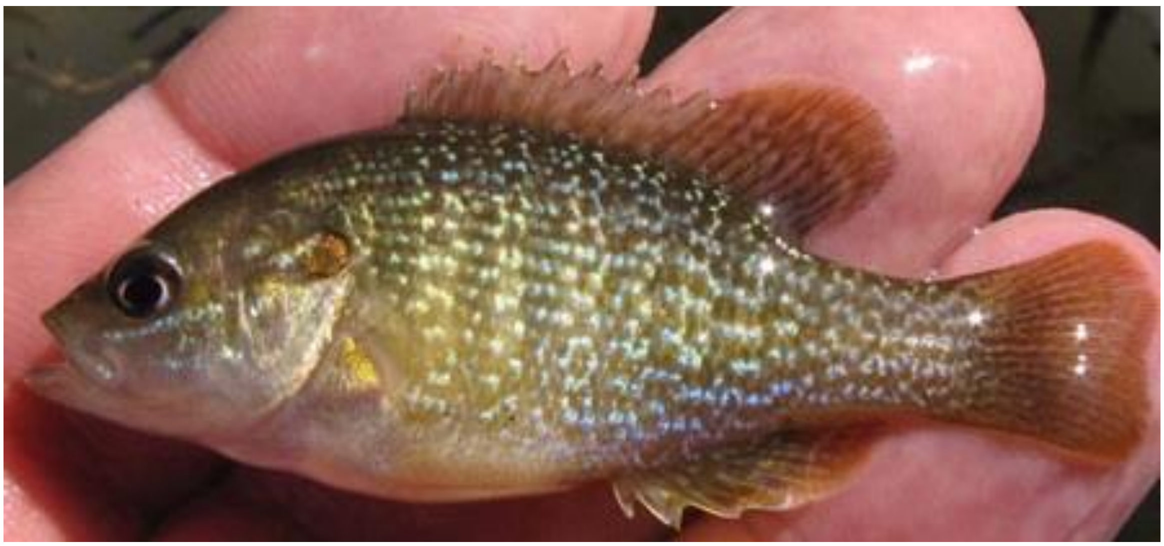
University of Oxford
Department of Continuing Education

A baseline survey of the fish community Fox Creek Ohio USA



Postgraduate Certificate in Ecological Survey Techniques

September 2015

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All Photographs by R. A. Harte-Chance 2015

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Abstract

Reduction in biodiversity due to the degradation of riverine habitats is an ongoing concern worldwide. Historically channelization was commonplace in the USA and elsewhere, and has had pronounced detrimental effects on the biodiversity of lotic ecosystems.

The objective of this project was to provide a baseline survey of the fish populations currently using a historically channelized section of Fox Creek, a second order headwater stream in Stark County Ohio. The stream will be the subject of a re-naturalization scheme in late 2015. This project will provide information both about the current state of the fish community in the stream, and inform the post-naturalization monitoring program.

A combination trap and net surveying was used, fish identified to species level and life stage and gender noted when possible. Environmental data was collected and details of the current thalweg prepared.

The fish community structure was heavily dominated by one generalist running-water cyprinid, *Semotitus atromaculatus*, and there was low species diversity. If possible, post-restoration surveys should aim to compare aim the results with the upstream forested stretch of the creek, and to an unmodified site, where natural river features such as the pool-riffle pattern will be more apparent. Findings from such studies will contribute to a greater understanding of the effects of stream restoration on fish assemblages small streams, and will be valuable in future stream restoration efforts within the wider area.

Acknowledgements

I would like to thank Course Director Dr Jocelyne Hughes and project tutor Dr Curt Lamberth who were immensely supportive helping me to keep me on track especially after unusually cold and wet weather caused an abortive start to my first project and impacted my second.

My thanks to Dr. Jeff Corney and the team at The Wilderness Center (TWC), for giving me such a warm welcome, offering access to specialist equipment and allowing me to work in such a special place. I would especially like to thank Gary Popotnik, Director of Conservation and Land Stewardship, and Senior Biologist at TWC, for being so accommodating to a strange British woman who called up out of the blue, and for all of the subsequent advice, support, and kindness I received throughout my project.

I would also like to offer especial thanks to Nichole Biglar and Kaylee McElhaney; Student Interns from Kent State University who gave up their time to act as field assistants – wading through head high vegetation to carry equipment to and from site, sharing mosquito repellent and loosing shoes in the deep sediment of the stream bed with unfailing good humour and courtesy.

Finally, I would like to thank my partner, who was a constant source of support and encouragement throughout the project, and gave up his limited free time to get wet and join in the fun of being eaten by mosquitoes.

1. Introduction

1.1. Historical Background and the Impact of Stream Channelization

Historically many natural stream channels in the Midwestern states of the USA were modified following European settlement of the area (Herman et al., 2008). Many of the streams flooded regularly and were connected with ecologically complex wetlands (Gorney et al., 2012). Streams and wetlands were channelized and realigned in an effort to inhibit flooding and increase the economic productivity of agricultural land. Such channelization was primarily undertaken in order to remove storm water more rapidly (Tomer and James, 2010), and was also thought to improve the aggradation of the watercourse which often occurred following European style land clearance and intensive cultivation. Adjacent land was usually logged and drained right up to the edge of a stream, with no riparian buffer (Alexander and Allan, 2006).

Far from being agriculturally and economically beneficial, this type of anthropogenic disturbance generally results greater extremes of flow, increased erosion and flooding, and decreased water quality; side effects include both “flashier” floods downstream, and lower base flows (Yan et al., 2010; Gorney et al., 2011). Modification of the natural stream course, depth and riparian zone also alters the hydromorphology of the stream, adversely affecting elements such as stream heterogeneity, shade, temperature, nutrient input and geomorphology, often resulting in limited and degraded meso-habitats within the stream (Huang et. al., 2009; Davis and Harden, 2010).

Such geomorphological modifications resulted in the degradation of many headwater streams in the Midwest, and compromised the health of both the stream and watershed (Davis and Harden, 2010, Gorney et al., 2011; Gorney et al., 2012).

1.2. The Significance of Small Streams

The importance of undisturbed small streams and the range of functions performed by them in the context of both hydrology and ecology are well recognised both nationally and internationally (Pinkham, 2000; Fieseler and Wolter, 2006). Such functions include maintaining or increasing biodiversity and providing nursery areas for a wide variety of species, trapping sediments and pollutants, replenishing groundwater and flood control Meyer et al.,2007).

The Ohio Environmental Protection Agency defines headwater streams as small watercourses (generally less than 2m wide), that are the source of most rivers with a watershed less than or equal to 51.8km^2(http://www.epa.state.oh.us/dsw/SurfaceWater.aspx). Such streams are generally either first or second order streams, with a distinct channel, and are an important rearing habitat for many fish, amphibian and invertebrate species, and are the primary water source for many people living further downstream (Meyer et al., 2006).

A lack of appreciation and inadequate grasp of the natural processes and biological importance of small stream communities have impeded attempts to effectively manage such streams worldwide, and hindered effective conservation and management of the wider river network (Storey and Quinn, 2008).

Small first and second order streams have the greatest surface area in contact with the soils within a river network, and therefore have an important part to play in ensuring that there is an uninterrupted flow of water to downstream freshwater ecosystems and ecosystem services. It is therefore imperative to ensure that the result of works undertaken on such streams is understood, and future management regimes can be better informed (Meyer et. al., 2007).

1.3.Channel Restoration

During the last two decades river and stream restoration, including both in-stream elements and the restoration of the riparian corridor has become big business all over the world (Billman et al., 2013), and considerable effort has been put into improving project monitoring in an effort to inform the process of restoration (Jenkinson et al, 2006; Brooks and Lake, 2007, Baldigo and Warren, 2008).

Alexander and Allan (2006) noted that only a small proportion of stream restoration projects in the Midwest had been adequately monitored, while progress has undoubtedly been made in post-restoration monitoring (Arletazz et al, 2010), pre-restoration faunal surveys are not generally incorporated into mitigation plans, and there is no requirement nationally under federal law or locally under Ohio law for a pre-restoration biotic survey to take place in small headwater streams. Detailed investigations into the effect and extent of these works on instream ecology are rarely publically available, and there has been little consideration of the impact of these changes in the context of the wider network of small streams in Ohio (Tomer and James 2010).

In addition to providing flood control naturally meandering small streams tend to have a variety of substrate types, effectively supporting the storage and recharge capacity of the river network. Channelization both straightens and deepens the natural channel and alters the bank profile; restored streams with more natural profiles tend towards slower moving water with a greater diversity of substrates and banks are therefore less easily eroded, reducing the sediment and debris flow downstream (Meyer et. al., 2007; Albertini, 2013).

2. Methodology

2.1.Objectives and questions

To provide baseline data for the proposed stream restoration project and subsequent long-term management plan. It is anticipated that the survey will provide data against which the assumption of a change in fish species abundance, diversity, richness and size structure following restoration (channel geomorphology and habitat) can be gauged. The project aims to answer the following questions:

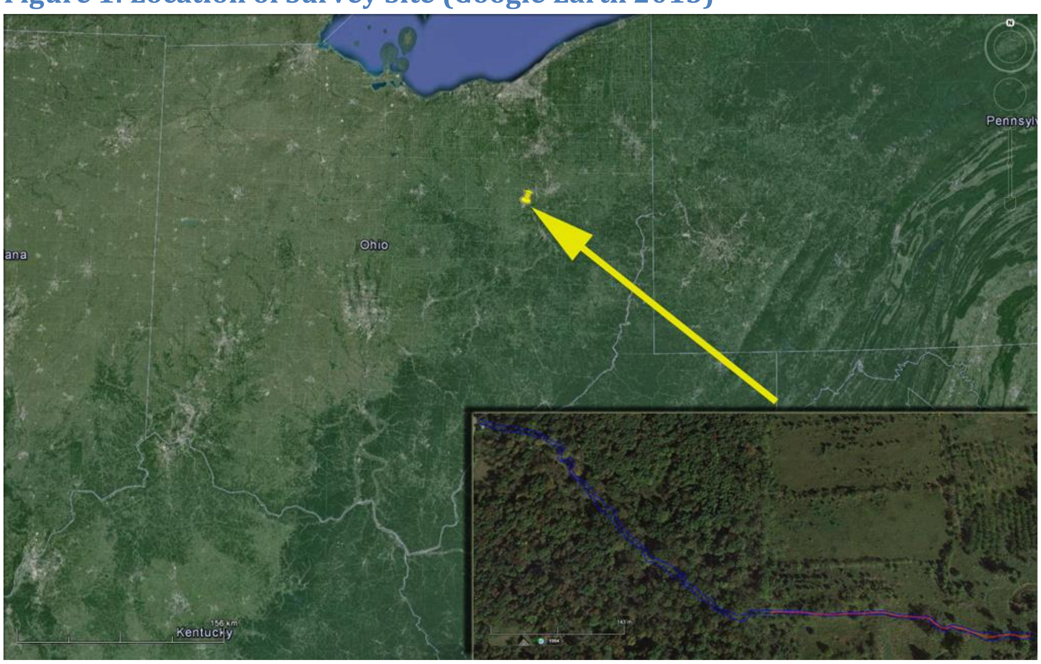
1. What are the differences in abundance, richness and diversity of fish species in the reach?
2. What are the differences in fish species diversity, relative abundance and size structure of each station?

Channelized streams generally have low species diversity and are dominated by eurytopic species that are generalist feeders with non-specialised spawning requirements. The study tested this basic hypothesis.

2.2.The study site

The study took place in a 320m section (hereafter called the reach); of Fox Creek as it flows through an area of land purchased by The Wilderness Center Land Conservancy (TWC), located north of Wilmot, Ohio, USA. The site is centred on latitude 40.672718°N, longitude -81.632883W° (figure 1).

Figure 1: Location of Survey Site (Google Earth 2015)



The land through which Fox Creek flows was historically channelized in the early twentieth century; land tile drains were installed in the bordering agricultural fields, potentially lowering the water table adjacent to the stream. The land adjacent to Fox Creek was purchased in two separate parcels by TWC during the latter half of the twentieth century. The section under study was taken out of agricultural production in 1988. The survey area remains a relatively straight, channelized ditch, with sparse nominal riparian buffer vegetation (Photo 1).

Photo 1: Fox creek riparian zone mid-reach late May 2015

The Fox Creek watershed encompasses approximately 2.56 km^2 (figure 2). The site forms part of the wider Tuscarawus river catchment area, and drains into the wider Tuscurawas watershed via Sugar Creek.

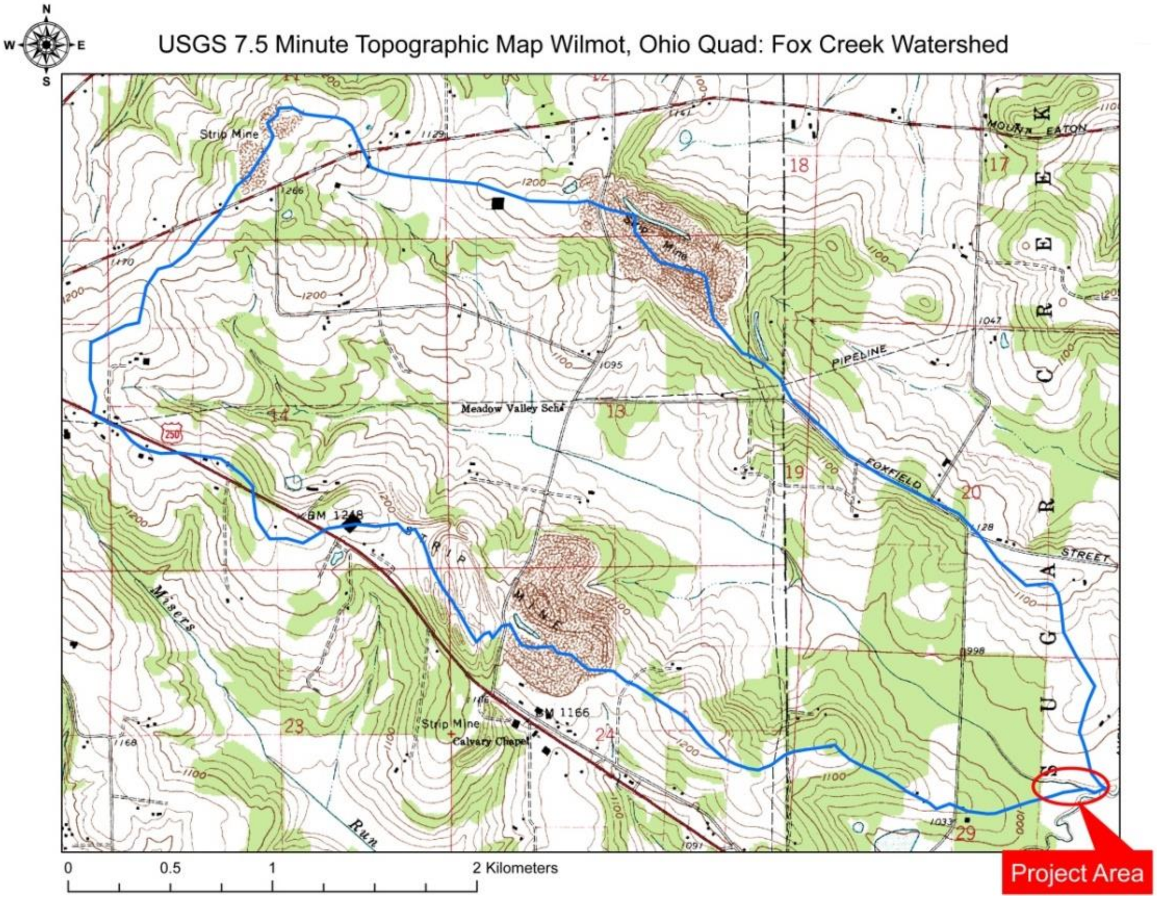


Figure 2: Project Area in context of Fox Creek Watershed

Fox Creek is categorized by Ohio EPA Division of Surface Water as a second order wadeable warm water tributary of the middle branch of Sugar Creek. Classification is based on the Rosgen system, and while such categorization can be problematic, it allows a framework to be set in restoration efforts (Kondolf, 1995; Doyle et al.; 1999, Harman & Jennings, 1999). Fox Creek flows into Sugar Creek at the downstream end of the study area (photo 2). Upstream is an area of secondary growth forest, also previously logged and drained, which has begun to regenerated naturally since being taken out of agriculture in the about 1978.

Photo2: View from the downstream end of Fox Creek looking into Sugar Creek

The reach fits the profile of the US Department of Agriculture soil series survey for Stark Chagrin silt loams (alkaline phase) with an shallow slope of up to 3% which dominate the soils in the area (USDA et al., 1971) (figure 3). The Federal Emergency Management Agency (FEMA) floodplain map (Panel 39151C0317E, effective 29/09/2011), indicates that the survey area fall within the FEMA 100-year floodplain.

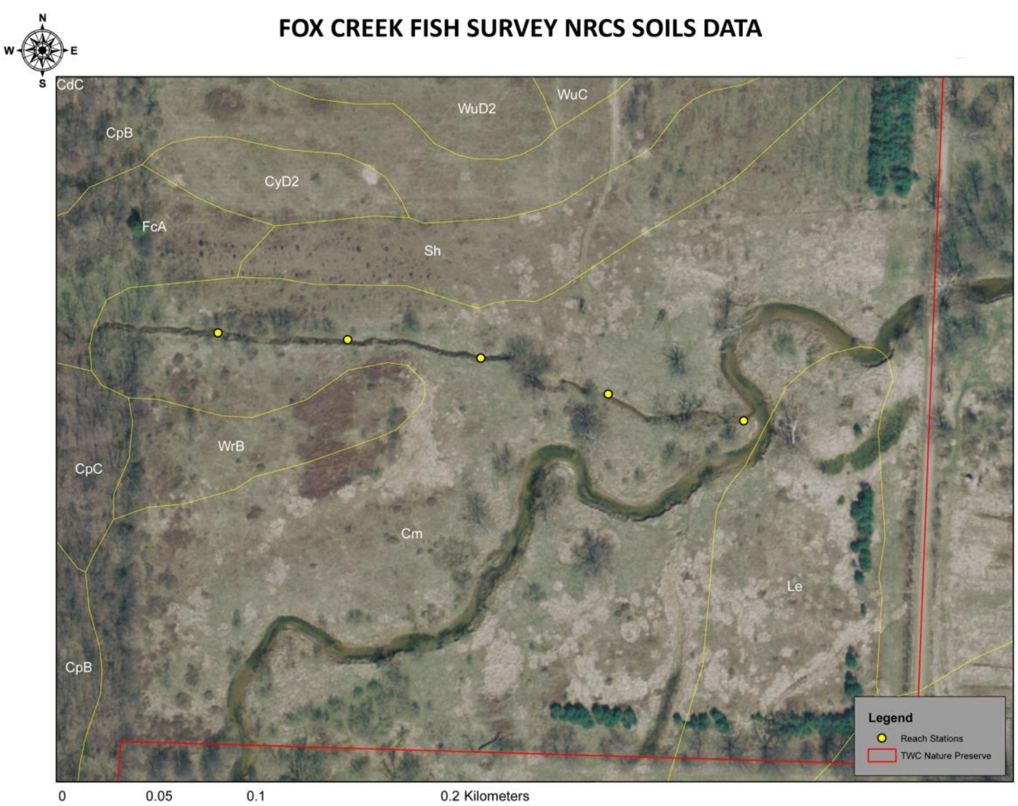


Figure 3: Survey area soil map

2.3.Rationale for undertaking fish survey

Fish species represent the primary top predators within Fox Creek, and were chosen for the survey because their populations react quickly to a large selection of environmental stressors. They will be quick to re-colonise the stream following the planned works and, as such will provide a relatively fast resource for analysing the biotic responses to re-naturalisation (Armstrong et al., 2001). They are also relatively long-lived and forage at varying trophic levels, therefore the effects of reproductive failure and mortality in many age groups within the fish population will provide a record of environmental stressors (Barbour et al., 1999), which can be utilised during the planned 10 year monitoring phase of the project.

2.4.Legislation

The study was initiated due to proposals for stream naturalization financed via the mitigation clause in Section 401 of the Clean Water Act, upheld by State of Ohio regulations. This requires that subject to gaining Section 401 Water Quality Certification (WQC) works that disrupt or destroy such watercourses offer mitigation. The Fox Creek Survey was undertaken as a prelude to mitigation works proposed as part of this process.

There are no restrictions within the State of Ohio upon the surveying of fish within small channelized headwater streams on privately owned property, and none of the expected species are considered rare or endangered.

2.5.Health and Safety

Following University of Oxford requirements, a risk assessment for the project was generated with The Wilderness Center to comply with relevant health and safety regulation.

2.6.Sampling Methods

In order to assist future surveys when the stream will be morphologically different, the reach was divided into 4 x 80m stations. Each station was given a unique identifier (1-4) from downstream to upstream (figure 4).

To facilitate the widest possible species catch, both minnow traps and nets were used. Traps were not baited (to ensure than no feeding bias was introduced), and were deployed for 24 hours (Portt et al., 2006; Bay et al., 2010; Joy et al., 2013).

7 survey trap and 7 net sessions were completed over a period of 9 weeks; due to the unusually wet and stormy summer it was not always possible to undertake trap and net surveys consecutively. Surveys were undertaken when the water was at, or as close to, base flow as possible and the flow rate was as near normal as possible. Attempts were made to ensure that all meso-scale habitats were surveyed. Environmental parameters were taken when traps were

raised or at the start of the netting session, and during a final morphological and densiometry survey.

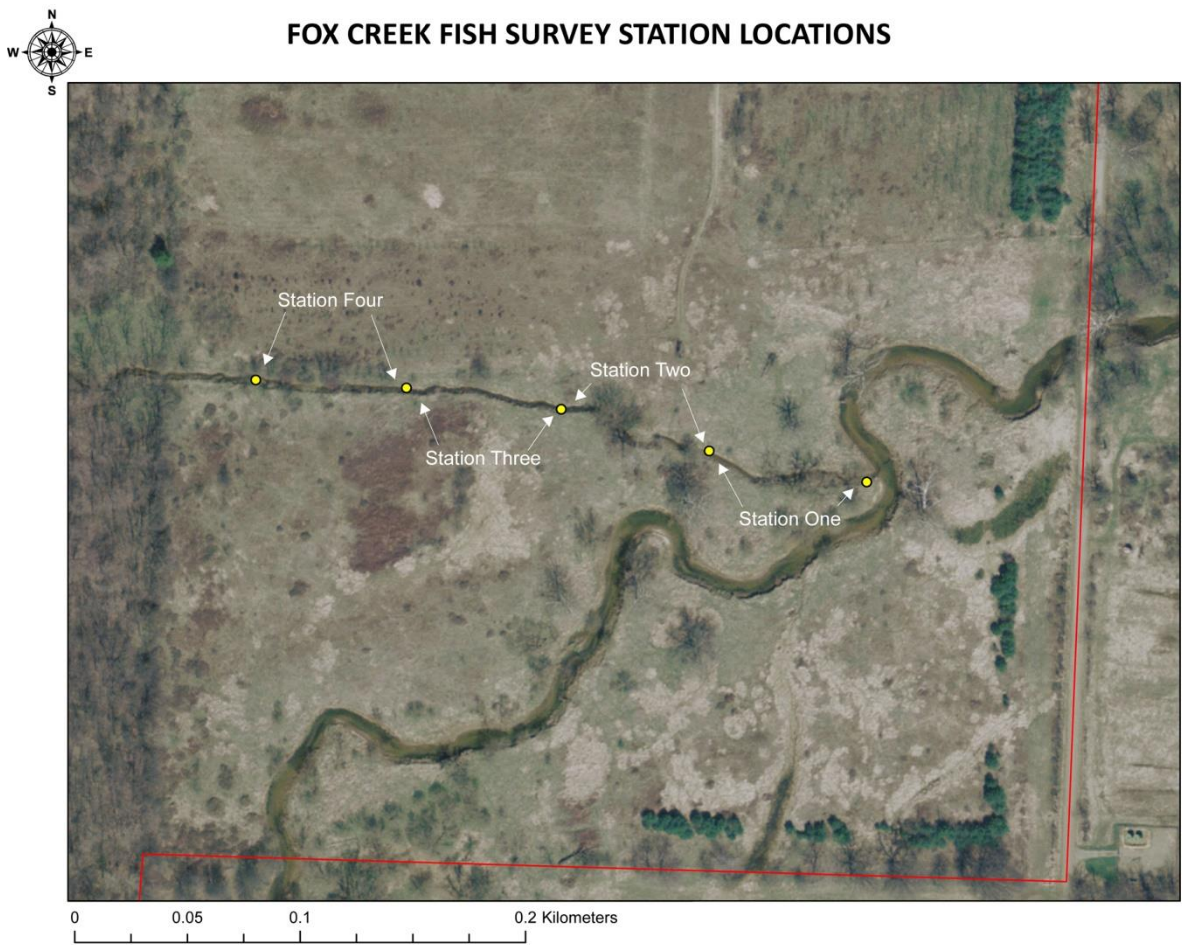


Figure 4: Station Locations

Netting was undertaken in an upstream direction and timed at 30 minutes per station for a single operator (15 minutes with two operators). Net sampling was undertaken by wading in a zig-zag fashion from bank to bank (or bank to centre point with two operators) using kick-nets (photo 3). Seine nets were installed at the each end of the station to act as stop nets, the back net was moved upstream as the survey progressed.

All captured fish were held in a bucket of fresh stream water, identified to species level, and enumerated; where possible gender and life stage were also noted in order to determine species recruitment. If positive species identification was not possible, individuals were noted as 'uncertain' and excluded from data analysis. Air and water temperature and dissolved oxygen (DO) were measured in-stream at a consistent depth of 15cm. Conductivity measurements were taken using a plastic bucket, and pH was measured from a sample taken mid-stream. Turbidity was measured using a standard turbidity tube, and densiometry readings taken at 10m intervals.

Photo 3: Field Assistant Nichole netting at an obstruction point

Meters were checked for accuracy regularly using standard calibration solutions. Manufacturer's instructions were followed for all calibrations; pH 4, 7 and 10 buffer solutions and 1413 µS/cm conductivity standard solution was used to calibrate the pH and conductivity meters. If the meters produced readings during the survey that were outside of the expected norm post-survey testing and re-calibration was undertaken. Data from meters that failed to meet such post-survey testing were noted and excluded from the analyses.

Field data and observations were recorded in an all-weather notebook. Fish assemblage data including species and quantity, chemical/physical data, site name, station and numbers/GPS locational data were noted along with weather and any unusual occurrences (Appendix 1 and 5). (See Appendices 2 & 3 for further information on fish metrics).

Stream flow was categorized as either at base flow or an in cm above the base flow. Base flow was calculated using figures supplied by The Wilderness Center which were taken during analysis undertaken for the mitigation proposal.

The thalweg was measured at base flow following the completion of the fish survey using the techniques outlined in Kaufman et al. 1999 (Figure 5). Channel slope was estimated to the nearest 1.0% using contour data from the USGS mapping service, and results were calculated using the formula change in elevation/horizontal distance (100) = % slope.

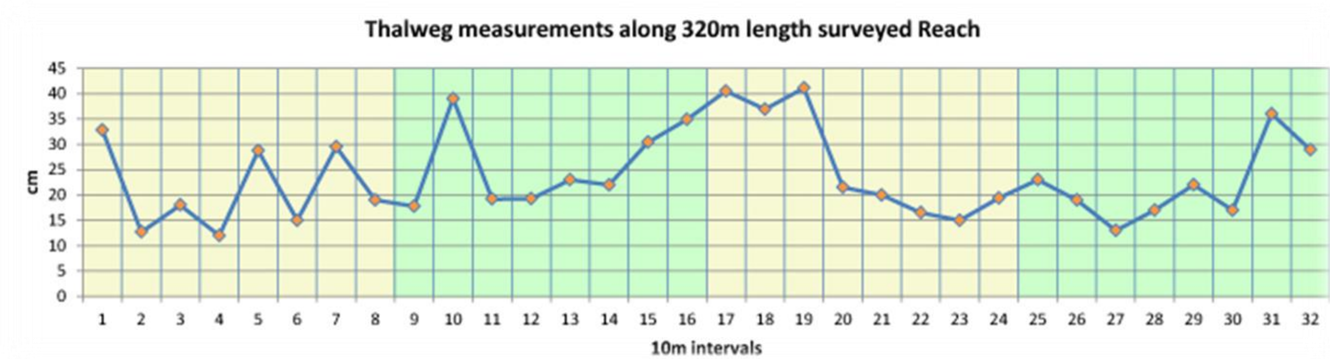


Figure 5: Measurement of Thalweg (stations indicated by change in background colour)

Substrate structure was examined visually categorised subjectively as the 'norm' for station through repeated traversing and examination using Ohio EPA Division of Surface Water recommended categories (Fritz et al., 2006).

Equipment	Model/Type	Supplier
Minnow Traps	Heavy-duty black vinyl dipped steel mesh construction model no. 1271, 42 x 22 cm with an opening of 5.7cm and 1.1 x 0.64cm mesh	Fraybill. Plano, Illinois, USA
Kick Nets	500 micron nylon mesh	LaMotte Company, Chestertown, Maryland, USA
Seine Nets	5mm nylon mesh	LaMotte Company, Chestertown, Maryland, USA
Dissolved Oxygen Meter	YSI ProODO optical	YSI Incorporated, Yellow Springs, Ohio, USA
Conductivity Meter	Oakton CON6^{+} handheld	Oakton Instruments, Vernon Hills, Illinois, USA
pH Meter	Waterproof Eco Testr pH 2	Water Monitoring Equipment and Supply, Seal Harbor, Maine, USA
Densiometer	Model-A spherical concave densiometer	Forestry Suppliers, Inc., Jackson, Mississippi, USA
GPS	Garmin GPSMAP 62sc	Garmin International, Inc., Olathe, Kansas, USA
Notebook	Rite in the Rain No. 353 Field Notebook	JL Darling LLC, Tacoma, Washington, USA

Table 1: Equipment used during survey

Geographic Positioning System (GPS) coordinates for survey sites were taken for future reference.

2.7. Data Analysis

Microsoft Excel and QED Statistics (Pisces Conservation Ltd release 9.0.1) were used for data analysis. Station catch data were sorted by species and method of capture, and the data used to develop the data set for the reach.

Data were tested for normal distribution using the Shapiro-Wilk test, and the probability plot function, demonstrating frequency distribution (Appendix 7), and diversity was calculated using Simpson's index because it takes into account both richness and evenness (McDonald 2014).

Standard deviation and variance were used to describe the count data (Appendix 5). Differences over the surveying period between each sampling method ***and*** each station were compared. McDonald (2014) states that "an ANOVA is not very sensitive to moderate deviations from normality" to test this supposition data was analysed using both parametric one-way ANOVA and non-parametric Kruskal–Wallis tests. To ensure that data was not skewed due to zero counts in one or more stations; analysis is based only on survey sessions where results were recorded from all 4 stations.

Mann-Whitney U tests were used to compare medians between methods of capture across stations, and correlations were tested using the parametric Spearman Rank Correlation.

Fish were categorised after Trautman (1968), Barbour et. al., (1999) and Eakins, R. J. (2015) to understand differences in site utilisation and catch biases (Table 2):

Site Utilisation	Catch Biases
Tolerance	Thermal regime
Trophic groups based on food preferences	Preferred water temperature
Reproductive Guilds	Spawning months
Habitat preference	Spawning temperature
	Fecundity

Table 2: Categories used to understand utilisation and biases

For more information on fish metrics and results see figure 6 and Appendices 2 and 3.

3. Results

3.1. Fish

In all a total of 461 individuals were captured, representing 8 species and 4 families (Table 3 & Figure 6), all were native species common to the area. By far the most widespread was Creek Chub (*Semotitus atromaculatus)*, occurring at 57.5% within the reach (Table 3 & Photo 4). All four of the most abundant species occurred in all stations.

Photo 4: Juvenile Creek Chub

Species composition and relative abundance within the station subgroups of the reach are summarised in Table 3. The highest numbers of species were observed in stations 1-3 (6 species in each station), however the greatest species diversity was observed in station 4 (Simpson's Diversity values of 1-D= 0.59, 0.59, 0.63, and 0.39 respectively).

All stations were dominated by generalist tolerant species, with non-specialised spawning requirements that are normally known to spawn during May and June in this area (Trautman, 1986). (Table 3 and Appendix 3).

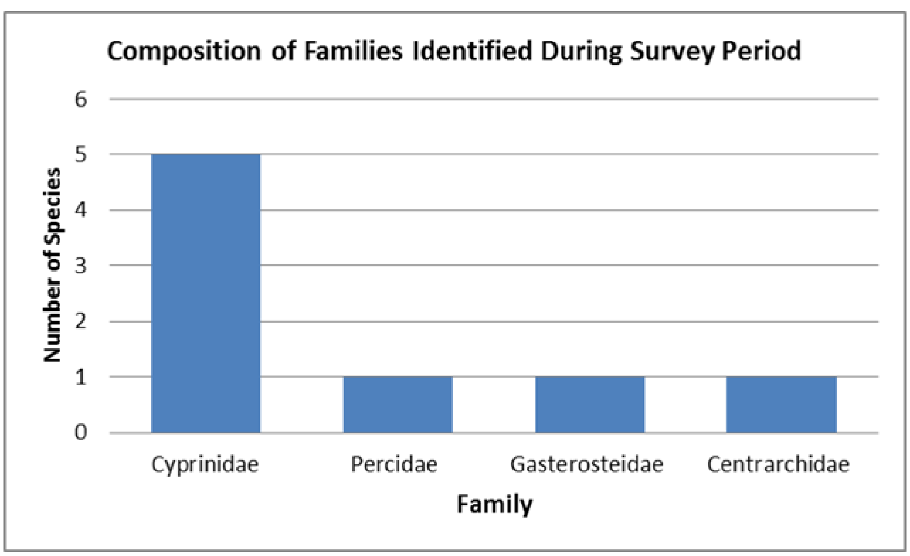


Figure 6: Number of Species by Family

The 4 most abundant species represented 3 families Cyprinidae, Percidae and Gasterosteidae (Appendix 3). Although these 4 species were numerically dominant, the focus of this study was to enumerate and examine fish assemblage structure; therefore, all individuals were included in statistical analyses, however mean and median data were calculated without zero results in results tables using the AVERAGEIF AND MEDIAN(IF(functions in excel).

Taxonomic Serial Number (TSN)	Taxon	Vernacular	Code	Tropic Group	Tolerance	No. of Individuals	Abundance
163376	*Semotitus atromaculatus*	Creek Chub	CC	Generalist	Tolerant	265	57.50%
689949	*Rhinichthus obtusus*	Western Blacknose Dace	BD	Generalist	Tolerant	77	16.70%
168369	*Etheostoma nigrum*	Johnny Darter	JD	Invertivore	Tolerant	46	10.00%
166399	*Culaea inconstants*	Brook Stickleback	BS	Invertivore	Tolerant/ Intermediate	59	12.80%
163502	*Phenacobius mirabilis*	Suckermouth minnow	SM	Insectivore	Intermediate	2	0.40%
163419	*Notropis stramineus*	Sand Shiner	SS	Insectivore	Intermediate	9	0.20%
163508	*Campostoma anomalum*	Central Stoneroller	CS	Herbivore	Intermediate	2	0.40%
	Lepomis cyanellus	Green Sunfish	GS	Invertivore/ Carnivore	Tolerant	1	0.20%

Table 3: Species Composition and Relative Abundance

All four stations were dominated by the Cyprinidae Creek Chub which is one of the most common fish in Ohio (Zimmerman, 2015).

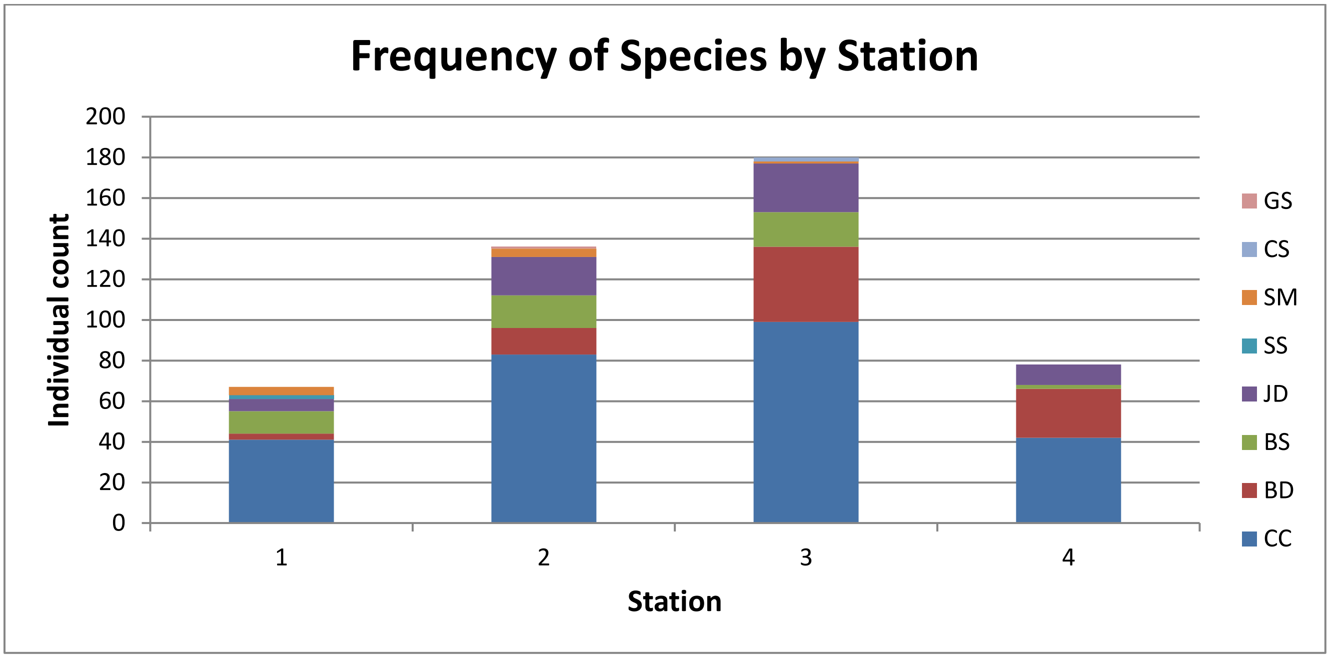


Figure 7: Species Frequency by Station

Data for species and individuals per survey session were tested for normality, and were not found to not deviate significantly from a normal distribution, however, species data in stations 2 and 4 was found to deviate significantly from a normal distribution even after data transformation.

No significant differences in means between stations across survey sessions were found using either the ANOVA or Kruskal –Wallis tests (DF = 3, p = >0.05). Probability plots confirmed normal distributions in stations 1 and 3 (Appendix 7), and small (but statistically insignificant) variances were present in the means returned on testing with stations 1 and 3 returning means of 2, station 2 a slightly higher mean of 2.4 and station 4 a lower mean of 1.6.

The greatest number of individuals per station by trap and net (76 and 104 respectively) was found at station 3, and the fewest number (30 and 37 respectively) was captured at station 1 (figure 8).

Abundance based fish assemblages suggest that there may be a potential separation of sites into two groups. However, due to time limitations no regression analysis was undertaken and therefore this was not tested and may be subject to misreading.

The two mid-reach sites (stations 2 and 3) characterised by higher numbers of individuals in both trap and net survey methods (figure 8), while the number of *Rhinichthus obtusus* was greater at the upstream sites.

Medians of trapping and netting were not significantly different between individual stations using the Mann Whitney U test (U = 6, n1 = 4, n2 = 10, P = >0.05).

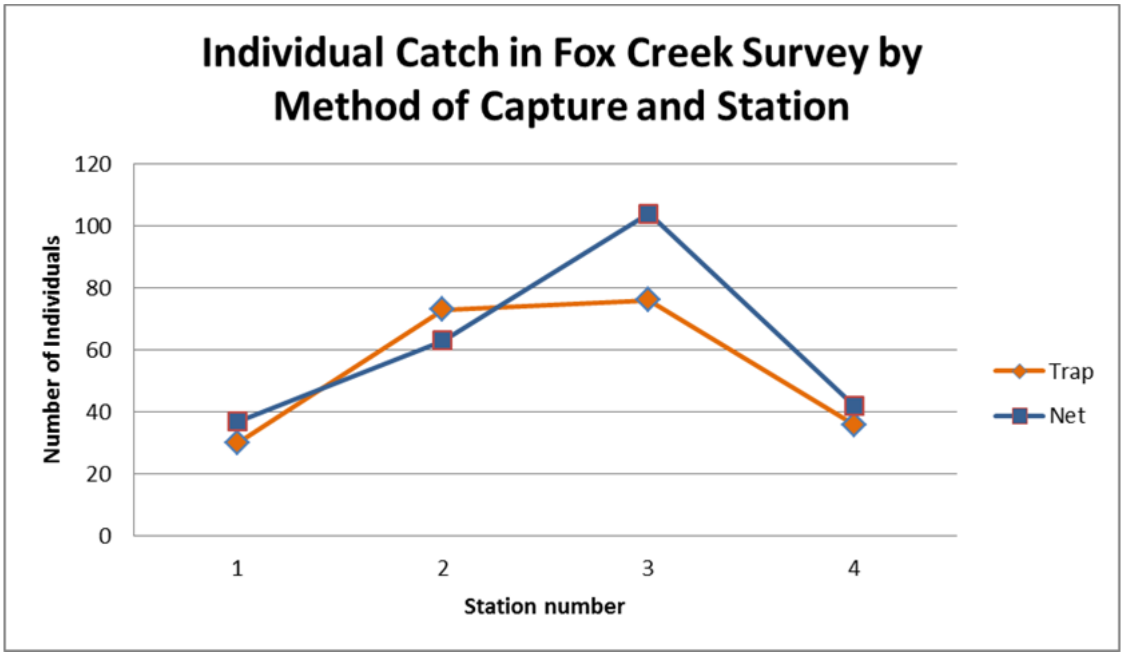


Figure 8: Individuals by station and method of capture

3.2. Habitat variables

The Creek varied in depth from a few cm in the shallowest riffles to >m in the deepest pools. The substrate was largely sandy silt and glacial till with occasional small patches of building rubble and small boulders with very sparse algae substrate cover only found on the small sections of rubble and boulders in stations 3 and 4.

Stations 2 and 4 contained a higher number of in-stream obstacles than stations 1 and 3, which had a low percentage of overhanging vegetation. Station 4 was characterized by a the highest percentage of riffle habitat, rubble/cobble and boulder presence, overhanging trees, and a more woodland riparian zone; while station 3 was characterized by a high percentage of pool habitat, with little overhanging vegetation, and a riparian zone comprised of a combination of overgrown meadow/grassland with few trees.

Long glides and runs made up 85% of the meso-habitat structure of the reach and were prevalent in stations 2 and 3. Station 3 was characterised by a single glide that made up approximately 75% of its length. Station 1 was the most diverse in terms of habitat abundance (figure 9), but exhibited least diversity in substrate with almost 100% silt and sand.

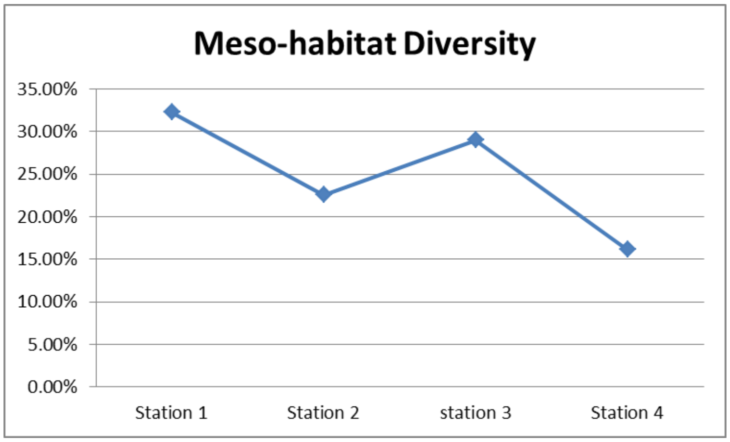


Figure 9: Variations in % habitat diversity between stations

Basic water quality data collected during fish surveys and during the final environmental survey indicated reaches were generally clear with maximum mean turbidity (NTU) in station 1 nearest the confluence with Sugar Creek. Maximum average water temperature occurred at 20.46°C and was found in station 4, and minimum (19.20) at stations 1 and 2). No significant difference was found in temperature among the stations p=>0.05, and pH was constant at 8.0.

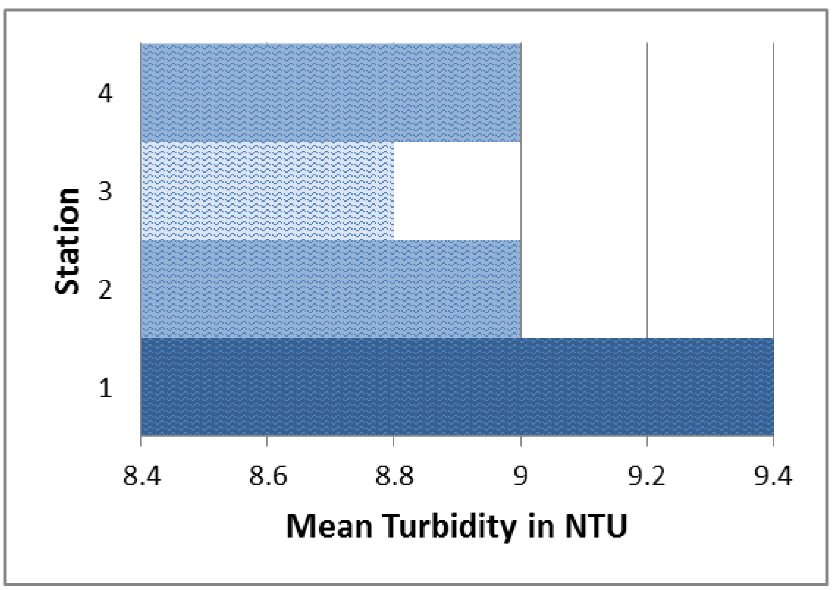


Figure 10: Mean Turbidity by station

Average dissolved oxygen conditions (> 9 mg/L), with very low conductivity 18.83µS/cm total mean. These data indicate that, on days where there had been no significant rainfall in 24 hours the stream had clear waters with low suspended solids and good water quality for fish spawning, no correlation was found between DO and water temperature.

Station 3 has the lowest average light density at full leaf (23.93), and station 4 the highest 83.01 (Figure 12). No correlations were found between species diversity, individual numbers and water temperature or dissolved oxygen content.

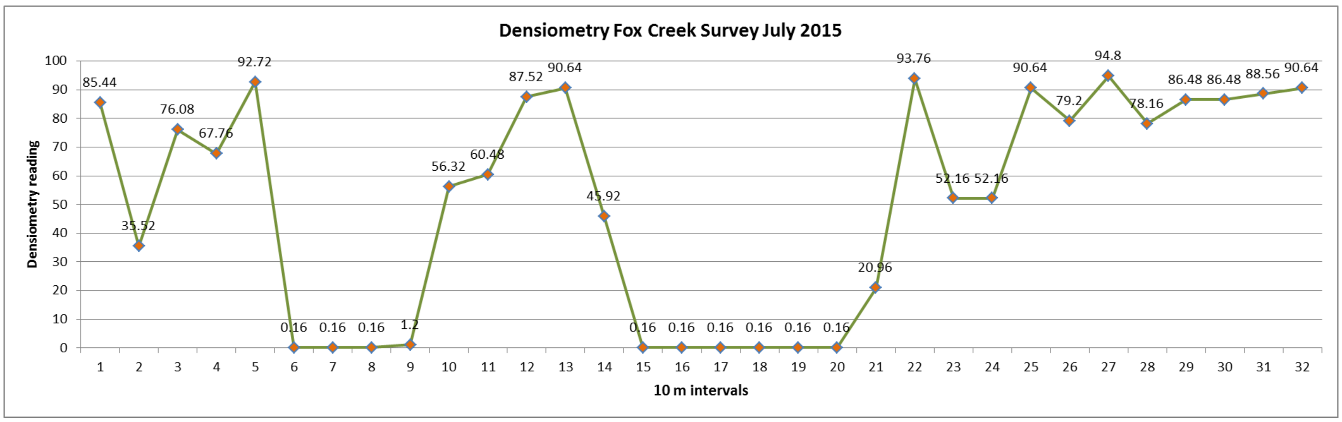


Figure 11: Densiometry results

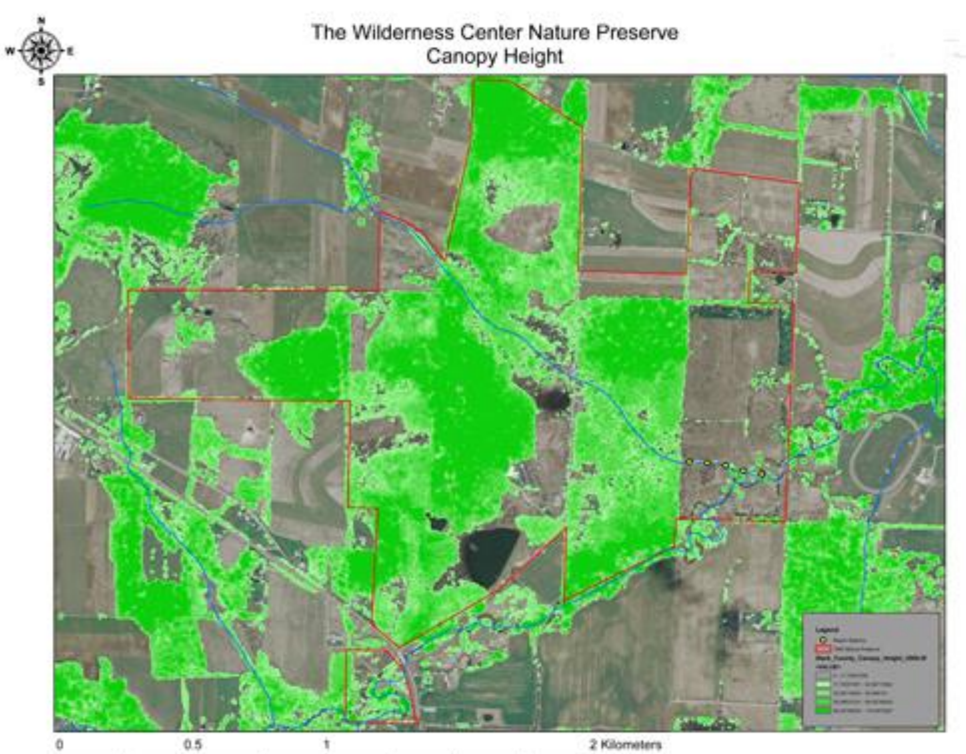


Figure 12: Canopy Height map using ArcMAP data supplied by TWC

4. Discussion

4.1. Overview

Small streams are typically inhabited by low numbers of species, and the differences in community composition between seasons may be high adding to potential sampling biases (Fieseler and Wolter, 2006; Gorney et. al., 2012).

The lower stretches of a summer-warm stream can be a considered a distinct stream type, and where such streams have been channelized, increasing the rate of flow, it is expected that they will be dominated by cyprinids that prefer swift flowing water (Fieseler, and Wolter, 2006).

The 8 species recorded during the survey represented 5% of the total inventory of 160 species of fish in the State of Ohio (Trautman, 1986), and is a greater number of species than expected; however only 4 of the species were present in any significant numbers. All four of the most abundant species are known to spawn within the survey period (Trutman, 1986, Eakins, 2015).

Since the restoration of the reach will include the installation of more riffles and (in-time) a more wooded riparian zone it would be useful to undertake further more rigorous statistical analysis of these elements to ascertain changes over time.

All stations were dominated by *S. atromaculatus* in both capture methods. *S. atromaculatus* is a highly tolerant generalist feeder, with a preference for pools in clear creeks and small rivers (Mims et. al., 2010); therefore its dominance within the minnow traps is not unexpected. That it was also dominant in the netting efforts, and therefore possibly in other meso-habitats may be due to its relatively high fecundity spawning dates and spawning water temperature range (Eakins, 2015) (Appendix 3). This tallied with the initial hypothesis that lack of meso-habitat heterogeneity within historically channelized streams may lead to the stream being dominated by a single cyprinid species.

Habitat and microhabitat use varies among or across species and from juvenile to adult (Sutherland et. al., 2002; Meyer et. al., 2007 and McDonough et. al., 2011), so it is plausible that meso and micro-habitat differences, which are unique to specific stations will support different fish community post-restoration.

The reach was characterized by a dominance of lithophilic, generalists, and tolerant fishes, with only one carnivore present (*Lepomis cyanellus*), although there several large adult *S. atromaculatus* were present and are known to eat smaller fish on occasion (Trautman, 1986), they are not considered fully carnivorous.

Meso-habitat heterogeneity was limited and riffle habitat very poorly represented on the reach. Fox Creek currently has a narrow riparian zone with low levels of diversity and little or no in-stream cover, additionally the creek used to flow through farmland and/or cattle pasture. Numerous studies have reported lower species diversity in agricultural streams due to increased siltation and subsequent reduction of riffle habitat (Zack, 2010) or riparian removal and channelization (McKinney, 2012). This is consistent with the results from this study, and it would therefore be expected that species diversity will be greater in the restored creek.

Zack (2010) points out that canopy cover, or the lack of it, may have an effect on fish community structure and composition. Since the restoration program includes considerable planting along the riparian zone, it would be most useful to assess variations in canopy cover in future studies on Fox Creek, and evaluate changes in light of increased canopy cover as trees mature.

Results suggest that in studies undertaken after restoration, the reach might be divided into separate groups based on habitat composition and future studies designed to take into consideration correlation analysis and potential clumping undertaken on that basis.

4.2.Limitations of the Study

Time for adequate planning and execution of this study was short; a more structured approach to planning especially with a view to measuring potential correlations between species diversity and environmental factors would greatly increase the research potential of the study.

Minnow traps can be selective and their effectiveness and bias is affected by a number of probabilities (Portt et al. 2006):

- Fish will encounter the trap
- Fish enter the trap
- Fish remain in the trap until it is lifted

Gear selectivity may explain the dominance of minnow species and lack of some trophic guilds in the current study, and could have a major impact on future research where families are underrepresented. Due to the possible inefficiency of the sampling methods used, the results of this study are best viewed as the first step in a long-term post-restoration monitoring regime.

In addition, because time was limited, and the late spring/early summer was unusually wet, sampling was confined to ad hoc days during a 7 week period and it was not always possible to undertake a netting session following raising of traps which may have led to biases in the data set. Neither was it possible to adequately test for distinctions in, for instance, hydrological conditions of different stations at different months.

5. Conclusion

It is important to note that the survey represents a brief snapshot in time of the fish community in the stream; it is possible that both the number and species present would show considerable variability through a longer season. The unusually late spring and wet summer encountered during the survey may also have adversely affected the data. More comprehensive study is recommended to thoroughly document fish use and timing of use in this fascinating small stream.

Future work should, if possible, focus on longer collecting periods. Use of a more effective or alternative sampling technique/s (i.e., backpack electroshocking, electric seining, etc.), during longer but, (weather permitting) regular, spring to late autumn collection period across a number of years would more effectively monitor changes in the fish community structure of Fox Creek post-restoration.

Further research comparing the restored section with the naturalized forested section upstream, and the inclusion of a more rigorous suite of habitat variables along with mark and recaptures, could produce a better understanding of meso-habitat use and movement patterns. This could prove highly useful both in terms of the long term management of Fox Creek and in the wider understanding of the benefits and pitfalls of restoration programmes in the future.

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Appendix 1: Primary Environmental Data

Environmental and Geomorphological Survey undertaken on 23.07.15												
Full sun normal baseflow												
Station	**1**			**2**			**3**			**4**		
Riffles	1			1			0			1		
Glides	2			1			1			0		
Pools	4			3			7			3		
Runs	3			2			1			1		
Densiomitry/11m	Raw	as %	Den	Raw	as %	Den	Raw	as %	Den	Raw	as %	Den
	14	14.56	85.44	95	98.8	1.2	96	99.84	0.16	9	9.36	90.64
	62	64.48	35.52	42	43.68	56.32	96	99.84	0.16	20	20.8	79.2
	23	23.92	76.08	38	39.52	60.48	96	99.84	0.16	5	5.2	94.8
	31	32.24	67.76	12	12.48	87.52	96	99.84	0.16	21	21.84	78.16
	7	7.28	92.72	9	9.36	90.64	76	79.04	20.96	13	13.52	86.48
	96	99.84	0.16	52	54.08	45.92	6	6.24	93.76	13	13.52	86.48
	96	99.84	0.16	96	99.84	0.16	46	47.84	52.16	11	11.44	88.56
	96	99.84	0.16	96	99.84	0.16	46	47.84	52.16	9	9.36	90.64

Date of survey	29.05.15				05.06.15				25.06.15				26.06.15				03.07.15			
Station	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Turbidity (ntu)	<8	<8	<8	<8	<8	<8	<8	<8	10	10	8	10	8	8	8	8	11	10	10	10
DO%	90	89	90	89	89	91	90	89	100	101	101	100	99	99	99	99	99	100	99	99
DO mg/L	8.4	8.3	8.4	8.3	8.2	8.3	8.4	8.3	9.4	9.4	9.4	9.3	9.2	9.3	9.2	9.2	9.3	9.4	9.2	9.2
Cond m/s					19	19	19	20	20	19	19	20	16	17	16	16	19	19	19	19
mmHg	740	738	739	739	736	736	736	736	737	737	737	737	736	736	736	736	740	738	738	739
Water Temp °C	19	19	19	19	20	20	19	19	19	19	19	19	19	19	19	22	18	19	19	22
Weather/ av Temp °C	Partial Cloud/23.48				Sunny with later cloud/23.90				Partial cloud + light rain/22.40				Sunny/21.75				Sunny/21.58			
Pricip/24hrs	None				None				Moderate				Light				None			
Velocity	Normal				Normal				> Normal				> Normal				> Normal			
Level	Base				Base				> 10cm				> 7cm				> 3cm			

Date of survey	05.07.15				06.07.15				12.07.15				18.07.15				22.07.15			
Station	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Turbidity (ntu)	<8	<8	<8	<8	9	8	9	8	9	9	9	9	<8	<8	<8	<8	<8	<8	<8	<8
DO%	100	101	100	100									100	100	100	101				
DO mg/L	9.4	9.4	9.3	9.3									9	9	9	9				
Cond m/s	20	19	19	19																
mmHg	736	736	737	737									734	734	734	734				
Water Temp °C	19	19	20	20									21	21	21	21				
Weather/ av Temp °C	Sunny/22.45				Light cloud and later rain/23.04				Partial cloud with sun/22.09				Sunny/28.03				Sunny/23.73			
Pricip/24hrs	None				Moderate				Light				Light				None			
Velocity	Normal				>Normal				Normal				>Normal				Normal			
Level	>2cm				>9cm				>5cm				>3cm				Base			

Appendix 2: Fish Survey Metrics and Trophic Group Designations

Metric	Rationale
Number of fish species and individuals	The total number of species and individuals supported by the stream will decrease with environmental degradation – this is a good general indicator of environmental quality. Number of Individuals - excluding tolerant species, serves as a measure of toxic sensitivity and total degradation
Number of darters	Darters are sensitive to environmental degradation, require clean water. Darter habitats may be degraded as the result of siltation, channelization, etc.
Number of species of sunfish	These species are particularly sensitive to silting in of pools and loss of in-stream cover, they favour quiet pools and in-stream cover and are indicative of the degree of preservation of original pool, riffle and channel components of the stream reach
Number of Minnow species	Minnows are relatively long-lived and favour high environmental quality. They can serve as long-term indicators of surrounding conditions
Number of species of suckers	Suckers are intolerant of chemical and habitat degradation and because they are long lived provide a multiyear perspective
Number of intolerant/sensitive species	Intolerant species are most affected by stream degradation and therefore would disappear by the time a stream is rated as 'fair'. A greater proportion of intolerant species indicates less degradation
Percentage of tolerant species	Tolerant species are present in moderate number but become dominant as stream degrades
Percentages different tropic groups	The trophic groups describe what the fish species eats and where it is in the food web.
Percentage of species with multiple age groups	Determines reproductive success of the fish population

TROPHIC GROUP DESIGNATIONS	**TOLERANCE DESIGNATIONS (relevant to non-specific stressors)**
Piscivore	Intolerant
Herbivore	Intermediate
Omnivore	Tolerant
Insectivore (including specialized insectivores but excluding generalists such as the Creek Chub and Western Blacknose Dace)	
Filter feeder	
Generalist feeder	
Invertivore	

Appendix 3: Fish Survey Metrics and Trophic Group Designation- Results

Species	Family	Common Name	Tropic Group	Tolerance	Environment	Habitat Preference	Reproductive Guild
Semotitus atromaculatus	Cyprinidae	Creek Chub	Generalist	Tolerant	benthopelagic	pools	Lithophils
Rhinichthus obtusus	Cyprinidae	Western Blacknose Dace	Generalist	Tolerant	benthic	riffles and runs	Lithophils
Etheostoma nigrum	Percidae	Johnny Darter	Invertivore	Tolerant	benthic	pools	Speleophils
Culaea inconstants	Gasterosteidae	Brook Stickleback	Invertivore	Tolerant/ Intermediate	benthopelagic	clear pools: usually associated with aquatic vegetation;	Ariadnophils
Phenacobius mirabilis	Cyprinidae	Suckermouth minnow	Insectivore	Intermediate	benthic	riffles and runs	lithophilic
Notropis stramineus	Cyprinidae	Sand Shiner	Insectivore	Intermediate	benthopelagic	warm clear runs and pools	Phyto-lithophils
Campostoma anomalum	Cyprinidae	Central Stoneroller	Herbivore	Intermediate	benthic	pool/riffle/run	Lithophils
Lepomis cyanellus	Centrarchidae	Green Sunfish	Invertivore/ Carnivore	Tolerant	benthopelagic	quiet pools often near aquatic vegetation	Polyphils

Species	Family	Preferred Water Temperature	Spawning Months	Spawning Temp °C	Fecundity	Thermal Regime
Semotitus atromaculatus	Cyprinidae	20.8°C	May-June	12 - 17	500-7,539	coolwater
Rhinichthus obtusus	Cyprinidae	19-25°C	May-June	15.5-21	264-1,360	coolwater
Etheostoma nigrum	Percidae	22.8°C	May-June	12-21	48-1,248	coolwater
Culaea inconstants	Gasterosteidae	21.3°C	May-July	8-19	40-451	coolwater
Phenacobius mirabilis	Cyprinidae	15-25°C	April-May	17-23	830-1640	coolwater
Notropis stramineus	Cyprinidae	Unknown	June-August	21-27	150-2,660	warmwater
Campostoma anomalum	Cyprinidae	19-27°C	May-June	14-24	150-4,801	coolwater
Lepomis cyanellus	Centrarchidae	27-31°C	June-August	20-28	2,000-10,000	warmwater

Appendix 4: Survey Forms

FISH SAMPLING FIELD DATA SHEET (FRONT)

FOX CREEK 2015	**Date**
page ______ of ______	**Form completed by** [redacted]
Stream state	

SAMPLE COLLECTION		
Method of capture		
Start time	End time	Duration

ENVIRONMENTAL DATA	
Water Temp	Conductivity
Air Temp	Densiometry
DO	
Weather	
Turbidity	

HABITAT TYPES	**Number**	**Sketch (if necessary)**
Riffles		
Pools		
Runs		
Glides		
Other		

Photo s	GPS Coordinates	Number	Description

GENERAL COMMENTS

FISH SAMPLING DATA SHEET (BACK)

Station	Trap/Net	Species	Count	M/F

Ohio EPA — **Qualitative Habitat Evaluation Index and Use Assessment Field Sheet** — ***QHEI Score:*** ☐

Stream & Location: ________ ***RM:*** _ _ _._ ***Date:*** _ _/_ _/_ _

________ ***Scorers Full Name & Affiliation:*** ________

River Code: _ _ - _ _ _ - _ _ _ ***STORET #:*** _ _ _ _ _ _ ***Lat./ Long.:*** (NAD 83 - decimal °) _ _ . _ _ _ _ _ /8 _ . _ _ _ _ *Office verified location* ☐

1] *SUBSTRATE*
Check ***ONLY*** **Two** substrate *TYPE BOXES*; estimate % or note every type present

BEST TYPES	POOL	RIFFLE	OTHER TYPES	POOL	RIFFLE
☐☐ BLDR /SLABS [10]	___	___	☐☐ HARDPAN [4]	___	___
☐☐ BOULDER [9]	___	___	☐☐ DETRITUS [3]	___	___
☐☐ COBBLE [8]	___	___	☐☐ MUCK [2]	___	___
☐☐ GRAVEL [7]	___	___	☐☐ SILT [2]	___	___
☐☐ SAND [6]	___	___	☐☐ ARTIFICIAL [0]	___	___
☐☐ BEDROCK [5]	___	___			

(Score natural substrates; ignore sludge from point-sources)

NUMBER OF BEST TYPES: ☐ 4 or more [2] ☐ 3 or less [0]

Comments

Check ONE (*Or 2 & average*)

ORIGIN
- ☐ LIMESTONE [1]
- ☐ TILLS [1]
- ☐ WETLANDS [0]
- ☐ HARDPAN [0]
- ☐ SANDSTONE [0]
- ☐ RIP/RAP [0]
- ☐ LACUSTURINE [0]
- ☐ SHALE [-1]
- ☐ COAL FINES [-2]

QUALITY

SILT
- ☐ HEAVY [-2]
- ☐ MODERATE [-1]
- ☐ NORMAL [0]
- ☐ FREE [1]

EMBEDDEDNESS
- ☐ EXTENSIVE [-2]
- ☐ MODERATE [-1]
- ☐ NORMAL [0]
- ☐ NONE [1]

Substrate ☐ *Maximum 20*

2] *INSTREAM COVER*
Indicate presence 0 to 3: **0**-Absent; **1**-Very small amounts or if more common of marginal quality; **2**-Moderate amounts, but not of highest quality or in small amounts of highest quality; **3**-Highest quality in moderate or greater amounts (e.g., very large boulders in deep or fast water, large diameter log that is stable, well developed rootwad in deep / fast water, or deep, well-defined, functional pools.

- ____ UNDERCUT BANKS [1]
- ____ OVERHANGING VEGETATION [1]
- ____ SHALLOWS (IN SLOW WATER) [1]
- ____ ROOTMATS [1]
- ____ POOLS > 70cm [2]
- ____ ROOTWADS [1]
- ____ BOULDERS [1]
- ____ OXBOWS, BACKWATERS [1]
- ____ AQUATIC MACROPHYTES [1]
- ____ LOGS OR WOODY DEBRIS [1]

AMOUNT
Check ONE (*Or 2 & average*)
- ☐ EXTENSIVE >75% [11]
- ☐ MODERATE 25-75% [7]
- ☐ SPARSE 5-<25% [3]
- ☐ NEARLY ABSENT <5% [1]

Comments

Cover ☐ *Maximum 20*

3] *CHANNEL MORPHOLOGY*
Check ONE in each category (*Or 2 & average*)

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY
☐ HIGH [4]	☐ EXCELLENT [7]	☐ NONE [6]	☐ HIGH [3]
☐ MODERATE [3]	☐ GOOD [5]	☐ RECOVERED [4]	☐ MODERATE [2]
☐ LOW [2]	☐ FAIR [3]	☐ RECOVERING [3]	☐ LOW [1]
☐ NONE [1]	☐ POOR [1]	☐ RECENT OR NO RECOVERY [1]	

Comments

Channel ☐ *Maximum 20*

4] *BANK EROSION AND RIPARIAN ZONE*
Check **ONE** in each category for ***EACH BANK*** (*Or 2 per bank & average*)

River right looking downstream

L R EROSION	L R RIPARIAN WIDTH	L R FLOOD PLAIN QUALITY	L R
☐☐ NONE / LITTLE [3]	☐☐ WIDE > 50m [4]	☐☐ FOREST, SWAMP [3]	☐☐ CONSERVATION TILLAGE [1]
☐☐ MODERATE [2]	☐☐ MODERATE 10-50m [3]	☐☐ SHRUB OR OLD FIELD [2]	☐☐ URBAN OR INDUSTRIAL [0]
☐☐ HEAVY / SEVERE [1]	☐☐ NARROW 5-10m [2]	☐☐ RESIDENTIAL, PARK, NEW FIELD [1]	☐☐ MINING / CONSTRUCTION [0]
	☐☐ VERY NARROW < 5m [1]	☐☐ FENCED PASTURE [1]	
	☐☐ NONE [0]	☐☐ OPEN PASTURE, ROWCROP [0]	

Indicate predominant land use(s) past 100m riparian.

Comments

Riparian ☐ *Maximum 10*

5] *POOL / GLIDE AND RIFFLE / RUN QUALITY*

MAXIMUM DEPTH
Check **ONE** (*ONLY!*)
- ☐ > 1m [6]
- ☐ 0.7-<1m [4]
- ☐ 0.4-<0.7m [2]
- ☐ 0.2-<0.4m [1]
- ☐ < 0.2m [0]

CHANNEL WIDTH
Check ONE (*Or 2 & average*)
- ☐ POOL WIDTH > RIFFLE WIDTH [2]
- ☐ POOL WIDTH = RIFFLE WIDTH [1]
- ☐ POOL WIDTH < RIFFLE WIDTH [0]

CURRENT VELOCITY
Check ALL that apply
- ☐ TORRENTIAL [-1]
- ☐ VERY FAST [1]
- ☐ FAST [1]
- ☐ MODERATE [1]
- ☐ SLOW [1]
- ☐ INTERSTITIAL [-1]
- ☐ INTERMITTENT [-2]
- ☐ EDDIES [1]

Indicate for reach - pools and riffles.

Recreation Potential
Primary Contact
Secondary Contact
(circle one and comment on back)

Comments

Pool / Current ☐ *Maximum 12*

Indicate for functional riffles; Best areas must be large enough to support a population of riffle-obligate species: Check ONE (*Or 2 & average*). ☐ **NO RIFFLE [metric=0]**

RIFFLE DEPTH	RUN DEPTH	RIFFLE / RUN SUBSTRATE	RIFFLE / RUN EMBEDDEDNESS
☐ BEST AREAS > 10cm [2]	☐ MAXIMUM > 50cm [2]	☐ STABLE (e.g., Cobble, Boulder) [2]	☐ NONE [2]
☐ BEST AREAS 5-10cm [1]	☐ MAXIMUM < 50cm [1]	☐ MOD. STABLE (e.g., Large Gravel) [1]	☐ LOW [1]
☐ BEST AREAS < 5cm [metric=0]		☐ UNSTABLE (e.g., Fine Gravel, Sand) [0]	☐ MODERATE [0]
			☐ EXTENSIVE [-1]

Comments

Riffle / Run ☐ *Maximum 8*

6] *GRADIENT* (ft/mi)
DRAINAGE AREA (mi²)

- ☐ VERY LOW - LOW [2-4]
- ☐ MODERATE [6-10]
- ☐ HIGH - VERY HIGH [10-6]

%POOL: ☐ **%GLIDE:** ☐
%RUN: ☐ **%RIFFLE:** ☐

Gradient ☐ *Maximum 10*

EPA 4520 06/16/06

Appendix 5: Summaries of Trapping and Netting Survey Data.

Legend of Species		
Semotitus atromaculatus	Creek Chub	CC
Rhinichthus obtusus	Western Blacknose Dace	BD
Etheostoma nigrum	Johnny Darter	JD
Culaea inconstants	Brook Stickleback	BS
Phenacobuis mirabilis	Suckermouth minnow	SM
Notropis stramineus	Sand Shiner	SS
Campostoma anomalum	Central Stoneroller	CS
Lepomis cyanellus	Green Sunfish	GS

Trap Survey **Station 1**								
	Count by species							
Survey number	**CC**	**BD**	**JD**	**BS**	**SM**	**SS**	**CS**	**GS**
1	6	2	1	0	1	0	0	0
2	10	0	1	0	0	0	0	0
3	2	0	1	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	1	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	5	0	0	0	0	0	0	0
Total	24	2	3	0	1	0	0	0
mean	4.8	2	1	0	1	0	0	0
Median	5	2	1	0	1	0	0	0
Variance s^2	14	0.57	0.29	0	0.14	0	0	0
Standard Deviation	3.74	0.76	0.53	0	0.38	0	0	0

Trap Survey Station 2								
	Count by species							
Survey number	**CC**	**BD**	**JD**	**BS**	**SM**	**SS**	**CS**	**GS**
1	6	0	1	0	0	1	0	0
2	4	0	0	2	0	1	0	0
3	23	1	0	0	0	0	0	1
4	2	0	0	0	0	0	0	0
5	5	1	0	0	0	0	0	0
6	9	6	0	0	0	0	0	0
7	10	0	0	0	0	0	0	0
Total	59	8	1	2	0	2	0	1
mean	8.43	2.67	1	2	0	1	0	1
Median	6	1	1	2	0	1	0	1
Variance s^2	49	4.81	0.14	0.57	0	0.24	0	0.14
Standard Deviation	7	2.19	0.38	0.76	0	0.49	0	0.38

Trap Survey Station 3								
	Count by species							
Survey number	**CC**	**BD**	**JD**	**BS**	**SM**	**SS**	**CS**	**GS**
1	7	2	1	0	0	0	0	0
2	12	3	0	0	0	0	0	0
3	12	2	0	0	0	0	0	0
4	1	3	0	0	0	0	0	0
5	16	0	0	0	0	0	0	0
6	6	0	1	0	0	0	1	0
7	8	1	0	0	0	0	0	0
Total	62	11	2	0	0	0	1	0
mean	8.86	2.2	1	0	0	0	1	0
Median	8	2	1	0	0	0	1	0
Variance s^2	24.1	1.62	0.24	0	0	0	0.14	0
Standard Deviation	4.91	1.27	0.49	0	0	0	0.38	0

Trap Survey Station 4								
	Count by species							
Survey number	**CC**	**BD**	**JD**	**BS**	**SM**	**SS**	**CS**	**GS**
1	3	0	0	0	0	0	0	0
2	4	4	0	0	0	0	0	0
3	3	0	0	0	0	0	0	0
4	2	0	0	0	0	0	0	0
5	3	2	0	0	0	0	0	0
6	1	0	0	0	0	0	0	0
7	7	7	0	0	0	0	0	0
Total	23	13	0	0	0	0	0	0
mean	3.29	4.33	0	0	0	0	0	0
Median	3	4	0	0	0	0	0	0
Variance s^2	3.57	7.48	0	0	0	0	0	0
Standard Deviation	1.89	2.73	0	0	0	0	0	0

Net Survey Station 1								
	Count by species							
Survey number	**CC**	**BD**	**JD**	**BS**	**SM**	**SS**	**CS**	**GS**
1	3	1	4	2	1	3	0	0
2	3	0	2	3	0	0	0	0
3	2	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	2	0	0	0	0	0
6	0	0	0	1	0	0	0	0
7	9	0	0	0	0	1	0	0
Total	17	1	8	6	1	4	0	0
mean	6.8	1	4	3	1	2.67	0	0
Median	3	1	2	2	1	2	0	0
Variance s^2	10.3	0.14	2.48	1.48	0.14	1.29	0	0
Standard Deviation	3.21	0.38	1.57	1.21	0.38	1.13	0	0

Net Survey Station 2								
	Count by species							
Survey number	**CC**	**BD**	**JD**	**BS**	**SM**	**SS**	**CS**	**GS**
1	10	0	5	4	0	0	0	0
2	2	1	0	1	0	0	0	0
3	3	3	0	2	0	0	0	0
4	0	0	0	1	0	1	0	0
5	0	0	7	1	0	0	0	0
6	0	0	0	0	0	0	0	0
7	9	1	3	8	0	1	0	0
Total	24	5	15	17	0	2	0	0
mean	9.6	2.5	7.5	4.86	0	1.33	0	0
Median	6	1	5	1.5	0	1	0	0
Variance s^2	18.6	1.24	8.48	7.62	0	0.24	0	0
Standard Deviation	4.31	1.11	2.91	2.76	0	0.49	0	0

Net Survey Station 3								
	Count by species							
Survey number	**CC**	**BD**	**JD**	**BS**	**SM**	**SS**	**CS**	**GS**
1	8	5	3	4	0	1	1	0
2	5	2	2	2	0	0	0	0
3	5	4	3	4	0	0	0	0
4	2	4	2	2	0	0	0	0
5	3	1	2	1	0	0	0	0
6	5	1	1	3	0	0	0	0
7	9	9	2	8	0	0	0	0
Total	37	26	15	24	0	1	1	0
mean	9.25	6.5	3.75	6	0	1	1	0
Median	5	4	2	3	0	1	1	0
Variance s^2	6.24	7.9	0.48	5.29	0	0.14	0.14	0
Standard Deviation	2.5	2.81	0.69	2.3	0	0.38	0.38	0

Net Survey Station 4								
	Count by species							
Survey number	**CC**	**BD**	**JD**	**BS**	**SM**	**SS**	**CS**	**GS**
1	2	0	0	5	0	0	0	0
2	1	1	0	1	0	0	0	0
3	1	2	0	0	0	0	0	0
4	2	3	0	0	0	0	0	0
5	4	0	1	1	0	0	0	0
6	2	0	1	0	0	0	0	0
7	7	5	0	3	0	0	0	0
Total	19	11	2	10	0	0	0	0
mean	4.75	4.4	1.33	4	0	0	0	0
Median	2	2.5	1	1	0	0	0	0
Variance s^2	4.57	3.62	0.24	3.62	0	0	0	0
Standard Deviation	2.14	1.9	0.49	1.9	0	0	0	0

Trap Survey Count by Station					
Survey number	**Station 1**	**Station 2**	**Station 3**	**Station 4**	**Total Reach**
1	10	8	10	3	31
2	11	7	15	8	41
3	3	25	14	3	45
4	0	2	4	2	8
5	1	6	16	5	28
6	0	15	8	1	24
7	5	10	9	14	38
Total	30	73	76	36	215
mean	6	10.4	10.9	5.14	30.7
Median	5	8	10	3	31
Variance s^2	21.2	57	18.8	20.5	155
Standard Deviation	4.61	7.55	4.34	4.53	12.5

Net Survey Count by Station					
Survey number	**Station 1**	**Station 2**	**Station 3**	**Station 4**	**Total Reach**
1	14	19	22	7	62
2	8	4	11	3	26
3	2	8	16	3	29
4	0	2	10	5	17
5	2	8	7	6	23
6	1	0	10	3	14
7	10	22	28	15	75
Total	37	63	104	42	246
mean	6.17	9	14.9	6	35.1
Median	5	8	11	5	26
Variance s^2	28.9	71	58.1	18.3	559
Standard Deviation	5.38	8.43	7.63	4.28	23.6

	Number of Species		
Station	**Trap**	**Net**	**Trap and Net**
1	1	4	6
2	2	6	5
3	3	4	6
4	4	2	4
mean		4	5.25
Median		4	5.5
Variance s^2		2.666667	0.916667
Standard Deviation		1.632993	0.957427

Trap data				
	Station number			
Survey #	1	2	3	4
1	4	3	3	1
2	2	3	2	2
3	2	3	2	1
5	1	2	1	2
7	1	1	2	2
Total	10	12	10	8
mean	2	2.4	2	1.6
Median	2	3	2	2
Variance	1.5	0.8	0.5	0.3
SD	1.22	0.89	0.71	0.55
Co Var	0.61	0.37	0.35	0.34

Net Data				
	Station number			
Survey #	1	2	3	4
1	6	3	6	2
2	2	2	4	3
3	1	3	4	2
5	1	2	4	3
7	1	5	4	3
Total	11	15	22	13
mean	2.2	3	4.4	2.6
Median	1	3	4	3
Variance	4	1.37	0.97	0.57
SD	2.17	1.22	0.89	0.55
Co var	0.99	0.41	0.2	0.21

Survey numbers 4 and 6 had 0 counts in at least one station for both methods of capture; therefore this data was left out of the analysis to prevent skewing.

Appendix 6: Normality Tests

4.1 Shapiro-Wilk Tests for Normal Distribution

a) Shapiro-Wilk Analysis of Species Caught by Trap/Net per Survey Session total of reach

Analysis of species caught by trap and net capture methods per survey session showed significant deviations from normal distribution even after the data had been log transformed.

	Species Caught by Trap per Survey Session
n	7
W	0.772226
Prob.	0.0215305
This means	The distribution of the variable Species Caught by Trap per Survey Session does deviate significantly from a normal distribution (Shapiro-Wilk test, W = 0.772226, n = 7, P = <0.05)

	Species Netted per Survey Session
n	7
W	0.747678
Prob.	0.0119978
This means	The distribution of the variable Species Netted per Survey Session does deviate significantly from a normal distribution (Shapiro-Wilk test, W = 0.747678, n = 7, P = <0.05)

b) Shapiro-Wilk Analysis of Individuals Caught by Trap/Net per Survey Session total of reach

	Individuals Trapped per Survey Session
n	7
W	0.941779
Prob.	0.654791
This means	The distribution of the variable Individuals Trapped per Survey Session does not deviate significantly from a normal distribution (Shapiro-Wilk test, W = 0.941779, n = 7, P = >0.05)

	Individuals Netted per Survey Session
n	7
W	0.821326
Prob.	0.0661314
This means	The distribution of the variable Individuals Netted per Survey Session does not deviate significantly from a normal distribution (Shapiro-Wilk test, W = 0.821326, n = 7, P = >0.05)

c) Shapiro-Wilk Analysis of means of species by Trap/Net per Survey Session – Station 1

	Station 1
n	5
W	0.832744
Prob.	0.145844
This means	The distribution of the variable Station 1 does not deviate significantly from a normal distribution (Shapiro-Wilk test, W = 0.832744, n = 5, P = >0.05)

d) Shapiro-Wilk Analysis of means of species by Trap/Net per Survey Session – Station 2

	Station 2
n	5
W	0.770908
Prob.	0.0459543
This means	The distribution of the variable Station 2 does deviate significantly from a normal distribution (Shapiro-Wilk test, W = 0.770908, n = 5, P = <0.05)

e) Shapiro-Wilk Analysis of means of species by Trap/Net per Survey Session – Station 3

	Station 3
n	5
W	0.883491
Prob.	0.325429
This means	The distribution of the variable Station 3 does not deviate significantly from a normal distribution (Shapiro-Wilk test, W = 0.883491, n = 5, P = >0.05)

f) Shapiro-Wilk Analysis of means of species by Trap/Net per Survey Session – Station 4

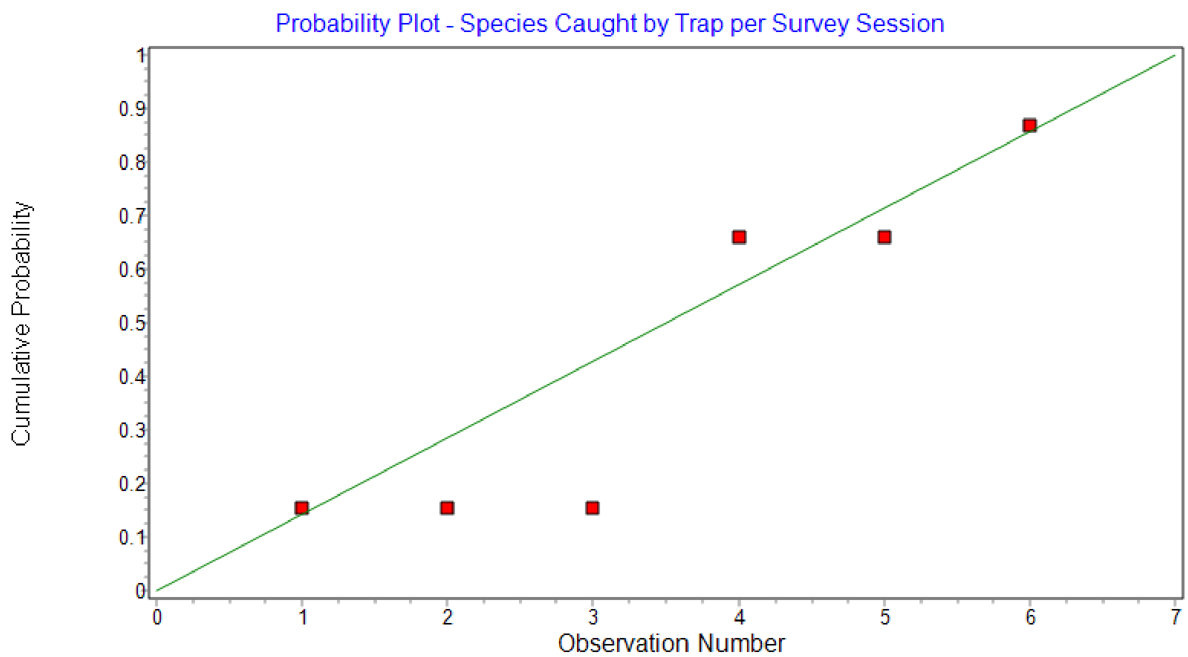
	Station 4
n	5
W	0.684029
Prob.	0.00647
This means	The distribution of the variable Station 4 does deviate significantly from a normal distribution (Shapiro-Wilk test, W = 0.684029, n = 5, P = <0.05)

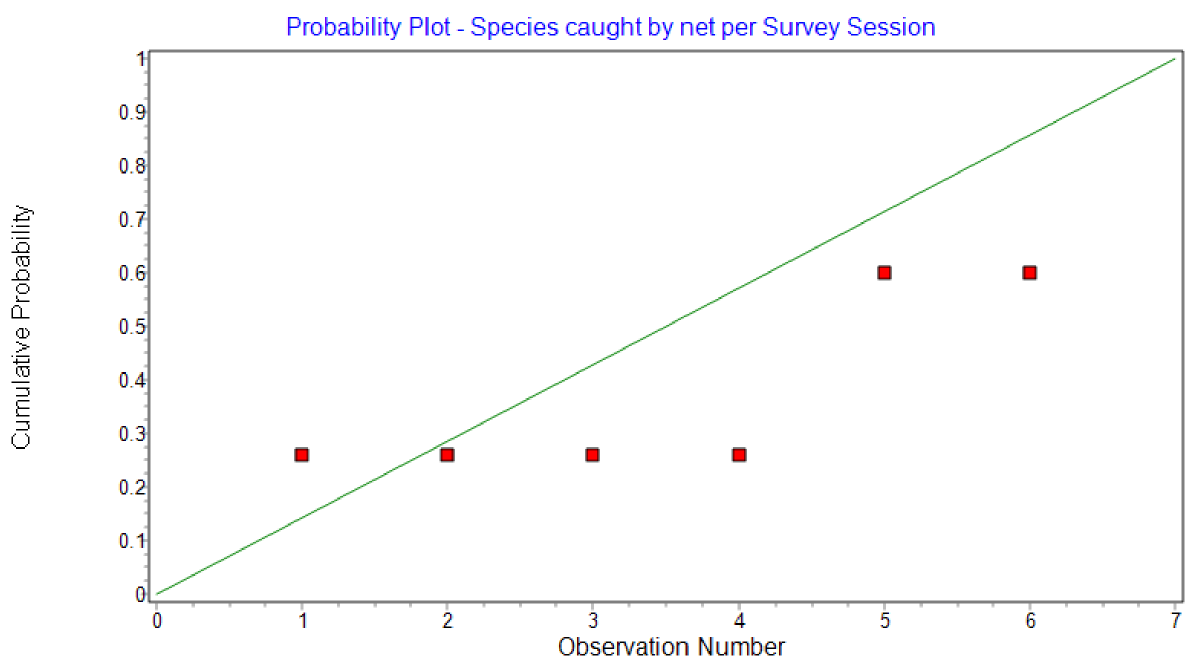
g) Average Water Temperature °C by station

	Av Water Temperature
n	4
W	0.743573
Prob.	0.0335673
This means	The distribution of the variable Av Water Temperature does deviate significantly from a normal distribution (Shapiro-Wilk test, $W = 0.743573$, $n = 4$, $P = <0.05$)

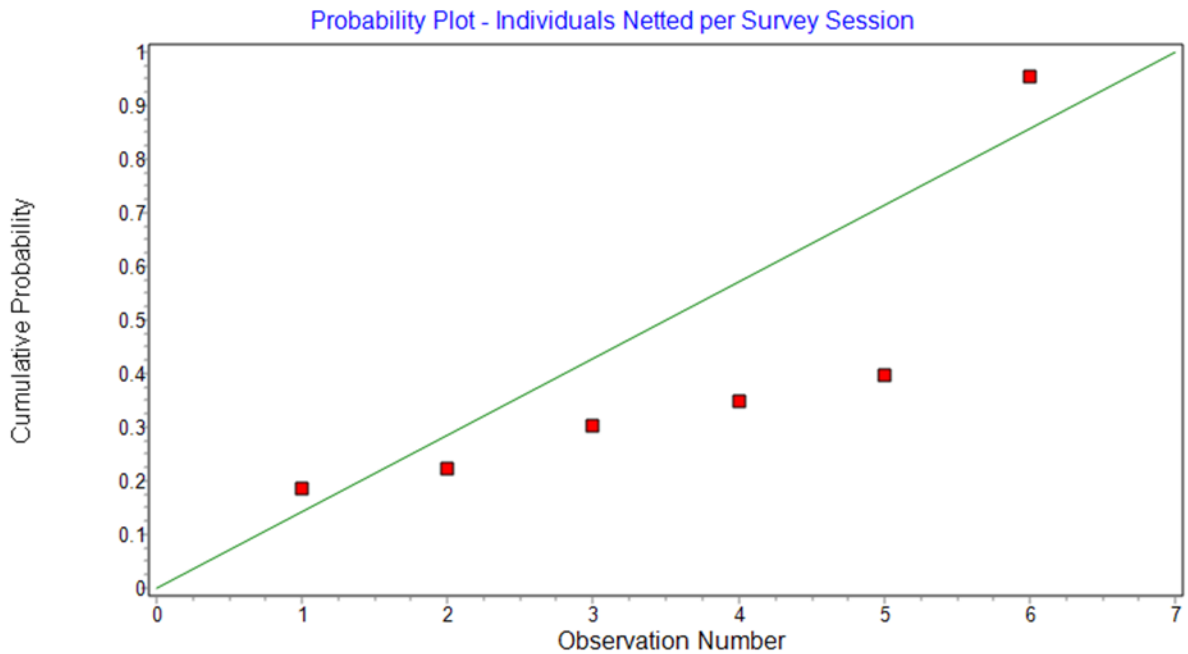
Appendix 7: Probability Plots

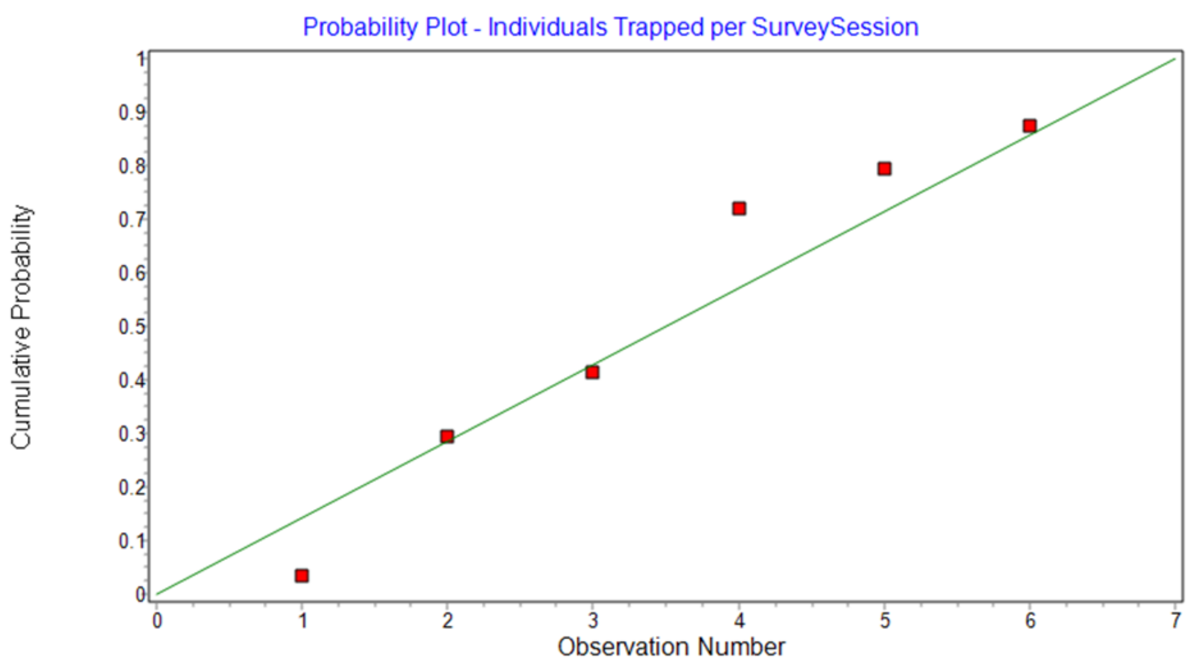
a) Analysis of count of species caught by trap and net methods per survey session



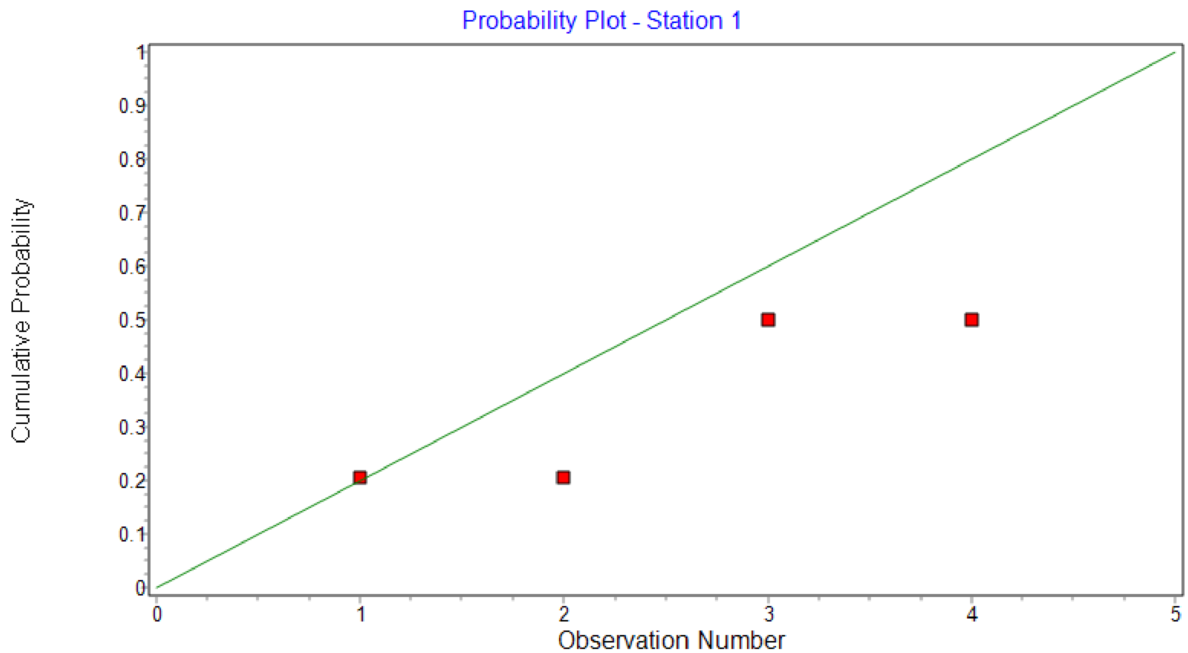


b) Analysis of count of individuals caught by trap and net methods per survey session

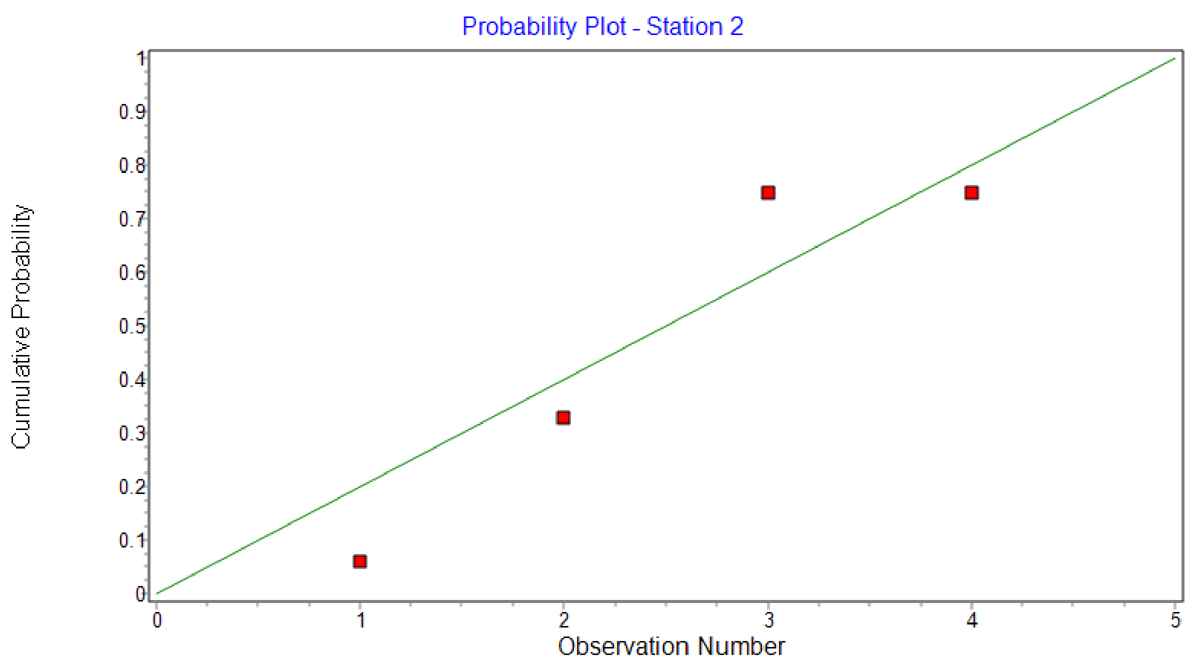




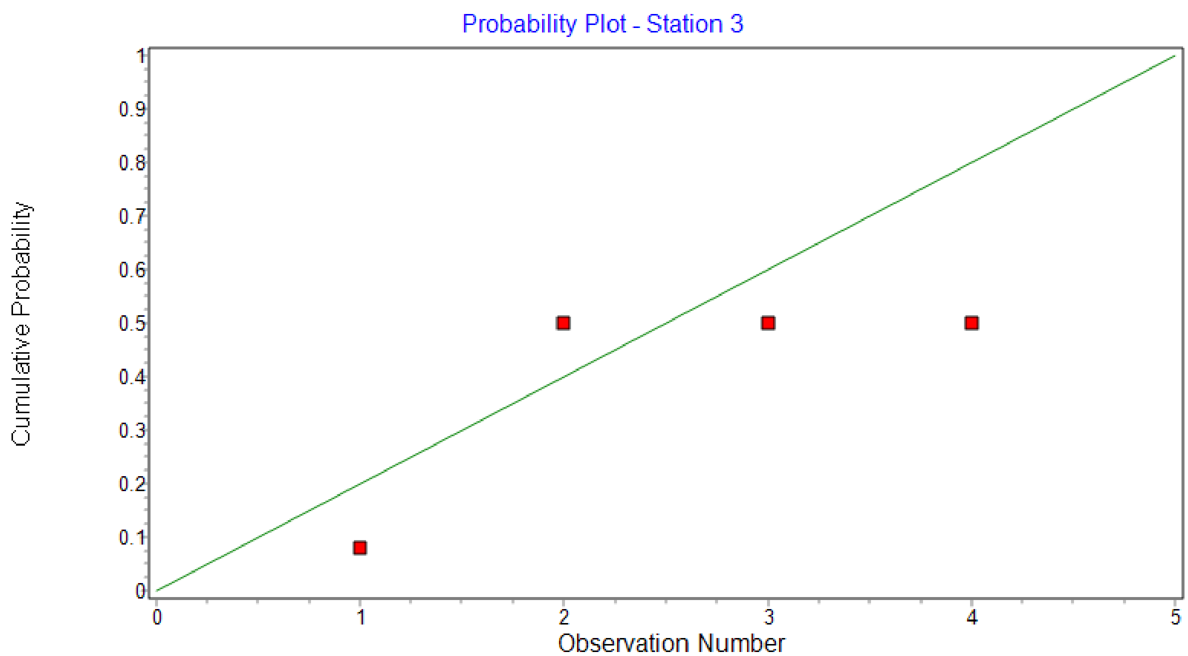
c) Analysis of means of species by Trap/Net per Survey Session – Station 1



d) Analysis of means of species by Trap/Net per Survey Session – Station 2



e) Analysis of means of species by Trap/Net per Survey Session – Station 3



f) Analysis of means of species by Trap/Net per Survey Session – Station 4