Influences of Fluctuating Releases on Stream Habitats for Brown Trout in the Smith River Below Philpott Dam

Annual Report
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Submitted to:

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Job 1. Characteristics of Spawning and Rearing Habitats for Brown Trout

Job Objective: To characterize instream habitat conditions in areas where successful spawning and juvenile rearing of brown trout occurs.

Procedures: Preliminary to a more detailed analysis of brown trout spawning and rearing habitat, we characterized microhabitat in locations where significant numbers of age-0 brown trout were captured by VDGIF personnel in August of 1998 and 1999. Three locations representing a range in abundance of age-0 brown trout were selected, corresponding to sites 2, 4, and 12 described below (3.4, 6.5, and 23 km downstream from Philpott Dam; Figure 1). Field work was performed November 22 - December 19, 1999. Twenty-five transects, 4 m apart, were established in 100 m reaches at each site. We measured habitat characteristics for a 1×1 m area at 5 m intervals along each transect. These characteristics included depth, mean column velocity, dominant and subdominant substrate type (modified Wentworth size scale: vegetation; sand < 2 mm diameter; small 2-6 mm, medium 7-25 mm, and large 26-51 mm gravel; small 52-152 mm and large 153-305 mm cobble; small 306-610 mm and large >610 mm boulder; bedrock), fine particles in substrate (0 = 0-25%, 1 = 26-50%, 2 = 51-75%, 3 = 76-100%), and embeddedness (0 = none, 1 = some, 2 = armored).

Preliminary Results: Habitat characteristics in the three potential spawning areas differed among sites in several respects and appeared to be related to distance downstream from Philpott Dam. For example, site 2 and 4 which are most upstream offered deeper, lower velocity spawning habitats compared to site 12 which is much further downstream (Table 1). Site 4 was characterized by a relatively even distribution of habitat that ranged from shallow to deeper water; however, depths did not exceed 1 m at any of the sites (Figure 2). By contrast, site 12 possessed a significant amount of shallow habitat (< 18 cm deep). Likewise, the distribution of velocities were similar between sites 2 and 4, but site 12 differed in that much wider range in velocities were present (Figure 3). We did not record a velocity > 100 cm s^{-1} in any of the sites. Characteristics of the substrates found in the study sites also differed substantially with distance downstream from the dam. Substrates tended to be larger upstream in site 2, but were increasingly dominated by smaller substrates at sites 4 and site 12 (Figure 4). Another notable difference among sites is the presence of bedrock in sites 2 and 4; however, this type of substrate was absent from site 12 where we found a large amount of sand. Vegetation was generally absent near the dam but abundant at downstream sites, perhaps due to differences in nutrients or temperature among the sites.

The presence of fine particle substrates also differed among upstream and downstream sites. Sites 2 and 4 were similar in the degree to which fine particles contributed to the overall composition of substrates (Table 1). Fines composed < 25% (< 1 on categorical scale) of the substrate at these sites, though approached 50% at site 12. In addition, we characterized site 2 and, to a lesser degree, site 4 as none to somewhat embedded, whereas site 12 was somewhat to highly embedded or armored.

The upstream to downstream pattern of differences in potential spawning habitat that we observed is consistent with the removal of fine substrates (e.g. small gravel and sand) from upstream sites and its deposition further downstream by peaking flows. Tributaries likely add fine substrates and sediment to downstream sites such as site 12. The pattern of abundance of age-0 brown trout, presented in Job 2, may reflect negative influences of fine sediments and lack of spawning gravels on the availability of redd sites and limited spawning success downstream. Based on information gathered to date, the most successful spawning and rearing sites are located in the upper 16 km of Smith River tailwater, upstream of site 9 (Job 2; Figure 5). Characterization of habitat in sites where redds have been constructed and monitoring the success of spawning and emergence of age-0 brown trout, planned for fall 2000 and spring 2001, will clarify which locations offer the best spawning and rearing habitat.

Job 2: Determinants of Brown Trout Growth and Abundance

Job Objective: To collect biological data to quantify relative abundance of trout and nongame fishes in Smith River from Philpott Dam to Martinsville, quantify temperature limits on fish occurrence, and monitor annual variation in brown trout recruitment success. To evaluate the bioenergetic constraints on growth under existing temperature regimes.

Procedures: We sampled fish populations in 12 sites from the Philpott Dam to Koehler (23 km; Figure 1) using paired multiple mobile anode, pulsed DC barge electrofishing gear. Three-pass depletion methods were conducted in 100-m sections enclosed by block nets (5 mm mesh) during June 12-27, 2000. We collected additional brown trout for tagging using a single pass across approximately 300 m either upstream or downstream of the blocknets. Age-1+ brown trout collected at each site were anesthetized with clove oil, implanted with a PIT (Passive Integrated Transponder) tag, measured to the nearest mm (total length), and weighed to the nearest 1 g, and given an adipose fin clip. Age-0 brown trout were measured to the nearest mm and released. Nongame fish species were also collected, counted, and a subsample of individuals representing the more common species measured for total length and weighed. Population estimates and 95% confidence intervals based on the three-pass catch rates were determined using the Microfish software program.

We also determined relative abundance of age-0 brown trout at the 12 study sites during May 9-16, 2000, using backpack electrofishing gear and a single sampling pass across 200 m. Water within 10 m of the bank on the side of the river offering suitable age-0 rearing habitat was sampled. Age-0 brown trout were counted and measured for total length.

In August, 2000, we resampled the 12 study sites to recapture age-1+ brown trout tagged in June. Again, we used paired barge electrofishing gear; however, a single electrofishing pass without block nets across the same reaches sampled in June was used at each site. All brown trout were anesthetized, checked for the presence of a PIT tag, measured, and weighed. Specific growth rates in length and weight were calculated for recaptured trout and movement among sites noted. We calculated a Lincoln-Petersen population estimate for age-1+ brown trout by pooling mark-recapture data among the 12 study sites and extrapolating the estimate to the upper 24 km of the tailwater.

Detailed characterization of temperature conditions in the upper 24 km of the Smith River tailwater is being conducted by Colin Krause (Progress Report by Newcomb et al. 2000[1]). Water temperatures were continuously monitored at 7 locations between Philpott Dam and Koehler.

Preliminary Results: Population estimates for age-1+ brown trout at the 12 sites ranged from 5 trout 100 m^{-1} at site 11, 20.5 km downstream from Philpott Dam, to 230 trout 100 m^{-1} at site 4, 6.5 km downstream from the dam (Figure 5). Abundance of age-1+ brown trout was low near the dam and increased to a maximum at site 4, then decreased with increasing distance from the dam. Population estimates for age-0 brown trout ranged from 5 trout 100 m^{-1} at site 11 and site 12, 20.5 and 23.0 km downstream from the dam, to 273 trout 100 m^{-1} at site 5, 9 km downstream from the dam (Figure 5). Abundance was moderately high at upstream sites, reaching a maximum at site 5, then declined with increasing distance from the dam.

Relative abundance of age-0 brown trout in May during and soon after emergence from redds demonstrates a similar overall pattern to population estimates in June: high abundance in upstream sites, lower abundance in downstream sites (Figure 6). However, comparisons of relative abundance within a particular site in May and June suggests high variability in the occurrence of age-0 trout between these dates. For example, abundance was high at site 3 in May but low in June. Conversely, abundance was low at site 1 in May but high in June. These patterns probably reflect dates of emergence (later at site 1) and possibly displacement or movement of age-0 downstream (site 3). In fact, the apparent right-ward shift in peaks in abundance between May and June is strongly suggestive of downstream movement.

We found that total length distributions from each of the 12 study sites indicated brown trout in sites farther downstream from Philpott Dam are larger than brown trout in upstream sites (Figure 7). A length-frequency distribution incorporating brown trout captured in June at all 12 sites suggests that few brown trout survive to reach lengths in excess of 415 mm (Figure 8).

The mark-recapture study using PIT tags provided useful information on growth, movement, and allowed estimation of the total number of age-1+ brown trout in the upper 24 km of the Smith River tailwater. In June, 1,874 age-1+ brown trout were tagged the 12 study sites (Table 2). In August, 797 of the tagged trout were recaptured; an additional 90 trout had adipose fin clips and scars from tag injectors but undetectable tags. Failure to detect a tag could be due to improper tagging (i.e. no tag was injected), expulsion and loss of the tag from the injection site, or failure of the scanner or personnel to detect the tag. Recapture rates were generally high, ranging from 9% at site 11 to 61% at site 4. Part of our success at recapturing tagged fish is due to a low degree of inter-site movement. Seventeen trout tagged at site 11 were recaptured at site 10 and 1 trout tagged at site 10 was recaptured at site 11; however, these sites are very close together (< 1 km). One trout moved from site 5 to site 6 (2.4 km).

Based on recapture data, specific growth in length and weight was determined for individual tagged age-1+ brown trout (Figure 9). Growth rates were somewhat low but on average were positive at all 12 sites. As distances from the dam increased, growth rates tended to decline.

We calculated a Lincoln-Petersen population estimate for age-1+ brown trout extrapolated to the upper 24 km of the Smith River tailwater (Philpott Dam downstream to Koehler) from mark-recapture data using the Index. The estimate (± 95% CI), based on brown trout with adipose fin clips (including trout with undetectable tags), was 35,346 ± 586. For comparison, extrapolation of the three-pass depletion population estimates from our 12 study sites (1.2 km) to 24 km yields an estimate of 21,880 age-1+ brown trout.

In contrast to patterns in abundance of brown trout, nongame fish species show a marked increase in abundance (Figure 10) and diversity (Figure 11) with increasing distance downstream from Philpott Dam. This pattern of distribution probably reflects more favorable conditions downstream (e.g. warmer temperatures, increased food availability) from the perspective of the pre-dam fish assemblage composed mostly of warmer-water species. Annual mean and maximum temperatures increase dramatically at downstream sites (Figure 12; Progress Report by Newcomb et al. 2000[1]). Maximum temperatures recorded between July 15, 1999, through July 15, 2000, were 10.9^{o}C higher at Koehler (site 12) than near Philpott Dam (site 1). Temperatures this extreme are likely stressful to brown trout but may be preferable to several of the nongame fishes that occur at downstream sites. Cooler mean temperatures upstream (8 - 9^{o}C) may reflect conditions that are too cool for successful reproduction and juvenile development of several non-game fishes that spawn in spring.

Of particular interest are the dramatic fluctuations in temperature that coincide with cold water releases for power generation at Philpott Dam (Progress Report by Newcomb et al. 2000[1]). During summer (e.g. July15, 1999), late-day releases may reduce temperature by more than 10^{o}C in 60 min at downstream sites (18.3 km from Philpott Dam) where solar heating has already warmed the temperature of the river. Rates of cooling of this degree might be stressful to brown trout and other fishes. By contrast, early morning releases for power generation may warm water temperatures during cooler months (e.g. November 15, 1999). Timing periods of power generation so that the temperature of released water matches the ambient temperature of the river (mainly a function of air temperatures) results in the smallest degree of temperature fluctuation (e.g. March 15, 2000).

Project Schedule: All phases of Jobs 1 and 2 are proceeding on schedule with no anticipated delays.

[1]Newcomb, T. J., Orth, D. J., and C. Krause. 2000. Options for modeling and managing stream temperature in the face of increasing water demands and minimum instream flows. Annual Progress Report to the Virginia Water Resources Research Center.

Table 1. Sample size, depth, velocity, presence of fine particles (fines), and embeddedness in sites 2, 4, and 12 on the Smith River, November – December, 1999. Means ± 2 SE are presented for each habitat attribute.

Site	n	Depth (cm)	Velocity (cm s^{-1})	Fines (scale: 0-3)	Embeddedness (scale: 0-2)
2	126	31 ± 3	23 ± 3	0.5 ± 0.1	0.8 ± 0.1
4	128	37 ± 4	22 ± 2	0.4 ± 0.1	0.4 ± 0.1
12	127	21 ± 2	36 ± 4	1.4 ± 0.2	1.4 ± 0.1

Table 2. Number of age-1+ brown trout tagged in the 12 study sites in June, 2000, number of tagged trout recaptured in August, 2000, and number of trout with undetectable tags (adipose fin clip but no tag could be found).

Site	Distance downstream from Philpott Dam (km)	Number tagged in June	Number recaptured in August	Number with undetectable tags
1	0.5	77	15	0
2	3.4	252	90	5
3	4.2	423	214	32
4	6.2	235	132	11
5	8.9	270	126	6
6	11.3	170	67	18
7	13.0	17	5	5
8	15.3	101	47	3
9	15.9	90	25	3
10	18.9	71	28	2
11	20.5	82	6	1
12	23.0	86	42	4

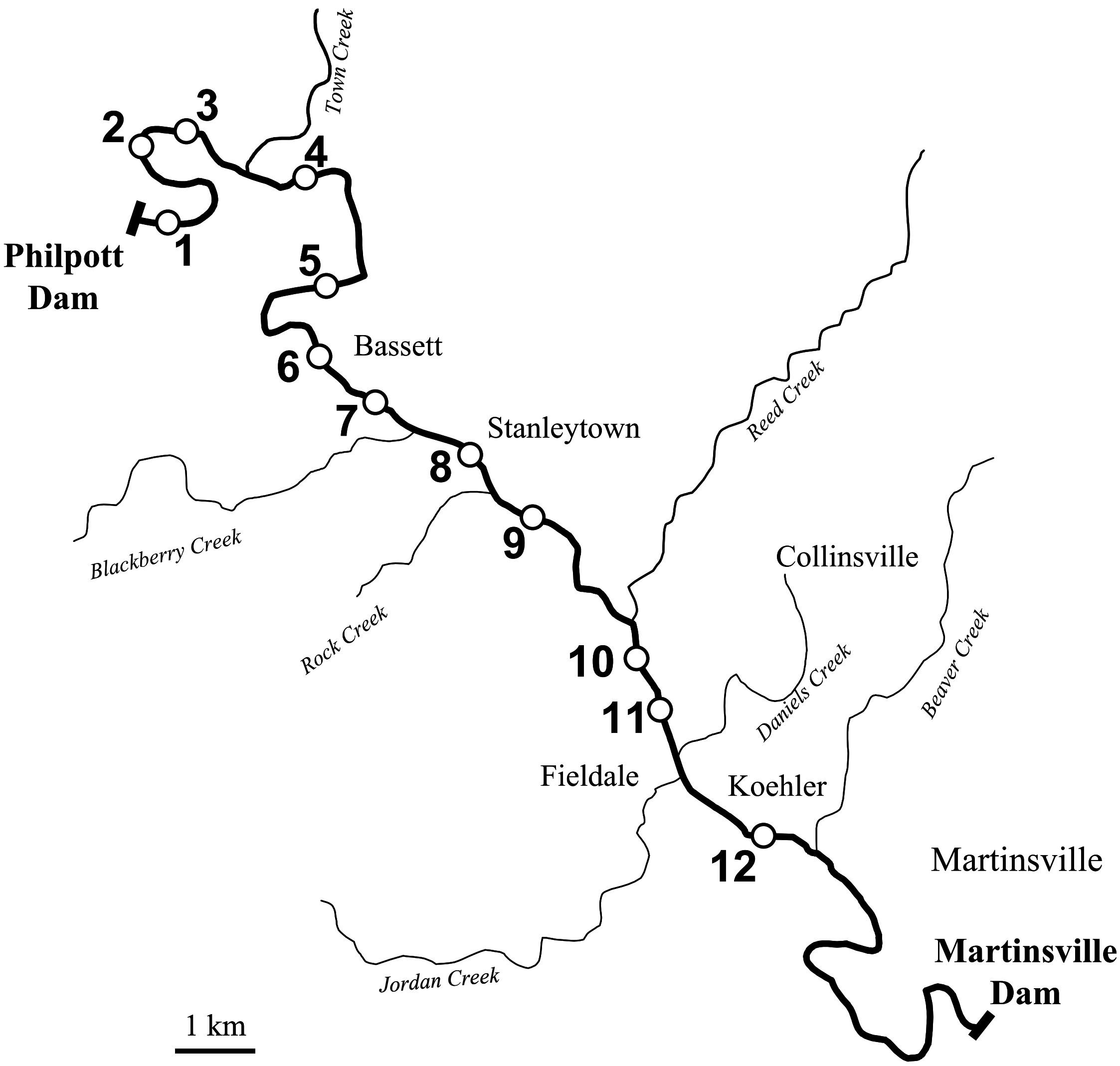

Figure 1. Map of the Smith River tailwater between Philpott Dam and Martinsville Dam with sampling sites numbered upstream to downstream.

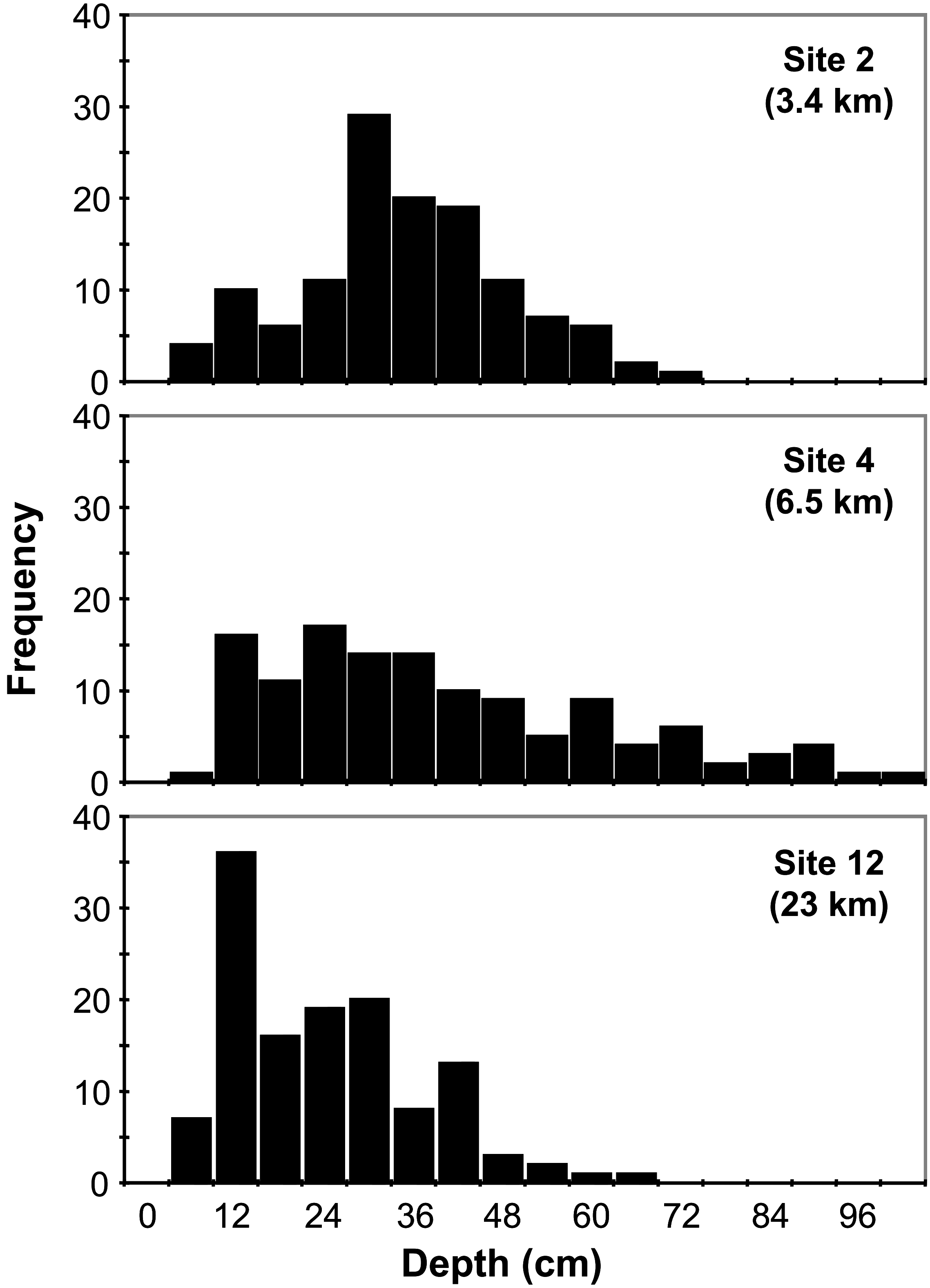

Figure 2. Frequency of depth measurements recorded in sites 2, 4, and 12 (3.4, 6.5, and 23 km downstream from Philpott Dam).

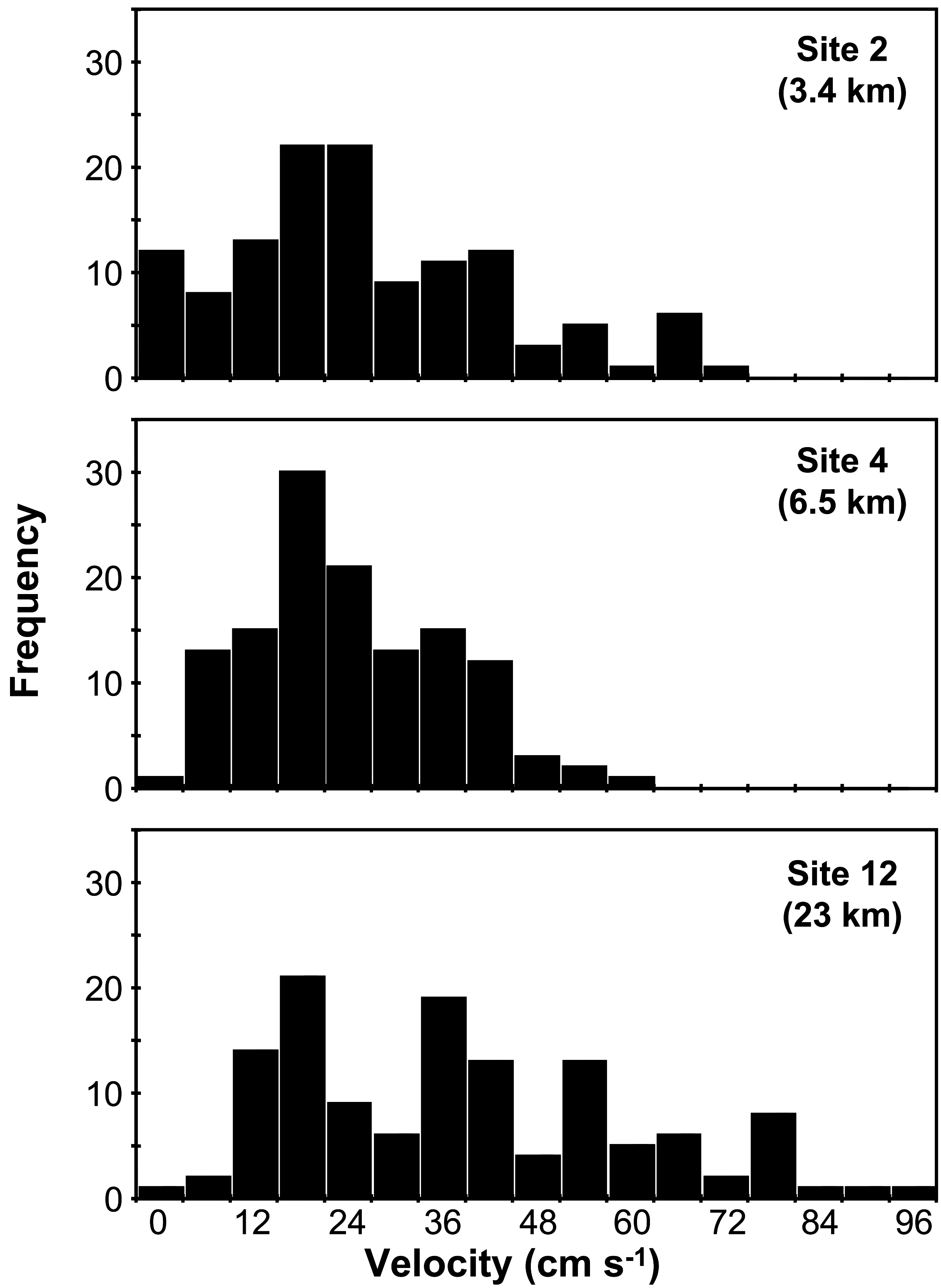

Figure 3. Frequency of velocity measurements recorded in sites 2, 4, and 12.

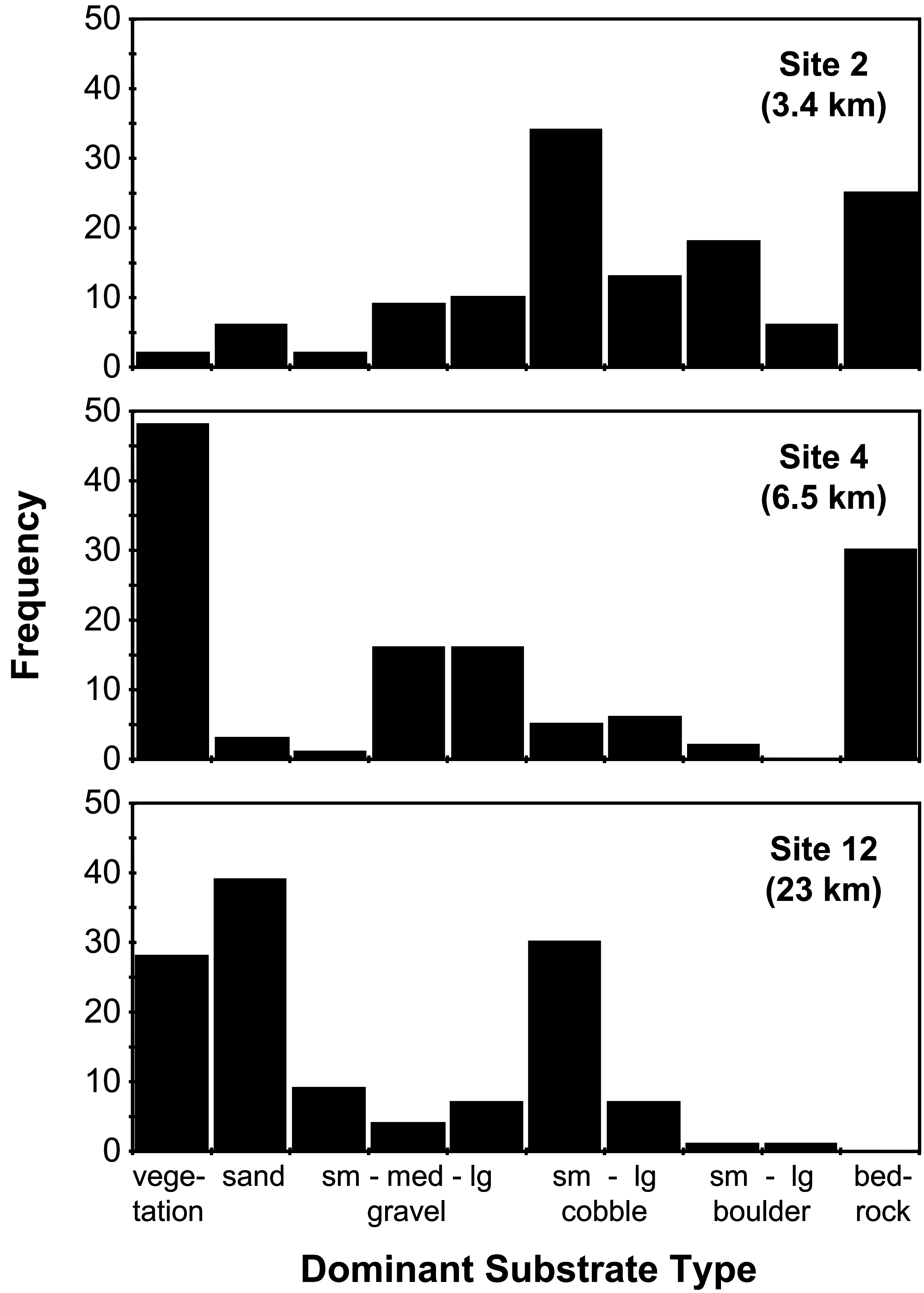

Figure 4. Frequency of dominant substrate types recorded in sites 2, 4, and 12.

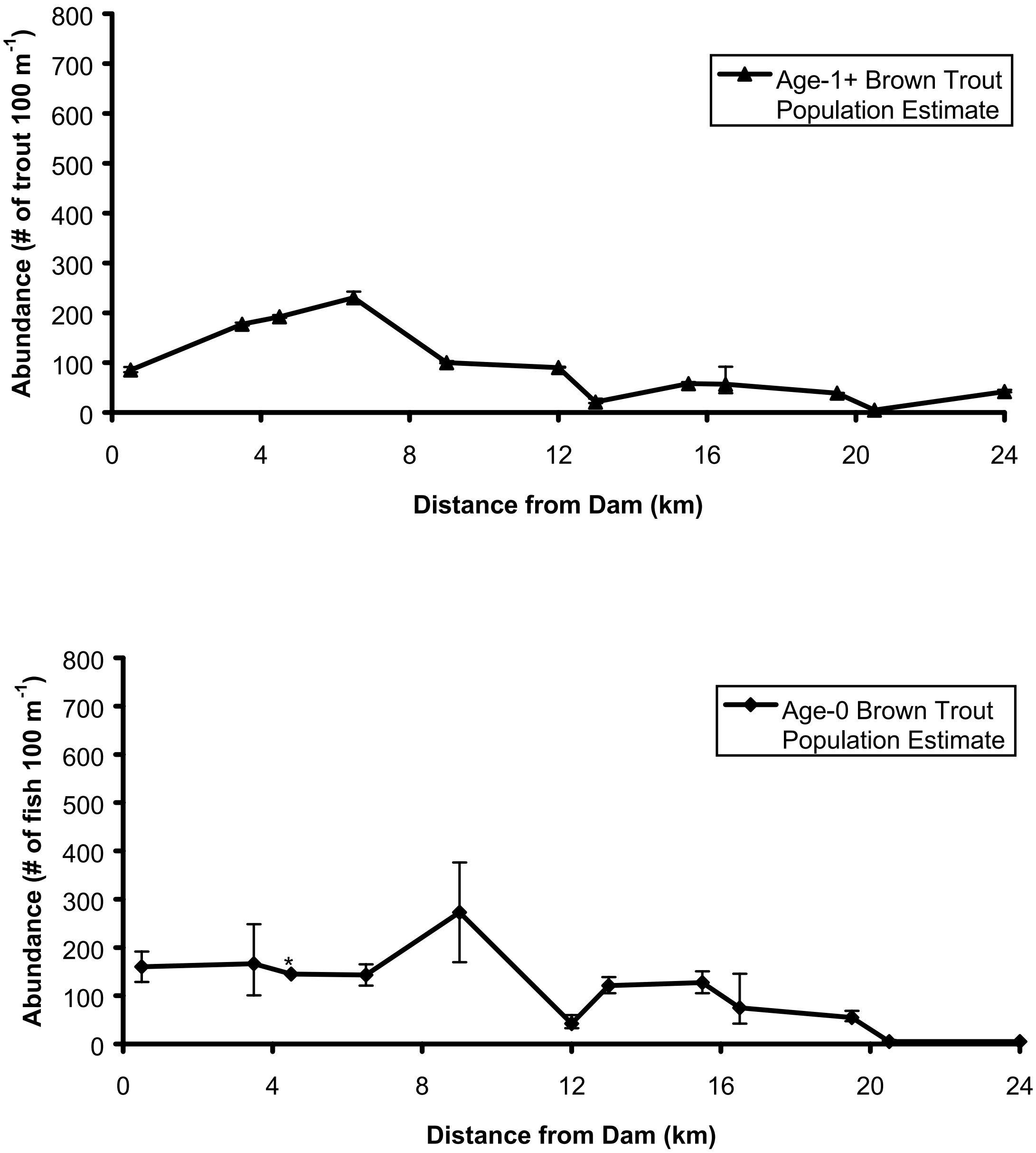

Figure 5. Population estimates (with 95% confidence intervals) for age-1+ (upper panel) and age-0 (lower panel) brown trout sampled by 3-pass depletion electrofishing in June, 2000. Asterisk indicates that the population estimate for the site is not reliable because of non-descending catch data.

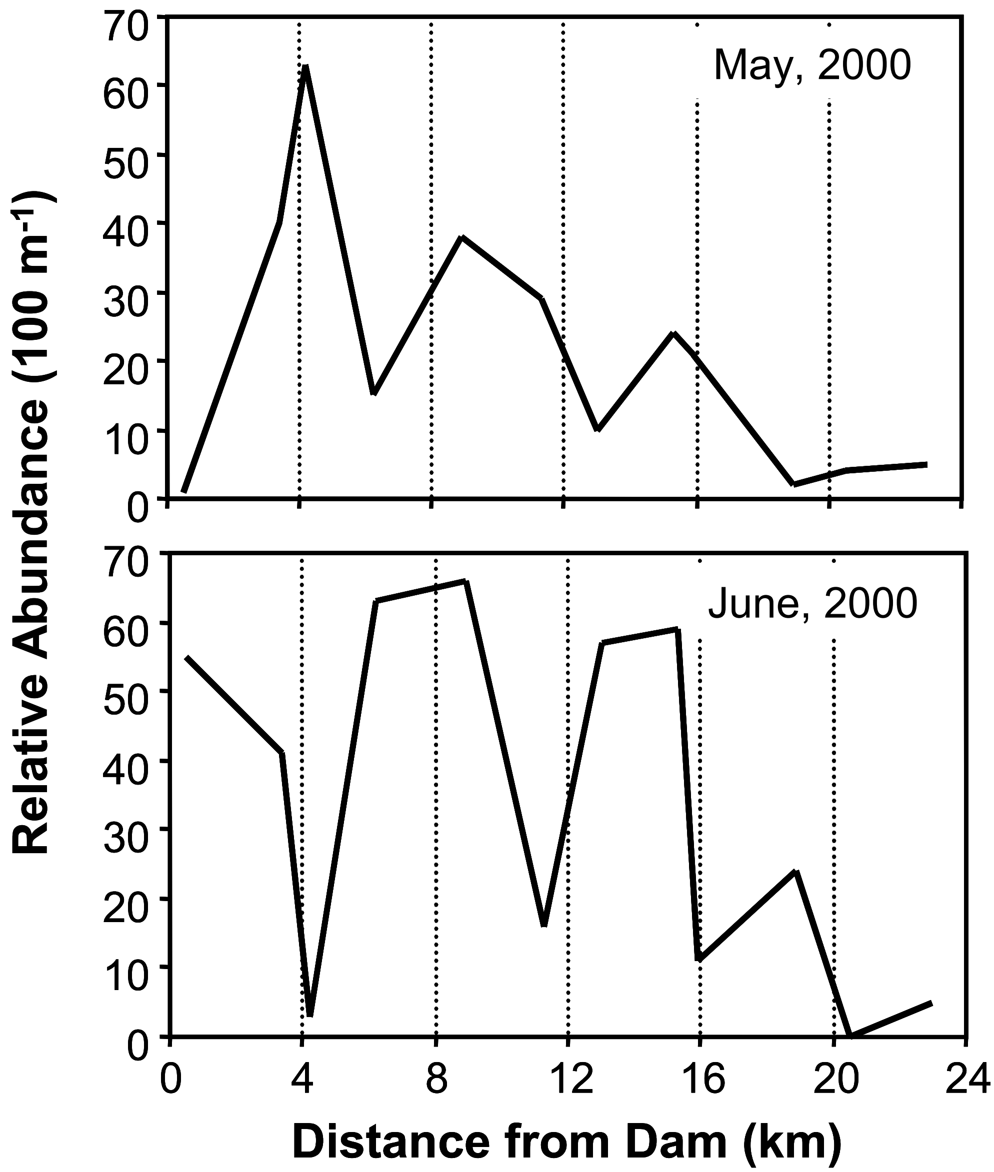

Figure 6. Relative abundance from single-pass electrofishing of age-0 brown trout in the12 study sites in May and June, 2000. Data for June constitute the first pass of a three-pass depletion sample.

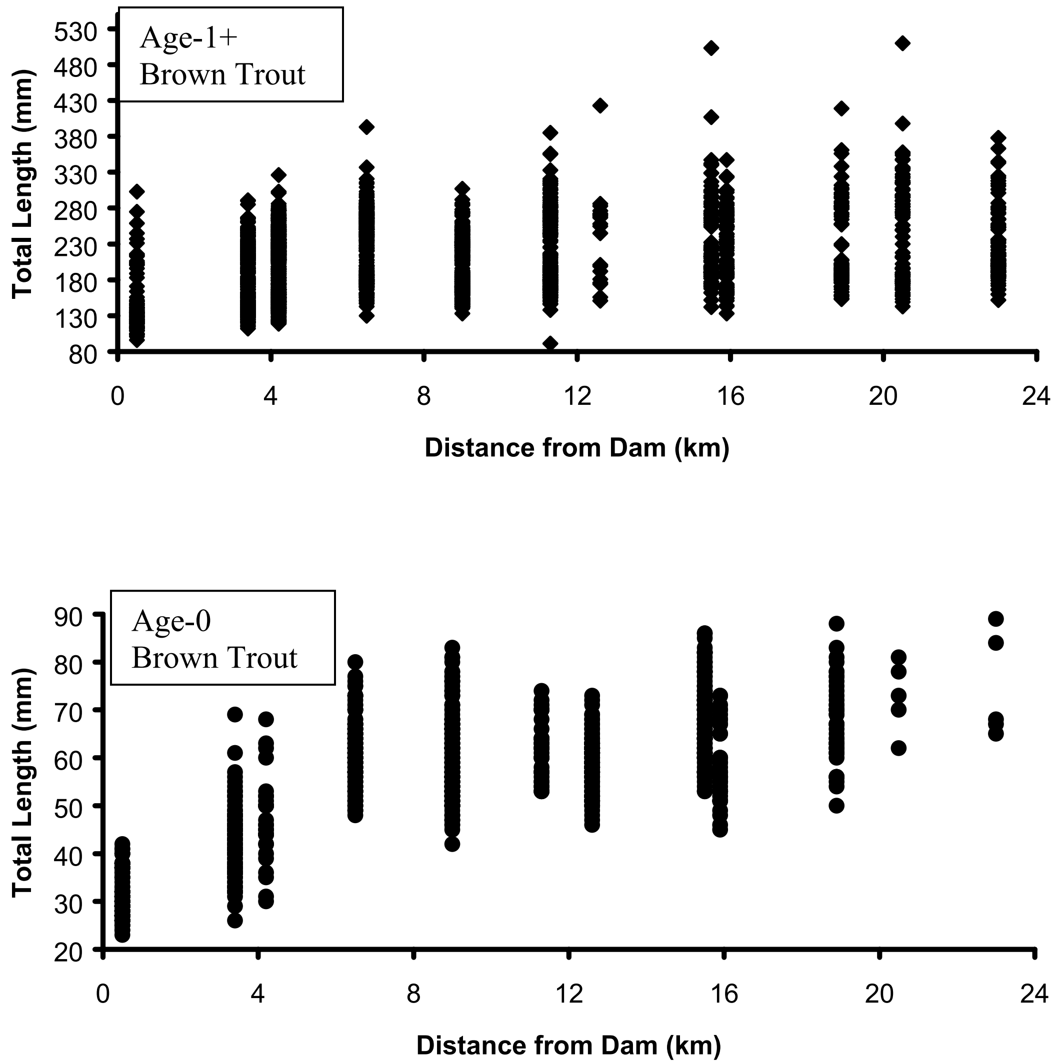

Figure 7. Total-length distributions for age-1+ (upper panel) and age-0 (lower panel) brown trout collected from 12 study sites in June, 2000.

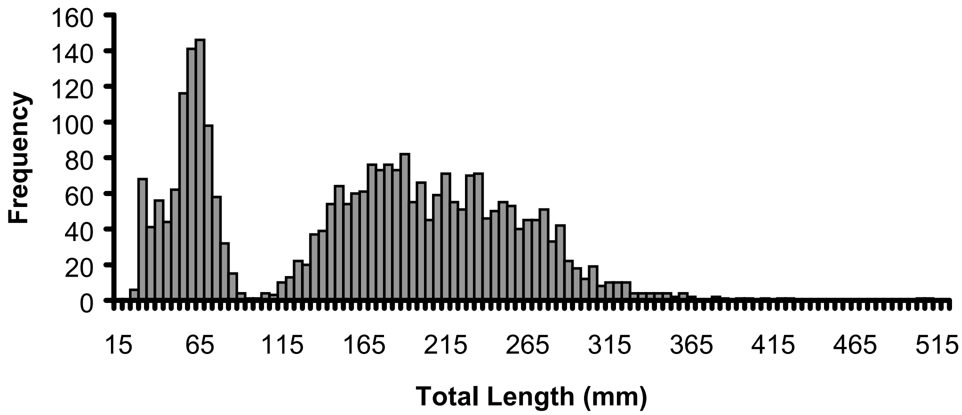

Figure 8. Length-frequency distribution for brown trout (n = 2,860) collected in the 12 study sites in June, 2000.

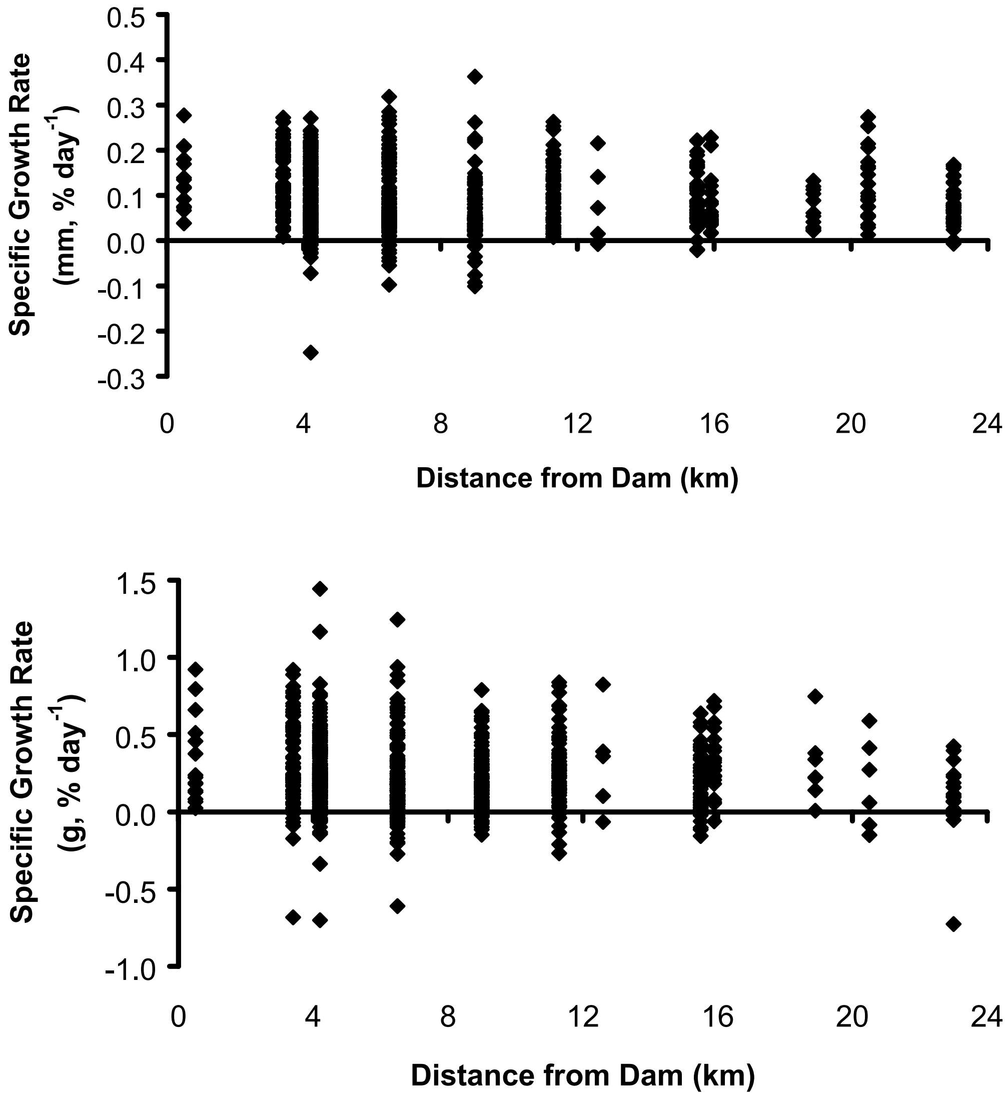

Figure 9. Specific growth rates in length (upper panel) and weight (lower panel) for tagged age-1+ brown trout between June and August, 2000 (42 days).

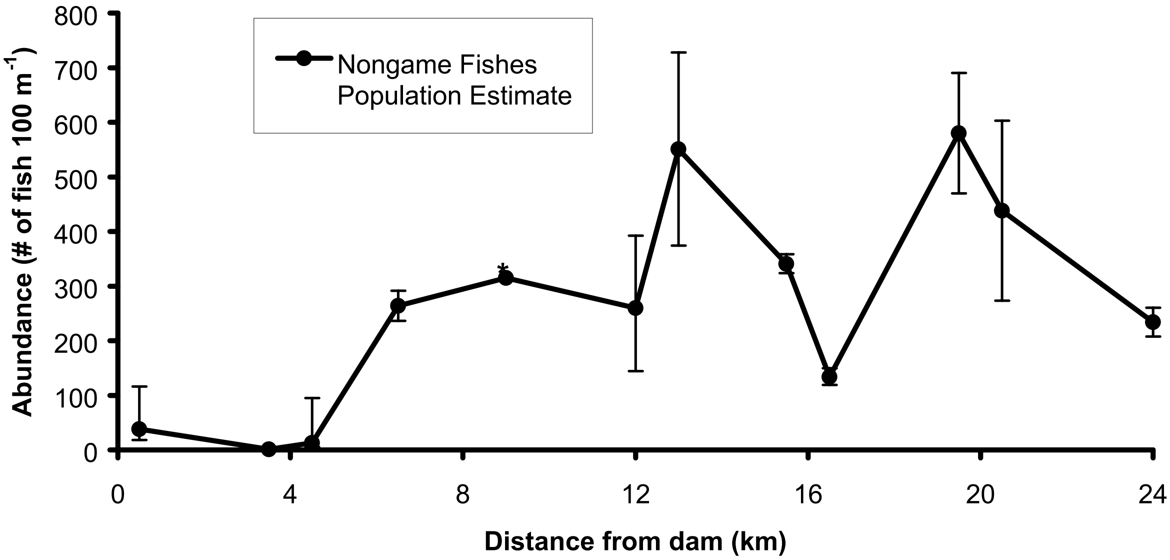

Figure 10. Population estimates (with 95% confidence intervals) for nongame fishes (in aggregate) in the 12 study sites in June, 2000. Asterisk indicates that the population estimate for the site is not reliable because of non-descending catch data.

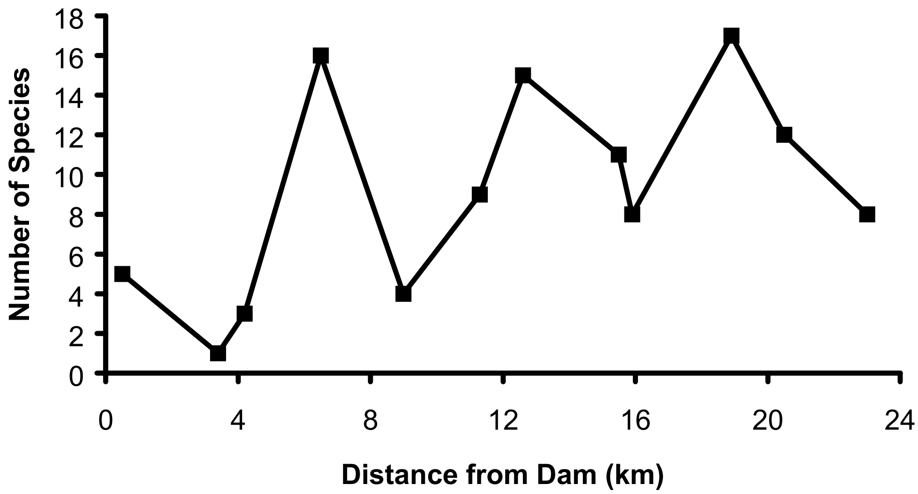

Figure 11. Number of nongame species in the 12 study sites in June, 2000.

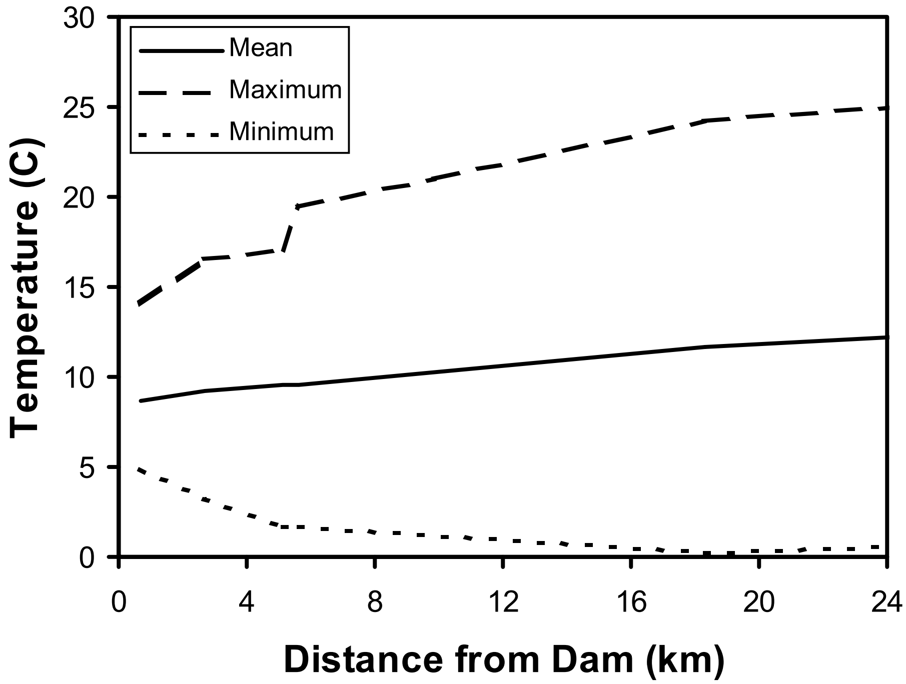

Figure 12. Annual mean, maximum, and minimum water temperatures recorded at 7 sites between July 15, 1999, through July 15, 2000.