6- 7 times greater than from upstream to downstream. Empirical temperature-discharge models indicated that water temperatures in the river, downstream of Morgan Falls Dam have increased with increasing urbanization from 1976 - 2006. Using these models, we estimate that 20% of stocked trout were lost, on average, during the summer months due to angling or other sources (e.g., high temperature) under pre-urbanized conditions, whereas 70% of fish are lost under current conditions. Our models suggest that increasing hypolimnetic releases from an upstream dam could mitigate the effects of increased urbanization during the summer. We suggest that conducting releases according to an adaptive monitoring program could mitigate rainbow trout mortality, while accounting for societal values such as hydropower generation and lake-based recreation.

1.0 Introduction

The increase in urban and suburban development is a global problem for aquatic resource managers. During the past decade, urban growth has increased dramatically in the southeastern United States (US Census Bureau 2004), potentially threatening the unique aquatic fauna in the region as well as managed sportfish populations. The resulting land use conversion and associated increases in water use can alter the dynamics of fish populations and communities, particularly in sensitive coldwater fisheries.

Metropolitan Atlanta, GA and the area surrounding it is a useful example of how changing land use can alter the dynamics of coldwater fisheries. In the last 30 years, urban development has expanded around the Chattahoochee River National Recreation Area (CRNRA), one of the southernmost trout fisheries in North America. Suitable water temperatures for the fishery are generally maintained year-round due to hypolimnetic releases from Buford Dam, a large hydroelectric facility at the upstream end of the CRNRA (Figure 1). However with the increasing impervious surface area (e.g., pavement, rooftops) that accompanies urban development, the ability of hypolimnetic water releases to mitigate summer warming trends diminishes. As more urban development occurs, surface water inputs from precipitation during the summer become increasingly warmer (Ferguson and Suckling 1990), because runoff is warmed and discharged into the river faster than would have occurred historically (Paul and Meyer 2001). Additionally, impervious surfaces inhibit the ability of storm water to recharge groundwater, thus sources of cool groundwater water input can be lost (Ferguson and Suckling 1990; Finkenbine et al. 2000; Wang et al. 2003; Krause et al. 2004). The resulting change in the temperature regimes can affect coldwater fisheries by decreasing fish survival and altering large-scale fish dispersal patterns.

Here we examine the effect of summer water temperatures on survival and dispersal of hatchery-raised rainbow trout *Onchorynchus mykiss* in two adjacent reaches of the Chattahoochee River; the upstream reach has moderate runoff from urbanized areas and the downstream reach has greater amounts of urban runoff. We hypothesize that several factors will affect fish survival. First, we propose that angling pressure will decrease fish survival in both reaches. Second, we expect that increases in summer water temperature have a negative effect on trout survival. In terms of large-scale (between reach) dispersal, we envision several hypothesized patterns related to water temperature, discharge, and location (i.e., study reach). First, during times of high temperature in the summer, we expect fish in the downstream reach to disperse to the cooler, upstream reach. However, when temperatures are low, we expect fish in the upstream reach to disperse downstream, perhaps passively. Alternatively, dispersal may be a one-way process in which fish seek out the cooler upstream regions, regardless of water temperature in downstream reach. Finally, dispersal may be passive if fish are continually pushed downstream, but the dispersal rate increases during times of high discharge.

We combine the trout survival and dispersal models with empirical stream temperature models under historic (1976) and current (2002-2006) land use conditions. We then estimate the effect of urbanization on the trout fishery by estimating the loss of stocked trout under the two land use scenarios. Our goal is to gain an understanding of the processes, direction, and trends in the coldwater fishery in response to land use change and to suggest potential remedial actions.

2.0 Methods

2.1 Study site

Our study took place on the Chattahoochee River between Atlanta, GA and Morgan Falls Dam (river km 487-502 from the mouth of the river) within the Chattahoochee River National

Recreation Area. Two reaches formed the study site (hereafter the ‘upstream’ and ‘downstream’ reaches), with Cochran Shoals (33º 15′ 36″ N 84º 26′ 16″ W) marking the boundary between the reaches (Figure 1). The up and downstream reaches were 8.1 and 6.4 km in length, respectively. The upstream reach consisted primarily of pool and run habitats and smaller amounts of shoal habitats, whereas the downstream reaches contained greater amounts of shoal habitats and fewer pool and run habitats. Four municipal water supply intakes are located on the river, two above Morgan Falls Dam and the other two are located on the upper and lower study reaches.

Water temperatures in this section of the Chattahoochee River are influenced by releases from both Morgan Falls Dam (0 km upstream from the upper end of the study site) and Buford Dam (58 km upstream; Figure 1), as well as by surfacewater inputs from precipitation events (Georgia Power 2006). Of these, hypolimnetic coldwater releases from Buford Dam exert the greatest influence on the water temperature (Georgia Power 2006).

2.2 Mark-recapture sampling design

Marked and unmarked hatchery-raised rainbow trout were released at a single location in each study reach (Figure 1), approximately monthly from March - October 2006. The number of marked fish per month ranged from 300-410 fish. The trout averaged 228 mm total length and were marked with floy tags, colored elastomer injections, or both, approximately one month prior to stocking. Following marking, fishes were held at the hatchery to estimate tag retention rates and survival of tagged fishes. Floy tags included a unique identifying number and contact information with which anglers could report a tagged fish. Information requested of anglers included tag number, date of catch, location caught, and whether the fish was released (with tag still inserted or with tag removed) or harvested.

Fishes were sampled for the three consecutive days following the release of the hatchery fish. Within each study reach, we established nine fish sampling sites that were uniformly distributed along the reach. During each sampling day, we sampled each site for 10 minutes using a boat-mounted, dual electrode Wisconsin ring electrofisher (Reynolds 1996) operating at approximately 3.0 A pulsed direct current (DC) for a total 1.5 h of pedal time per reach. However on a few occasions, we were only able to complete 1 h of sampling per reach. We adjusted for this unequal sampling effort by modeling electrofishing capture probabilities as a function of effort (detailed below). Captured fishes were identified, checked for a tag or elastomer mark, and released. Rainbow trout that were marked with elastomer were marked with an additional elastomer tag that was unique to the study reach and date before being released.

To estimate angler pressure, we conducted a concurrent bus-stop access creel survey (Robson and Jones 1989; Jones et al. 1990) for completed trip information. The river was divided into three areas with 3 - 5 access points in each area. The creel started April 1, 2005 and was completed September 30, 2006. The day was divided into morning and afternoon time periods. We used 14 day periods in which 10 days were sampled, including all weekend days. The creel clerk informed anglers of the tagging study and encouraged them to report tagged trout. He also provided stamped self-addressed envelopes to encourage reporting. Data recorded included: hours fished, fishing method (bank, boat, or wading), target species, species caught, fishing method and baits, number of times fished per year, county of residence, age, race, and whether the angler ate fish caught from the Chattahoochee River (and if not, why not?). We then used these data to estimate the total number of angler hours at each study reach for the period between sampling occasions. Because the creel ended in September, we fit a linear regression model between angler hours and reported number of fish caught from March - September and then used the reported number of fish caught in October to predict angler hours in October. This predicted value was used in the survival estimation modeling, detailed below.

To evaluate the influence of river discharge and water temperature on the survival and dispersal of trout, we obtained data recorded at 15-minute intervals from two US Geological Survey (USGS) water quality monitoring stations located at the upstream reach (station 02335810) and the downstream reach (02336000). Using these data, we estimated average and maximum temperature and discharge for the period between monthly fish sampling. We were primarily interested in estimating the effect of chronic (long term) temperatures on trout survival rather than acute lethal temperatures. Water temperature influences long term fish survival through altering their vulnerability to predation (Coutant 1973) and pathogens (Hbtrick et al. 1979) and through interspecific interactions, such as competition (Cunjak and Green 1986; Reese and Harvey 2002). The effect of these interactions is likely minimized when temperatures are within the optimal or preferred temperature (Reese and Harvey 2002). Thus, we estimated the total number of 15-minute intervals that temperatures exceeded 20ºC (hereafter termed "exceedence") for the period between monthly fish sampling based on reported upper limit of rainbow trout preferred and optimal temperatures (Coutant 1977; Hokanson et al. 1977).

2.3 Statistical analysis: mark-recapture

We used a multistrata, tag-recovery model (Barker and White 2001) implemented in program MARK (Burnham and White 1999) to estimate rainbow trout survival and dispersal in response to temperature and flow patterns. Here, the strata are the two study reaches. Multistrata, tag-recovery models produce four types of probability-based estimates: survival, movement, recapture, and reporting. The survival parameter (*S*) is defined as the probability of an individual surviving between sample periods (defined in one month intervals for this study). The movement parameter (ψ) is the monthly probability that an individual will move from one reach to another, the recapture parameter (p) is the probability that an individual will be recaptured either by biologists or by catch-and-release anglers, and the reporting parameter (r) is the probability that a tag will be reported by anglers given that a fish was harvested.

From water quality monitoring stations, we obtained data on maximum discharge and water temperature, average discharge and water temperature from a given month, and the total number of exceedences. Many of these variables were highly correlated. To avoid multicollinearity, we never modeled a single parameter type (e.g., survival, dispersal) with two variables having Pearson's correlation coefficient $r \geq |0.70|$.

To investigate the factors influencing monthly trout survival, we fit models with the following predictor variables: reach, angler pressure, temperature exceedence, and average discharge for the month prior to fish sampling. The global (most highly parameterized) model for survival was reach*exceedence + angler pressure + average discharge. We evaluated factors influencing large scale (between reach) fish movement (ψ) by considering direction of movement, temperature exceedence, and average discharge for each month. The most saturated models (most predictors) for ψ were direction * exceedence and direction *average discharge. Because the observed movement between reaches was very low, we lacked the data to fit a global model with both terms. The direction * exceedence model represents the hypothesis that trout move from the downstream to the upstream (cooler) reach in response to temperature much more readily than they would move from the upstream to the downstream reach. The direction * average discharge model represents the hypothesis that dispersal was related to discharge. The capture probability (p) was modeled as a constant or as a function of the number of hours of pedal time per month that biologists sampled. Catch and release angling also affected the estimate of this parameter, but the vast majority of recaptures were by biologists, thus we believe biologist effort would capture most of the temporal variation in this estimate. Finally, the reporting parameter (*r*) was modeled as constant across time and reaches because we could conceive no reason why anglers would change their reporting rate across the length of the study or depending upon the location where the fish was caught.

We evaluated the relative fit of candidate models of trout survival, movement, and by calculating Akaike's information criterion (AIC; 1973), ΔAIC, and Akaike weights (Burnham and Anderson 2002) that range from 0 - 1, with larger values indicating better fitting models. We summed Akaike weights to compare the weight of evidence regarding two hypotheses: whether temperature (exceedence) affected dispersal (ψ) and whether electrofishing effort affected the probability of recapture (p). For these comparisons, we summed equal numbers of models for each hypothesis.

To incorporate model selection uncertainty, we used Akaike weights to calculate model-averaged parameter estimates and unconditional standard errors following Burnham and Anderson (2002). We based all inferences and predictions on model-averaged parameter estimates and assessed the precision of model-averaged parameter estimates by calculating 95% confidence intervals.

2.4 Alternative temperature criteria

The Georgia Department of Natural Resources proposed six additional alternative criteria for estimating exceedence levels (Table 1). Here we estimated the number of 15 min. intervals that the temperature criteria were exceeded (e.g., Figure 2). To evaluate the efficacy of these criteria, we estimated survival rates by substituting the number of exceedence intervals for each of the criteria in place of the 20^{o}C exceedence for the best-fitting 20^{o}C exceedence model. We then used these models to estimate the monthly mortality (one minus survival) of trout as a function of the total number of violations to the criteria.

2.5 Estimating the effect of urbanization

Estimating the effect of urbanization on the trout fishery in the Chattahoochee River required estimates of the change in the number of exceedences that occurred during the summer months each year, after accounting for the effects of discharge and climate (i.e., temperature and precipitation). Thus, we fit models relating discharge, air temperature, and precipitation to the number of exceedences occurring in a 24 h period using historic and current daily data. We obtained water temperature data from the USGS water quality station (02336000) located at the downstream study reach for the years 1976, 2002, 2004-2006 and supplemented these with our own measurements collected at the same location from 1991-1993, 1999, and 2003. To examine the relationship between Buford Dam discharge and water temperature at the downstream study reach, we constrained our analysis to the months June-August, when we expected exceedences to occur. For 2002, 2004 - 2006, the data were collected in 15 minute intervals. From 1991 - 1993, the data were collected in 30-minute intervals. For 1999 and 2003 the data were collected in hourly intervals. To transform the hourly and 30 minute data (1990-1993, 1999, 2003), we summed the number of exceedences per day then multiplied this sum by four and two, respectively, to obtain an estimate of the number of 15 minute exceedence intervals per day.

Maximum daily water temperature was only available for 1976. To transform the 1976 data from maximum daily temperature to the number of 15-minute exceedence intervals per day, we performed a linear regression (Neter et al. 1990) on the 2004 - 2006 data for which both exceedence and maximum daily water temperature were known. We used the latter as the predictor variable and the former as a response variable. Because the threshold used was 20ºC, we subtracted 20 from the 15 minute interval temperatures in the regression and constrained the regression to pass through the origin. From this analysis we obtained a slope of 20.79, which indicates that for every degree Celsius that maximum daily water temperature increases, the number of daily exceedences increases by an average of 20.79. We then applied this slope to the 1976 maximum daily water temperature data to estimate the number of exceedences in that year.

To investigate the effect of Buford Dam releases and urbanization on water temperature in the downstream study reach, we fit candidate linear regression models relating discharge at Buford Dam, daily precipitation, and maximum air temperature to daily exceedences at the downstream study reach (Appendix A). Candidate models included one and two day lags between the discharge at Buford Dam and daily exceedences, based on information from Georgia Power (2006) that water temperatures below Buford Dam are strongly related to water temperatures above Morgan Falls Dam 12 hours later. We included daily maximum air temperature at Atlanta Hartsfeld Airport (24 km from the study site) and daily precipitation at the NOAA Atlanta-Bolton weather station (4.3 km from the study site) as covariates in every model. Candidate models also included year as a predictor variable and year by discharge, year by precipitation, and year by temperature interactions to examine whether the relationships have changed with increasing urbanization in the Region from 1976 - 2006. Nineteen seventy-six was coded as the intercept (baseline) for the year term. We compared relative fit of the candidate models by calculating AIC, ΔAIC, and AIC weights. Goodness-of-fit was assessed for the best-fitting models by examining residual and normal probability plots.

To predict the effects of urbanization on trout loss, we used the best-fitting models from both the discharge-exceedence and survival analyses. For the discharge-exceedence model, we estimated total monthly exceedence using average daily values for maximum air temperature, precipitation, and discharge from Buford Dam observed from 1991-2006. For the pre-urbanization scenario, we estimated expected exceedences with the year term = 1976, and for the urbanization scenario with the year = 2006. This resulted in two sets of predicted daily exceedences. We summed these predicted daily exceedences over each month and used these values along with the estimated relationship between survival and exceedences obtained from the mark-recapture model to estimate monthly trout mortality. We assumed that mortality equaled one minus survival for summer months, because trout in this system could not emigrate successfully: emigration upstream was blocked by Morgan Falls Dam and emigration downstream would be lethal due to water temperatures > 25ºC. We then used the mortality estimates and GA DNR stocking records from 1991 - 2006 (Appendix B) to predict the number of trout lost to increased urbanization. Finally, we predicted trout mortality under a range of discharges from Buford Dam in pre-urbanization (1976) vs. current conditions (2006) using air temperature and precipitation data from 2006. The estimates were for discharges at Buford Dam that ranged 12 - 237 cms, the minimum and maximum discharge observed during summer months.

We evaluated the effect of increased water use on the discharge at the downstream study reach by fitting candidate linear regression models relating daily discharge at Buford Dam to daily discharge at the downstream study reach for pre-urbanization (1976-1980) and current (2002-2006) time periods. Similar to the exceedence models, candidate models included one and two day lags between the discharge at Buford Dam and discharge at the downstream reach. Candidate models also included a binary indicator that was coded as 1 for current time period (2002-2006), otherwise 0 and an indicator variable by discharge interaction to examine whether the relationships have changed with increasing urbanization. We compared relative fit of the candidate models by calculating AIC and ΔAIC. Goodness-of-fit was assessed for the best-fitting model by examining residual and normal probability plots.

3.0 Results

We released 14,400 rainbow trout, 5918 of which were marked. Of these, 3988 were marked with floy (FD-68B) tags, 2080 were marked with elastomer only, and 357 were marked with both (Appendix C). One hundred and thirteen of these were recaptured by biologists at least once, 29 were caught by anglers, released, and reported, and 35 were caught by anglers, harvested or tag removed, and reported during the study period. Tag retention rates one month following tagging averaged 97.8% and were smaller for the elastomer (89.8%) than the floy tags (99.5%). One month survival for tagged fish prior to stocking averaged 89.9%.

Angler pressure during the study was, on average, greatest during the spring and lowest during the summer (Table 2). However, there was considerable overlap between the amounts of angling pressure at each study reach. Discharge and temperature were inversely related, with discharge highest and temperature lowest during the spring (Table 2). Discharge and temperature also were, on average, greater at the downstream reach, with maximum temperatures during July and August reaching reported lethal temperatures (25ºC; Cherry et al. 1977) for rainbow trout.

3.1 Mark-recapture

The best-fitting multistrata, tag-recovery model was *S* (exceedence + angler pressure), *p* (effort), ψ (direction), *r* (**.**) (Table 3). This model was 2.0 times more likely to be the best approximating model compared to the next best fitting, which differed only by eliminating the effort term from the electrofishing recapture probability. Evidence ratios based upon Akaike importance weights suggested that models without the effect of temperature on dispersal (ψ) were 1.8 times more likely to explain the data than models with the temperature effect (Table 4). Of the dispersal models with no temperature effect, the direction-specific models were 4.1 times more likely to explain the data than models with dispersal randomly occurring between upstream and downstream sites. Evidence ratios also suggested that capture probability models with electrofishing effort were 2.1 times more likely to explain the data than models where capture probability was assumed constant (Table 4). Five of six best fitting models had survival varying with exceedence and angling pressure only (Table 3).

Estimated rates of survival decreased during summer (Figure 3a), especially in the downstream reach, where water levels were low, and temperatures high during summer 2006. The decrease in survival was primarily due to the influence of increased number of exceedences during summer months (Figure 4a), because angler pressure decreased in the downstream reach in summer (Table 2), which we would expect to increase survival. Model-averaged estimates indicated that both angler pressure and exceedence intervals influenced rates of survival (Table 5). We estimate that survival was, on average, 1.03 times lower for each 1 h increase in angler pressure, whereas survival was 1.1 times lower with each 1-unit increase in exceedence. Thus, the effect of exceedence on survival was greater than the effect of angler pressure (Figures 3b).

There also was some evidence that survival differed among study reaches. At the intercept of 0 hours of angler effort and 0 exceedence intervals, we estimate that monthly trout survival in the upstream reach was, on average, 1.22 times higher than in the downstream reach (0.20 on the logit scale with 95% CI [-0.35, 0.74]). Survival also was 1.13 times lower with every 100 exceedence intervals increase per month in the upstream reach. However, the estimate of the reach* by exceedence interaction term suggested that for every 100 exceedence intervals per month, survival in the downstream reach 1.02 times lower than in the upstream reach (Figure 4a). The parameter estimates for reach differences, however, were relatively imprecise and the confidence intervals for all reach effects contained zero (no effect).

Dispersal between study reaches tended to occur more from downstream to upstream areas than vice versa (Figure 3b). Model-averaged estimates indicated that upstream dispersal averaged just above 0.06 for the study period, whereas downstream dispersal averaged just under 0.02. Although 95% confidence intervals on direction-specific dispersal were large and overlapped (Table 5; Figure 3b), Akaike importance weights indicate that models including direction specific dispersal were better supported by the data with an evidence ratio of 4.1 (Tables 3 and 4).

3.2 Alternative temperature criteria

Plots of predicted mortality (i.e., one minus survival) versus number of threshold violations per month suggested that criteria 1-3 were very sensitive with regard to gauging the effect of exceeding threshold values on rainbow trout mortality (Figure 5). For example, after very few cumulative hours of exceeding these thresholds, mortality of rainbow trout neared 1.0 (Figure 5a). In addition, the intercepts of the plots indicated that mortality was higher under criteria 1, 3, and 5 than the other criteria when no violations occurred. When contrasted with criteria 6 (i.e., the 5-day running average at 20^{o}C; Table 1), this suggests that fishes are being lost to high temperatures even before the thresholds are exceeded. In contrast, criterion 4 proved to be the most insensitive. Changes in this threshold over the study period resulted in very small changes in trout survival and were ill supported statistically. That is, survival models using this threshold fit poorly and hence, it is not included in the Figure 5. If the goal is to use a measure that accurately predicts a response in trout survival but that does not respond only to the most extreme temperature conditions, then the exceedence measure used throughout this report (criterion 6) appears sufficient, either expressed as a cumulative monthly count or a 5-day running average (Figure 5). Choosing the number of acceptable times that the criteria can be exceeded would be based on the acceptable loss in terms of number of fish lost or change in mortality probability.

3.3 Effects of urbanization

The best-fitting model for estimating exceedence at the downstream reach from 1976 - 2006 included terms for discharge at Buford Dam with a one day lag (hereafter 'discharge'), year, daily precipitation, maximum daily air temperature, a discharge quadratic term, and a discharge by year interaction (Table 6). The model was 1.31 times more likely than the next best fitting model, which was similar but contained a daily precipitation by year interaction. Parameter estimates from the best fitting model indicate that for every cubic meter of water released at Buford Dam in 1976, an estimated 1.16 fewer exceedence intervals occurred per day in the downstream reach; whereas the discharge by year interaction indicated that for every year after 1976, a greater volume of water was required to maintain pre-urbanization water temperatures (Table 7, Figure 6a). Similarly, the precipitation by year interaction in the second-best model suggested that for every progressive year since 1976, one cm of rain caused, on average, 0.12 more exceedence intervals per day, though the 95% CI were relatively large and contained 0 (Table 7).

Assuming average daily values from 1991 - 2006 for precipitation, maximum air temperature, and discharge, we estimate 40 more water temperature exceedences occur per day under current (2006) conditions than under pre-urbanization (1976) conditions (Figure 6b). The greater number of exceedences also had a substantial influence on the trout fishery at the downstream reach. We estimate that given average daily values from 1991 - 2006 for precipitation, maximum air temperature, and discharge, 20% of stocked trout were lost during the summer months due to angling or other sources (e.g., high temperature) under pre-urbanized conditions, whereas 70% of fish would be lost under current conditions (Figure 7b). These values equate to a loss of 6,643 stocked fish under pre-urbanization conditions and 22,762 under current conditions assuming average stocking levels from 1991 - 2006. We also estimate that greater discharges are needed at Buford Dam to maintain equivalent trout mortality rates under current conditions compared with pre-urbanization conditions (Figure 7a).

The best approximating model for estimating stream discharge at the downstream reach during pre-urbanization and current time periods included discharge at Buford Dam with a one day lag and a current time period indicator variable by discharge interaction. Parameter estimates indicated that discharge at the downstream reach in June - August under current conditions do not differ from pre-urbanization conditions during low flows, but are greater under current conditions during high flows (Table 8).

4.0 Discussion

Water temperatures during the summer strongly affected the survival of stocked rainbow trout in the Chattahoochee River. The negative effect of warm water temperatures on salmonids is certainly not a new finding (e.g., Fry et al. 1946; Hughes and Roberts 1970). However, we also found that water temperatures were increasing through time in the Chattahoochee River downstream of Morgan Falls Dam, negatively affecting a popular recreational trout fishery. Based on recorded stocking levels, we estimated that 9400 fewer trout are available, on average, for angling each month under current conditions than under pre-urbanization conditions, which represents a reduction of about one third to the stocked trout population. We believe that the increased temperatures were primarily due to increased urbanization and the concomitant increase in impervious surface, rather than increased water demand. We estimate that, on average, 60 cms of additional discharge is currently needed from Buford Dam to maintain the same level of trout survival at the downstream reach as under pre-urbanization conditions (Figure 7a). Impervious surfaces decrease infiltration, which increases surface water runoff directly into the stream, increasing temperatures during warm seasons (Ferguson and Suckling 1990; Wang et al. 2003; Krause et al. 2004). The effect of increased surface runoff is further exacerbated when impervious surfaces, such as roadways and parking lots, are very warm and in turn warm precipitation runoff before it enters the river. This is consistent with the observed precipitation by year interaction in the exceedence-discharge models that suggests that precipitation under current conditions increases water temperatures more than pre-urbanization.

Despite the occurrence of lethal water temperatures in the lower study reach, some fish did survive during the warmest months. Physical habitat in this area was higher quality with more riffles, shoals, and deep pools (Nestler et al. 1984) that may have aided fish survival. The more likely mechanism, however, is that this section of the river contains numerous seeps where groundwater enters the river (Couch et al. 1996). The groundwater is cooler (17-19^{o}C) than surface waters during the summer and hence, these areas likely function as thermal refugia (e.g., Kaya et al. 1971). The relative amounts of these thermal refugia are influenced, in part, by infiltration of precipitation into the groundwater. Thus, we expect the relative number of refugia to decrease with increased urbanization, negatively influencing the trout fishery.

In contrast to the lower reach, temperatures in the upper reach did not reach acute lethal levels during the summer. Nonetheless, fish survival was lowest in the upstream reach during summer months and much of this was due to the increased number of exceedences. We believe that this was likely due to chronic effects resulting from frequent but short duration exposure to higher, but sub-lethal temperatures. Rainbow trout that are exposed to high but non-lethal temperatures for short durations are more susceptible to predation (Coutant 1973) and pathogens (Hbtrick et al. 1979). Indeed, stocked trout were the most abundant food item in the diet of striped bass *Morone saxatilis* in this section of the Chattahoochee River (Hess and Jennings 2002). Water temperatures also reached 23°C several times during the months of July and August in the upstream reach, sufficient to cause detrimental chronic effects (Bartholow 1991). Our results and those of previous cited studies support the contention that fishery managers should consider the influence of chronic exposure to higher non-lethal temperatures when developing regulations and management strategies.

Increased flows from Buford Dam could mitigate trout loss, but current releases from Buford Dam are insufficient to curtail the effects of increasing impervious surface area. During summer 2001 to 2006, 19 months (out of a possible 30) experienced average monthly releases less than 20 cms at Buford Dam. Under current urbanization conditions, an average flow of 20 cms will result in less than 10% monthly survival. Under pre-urbanization, 20 cms would have resulted in about 45% survival. Therefore, if current trends in both water release from Buford Dam and increasing impervious surface area in the Chattahoochee Basin continue, we can expect near 0% monthly survival in summer for stocked rainbow trout in the Chattahoochee River below Cochran Shoals.

Reporting Rates

Reporting rates for this study were much lower than the reported 69 - 97% from previous studies of the Chattahoochee River trout fishery (Martin 1985b; Beisser 1991; Klein 2003). These differences were likely due to the different method that we used to estimate reporting.

The previous studies estimated reporting rate as the number tags returned that were originally reported by telephone divided by the number of total tags reported by telephone. This estimate does not account for the tags of harvested fish that were never reported, which can be substantial (Pollock et al. 2001). To derive a true estimate of reporting rate, the correct formulation would be the number of tags returned in any manner divided by the number of tagged fish harvested. Unfortunately, the denominator of that estimate is never known with certainty. However, more sophisticated estimation methods can be used to obtain unbiased estimates of the reporting rate (e.g., Seber 1970; Brownie et al. 1978; Barker and White 2001). Because biased estimates of reporting rates can bias inferences regarding fish harvest rates and potentially influence management decisions, we recommend that fishery biologists use unbiased estimation methods.

Dispersal

Interestingly, dispersal patterns of stocked trout suggested that large-scale (between reach) movement from the downstream to the upstream reach was 6 - 7 times greater than downstream movement. This provides evidence against the strategy of passive (downstream) or random dispersal for stocked trout and was surprising given that trout habitat is better in the downstream reach due to the presence of several large shoal habitats. We also found little evidence that average discharge or exceedence influenced trout dispersal. However given the low number of trout that were recaptured after dispersing, it may have been difficult to estimate the influence of environmental factors, such as temperature and flow, on dispersal with sufficient precision. Salmonids are known to behaviorally thermoregulate (Torgersen et al. 1999; Ebersole et al. 2001; Goniea et al. 2006), which suggests that rainbow trout should seek out areas with the proper temperature. Thus, we hypothesize that decreasing water quality (i.e., increasing temperature) in the downstream reach in summer is primarily responsible for the greater upstream movement.

Past studies have found predominantly downstream movement between reaches for stocked rainbow trout (Cresswell 1981; Helfrich and Kendall 1982; Bettinger and Bettoli 2002) with at least one exception (Hazzard and Shetter 1938). We note that one study in the Adirondack Mountains, New York reported that dispersal was predominantly upstream one year and downstream the next (Baird et al. 2006). Although no reach-specific temperature differences between years were mentioned in that study, temperature differences certainly could have explained the upstream dispersal we observed. In an Idaho reservoir, downstream dispersal of rainbow trout was related to increased water temperature (Casey 1965). The hypothesis that temperature differences between reaches can reverse the predominant direction of successful dispersal for rainbow trout is intriguing but needs further investigation. Certainly, our analysis supports such a hypothesis, but with only one year of data upon which to base this observation, our inferences are limited. This question may be better investigated using a meta-analysis of studies that have measured directional dispersal and temperature differences between reaches.

As discussed earlier, temperatures in the lower reach attained lethal levels during the summer, yet the movement rates from the downstream reach to the cooler upstream reach averaged only 6%. We believe that the relatively low rates were due to the general inexperience of fishes stocked into a new environment. Hatchery trout are naïve and their general tendency is to disperse downstream (Cresswell 1981; Helfrich and Kendall 1982), especially when discharge is high (Bettinger and Bettoli 2002). Thus, two competing forces may exist, the desire to behaviorally thermoregulate (upstream) and the general inexperience of the fishes. Perhaps a portion of the fish stocked upstream passively dispersed downstream but when experiencing warmer temperatures, returned to where they previously experienced colder water. If a similar proportion of fish stocked downstream passively dispersed downstream during the summer, they would have quickly reached a section of the river where temperatures were lethal. Thus, we hypothesize that the direction in which a fish disperses is a tradeoff between previous experience and the instinct to thermoregulate, with the general tendency of stocked fishes to disperse downstream.

Management implications

Our findings add to the growing body of literature demonstrating the negative relationship between urbanization and stream water temperature (Bartholow 1991, LeBlanc et al. 1997, Paul and Meyer 2001, Wang et al. 2003, Krause et al. 2004) and strongly suggest that urbanization increases mortality in rainbow trout. Increased water temperatures result in decreases in angler success and satisfaction; even at temperatures lower (19°C; McMichael and Kaya 1991) than we observed in the downstream reaches during the summer. Traditionally, the best physical habitat for trout (e.g., shoals) occurred in the downstream reaches of the Chattahoochee River (Nestler et al. 1984) and correspondingly, that area experienced the most angler effort (Martin 1985a, b). Unfortunately, expected increases in urbanization and water use will likely result in even greater loses in trout angling opportunities on Chattahoochee River unless effective water temperature management plans can be developed.

We also found that releases from Buford Dam, or lack thereof, significantly influence summer temperatures in the Chattahoochee River between Atlanta and Lake Lanier. This suggests that water temperatures can be managed by controlling the rate at which water is released from an upstream dam. For example, we estimate that for every 100 cubic meters of water released each day during the summer, exceedence intervals decline by an estimated 53 per month. Such a management strategy would require the consideration of other values that serve society at large, such as power generation, recreation on Lake Lanier, and municipal water supplies, in addition to the trout fishery. Thus, the development of effective strategies will be complicated by the complexity and uncertainty associated with the response of the fishery and the consideration of multiple and competing objectives. Decision analysis is a valuable tool for developing and evaluating management strategies under uncertainty (e.g., Peterson and Evans 2003) and would be a useful next step toward managing the trout fishery in the Chattahoochee River.

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Table 1. Proposed alternative water temperature criteria for the Chattahoochee River.

Criteria No.	Criterion
1	Water temperature should never exceed 25°C (77°F) more than once in any 30-day period.
2	Water temperature should never exceed 23.9°C (75°F) for more than two consecutive hours, or three total hours in any 7-day period.
3	Water temperature should never exceed 21.7°C (71 °F) for more than twelve consecutive hours, 18 total hours in any 24-hour period.
4	The 7-day moving-average water temperature should never exceed 18.9°C (66 °F).
5	Temperature should not exceed 22°C (71.6°F)
6	The 5-day moving-average water temperature should never exceed 20°C (68°F).

Table 2. Mean, standard deviation (SD), and range for angling pressure, discharge, and stream temperature by study reach and month.

	Upstream reach		Downstream reach	
Period	Mean (SD)	Range	Mean (SD)	Range
Angler pressure (no./day)				
March	11.09 (22.18)	0 - 44.4	54.21 (79.49)	0 - 274.7
April	58.06 (54.22)	0 - 112.9	29.91 (29.28)	0 - 79.7
May	37.57 (37.78)	0 - 85.4	49.33 (57.90)	0 - 171.8
June	8.06 (16.13)	0 - 32.3	31.64 (42.74)	0 - 153.1
July	39.73 (40.18)	0 - 91.5	21.24 (32.79)	0 - 119.0
August	36.59 (51.74)	0 - 73.2	24.53 (33.67)	0 - 115.6
September	16.13 (36.07)	0 - 80.6	20.24 (35.45)	0 - 131.0
Discharge (cms)				
March	52.90 (25.13)	28.7 - 176.9	66.00 (34.65)	32.5 - 233.5
April	55.49 (24.97)	28.2 - 167.7	67.27 (29.13)	32.8 - 167.9
May	60.40 (29.48)	29.3 - 196.6	69.56 (33.79)	30.5 - 206.2
June	44.52 (21.31)	27.4 - 195.7	50.32 (25.44)	27.1 - 186.6
July	32.46 (7.70)	24.8 - 80.1	33.09 (8.57)	22.8 - 99.6
August	38.65 (12.23)	26.7 - 107.2	40.51 (13.36)	28.0 - 103.3
September	38.29 (14.08)	28.2 - 116.1	39.36 (14.69)	27.3 - 120.3
October	38.73 (19.99)	27.5 - 196.2	40.37 (21.86)	27.1 - 194.1
Temperature (^{o}C)				
March	11.59 (1.61)	9.0 - 16.2	11.95 (1.78)	8.5 - 17.1
April	14.91 (1.90)	11.4 - 19.9	15.67 (1.97)	12.4 - 21.6
May	15.27 (2.28)	10.9 - 21.6	16.29 (2.57)	12.2 - 23.2
June	18.20 (2.02)	12.0 - 22.2	19.64 (2.11)	14.4 - 24.4
July	20.12 (1.39)	16.9 - 24.9	22.04 (1.61)	18.5 - 27.7
August	19.88 (1.19)	16.5 - 23.5	21.77 (1.50)	17.5 - 25.6
September	17.85 (1.24)	14.9 - 21.5	19.10 (1.50)	14.9 - 23.3
October	15.00 (1.86)	10.8 - 18.2	15.62 (2.22)	10.8 - 20.4

Table 3. Number of parameters (K), ΔAIC, Akaike weights (*w*), for the candidate multistrata models for estimating rainbow trout survival (S), dispersion (*ψ*), and recapture (p) in two study reaches on the Chattahoochee River, GA. Models included here had an Akaike weight of at least 0.01.

Model[1]	K	ΔAIC	*w*
S(exceedence + angler pressure), *p(*effort), *ψ(*directional)	8	0.000	0.178
S(exceedence + angler pressure), *p(*.), *ψ(*directional)	7	1.445	0.087
S(reach + exceedence + angler pressure), *p(*effort), *ψ(*directional)	9	1.493	0.085
S(exceedence + angler pressure), *p(*effort), *ψ(*directional + exceedence)	9	1.999	0.066
S(exceedence + angler pressure), *p(*effort), *ψ(*directional*exceedence)	10	2.466	0.052
S(exceedence + angler pressure), *p(*effort), *ψ(*.)	7	2.502	0.051
S(reach + exceedence + angler pressure), *p(*.), *ψ(*directional)	8	3.084	0.038
S(reach*exceedence + angler pressure), *p(*effort), *ψ(*directional)	10	3.216	0.036
S(exceedence + angler pressure), *p(*effort), *ψ(*directional*average discharge)	10	3.387	0.033
S(exceedence + angler pressure), *p(*.), *ψ(*directional + exceedence)	8	3.424	0.032
S(reach + exceedence + angler pressure), *p(*effort), *ψ(*directional + exceedence)	10	3.492	0.031
S(exceedence + angler pressure), *p(*.), *ψ(*directional*exceedence)	9	3.651	0.029
S(reach + exceedence + angler pressure), *p(*effort), *ψ(*directional*exceedence)	11	3.839	0.026
S(reach + exceedence + angler pressure), *p(*effort), *ψ(*.)	8	4.240	0.021
S(reach*exceedence + angler pressure), *p(*.), *ψ(*directional)	9	4.440	0.019
S(exceedence), *p(*effort), *ψ(*directional)	7	4.670	0.017
S(exceedence + angler pressure), *p(*.), *ψ(*.)	6	4.783	0.016
S(reach + exceedence + angler pressure), *p(*effort), *ψ(*directional*average discharge)	11	4.853	0.016
S(exceedence + angler pressure), *p(*.), *ψ(*directional*average discharge)	9	4.974	0.015

[1](.) indicates that the parameter was modeled as a constant.

Table 3. (continued)

Model[1]	K	ΔAIC	*w*
S(reach + exceedence + angler pressure), *p(*.), *ψ(*directional + exceedence)	9	5.057	0.014
S(reach*exceedence + angler pressure), *p(*effort), *ψ(*directional + exceedence)	11	5.214	0.013
S(reach + exceedence + angler pressure), *p(*.), *ψ(*directional*exceedence)	10	5.229	0.013
S(exceedence), *p(*.), *ψ(*directional)	6	5.448	0.012
S(reach*exceedence + angler pressure), *p(*effort), *ψ(*directional*exceedence)	12	5.636	0.011

[1](.) indicates that the parameter was modeled as a constant.

Table 4. Akaike importance weights for hypotheses regarding rainbow trout dispersal (ψ) and recapture (p) in the Chattahoochee River.

Hypothesis	Akaike weight	Number of models	Evidence ratio
***ψ*:**			
No temperature effect	0.590	16	1.8
Temperature	0.324	16	
No directional effect	0.116	8	
Direction-specific	0.474	8	4.1
***p*:**			
No electrofishing effort effect	0.325	20	
Effort	0.675	20	2.1

Table 5. Model-averaged parameter estimates, standard errors, and upper and lower 95% confidence intervals of rainbow trout survival, recapture, dispersal, and recovery. Models used to calculate model-averaged estimates are in Table 3.

Parameter	Estimate[1]	SE	95% CI
Survival			
Intercept	1.81	0.66	(0.51, 3.11)
Reach	0.20	0.28	(-0.35, 0.75)
Angler pressure (h/day)	-0.03	0.01	(-0.06, 0.00)
Exceedence (no./month)	-0.12	0.03	(-0.17, -0.06)
Reach* exceedence	-0.02	0.04	(-0.10, 0.05)
Recapture			
Intercept	-4.27	0.90	(-6.03, -2.51)
Effort	0.05	0.03	(-0.00, 0.11)
Dispersal			
Intercept	-4.47	1.72	(-7.84, -1.11)
Direction	1.86	1.87	(-1.81, 5.52)
Exceedence	-0.49	1.36	(-3.17, 2.18)
Direction*exceedence	1.11	1.86	(-2.53, 4.75)
Average discharge (cms)	0.03	0.10	(-0.17, 0.22)
Direction*average discharge	0.01	0.10	(-0.21, 0.20)
Recovery			
Intercept	-4.87	0.17	(-5.21, -4.53)

[1]Parameter estimates are on a logit scale.

Table 6. Number of parameters (K), ΔAICc, and AIC weights (*w*) for the set of models for estimating the number of 15 min intervals with temperatures greater that 20°C at the downstream study reach on the Chattahoochee River, GA.

Model[1]	K	ΔAIC	*w*
maximum daily air temperature, daily precipitation, Q-lag1*year, Q-lag1^2	8	0.00	0.485
maximum daily air temperature, Q-lag1*year, Q-lag1^2, daily precipitation *year	9	0.55	0.369
Q-lag1*year, Q-lag1^2, daily precipitation *year, maximum daily air temperature *daily precipitation	10	2.40	0.146
Q-lag1, Q-lag1^2, maximum daily air temperature, daily precipitation, year	7	105.16	0
Q-lag1, Q-lag1^2, maximum daily air temperature, daily precipitation *year	8	105.48	0
maximum daily air temperature, Q-lag1*year, daily precipitation*year	8	181.97	0
maximum daily air temperature , Q-lag1*year	7	183.02	0
Q-lag1, Q-lag1^2, maximum daily air temperature, daily precipitation	6	206.15	0
maximum daily air temperature, Q-lag2*year, daily precipitation *year	8	243.61	0
maximum daily air temperature , Q-lag2*year	7	250.34	0
Q-lag1, maximum daily air temperature, daily precipitation *year	7	279.09	0
Q-lag1, maximum daily air temperature, daily precipitation, year	6	280.46	0
Q-lag2, maximum daily air temperature, daily precipitation *year	7	317.79	0
Q-lag2, maximum daily air temperature, daily precipitation, year	6	322.37	0
Q-lag1, maximum daily air temperature, daily precipitation	5	374.96	0
Q-lag2, maximum daily air temperature, daily precipitation	5	415.81	0

[1] Q-lag1 = discharge volume at Buford Dam 1 day previous to water temperature reading, and Q-lag2 = discharge volume at Buford Dam 2 days previous.

Table 7. Parameter estimates, standard errors, and upper and lower 95% confidence limits for the two best-fitting models (best, top) for estimating the number of 15 minute intervals per day with temperatures greater that 20°C at the downstream study reach on the Chattahoochee River, GA.

Parameter[1]	Estimate	SE	Lower	Upper
Intercept	-30.76	9.69	-49.75	-11.76
Q-lag1 (cms)	-1.16	0.08	-1.32	-1.00
maximum daily air temperature (°C)	2.57	0.29	2.00	3.14
daily precipitation (cm)	0.99	0.80	-0.58	2.57
year	2.50	0.17	2.18	2.83
Q-lag1^2	0.01	0.01	0.00	0.01
Q-lag1*year	-0.02	0.00	-0.02	-0.02
Intercept	-29.10	9.78	-48.27	-9.93
Q-lag1 (cms)	-1.15	0.08	-1.31	-0.99
maximum daily air temperature (°C)	2.54	0.29	1.97	3.11
daily precipitation (cm)	-1.97	2.59	-7.05	3.11
year	2.46	0.17	2.13	2.79
daily precipitation *year	0.12	0.10	-0.08	0.33
Q-lag1^2	0.01	0.01	0.00	0.01
Q-lag1*year	-0.02	0.01	-0.02	-0.02

[1] Q-lag1 = discharge volume at Buford Dam 1 day previous to water temperature reading

Table 8. Parameter estimates, standard errors (SE), and upper and lower 95% confidence limits for the two best-approximating models (best, top) for estimating discharge at the downstream study reach during pre-urbanization (1976-1980) and current (2002-2006) time periods on the Chattahoochee River, GA.

Parameter[1]	Estimate	SE	Lower	Upper
Intercept	20.86	3.58	12.76	28.97
Q-lag1 (cms)	0.80	0.04	0.72	0.88
Q-lag1* current	0.09	0.06	-0.03	0.20
Intercept	20.93	3.81	12.32	29.53
Q-lag1 (cms)	0.84	0.03	0.77	0.90

[1] Q-lag1 = discharge volume at Buford Dam 1 day previous

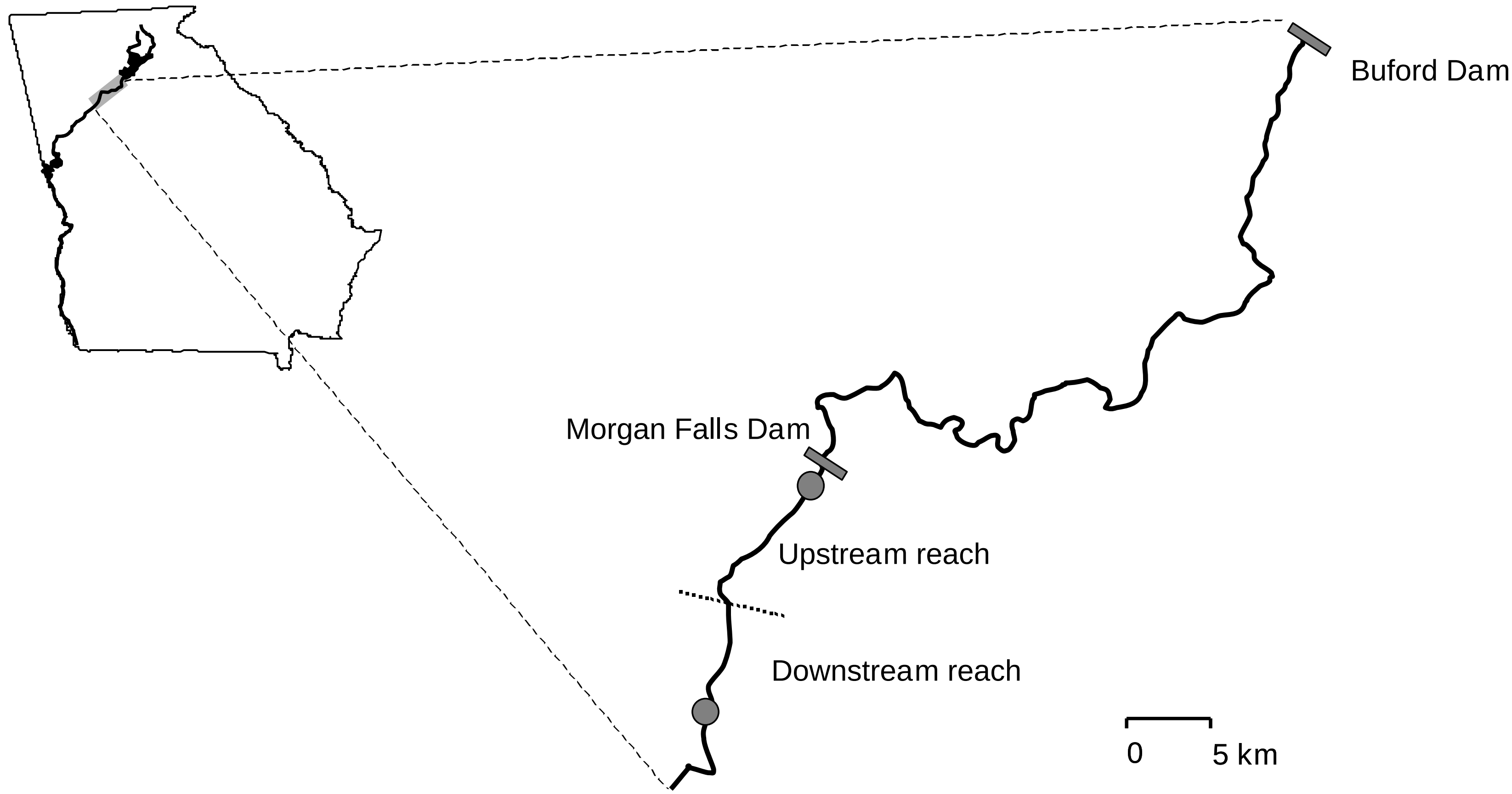


Figure 1. The location of Chattahoochee River, the up and downstream study reaches, and Buford and Morgan Falls Dams. The boundary between the up and downstream study sites is shown with a broken line and trout stocking locations with shaded circles.

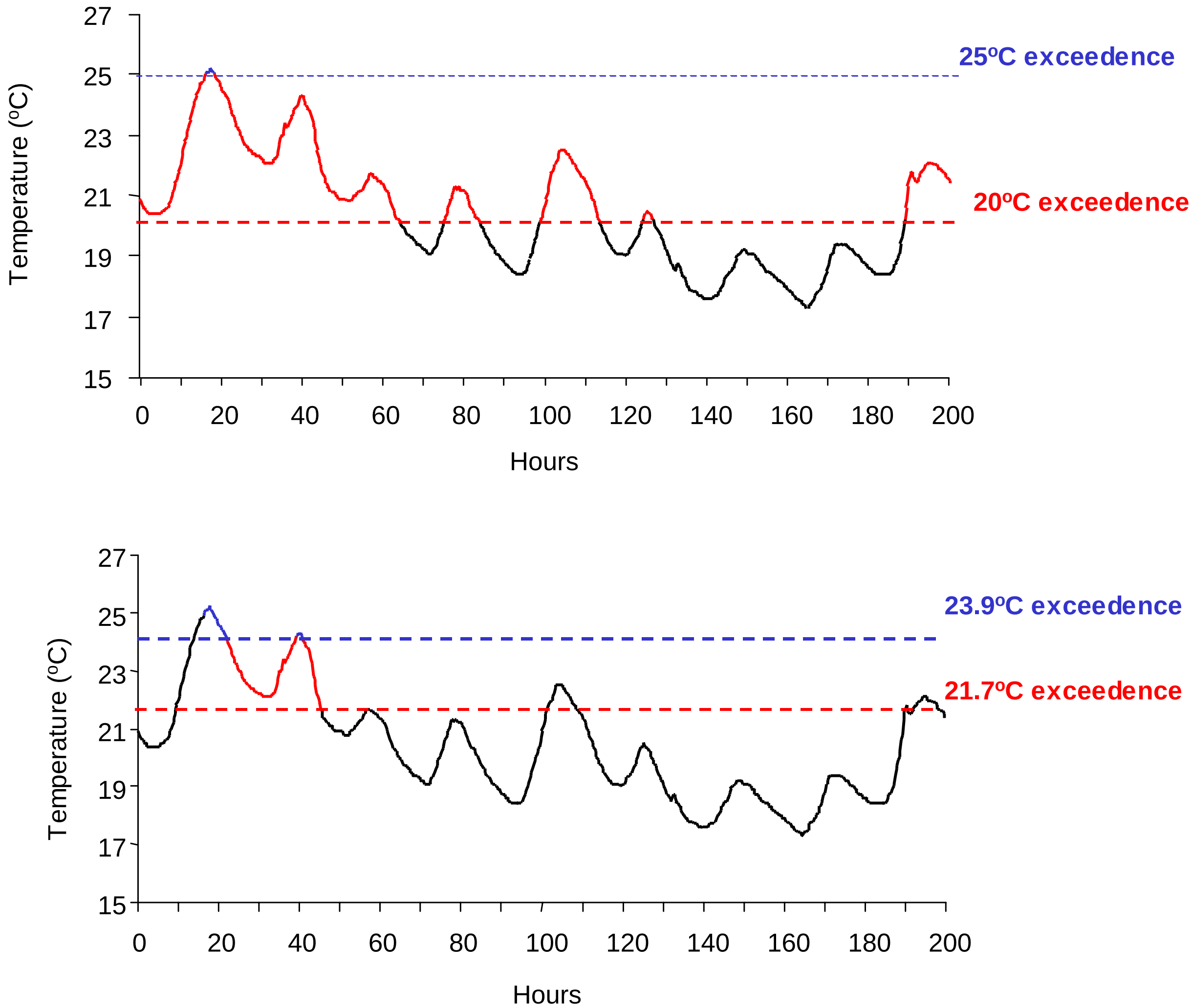


Figure 2. Example of estimating total number of exceedences (top) for 25 (blue) and 20°C thresholds (red) and for criteria (bottom) where water temperature should not exceed 23.9°C for more than two consecutive hours or three total hours in any 7-day period (blue), and water temperature should not exceed 21.7°C for more than twelve consecutive hours, 18 total hours in any 24-hour period (red). Broken horizontal lines represent temperature thresholds. Sections of curves that are colored represent the 15 min. intervals that would be summed to estimate the cumulative number of exceedences for corresponding thresholds.

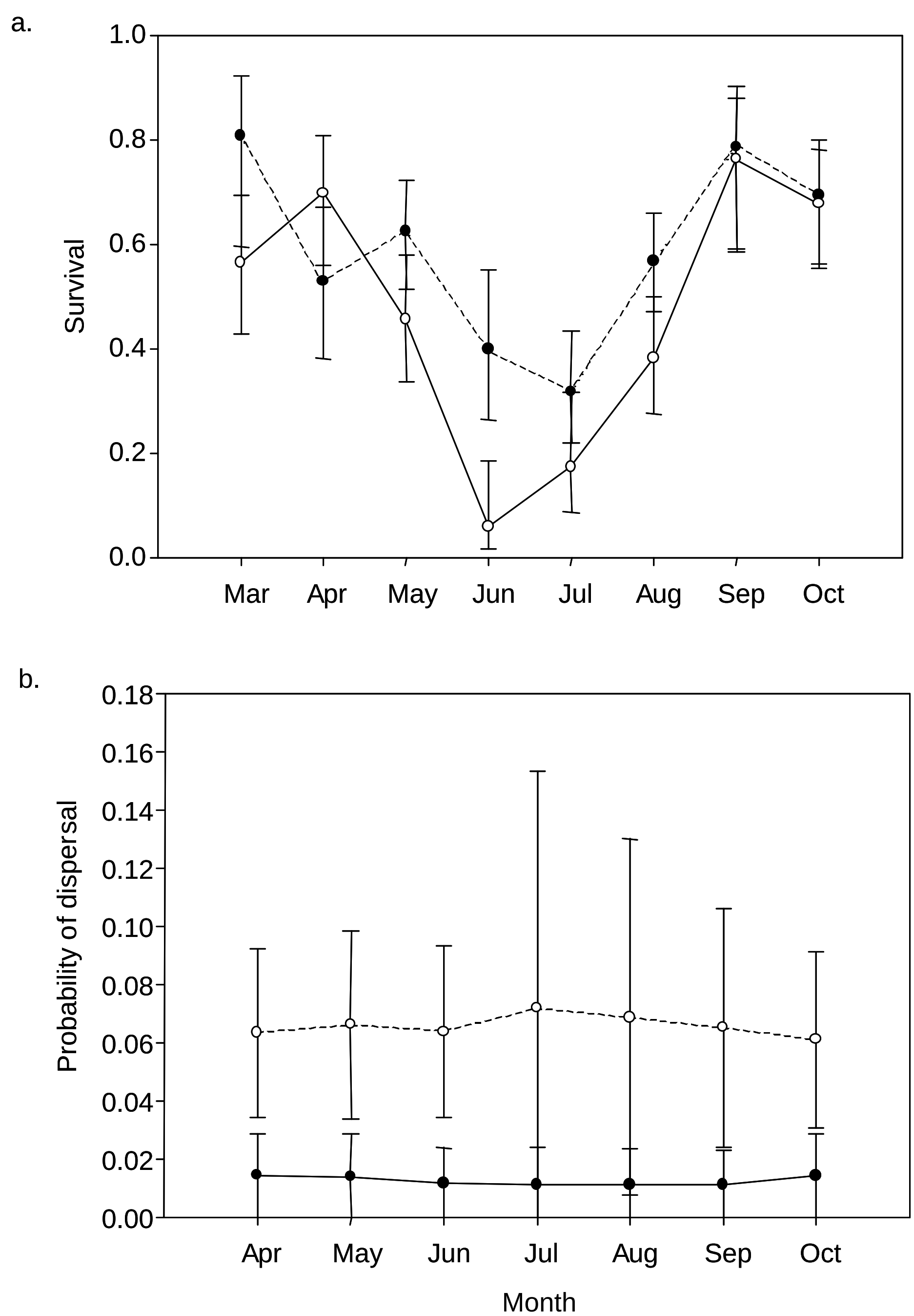


Figure 3. Model-averaged estimates (and 95% CIs) of hatchery-raised rainbow trout (a) survival (1- mortality) at the up (filled circles) and downstream (open) study reaches and (b) estimated dispersal from upstream to downstream (filled circles) and downstream to upstream (open circles) reaches in the Chattahoochee River from March-October 2006. Dispersal was estimated using both angler returns and electrofishing recaptures.

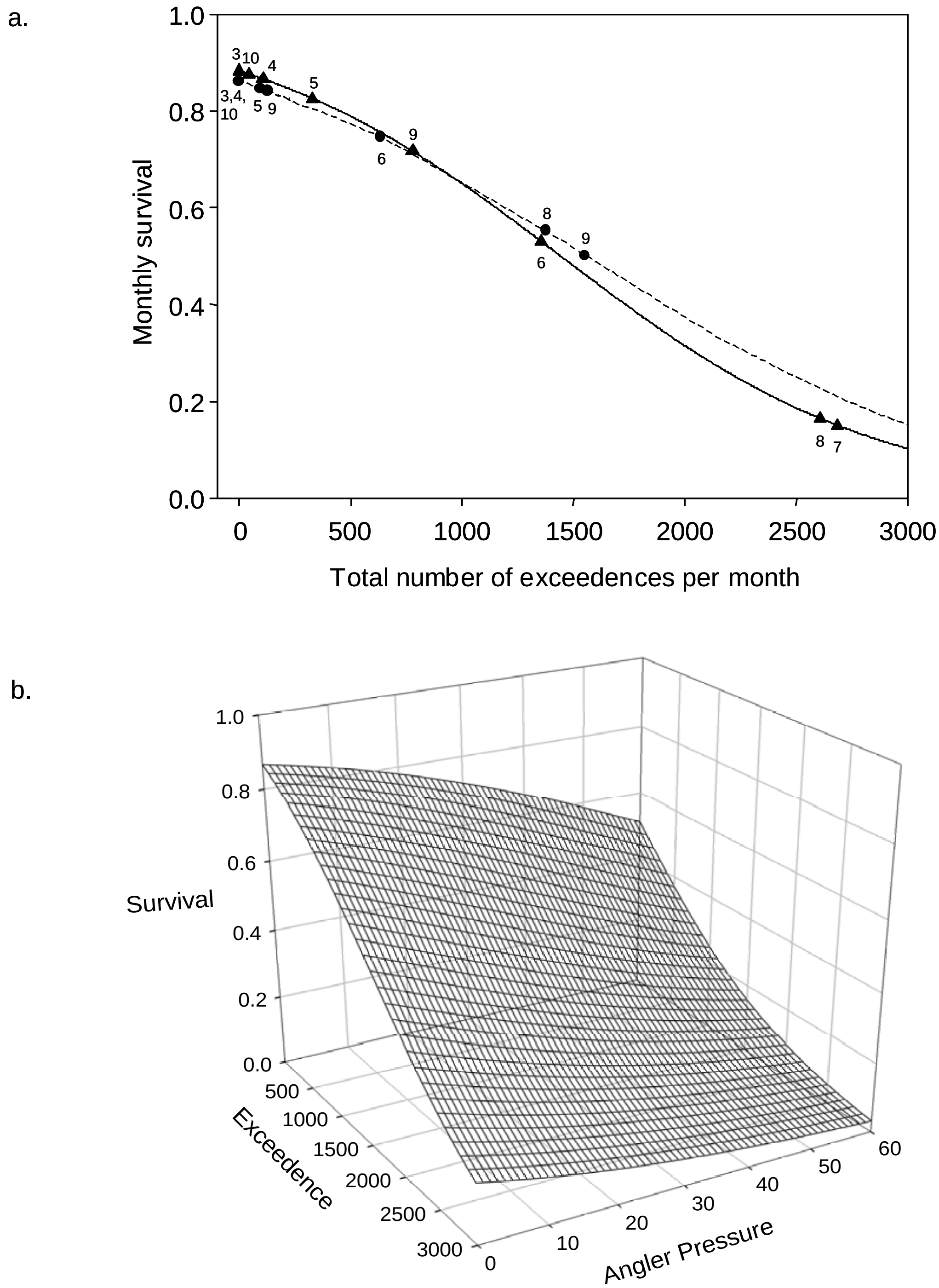
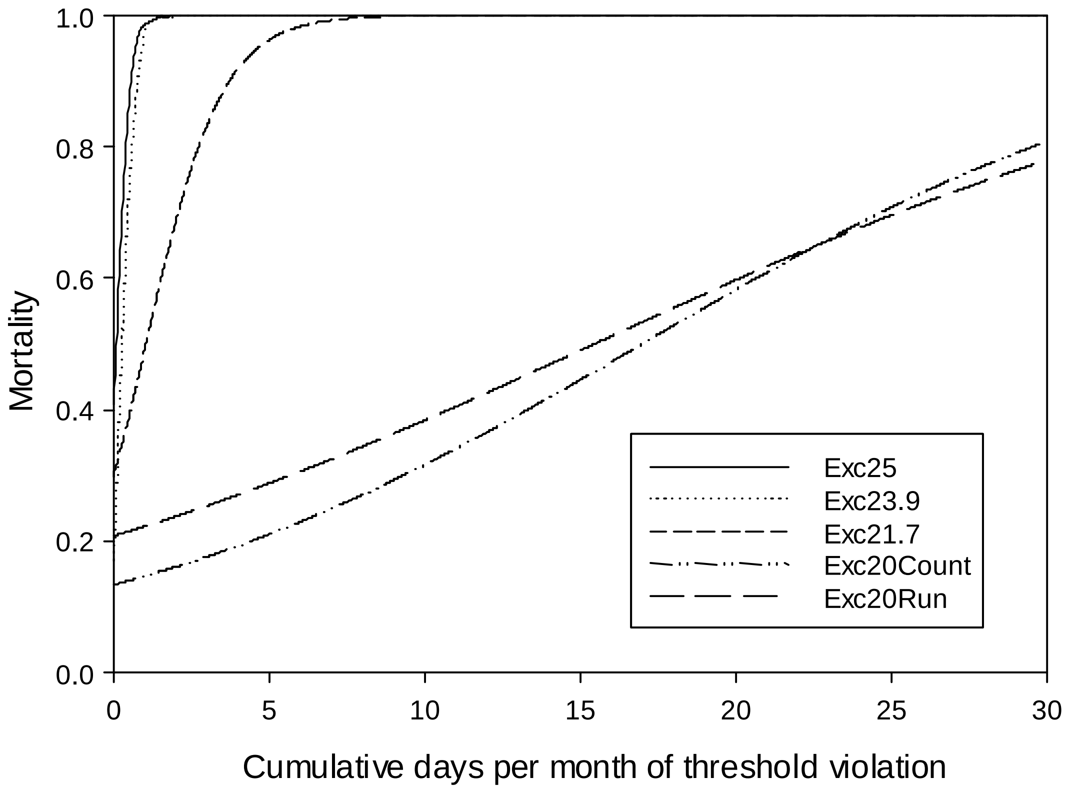


Figure 4. Model-averaged estimates of (a) trout survival (1 - mortality) versus the number of exceedences at the up (circles, broken line) and downstream (triangles, solid line) study reaches and (b) the effect of exceedence and angler pressure on rainbow trout survival in the Chattahoochee River. Small numbers (a) represent the month in which a particular exceedence measure was recorded at each reach.


Mortality
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
25
30
Cumulative days per month of threshold violation
Exc25
Exc23.9
Exc21.7
Exc20Count
Exc20Run

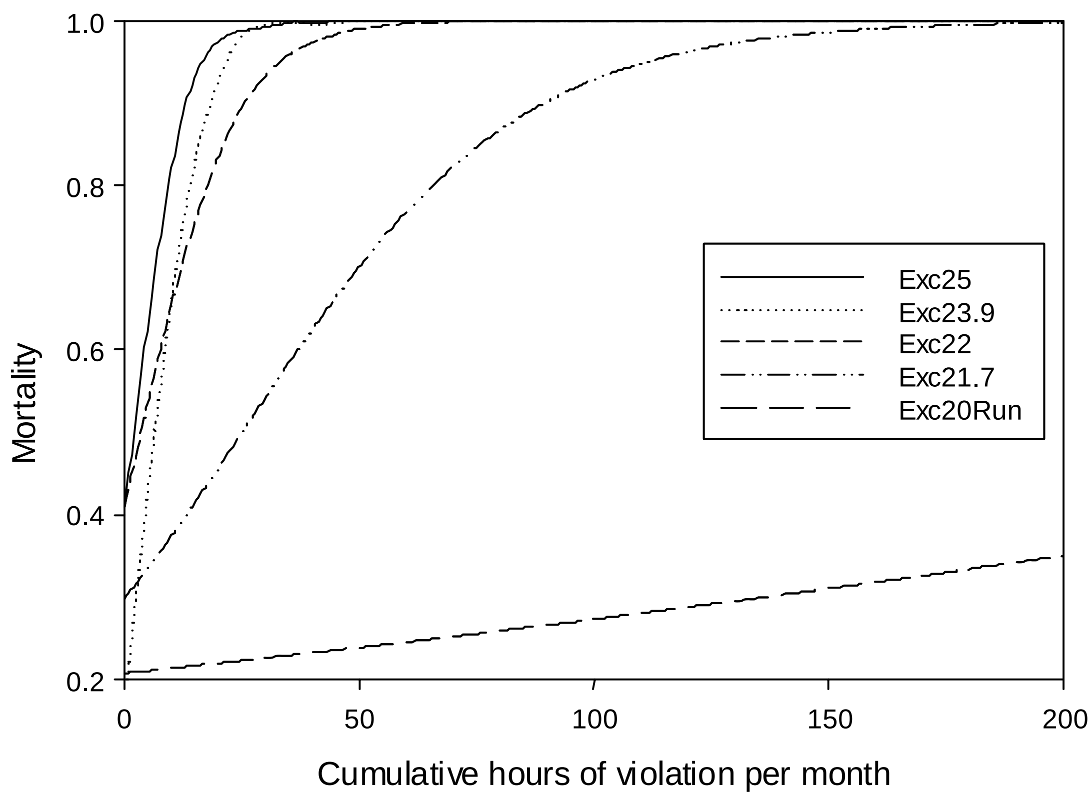

Mortality
1.0
0.8
0.6
0.4
0.2
0
50
100
150
200
Cumulative hours of violation per month
Exc25
Exc23.9
Exc22
Exc21.7
Exc20Run

Figure 5 (previous page). Estimated monthly trout mortality (1- survival) of four alternative temperature criteria on rainbow trout survival; Exc25: water temperature should never exceed 25^{o}C more than once in any 30-day period; Exc23.9: water temperature should never exceed 23.9^{o}C for more than two consecutive hours, or three total hours in any 7-day period; Exc22: water temperature should never exceed 22^{o}C for a 15 minute interval; Exc21.7: water temperature should never exceed 21.7^{o}C for more than twelve consecutive hours, 18 total hours in any 24-hour period; Exc20Count: water temperature should never exceed 20^{o}C for a 15 minute interval (exceedence criterion used in the statistical models); and Exc20Run: running average equivalent of Exc20Count. Examples of exceedence calculations can be found in Figure 2.

a.

b.

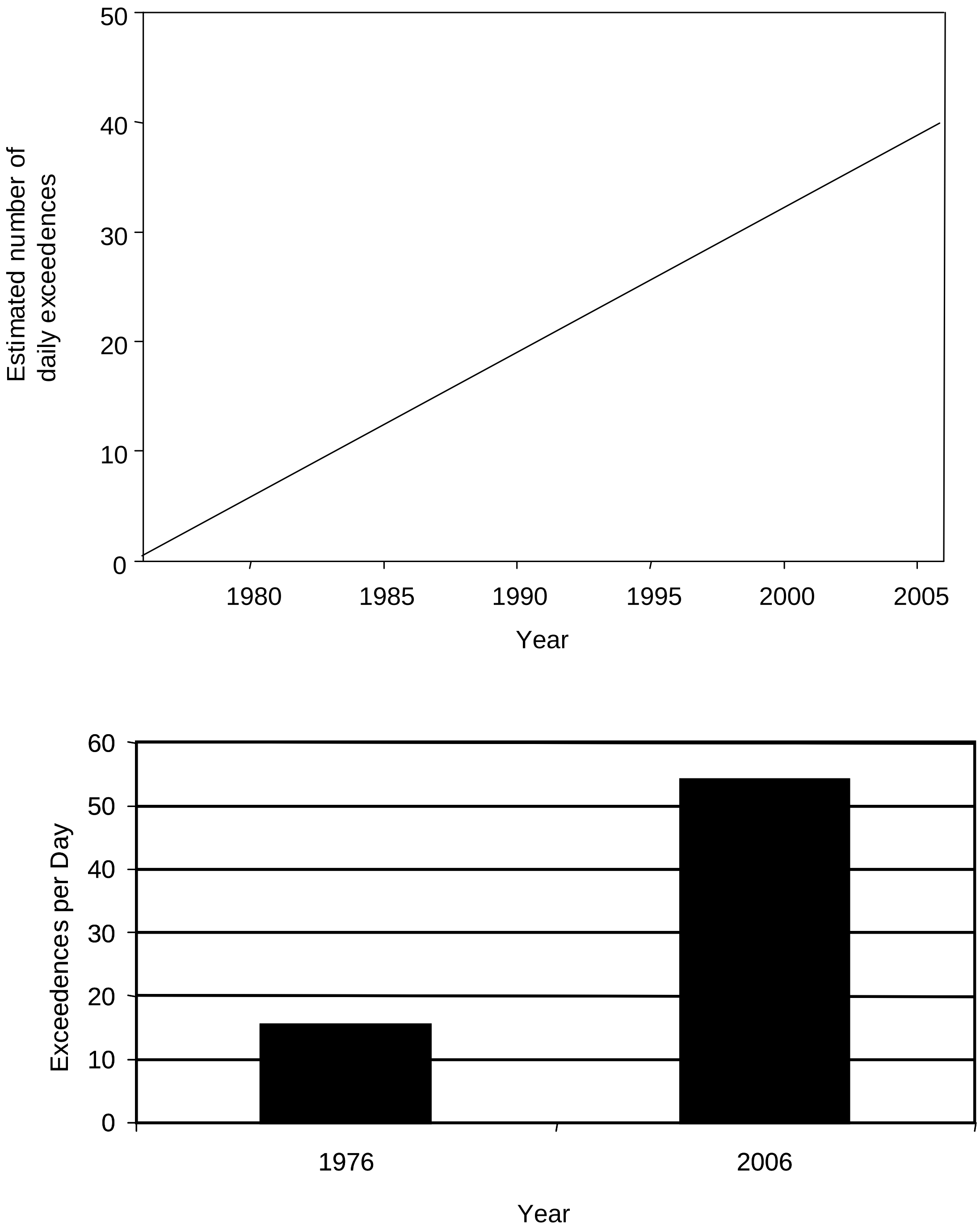


Figure 6. Estimated (a) number of daily number of exceedences in summer by year assuming maximum air temperature = 31.1 C, precipitation = 0.38 cm, discharge = 60 cms and (b) number of estimated exceedences under pre-urbanization (year = 1976) and current conditions (year = 2006).

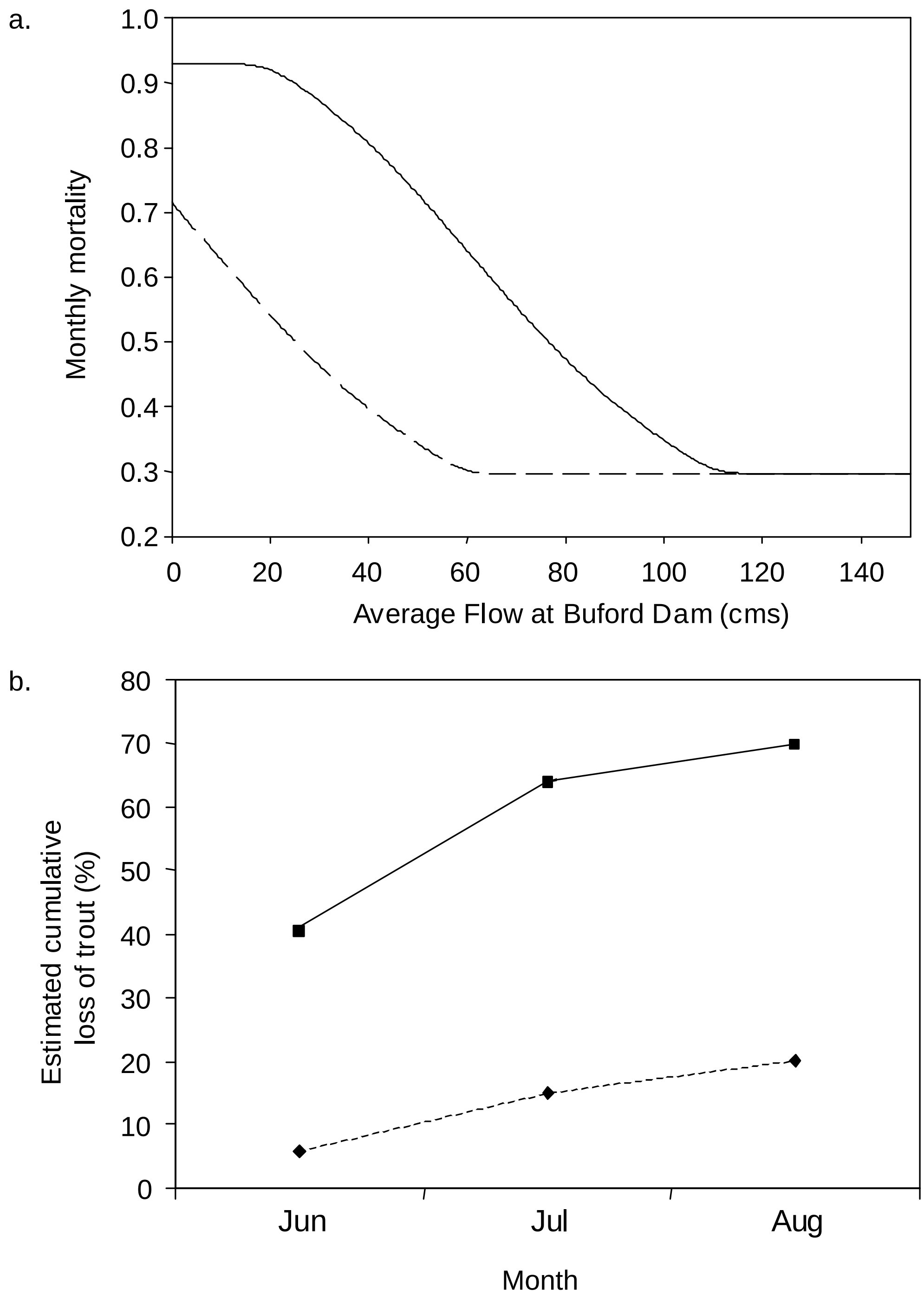


Figure 7. Monthly mortality (1 - survival) of rainbow trout for varying flow rates under pre-urbanization (1976; broken line) and current (2006; solid line) conditions assuming equivalent values of air temperature and precipitation (average values in summer from 1991-2006) and (b) the cumulative percentage of rainbow trout lost per month during summer due to mortality under pre-urbanization (diamond) and current conditions (square).

Appendix A. Data used to fit candidate linear regression models relating discharge at Buford Dam, daily precipitation, and maximum air temperature to daily exceedences at the downstream study reach. Note that exceedences are estimated daily values for 1976.

				Buford discharge (cms)			Average air	
Year	Month	Day	15-minute exceedences	No lag	1-day lag	2-day lag	temperature (°C)	Precipitation (cm)
1976	6	1	0	182.25	183.38	68.20	27.78	0.00
1976	6	2	0	179.71	182.25	183.38	27.78	3.71
1976	6	3	0	177.16	179.71	182.25	28.33	0.10
1976	6	4	0	179.99	177.16	179.71	18.89	0.20
1976	6	5	0	17.60	179.99	177.16	22.78	0.00
1976	6	6	0	17.60	17.60	179.99	24.44	0.00
1976	6	7	0	178.29	17.60	17.60	26.67	0.00
1976	6	8	0	179.99	178.29	17.60	30.56	0.00
1976	6	9	0	180.55	179.99	178.29	30.56	0.00
1976	6	10	0	180.55	180.55	179.99	31.67	0.00
1976	6	11	0	181.12	180.55	180.55	32.22	0.00
1976	6	12	0	62.54	181.12	180.55	33.89	0.00
1976	6	13	0	36.22	62.54	181.12	33.33	0.00
1976	6	14	0	129.33	36.22	62.54	29.44	0.00
1976	6	15	0	129.05	129.33	36.22	30.56	0.00
1976	6	16	0	129.33	129.05	129.33	32.78	0.00
1976	6	17	0	130.46	129.33	129.05	30.00	0.00
1976	6	18	0	129.61	130.46	129.33	28.33	3.28
1976	6	19	0	17.83	129.61	130.46	26.67	1.04
1976	6	20	0	26.91	17.83	129.61	25.00	0.66
1976	6	21	4	122.26	26.91	17.83	26.11	0.84
1976	6	22	0	121.12	122.26	26.91	27.78	0.00
1976	6	23	0	121.41	121.12	122.26	28.33	0.00
1976	6	24	0	121.97	121.41	121.12	28.33	0.00
1976	6	25	0	121.69	121.97	121.41	29.44	0.00
1976	6	26	0	18.06	121.69	121.97	30.56	0.00
1976	6	27	0	27.14	18.06	121.69	28.89	0.69
1976	6	28	21	96.22	27.14	18.06	31.11	0.00
1976	6	29	21	96.50	96.22	27.14	30.00	0.00
1976	6	30	0	96.50	96.50	96.22	28.33	0.74
1976	7	1	0	110.09	96.50	96.50	26.67	0.30
1976	7	2	0	96.22	110.09	96.50	27.78	0.00
1976	7	3	0	18.28	96.22	110.09	29.44	0.00
1976	7	4	0	27.17	18.28	96.22	22.78	1.04
1976	7	5	0	27.42	27.17	18.28	21.67	1.93
1976	7	6	0	182.25	27.42	27.17	23.33	1.12
1976	7	7	0	182.82	182.25	27.42	26.67	1.24
1976	7	8	0	182.82	182.82	182.25	28.89	0.00

Year	Month	Day	15-minute exceedences	Buford discharge (cms) No lag	1-day lag	2-day lag	Average air temperature (^oC)	Precipitation (cm)
1976	7	9	0	183.95	182.82	182.82	30.56	0.00
1976	7	10	0	16.30	183.95	182.82	31.11	0.00
1976	7	11	23	24.76	16.30	183.95	31.11	0.00
1976	7	12	52	131.31	24.76	16.30	32.22	0.00
1976	7	13	52	131.03	131.31	24.76	31.67	0.00
1976	7	14	0	107.82	131.03	131.31	31.67	0.00
1976	7	15	0	102.73	107.82	131.03	32.78	0.00
1976	7	16	0	108.67	102.73	107.82	31.67	0.00
1976	7	17	0	15.14	108.67	102.73	29.44	0.08
1976	7	18	12	24.76	15.14	108.67	29.44	0.00
1976	7	19	67	47.54	24.76	15.14	30.00	0.00
1976	7	20	67	47.54	47.54	24.76	30.56	0.00
1976	7	21	0	70.75	47.54	47.54	31.67	0.46
1976	7	22	0	66.51	70.75	47.54	32.78	0.00
1976	7	23	0	50.94	66.51	70.75	33.33	0.00
1976	7	24	42	84.62	50.94	66.51	33.89	0.00
1976	7	25	0	24.51	84.62	50.94	34.44	0.00
1976	7	26	31	106.41	24.51	84.62	33.33	0.00
1976	7	27	29	28.58	106.41	24.51	32.22	0.00
1976	7	28	37	44.15	28.58	106.41	30.56	0.79
1976	7	29	39	47.54	44.15	28.58	31.11	0.00
1976	7	30	33	47.54	47.54	44.15	28.33	0.00
1976	7	31	12	15.23	47.54	47.54	30.56	0.18
1976	8	1	31	24.82	15.23	47.54	31.11	0.00
1976	8	2	56	49.24	24.82	15.23	28.89	0.00
1976	8	3	56	41.04	49.24	24.82	26.11	0.00
1976	8	4	44	48.96	41.04	49.24	28.33	0.00
1976	8	5	4	49.24	48.96	41.04	28.33	0.00
1976	8	6	4	48.96	49.24	48.96	31.67	0.00
1976	8	7	0	15.42	48.96	49.24	28.89	1.17
1976	8	8	27	24.79	15.42	48.96	27.78	0.00
1976	8	9	62	111.22	24.79	15.42	28.33	0.00
1976	8	10	46	111.22	111.22	24.79	30.56	0.00
1976	8	11	0	111.50	111.22	111.22	31.11	0.00
1976	8	12	0	142.35	111.50	111.22	31.11	0.00
1976	8	13	0	111.79	142.35	111.50	31.11	0.20
1976	8	14	0	15.23	111.79	142.35	32.22	0.00
1976	8	15	6	24.82	15.23	111.79	32.22	0.00
1976	8	16	31	112.35	24.82	15.23	31.11	1.55
1976	8	17	31	112.92	112.35	24.82	29.44	0.00
1976	8	18	0	67.64	112.92	112.35	28.33	0.00

Year	Month	Day	15-minute exceedences	Buford discharge (cms) No lag	1-day lag	2-day lag	Average air temperature (^oC)	Precipitation (cm)
1976	8	19	0	61.13	67.64	112.92	27.22	0.00
1976	8	20	0	112.35	61.13	67.64	26.11	0.00
1976	8	21	0	15.45	112.35	61.13	30.56	0.20
1976	8	22	0	24.96	15.45	112.35	31.11	0.00
1976	8	23	35	146.03	24.96	15.45	31.11	0.00
1976	8	24	35	132.73	146.03	24.96	31.67	0.00
1976	8	25	0	136.12	132.73	146.03	30.56	0.00
1976	8	26	0	113.20	136.12	132.73	30.56	0.00
1976	8	27	0	65.37	113.20	136.12	29.44	3.53
1976	8	28	0	15.54	65.37	113.20	30.00	0.13
1976	8	29	25	25.05	15.54	65.37	31.67	0.00
1976	8	30	60	83.77	25.05	15.54	28.33	0.36
1976	8	31	52	51.79	83.77	25.05	26.67	0.00
1991	6	1	24	16.59	74.35	73.79	32.78	0.76
1991	6	2	50	16.83	16.59	74.35	31.11	0.00
1991	6	3	82	55.41	16.83	16.59	33.89	0.00
1991	6	4	4	52.63	55.41	16.83	33.33	0.25
1991	6	5	0	53.21	52.63	55.41	26.11	0.00
1991	6	6	0	52.76	53.21	52.63	25.56	0.00
1991	6	7	0	54.17	52.76	53.21	25.56	0.00
1991	6	8	8	16.68	54.17	52.76	27.78	0.00
1991	6	9	32	16.80	16.68	54.17	29.44	0.00
1991	6	10	32	75.97	16.80	16.68	30.00	0.00
1991	6	11	0	73.71	75.97	16.80	30.00	0.00
1991	6	12	0	73.88	73.71	75.97	30.56	0.00
1991	6	13	0	73.90	73.88	73.71	31.11	0.61
1991	6	14	0	74.61	73.90	73.88	28.89	1.37
1991	6	15	10	16.66	74.61	73.90	31.67	0.00
1991	6	16	40	16.77	16.66	74.61	30.56	0.97
1991	6	17	50	80.37	16.77	16.66	32.78	0.97
1991	6	18	6	12.10	80.37	16.77	30.00	1.40
1991	6	19	18	115.35	12.10	80.37	31.11	3.33
1991	6	20	0	115.30	115.35	12.10	31.11	3.07
1991	6	21	0	116.17	115.30	115.35	31.11	1.63
1991	6	22	28	16.66	116.17	115.30	30.00	0.30
1991	6	23	44	16.83	16.66	116.17	32.22	0.00
1991	6	24	14	106.65	16.83	16.66	23.33	2.64
1991	6	25	0	105.34	106.65	16.83	21.11	3.20
1991	6	26	0	52.49	105.34	106.65	21.11	3.00
1991	6	27	0	32.40	52.49	105.34	28.33	0.56
1991	6	28	34	33.70	32.40	52.49	30.00	0.76
1991	6	29	82	16.79	33.70	32.40	32.78	0.00

Year	Month	Day	15-minute exceedences	Buford discharge (cms) No lag	1-day lag	2-day lag	Average air temperature (°C)	Precipitation (cm)
1991	6	30	96	16.91	16.79	33.70	33.89	0.00
1991	7	1	96	45.42	16.91	16.79	34.44	0.00
1991	7	2	58	46.96	45.42	16.91	35.00	0.00
1991	7	3	50	42.59	46.96	45.42	33.89	0.00
1991	7	4	44	42.79	42.59	46.96	32.78	1.14
1991	7	5	38	43.89	42.79	42.59	30.00	0.25
1991	7	6	60	16.80	43.89	42.79	32.78	0.00
1991	7	7	96	16.96	16.80	43.89	31.11	0.10
1991	7	8	52	66.00	16.96	16.80	28.89	0.10
1991	7	9	6	63.52	66.00	16.96	31.67	0.18
1991	7	10	0	62.44	63.52	66.00	33.89	3.73
1991	7	11	10	62.98	62.44	63.52	32.22	0.03
1991	7	12	16	64.76	62.98	62.44	33.89	0.00
1991	7	13	38	43.03	64.76	62.98	33.89	0.00
1991	7	14	76	16.82	43.03	64.76	34.44	0.00
1991	7	15	32	100.05	16.82	43.03	30.00	0.00
1991	7	16	0	63.49	100.05	16.82	27.22	0.99
1991	7	17	0	63.70	63.49	100.05	26.11	6.65
1991	7	18	2	64.03	63.70	63.49	30.00	2.79
1991	7	19	0	85.12	64.03	63.70	31.11	0.10
1991	7	20	38	16.50	85.12	64.03	33.33	0.00
1991	7	21	96	16.77	16.50	85.12	34.44	0.48
1991	7	22	48	86.61	16.77	16.50	34.44	0.00
1991	7	23	0	95.02	86.61	16.77	34.44	0.00
1991	7	24	0	95.07	95.02	86.61	34.44	1.02
1991	7	25	0	94.68	95.07	95.02	31.11	0.00
1991	7	26	0	95.33	94.68	95.07	30.00	0.46
1991	7	27	0	56.37	95.33	94.68	32.22	0.13
1991	7	28	0	62.93	56.37	95.33	30.00	0.00
1991	7	29	0	76.27	62.93	56.37	30.00	0.13
1991	7	30	0	73.91	76.27	62.93	32.22	0.08
1991	7	31	0	74.12	73.91	76.27	30.56	0.00
1991	8	1	0	74.03	74.12	73.91	29.44	0.03
1991	8	2	0	74.94	74.03	74.12	32.22	0.00
1991	8	3	30	16.74	74.94	74.03	33.89	0.00
1991	8	4	96	17.03	16.74	74.94	33.89	0.00
1991	8	5	84	66.04	17.03	16.74	35.56	0.00
1991	8	6	0	65.49	66.04	17.03	34.44	0.97
1991	8	7	18	62.27	65.49	66.04	34.44	0.00
1991	8	8	2	63.70	62.27	65.49	33.89	0.00
1991	8	9	0	65.14	63.70	62.27	33.33	2.54
1991	8	10	36	17.03	65.14	63.70	31.11	0.20

Year	Month	Day	15-minute exceedences	Buford discharge (cms) No lag	1-day lag	2-day lag	Average air temperature (°C)	Precipitation (cm)
1991	8	11	96	17.12	17.03	65.14	27.78	1.73
1991	8	12	32	66.37	17.12	17.03	29.44	0.30
1991	8	13	0	63.66	66.37	17.12	27.22	0.25
1991	8	14	0	63.93	63.66	66.37	22.78	1.93
1991	8	15	0	63.85	63.93	63.66	29.44	0.08
1991	8	16	0	65.13	63.85	63.93	31.67	0.00
1991	8	17	0	17.02	65.13	63.85	31.67	0.00
1991	8	18	42	35.80	17.02	65.13	32.22	0.00
1991	8	19	6	76.98	35.80	17.02	31.67	0.00
1991	8	20	0	74.55	76.98	35.80	28.33	0.00
1991	8	21	0	74.76	74.55	76.98	28.89	0.00
1991	8	22	0	74.71	74.76	74.55	30.00	0.00
1991	8	23	0	75.59	74.71	74.76	29.44	0.00
1991	8	24	0	17.33	75.59	74.71	30.56	0.25
1991	8	25	26	17.44	17.33	75.59	25.56	0.56
1991	8	26	88	36.04	17.44	17.33	30.00	0.03
1991	8	27	2	169.55	36.04	17.44	29.44	0.00
1991	8	28	0	136.38	169.55	36.04	32.78	0.00
1991	8	29	0	136.87	136.38	169.55	31.11	1.70
1991	8	30	0	167.97	136.87	136.38	31.67	0.00
1991	8	31	0	118.96	167.97	136.87	32.22	0.00
1992	6	1	0	75.16	16.96	16.84	22.78	0.00
1992	6	2	0	73.25	75.16	16.96	26.67	0.00
1992	6	3	0	73.79	73.25	75.16	22.22	0.08
1992	6	4	0	73.62	73.79	73.25	26.67	2.51
1992	6	5	0	74.75	73.62	73.79	28.33	0.13
1992	6	6	0	16.83	74.75	73.62	31.67	0.00
1992	6	7	28	16.98	16.83	74.75	30.56	0.00
1992	6	8	40	35.51	16.98	16.83	28.33	0.00
1992	6	9	58	12.52	35.51	16.98	28.33	0.61
1992	6	10	36	32.82	12.52	35.51	30.56	0.89
1992	6	11	96	32.74	32.82	12.52	28.33	0.00
1992	6	12	14	34.01	32.74	32.82	18.33	1.37
1992	6	13	0	17.06	34.01	32.74	20.00	0.05
1992	6	14	0	17.13	17.06	34.01	27.78	1.12
1992	6	15	30	35.54	17.13	17.06	29.44	0.00
1992	6	16	66	32.70	35.54	17.13	31.11	0.00
1992	6	17	58	32.75	32.70	35.54	28.33	0.00
1992	6	18	42	32.68	32.75	32.70	29.44	0.00
1992	6	19	40	33.94	32.68	32.75	31.67	1.09
1992	6	20	46	16.99	33.94	32.68	31.11	0.00
1992	6	21	72	17.22	16.99	33.94	28.33	0.00

Year	Month	Day	15-minute exceedences	Buford discharge (cms) No lag	1-day lag	2-day lag	Average air temperature (°C)	Precipitation (cm)
1992	6	22	64	35.39	17.22	16.99	26.67	0.00
1992	6	23	84	32.74	35.39	17.22	29.44	0.00
1992	6	24	62	32.80	32.74	35.39	31.67	0.00
1992	6	25	62	65.57	32.80	32.74	33.33	0.00
1992	6	26	6	64.75	65.57	32.80	31.67	0.00
1992	6	27	0	16.84	64.75	65.57	29.44	0.15
1992	6	28	0	17.08	16.84	64.75	29.44	0.00
1992	6	29	42	96.60	17.08	16.84	30.56	0.00
1992	6	30	18	94.84	96.60	17.08	30.00	0.00
1992	7	1	0	94.85	94.84	96.60	31.67	0.00
1992	7	2	0	95.41	94.85	94.84	31.67	5.33
1992	7	3	0	96.27	95.41	94.85	28.89	0.38
1992	7	4	0	16.82	96.27	95.41	30.56	0.46
1992	7	5	38	16.92	16.82	96.27	32.78	0.00
1992	7	6	92	107.61	16.92	16.82	31.11	0.25
1992	7	7	34	105.27	107.61	16.92	32.78	0.00
1992	7	8	0	105.31	105.27	107.61	35.00	0.00
1992	7	9	0	105.52	105.31	105.27	34.44	0.00
1992	7	10	0	100.15	105.52	105.31	35.56	0.00
1992	7	11	0	20.50	100.15	105.52	34.44	0.00
1992	7	12	36	16.85	20.50	100.15	35.56	0.00
1992	7	13	96	97.48	16.85	20.50	33.89	0.00
1992	7	14	36	85.02	97.48	16.85	32.78	2.74
1992	7	15	0	84.73	85.02	97.48	30.56	0.00
1992	7	16	0	85.10	84.73	85.02	30.00	3.20
1992	7	17	0	85.86	85.10	84.73	31.11	0.03
1992	7	18	0	16.70	85.86	85.10	28.33	2.08
1992	7	19	32	37.41	16.70	85.86	32.22	0.41
1992	7	20	60	65.34	37.41	16.70	32.22	0.00
1992	7	21	46	63.99	65.34	37.41	32.78	0.00
1992	7	22	0	85.10	63.99	65.34	30.00	0.28
1992	7	23	0	85.28	85.10	63.99	30.00	2.06
1992	7	24	0	85.85	85.28	85.10	30.00	0.08
1992	7	25	0	16.99	85.85	85.28	32.22	0.03
1992	7	26	32	36.86	16.99	85.85	31.67	0.00
1992	7	27	70	87.88	36.86	16.99	32.78	0.00
1992	7	28	28	12.52	87.88	36.86	29.44	0.33
1992	7	29	20	81.68	12.52	87.88	31.11	0.00
1992	7	30	14	81.37	81.68	12.52	31.67	0.00
1992	7	31	0	82.66	81.37	81.68	31.67	0.00
1992	8	1	0	17.01	82.66	81.37	29.44	0.15
1992	8	2	34	37.27	17.01	82.66	30.00	0.00

Year	Month	Day	15-minute exceedences	Buford discharge (cms) No lag	1-day lag	2-day lag	Average air temperature (°C)	Precipitation (cm)
1992	8	3	58	67.07	37.27	17.01	31.11	0.00
1992	8	4	6	64.97	67.07	37.27	31.67	0.00
1992	8	5	0	64.74	64.97	67.07	31.67	0.00
1992	8	6	0	65.10	64.74	64.97	27.22	0.00
1992	8	7	0	55.81	65.10	64.74	25.56	0.00
1992	8	8	0	17.06	55.81	65.10	31.11	0.00
1992	8	9	22	17.31	17.06	55.81	33.33	0.00
1992	8	10	44	67.66	17.31	17.06	35.00	0.00
1992	8	11	66	65.18	67.66	17.31	33.33	0.00
1992	8	12	0	64.96	65.18	67.66	32.78	0.00
1992	8	13	0	65.39	64.96	65.18	22.78	3.18
1992	8	14	0	65.96	65.39	64.96	28.33	1.83
1992	8	15	0	17.12	65.96	65.39	27.78	0.00
1992	8	16	0	17.11	17.12	65.96	23.33	0.51
1992	8	17	28	77.90	17.11	17.12	28.89	0.97
1992	8	18	0	75.32	77.90	17.11	28.89	0.36
1992	8	19	0	75.54	75.32	77.90	28.89	0.00
1992	8	20	0	75.52	75.54	75.32	28.89	0.00
1992	8	21	0	77.06	75.52	75.54	22.22	0.00
1992	8	22	0	17.38	77.06	75.52	28.89	5.44
1992	8	23	36	17.39	17.38	77.06	30.00	0.69
1992	8	24	96	35.96	17.39	17.38	28.89	0.00
1992	8	25	96	62.25	35.96	17.39	29.44	0.00
1992	8	26	22	33.05	62.25	35.96	30.00	0.00
1992	8	27	34	12.66	33.05	62.25	30.00	0.13
1992	8	28	62	34.33	12.66	33.05	26.11	2.57
1992	8	29	86	17.25	34.33	12.66	27.22	0.00
1992	8	30	64	17.29	17.25	34.33	28.89	0.00
1992	8	31	72	35.66	17.29	17.25	30.00	0.00
1993	6	1	0	67.34	68.04	77.05	27.22	0.00
1993	6	2	0	67.16	67.34	68.04	30.00	0.00
1993	6	3	0	67.19	67.16	67.34	32.22	0.00
1993	6	4	0	67.32	67.19	67.16	31.67	0.00
1993	6	5	0	16.28	67.32	67.19	32.22	0.00
1993	6	6	20	20.36	16.28	67.32	31.11	0.48
1993	6	7	40	67.54	20.36	16.28	34.44	0.00
1993	6	8	38	95.43	67.54	20.36	35.00	0.00
1993	6	9	0	67.42	95.43	67.54	35.00	0.00
1993	6	10	0	67.68	67.42	95.43	35.00	0.00
1993	6	11	0	67.64	67.68	67.42	35.00	0.00
1993	6	12	0	26.68	67.64	67.68	34.44	0.00
1993	6	13	14	26.88	26.68	67.64	31.67	0.30

Year	Month	Day	15-minute exceedences	Buford discharge (cms) No lag	1-day lag	2-day lag	Average air temperature (°C)	Precipitation (cm)
1993	6	14	22	68.01	26.88	26.68	26.67	2.67
1993	6	15	10	67.92	68.01	26.88	31.11	0.00
1993	6	16	0	89.22	67.92	68.01	32.78	0.00
1993	6	17	0	67.52	89.22	67.92	32.78	0.00
1993	6	18	0	68.02	67.52	89.22	32.22	0.00
1993	6	19	0	16.62	68.02	67.52	32.22	0.00
1993	6	20	0	16.77	16.62	68.02	32.22	0.00
1993	6	21	26	89.44	16.77	16.62	26.67	0.00
1993	6	22	14	89.36	89.44	16.77	30.56	0.43
1993	6	23	0	89.10	89.36	89.44	33.89	0.00
1993	6	24	0	89.93	89.10	89.36	30.56	0.05
1993	6	25	0	89.66	89.93	89.10	27.78	1.37
1993	6	26	0	16.81	89.66	89.93	31.67	2.26
1993	6	27	0	17.08	16.81	89.66	32.78	0.56
1993	6	28	48	121.23	17.08	16.81	31.67	1.93
1993	6	29	28	120.74	121.23	17.08	30.56	0.00
1993	6	30	0	120.45	120.74	121.23	33.89	0.28
1993	7	1	0	126.14	120.45	120.74	33.89	0.25
1993	7	2	0	120.56	126.14	120.45	33.33	0.00
1993	7	3	0	16.77	120.56	126.14	34.44	0.00
1993	7	4	26	26.90	16.77	120.56	35.56	0.00
1993	7	5	50	110.72	26.90	16.77	34.44	0.00
1993	7	6	28	110.06	110.72	26.90	35.56	0.05
1993	7	7	0	110.39	110.06	110.72	36.67	0.00
1993	7	8	0	110.41	110.39	110.06	37.22	0.00
1993	7	9	0	110.64	110.41	110.39	35.56	0.00
1993	7	10	0	16.89	110.64	110.41	35.56	0.00
1993	7	11	28	26.95	16.89	110.64	34.44	0.00
1993	7	12	60	68.54	26.95	16.89	35.56	0.00
1993	7	13	80	70.16	68.54	26.95	33.89	3.02
1993	7	14	0	90.82	70.16	68.54	34.44	0.00
1993	7	15	0	69.18	90.82	70.16	35.56	0.00
1993	7	16	0	69.28	69.18	90.82	33.89	0.00
1993	7	17	0	16.87	69.28	69.18	36.67	0.00
1993	7	18	30	27.00	16.87	69.28	37.78	0.00
1993	7	19	96	60.70	27.00	16.87	37.22	0.00
1993	7	20	86	58.34	60.70	27.00	37.22	0.00
1993	7	21	28	58.89	58.34	60.70	37.78	0.00
1993	7	22	18	90.41	58.89	58.34	38.89	0.00
1993	7	23	0	49.50	90.41	58.89	37.22	0.00
1993	7	24	18	37.43	49.50	90.41	37.78	0.00
1993	7	25	38	37.15	37.43	49.50	35.00	0.74

Year	Month	Day	15-minute exceedences	Buford discharge (cms) No lag	1-day lag	2-day lag	Average air temperature (°C)	Precipitation (cm)
1993	7	26	88	83.18	37.15	37.43	36.11	0.00
1993	7	27	0	90.50	83.18	37.15	38.33	0.84
1993	7	28	0	91.42	90.50	83.18	37.78	0.84
1993	7	29	0	109.22	91.42	90.50	37.78	0.00
1993	7	30	0	79.98	109.22	91.42	33.89	0.00
1993	7	31	0	37.39	79.98	109.22	35.00	0.00
1993	8	1	4	37.41	37.39	79.98	35.56	0.00
1993	8	2	24	69.77	37.41	37.39	33.89	0.00
1993	8	3	0	70.07	69.77	37.41	30.56	0.00
1993	8	4	0	70.26	70.07	69.77	30.00	0.51
1993	8	5	0	69.00	70.26	70.07	30.56	0.89
1993	8	6	0	33.51	69.00	70.26	27.78	0.03
1993	8	7	0	37.91	33.51	69.00	27.78	1.09
1993	8	8	32	37.73	37.91	33.51	31.11	3.43
1993	8	9	42	69.81	37.73	37.91	30.56	0.00
1993	8	10	0	70.09	69.81	37.73	31.11	0.00
1993	8	11	0	69.59	70.09	69.81	32.78	0.00
1993	8	12	0	69.75	69.59	70.09	32.78	0.00
1993	8	13	0	70.16	69.75	69.59	31.67	0.00
1993	8	14	0	16.95	70.16	69.75	33.33	0.23
1993	8	15	0	16.83	16.95	70.16	32.22	0.00
1993	8	16	42	70.33	16.83	16.95	34.44	0.00
1993	8	17	38	70.31	70.33	16.83	35.56	0.00
1993	8	18	0	69.92	70.31	70.33	35.56	0.00
1993	8	19	0	70.00	69.92	70.31	33.89	0.00
1993	8	20	0	69.95	70.00	69.92	35.56	0.00
1993	8	21	0	37.69	69.95	70.00	35.56	0.05
1993	8	22	28	37.39	37.69	69.95	35.00	0.00
1993	8	23	22	58.99	37.39	37.69	32.22	0.00
1993	8	24	0	59.28	58.99	37.39	32.78	0.00
1993	8	25	0	59.54	59.28	58.99	33.89	0.00
1993	8	26	0	59.37	59.54	59.28	33.89	0.00
1993	8	27	0	70.33	59.37	59.54	33.89	0.00
1993	8	28	0	37.46	70.33	59.37	34.44	0.00
1993	8	29	26	37.32	37.46	70.33	33.89	0.00
1993	8	30	30	59.23	37.32	37.46	34.44	0.00
1993	8	31	0	59.43	59.23	37.32	35.00	0.00
1999	6	1	60	47.42	35.51	26.97	26.67	0.91
1999	6	2	0	47.95	47.42	35.51	29.44	0.10
1999	6	3	28	47.64	47.95	47.42	28.89	0.51
1999	6	4	0	57.21	47.64	47.95	30.56	0.00
1999	6	5	0	26.80	57.21	47.64	30.00	0.00

Year	Month	Day	15-minute exceedences	Buford discharge (cms) No lag	1-day lag	2-day lag	Average air temperature (^{o}C)	Precipitation (cm)
1999	6	6	68	26.72	26.80	57.21	29.44	0.00
1999	6	7	96	58.68	26.72	26.80	31.11	0.00
1999	6	8	32	58.57	58.68	26.72	31.67	0.00
1999	6	9	28	81.19	58.57	58.68	34.44	0.00
1999	6	10	0	57.86	81.19	58.57	31.67	0.00
1999	6	11	24	52.69	57.86	81.19	24.44	1.98
1999	6	12	0	26.54	52.69	57.86	27.78	0.00
1999	6	13	40	26.95	26.54	52.69	29.44	0.00
1999	6	14	88	80.75	26.95	26.54	28.89	1.45
1999	6	15	0	80.01	80.75	26.95	27.78	0.28
1999	6	16	28	58.93	80.01	80.75	27.78	3.00
1999	6	17	0	58.00	58.93	80.01	26.67	0.00
1999	6	18	0	32.12	58.00	58.93	25.56	0.00
1999	6	19	16	21.73	32.12	58.00	25.56	0.00
1999	6	20	48	27.00	21.73	32.12	25.00	0.00
1999	6	21	72	32.36	27.00	21.73	26.11	0.00
1999	6	22	72	42.60	32.36	27.00	27.78	0.00
1999	6	23	52	37.38	42.60	32.36	25.00	0.00
1999	6	24	48	25.34	37.38	42.60	25.56	2.34
1999	6	25	56	32.33	25.34	37.38	28.89	0.00
1999	6	26	96	16.67	32.33	25.34	26.67	1.02
1999	6	27	96	31.17	16.67	32.33	26.11	0.13
1999	6	28	96	37.18	31.17	16.67	25.56	1.60
1999	6	29	72	37.21	37.18	31.17	28.33	1.02
1999	6	30	96	27.31	37.21	37.18	30.56	2.34
1999	7	1	96	27.35	27.31	37.21	28.89	0.00
1999	7	2	96	27.33	27.35	27.31	27.78	0.00
1999	7	3	96	22.04	27.33	27.35	30.56	0.00
1999	7	4	96	27.32	22.04	27.33	31.11	0.00
1999	7	5	96	32.49	27.32	22.04	32.22	0.00
1999	7	6	96	27.41	32.49	27.32	32.78	1.19
1999	7	7	96	32.60	27.41	32.49	28.33	0.91
1999	7	8	96	37.18	32.60	27.41	30.00	0.00
1999	7	9	96	30.40	37.18	32.60	30.56	0.00
1999	7	10	96	21.85	30.40	37.18	30.56	0.51
1999	7	11	96	16.63	21.85	30.40	28.33	6.99
1999	7	12	96	18.05	16.63	21.85	25.00	1.27
1999	7	13	84	18.62	18.05	16.63	23.33	0.00
1999	7	14	96	23.97	18.62	18.05	27.22	0.00
1999	7	15	96	34.58	23.97	18.62	27.22	0.00
1999	7	16	96	34.65	34.58	23.97	30.00	0.00
1999	7	17	88	18.51	34.65	34.58	27.78	0.00

Year	Month	Day	15-minute exceedences	Buford discharge (cms) No lag	1-day lag	2-day lag	Average air temperature (°C)	Precipitation (cm)
1999	7	18	96	27.34	18.51	34.65	30.56	1.78
1999	7	19	96	39.81	27.34	18.51	31.11	0.97
1999	7	20	96	32.56	39.81	27.34	32.22	0.00
1999	7	21	96	29.18	32.56	39.81	32.22	0.00
1999	7	22	96	29.00	29.18	32.56	33.33	0.00
1999	7	23	96	29.90	29.00	29.18	34.44	0.00
1999	7	24	96	20.16	29.90	29.00	34.44	0.23
1999	7	25	96	35.75	20.16	29.90	32.78	0.00
1999	7	26	96	35.99	35.75	20.16	33.89	0.00
1999	7	27	96	24.94	35.99	35.75	34.44	0.00
1999	7	28	96	29.73	24.94	35.99	33.89	0.00
1999	7	29	96	27.96	29.73	24.94	34.44	0.00
1999	7	30	96	26.78	27.96	29.73	36.11	0.00
1999	7	31	96	25.43	26.78	27.96	37.22	0.00
1999	8	1	96	40.76	25.43	26.78	35.56	0.00
1999	8	2	96	43.67	40.76	25.43	34.44	0.00
1999	8	3	96	23.94	43.67	40.76	31.11	0.00
1999	8	4	96	43.12	23.94	43.67	31.67	0.00
1999	8	5	96	32.14	43.12	23.94	33.33	0.00
1999	8	6	96	31.18	32.14	43.12	33.89	0.00
1999	8	7	96	31.13	31.18	32.14	34.44	0.00
1999	8	8	96	31.25	31.13	31.18	34.44	0.18
1999	8	9	96	29.10	31.25	31.13	33.33	0.00
1999	8	10	96	30.56	29.10	31.25	32.22	0.00
1999	8	11	96	37.36	30.56	29.10	35.56	0.00
1999	8	12	96	43.10	37.36	30.56	36.67	0.00
1999	8	13	96	44.13	43.10	37.36	36.11	0.00
1999	8	14	80	37.90	44.13	43.10	36.67	0.00
1999	8	15	96	35.39	37.90	44.13	33.89	0.00
1999	8	16	96	36.25	35.39	37.90	34.44	0.00
1999	8	17	96	38.19	36.25	35.39	35.56	0.00
1999	8	18	96	40.30	38.19	36.25	36.67	0.00
1999	8	19	96	43.60	40.30	38.19	36.67	0.00
1999	8	20	60	43.18	43.60	40.30	31.67	0.28
1999	8	21	60	32.46	43.18	43.60	33.33	0.00
1999	8	22	96	37.10	32.46	43.18	33.33	0.00
1999	8	23	80	42.51	37.10	32.46	32.22	0.00
1999	8	24	40	36.01	42.51	37.10	26.67	2.46
1999	8	25	16	39.35	36.01	42.51	28.33	0.89
1999	8	26	48	45.81	39.35	36.01	31.67	0.00
1999	8	27	48	41.34	45.81	39.35	31.11	0.00
1999	8	28	60	36.66	41.34	45.81	32.22	0.00

Year	Month	Day	15-minute exceedences	Buford discharge (cms) No lag	1-day lag	2-day lag	Average air temperature (^oC)	Precipitation (cm)
1999	8	29	72	37.60	36.66	41.34	32.78	0.00
1999	8	30	60	34.31	37.60	36.66	32.78	0.00
1999	8	31	56	39.05	34.31	37.60	28.89	0.00
2002	6	1	96	18.84	19.06	18.83	31.67	0.00
2002	6	2	96	19.13	18.84	19.06	32.22	0.00
2002	6	3	96	28.97	19.13	18.84	33.89	0.00
2002	6	4	96	18.87	28.97	19.13	33.33	3.94
2002	6	5	96	18.86	18.87	28.97	31.67	0.15
2002	6	6	96	18.72	18.86	18.87	29.44	0.00
2002	6	7	96	18.83	18.72	18.86	30.56	0.00
2002	6	8	96	18.78	18.83	18.72	26.67	0.00
2002	6	9	96	19.02	18.78	18.83	27.78	0.00
2002	6	10	96	18.75	19.02	18.78	29.44	0.00
2002	6	11	96	19.67	18.75	19.02	31.11	0.00
2002	6	12	96	24.44	19.67	18.75	33.33	0.00
2002	6	13	96	25.37	24.44	19.67	32.78	0.00
2002	6	14	96	23.18	25.37	24.44	27.22	1.96
2002	6	15	96	23.15	23.18	25.37	26.11	0.00
2002	6	16	80	23.10	23.15	23.18	26.67	0.00
2002	6	17	96	23.76	23.10	23.15	28.33	0.00
2002	6	18	96	23.10	23.76	23.10	29.44	0.00
2002	6	19	96	21.65	23.10	23.76	28.89	0.00
2002	6	20	96	30.64	21.65	23.10	30.56	0.00
2002	6	21	96	34.86	30.64	21.65	27.78	0.00
2002	6	22	96	21.98	34.86	30.64	27.22	1.27
2002	6	23	96	22.18	21.98	34.86	29.44	0.00
2002	6	24	96	22.66	22.18	21.98	30.56	0.00
2002	6	25	96	25.32	22.66	22.18	27.22	0.64
2002	6	26	96	23.44	25.32	22.66	28.89	0.00
2002	6	27	96	25.35	23.44	25.32	30.00	0.33
2002	6	28	96	23.84	25.35	23.44	27.22	0.00
2002	6	29	96	23.23	23.84	25.35	28.89	0.00
2002	6	30	96	19.64	23.23	23.84	31.11	0.00
2002	7	1	96	28.04	19.64	23.23	32.22	0.00
2002	7	2	96	23.72	28.04	19.64	32.22	1.65
2002	7	3	96	23.59	23.72	28.04	30.56	0.53
2002	7	4	96	19.93	23.59	23.72	31.67	0.00
2002	7	5	96	27.63	19.93	23.59	33.89	0.00
2002	7	6	96	22.44	27.63	19.93	34.44	0.00
2002	7	7	96	26.68	22.44	27.63	31.67	0.00
2002	7	8	96	23.21	26.68	22.44	31.67	0.00
2002	7	9	96	28.15	23.21	26.68	32.22	0.00

Year	Month	Day	15-minute exceedences	Buford discharge (cms) No lag	1-day lag	2-day lag	Average air temperature (^oC)	Precipitation (cm)
2002	7	10	96	23.75	28.15	23.21	32.78	0.10
2002	7	11	96	27.05	23.75	28.15	29.44	0.51
2002	7	12	96	23.42	27.05	23.75	25.00	0.00
2002	7	13	96	19.38	23.42	27.05	28.33	1.04
2002	7	14	96	20.02	19.38	23.42	31.11	0.89
2002	7	15	96	24.82	20.02	19.38	32.78	0.00
2002	7	16	96	25.19	24.82	20.02	33.89	0.00
2002	7	17	96	24.42	25.19	24.82	34.44	0.00
2002	7	18	96	22.99	24.42	25.19	33.89	0.00
2002	7	19	96	29.95	22.99	24.42	34.44	0.00
2002	7	20	96	24.30	29.95	22.99	33.33	0.00
2002	7	21	96	23.74	24.30	29.95	35.00	2.29
2002	7	22	96	35.04	23.74	24.30	32.78	0.00
2002	7	23	96	29.87	35.04	23.74	31.67	3.58
2002	7	24	96	24.72	29.87	35.04	30.56	0.00
2002	7	25	96	24.87	24.72	29.87	29.44	0.00
2002	7	26	96	22.96	24.87	24.72	30.00	0.43
2002	7	27	96	23.92	22.96	24.87	31.67	0.00
2002	7	28	96	24.41	23.92	22.96	32.78	0.00
2002	7	29	96	27.98	24.41	23.92	32.78	0.00
2002	7	30	96	24.32	27.98	24.41	31.11	0.00
2002	7	31	96	27.60	24.32	27.98	32.22	0.00
2002	8	1	96	24.75	27.60	24.32	33.89	0.00
2002	8	2	96	30.31	24.75	27.60	33.33	0.00
2002	8	3	96	18.19	30.31	24.75	32.78	0.00
2002	8	4	96	19.42	18.19	30.31	33.33	0.00
2002	8	5	96	30.10	19.42	18.19	34.44	0.00
2002	8	6	96	29.81	30.10	19.42	36.11	0.00
2002	8	7	96	30.34	29.81	30.10	30.56	0.00
2002	8	8	96	29.64	30.34	29.81	30.56	0.00
2002	8	9	96	29.37	29.64	30.34	30.00	0.00
2002	8	10	96	19.62	29.37	29.64	31.11	0.00
2002	8	11	96	19.60	19.62	29.37	31.67	0.00
2002	8	12	96	28.99	19.60	19.62	32.78	0.00
2002	8	13	96	33.39	28.99	19.60	33.33	0.00
2002	8	14	96	34.59	33.39	28.99	31.67	0.00
2002	8	15	80	30.08	34.59	33.39	31.11	0.38
2002	8	16	72	33.46	30.08	34.59	32.22	0.00
2002	8	17	96	24.44	33.46	30.08	32.78	0.10
2002	8	18	96	24.41	24.44	33.46	33.89	0.41
2002	8	19	96	34.48	24.41	24.44	32.78	0.00
2002	8	20	96	24.25	34.48	24.41	34.44	0.00

Year	Month	Day	15-minute exceedences	Buford discharge (cms) No lag	1-day lag	2-day lag	Average air temperature (°C)	Precipitation (cm)
2002	8	21	96	29.97	24.25	34.48	34.44	0.00
2002	8	22	96	36.86	29.97	24.25	32.78	0.00
2002	8	23	96	34.96	36.86	29.97	35.00	0.00
2002	8	24	96	24.93	34.96	36.86	34.44	0.00
2002	8	25	96	24.74	24.93	34.96	33.33	0.00
2002	8	26	96	33.71	24.74	24.93	31.11	0.41
2002	8	27	96	34.69	33.71	24.74	28.89	0.00
2002	8	28	92	34.27	34.69	33.71	28.33	0.00
2002	8	29	32	36.29	34.27	34.69	28.33	0.00
2002	8	30	0	38.39	36.29	34.27	25.56	0.00
2002	8	31	0	27.85	38.39	36.29	25.00	0.00
2003	7	1	48	18.04	52.15	24.35	22.78	3.56
2003	7	2	44	62.07	18.04	52.15	27.22	5.72
2003	7	3	60	163.83	62.07	18.04	30.56	0.00
2003	7	4	0	190.15	163.83	62.07	30.00	0.00
2003	7	5	0	167.93	190.15	163.83	26.67	1.07
2003	7	6	0	189.97	167.93	190.15	28.89	0.08
2003	7	7	0	171.93	189.97	167.93	30.56	0.36
2003	7	8	0	157.40	171.93	189.97	32.22	0.00
2003	7	9	0	168.01	157.40	171.93	31.67	0.00
2003	7	10	0	122.06	168.01	157.40	29.44	0.00
2003	7	11	0	32.69	122.06	168.01	29.44	4.70
2003	7	12	56	37.39	32.69	122.06	30.00	0.00
2003	7	13	96	37.96	37.39	32.69	30.56	1.52
2003	7	14	72	72.80	37.96	37.39	28.89	0.64
2003	7	15	52	163.35	72.80	37.96	30.00	0.00
2003	7	16	0	180.77	163.35	72.80	31.11	0.00
2003	7	17	0	180.77	180.77	163.35	31.11	0.38
2003	7	18	0	164.63	180.77	180.77	31.11	0.00
2003	7	19	0	58.64	164.63	180.77	31.11	0.15
2003	7	20	0	56.41	58.64	164.63	31.11	0.00
2003	7	21	32	56.79	56.41	58.64	31.67	0.00
2003	7	22	12	47.91	56.79	56.41	30.00	0.00
2003	7	23	56	32.23	47.91	56.79	27.22	0.94
2003	7	24	48	71.37	32.23	47.91	28.33	1.93
2003	7	25	36	88.12	71.37	32.23	29.44	0.00
2003	7	26	0	38.70	88.12	71.37	30.56	0.00
2003	7	27	0	41.04	38.70	88.12	30.56	0.00
2003	7	28	36	65.26	41.04	38.70	31.67	0.00
2003	7	29	16	16.16	65.26	41.04	31.11	0.00
2003	7	30	16	80.06	16.16	65.26	30.00	0.81
2003	7	31	0	73.34	80.06	16.16	31.11	1.22

Year	Month	Day	15-minute exceedences	Buford discharge (cms) No lag	1-day lag	2-day lag	Average air temperature (°C)	Precipitation (cm)
2003	8	1	0	68.15	73.34	80.06	29.44	1.02
2003	8	2	0	21.34	68.15	73.34	28.89	0.00
2003	8	3	52	32.44	21.34	68.15	28.89	0.00
2003	8	4	96	52.53	32.44	21.34	28.33	1.88
2003	8	5	88	70.79	52.53	32.44	29.44	0.00
2003	8	6	28	67.71	70.79	52.53	27.78	0.30
2003	8	7	0	52.74	67.71	70.79	28.89	0.25
2003	8	8	28	57.94	52.74	67.71	29.44	0.00
2003	8	9	0	31.79	57.94	52.74	30.00	0.00
2003	8	10	40	21.70	31.79	57.94	30.56	0.00
2003	8	11	92	83.63	21.70	31.79	29.44	0.00
2003	8	12	28	94.14	83.63	21.70	27.22	0.00
2003	8	13	0	103.68	94.14	83.63	30.56	0.43
2003	8	14	0	92.43	103.68	94.14	31.67	0.38
2003	8	15	0	94.01	92.43	103.68	32.22	0.00
2003	8	16	0	42.23	94.01	92.43	30.00	0.00
2003	8	17	36	37.11	42.23	94.01	31.67	0.00
2003	8	18	52	83.60	37.11	42.23	32.22	0.00
2003	8	19	20	89.96	83.60	37.11	32.22	0.00
2003	8	20	0	99.78	89.96	83.60	30.56	1.40
2003	8	21	0	95.91	99.78	89.96	31.11	0.00
2003	8	22	0	80.17	95.91	99.78	31.11	0.00
2003	8	23	0	23.23	80.17	95.91	32.22	0.00
2003	8	24	44	23.27	23.23	80.17	31.67	0.00
2003	8	25	96	78.89	23.27	23.23	31.11	0.84
2003	8	26	40	73.98	78.89	23.27	31.67	0.00
2003	8	27	0	73.50	73.98	78.89	32.22	0.00
2003	8	28	12	78.82	73.50	73.98	33.33	0.00
2003	8	29	8	62.21	78.82	73.50	31.67	1.12
2003	8	30	48	38.26	62.21	78.82	31.11	1.65
2003	8	31	64	26.67	38.26	62.21	31.67	0.00
2004	6	1	35	26.58	25.70	24.97	23.89	1.80
2004	6	2	48	24.78	26.58	25.70	23.89	0.00
2004	6	3	50	27.33	24.78	26.58	27.22	0.00
2004	6	4	57	26.09	27.33	24.78	28.89	0.00
2004	6	5	64	26.56	26.09	27.33	27.78	0.00
2004	6	6	94	26.16	26.56	26.09	28.89	0.00
2004	6	7	95	27.70	26.16	26.56	28.89	0.00
2004	6	8	9	26.24	27.70	26.16	26.67	2.59
2004	6	9	42	26.43	26.24	27.70	27.22	0.00
2004	6	10	65	42.04	26.43	26.24	30.00	0.00
2004	6	11	76	25.70	42.04	26.43	32.22	0.00

Year	Month	Day	15-minute exceedences	Buford discharge (cms) No lag	1-day lag	2-day lag	Average air temperature (°C)	Precipitation (cm)
2004	6	12	78	27.21	25.70	42.04	33.33	0.00
2004	6	13	96	26.01	27.21	25.70	27.22	0.00
2004	6	14	96	26.96	26.01	27.21	27.78	1.60
2004	6	15	96	27.09	26.96	26.01	28.89	0.13
2004	6	16	96	25.80	27.09	26.96	31.11	2.08
2004	6	17	95	27.00	25.80	27.09	31.11	1.80
2004	6	18	96	26.14	27.00	25.80	30.56	0.00
2004	6	19	96	27.42	26.14	27.00	31.67	0.00
2004	6	20	96	26.85	27.42	26.14	31.67	0.00
2004	6	21	92	26.45	26.85	27.42	28.33	0.00
2004	6	22	96	24.52	26.45	26.85	30.56	1.32
2004	6	23	96	26.44	24.52	26.45	28.89	0.86
2004	6	24	96	27.57	26.44	24.52	26.67	0.53
2004	6	25	96	27.36	27.57	26.44	28.89	0.05
2004	6	26	96	24.76	27.36	27.57	25.56	0.08
2004	6	27	89	25.98	24.76	27.36	27.78	0.00
2004	6	28	95	25.98	25.98	24.76	26.67	3.94
2004	6	29	96	25.87	25.98	25.98	28.33	0.58
2004	6	30	94	30.15	25.87	25.98	26.67	0.00
2004	7	1	87	45.06	30.15	25.87	28.33	0.58
2004	7	2	0	69.22	45.06	30.15	27.22	0.43
2004	7	3	0	45.07	69.22	45.06	30.00	0.51
2004	7	4	20	46.11	45.07	69.22	31.11	0.00
2004	7	5	35	36.74	46.11	45.07	32.22	0.00
2004	7	6	36	78.69	36.74	46.11	32.22	0.00
2004	7	7	25	70.55	78.69	36.74	31.67	0.00
2004	7	8	0	75.85	70.55	78.69	30.56	0.36
2004	7	9	0	68.81	75.85	70.55	31.11	0.00
2004	7	10	0	30.15	68.81	75.85	31.67	0.00
2004	7	11	38	33.52	30.15	68.81	32.22	0.00
2004	7	12	80	32.87	33.52	30.15	31.67	0.00
2004	7	13	96	44.77	32.87	33.52	32.78	0.00
2004	7	14	96	36.63	44.77	32.87	33.33	0.00
2004	7	15	53	40.77	36.63	44.77	29.44	0.00
2004	7	16	96	36.16	40.77	36.63	29.44	0.00
2004	7	17	96	35.15	36.16	40.77	28.89	0.00
2004	7	18	69	39.81	35.15	36.16	30.56	0.28
2004	7	19	96	43.43	39.81	35.15	29.44	0.00
2004	7	20	68	52.94	43.43	39.81	31.11	0.00
2004	7	21	10	52.76	52.94	43.43	31.67	0.00
2004	7	22	0	51.14	52.76	52.94	31.67	0.00
2004	7	23	7	33.02	51.14	52.76	34.44	0.00

Year	Month	Day	15-minute exceedences	Buford discharge (cms) No lag	1-day lag	2-day lag	Average air temperature (°C)	Precipitation (cm)
2004	7	24	51	44.04	33.02	51.14	35.00	0.00
2004	7	25	80	39.93	44.04	33.02	31.67	0.00
2004	7	26	80	19.46	39.93	44.04	30.56	10.06
2004	7	27	96	19.39	19.46	39.93	29.44	1.40
2004	7	28	95	52.10	19.39	19.46	31.67	0.00
2004	7	29	81	51.93	52.10	19.39	30.56	0.00
2004	7	30	0	50.27	51.93	52.10	31.67	0.00
2004	7	31	9	38.12	50.27	51.93	32.22	0.00
2004	8	1	49	48.45	38.12	50.27	32.78	0.00
2004	8	2	34	52.36	48.45	38.12	32.22	0.00
2004	8	3	0	45.23	52.36	48.45	32.78	0.25
2004	8	4	34	49.77	45.23	52.36	33.33	0.00
2004	8	5	24	19.35	49.77	45.23	32.22	0.00
2004	8	6	70	32.44	19.35	49.77	28.89	0.94
2004	8	7	80	33.82	32.44	19.35	27.22	0.00
2004	8	8	96	39.96	33.82	32.44	28.33	0.00
2004	8	9	51	58.36	39.96	33.82	28.89	0.00
2004	8	10	0	67.98	58.36	39.96	23.89	0.00
2004	8	11	0	61.93	67.98	58.36	27.78	0.00
2004	8	12	0	22.64	61.93	67.98	26.67	3.05
2004	8	13	1	62.22	22.64	61.93	25.00	0.00
2004	8	14	28	37.28	62.22	22.64	27.78	0.00
2004	8	15	0	29.64	37.28	62.22	27.78	0.00
2004	8	16	25	45.24	29.64	37.28	28.89	0.00
2004	8	17	27	44.66	45.24	29.64	30.00	0.00
2004	8	18	0	46.50	44.66	45.24	30.00	0.00
2004	8	19	0	44.88	46.50	44.66	31.67	0.00
2004	8	20	0	43.42	44.88	46.50	31.11	0.00
2004	8	21	0	31.04	43.42	44.88	28.33	1.04
2004	8	22	0	43.19	31.04	43.42	29.44	0.00
2004	8	23	11	38.43	43.19	31.04	28.89	0.00
2004	8	24	0	46.42	38.43	43.19	30.56	0.00
2004	8	25	4	45.12	46.42	38.43	28.33	0.00
2004	8	26	0	52.58	45.12	46.42	30.00	3.86
2004	8	27	20	51.50	52.58	45.12	31.11	0.00
2004	8	28	0	30.74	51.50	52.58	32.22	0.00
2004	8	29	39	32.50	30.74	51.50	30.56	0.00
2004	8	30	51	51.25	32.50	30.74	31.11	5.33
2004	8	31	2	57.45	51.25	32.50	30.56	0.00
2005	6	1	0	45.79	43.10	30.30	17.78	1.42
2005	6	2	0	44.31	45.79	43.10	22.78	0.79
2005	6	3	0	45.15	44.31	45.79	23.89	0.00

Year	Month	Day	15-minute exceedences	Buford discharge (cms) No lag	1-day lag	2-day lag	Average air temperature (°C)	Precipitation (cm)
2005	6	4	0	36.72	45.15	44.31	28.89	0.00
2005	6	5	0	29.19	36.72	45.15	29.44	0.00
2005	6	6	41	31.91	29.19	36.72	31.11	1.78
2005	6	7	58	44.20	31.91	29.19	30.56	0.00
2005	6	8	78	41.59	44.20	31.91	30.00	0.76
2005	6	9	89	43.06	41.59	44.20	30.00	2.03
2005	6	10	49	43.20	43.06	41.59	28.33	0.00
2005	6	11	0	18.32	43.20	43.06	26.11	0.51
2005	6	12	57	18.27	18.32	43.20	29.44	1.93
2005	6	13	95	18.45	18.27	18.32	31.11	1.65
2005	6	14	96	180.10	18.45	18.27	31.67	0.00
2005	6	15	7	184.42	180.10	18.45	32.22	0.00
2005	6	16	0	202.43	184.42	180.10	30.56	0.00
2005	6	17	0	190.08	202.43	184.42	27.78	0.00
2005	6	18	0	101.59	190.08	202.43	28.89	0.00
2005	6	19	0	102.88	101.59	190.08	27.22	0.00
2005	6	20	0	129.07	102.88	101.59	27.22	0.00
2005	6	21	0	128.94	129.07	102.88	26.11	3.10
2005	6	22	0	129.54	128.94	129.07	29.44	0.51
2005	6	23	0	97.54	129.54	128.94	31.67	0.00
2005	6	24	0	115.87	97.54	129.54	30.56	0.00
2005	6	25	0	27.52	115.87	97.54	29.44	0.00
2005	6	26	0	29.50	27.52	115.87	25.00	1.02
2005	6	27	39	82.36	29.50	27.52	31.11	1.04
2005	6	28	19	63.98	82.36	29.50	28.33	0.30
2005	6	29	0	55.18	63.98	82.36	29.44	0.00
2005	6	30	4	53.24	55.18	63.98	32.78	0.00
2005	7	1	74	52.41	53.24	55.18	32.78	0.00
2005	7	2	46	22.85	52.41	53.24	31.67	0.00
2005	7	3	61	23.56	22.85	52.41	30.00	0.00
2005	7	4	96	28.78	23.56	22.85	30.00	2.41
2005	7	5	95	90.13	28.78	23.56	31.67	0.10
2005	7	6	23	17.34	90.13	28.78	27.78	3.56
2005	7	7	63	20.91	17.34	90.13	24.44	5.33
2005	7	8	73	166.94	20.91	17.34	31.11	0.00
2005	7	9	26	165.22	166.94	20.91	31.67	0.00
2005	7	10	7	16.83	165.22	166.94	25.56	5.49
2005	7	11	83	18.89	16.83	165.22	28.33	10.29
2005	7	12	78	17.93	18.89	16.83	30.00	2.01
2005	7	13	85	146.47	17.93	18.89	28.89	0.15
2005	7	14	7	157.67	146.47	17.93	30.56	1.17
2005	7	15	2	145.50	157.67	146.47	28.89	0.00

Year	Month	Day	15-minute exceedences	Buford discharge (cms) No lag	1-day lag	2-day lag	Average air temperature (^{o}C)	Precipitation (cm)
2005	7	16	0	154.03	145.50	157.67	29.44	1.63
2005	7	17	0	153.07	154.03	145.50	31.67	0.18
2005	7	18	0	132.02	153.07	154.03	32.22	0.00
2005	7	19	0	134.67	132.02	153.07	31.67	0.00
2005	7	20	7	134.15	134.67	132.02	31.67	0.25
2005	7	21	16	129.78	134.15	134.67	32.22	0.08
2005	7	22	0	133.17	129.78	134.15	32.78	0.00
2005	7	23	0	42.32	133.17	129.78	32.78	0.00
2005	7	24	38	52.07	42.32	133.17	32.22	0.00
2005	7	25	51	107.20	52.07	42.32	33.33	0.00
2005	7	26	8	119.64	107.20	52.07	34.44	0.00
2005	7	27	0	103.07	119.64	107.20	33.33	0.00
2005	7	28	0	114.68	103.07	119.64	32.22	0.00
2005	7	29	0	79.98	114.68	103.07	28.33	0.05
2005	7	30	0	28.17	79.98	114.68	25.56	0.08
2005	7	31	28	30.26	28.17	79.98	28.89	0.30
2005	8	1	96	77.42	30.26	28.17	27.78	0.10
2005	8	2	18	62.28	77.42	30.26	30.00	0.03
2005	8	3	9	76.06	62.28	77.42	31.11	0.00
2005	8	4	0	74.68	76.06	62.28	32.78	0.00
2005	8	5	0	75.57	74.68	76.06	31.11	0.28
2005	8	6	0	32.85	75.57	74.68	30.00	0.00
2005	8	7	43	30.07	32.85	75.57	26.67	0.00
2005	8	8	66	17.21	30.07	32.85	27.78	3.91
2005	8	9	96	156.98	17.21	30.07	29.44	3.15
2005	8	10	18	194.91	156.98	17.21	28.33	0.91
2005	8	11	4	146.34	194.91	156.98	30.56	1.80
2005	8	12	2	115.07	146.34	194.91	31.11	0.00
2005	8	13	16	101.18	115.07	146.34	30.00	0.86
2005	8	14	39	90.04	101.18	115.07	32.22	4.70
2005	8	15	58	143.38	90.04	101.18	33.33	0.08
2005	8	16	7	136.48	143.38	90.04	31.67	0.00
2005	8	17	2	146.53	136.48	143.38	32.22	0.76
2005	8	18	0	126.18	146.53	136.48	32.22	0.00
2005	8	19	0	137.75	126.18	146.53	31.67	0.00
2005	8	20	0	44.58	137.75	126.18	33.33	0.00
2005	8	21	62	45.62	44.58	137.75	34.44	0.00
2005	8	22	93	87.85	45.62	44.58	33.89	0.00
2005	8	23	24	81.13	87.85	45.62	30.56	0.00
2005	8	24	0	16.54	81.13	87.85	29.44	0.41
2005	8	25	0	237.87	16.54	81.13	28.89	0.00
2005	8	26	0	148.09	237.87	16.54	28.89	0.00

				Buford discharge (cms)			Average air	
Year	Month	Day	15-minute exceedences	No lag	1-day lag	2-day lag	temperature (^{o}C)	Precipitation (cm)
	8	27	0	61.24	148.09	237.87	30.00	0.00
2005								
2005	8	28	25	44.26	61.24	148.09	30.00	0.00
2005	8	29	52	37.67	44.26	61.24	29.44	0.00
2005	8	30	91	16.86	37.67	44.26	29.44	3.58
2005	8	31	95	89.24	16.86	37.67	29.44	0.00
2006	6	1	20	45.08	48.64	51.66	31.67	0.00
2006	6	2	0	44.45	45.08	48.64	30.00	0.76
2006	6	3	15	17.78	44.45	45.08	28.33	0.89
2006	6	4	47	17.78	17.78	44.45	28.89	0.00
2006	6	5	70	51.13	17.78	17.78	26.67	1.27
2006	6	6	80	49.83	51.13	17.78	27.78	0.00
2006	6	7	0	65.41	49.83	51.13	29.44	0.00
2006	6	8	0	64.73	65.41	49.83	31.11	0.00
2006	6	9	0	107.46	64.73	65.41	30.56	0.00
2006	6	10	0	38.49	107.46	64.73	32.78	0.00
2006	6	11	28	30.42	38.49	107.46	33.89	0.00
2006	6	12	50	64.65	30.42	38.49	31.11	0.00
2006	6	13	15	63.37	64.65	30.42	24.44	0.00
2006	6	14	0	62.41	63.37	64.65	30.56	0.00
2006	6	15	0	63.26	62.41	63.37	31.11	0.00
2006	6	16	0	63.59	63.26	62.41	31.11	0.00
2006	6	17	0	31.02	63.59	63.26	30.00	0.00
2006	6	18	38	24.15	31.02	63.59	30.00	0.00
2006	6	19	52	36.67	24.15	31.02	31.11	0.00
2006	6	20	96	44.20	36.67	24.15	35.00	0.00
2006	6	21	80	29.69	44.20	36.67	36.11	0.00
2006	6	22	80	31.72	29.69	44.20	36.11	0.00
2006	6	23	96	58.43	31.72	29.69	35.00	0.00
2006	6	24	93	17.91	58.43	31.72	32.22	0.25
2006	6	25	88	18.03	17.91	58.43	28.89	7.09
2006	6	26	82	45.54	18.03	17.91	25.56	4.98
2006	6	27	87	30.56	45.54	18.03	30.00	2.90
2006	6	28	54	39.27	30.56	45.54	30.56	0.00
2006	6	29	95	22.46	39.27	30.56	31.67	0.00
2006	6	30	87	28.67	22.46	39.27	32.22	0.00
2006	7	1	96	20.75	28.67	22.46	33.89	1.55
2006	7	2	95	30.89	20.75	28.67	34.44	0.00
2006	7	3	89	43.34	30.89	20.75	34.44	0.00
2006	7	4	90	20.55	43.34	30.89	33.33	0.00
2006	7	5	75	28.52	20.55	43.34	32.22	0.00
2006	7	6	96	28.18	28.52	20.55	27.22	0.00

Year	Month	Day	15-minute exceedences	Buford discharge (cms) No lag	1-day lag	2-day lag	Average air temperature (°C)	Precipitation (cm)
2006	7	7	95	27.84	28.18	28.52	26.67	0.79
2006	7	8	96	21.65	27.84	28.18	27.78	0.00
2006	7	9	96	20.56	21.65	27.84	28.89	0.00
2006	7	10	88	43.38	20.56	21.65	29.44	0.00
2006	7	11	95	32.49	43.38	20.56	32.22	0.00
2006	7	12	70	35.72	32.49	43.38	32.78	0.00
2006	7	13	96	30.71	35.72	32.49	33.33	0.00
2006	7	14	96	32.62	30.71	35.72	33.33	0.00
2006	7	15	96	18.00	32.62	30.71	32.78	0.00
2006	7	16	74	14.64	18.00	32.62	32.78	0.28
2006	7	17	94	32.62	14.64	18.00	33.89	0.00
2006	7	18	96	44.75	32.62	14.64	34.44	0.00
2006	7	19	96	31.16	44.75	32.62	35.56	0.00
2006	7	20	96	45.28	31.16	44.75	33.89	0.00
2006	7	21	96	40.23	45.28	31.16	34.44	0.00
2006	7	22	75	40.99	40.23	45.28	32.78	0.53
2006	7	23	57	31.91	40.99	40.23	30.00	0.00
2006	7	24	51	32.73	31.91	40.99	30.56	0.00
2006	7	25	58	32.05	32.73	31.91	31.11	0.51
2006	7	26	61	42.26	32.05	32.73	33.89	1.12
2006	7	27	95	36.34	42.26	32.05	35.00	0.00
2006	7	28	88	44.80	36.34	42.26	35.56	0.00
2006	7	29	96	31.12	44.80	36.34	32.78	0.00
2006	7	30	87	32.07	31.12	44.80	32.78	0.00
2006	7	31	96	39.10	32.07	31.12	34.44	0.00
2006	8	1	88	31.35	39.10	32.07	35.00	0.00
2006	8	2	96	45.46	31.35	39.10	35.00	2.39
2006	8	3	96	35.97	45.46	31.35	36.11	0.00
2006	8	4	96	44.38	35.97	45.46	36.67	0.00
2006	8	5	96	31.36	44.38	35.97	35.56	0.00
2006	8	6	84	30.54	31.36	44.38	31.67	0.15
2006	8	7	96	44.88	30.54	31.36	36.11	0.23
2006	8	8	96	30.99	44.88	30.54	35.56	0.00
2006	8	9	96	43.80	30.99	44.88	35.00	0.00
2006	8	10	96	33.23	43.80	30.99	35.56	0.97
2006	8	11	86	43.58	33.23	43.80	31.11	3.58
2006	8	12	33	24.47	43.58	33.23	28.89	0.00
2006	8	13	41	32.09	24.47	43.58	27.22	1.17
2006	8	14	96	41.66	32.09	24.47	30.56	0.00
2006	8	15	84	32.97	41.66	32.09	30.00	0.00
2006	8	16	61	45.33	32.97	41.66	31.67	0.61
2006	8	17	96	27.99	45.33	32.97	30.00	0.03

Year	Month	Day	15-minute exceedences	Buford discharge (cms) No lag	1-day lag	2-day lag	Average air temperature (°C)	Precipitation (cm)
2006	8	18	82	26.80	27.99	45.33	31.11	0.00
2006	8	19	96	34.84	26.80	27.99	31.11	0.00
2006	8	20	92	29.27	34.84	26.80	33.89	0.00
2006	8	21	96	37.22	29.27	34.84	32.78	1.35
2006	8	22	94	30.38	37.22	29.27	31.11	2.57
2006	8	23	93	40.40	30.38	37.22	30.56	1.75
2006	8	24	96	34.19	40.40	30.38	28.33	0.00
2006	8	25	52	40.39	34.19	40.40	29.44	2.92
2006	8	26	53	21.46	40.39	34.19	31.11	0.00
2006	8	27	56	20.34	21.46	40.39	31.11	0.00
2006	8	28	95	37.33	20.34	21.46	32.22	0.00
2006	8	29	96	35.11	37.33	20.34	32.22	1.42
2006	8	30	94	46.00	35.11	37.33	31.11	2.39
2006	8	31	75	35.60	46.00	35.11	26.67	0.41

Appendix B. Georgia Department of Natural Resources rainbow trout stocking records for Paces Mill from 1991-2006.

Year	Month	Number stocked
1991	June	25400
	November	19500
1993	January	55800
	August	34252
1995	January	50000
	May	25000
1996	September	50000
1997	December	50000
1998	March	15360
	July	50000
1999	October	50000
2000	September	43000
	October	17000
	November	14693
	December	8552
2001	January	4315
	February	3740
	March	3885
	April	3800
	May	3800
	September	39000
	October	51700
	November	15000
2002	January	3938
	February	3738
	March	3738
	April	3738
	October	78175
	November	17024
	December	2992
2003	January	2000
	February	5652
	March	8152
	April	8152
	May	2500
	June	2500
	July	2500
	August	2500
	September	2500

Appendix B (cont.)

Year	Month	Number stocked
2003	October	83054
	November	19245
	December	5100
2004	February	4780
	March	4760
	April	7280
	May	2500
	June	2500
	July	2500
	August	2500
	September	2483
	October	2500
	November	18950
	December	8600
2005	January	8250
	February	4200
	March	4525
	April	4325
	May	2500
	June	2500
	July	2500
	August	2500
	September	2500
	October	2500
	November	6180
	December	9502
2006	February	6280
	March	5730
	April	5960
	May	1800
	June	1800
	July	1800
	August	1800
	September	1800
	October	6125
	November	4369
	December	6382

Appendix C. Summary of trout stocking, electrofishing, and angler reporting data for the upstream (Up) and downstream (Down) study sites used to fit multistrata tag recovery models.

Month	Number stocked		Number recaptured[1]		Number harvested and reported		Number reported by anglers and Released with tag		Number reported by anglers and Released without tag	
	Up	Down	Up	Down	Up	Down	Up	Down	Ups	Down
March	293	287	35	28	0	0	0	4	1	1
April	368	370	28	20	1	0	0	2	1	3
May	380	356	34	25	1	11	1	1	0	2
June	371	375	38	27	2	4	0	1	0	0
July	341	350	17	1	1	1	2	0	0	0
August	362	363	15	7	0	0	0	0	0	0
September	363	368	14	12	3	0	0	14	0	0
October	333	320	26	7	0	1	2	2	2	0

[1]Number recaptured by electrofishing includes trout stocked from previous months.