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Natural History
Survey

Population Viability of Mottled Sculpin (*Cottus bairdi*) in Black Partridge Creek

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Background

The Illinois State Toll Highway Authority (ISTHA) and the Illinois Department of Transportation (IDOT) have planned the construction of FAP 340, Route 355 South, connecting I-55 and I-80. The upper end of the Black Partridge Creek watershed extends from near the proposed FAP Route 340/ I-55 interchange south to Lemont Road and I-55. The creek parallels the proposed road for approximately 1.7 miles before dissipating into wetlands north of the Des Plaines River. One species of potential concern in Black Partridge Creek is the mottled sculpin (*Cottus bairdi*) (Figure 1). The mottled sculpin is only found in two locations in the Des Plaines drainage. In Illinois, it is common in a few tributaries of the Fox River, but extremely sporadic elsewhere. It is likely that these populations have been isolated from other sculpin populations for some time, and are relicts left behind in pockets of suitable habitat after the last glacial retreat. Sculpin are more typically found in higher gradient cold water streams. Its occurrence in Black Partridge Creek is most likely due to the unique stream characteristics found within the Black Partridge Forest Preserve: high gradient and spring-fed water create a cool, clear, high gradient stream. This habitat is somewhat unique in Illinois, and may contain other species with limited occurrences within the state.

Reasons for Concern

The construction of roadways has the potential to increase run-off into the stream, which could increase sedimentation and increase the ratio of run-off/groundwater inputs. Both of these effects could potentially harm the sculpin, by 1) reducing the amount of cobble substrate they prefer, 2) decreasing their feeding efficiency, and/or 3) increasing stream temperatures. However, extensive development in the Black Partridge drainage basin may already have imposed these and other potentially negative effects on the population. Thus there is some belief that the sculpin population is already threatened, and, barring any recovery efforts, will become extinct regardless of whether the road is built or not. To assess both the current status of the sculpin population and the potential impacts of the roadway, some form of Population Viability Analysis (PVA) must be performed.

Population Viability Studies

A Population Viability Analysis (PVA) is broadly defined as the use of quantitative methods to predict the likely future status of a population or collection of populations of conservation concern (Morris et al. 1999). The foundation of most PVAs is a demographic model of the population of interest, frequently some form of life table analysis. The basic information needed for these models includes the population size structure, age-specific birth and death rates, etc. However, for real populations these factors are rarely constant. Habitat loss, environmental uncertainty, demographic stochasticity, genetic factors, etc. all interact to determine extinction probabilities for individual species (Soule 1987, cited in Meffe and Carroll 1994). More comprehensive PVA models incorporate additional factors such as these into their analyses. An important caveat to PVA analyses is that because they are based on limited data, they must be viewed as a tentative assessment of extinction risk, based upon current knowledge. They are not meant to be ironclad predictions, but rather serve as a guide to the range of possible fates for the populations (Morris et al. 1999).

Project Overview

The main goal of the proposed project is to conduct a PVA of the sculpin population in Black Partridge Creek. The resulting analysis would allow for informed management decisions regarding the proposed highway extension, and provide a basis for assessing the impacts of future development on the sculpin population.

A PVA requires: life history information, population demographics, and in some cases genetic information. This study explored only life history information and population demographics. Field work was done to estimate existing population size/age structure. Sculpin populations were estimated using both depletion estimates and benthic (bottom) area sampling. Temperature profiles were obtained for several points along the stream using temperature data loggers. Lab experiments were done to determine the effects of turbidity on sculpin foraging. The resulting information was incorporated into a PVA model using the program RAMAS/Metapop (Akçakaya and Root. 1998) to estimate survival probabilities of the population under a variety of scenarios. It should be noted that two years of population data is the bare minimum needed for a PVA, and thus the results of these models must be interpreted as tentative predictions. Based on the natural history data, demographic information, and computer simulations, we made an assessment of the viability of the sculpin population in Black Partridge Creek.

Population Description

Population Distribution

We conducted several sampling trips to simply look for sculpin along the length of Black Partridge Creek, using both seines and a backpack electroshocker. We assumed that most of the sculpin would be found in the area of the stream within Black Partridge Forest preserve, due to the unique aspects of the stream at that location. We sampled upstream and downstream from the park until we consistently did not find any sculpin. We additionally sampled several large reaches upstream from the park, into the headwaters, to ensure that no sculpin were living upstream of that area. It appears that the sculpin are restricted to a relatively small stretch of the stream, approximately 1700ft. (518m) long (Map 1).

Population Size and Structure

Any single method of estimating a population will have error associated with it, thus we employed two different sampling techniques. For the first method we used a 5.38ft^2 (1/2m^2) benthic sampling device. The sampler frame is constructed out of PVC pipe, with ¼" netting sewn onto three sides and a lead-line attached to the bottom. The lead-line allows for a close seal over cobble substrate. The fourth side of the sampler is open, and a removable collecting bag can be placed into this opening (Figure 2). The sampler is placed on the substrate, and the area within the sampler disturbed in an upstream to downstream direction, herding any sculpin into the collecting bag. The bag can then be removed, and the captured fish measured and released.

We began sampling at the downstream edge of the sculpin's range. We established transects at 40ft (12m) intervals, unless there was some obstruction, in which case we would move upstream of the obstruction. Along each transect, we took one to three benthic samples, the exact number depending on the width of the stream. Sculpin in each sample were measured and their sex identified when possible. Adult males greater than 1.97–2.36in. (50-60mm) total length can be distinguished by the presence of genital papilla near their anus (Bailey 1954). After measurement, the fish were placed into a holding container until sampling at that transect was complete, after which they were released back into the stream. Sculpin have very small home ranges and typically move only small distances (Brown and Downhower 1982, Hill and Grossman 1987), thus it is extremely unlikely that fish would have swum upstream into the next transect area. We stopped sampling when we had done three transects without finding a single sculpin, resulting in a total of 44 transects in 2000 and 47 transects in 2001. The average number of sculpin per sample was taken for a 5 transect reach, and multiplied by the total area for that reach to obtain a population estimate for that reach. The estimates for each reach were summed to obtain a population estimate for the entire stream.

The second sampling method employed was a three-pass removal estimate (Li and Li 1996). Four reaches were sampled, each being approximately 200 feet long. Thus slightly less than half of the region with sculpin was sampled. Before sampling, block nets were placed at the upstream and downstream end of the sample reach. Three passes were then made through the section using a backpack electroshocker. After each pass, captured fish were placed into a holding container. After all three passes, fish were measured, sexed when possible, and released back into the study section. Fish were released throughout the study section, and care was taken to return approximately the same number of small, medium, and large fish the same general area where they were captured. The resulting numbers were run through a program called CAPTURE, which estimates population sizes. We assumed that densities of adjacent sections would be more similar than sections on either end of the reach. We therefore used the average densities in a given reach to estimate sculpin populations in both that reach and the unsampled reach immediately upstream.

We obtained two very different estimates with the separate sampling techniques (Table 1). Using the benthic sampler, we estimated a total population size of 2,109 fish in 2000 and 1968 fish in 2001, while the removal method produced an estimate of only 1200 fish in 2000 and 1463 fish in 2001. The benthic sampler method averaged 0.075 sculpin/ft^2 (0.81/m^2) in 2000 and 0.076sculpin/ft^2 (0.82/m^2) in 2001, while the depletion method averaged 0.044 sculpin/ft^2 (0.47m^2) in 2000 and 0.054/ft^2 (0.57/m^2) in 2001. Other published densities of mottled sculpin range from 0.0009/ft^2 (0.0097/m^2) to 0.1236ft^2 (1.33m^2) (Anderson 1985), thus our estimates represent average densities for mottled sculpin. However, we believe both of our estimates to be fairly conservative, as both methods have problems that will lead to an underestimate of total fish density. For the benthic sampler, small fish have a greater probability of being able to slip under the collection net placed upon a rocky, uneven bottom, and thus numbers in this size class are most likely underestimates. Electrofishing works by stunning the fish so that they may be collected. Sculpin, however, have no swim bladder, so that fish stunned while under a rock or those washed under a rock by the current will not be collected, leading to an underestimate for all size classes, and hence a lower total estimate.

The sculpin size distribution has two distinct peaks (Figure 3). The first of these represents this year's recruits. The second peak is composed of Age Class II+ fish. This size distribution is similar to other published distributions for mottled sculpin (Bailey 1952). We broke sculpin into four size classes based on existing data (Bailey 1952, Docker et al. 1985). During August, individuals <2.36in (60mm) were Age I, 2.36-3.11in (60-79mm) were Age II, 3.12-3.7in (80-94mm) were Age III, and those >3.7in (94mm) were Age IV. Female mottled sculpin may start breeding when they reach a size of 2.36in. (60mm), and all fish 2.95in (75mm) and greater are reproductively active (Bailey 1952). Thus most of the fish in the second peak represent actively breeding individuals.

Temperature Profiles of Black Partridge

Because sculpin are generally a cool water species, we wanted to test whether temperature affects their distribution within Black Partridge Creek. One idea as to why sculpin are able to persist in this stream is that the seeps flowing into the stream in the Black Partridge Forest Preserve provide the cooler waters sculpin generally require. To test this idea we placed four temperature loggers in the stream. The first was placed in the headwaters, well above the reach where we found sculpin. The second was placed at the upper edge of the sculpin distribution, above where most of the springs and seeps enter the stream. The third was placed in the middle of the reach containing sculpin. The last was placed at the bottom edge of the reach where we found sculpin.

Due to some problems with the loggers (one failed to trigger correctly, another was buried in sediment for part of measurement period, another was lost) we were unable to get complete two year temperature profiles for all four sites. We did obtain complete two year profiles for the upper site and the site in the middle of the sculpin reach, as well as a complete one year profile for the other two sites.

We found that the temperature profiles did differ among these four location (Figures 4, 5). Temperatures from the middle of the sculpin reach were the most stable, showing cooler summer temperatures and higher winter temperatures than the other sites. The upper portion of the watershed had the warmest summer temperatures, as much as 10°C (18°F) warmer than the middle of the sculpin reach (Figure 4). The upper and lower edges of the sculpin reach had similar temperature profiles; both were intermediate between the other two sites (Figure 5).

Effects of Turbidity on Sculpin Foraging

One potential negative effect of development in the headwaters of the watershed is increased sedimentation and turbidity. Fish detect prey through either visual cues, physical cues detected by their lateral line, or some combination of these. Turbidity has the potential to reduce at least the visual component of prey detection. We therefore conducted an experiment to see whether increased turbidity could negatively affect sculpin populations by reducing their feeding efficiency.

Study Species

Because we were uncertain of the population status of sculpin in Black Partridge Creek, fish for this experiment were collected from Augusta Creek in Kalamazoo County, Michigan and Sevenmile Creek in Calhoun County, Michigan on 6 March 2002. All fish were collected using a Smith-Root Inc. Model 12 Electrofisher. Sculpin were transported to the lab in aerated coolers. Fish were then placed into aquaria in a cold room set to 12 °C with a 12:12 hour light:dark schedule. Sculpin were fed every three days with invertebrates collected from local streams. Forty-eight hours prior to being used in the study sculpin were placed in stream tanks identical to those used in the study and feeding was discontinued.

Larval mayflies from the family Heptageniidae were used as prey in the study. Mayflies were collected by kick-netting in Jordan Creek in Vermilion County, Illinois and transported to the lab in aerated coolers. Larvae were held in the same cold room as the sculpin for between 24 and 96 hours before being used. Larvae used within 48 hours of collecting were held only in the aerated coolers. Larvae held for greater than 48 hours were placed into a stream tank identical to those used in the study.

Experimental design and procedures

A randomized complete block design was used to examine the effects of turbidity on the foraging ability of mottled sculpin. Treatment factors were sculpin (present/absent) and turbidity (low/ambient/high). Twelve 57 L stream tanks were placed on two benches in a cold room, with each bench serving as a block containing all 6 treatments. The experiment was run for 48 h and was replicated 8 times between 14 and 28 March 2002. Each time the experiment was run, all tanks were emptied and cleaned. Five medium-sized stones were haphazardly chosen and placed into each tank, the tanks were filled with dechlorinated water, and the maximum flow rates through the top portion of the tanks was adjusted to 0.202 (±0.003) m/s using an Autonnic Speed 2000 flow meter. The tanks were allowed to run for 24 h, after which the turbidity was raised to the specified levels in each tank using sediment from a nearby pond and measured with a YSI Model 6820 Water Quality Meter. Sediment levels were chosen to represent the current range of turbidity values in Black Partridge Creek (D. Soluk, unpublished data). Sediment was rinsed through a 500 μm sieve and pressure sterilized in a steam autoclave before use. Mayflies were haphazardly placed into 12 groups of 25 and a photograph was taken of each group. They were then added to the tanks and given 2 hours to acclimate—1 hour with the flow turned off and 1 hour with the flow resumed to its pre-measured value. Mottled sculpin were then haphazardly chosen, measured, and added to the appropriate tanks. After 48 hours the sculpin were removed and then the remaining mayflies in each tank were carefully removed and counted. The photographs of the mayflies were scanned into a computer and the average mayfly length for each group was determined using Scion Image 4.0.2.

Statistical analysis

The amount of prey missing in each tank at the end of a trial is expressed as a proportion of the initial number of mayflies in the tank. The proportion of prey lost in the fishless control tanks was compared to 0 using a t-Test (Proc. Univariate, SAS, SAS Institute, Cary, North Carolina). Differences in treatments were compared using a one-way analysis of variance (Proc. GLM, SAS).

Results and conclusions

Mean turbidity levels in the tanks during the trials were 8.01 (±0.58 SE) nephelometric turbidity units (NTUs) for the low turbidity treatment, 29.97 (±1.69 SE) NTUs for the ambient turbidity treatment, and 71.14 (±1.17 SE) NTUs for the high turbidity treatment.
The mean proportion of prey lost from the control tanks across all treatments was 0.0017 (±0.0056), with no significant difference in the proportion of prey lost due to the treatments ($F_{2,21} = 0.08$, $p = 0.92$). The proportion of prey lost in all of the control tanks was not significantly different from 0 ($t = 0.30$, $p = 0.77$), so all prey lost in the tanks containing fish is assumed to have been consumed by the sculpin.

The mean proportion of prey consumed was 0.415 (±0.055 SE) in the low turbidity treatment, 0.395 (±0.075 SE) in the ambient turbidity treatment, and 0.33 (±0.052 SE) in the high turbidity treatment (Figure 6). There was not a significant difference in the proportion of prey consumed either due to the model ($F_{18,5} = 1.40$, $p = 0.38$) or due to the treatments ($F_{2,5} = 0.72$, $p = 0.53$). It is therefore clear that in the current range of turbidity experienced by mottled sculpin there is no significant effect of higher turbidity on foraging success. Sculpin are most likely relying heavily on their lateral line system to locate prey in turbid conditions.

Population Viability Model

Matrix Creation

Most PVA models use a form of life table analysis as the basis for their calculations. This involves the construction of a "transition matrix" which contains information on birth rate and survivorship, and an initial age "vector," which is simply the number of individuals in each age class at the start of the simulation. By using matrix algebra, the transition matrix is multiplied by the initial age vector to determine the population size the next year (Ricklefs 1990).

We examined papers on sculpin life history in order to produce more informed and reliable matrices. We used the literature to determine which age classes were reproductively active, and what their relative fecundities were. This information could not be obtained from Black Partridge without killing and dissecting sculpin, which was not an option. One aspect of fecundity is the age or size at which individuals begin breeding. For mottled sculpin, females begin breeding at 2.36in. (60mm) and all fish greater than 2.95in (75mm) are reproductively active (Bailey 1952). The other important factor is how many eggs are laid per female. For sculpin, larger fish produce more eggs than smaller individuals. Age III individuals produce about twice as many eggs as Age II individuals (Docker et al. 1986), and we incorporated this difference into the model (Table 2,3). We also conservatively assumed that Age IV individuals had the same fecundities as Age III, although they were most likely slightly higher.

We used our two years of population data to determine the survival rates and actual fecundities. Survival rates are used to determine what percentage of individuals in a given age class survive to reach the next age class. To calculate this we simply divided the number of individuals in age class x+1 in year two, by the number of individual in age class x in year one. For example, to determine the survival rate of Age Class I, the number of individuals in Age Class II in 2001 was divided by the number of individuals in Age Class I in 2000. Fecundities are simply age specific birth rates. To calculate this, we simply looked at how many Age Class I individuals their were in 2001 and related that back to the number of breeding individuals in 2000, assuming Age Classes III and IV were twice as fecund as those in Age Class II (see above). We used this method to produce transition matrices for both the benthic estimate (Table 2) and depletion estimate (Table 3). We simply used the number of individuals in each age class in 2001 for our initial age vectors.

Model Variations

As noted above, PVAs are really tools for assessing the potential risk of extinction under a given set of conditions. PVAs are most informative when run under a variety of scenarios to see how changes in certain factors affect the population's stability. We chose to vary four key population factors: carrying capacity, maximum birth rate, catastrophe frequency, and catastrophe severity.

The carrying capacity (K) is a key factor influencing final population size, because it determines the maximum number of individuals allowed in the model. We used a combination of our own data and published studies to choose the range of carrying capacities used in the model. The "carrying capacity" is the upper limit on population densities, beyond which there are not enough resources to support additional individuals. We ran the model with four different carrying capacities for the population, ranging from low to high. The low range corresponded to a density of 0.023/ft2 (0.25m2), which is about half the lowest estimate for current sculpin densities and was chosen to examine what would happen if the carrying capacity was significantly lowered. The next highest value was 0.046/ft2 (0.5/m2), which is the low end of the current sculpin estimates (Table 1), and a conservative value for the current population. The next value was 0.092/ft2 (1/m2), slightly higher than our highest estimated value, and an optimistic value for the current population. The high value was the maximum reported density of mottled sculpin in the literature, 0.121/ft^2 (1.3/m^2) (Anderson 1985). We multiplied these densities by the total area in the sculpin's range to determine the carrying capacity for Black Partridge Creek.

The maximum growth rate (r) is another key factor influencing populations. The maximum growth rate is defined as the maximum percent increase in population size per year. A faster growing population can recover more quickly from a disturbance and thus is generally more stable. Development in the watershed could potentially affect maximum growth rates through altered temperature regimes and increased sedimentation, both of which could negatively affect population growth rates. We ran the model at three different maximum growth rates: 1% per year, 5% per year, and 10% per year. This represents a range from relatively low to relatively high growth rates.

Lastly, we also ran the model with a variety of catastrophe probabilities and severities. The probability of a catastrophe is how likely it is to occur, while the severity determines how much of the population is eliminated by the event. We ran the model with two different catastrophe probabilities: once every hundred years and once every ten years. We did not specify what the catastrophe is, but natural events in streams include flooding and drought, while anthropogenic ones could include contaminant spills, as well as altered flooding probabilities and temperature regimes. We also modeled two different severities: with 60% of the population surviving and with 20% of the population surviving. The 60% figures is a minimal number to term something a "catastrophe", rather than normal population fluctuations, while the 20% was chosen to represent a truly extreme event.

Simulation Results

We ran the simulation under all possible combination of the above scenarios for both the benthic and depletion estimates, a total of 72 in all (Table 4,5). All scenarios were run for 1000 replications and ran for 50 years. Thus, all the models predict the population size in 50 years, as well as the extinction probability. The extinction probability can be interpreted as there being an X% chance that the population will be extinct within 50 years. Note that although some trials have 0% probability of extinction within 50 years, their population sizes showed a steady decline to well below the carrying capacity, sometimes to close to zero, and would probably go extinct if the model were to be run for a longer time period. We chose a 50 year time period as we felt that was as far as we could reliably predict based on the data we have.

There was little difference in the models based on benthic versus depletion estimates. With both estimates, the models using the lowest, most conservative current conditions (K=0.5, r=0.01, Catastrophe: Probability=1/100years, Severity=20% Survival), and more realistic and optimistic current conditions (higher growth rate, lower severity) all predicted the sculpin population to be at or near its carrying capacity in 50 years, with a 0% risk of extinction.

Aside from the carrying capacity, which by definition determines the maximum possible population size, the factor that appeared to have the greatest impact on the populations was the probability of catastrophe. All scenarios with a 10% chance of a catastrophe had populations well below their carrying capacities within 50 years, frequently with less than 100 individuals (Table 4,5). All scenarios with a 10% probability and with only 20% of the population surviving had a great than 30% risk of extinction in 50 years.

Conclusions and Recommendations

The population of mottled sculpin in Black Partridge Creek is currently healthy and stable. The population shows a healthy age distribution (Figure 3) and under all realistic scenarios the PVA model predicts a population at or near its carrying capacity in 50 years, with a 0% risk of extinction (Tables 4, 5). Under the existing range of turbidity values, there appears to be no negative effects on sculpin foraging rate (Figure 6). The population is most likely restricted to its limited distribution by physical factors such as temperature (Figure 4,5).

Given the population's apparent dependency on the more stable temperatures found downstream of the seeps and springs in the Black Partridge Forest Preserve, the greatest threats to this population are those which would alter this temperature and flow regime in some manner. A lowering of the water table, for instance, could have extremely negative consequences for this population by decreasing the amount of cool water entering the stream through the seeps and springs. The PVA model also reveals that anything that either lowers the carrying capacity or greatly increases the frequency of catastrophes would also have a substantial negative effect on the population. Factors which could lower the carrying capacity would include altered temperature regimes that shorten the cooler reach of stream, increased sedimentation which could affect breeding success, etc.

One caveat to this analysis is that with only two years of data, we have only the very basic information necessary to do a PVA. Additional years of data create better models, primarily by allowing for estimates of variance in survivorship and fecundity. Given the concern with this stream, and the continued development of roads and businesses in the headwaters and near the forest preserve, we therefore recommend continued monitoring of this population so that the model may be refined and improved.

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Table 1: Population Estimates for Mottled Sculpin (*Cottus bairdi*) in Black Partridge Creek Age classes are based on data in Bailey (1952) and Docker et al. (1985).

Grouping	**Benthic Estimates**		**Depletion Estimates**	
	2000	*2001*	*2000*	*2001*
Total Sculpin	2109	1968	1200	1463
Age I (<60mm)	761	982	660	921
Age II (60-79mm)	905	590	282	315
Age III (80-94mm)	443	396	256	224
Age IV (>95mm)	0	0	2	3

Table 2: Stage matrix for mottled sculpin in Black Partridge Creek based on the benthic sampler estimates. The first row represents fecundity for each age class, while the diagonal represents survival probabilities.

	Age I	Age II	Age III	Age IV
Age I	0.0	0.5483	1.0966	1.0966
Age II	0.7753			
Age III		0.4376		
Age IV			0.0	

Table 3: Stage matrix for mottled sculpin in Black Partridge Creek based on the three-pass removal depletion estimates. The first row represents fecundity for each age class, while the diagonal represents survival probabilities.

	Age I	Age II	Age III	Age IV
Age I	0.0	1.0887	2.3984	2.3984
Age II	0.4773			
Age III		0.7943		
Age IV			0.0117	

Table 4: RAMAS/Metapop results for mottled sculpin population sizes and extinction probabilities in 50 years, based on benthic sampling data. (K=carrying capacity; r=maximum growth rate; S.D.= standard deviation)

Initial Population Size	**K (#/m2)**	**r (max % incr/yr)**	**Catastrophe (probability/ severity)**	*-1 S.D.*	*Population Size in 50 Years*	*+1 S.D*	*Probability of Extinction*
1968	0.25	1	0.01/0.6	745	948	1150	0
1968	0.25	5	0.01/0.6	549	640	731	0
1968	0.25	10	0.01/0.6	563	627	693	0
1968	0.25	1	0.01/0.2	366	776	1186	0
1968	0.25	5	0.01/0.2	326	542	758	0
1968	0.25	10	0.01/0.2	388	560	732	0
1968	0.25	1	0.10/0.6	20	207	394	0
1968	0.25	5	0.10/0.6	109	254	400	0
1968	0.25	10	0.10/0.6	202	351	500	0
1968	0.25	1	0.10/0.2	-85	24	133	0.61
1968	0.25	5	0.10/0.2	-62	38	137	0.47
1968	0.25	10	0.10/0.2	-61	64	189	0.38
1968	0.7	1	0.01/0.6	1074	1392	1710	0
1968	0.7	5	0.01/0.6	1034	1224	1414	0
1968	0.7	10	0.01/0.6	1113	1250	1318	0
1968	0.7	1	0.01/0.2	507	1143	1778	0
1968	0.7	5	0.01/0.2	605	1036	1468	0
1968	0.7	10	0.01/0.2	772	1114	1456	0
1968	0.7	1	0.10/0.6	14	275	537	0
1968	0.7	5	0.10/0.6	166	447	727	0
1968	0.7	10	0.10/0.6	388	689	991	0
1968	0.7	1	0.10/0.2	-125	34	193	0.57
1968	0.7	5	0.10/0.2	-101	56	213	0.41
1968	0.7	10	0.10/0.2	-123	127	377	0.3
1968	1	1	0.01/0.6	1334	1801	2267	0
1968	1	5	0.01/0.6	1934	2307	2680	0
1968	1	10	0.01/0.6	2240	2492	2745	0
1968	1	1	0.01/0.2	680	1530	2380	0
1968	1	5	0.01/0.2	1066	1908	2750	0
1968	1	10	0.01/0.2	1523	2200	2877	0
1968	1	1	0.10/0.6	4	320	635	0
1968	1	5	0.10/0.6	244	743	1241	0
1968	1	10	0.10/0.6	768	1354	1941	0
1968	1	1	0.10/0.2	-156	43	243	0.55
1968	1	5	0.10/0.2	-210	110	431	0.36
1968	1	10	0.10/0.2	-237	209	656	0.25
1968	1.3	1	0.01/0.6	1411	1937	2463	0
1968	1.3	5	0.01/0.6	2424	2894	3364	0
1968	1.3	10	0.01/0.6	2920	3240	3560	0
1968	1.3	1	0.01/0.2	632	1584	2535	0
1968	1.3	5	0.01/0.2	1340	2409	3477	0
1968	1.3	10	0.01/0.2	1988	2861	3733	0
1968	1.3	1	0.10/0.6	6	361	717	0
1968	1.3	5	0.10/0.6	297	962	1628	0
1968	1.3	10	0.10/0.6	908	1696	2485	0
1968	1.3	1	0.10/0.2	-106	28	162	0.59
1968	1.3	5	0.10/0.2	-257	116	490	0.38
1968	1.3	10	0.10/0.2	-285	252	788	0.24

Table 5: RAMAS/Metapop results for mottled sculpin population sizes and extinction probabilities in 50 years, based on depletion data. (K=carrying capacity; r=maximum growth rate; S.D.= standard deviation)

Initial Population Size	**K (#/m2)**	**r (max % incr/yr)**	**Catastrophe (probability/ severity)**	*-1 S.D.*	*Population Size in 50 Years*	*+1 S.D*	*Probability of Extinction*
1463	0.25	1	0.01/0.6	636	826	1016	0
1463	0.25	5	0.01/0.6	534	625	717	0
1463	0.25	10	0.01/0.6	567	634	701	0
1463	0.25	1	0.01/0.2	284	667	1051	0
1463	0.25	5	0.01/0.2	295	521	746	0
1463	0.25	10	0.01/0.2	391	567	743	0
1463	0.25	1	0.10/0.6	7	172	337	0
1463	0.25	5	0.10/0.6	98	245	392	0
1463	0.25	10	0.10/0.6	200	353	507	0
1463	0.25	1	0.10/0.2	-79	23	125	0.58
1463	0.25	5	0.10/0.2	-52	29	110	0.58
1463	0.25	10	0.10/0.2	-58	53	164	0.46
1463	0.7	1	0.01/0.6	852	1126	1420	0
1463	0.7	5	0.01/0.6	1019	1203	1386	0
1463	0.7	10	0.01/0.6	1115	1245	1374	0
1463	0.7	1	0.01/0.2	382	921	1461	0.001
1463	0.7	5	0.01/0.2	586	1011	1436	0
1463	0.7	10	0.01/0.2	782	1113	1444	0
1463	0.7	1	0.10/0.6	-5	220	444	0
1463	0.7	5	0.10/0.6	149	418	688	0
1463	0.7	10	0.10/0.6	385	688	991	0
1463	0.7	1	0.10/0.2	-80	21	121	0.59
1463	0.7	5	0.10/0.2	-99	51	202	0.53
1463	0.7	10	0.10/0.2	-128	119	366	0.33
1463	1	1	0.01/0.6	1060	1440	1819	0
1463	1	5	0.01/0.6	1845	2202	2559	0
1463	1	10	0.01/0.6	2196	2464	2731	0
1463	1	1	0.01/0.2	429	1130	1831	0
1463	1	5	0.01/0.2	996	1806	2615	0
1463	1	10	0.01/0.2	1523	2196	2869	0
1463	1	1	0.10/0.6	-25	243	511	0
1463	1	5	0.10/0.6	223	702	1192	0
1463	1	10	0.10/0.6	757	1226	1926	0
1463	1	1	0.10/0.2	-92	23	139	0.57
1463	1	5	0.10/0.2	-170	76	323	0.51
1463	1	10	0.10/0.2	-226	182	590	0.32
1463	1.3	1	0.01/0.6	1134	1538	1943	0
1463	1.3	5	0.01/0.6	2333	2766	3199	0
1463	1.3	10	0.01/0.6	2853	3200	3547	0
1463	1.3	1	0.01/0.2	554	1279	2004	0
1463	1.3	5	0.01/0.2	1171	2234	3297	0
1463	1.3	10	0.01/0.2	1899	2802	3705	0
1463	1.3	1	0.10/0.6	-17.32	271	559	0
1463	1.3	5	0.10/0.6	200	799	1398	0
1463	1.3	10	0.10/0.6	880	1638	2397	0
1463	1.3	1	0.10/0.2	-117	33	183	0.57
1463	1.3	5	0.10/0.2	-156	71	298	0.5
1463	1.3	10	0.10/0.2	-316	248	812	0.29

Figure 1: Mottled Sculpin (*Cottus bairdi*). Photo by Jason Cashmore.

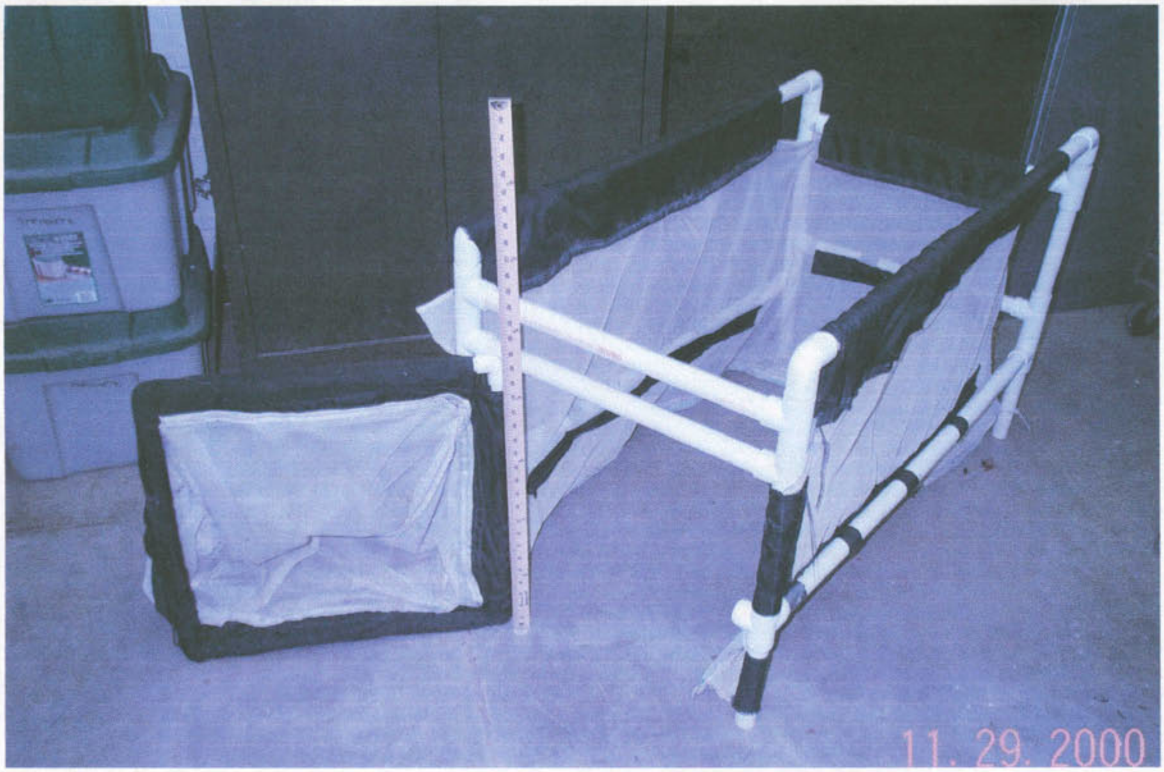

Figure 2: Benthic sampler used to estimate population size of mottled sculpin (*Cottus bairdi*) in Black Partridge Creek. The sampler is 5.38in^2 (1/2m^2) in area.

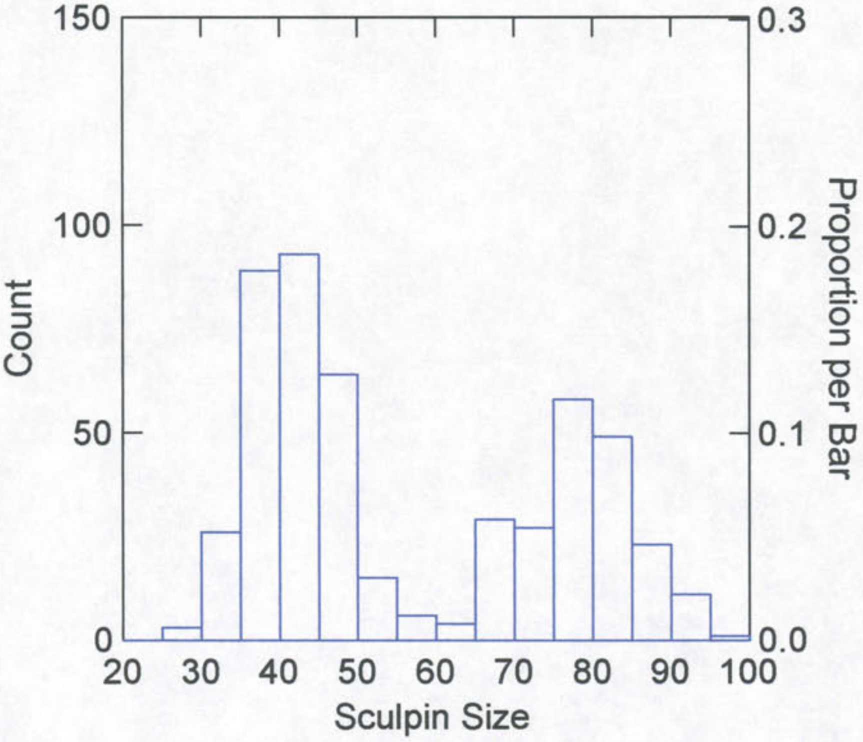

Figure 3: Example of size distribution of mottled sculpin (*Cottus bairdi*) in Black Partridge Creek. The first peak represents young of the year. The second peak represents individuals aged one year or greater. Samples were collected on August 2nd and 3rd, 2000.

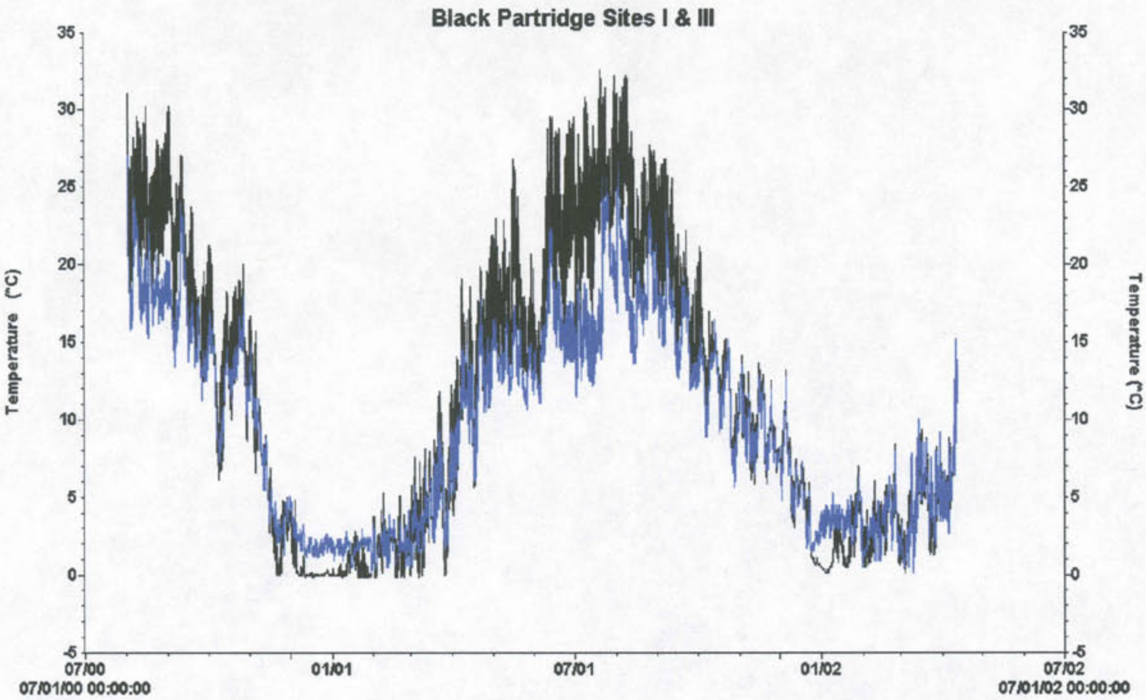

Figure 4: Two years of temperature readings from Black Partridge Creek. The black is from a data logger placed in the upper portion of the watershed. The blue line is from a data logger placed in the middle of the reach containing sculpin.

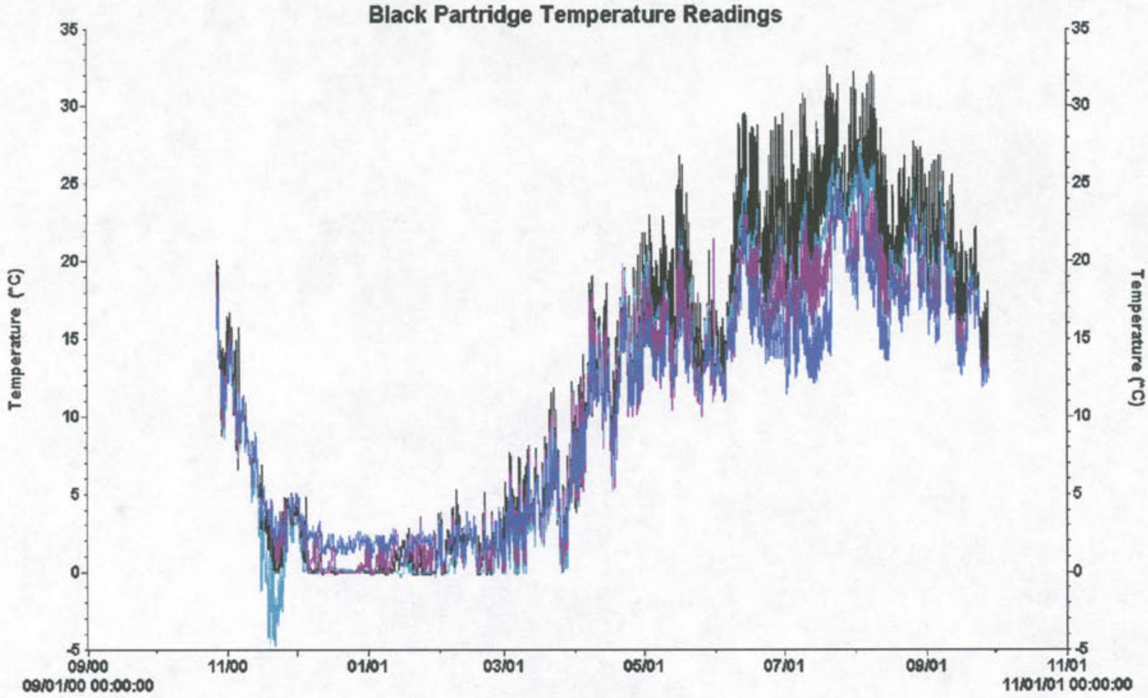

Figure 5: One year of temperature data from Black Partridge Creek. The black line is from a logger placed in the upper portions of the watershed. The green line is from a logger placed at the upper edge of the reach containing sculpin, above where most of the seeps and springs enter the stream. The blue line is from a logger placed in the middle of the sculpin reach. The purple line is from a logger placed just below the reach containing sculpin.

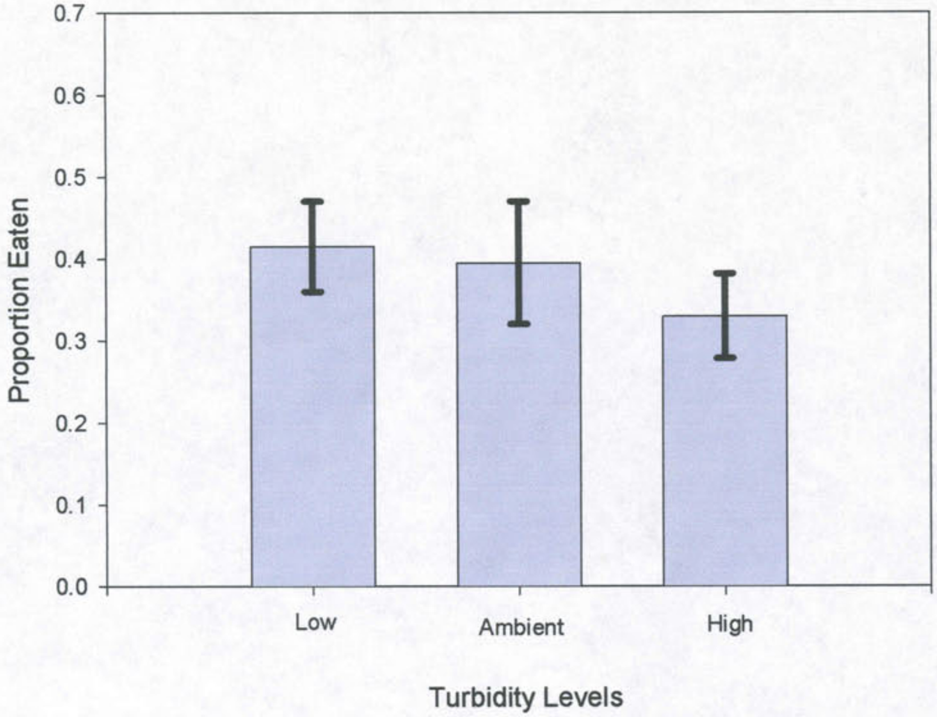

Figure 6: Percent of prey consumed by mottled sculpin (*Cottus bairdi*) at three different turbidity levels (8, 30, and 70 NTUs) during 48 hour feeding trials. Turbidity levels represent the current range of turbidity occurring in Black Partridge Creek. There were no significant differences among the three turbidity levels ($F_{2,5} = 0.72$, $p = 0.53$).

Map 1: Area sampled in Black Partridge Creek. Dark blue shows areas where mottled sculpin were not found. Light blue shows areas where sculpin were found.

Areas with mottled sculpin
Areas without mottled sculpin
Streams