Fish Assemblages in the Vicinity of the Cuddebackville Dam Site Prior to and After Removal of the Cuddebackville Dam

Final Report

Submitted by

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Executive Summary

In September, 2004, the southwest portion of the Cuddebackville Dam on the Neversink River was removed. The Academy of Natural Sciences (ANS) studied fish assemblages in the vicinity of the dam in 2004-2006 to investigate possible effects of dam removal and recovery from presence of the dam. Sampling was done at four stations, all containing similar cobble-boulder riffle habitats. Stations 1 and 2 were upstream of the dam site. Station 1 was physically unaffected by the dam removal. Station 2 contained the former impoundment of the dam, and the station showed large changes in habitat resulting from headcutting, sediment deposition and channel reworking following dam removal. Stations 3 and 4 were located downstream of the dam. While Station 3 and, to a lesser extent, Station 4, would be expected to show effects of sediment transport and deposition following dam removal, there were no obvious changes in channel morphology following dam removal. In addition to removal of the dam, the river experienced a large flood in April, 2005, so temporal changes in the riverine fauna could be due to geomorphic or other effects of the flood.

The primary sampling method was electrofishing 5x5 m patches of riffles using a backpack electrofisher. The sides and downstream ends of each patch were blocked with nets, and fish were collected within the sampling area during sampling or in the downstream block net at the end of sampling. Six samples (seven in one case) were taken in each station in each of the three years 2004-2006. Statistical analyses were done using year and station as main effects, microhabitat (average depth, velocity and substrate coarseness) as covariates and treating each sample as a replicate. Linear contrasts were used to test specific hypotheses of changes in specific stations following dam removal. Longnose dace made up 51% of all fish caught in these samples, and margined madtom, blacknose dace, and American eel comprised 33% of the fish caught in these samples. Statistical analyses of the abundance of these four species found no patterns of abundance attributable to response to dam removal, although there were significant differences among stations or years for some species, and several species showed significant relationships with microhabitat characteristics. Since the station and year effects occurred across all years or stations, respectively, they show inherent spatial or temporal differences rather than effects of dam removal. The abundance of longnose dace was negatively related to average depth in samples. The abundance of margined madtom was significantly related to station and average depth.The station difference was related to lower abundance at Station 2 relative to the other stations. The abundance of blacknose dace was significantly related to year and average velocity. The year effect reflected higher abundance in 2004 than in 2005 and 2006. The abundance of American eel was significantly related to year and substrate index. The year difference reflected higher abundance in 2004 than in the other two years.

Length-frequency histograms of fish caught in the small area samples showed two main modes for longnose dace, blacknose dace, and American eel, but no clear modal pattern for margined madtom. At Station 2, blacknose dace were primarily small (putative young-of-year), while there was a mix of sizes at the other stations. The relative proportion of small American eels also varied among stations and years, with the highest proportion at Station 3 in 2004.

Reach-level sampling was done with one or two backpack electrofishers in pool and riffle habitat in Station 2. Two passes in one area were taken in each year, and the total population was estimated from the pattern of catches in the two passes. In 2004, the sampling was done during the dewatering during dam removal. The sampling was done in a long reach which included the pool upstream of the dam and shallow riffles and run habitats. In 2005 and 2006, following changes in channel form after dam removal, the reach samples were taken in smaller pool-riffle habitats on the right channel around the island which had formed upstream of the dam site. Species composition was generally similar across the three years. Even before dam removal, the substrate of the upstream reach was coarse, and the reach did not contain species typical of large impoundments. In 2004, a number of relatively large brown trout and white sucker were caught in the pool immediately upstream of the dam. No large trout or sucker were caught in the other two years, but large individuals could have occurred in deep pool and run habitat which could not be sampled.

The pattern of occurrence of species upstream and downstream of the dam prior to removal did not provide strong evidence of blockage by the dam. Both American eel and sea lamprey were found upstream of the dam prior to removal. Comparisons of species occurrence and abundance upstream and downstream of the dam site following dam removal did not provide evidence of colonization of species across the dam site or loss of species resulting from the dam removal. The study was not directed at detecting migration of anadromous fish such as American shad, and sampling was not targeted at times and habitats to detect such migration. A skull of a herring, tentatively identified as a gizzard shad (possibly river herring or American shad) was found on a gravel bar in Station 2, upstream of the dam site. The occurrence could reflect upstream movement from downstream populations.

In summary, the study did not demonstrate any change in the fish assemblage in the immediate vicinity of the dam site attributable to the dam removal. There were major changes in the geomorphology of the reach upstream of the dam. While the location of individual habitat features changed, a mix of habitats was produced after dam removal. For example, the abundance and species composition of fishes in new riffle habitat was similar to that in similar riffle habitat prior to removal. More information on occurrence and movements of migratory fish will be necessary to detect effects of the removal on other species, such as American shad.

Introduction

Dams have pervasive effects on river systems. Even small dams can block upstream movement of organisms and modify hydrology and sediment transport downstream of the dam. These changes can translate into reduced diversity and nutrient inputs upstream of dams, geomorphological changes such as widening and armoring downstream of dams, and concomitant changes in biotic communities downstream of dams. Dam removal can be a powerful restoration activity, but the process of dam removal may impact streams as well. In particular, transport of materials accumulated in the impoundment of the dam may create downstream impacts through scour and deposition. Thus, monitoring before and after dam removal can show both transient effects of the removal and recovery of the system from dam removal effects and from the presence of the dam. The magnitude and timing of these effects is valuable in developing best management practices for dam removal.

This report documents studies of fish populations in the Neversink River in the vicinity of Cuddebackville Dam prior to removal (August, 2004), during removal (September, 2004) and after removal (2005 and 2006). Monitoring was done at stations upstream and downstream of the damsite. The before-after and upstream-downstream design allows separation of removal and recovery effects from intrinsic station differences or among-year variation in fish populations. This study was part of a larger study of removal effects (see Apse 2005).

Study Site and Sampling Stations

The Cuddebackville Dam was located on the Neversink River, 1.8 km upstream of the Route 209 bridge and 19 km upstream of the mouth. The dam was approximately 1.7 m high and consisted of two sections, each damming the channels on either side of an island. At its upstream end, the island was bounded by a small channel connecting the two main channels. Upstream of this channel was another island about 220 m long. The original design included removal of the segment on the right channel (the southwest dam) and building a rock ramp on the downstream face of the dam on the left channel (the northeast dam). Together, the removal and rock ramp would provide fish passage through both channels. Dam removal was done by building two coffer dams, one near the upstream end of the island (about 220 m upstream of the southwest dam) and the other across the small channel connecting the two main channels upstream of the dam. The first breaching and removal of the southwest dam was done on 15 September, 2004. However, on 18 September, 2004, a large storm associated with Hurricane Ivan raised river levels (to about 600 cfs at the Bridgeville gage upstream of the dam), so that the coffer dams failed to divert water from the right channel. Dam removal was completed in mid-October, 2004, under conditions with little water diversion from the right channel. Following the removal of the southwest dam, a large storm in April, 2005, raised river levels to about 20,000 cfs at Bridgeville (on 5 April, 2005). This storm had major effects on channel shape near the dam, including deposition of large amounts of sediment in the left channel upstream of the northeast section, so that most flow went through the open right channel. As a result, a rock ramp was considered unnecessary and was not built.

Sampling was done at 5 stations (Figure 1). Stations 1 and 2 were upstream of the Cuddebackville Dam and coffer dam. The reach at Station 2 between the upstream riffle and the dam experienced dewatering. Stations 3 and 4 were downstream of the dam and would be expected to show any physical effects of dam removal or recovery.

Station 1. This station was about 500 to 600 m upstream of the Cuddebackville Dam and consisted of the riffle located just upstream of a river bend. Channel morphology at Station 1 was apparently unaffected by dam removal, so the station is treated as a reference station with respect to physical effects of dam removal. However, the station could show colonization by species formerly restricted by the Cuddebackville Dam.

Station 2. This station included the 220 m reach starting just upstream of the Cuddebackville dam and ending at the site of the main coffer dam. The reach changed appreciably after dam removal, presumably due to headcutting upstream of the dam site. Before removal, the area consisted of a small pool just upstream of the dam and a run-shallow riffle sequence with a steep, high-velocity riffle at the upstream end. After removal, the reach changed to a mix of steep riffles and short pools. An island was formed within the station, with runs and steep riffles in the left channel and a steep riffle and pool in the right channel. The area between the downstream end of this island and the dam site was a riffle, in contrast to the pool-shallow riffle conditions prior to removal. In 2004, prior to dam removal, small area (5x5 m) sampling was done in the steep riffle at the upstream end of the station. This area was unsuitable for sampling after removal. In 2005 and 2006, the riffle between the dam site and the island was sampled. This riffle contained habitats similar to those sampled in 2004 and at the other stations.

Station 3. This station included the riffle downstream of the Cuddebackville Dam. The downstream end of the station was the confluence of the two main channels at the downstream end of the island at the dam site. This confluence was about 100 m downstream of the dam site. This station would be expected to show effects of dam removal related to sediment transport and scouring. However, the general appearance of the station did not appear to change greatly following dam removal.

Station 4. This station included the long riffle downstream of station 3. Station 4 was located about 125 to 225 m downstream of the dam site and was downstream of the junction of the left and right channels.

Station 5. Station 5 consisted of the pool and stream downstream of the dam at the left channel of the river, i.e., downstream of the northeast portion of the Cuddebackville Dam (which was not removed). Flow through this channel decreased after dam removal, presumably due to deposition of sediment in the channel upstream of the dam. Limited sampling was done at this station.

Methods

Sampling methods

The study design (Table 1) included two primary methods and some additional sampling. The primary technique was small area sampling, in which small areas within riffles at each station were sampled for each of the three years. This technique provides the primary technique for detecting effects of dam removal and recovery across the study site. Reach-level sampling was done in areas upstream of the dam site in each of the three years. These samples provide information on changes in fish assemblages in the former impoundment area, including possible colonization by species from downstream following dam removal.

Small-area sampling. Electrofishing was done in 5x5 m areas within riffles in each of the four main stations. Sample sites were selected to include a range of depth and velocity conditions, excepting very fast, deep riffles, which could not be sampled. Six samples were taken at each of the stations 1-4 in each year, except that eight were taken at Station 1 in 2005. Three sides of each sampling area was blocked during sampling. A 6.2 m (0.31 cm mesh) bag seine was fixed at the downstream end of the area, and nets were placed along each side. Backpack electrofishing was done within this area, using a Smith-Root electrofishing unit, with voltage and current settings adjusted to effectively stun fish with minimum mortality. Stunned fish were collected with a dip net during the electroshocking, and fish washed into the block net were collected from the downstream block net at the end of sampling. Measurements of depth and current velocity (at 60% of depth) and notes on substrate types, algal and macrophyte cover were taken at 5 evenly-spaced points within each sampling area. One point was located at the center of the area, and four points were located 0.86 m from each edge of the area.

Reach-level samples. During each year, a reach upstream of the former dam site was sampled using two backpack electrofishers. Two passes were made through each area, so that estimates of the total number of fish in the area could be made based on the pattern of abundance in the two passes. In 2004, the reach between the dam and the coffer dam was sampled. The area consisted of the small pool upstream of the dam, and upstream run and riffle habitat.The two dams formed blocks preventing escape of fish from the area. Sampling was interrupted during the first pass, which may have allowed fish from the unsampled (upper) part of the area to move into the downstream area, which had been sampled. Following removal of the dam, the morphology of the area changed greatly. In 2005, an area on the right channel around a newly formed rock bar was sampled. A block net was placed at the downstream end, and a steep riffle formed a barrier at the upstream end. The same general area was sampled in 2006, as well.

Fish Handling. An attempt was made to capture every fish observed during sampling. All captured fish were identified, enumerated, measured (total length) and tabulated. Most fish were processed in the field and returned alive. A few fish were preserved in 10% formalin as voucher species or to allow laboratory identification. In the laboratory, preserved fish were transferred to 70% ethanol after a water rinse.

Search for stranded fish and mussels. On 14 September, 2007, visual search of the river channel was made during drawdown of the river downstream of the coffer dam and upstream of Cuddebackville Dam. The search collected mussels for relocation. In addition, dead or moribund fish were noted

Statistical analyses

Variables. Density of fish in the small area (5x5 m) samples was expressed as number of fish per 25 m^2 (equivalent to number of fish per sample). For statistical analyses, the transformed density

$$LD = \ln(D+1)$$

was used, where D is the untransformed density.

The average of depth and velocity measurements at the 5 points within each sampling area were used as measures of microhabitat characteristics. An ordinal scale of substrate (ranging from boulder through silt) was calculated, and the average of these numbers was used as the average substrate in the area. The maximum depth within each sampling area was also used.

Small area (5x5 m) samples. The patterns of abundance were compared using general linear models testing year, station, year-station interactions and microhabitat relationships (average depth, average velocity and substrate coarseness index). Final models were selected which included only significant terms. Pairwise comparisons of years and stations were done using the HSD unequal-n test on unweighted means, and by linear contrasts on least squares means (least squares means are adjusted for the effects of continuous variables). Specific linear contrasts for stations were: upstream vs downstream stations (1 and 2 versus 3 and 4), and Station 3 vs other stations. Specific linear contrasts for year was pre-removal versus post-removal (2004 versus 2005 and 2006). Specific effects of dam removal would be shown as differences at some stations only after dam removal. Statistically, these would be seen as significant year-station interactions, with specific linear contrasts testing the before-after control-treatment effects, i.e., that the difference between upstream and downstream stations differs between the pre-removal and post-removal samples.

This method of analysis treats samples from different parts of the same station at the same date as independent samples. These samples are pseudo-replicates, and correlated response to the “treatment” (dam removal) among these samples may decrease apparent variability. To the extent that this correlation is present, these analyses would overestimate statistical significance of apparent differences.

Reach samples. The two passes taken in each of the three reach samples was used to estimate total population size, using maximum likelihood depletion estimates for each species (performed with MicroFish for windows). Where only one fish of a species was caught or all fish were caught in the first pass, the population was assumed to be the total number caught. Where the pattern of removals prohibited estimation of abundances (e.g., more fish caught on second pass than first), the total abundance was arbitrarily set at 1.5 times the total number of fish caught.

The abundances were standardized to the number of fish per 100 m of shoreline sampled.

Results

Pattern of species occurrence among all samples. A total of 3763 fish of 19 species was caught in the three years of sampling (Table 2). The most common species were longnose dace, blacknose dace, cutlip minnow, American eel, and margined madtom. There were a few patterns of occurrence consistent with effects of the dam or dam removal upstream or downstream of the dam. However, these involved rare species, so their presence or absence provides little support for any real effect of the dam or its removal. The only species found downstream of the dam but not upstream prior to removal (i.e., in 2004) was golden shiner, a species typically found in pools and ponds. A single golden shiner, was caught at Station 4 in 2004. Rock bass was the only species found upstream of the dam only after removal. Two specimens, the only ones caught in the entire study, were caught at Station 2 in 2005. Thus, the results provide little evidence for blockage of fish by the dam or upstream colonization after removal. Redbreast sunfish, sea lamprey, smallmouth bass, largemouth bass, golden shiner and brown trout were the only species found downstream off the dam prior to removal, but not after. Five or less specimens of each of these species was caught. No species was found downstream of the dam only after dam removal.

Observations during dewatering

On 14 September, 2004, the partly dewatered area in the right channel (between the upper coffer dam and the confluence of the two main channels) were searched for mussels and for stranded fish. Three dead margined madtoms (4.4-7.5 cm total length), 21 blacknose dace (3.2-7.0 cm total length), and two tesselated darters (4.8 cm total length) were observed within the dewatered area. In addition, 8 margined madtoms, 4 sea lampreys, two longnose dace and three crayfish were captured and released into deeper water.

Small area sampling

A total of 15 species were caught in the small area (5x5 m) samples (Table 3, Figures 2-9). The most common species were longnose dace (51% of all fish), margined madtom (12%), blacknose dace (11%), and American eel (10%). A few uncommon species (brown trout, common shiner, golden shiner, redbreast sunfish and sea lamprey) were collected only at the downstream stations (Stations 3 and 4), while the smallmouth bass was caught only upstream of the dam. Shield darter was the only species showing a pattern of occurrence suggestive of response to dam removal: it was found at Stations 3 and 4 in all three years of study, but was caught at Stations 1 and 2 only after removal (at Station 1 in 2005 and 2006 and at Station 2 in 2006). However, shield darter was found in reach samples at Station 2 prior to removal.

Statistical analyses of the abundance of the four most common species found no patterns of abundance attributable to response to dam removal, although there were significant differences among stations or years for some species, and several species showed significant relationships with microhabitat characteristics. Since the station and year effects occurred across all years or stations, respectively, they show inherent spatial or temporal differences rather than effects of dam removal. The abundance of longnose dace was not significantly related to year, station or year-station interactions. The abundance of longnose dace was negatively related to average depth ($p<0.0000001$) in samples. The abundance of margined madtom was significantly related to station ($p<0.041$) and average depth ($p<0.040$).The station difference was related to lower abundance at Station 2 relative to the other stations. There were significant linear contrasts of the abundance at Station 2 versus all other stations ($p<0.0051$), stations 1 and 3 ($p< 0.0051$), and versus 3 and 4 ($p<0.012$). The least squares means (i.e., station means adjusted for the depth effect) and unadjusted means showed the same pattern, indicating that the depth relationship reflected differences in microhabitat among samples within stations, rather than differences in microhabitats at stations. The abundance of blacknose dace was significantly related to year ($p<0.013$) and average velocity ($p<0.0017$). The year effect reflected higher abundance in 2004 than in 2005 and 2006. The linear contrast of 2004 versus 2005 and 2006 was highly significant ($p<0.0038$). The least square means were similar to the unadjusted means. The abundance of American eel was significantly related to year ($p<0.011$) and substrate index ($p<0.0051$). The year difference reflected higher abundance in 2004 than in the other two years, as demonstrated by the highly significant ($p<0.0029$) linear contrast between 2004 and the other two years.

All fishes captured were measured, so that length-frequency distributions can be calculated (Figures 6-9). Longnose dace and blacknose dace showed two main modes, likely corresponding to young-of-year (mode 4-5 cm in blacknose dace and 5-6 cm in longnose dace) and older fish (mode 6-7 cm in blacknose dace and 9-10 cm in longnose dace). Most blacknose dace caught at Station 2 were small (less than 5 cm total length), while other stations showed a mix of sizes. The size distribution at Station 2 differed among years. There was also a difference among years, with small fish (less than 5 cm) comprising 68% of the total in 2004, 81% in 2005 and 7% in 2006. Blacknose dace were much more common in 2004 than the other years, so the station difference largely reflects patterns in 2004. In 2004, small blacknose dace were least common at Station 3 (43%) and most common at Station 2 (86%). In 2005, all blacknose dace at Station 2 were less than 5 cm, while there none in this size group at Station 3. Although the length frequencies vary among stations and years, the differences do not fit simple models of dam removal effects. There was no clear difference in length frequency distributions of longnose dace among station. Only one mode of margined madtom was evident (9-12 cm total length), with no clear station difference. American eel showed two main modes, at 15-21 cm and 36-41 cm. The record of one 6.5 cm fish possibly and error (correct length possibly 16.5 cm), since eels generally reach 6.5 cm in length soon after arrival in freshwater. There were apparent differences in length-frequency distribution among stations, with no eels less than 16 cm at Station 1 or 4. The proportion of small eels (less than or equal to 20 cm total length) varied among years and stations. For most cases, proportions were between 0.16 and 0.25. Smaller proportions were seen at Station 1 in 2005 (0.05), Station 2 in 2004 (0) and Station 4 in 2005 (0). The highest proportions were seen at Station 3 in 2004 (0.875, including the 6.5 cm fish as less than 20 cm) and Station 2 in 2006 (0.6). The number of eels caught was relatively small for a number of these comparisons, so these proportions are not very precise). The high proportion of small eels at Station 3 in 2004 (14 of 16, including at least 6 less than 16 cm) is notable.

<u>Reach samples</u>

In each year, paired (depletion) samples were taken in the reach upstream of the dam site (Figure

10). Total populations in the sampling areas were estimated from the pattern of catches in the pairs (Table 4, Figures 11-12). In 2004, a large reach was sampled which included the pool upstream of the partially-removed dam, and riffle and run habitats upstream of this pool. Catches from these two habitats were tabulated separately on the first pass. They were not separated on the second pass, so that depletion estimates are for the entire reach. For comparison among the three sets of samples, population estimates were normalized (Tables 5 and 6) to the length of the sample reach (all three years) and the area of the sample reach (2005 and 2006 only). Longnose dace, blacknose dace, tesselated darter, American eel, cutlip minnow and margined madtom were common in all three years, although the proportions of catch varied somewhat among years. The impoundment area of the dam had been small, with predominantly coarse sediment. With the exception of a single specimen of largemouth bass, fish species typical of larger impoundments (e.g., common carp, bluegill, golden shiner) were not found. For several species, the catch patterns did not allow accurate depletion estimates. These occurred where there was a non-descending pattern between passes, precluding estimation (Nde in Table 7), or catches were similar in the two passes, resulting in low estimated capture probabilities (Figure 13) and large confidence intervals of the population estimates (Figure 12). As a result, it is difficult to compare populations among the three years. However, there did appear to be differences in densities of white suckers and brown trout, which were common in the 2004 samples but rare in the 2005 and 2006 samples. Both species were especially common in the pool upstream of the impoundment in 2004. Large individuals of both species were found in the 2004 sample, mainly in the pool upstream of the dam. Nine of the 190 white suckers measured from the 2004 samples at Station 2 were greater than 30 cm in total length, and 42 were greater than10 cm in length. The 34 brown trout measured in the 2004 samples ranged from 20.0 to 40.0 cm, with 7 fish 30 cm or greater in total length. The only trout caught in the later samples was a 20.1 cm fish caught in 2005. All white suckers caught in 2005 and 2006 were less than 10 cm in length. The absence of larger trout and suckers in the later sampling may partly reflect differences in habitat structure and sampling conditions between the 2004 and later samples. There were large changes in channel shape after 2004. In the 2005 and 2006 samples, an island was present in the station, with pool habitat at the base and in the right channel. The left channel had deep riffle and run habitats. Only the pool in the right channel of the island could be sampled, and large fish may have been present in other parts of the pool and in run habitats in the left channel. Only two species, rock bass and fallfish, were caught only after 2004. Two species of fish, largemouth bass and swallowtail shiner, were caught only in 2004. However, these were caught in small numbers and do not provide strong evidence of loss or colonization of the former impoundment habitat following dam removal.

Discussion

Changes in biotic communities following dam removal will be a combination of effects of the dam removal, recovery from the presence of the dam, and temporal changes not caused by the removal. Effects will occur over different time scales. Effects of dewatering would have occurred in the few days prior and during the first breaching (the dam was fully removed under higher flow conditions following partial failure of the upstream coffer dam), and loss of impoundment habitat would occur during removal. Upstream movement of fish following removal of the barrier could start almost immediately after removal. In a study of removal of a small dam on Manatawny Creek in Pennsyvlania, Horwitz (unpubl. data) found upstream movement within a few weeks after removal, based on recovery of fish tagged below the dam. Erosion of sediments from the former impoundment may occur episodically with spates following dam removal. This erosion can have effects on downstream communities by scouring and by deposition deposition. Habitat structure may be greatly affected by deposition, but subsequent storms can wash sediments further downstream, restoring habitat characteristics. Geomorphic recovery from the dam presence is expected to take a number of years, involving narrowing of the channel upstream and downstream of the former dam, growth of riparian vegetation, and stabilization of instream habitat structure. Many aspects of removal effect and recovery have been studied by TNC and other groups, including mussel mortality, changes in geomorphogy chemistry, and diatom assemblages (Apse 2005, Eichman, et al. 2006). Potential effects on fishes are discussed here, with discussion of observed changes in channel form observed during fish sampling.

Mortality during dewatering

Even during dewatering, substantial areas of refuge habitat remained in the deeper parts of the channel. As a result, extensive fish stranding and mortality would not be expected. Observations upstream and downstream of the dam during dewatering recorded 26 dead fish of three species. While it is unlikely that all mortality was documented, coverage of shallow water (where stranding would occur) was thorough. Based on captures in the reach the following day and estimated population sizes, these represent a small proportion of fish in the reach.

Loss of impoundment habitat

Prior to removal, the impounded pool was relatively small because of the relatively low height and width of the dam relative to channel gradient and width. A number of trout, white sucker and American eels were caught in this pool during dewatering. While some of these fish may used habitats upstream of the pool prior to dewatering, it is likely that the pool had provided habitat for many of these fish prior to dewatering. All of these species are typical of riverine conditions. It is likely that few fish typical of ponds were present even before removal. Similarly, deeper habitats occurred in at the base of the dam prior to removal; this area could not be sampled. Both pools disappeared with removal of the dam. However, deep pool habitats were created upstream of the dam site. During sampling in 2005 and 2006, areas of about 2 m in depth were present at the base of an island which had formed upstream of the dam site. While portions of pool habitat were sampled by the reach sampling, the deeper parts of the pool could not be sampled. It is expected that channel form and habitat conditions upstream of the dam will continue to change, so the ultimate amount of pool habitat cannot be predicted.

Creation of riffle habitat

With removal of the dam, it is expected that a pool-riffle-run structure will form in the area upstream of the damsite. In 2005 and 2006, a variety of such habitats were present upstream of the dam. The riffle habitat which had been sampled at Station 2 prior to removal was faster and deeper after removal, but habitat was present just upstream of the dam site which was similar to the habitat sampled in 2004. The small area sampling in 2004-2006 did not find any patterns of occurrence or abundances indicating changes of fish assemblages in these riffle habitats due to the dam removal. While blacknose dace and American eel were less abundant in the post-removal samples, the decrease was seen across stations, including Station 1, which was unaffected by the removal.

Upstream movement of fish

Removing a barrier to upstream migration of fish was a primary goal of the dam removal. Removal could result in increased movement of species partly blocked by the dam or new presence of species completely blocked by the dam. Two of the species collected are clearly migratory. Adult sea lamprey ascend rivers to spawn, and juvenile American eels, born in the ocean, ascend rivers. Mature adult American eels migrate downstream. Both species are generally able to ascend or bypass many barriers, by climbing the face of dams, following cracks in dams or climbing around dams. However, dams may provide partial blocks to movement. Both species were found upstream of the dam in 2004, so neither were fully blocked by the dam. American eel decreased at all stations in 2005-2006, providing no evidence of increased abundance upstream of the dam after removal. The proportion of small eels (less than or equal to 20 cm) was higher at Station 3 in 2004 than in any other year-station group. This might be related to the presence of the dam, e.g., small eels may have had more difficulty ascending the dam and tended to accumulate near the base of the dam. Similarly, the relatively high proportion fo small eels at Station 2 in 2006 could reflect greater ability to move upstream after dam removal. However, this pattern was not consistent among all the pre- and post- removal stations and years and is speculative. Larval sea lampreys were caught upstream of the dam in all three years. The larvae (ammocoetes) are found in depositional areas with fine substrates. The small area sampling of riffles did not sample such habitat, and suitable areas were local in the reaches sampled at Station 2. There have been reports (C. Apse, pers. comm.) of increased numbers of adult sea lampreys upstream of the Neversink Gorge, well upstream of Cuddebackville, suggesting that increased passage may have occurred. Upstream movement of American shad was one of the specific goals of the dam removal. This program was not designed to detect passage by American shad. Pre-spawning upstream and post-spawning downstream movement of adults occurs in spring and downstream movement of juveniles occurs in late fall, so the sampling times for this program would be unlikely to detect passage. In 2006, a skull of a clupeid (herring and shads) was found on a gravel bar at Station 2. This was tentatively identified as a gizzard shad, which is most likely to have occurred through upstream migration.

Factors unrelated to dam removal

The consistent station or year differences for some species demonstrate effects unrelated to dam removal. In particular, the abundance of American eel and blacknose dace decreased in 2005 and 2006. While the cause of these decreases cannot be determined, they might be related to the major flood which occurred in the Neversink in April, 2005. This could have affected fish by impeding upstream movement (e.g., of juvenile American eels in spring), by producing unsuitable spawning conditions for early spring spawners (blacknose dace typically spawn in late April or May), by washing small fish downstream, or by reduction of habitat suitability or food conditions.

Literature Cited

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Table 1. Summary of study design for 2004-2006 ANSP Cuddebackville dam removal study.

Type	Dates and number	2004	2005	2006
Small area (5x5 m) samples				
	Dates	26-27 Aug.	13-15 Sept.	25-28 Sept.
	Number of samples	24	26	24
Reach samples				
	Dates	15 Sept.	14 Sept.	28 Sept.
Other				
	Observation of stranded fish and mussels	14 September at Stations 2 and 3		
	Dip net samples	1 at Station 2 1 at Station 3		
	Backpack electrofishing sample	1 at Station 4		
	Tow-barge electrofishing	1 at Station 5		

Table 2. Numbers of fish caught by all techniques in 2004-2006 ANSP Cuddebackville Dam Removal study.

		Upstream of Dam Site							Downstream of Dam Site							TOTAL
Station		1			2			2-3	3			4			5	
Year		2004	2005	2006	2004	2005	2006	2004	2004	2005	2006	2004	2005	2006	2004	
Ambloplites rupestris	Rock bass					2										2
Anguilla rostrata	American eel	20	27	13	128	39	57		15	5	14	16	4	13	22	373
Catostomus commersoni	White sucker	1	2	1	137	2	1			6		8	8		9	175
Etheostoma olmstedi	Tesselated darter	2	1	2	103	6	14	2	2	7	5	2	4	3	21	174
Exoglossum maxillingua	Cutlip minnow	8	9	14	212	15	75		10	1	7	6	2	1	22	382
Lepomis auritus	Redbreast sunfish				5		1		2			2			5	15
Lepomis macrochirus	Bluegill														1	1
Luxilus cornutus	Common shiner			4	66	15	38	1	8	10		2	4		5	153
Micropterus dolomieu	Smallmouth bass		3		12	16	12					1			3	47
Micropterus salmoides	Largemouth bass		1		1							1			1	4
Notemigonus crysoleucas	Golden shiner											1				1
Notropis procne	Swallowtail shiner				1										3	4
Noturus insignis	Margined madtom	13	14	15	93	25	57	12	15	12	22	22	10	15	9	334
Percina peltata	Shield darter		6	5	10	7	21		11	3	8	23	4	4	14	116
Petromyzon marinus	Sea lamprey		2		25		1	4	3			4			27	66
Rhinichthys atratulus	Blacknose dace	29		9	277	145	163	21	55	2	3	14	4	1	11	734
Rhinichthys cataractae	Longnose dace	57	37	35	291	90	224	2	44	47	34	25	161	85		1132
Salmo trutta	Brown trout				27	1			1							29
Semotilus corporalis	Fallfish	1	2		1	1	1		2	1			9		3	21
TOTAL		131	104	98	1389	364	665	42	168	94	93	127	210	122	156	3763

Table 3. Average number of fish per sample collected in 5x5 m small area electroshocking sampling at each of four stations during the years 2004, 2005, and 2006.						
Common Name	Scientific Name	Station 1	Station 2	Station 3	Station 4	Average
American eel	*Anguilla rostrata*	3.02	1.17	1.89	1.72	1.95
Blacknose dace	*Rhinichthys atratulus*	2.11	2.00	3.28	1.06	2.11
Brown trout	*Salmo trutta*	0	0	0.06	0	0.01
Common shiner	*Luxilus cornutus*	0.22	0.22	1.00	0.22	0.42
Crayfish	*Orconectes limosus*	0	0	0.08	0.07	0.04
Cutlip minnow	*Exoglossum maxillingua*	1.65	0.44	1.00	0.44	0.88
Fallfish	*Semotilus corporalis*	0.06	0	0.17	0.5	0.18
Golden shiner	*Notemigonus crysoleucas*	0	0	0	0.06	0.01
Longnose dace	*Rhinichthys cataractae*	6.87	10.39	6.94	15.06	9.82
Margined madtom	*Noturus insignis*	2.22	1.67	2.97	2.61	2.37
Redbreast sunfish	*Lepomis auritus*	0	0	0.11	0	0.03
Sea lamprey	*Petromyzon marinus*	0	0	0.06	0.11	0.04
Shield darter	*Percina peltata*	0.56	0.28	1.22	1.72	0.95
Smallmouth bass	*Micropterus dolomieu*	0.14	0.06	0	0	0.05
Tesselated darter	*Etheostoma olmstedi*	0.27	0.11	0.78	0.39	0.39
White sucker	*Catostomus commersoni*	0.11	0	0.33	0.5	0.24
TOTAL		17.25	16.33	19.88	24.46	19.48

Table 4. Captures and estimated total number of fish in depletion samples at Station 2 in the ANSP Cuddebackville Dam Removal study. Italics indicate species with larger catches in pass 2, so that depletion estimates could not be made; 1.5 x the total catch was arbitrarily used as estimates for these species.

Common Name	Scientific Name	9/15/2004				9/14/2005			9/28/2006		
		Pass 1 Pool	Pass 1 Upstream riffle-run	Pass 2	Est	Pass 1	Pass 2	Est	Pass 1	Pass 2	Est
rock bass	*Ambloplites rupestris*					2		2			
American eel	*Anguilla rostrata*	11	61	46	190	18	15	72	40	12	56
white sucker	*Catostomus commersoni*	42	49	45	176	2		2	1		1
spinycheek crayfish	*Orconectes limosus*		1	3	*6*						
tesselated darter	*Etheostoma olmstedi*	3	44	54	*152*	4	1	5	7	7	31
cutlip minnow	*Exoglossum maxillingua*	11	76	119	*309*	11	2	13	57	17	80
redbreast sunfish	*Lepomis auritus*	3	0	2	5					1	1
common shiner	*Luxilus cornutus*	5	29	31	244	9	3	12	29	8	39
smallmouth bass	*Micropterus dolomieu*	4	7		11	12	4	16	8	4	13
largemouth bass	*Micropterus salmoides*		1		1						
margined madtom	*Noturus insignis*	1	43	28	112	12	8	28	22	25	*71*
swallowtail shiner	*Notropis procne*	1			1						
sea lamprey	*Petromyzon marinus*	7	7	8	28					1	1
shield darter	*Percina peltata*		4	6	*15*	5	2	7	13	3	16
blacknose dace	*Rhinichthys atratulus*		167	79	320	40	95	*203*	118	44	186
longnose dace	*Rhinichthys cataractae*		114	106	1042	28	19	76	84	64	328
brown trout	*Salmo trutta*	12	8	7	29	1		1			
fallfish	*Semotilus corporalis*					1		1	1		1
Total		100	611	534	2641	145	149	438	380	186	824

Table 5. Total population estimates of fish captured during depletion sampling in 2004, 2005, and 2006.										
		2004		**2005**			**2006**		
Common name	Scientific name	Total population estimate	Number caught/100 m	Total population estimate	Number caught/100 m	Number caught/500m²	Total population estimate	Number caught/100 m	Number caught/500m²
rock bass	*Ambloplites rupestris*	0	0	2	3.85	2.23	0	0.00	0.00
American eel	*Anguilla rostrata*	190	88	72	138.46	80.22	56	74.67	42.47
white sucker	*Catostomus commersoni*	176	81	2	3.85	2.23	1	1.33	0.76
crayfish	*Orconectes limosus*	6	1	0	0.00	0.00	0	0.00	0.00
tesselated darter	*Etheostoma olmstedi*	152	70	5	9.62	5.57	31	41.33	23.51
cutlip minnow	*Exoglossum maxillingua*	309	142	13	25.00	14.48	80	106.67	60.68
redbreast sunfish	*Lepomis auritus*	5	2	0	0.00	0.00	1	1.33	0.76
common shiner	*Luxilus cornutus*	244	112	12	23.08	13.37	39	52.00	29.58
smallmouth bass	*Micropterus dolomieu*	11	5	16	30.77	17.83	13	17.33	9.86
largemouth bass	*Micropterus salmoides*	1	0	0	0.00	0.00	0	0.00	0.00
margined madtom	*Noturus insignis*	112	52	28	53.85	31.20	71	94.67	53.85
swallowtail shiner	*Notropis procne*	1	0	0	0.00	0.00	0	0.00	0.00
sea lamprey	*Petromyzon marinus*	28	13	0	0.00	0.00	1	1.33	0.76
shield darter	*Percina peltata*	15	7	7	13.46	7.80	16	21.33	12.14
blacknose dace	*Rhinichthys atratulus*	313	147	203	390.38	226.18	186	248.00	141.07
longnose dace	*Rhinichthys cataractae*	1066	480	76	146.15	84.68	328	437.33	248.77
brown trout	*Salmo trutta*	29	13	1	1.92	1.11	0	0.00	0.00
fallfish	*Semotilus corporalis*	0	0	1	1.92	1.11	1	1.33	0.76
	All species	2638	1216	438	842.31	488.01	824	1098.67	624.95
Sample length			217		52			75	
Sample width			NA		8.63			8.79	

Table 6. Percent of each species, based on population estimates from reach-level depletion sampling in 2004, 2005 and 2006.

		2004	**2005**	**2006**
Common name	Scientific name	Percent of population captured	Percent of population captured	Percent of population captured
rock bass	*Ambloplites rupestris*	0.00%	0.50%	0.00%
American eel	*Anguilla rostrata*	7.10%	16.40%	6.80%
white sucker	*Catostomus commersoni*	6.60%	0.50%	0.10%
crayfish	*Orconectes limosus*	0.20%	0.00%	0.00%
tesselated darter	*Etheostoma olmstedi*	5.70%	1.10%	3.80%
cutlip minnow	*Exoglossum maxillingua*	11.60%	3.00%	9.70%
redbreast	*Lepomis auritus*	0.20%	0.00%	0.10%
common shiner	*Luxilus cornutus*	9.20%	2.70%	4.70%
smallmouth bass	*Micropterus dolomieu*	0.40%	3.70%	1.60%
largemouth bass	*Micropterus salmoides*	0.00%	0.00%	0.00%
margined	*Noturus insignis*	4.20%	6.40%	8.60%
swallowtail	*Notropis procne*	0.00%	0.00%	0.00%
sea lamprey	*Petromyzon marinus*	1.10%	0.00%	0.10%
shield darter	*Percina peltata*	0.60%	1.60%	1.90%
blacknose dace	*Rhinichthys atratulus*	11.80%	46.30%	22.60%
longnose dace	*Rhinichthys cataractae*	40.10%	17.40%	39.80%
brown trout	*Salmo trutta*	1.10%	0.20%	0.00%
fallfish	*Semotilus corporalis*	0.00%	0.20%	0.10%
	All species	**100.00%**	**100.00%**	**100.00%**

Table 7. Estimated probability of capture of each individual on each pass for pairs of depletion samples taken at Station 2 in the ANSP Cuddebackville Dam Removal study. S indicates that no estimate can be made since only one fish was caught or all fish were caught on the first pass, NDe indicates that no estimate could be made since the captures did not show a decreasing pattern, and x indicates that a species was not caught at that site.

Common Name	Scientific Name	9/15/2004	9/14/2005	9/28/2006
rock bass	*Ambloplites rupestris*	x	S	x
American eel	*Anguilla rostrata*	0.38	0.26	0.72
white sucker	*Catostomus commersoni*	0.52	S	S
crayfish	*Orconectes limosus*	NDe	x	x
tesselated darter	*Etheostoma olmstedi*	NDe	0.83	0.25
cutlip minnow	*Exoglossum maxillingua*	NDe	0.87	0.72
redbreast sunfish	*Lepomis auritus*	0.71	x	S
common shiner	*Luxilus cornutus*	0.14	0.80	0.76
smallmouth bass	*Micropterus dolomieu*	S	0.80	0.67
largemouth bass	*Micropterus salmoides*	S	x	x
margined madtom	*Noturus insignis*	0.40	0.45	NDe
swallowtail shiner	*Notropis procne*	S	x	x
sea lamprey	*Petromyzon marinus*	0.52	x	S
shield darter	*Percina peltata*	NDe	0.78	0.84
blacknose dace	*Rhinichthys atratulus*	0.54	NDe	0.64
longnose dace	*Rhinichthys cataractae*	0.11	0.38	0.26
brown trout	*Salmo trutta*	0.71	S	x
fallfish	*Semotilus corporalis*	x	S	S

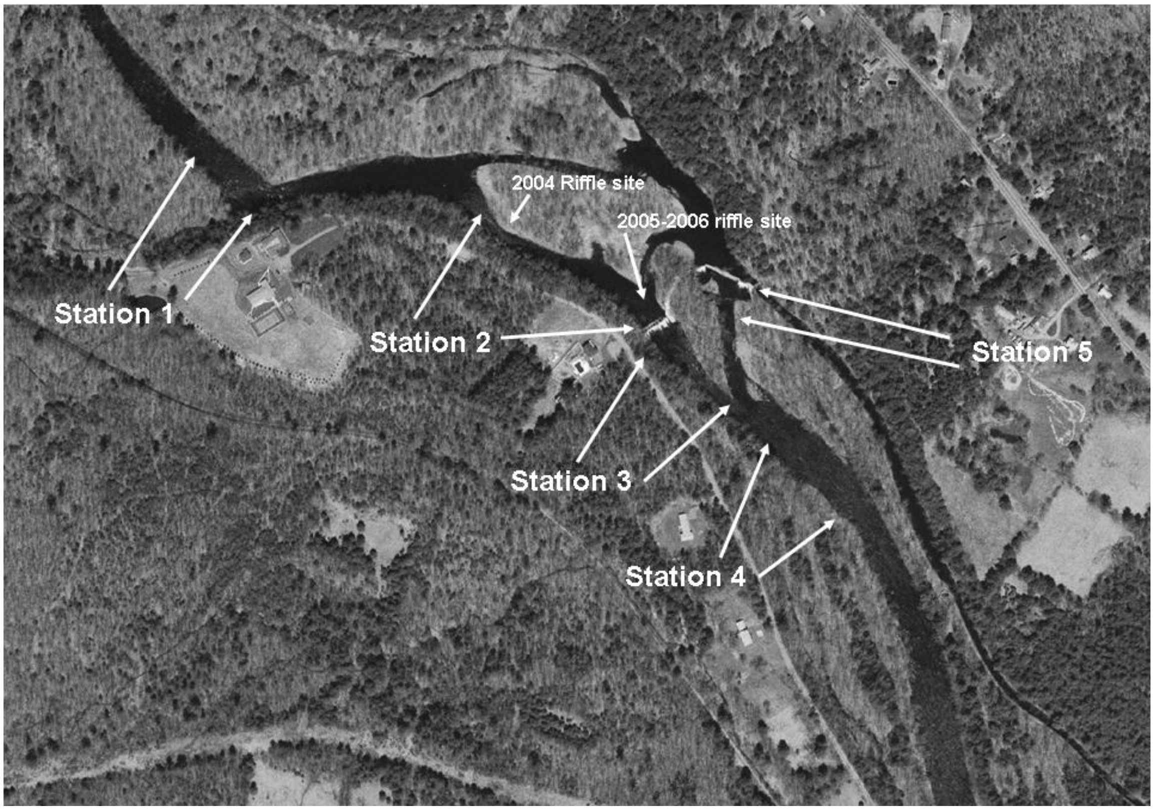

Figure 1. Map of sample sites for 2004-2006 ANSP Cuddebackville dam removal study, based on pre-removal aerial photograph. Arrows by station names show the approximate upper and lower boundaries of each station. The location of small area samples at Station 2 in 2004 (pre-removal) and in 2005-2006 (post-removal) are shown. The locations changed because of changes in geomorphology after removal.

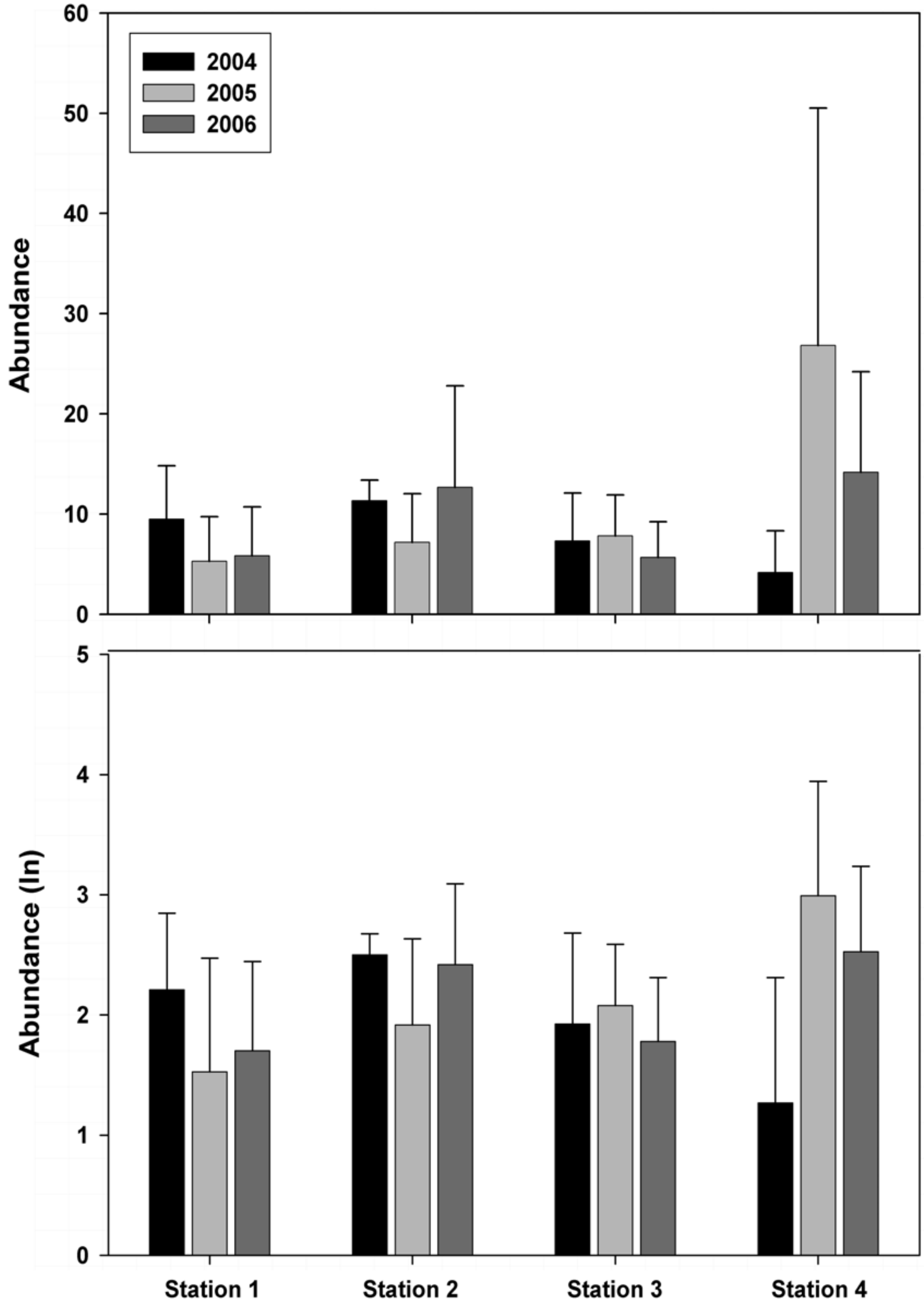

Figure 2 Abundance of longnose dace collected in 2004, 2005, and 2006 in 5x5 small area samples at four stations in the ANS Cuddebackville dam removal study. (Top) Arithmetic mean.. (Bottom) Logarithmic mean.

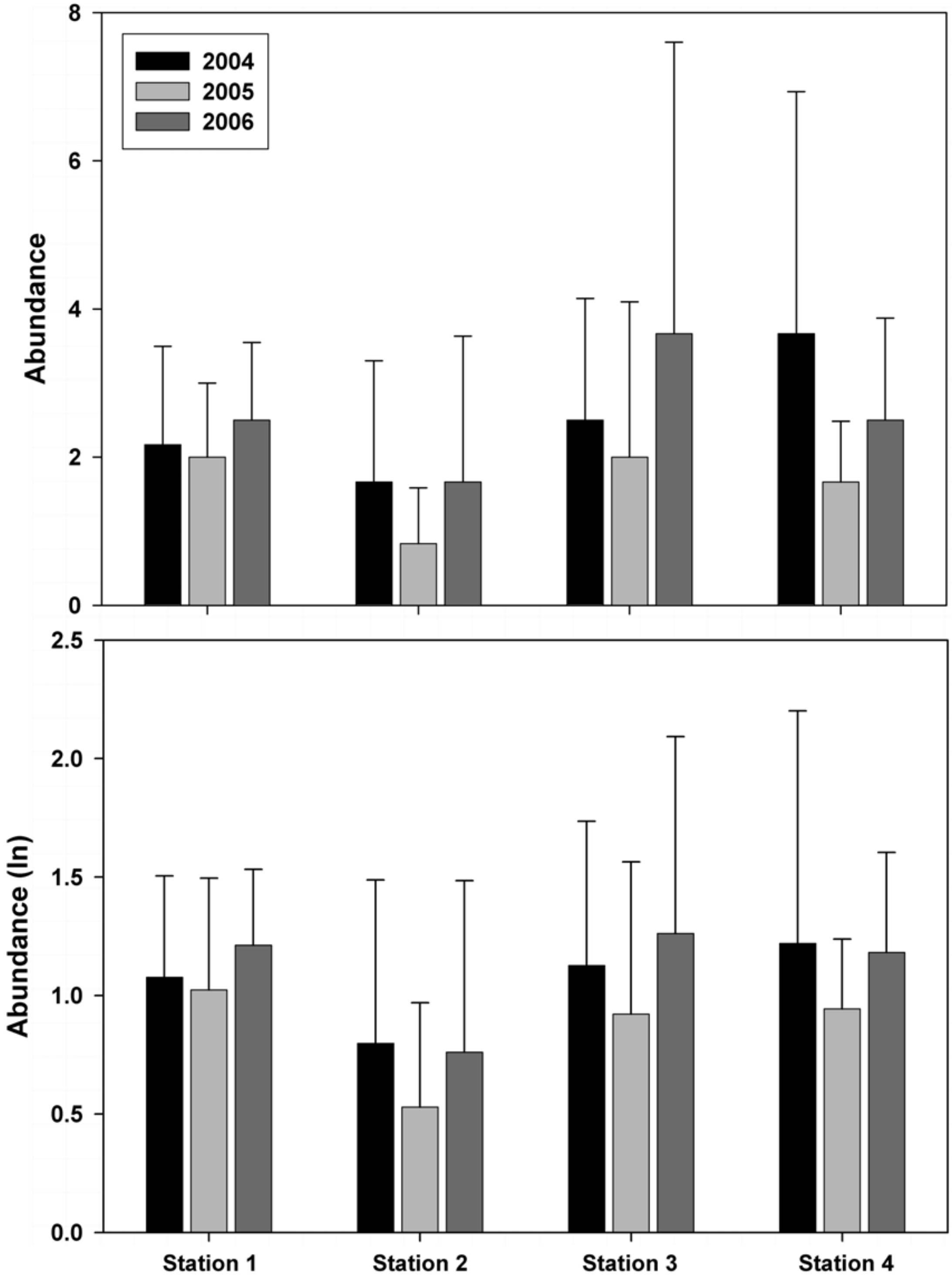

Figure 3 Abundance of margined madtom collected in 2004, 2005, and 2006 in 5x5 small area samples at four stations in the ANS Cuddebackville dam removal study. (Top) Arithmetic mean.. (Bottom) Logarithmic mean.

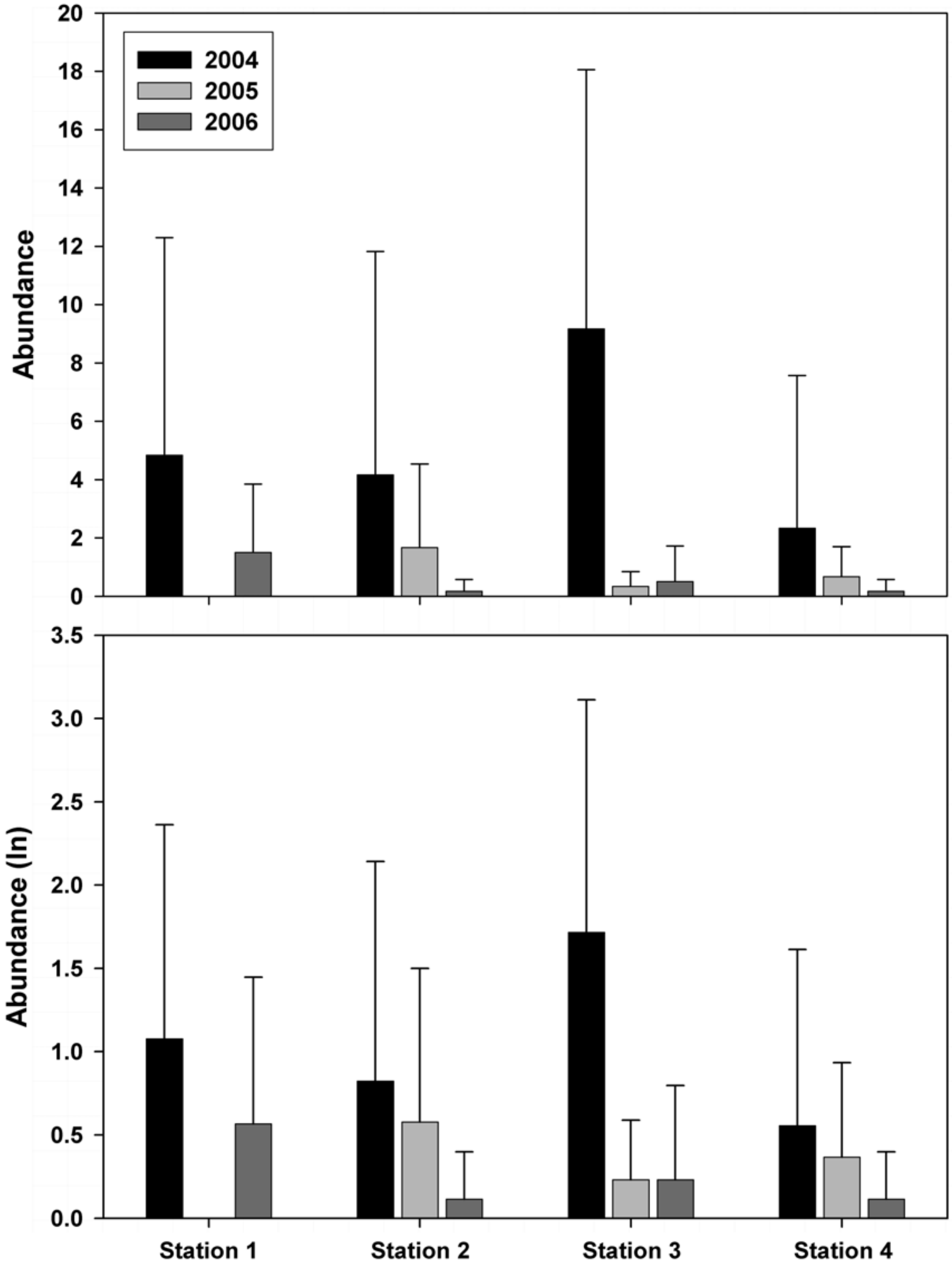

Figure 4. Abundance of blacknose dace collected in 2004, 2005, and 2006 in 5x5 small area samples at four stations in the ANS Cuddebackville dam removal study. (Top) Arithmetic mean.. (Bottom) Logarithmic mean.

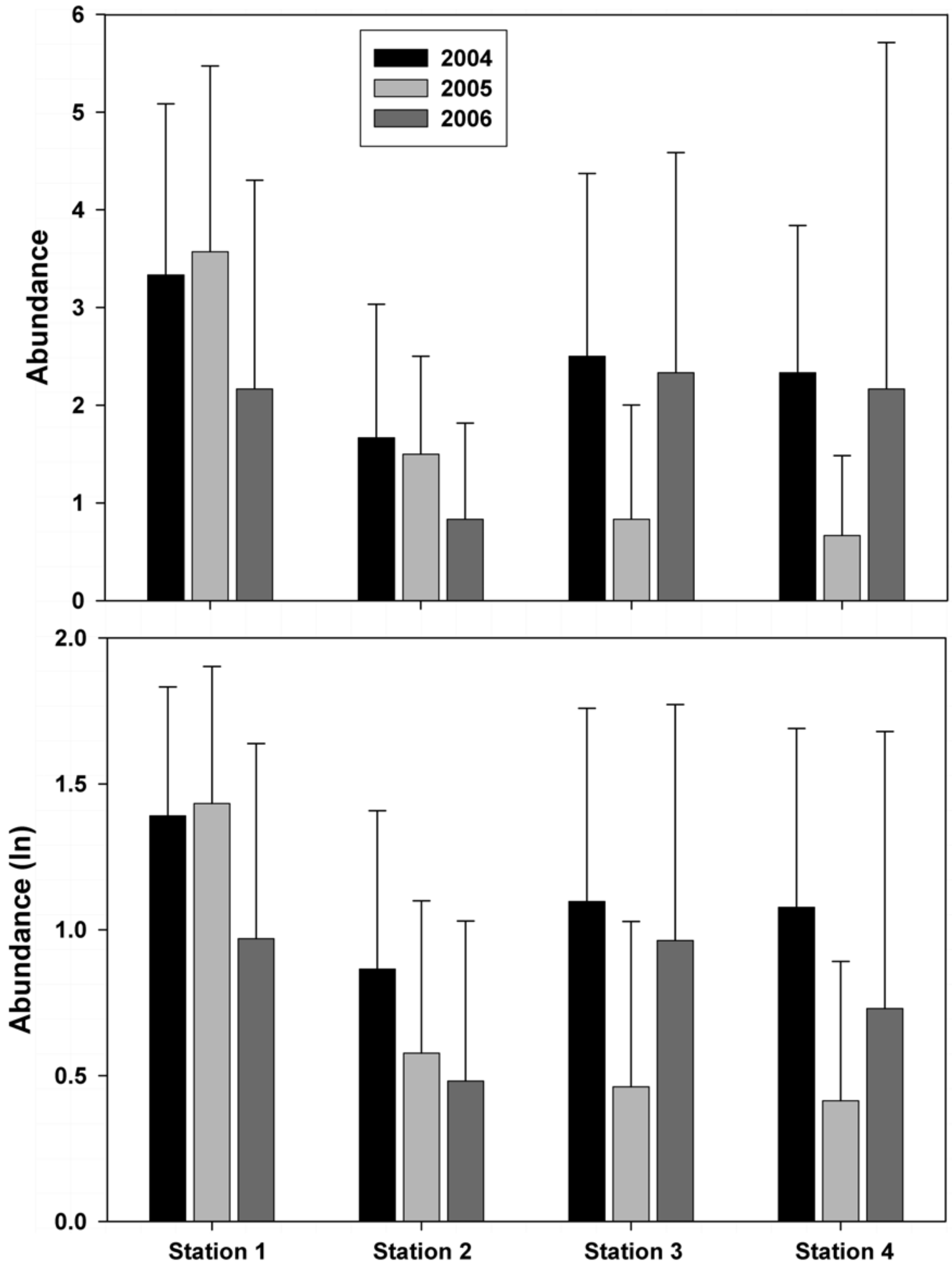

Figure 5. Abundance of American eel collected in 2004, 2005, and 2006 in 5x5 small area samples at four stations in the ANS Cuddebackville dam removal study. (Top) Arithmetic mean.. (Bottom) Logarithmic mean.

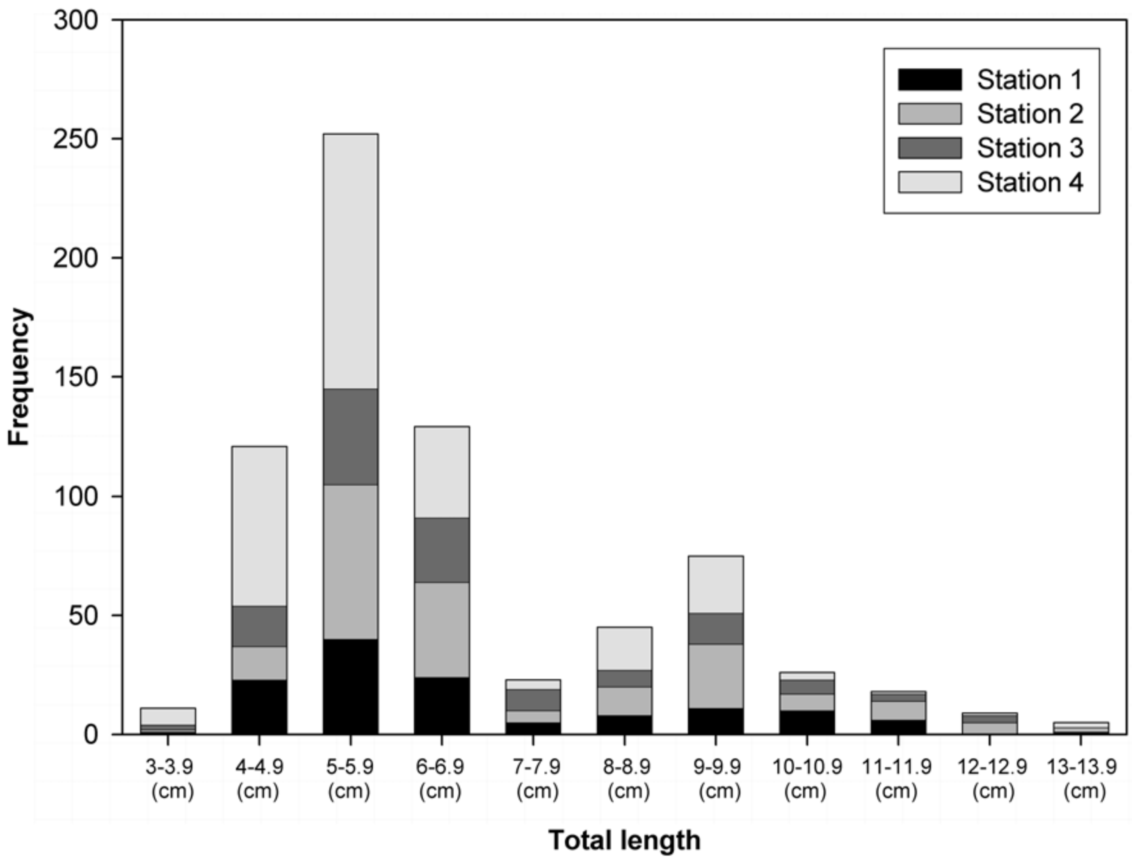

Figure 6. Total length frequency of longnose dace collected during the years 2004, 2005, and 2006 in 5x5 m small area samples at four stations in the ANS Cuddebackville dam removal study.

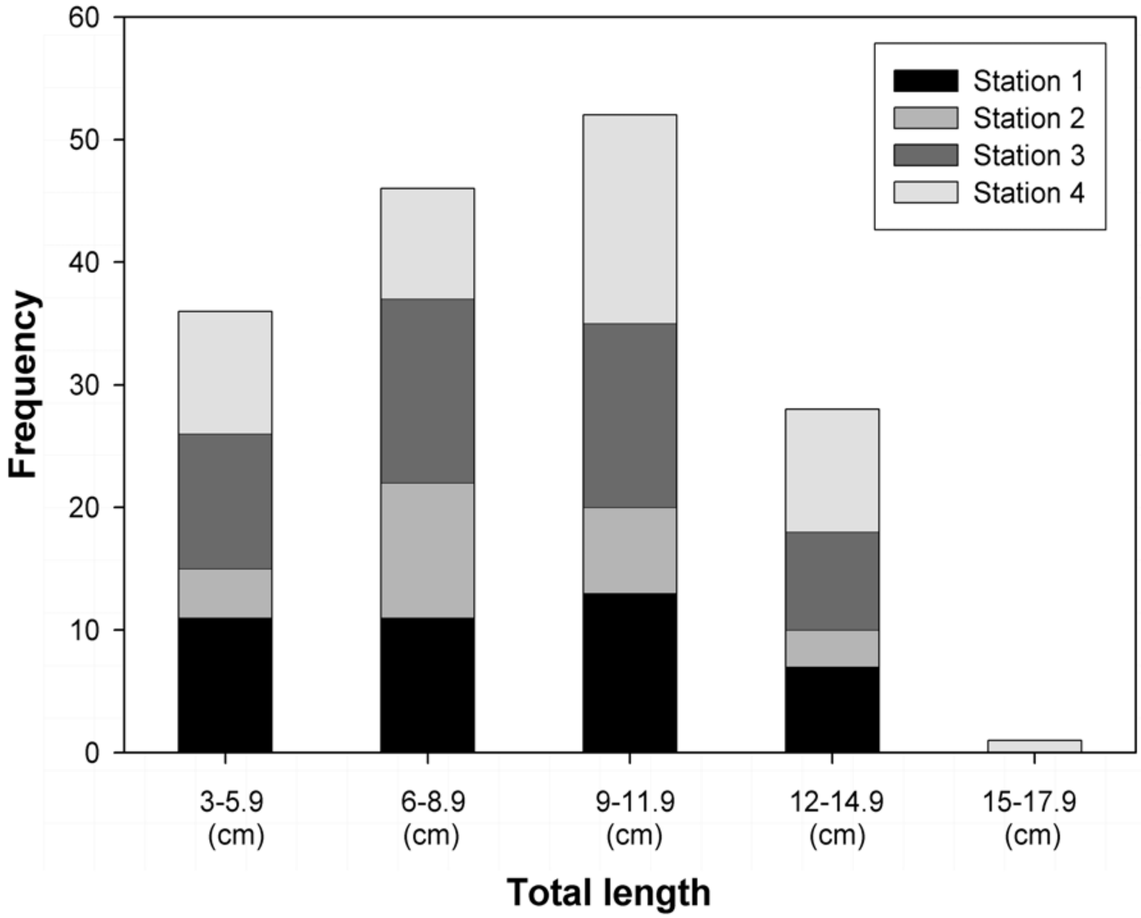

Figure 7. Total length frequency of margined madtom collected during the years 2004, 2005, and 2006 in 5x5 small area samples at four stations in the ANSP Cuddebackville dam removal study..

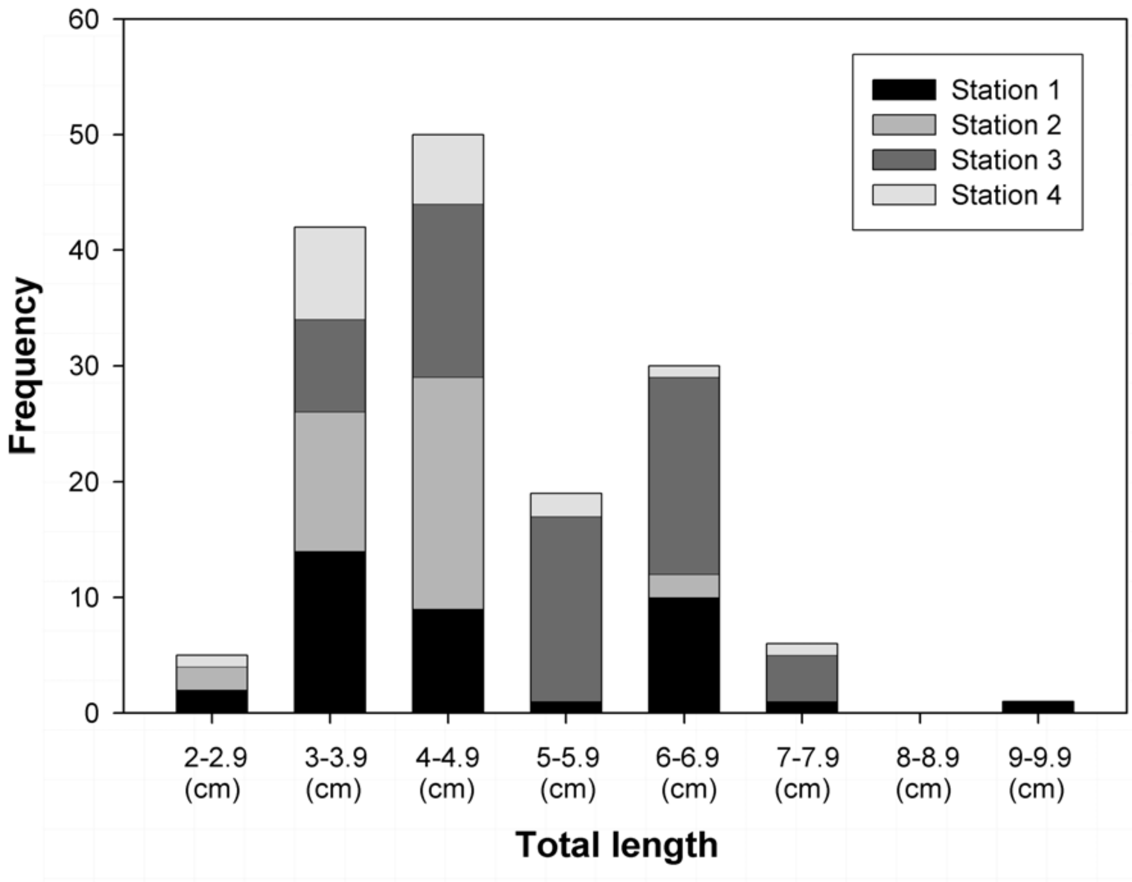

Figure 8. Total length frequency of blacknose dace collected during the years 2004, 2005, and 2006 in 5x5 small area samples at four stations in the ANSP Cuddebackville dam removal study..

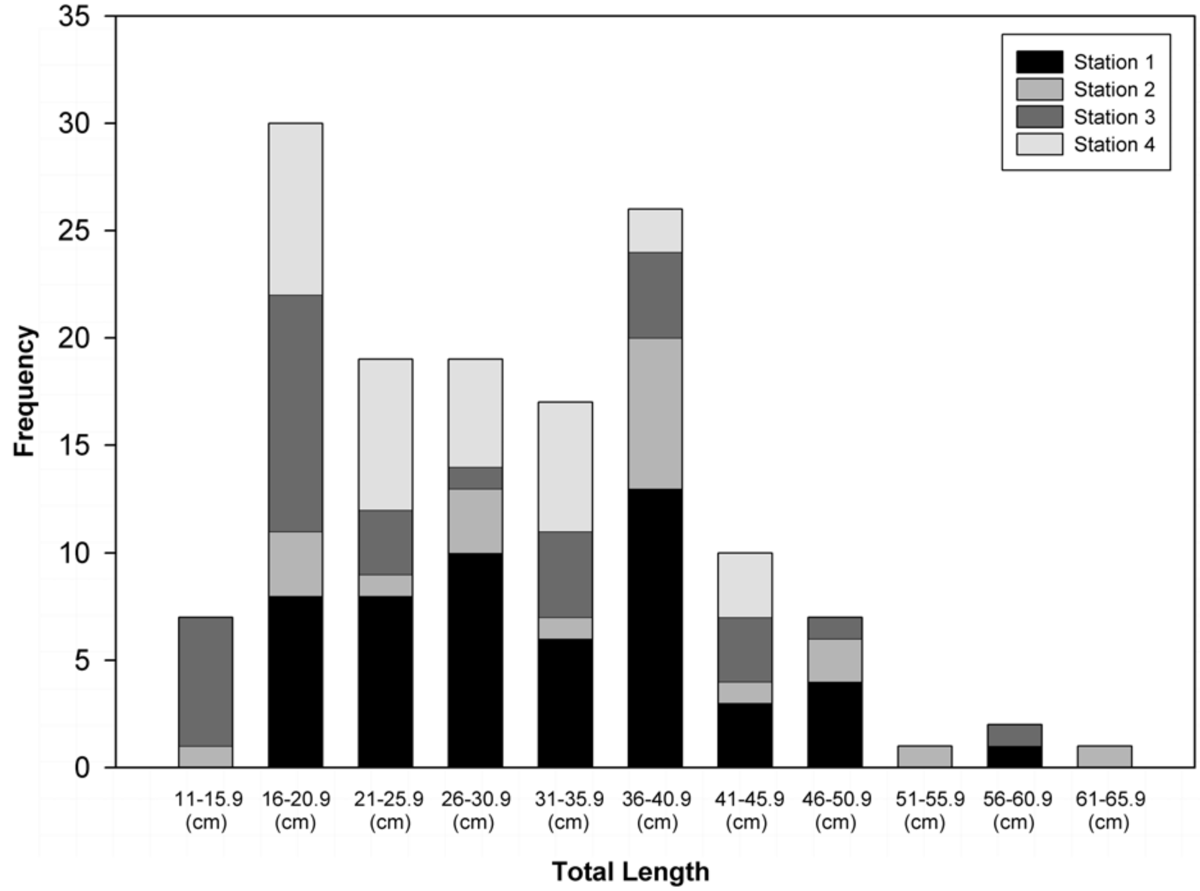

Figure 9. Total length frequency of American eel collected during the years 2004, 2005, and 2006 in 5x5 small area samples at four stations in the ANS Cuddebackville dam removal study.

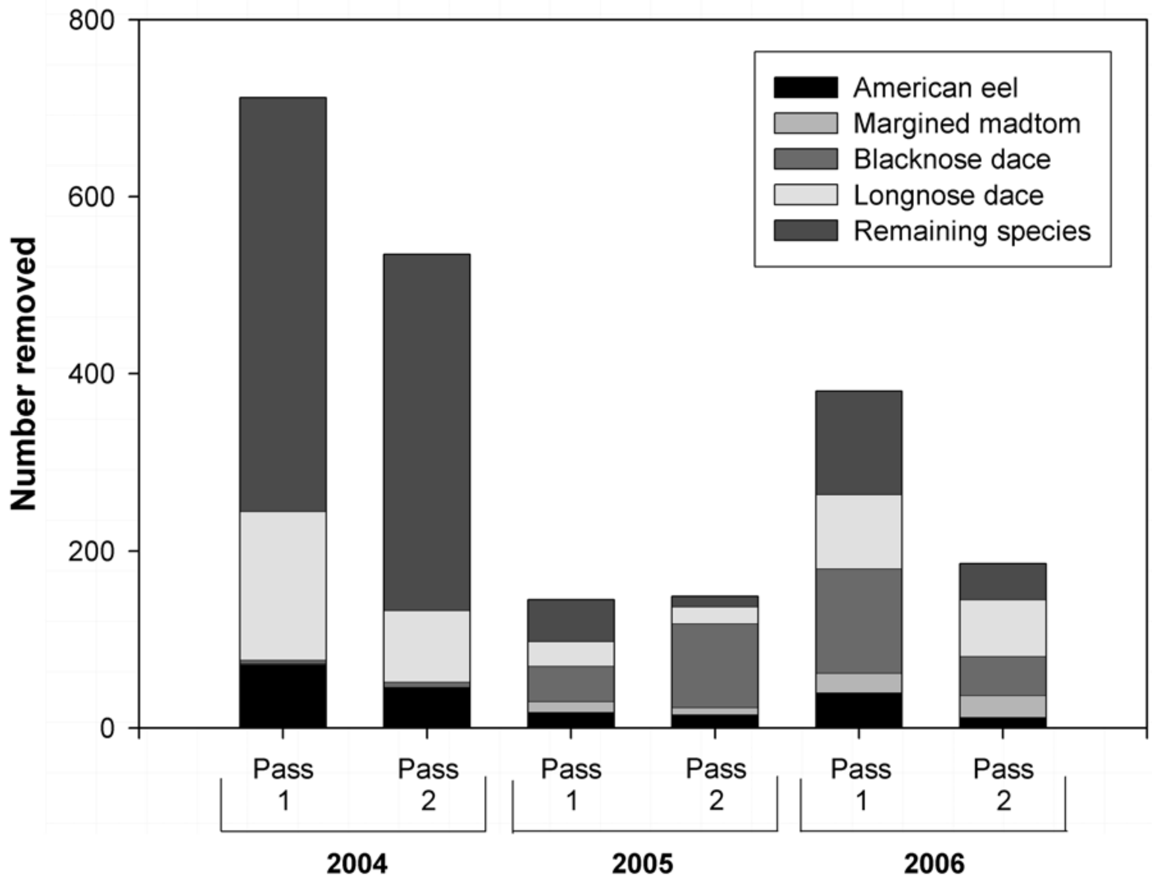

Figure 10. Number of fish removed on consecutive passes in 2004, 2005, and 2006 depletion sampling at Station 2

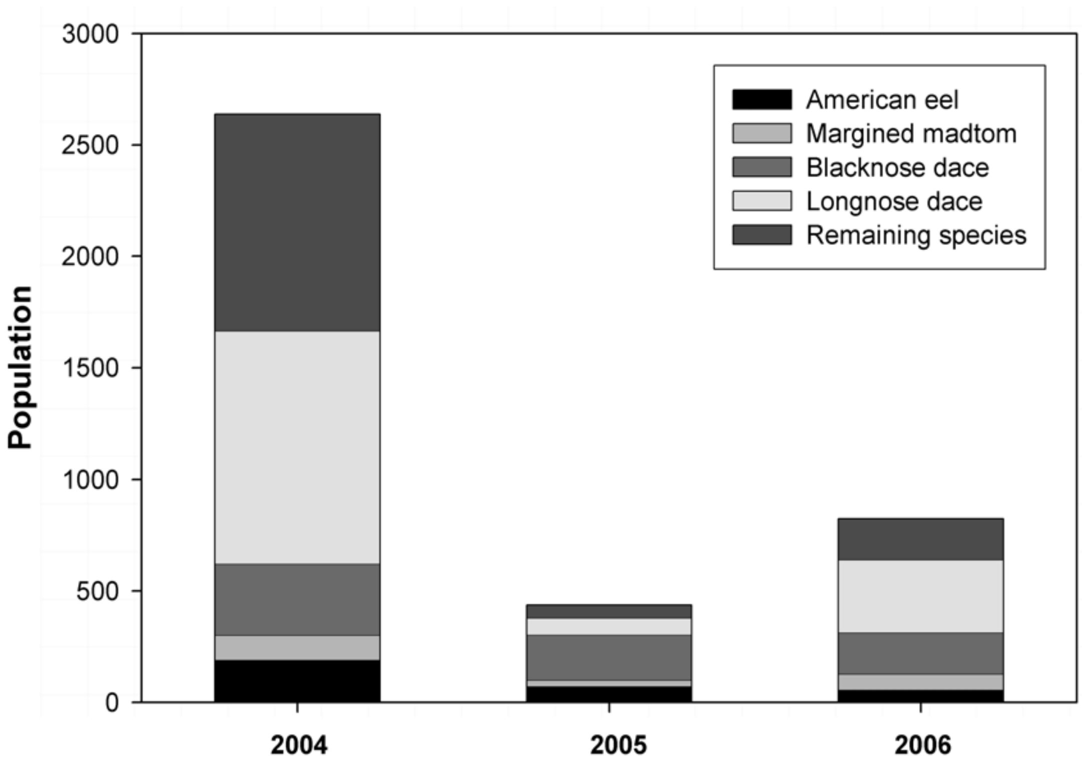

Figure 11. Estimated total population size of the four single most common species and sum of remaining species in 2004, 2005, and 2006 depletion samples at Station 2.

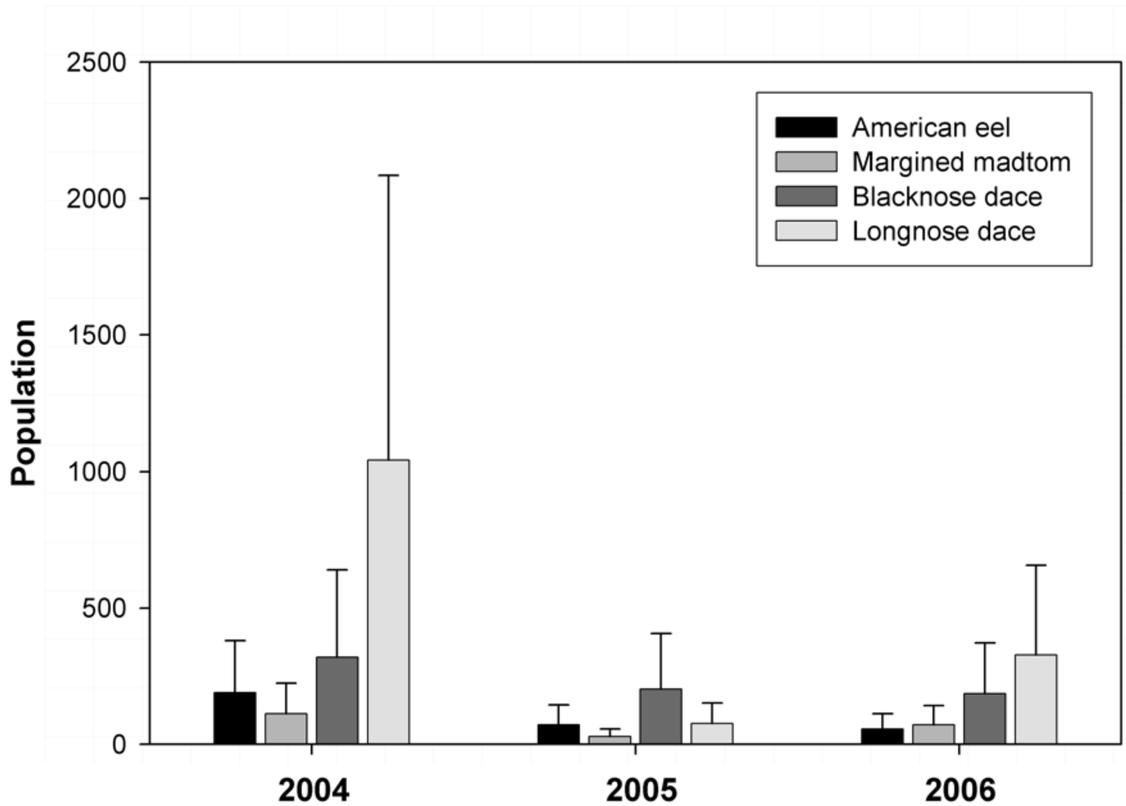

Figure 12. Estimated total population size and standard deviation of the four most common species in the 2004, 2005, and 2006 depletion samples at Station 2.

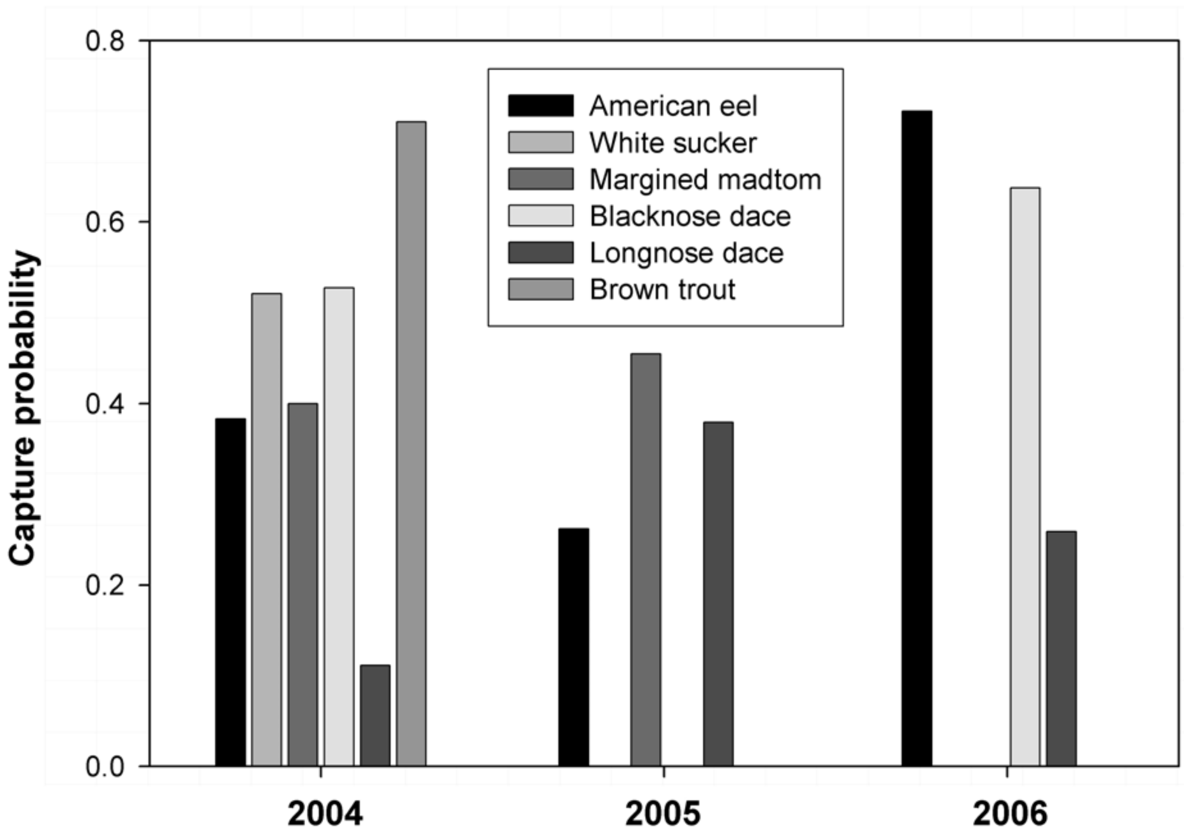

Figure 13. Estimated probabilities of capture (per individual per pass) of common species in depletion samples at Station 2 in 2004, 2005, and 2006

Appendix: Photographs of Study Site and Sampling

Appendix Figure 1. Small area (5x5 m) sampling at Station 1 in August, 2004. Small area samples were taken in a mix of riffle microhabitat conditions. This particular sample was taken in relatively slow, shallow habitat within the riffle.

Appendix Figure 2. Riffle at Station 2 in 2004, prior to dam removal. Small area samples were taken at this riffle in 2004.

Appendix Figure 3. Looking upstream at Station 2 in 2006, after dam removal. The reach samples in 2005 and 2006 were taken in the run and pool habitat to the right (facing downstream) of the island.

Appendix Figure 4. Station 3 (background, in upper left part of image) and part of Station 4 (foreground) in 2006, after dam removal.

Appendix Figure 5. Neversink River and Cuddebackville Dam during dewatering period in September, 2004.