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Summary of Grass Pickerel Surveys in Beaver Creek, Ontario, 2009–2015

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Canada

Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

Agricultural drain maintenance may impact fish and fish habitat, and this is of particular concern where Species at Risk are present. Grass Pickerel (*Esox americanus vermiculatus*) is listed as a species of Special Concern in Canada and is a common resident of municipal drains in the Niagara Region. Drain maintenance was required in Beaver Creek, a municipal drain that supports a large population of Grass Pickerel. A six year study was conducted by Fisheries and Oceans Canada to better understand the variability in the fish community and habitat in a typical Grass Pickerel population in the Niagara Region in order to inform future drain maintenance projects where Grass Pickerel exist. A total of 27,310 fishes representing 37 species were captured throughout the study. There were 4,971 Grass Pickerel caught, including 446 young-of-year; Grass Pickerel was the second most abundant species caught, representing 18% of all fishes over the six years. Grass Pickerel declined in abundance at two points during this study, first after 2009 and again after 2011; this may be related to high density and drought in those years, respectively. The habitat in Beaver Creek differed between sites, even adjacent sites in the same tributary. Some sites supported more fish, species and Grass Pickerel than other sites, and these trends remained consistent at each site through the study period. This study suggests that some sites offer better habitat for Grass Pickerel than others and this may be life-stage dependent, and that Grass Pickerel populations experience fluctuations in abundance likely resulting from variable environmental conditions.

INTRODUCTION

The Grass Pickerel (*Esox americanus vermiculatus*) is listed as Special Concern under Schedule 1 of the federal *Species at Risk Act*. It prefers warm, shallow, slow flowing streams and wetlands and protected bays of larger lakes with dense aquatic vegetation (Crossman and Holm 2005). In Canada, it is found in southern Ontario and southwestern Quebec. It is frequently found in agricultural drains and small creeks in the Niagara region, including Beaver Creek, known to contain a large population of the species (Crossman and Holm 2005).

Beaver Creek is a low gradient stream that is classified as a municipal drain in the town of Fort Erie. The creek consists of 2 branches that converge half-way between the headwaters and the mouth at Black Creek. A drain clean-out with reconstruction incorporating natural channel design elements was conducted in the fall of 2011 to improve drainage and increase water storage in the system while trying to mitigate loss of important habitat features for Grass Pickerel (GP). Fisheries and Oceans Canada (DFO) undertook a six year study to assess the impacts of this drain maintenance on resident GP and to monitor various aspects of the fish community and aquatic habitat before and after drain maintenance. Part of this study included tagging GP with Passive Integrated Transponder (PIT) tags to better understand GP movement and habitat use in the creek before (Kramski 2014) and after drain maintenance. Regular monitoring occurred throughout the summer seasons from 2009–2013 and 2015 at core sites. This report summarizes the fish community data, Grass Pickerel-specific data, and habitat data collected by DFO from 2009–2013, 2015. Data are summarized by year for each monitoring site.

METHODS

SAMPLING SITES

Beaver Creek is located in the town of Fort Erie, Ontario and is classified as a municipal drain. The creek is approximately 10 km long and consists of two tributaries, the west and east; the headwaters are located south of Nigh Road on the west side of Point Abino Road and Gorham Road, respectively. The tributaries converge approximately 500 m upstream of Winger Road and the creek drains into Black Creek, a tributary of the Niagara River, approximately 800 m downstream of College Road; this section is referred to as the north branch. Beaver Creek is a low-gradient, surface-fed stream and the predominant land use in the area is row-crop agriculture (Figure 1).

In the fall of 2011, a one kilometer section of the west branch was cleaned out and reconstructed for drainage purposes, beginning on the north (downstream) side of Garrison Road West (Figure 2). A natural channel design was implemented to mitigate the impacts of a traditional drain clean-out. Five in-line pools were dug out to improve water storage, and two offline pools were added to create additional fish habitat. A section of the creek further downstream in the west branch (on Bertie Road, approximately 370 m west of Ott Road, referred to as the Bertie Right-of-Way (ROW)) was also reconstructed. One in-line pool, one offline pool, and Newbury weirs (Newbury and Gaboury 1993) were installed at this site to help improve drainage and retain flow through this section.

Ten core sampling sites were chosen in the creek (Table 1), three in each of the west and east tributary, and 4 in the north branch. Two sites in the east branch, Gorham and Nigh, were replaced with Ben's Place after 2010 due to accessibility. Additional sites were sampled periodically, most notably in the reconstructed reach of the west branch. Sites were selected at

road crossings for ease of access. The pools located at these road crossings had similar natural and anthropogenic habitat features and retained water permanently throughout the year.

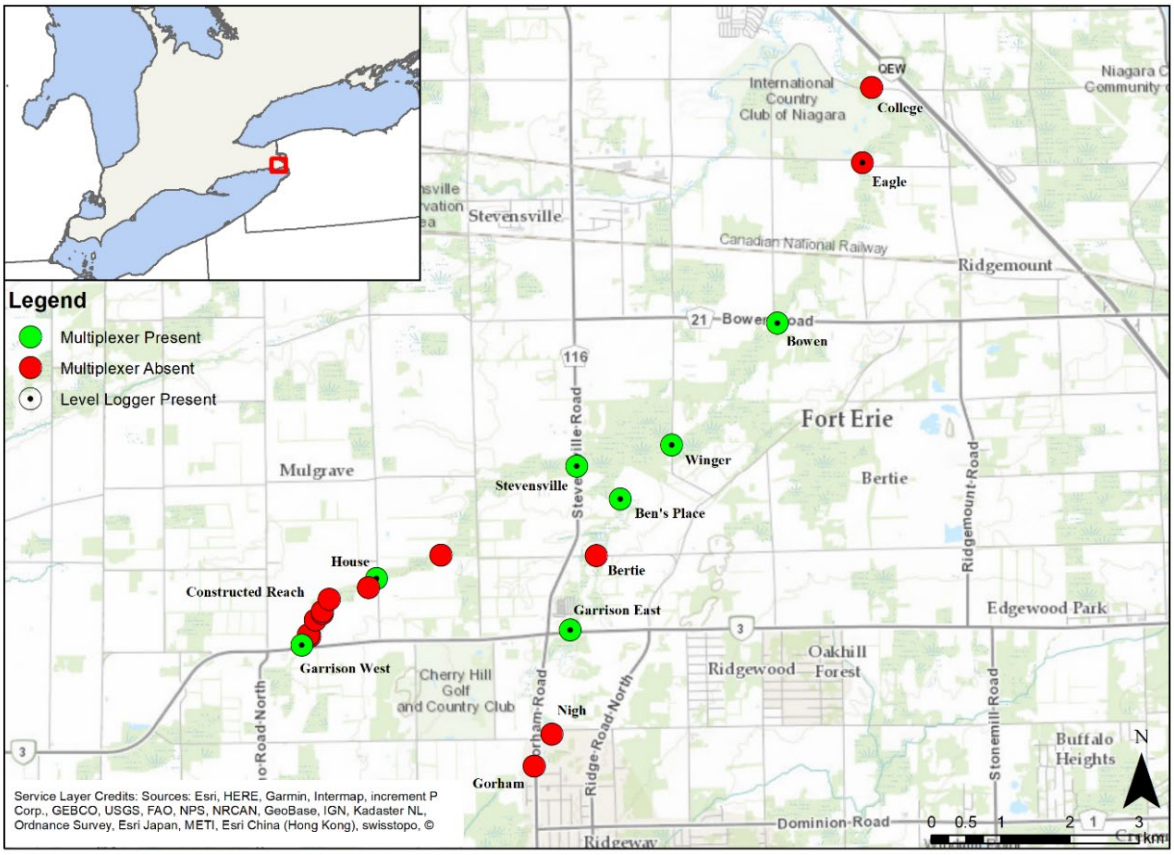

Figure 1. Map of core sampling sites in the west, east and north branches of Beaver Creek, Fort Erie, Ontario.

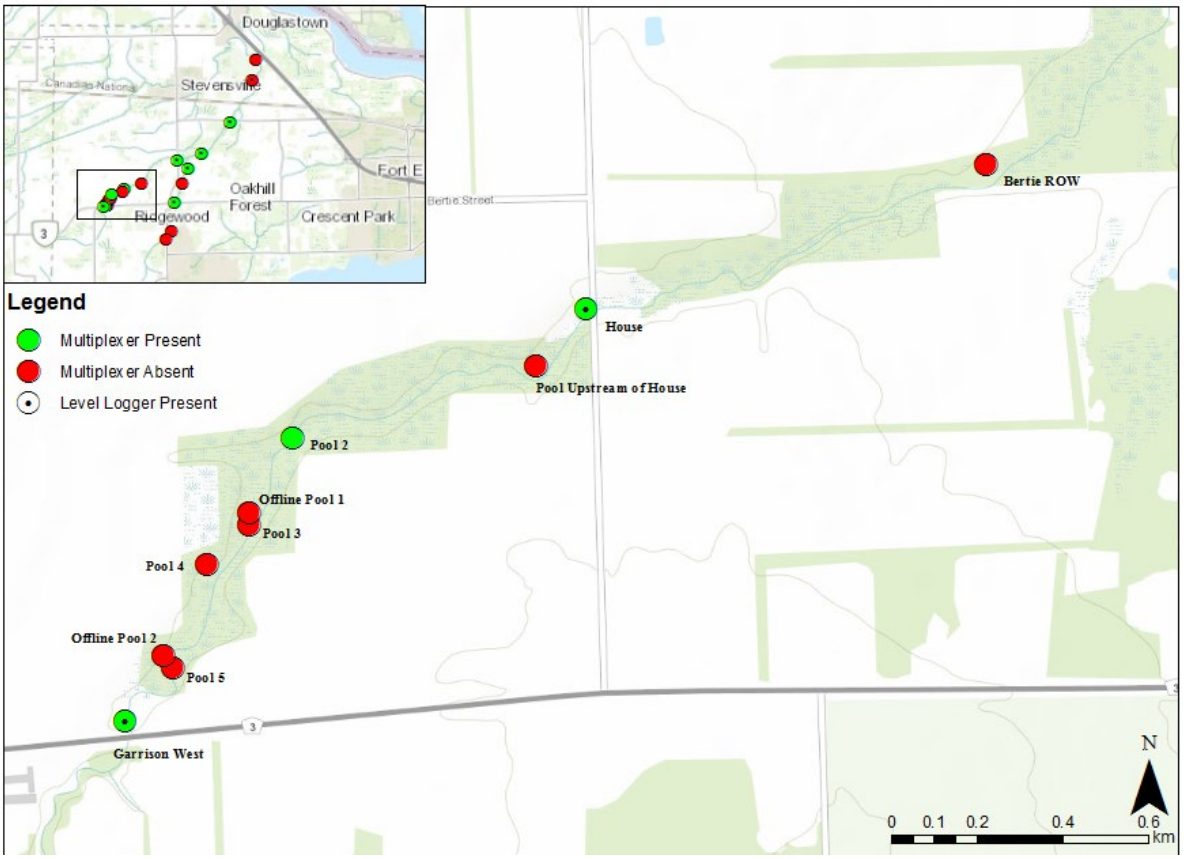

Figure 2. Map of sampling sites in reconstructed reach of the west branch of Beaver Creek.

*Table 1. Ten core sampling sites on Beaver Creek sampled 2009–2015, presented from downstream to upstream. Sites listed with an * were sampled only occasionally throughout the study period.*

Site Name	Branch	Latitude	Longitude	Multiplexer station	Level Logger
College	North	42.95520	-79.01582	N	N
Eagle	North	42.94807	-79.01698	N	Y
Bowen	North	42.93282	-79.02800	Y	Y
Winger	North	42.92125	-79.04175	Y	Y
Ben's Place*	East	42.91614	-79.04842	Y	Y
Bertie	East	42.91075	-79.05157	N	N
Garrison East	East	42.90371	-79.05490	Y	Y
Nigh*	East	42.89380	-79.05730	N	N
Gorham*	East	42.89075	-79.05960	N	N
Stevensville	West	42.91959	-79.05395	Y	Y
Bertie ROW*	West (reconstructed)	42.91080	-79.07170	N	N
House	West	42.90859	-79.08007	Y	Y
Upstream of House*	West	42.90770	-79.08115	N	N
Pool 5*	West (reconstructed)	42.90306	-79.08874	N	N
Offline Pool 2*	West (reconstructed)	42.90325	-79.08895	N	N
Pool 4*	West (reconstructed)	42.90465	-79.08805	N	N
Pool 3*	West (reconstructed)	42.90525	-79.08715	N	N
Offline Pool 1*	West (reconstructed)	42.90545	-79.08715	N	N
Pool 2*	West (reconstructed)	42.90660	-79.08625	Y	N
Garrison West	West (reconstructed)	42.90225	-79.08974	Y	Y

Regular sampling occurred May-August in 2009–2013 and in July 2015 (Table 2). The core sites were sampled on a rotating schedule, approximately once every two weeks. Additional sampling occurred in November 2009 and in April 2011 as part of a GP larval survey; these data are provided in appendices to this report.

FISH COMMUNITY SAMPLING

The fish community was sampled using a 9.1 m bag seine with 0.32 cm mesh on the bag and wings. Generally, three hauls were conducted during each sampling event (Table 2; Portt et al. 2008, Reid and Hogg 2014). Edges of the culvert pools were targeted as this is where GP are

known to be found (Crossman and Holm 2005). Hauls were processed separately. All fishes captured were identified, tallied, and the maximum and minimum total length (TL) of each species was recorded. Specimens not identified in the field were kept in 10% formalin for verification and all other fishes were released after processing.

GRASS PICKEREL SAMPLING

All GP caught were placed in a separate bin for processing. All GP were measured for total length (TL) on a fork board and weighed using an O'Haus three kilogram scale. Scale samples were taken from most GP captured from the left side of the body, on the dorso-lateral surface behind the dorsal fin. Scale samples were taken to age a sub-sample of GP. Fin clips were also taken from GP in 2013 and 2015 as part of a range-wide genetic analysis.

Certain size ranges of GP were targeted for further processing throughout the project. All GP over 120 mm total length were checked for a PIT tag using a hand-held PIT tag reader. If a tag was detected, the code was recorded. If no tag was present and the GP measured at least 160 mm TL and/or weighed at least 20 g, it was anaesthetized and tagged. In 2011, GP measuring 100 mm TL or less (presumed to be young-of-year) were harvested and preserved in 95% ethanol for an aging study (Colm et al. 2020).

Multiplexer stations were established at eight sampling sites (Table 1) to record PIT-tagged GP detections. The multiplexer stations consisted of three or four antenna arrays spread across the creek bottom connected to a reader/logger device. The multiplexer antenna array at Garrison West was set as a pass-through after 2011 to accommodate the increased water depth from the construction works. When PIT-tagged GP passed over the antenna arrays, their unique code was recorded.

HABITAT ASSESSMENT

Chemical and physical site characteristics were measured during each sampling event to assess habitat spatially and temporally. Air temperature (°C) was measured using a Kestrel 3000 weather meter. A YSI 6600 Surveyor 4A sonde was used to measure water temperature (°C), conductivity (µs/cm), dissolved oxygen (mg/L), pH and turbidity (ntu). A secchi tube (m) was used to measure the depth of visibility through the water. Physical site characteristics were also measured, including stream wetted width, maximum sampling depth, and percent channel cover (defined as the percent of the site area covered by an object that blocks 75% of light from penetrating).

The percent composition of substrate types found in the sampling area was recorded. Substrate types were categorized based on particles sizes according to the Wentworth scale. From 2009–2012, the percent composition of the four most abundant substrate types was recorded; in 2013 and 2015, the percent composition of all substrate types present was recorded. Aquatic and riparian vegetation types were assessed visually based on their percent composition in the sampling area.

Table 2. Sampling effort (number of visits and seine hauls) conducted per year by site.

Site Name	2009		2010		2011		2012		2013		2015		**Total**	
	Sampling Events	Hauls	Sampling Events	Hauls	Sampling Events	Hauls	Sampling Events	Hauls	Sampling Events	Hauls	Sampling Events	Hauls	Sampling Events	Hauls
Ben's Place	0	0	0	0	2	5	4	12	2	4	1	1	9	22
Bertie	3	11	4	12	2	2	5	14	2	6	1	1	17	46
Bertie ROW	0	0	0	0	0	0	2	3	0	0	0	0	1	3
Bowen	4	27	4	15	3	9	5	15	3	9	1	3	20	78
College	4	21	4	12	2	6	5	15	3	9	1	3	19	66
Eagle	4	34	6	24	2	6	5	14	3	9	1	2	21	89
Garrison East	4	10	3	9	3	9	5	15	3	9	1	1	19	53
Garrison West	3	13	5	17	2	7	5	15	3	9	1	3	19	64
Gorham	2	4	2	7	0	0	0	0	0	0	0	0	4	11
House	3	9	6	28	3	11	4	18	3	9	1	2	20	77
Nigh	1	1	3	9	0	0	0	0	0	0	0	0	4	10
Offline Pool 1	0	0	0	0	0	0	1	2	0	0	0	0	1	2
Offline Pool 2	0	0	0	0	0	0	1	2	1	2	1	3	3	7
Pool 2	0	0	0	0	0	0	2	6	1	3	1	3	4	12
Pool 3	0	0	0	0	0	0	2	6	1	3	1	3	4	12
Pool 4	0	0	0	0	0	0	2	6	1	3	1	3	4	12

Site Name	2009		2010		2011		2012		2013		2015		**Total**	
	Sampling Events	Hauls	Sampling Events	Hauls	Sampling Events	Hauls	Sampling Events	Hauls	Sampling Events	Hauls	Sampling Events	Hauls	Sampling Events	Hauls
Pool 5	0	0	0	0	0	0	0	0	0	0	1	1	1	1
Stevensville	3	8	2	6	3	9	6	18	3	9	1	1	18	51
Upstream of House	0	0	0	0	0	0	1	3	0	0	0	0	1	3
Winger	3	19	2	6	2	5	5	14	3	9	1	3	16	56
Total	34	157	41	145	24	69	60	178	32	93	15	33	205	675

STATISTICAL ANALYSES

Descriptive statistics (mean and standard deviation) are provided for each parameter in summary tables for each site per year. Figures of each parameter are provided for each site by sampling date.

Non-parametric Kruskal Wallis tests were conducted to compare differences in fish and habitat parameters between years at each site. The data violate the independence assumption of this test (as sampling occurred at the same site multiple times each year); however, the samples were not balanced between years making a repeated measures test unfeasible. The results should, therefore, be interpreted cautiously. Statistics are reported where significant ($\alpha = 0.05$) differences lie.

RESULTS

FISH COMMUNITY SAMPLING

A total of 27,310 fishes from 37 different species were captured throughout the study. Summaries of the sampling effort (Table 2), the catch per unit effort (CPUE) (Table 3), and species data (Table 4) are provided for each site per year. The most abundant species captured across all sites and years were Emerald Shiner (*Notropis atherinoides*) (36% of all fishes captured), Grass Pickerel (18%), and Golden Shiner (*Notemigonus crysoleucas*) (16%). The most frequently detected species were Grass Pickerel (at 91% of sampling events), Golden Shiner (75%), and Pumpkinseed (*Lepomis gibbosus*) (74%). Four invasive species were detected in Beaver Creek: Common Carp (*Cyprinus carpio*), Goldfish (*Carassius auratus*), Round Goby (*Neogobius melanostomus*), and Rudd (*Scardinius erythrophthalmus*).

The following parameters are summarized for each site:

- Mean CPUE;
- Number of unique species detected and mean number of species per year;
- The most abundant species captured;
- The most frequently detected species.

Table 3. Mean catch per unit effort (CPUE) and standard deviation (SD) per year by site. Dash (-) indicates sampling did not occur that year, "na" indicates field was not calculable.

Site Name	2009		2010		2011		2012		2013		2015		**Total**	
	Mean CPUE	SD CPUE	Mean CPUE	SD CPUE	Mean CPUE	SD CPUE	Mean CPUE	SD CPUE	Mean CPUE	SD CPUE	Mean CPUE	SD CPUE	Mean CPUE	SD CPUE
Ben's Place	-	-	-	-	7	3	14	18	3	na	3	na	9	12
Bertie	22	3	20	14	73	60	19	18	12	1	8	na	24	26
Bertie ROW	-	-	-	-	-	-	68	na	-	-	-	-	-	-
Bowen	33	28	44	23	38	25	34	16	31	35	39	na	38	21
College	62	75	45	58	26	26	23	13	10	4	10	na	32	48
Eagle	121	182	104	107	19	15	70	104	23	16	14	na	83	128
Garrison East	44	22	30	15	23	4	30	22	13	6	96	na	42	54
Garrison West	17	9	26	13	26	3	20	6	49	45	62	na	29	21
Gorham	32	37	4	3	-	-	-	-	-	-	-	-	18	27
House	28	21	10	5	18	9	8	2	21	15	12	na	16	13
Nigh	21	-	21	22	-	-	-	-	-	-	-	-	21	18
Offline Pool 1	-	-	-	-	-	-	118	na	-	-	-	-	-	-
Offline Pool 2	-	-	-	-	-	-	49	na	6	na	35	na	-	20
Pool 2	-	-	-	-	-	-	32	13	35	na	97	na	-	33
Pool 3	-	-	-	-	-	-	30	5	13	na	61	na	-	21
Pool 4	-	-	-	-	-	-	21	3	19	na	60	na	-	20

Site Name	2009		2010		2011		2012		2013		2015		**Total**	
	Mean CPUE	SD CPUE	Mean CPUE	SD CPUE	Mean CPUE	SD CPUE	Mean CPUE	SD CPUE	Mean CPUE	SD CPUE	Mean CPUE	SD CPUE	Mean CPUE	SD CPUE
Pool 5	-	-	-	-	-	-	-	-	-	-	116	na	-	-
Stevensville	59	62	71	7	40	24	36	31	24	14	71	na	47	35
Upstream of House	-	-	-	-	-	-	11	na	-	-	-	-	-	-
Winger	15	12	9	2	7	6	56	79	16	7	33	na	28	46
Total	57	86	39	53	28	25	35	55	21	20	48	36		

Table 4. Mean (and standard deviation (SD)) number of species detected per year by site. The most abundant species detected across all years is listed. Dash (-) indicates sampling did not occur that year.

Site Name	Number of Unique Species	2009		2010		2011		2012		2013		2015		Most abundant Species
		Mean # Species	SD # Species	Mean # Species	SD # Species	Mean # Species	SD # Species	Mean # Species	SD # Species	Mean # Species	SD # Species	# Species	SD # Species	
Ben's Place	11	-	-	-	-	7	2	5	2	2	1	6	na	Grass Pickerel
Bertie	14	3	1	3	2	18	8	6	3	7	2	9	na	Grass Pickerel
Bertie ROW	11	-	-	-	-	-	-	11	na	-	-	-	-	Green Sunfish
Bowen	21	4	2	8	3	7	1	10	1	6	2	9	na	Grass Pickerel
College	31	8	3	10	1	7	3	12	3	9	4	9	na	Emerald Shiner
Eagle	31	5	3	6	3	7	3	12	6	7	6	8	na	Emerald Shiner
Garrison East	18	5	1	5	2	7	2	9	3	6	2	12	na	Grass Pickerel

Site Name	Number of Unique Species	2009		2010		2011		2012		2013		2015		Most abundant Species
		Mean # Species	SD # Species	Mean # Species	SD # Species	Mean # Species	SD # Species	Mean # Species	SD # Species	Mean # Species	SD # Species	# Species	SD # Species	
Garrison West	23	5	4	6	1	9	1	9	2	10	1	10	na	Pumpkinseed
Gorham	6	9	8	3	0	-	-	-	-	-	-	-	-	Grass Pickerel
House	18	7	3	5	2	9	4	6	3	7	2	8	na	Grass Pickerel
Nigh	6	9	na	4	2	-	-	-	-	-	-	-	-	Central Mudminnow
Offline Pool 1	11	-	-	-	-	-	-	15	na	-	-	-	-	Green Sunfish
Offline Pool 2	10	-	-	-	-	-	-	11	na	8	na	7	na	Golden Shiner
Pool 2	17	-	-	-	-	-	-	12	3	11	na	9	na	Golden Shiner
Pool 3	16	-	-	-	-	-	-	12	1	7	na	11	na	Golden Shiner
Pool 4	17	-	-	-	-	-	-	11	1	13	na	12	na	Golden Shiner
Pool 5	6	-	-	-	-	-	-	-	-	-	-	18	na	Johnny Darter
Stevensville	18	6	4	6	1	9	2	6	2	7	4	6	na	Grass Pickerel
Upstream of House	6	-	-	-	-	-	-	7	na	-	-	-	-	Grass Pickerel
Winger	16	6	3	6	1	6	1	7	3	5	1	7	na	Golden Shiner

Ben's Place

The mean catch at Ben's Place across all years was 9 (± 12) fishes per haul; this was the lowest mean number of fishes caught per haul of any site in Beaver Creek. The greatest mean CPUE at Ben's was in 2012 (Figure 3); approximately 14 (± 18) fishes were captured per haul that year. The fewest fishes were captured in 2013 and 2015, when only three were caught per haul both years. The CPUE was generally low and consistent across all years at Ben's Place, except for one sampling event in 2012.

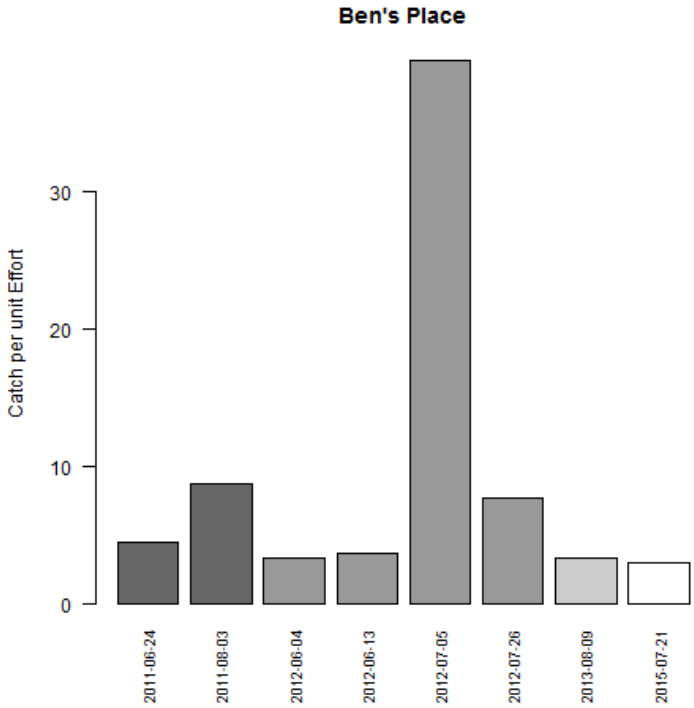

Figure 3. Catch per unit effort of all fishes at Ben's Place per sampling event.

A total of 11 unique species were detected at Ben's Place from 2011–2015. GP was the most abundant species caught in all years except 2015 when Largemouth Bass (*Micropterus salmoides*) was the most abundant. A mean of approximately 3 (± 3) GP were captured per haul in 2011, 7 (± 9) in 2012, and 10 in 2013. In 2015, two Largemouth Bass were captured per haul (Figure 4). The species that was detected most frequently at Ben's Place was the GP, appearing in 89% of the sampling events and all four years when sampling occurred there. Pumpkinseed and Central Mudminnow (*Umbra limi*) were the next most frequent species, occurring in 67% and 56% of sampling events, respectively, each in two years of sampling.

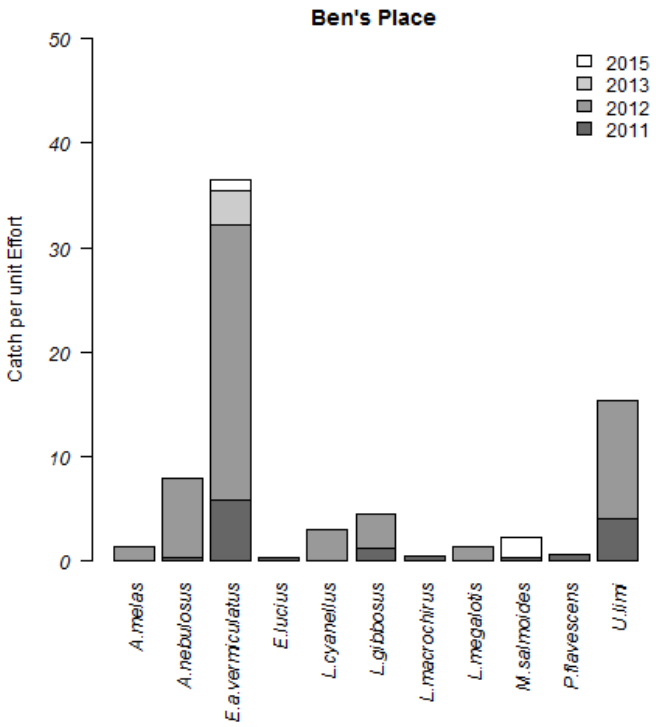

Figure 4. Catch per unit effort by species at Ben's Place.

Bertie

The mean CPUE at Bertie was 24 (± 26) fishes (Table 3). The mean number of fishes captured per haul in 2011 was 73 (± 60) (Figure 5). Only 8 fish were captured per haul in 2015, this was the lowest mean catch of all years. There was a lot of variation in CPUE within 2010, 2011 and 2012; however, CPUE varied little between these years, with the exception of 2011.

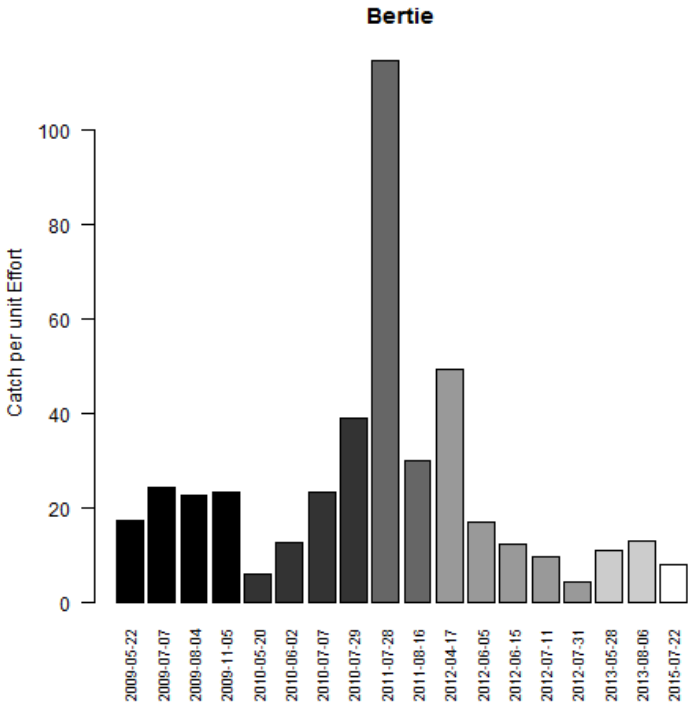

Figure 5. Catch per unit effort of all fishes at Bertie per sampling event.

A total of 14 unique species were detected at Bertie from 2009–2015. The number of species was higher in 2011 than all years except 2015. GP was the most abundant species captured at Bertie in 2009–2011 and in 2015, when means of approximately 21 (± 4), 18 (± 12), 47 (± 36), and six were captured per haul in each year, respectively (Figure 6). Emerald Shiner was the most abundant species at Bertie in 2012, approximately 12 (± 16) were captured per haul; and Pumpkinseed was the most abundant species in 2013, approximately 4 (± 4) were captured per haul. GP was the most frequently detected species at Bertie, appearing in 100% of sampling events and all six years of sampling. Pumpkinseed was detected during 76% of sampling events and in all six years, and Green Sunfish (*Lepomis cyanellus*) was detected during 53% of sampling events over five years of the study.

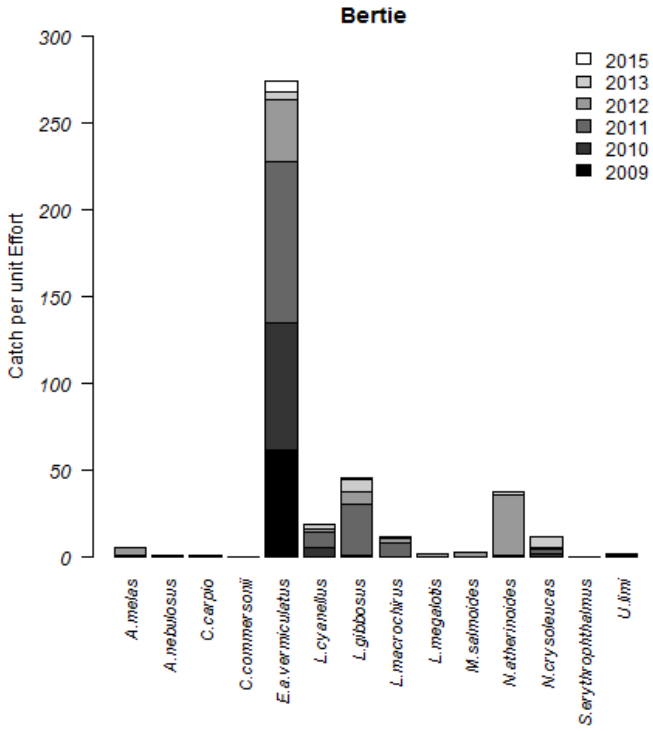

Figure 6. Catch per unit effort by species at Bertie.

Bowen

The mean CPUE at Bowen was 38 (± 21) fishes across all years (Table 3). The greatest mean number of fishes captured at Bowen was 44 (± 23) per haul in 2011 (Figure 7). In 2012, the lowest mean number of fishes captured per haul was (31 (± 35)). There was substantial variation in CPUE within each year at Bowen.

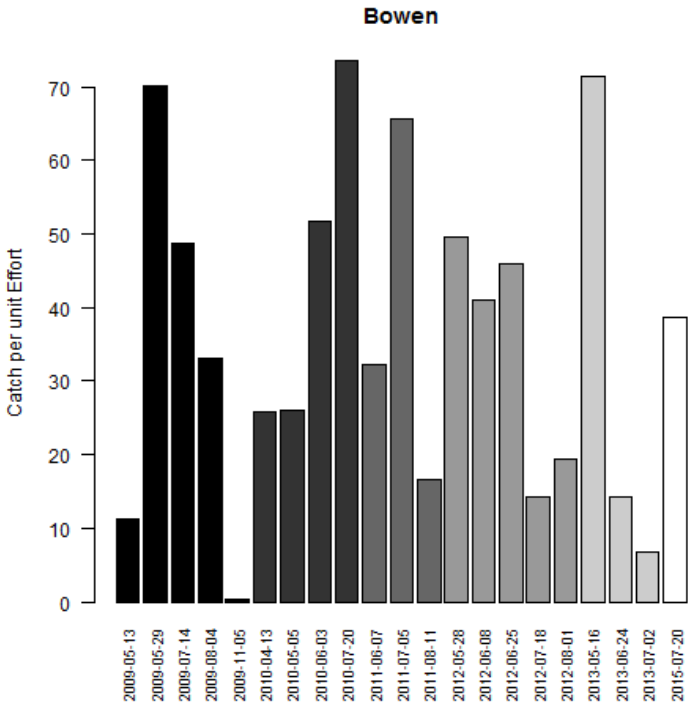

Figure 7. Catch per unit effort of all fishes at Bowen per sampling event.

A total of 21 unique species were detected at Bowen from 2009–2015. There was a significant difference in the number of species detected between years ($\chi^2 = 13.576$, df = 5, p = 0.018).The most species were detected in 2012 and the fewest in 2009. The most abundant species captured at Bowen in 2009–2011 was GP; means of 22 (± 16), 31 (± 26), 18 (± 14) GP were captured each year (Figure 8). The most abundant species in 2012 was Pumpkinseed (mean of 15 (± 6) per haul), in 2013 was Emerald Shiner (mean of 63 per haul), and in 2015 was Largemouth Bass (17 per haul). GP was the most frequently detected species at Bowen, occurring in 100% of sampling events over six years. Golden Shiner and Pumpkinseed were the next most frequently detected species, occurring in 95% and 90% of sampling events, respectively, in all six years. Largemouth Bass and White Sucker (*Catostomus commersonii*) were both detected all years as well.

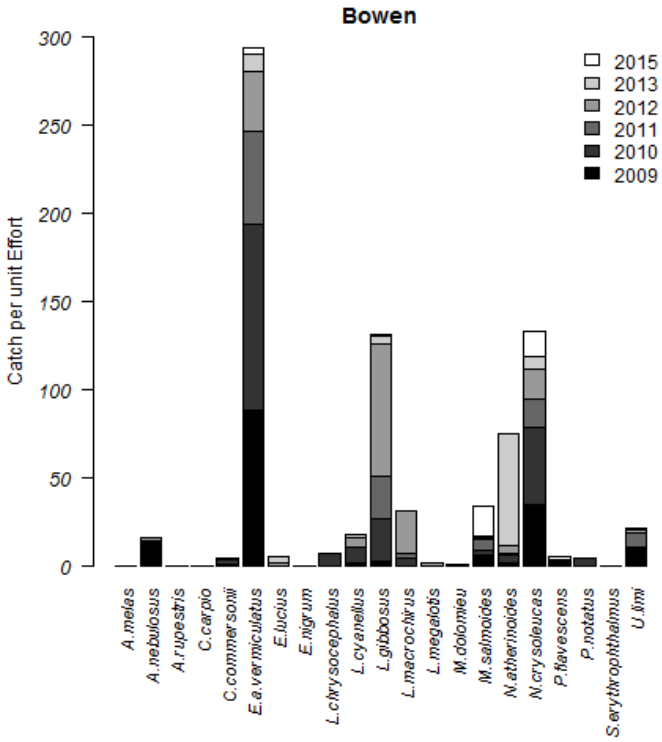

Figure 8. Catch per unit effort by species at Bowen.

College

The mean CPUE at College was 35 (± 48) (Table 3). The year 2009 yielded the largest catches of fishes at College, a mean of 62 (± 75) per haul (Figure 9). The mean number of fishes captured declined in each subsequent year, and was lowest in 2013 and 2015 when a mean of 10 (± 4) fishes were captured per haul. There was substantial variation in CPUE within 2009 and 2010 at College, as catches declined during these two years; there was less variation in catches within and between years after this.

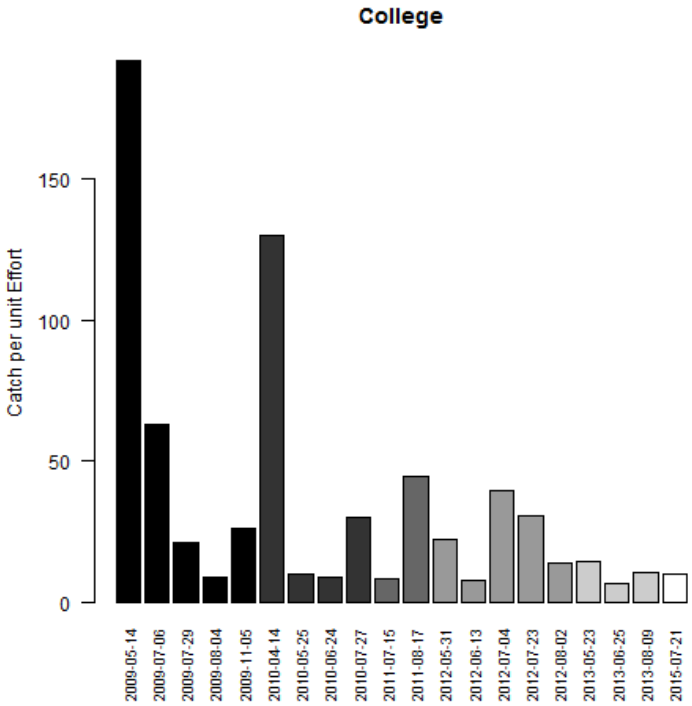

Figure 9. Catch per unit effort of all fishes at College per sampling event.

A total of 31 unique species were detected at College from 2009–2015 (Table 4), the most species detected of all sites (along with Eagle). Emerald Shiner was the most abundant species captured at College in 2009 (mean of 66 (± 94) per haul), 2012 (mean of 6 (± 7) per haul), and 2013 (mean of 5 per haul) (Figure 10). Golden Shiner was most abundant in 2010 and 2011, (mean of 9 (± 14) and 33 per haul, respectively). Pumpkinseed was the most abundant species captured at College in 2015, six were captured per haul. The species that occurred most frequently at College were GP and Pumpkinseed, both detected 95% of the time and in six years. Largemouth Bass and Yellow Perch were the next most frequently captured species, both detected during 79% of the sampling events and in six years. Golden Shiner, Bluegill (*Lepomis macrochirus*) and Round Goby (*Neogobius melanostomus*) were also detected in all six years of sampling at College.

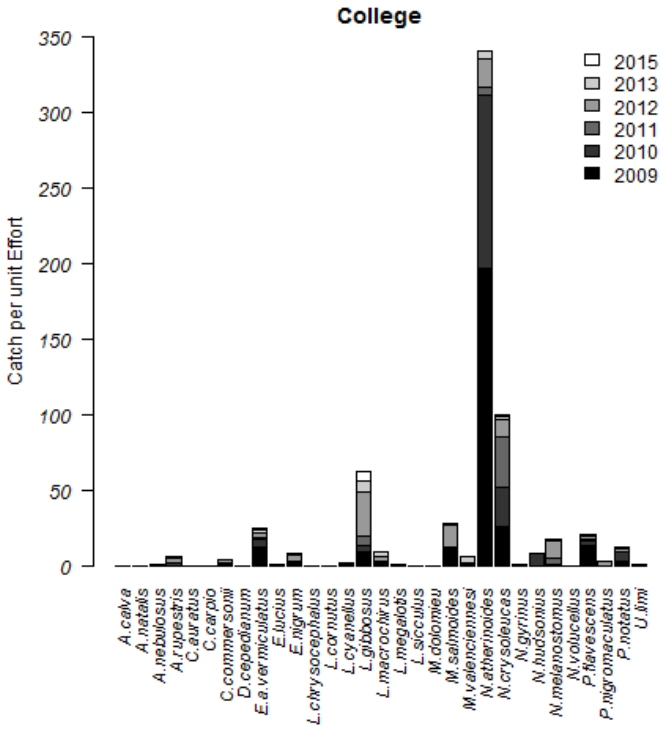

Figure 10. Catch per unit effort by species at College.

Eagle

The mean CPUE at Eagle was 83 (± 128) (Table 3); this was the largest mean number of fishes captured per haul in Beaver Creek. The highest number of fishes were captured in 2009 at Eagle when approximately 121 (± 182) were captured per haul (Figure 11). The fewest fishes were captured at Eagle in 2015 (12 per haul) and 2011 (19 (± 15) per haul). There was a lot of variation in CPUE within 2009, 2010 and 2012; catches tended to decline throughout each sampling season. There was minimal variation within or between 2011, 2013, and 2015.

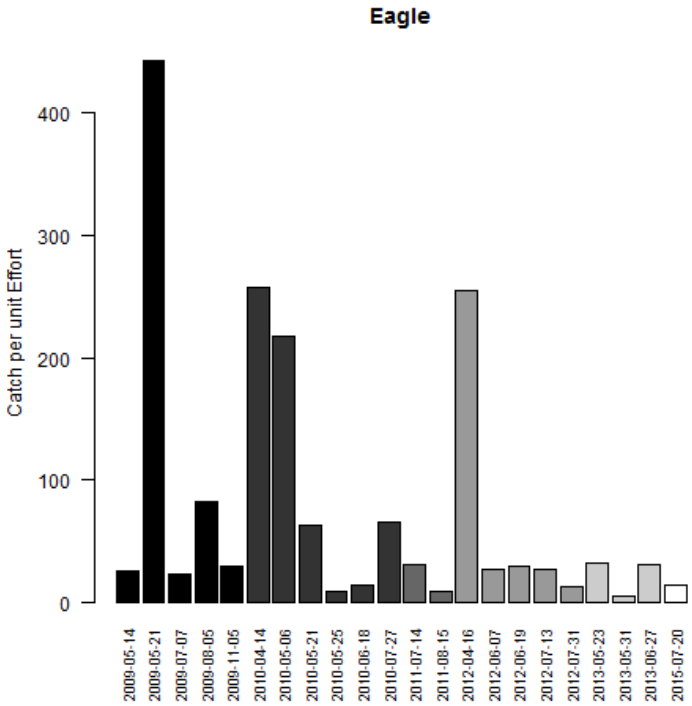

Figure 11. Catch per unit effort of all fishes at Eagle per sampling event.

Thirty-one unique species were detected at Eagle from 2009–2015, the most species detected of all sites (along with College). The most abundant species varied each year. In 2009, Emerald Shiner was most abundant, with a mean of approximately 138 (± 221) captured per haul (Figure 12). In 2010, Striped Shiner (*Luxilus chrysocephalus*) was most abundant; approximately 95 were captured per haul. Golden Shiner was the most abundant species in both 2011 and 2015, when approximately 7 (± 8) and 5 individuals were captured per haul, respectively. Spottail Shiner (*Notropis hudsonius*) was the most abundant species in 2012; approximately 62 were captured per haul. Bluegill was the most abundant species in 2013; approximately 9 (± 6) were captured per haul. GP and Pumpkinseed were the most frequently detected species at Eagle, occurring in 90% of sampling events and all six years, and Golden Shiner was detected in 86% of sampling events over all years. Brown Bullhead (*Ameiurus nebulosus*), Central Mudminnow and Largemouth Bass were detected in all six years of sampling as well.

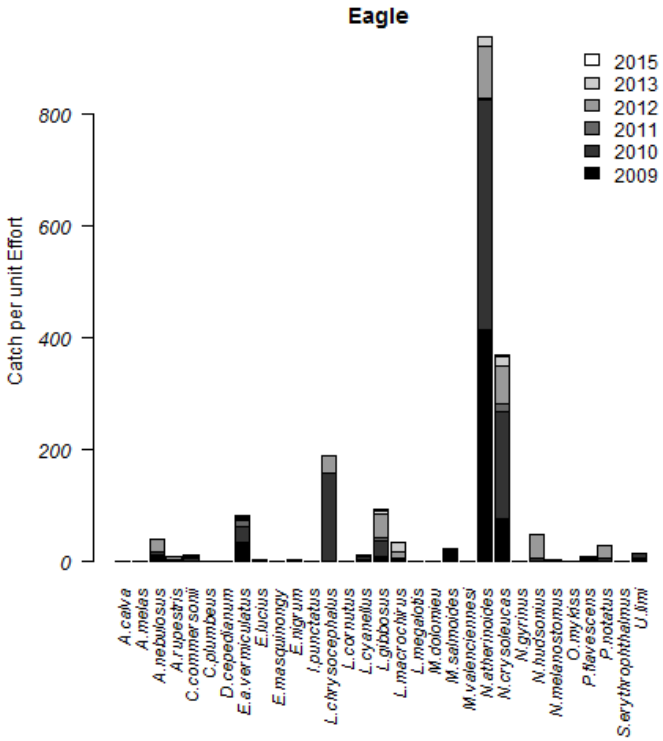

Figure 12. Catch per unit effort by species at Eagle.

Garrison East

At Garrison East, the mean CPUE was 42 (± 54) fishes (Table 3). The greatest mean number of fishes captured per haul was in 2015 (96 fishes), while the lowest mean number of fishes captured per haul was in 2013 (13 (± 6) fishes) (Figure 13). There was substantial variation in CPUE within and between years at Garrison East.

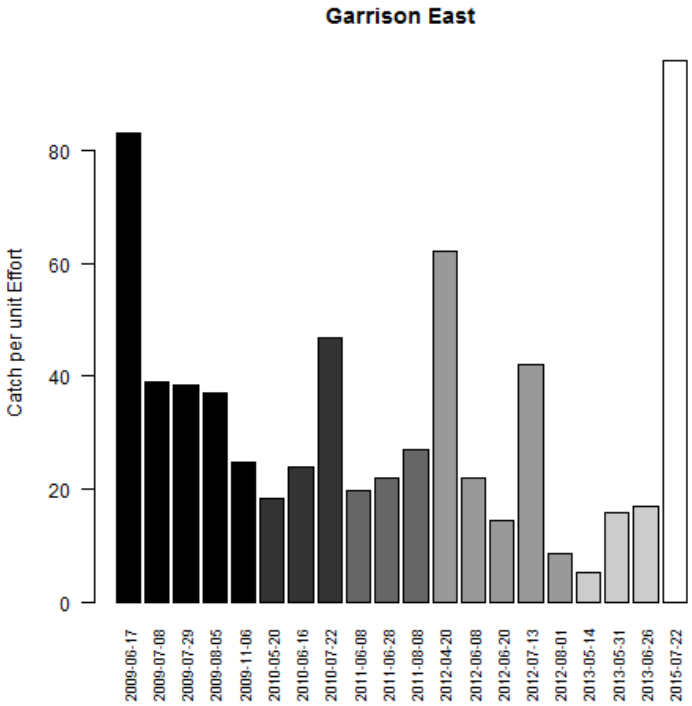

Figure 13. Catch per unit effort of all fishes at Garrison East per sampling event.

A total of 18 unique species were detected from 2009–2015. The fewest species were detected in 2010. The most abundant species captured at Garrison East in 2009–2011 was GP. Means of 84 (± 110), 30 (± 11), and 11 (± 4) were captured per haul in each year, respectively (Figure 14). A mean of 22 Brown Bullhead were captured per haul in 2012, 12 Emerald Shiner in 2013, and 83 Golden Shiner in 2015; these were the most abundant species in each of those years. GP was the most frequently detected species at Garrison East, occurring in 100% of events over six years. Golden Shiner was detected during 68% of sampling events and in six years. Green Sunfish and Central Mudminnow were detected in 68% of sampling events over five years.

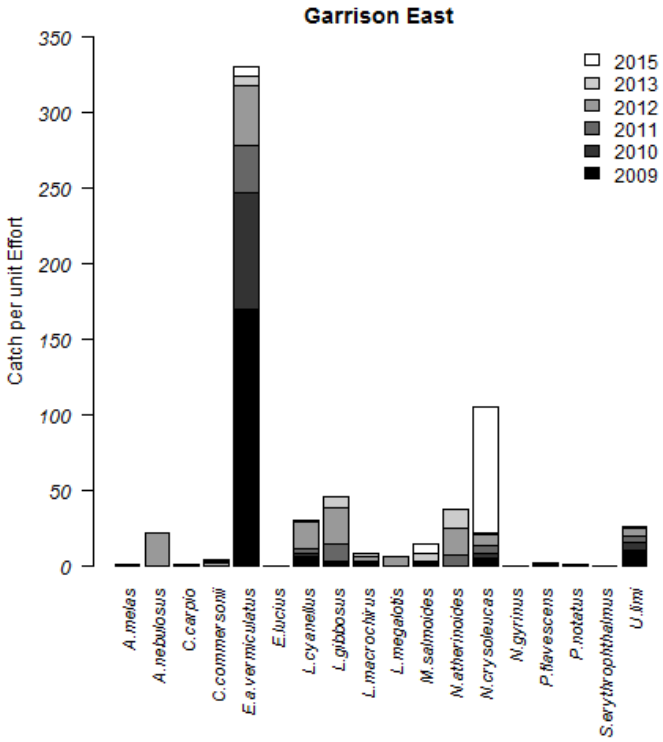

Figure 14. Catch per unit effort by species at Garrison East.

Garrison West

The mean catch of fishes at Garrison West was 29 (± 21) per haul (Table 3). The greatest mean number of fishes was captured in 2015 (62 fishes per haul), while the lowest mean number of fishes captured was captured in 2009 (17 (± 9) fishes per haul) (Figure 15). There was substantial variation in CPUE within 2009, 2010 and 2013; however variation between years was relatively low, with the exception of May 2013.

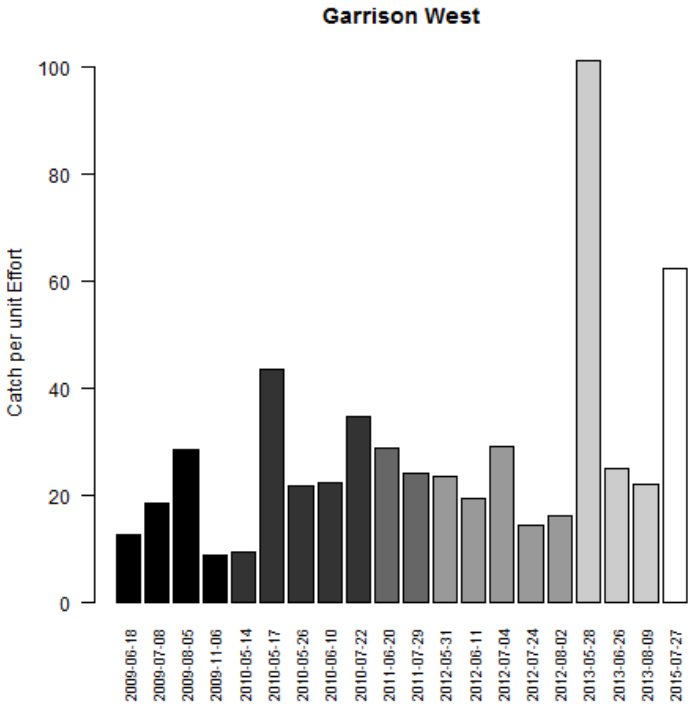

Figure 15. Catch per unit effort of all fishes at Garrison West per sampling event.

A total of 23 unique species were detected from 2009–2015 (Table 4). The number of species detected increased each year. The most abundant species captured at Garrison West varied between years. In 2009, Brown Bullhead was the most abundant species (mean of 20 per haul) (Figure 16). In 2010, Central Mudminnow was most abundant (mean of 11 (± 11) per haul). In 2011 and 2012, Pumpkinseed was the most abundant species, (mean of 14 (± 1) and 7(± 3) per haul, respectively). Bluntnose Minnow (*Pimephales notatus*) was the most abundant species in 2013 (mean of 36 per haul), and Golden Shiner was the most abundant species captured in 2015 (29 per haul). The most frequently detected species at Garrison West was the Green Sunfish, appearing in 100% of sampling events over all six years. Pumpkinseed and GP were detected 84% of the time, also in all six years. Central Mudminnow, Golden Shiner and White Sucker were detected in all six years of sampling at Garrison West as well.

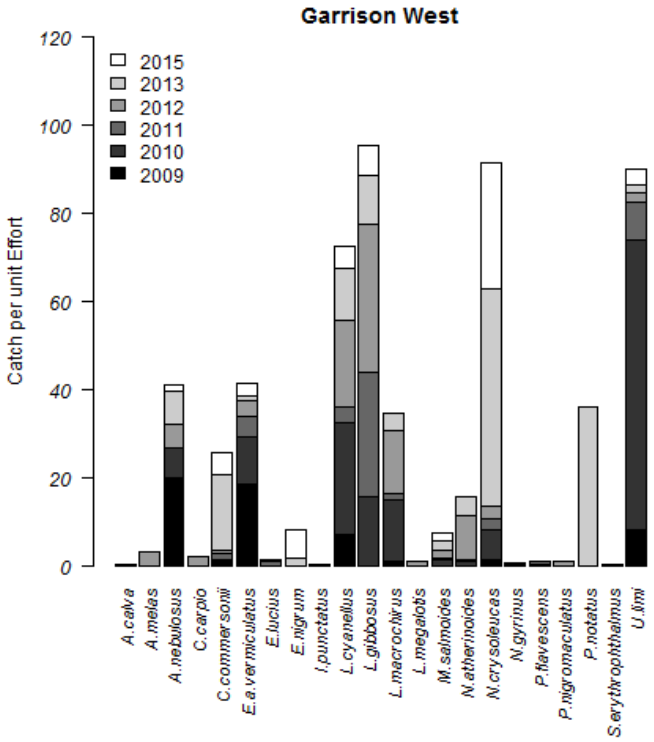

Figure 16. Catch per unit effort by species at Garrison West.

Reconstructed Reach

The CPUE at Pool 5 was 116 fishes (sampled in 2015 only) (Table 3). Six species were detected; Johnny Darter (*Etheostoma nigrum*) was the most abundant (Figure 17).

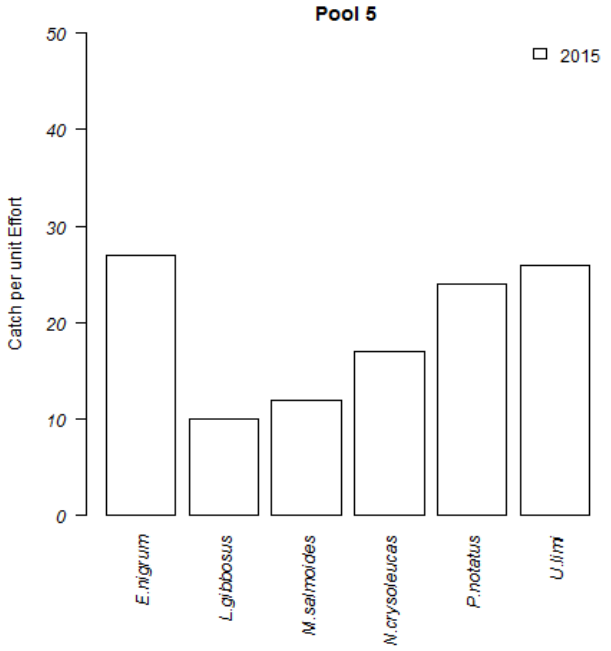

Figure 17. Catch per unit effort by species at Pool 5.

The mean CPUE at Pool 4 was 30 (± 20) fishes (Table 3). CPUE was relatively consistent in 2012 and 2013 but substantially higher in 2015 (Figure 18). Seventeen species were detected (Table 4). The most abundant species in 2012 was Emerald Shiner (mean of 6 (± 4) per haul), and Golden Shiner was most abundant in 2013 (5 per haul) and 2015 (30 per haul) (Figure 19). The most frequently detected species in Pool 4 were Golden Shiner, GP, Green Sunfish, Largemouth Bass, Pumpkinseed, and White Sucker, detected in all four sampling events and three years.

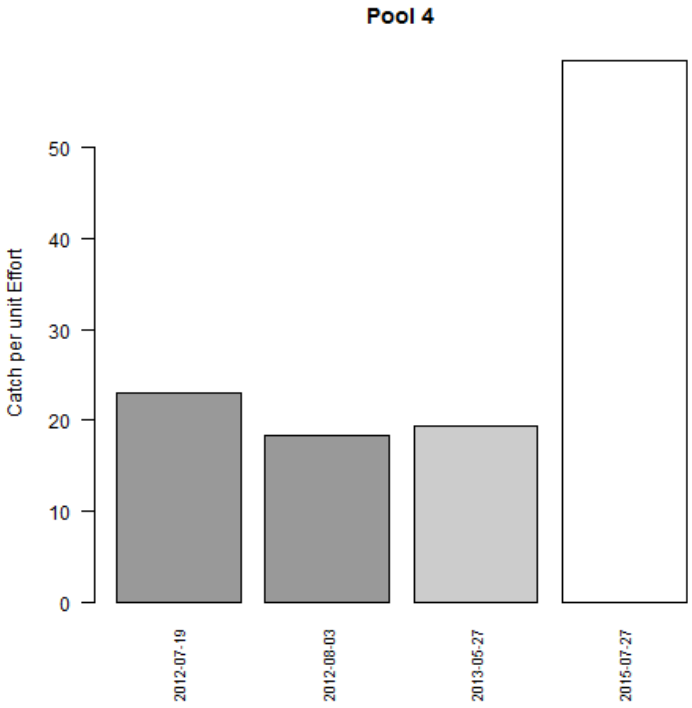

Figure 18. Catch per unit effort of all fishes at Pool 4 per sampling event.

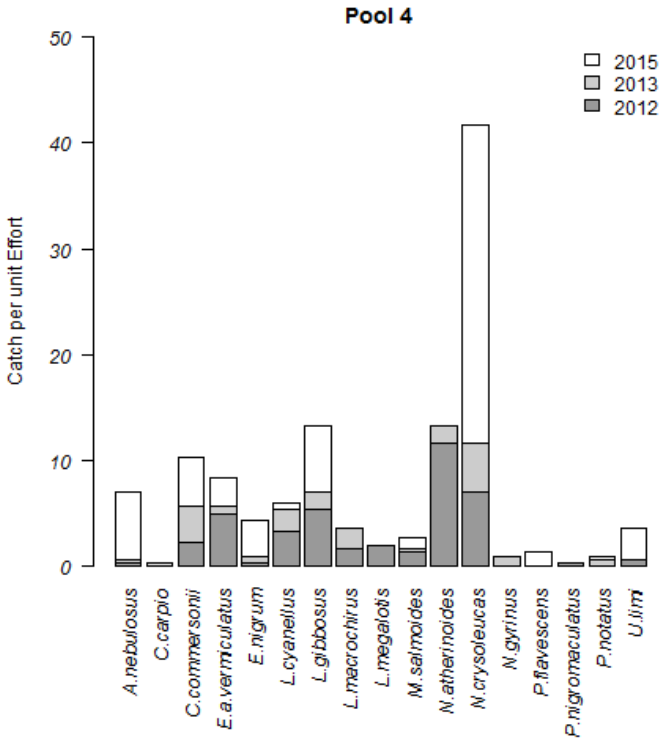

Figure 19. Catch per unit effort by species at Pool 4.

The mean CPUE at Offline Pool 2 was 31 (± 20) fishes (Table 3); CPUE was variable between years (Figure 20). Ten species were detected (Table 4). Golden Shiner was the most abundant species in both 2012 (18 per haul) and 2015 (20 per haul), while Green Sunfish was the most abundant species in 2013 (4 per haul) (Figure 21). In Offline Pool 2, Brown Bullhead, Green Sunfish and Pumpkinseed were detected during each sampling event in the three years that sampling occurred there.

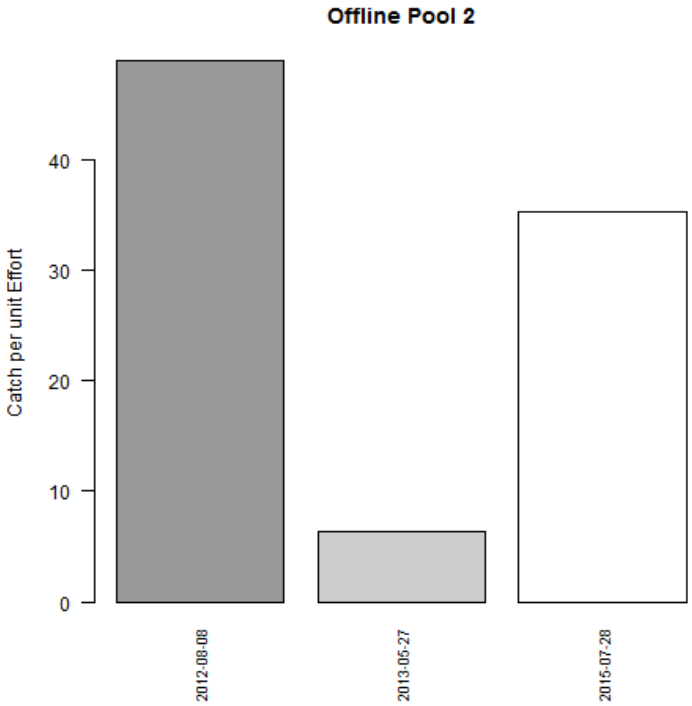

Figure 20. Catch per unit effort of all fishes at Offline Pool 2 per sampling event.

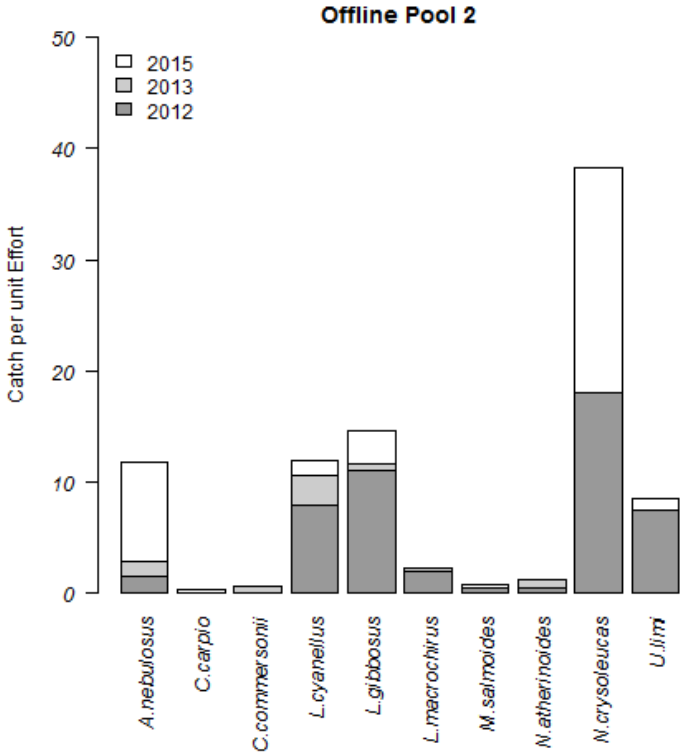

Figure 21. Catch per unit effort by species at Offline Pool 2.

The mean CPUE at Pool 3 was 33 (± 21) fishes (Table 3); CPUE varied greatly between years (Figure 22). Sixteen species were detected (Table 4). The most abundant species in 2012 was Pumpkinseed (mean of 9 (± 2) per haul), and Golden Shiner was most abundant in 2013 (5 per haul) and 2015 (20 per haul) (Figure 23). In Pool 3, Brown Bullhead, Pumpkinseed, Golden Shiner, and White Sucker were detected at all four sampling events over the three years, and GP was detected during three of these events in two years.

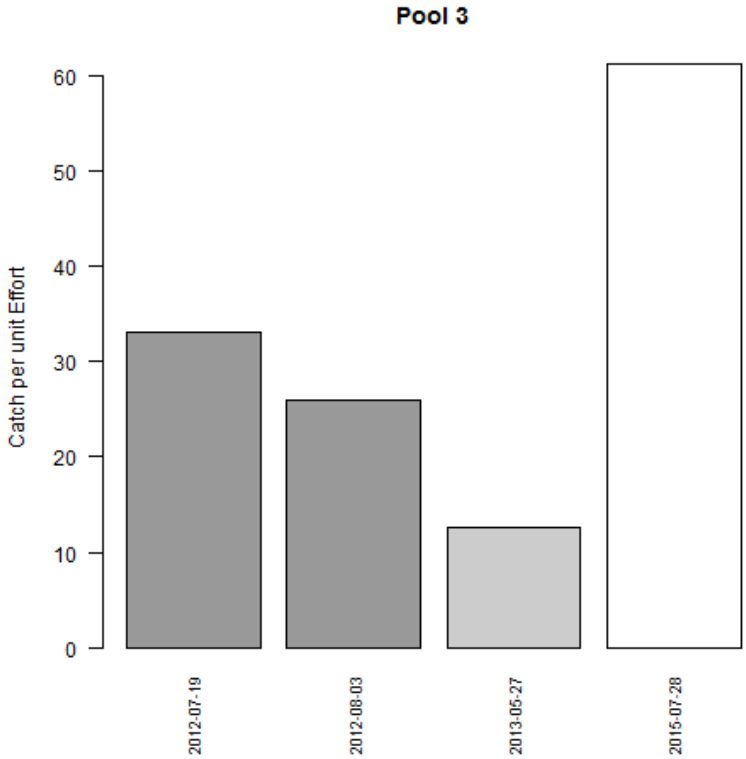

Figure 22. Catch per unit effort of all fishes at Pool 3 per sampling event.

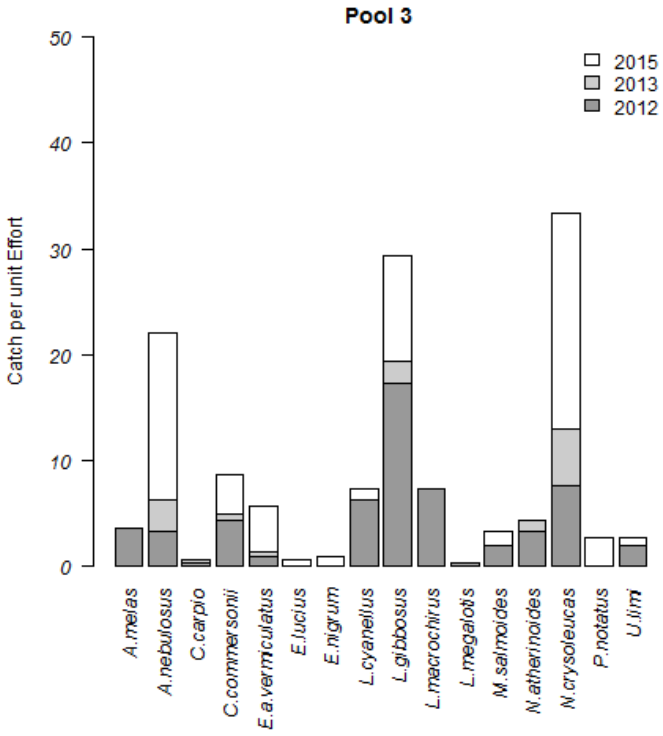

Figure 23. Catch per unit effort by species at Pool 3.

The CPUE at Offline Pool 1 was 118 fishes (Table 3). Ten species were detected (Table 4). Green Sunfish was the most abundant species in 2012, when approximately 66 were caught per haul (Figure 24).

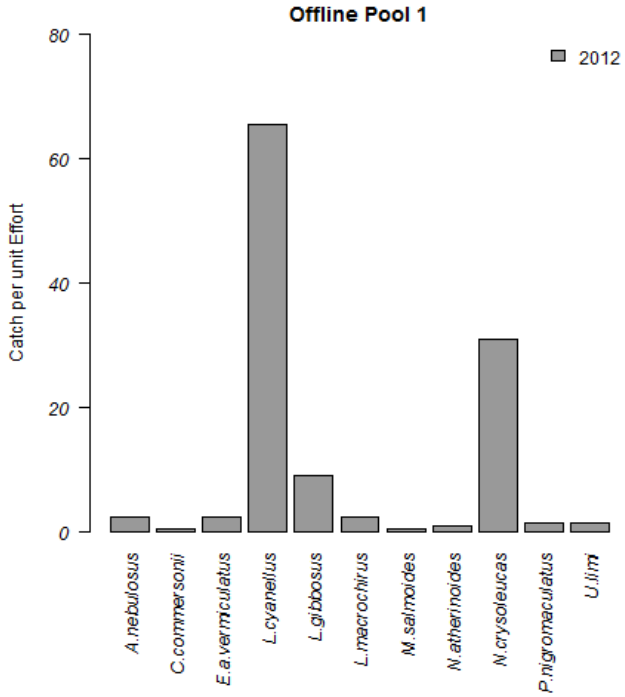

Figure 24. Catch per unit effort by species at Offline Pool 1.

The mean CPUE at Pool 2 was 49 (± 33) fishes (Table 3). CPUE was relatively consistent in 2012 and 2013 but substantially higher in 2015 (Figure 25). Seventeen species were detected (Table 4).

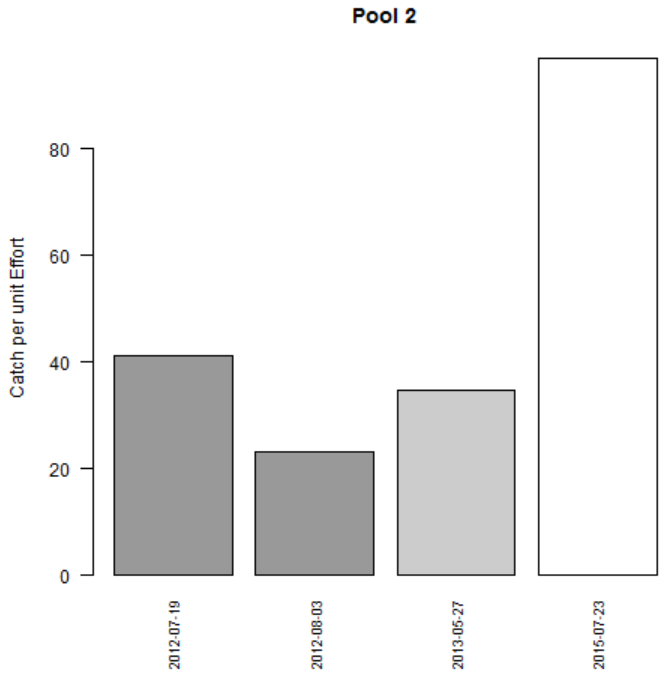

Figure 25. Catch per unit effort of all fishes at Pool 2 per sampling event.

Common Carp was the most abundant species captured in Pool 2 in 2012 (mean of 6 (± 4) per haul), and Golden Shiner was the most abundant in both 2013 (15 per haul) and 2015 (50 per haul) (Figure 26). In Pool 2, Brown Bullhead, GP, Golden Shiner, and Pumpkinseed were detected at all four sampling events over the three years.

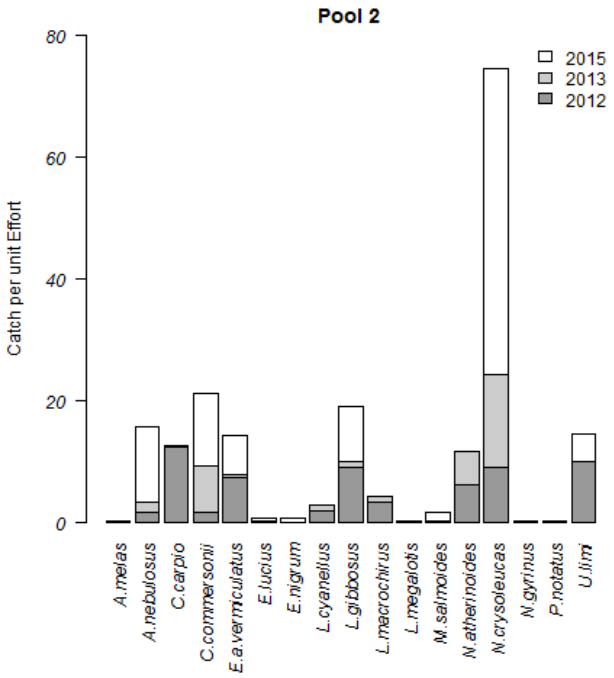

Figure 26. Catch per unit effort by species at Pool 2.

The CPUE at the pool upstream of House was 11 fishes (Table 3). Six species were detected (Table 4). GP was the most abundant species, approximately three were captured per haul (Figure 27).

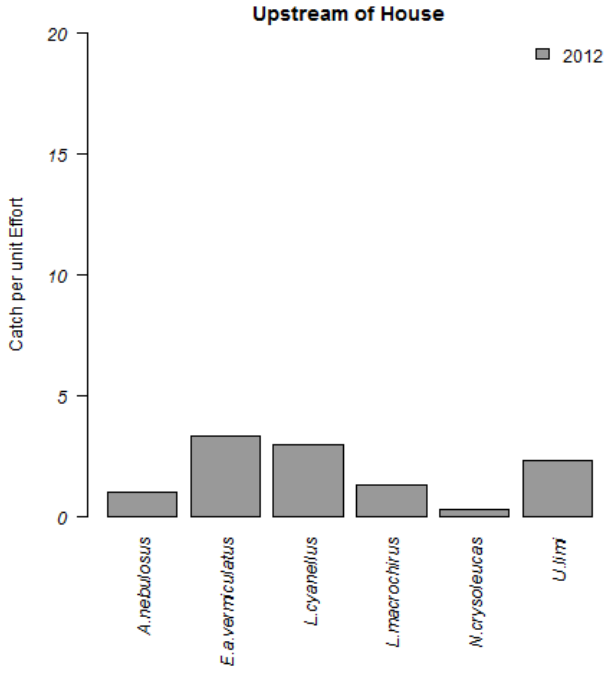

Figure 27. Catch per unit effort by species at the pool upstream of House.

The CPUE at Bertie ROW was 45 fishes (Table 3). Eleven species were detected (Table 4). Green Sunfish was the most abundant species captured (approximately 14 per haul) (Figure 28).

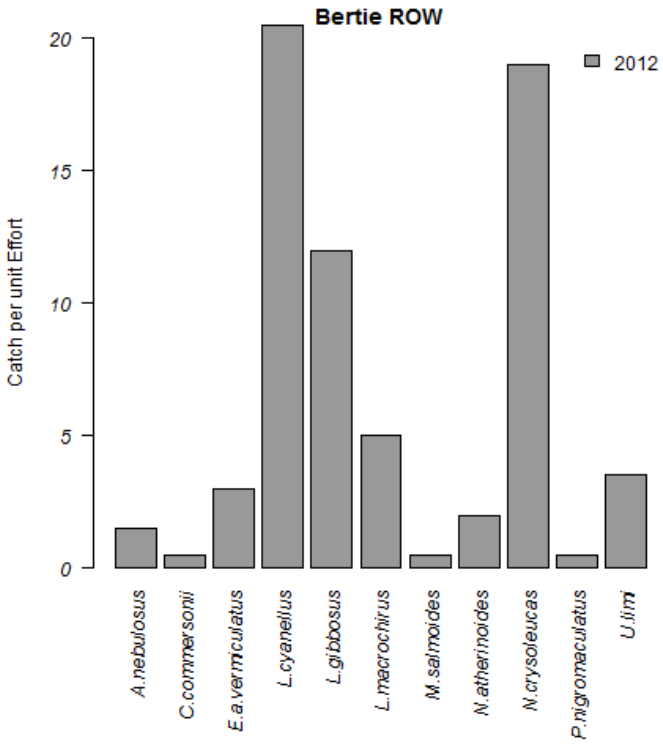

Figure 28. Catch per unit effort by species at Bertie ROW.

Gorham

The mean CPUE at Gorham was 18 (± 27) fishes (Table 3). More fishes were captured in 2009 than 2010, and there was substantial variation in CPUE in 2009 (Figure 29).

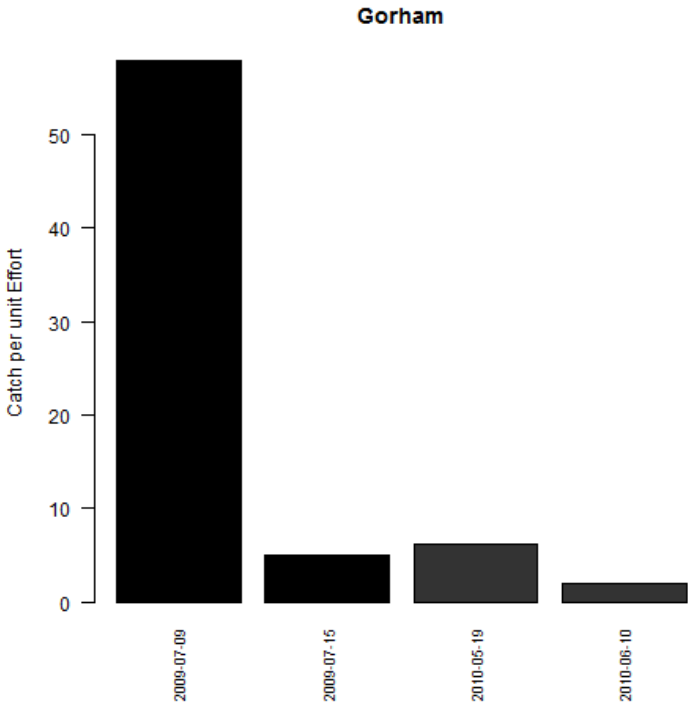

Figure 29. Catch per unit effort of all fishes at Gorham per sampling event.

Six species were detected at Gorham in 2009 and 2010. GP was the most abundant species captured in both 2009 and 2010. A mean of 23 (± 27) GP were captured per haul in 2009 and 3 (± 2) per haul in 2010 (Figure 30). GP and Central Mudminnow were the most frequently detected species at Gorham, occurring in all four sampling events over both years of sampling. Green Sunfish occurred in three sampling events over the two years.

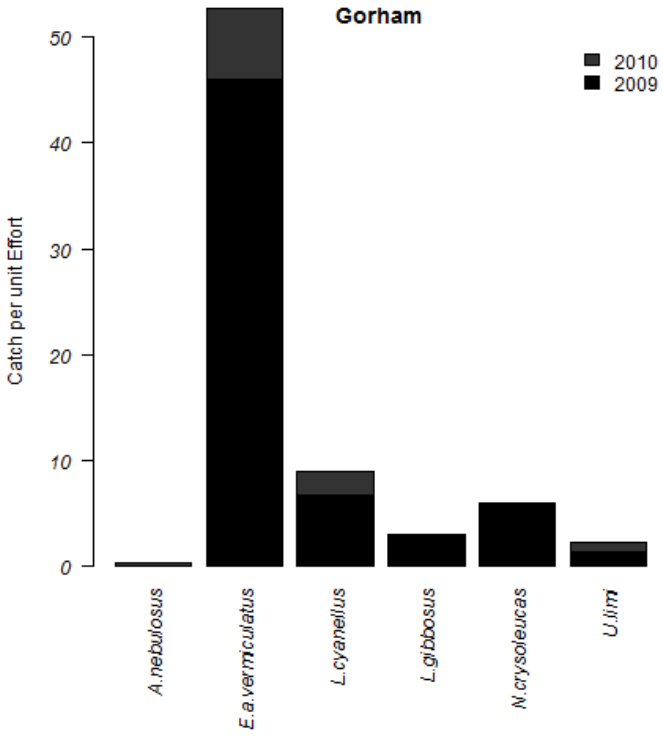

Figure 30. Catch per unit effort by species at Gorham.

House

The mean CPUE at House was 16 (± 13) fishes (Table 3). The most fishes were captured in 2009 at House (28 (± 21) fishes per haul), while the fewest were captured in 2012 (8 (± 2) fishes per haul). There is substantial variation in CPUE within and between years at House, 2009 showing the greatest variability through the season (Figure 31).

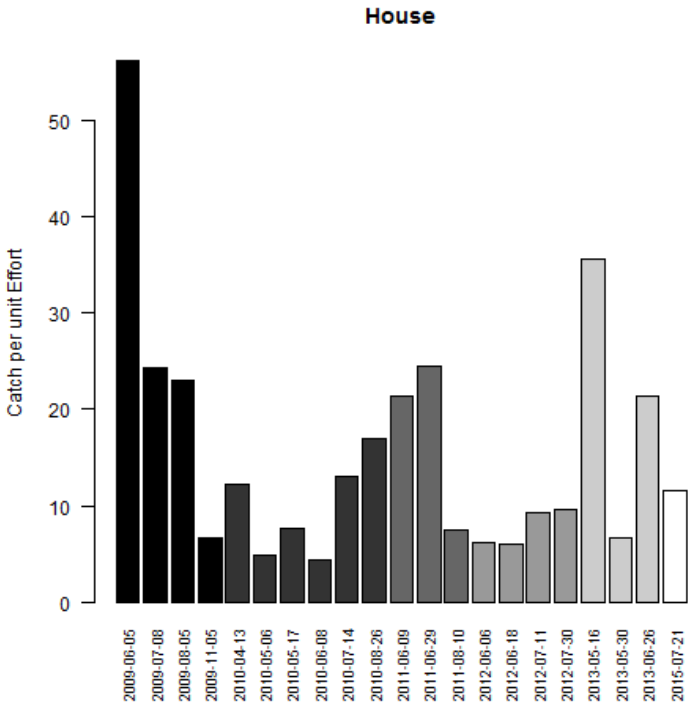

Figure 31. Catch per unit effort of all fishes at House per sampling event.

A total of 18 unique species were detected at House from 2009–2015 (Table 4). GP was the most abundant species captured in 2009 and 2010; approximately 21 (± 15) were captured per haul in 2009 and 2 (± 1) per haul in 2010 (Figure 32). In 2011, Brown Bullhead was the most abundant species captured (mean of 4 (± 3) per haul). Central Mudminnow was the most abundant in 2012 (mean of 3 (± 1) per haul). In 2013, Green Sunfish was the most abundant species captured (mean of 12 (± 16) per haul), and in 2015, Golden Shiner was the most abundant (six per haul). The most frequently detected species at House was GP, occurring in 95% of sampling events and six years. Central Mudminnow and Green Sunfish were the next most frequently detected species occurring in 80% of sampling events in five years each. Golden Shiner and White Sucker were detected in all six years.

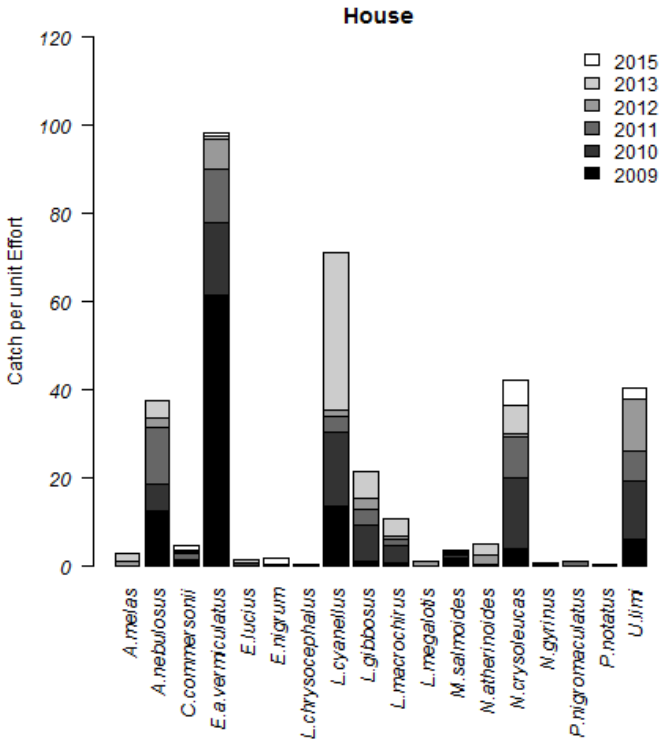

Figure 32. Catch per unit effort by species at House.

Nigh

The mean CPUE at Nigh was 21 (± 18) fishes (Table 3). The mean number of fishes caught per haul was approximately 21 (± 22) in both 2009 and 2010 at Nigh. There was substantial variation in CPUE within and between years at Nigh (Figure 33).

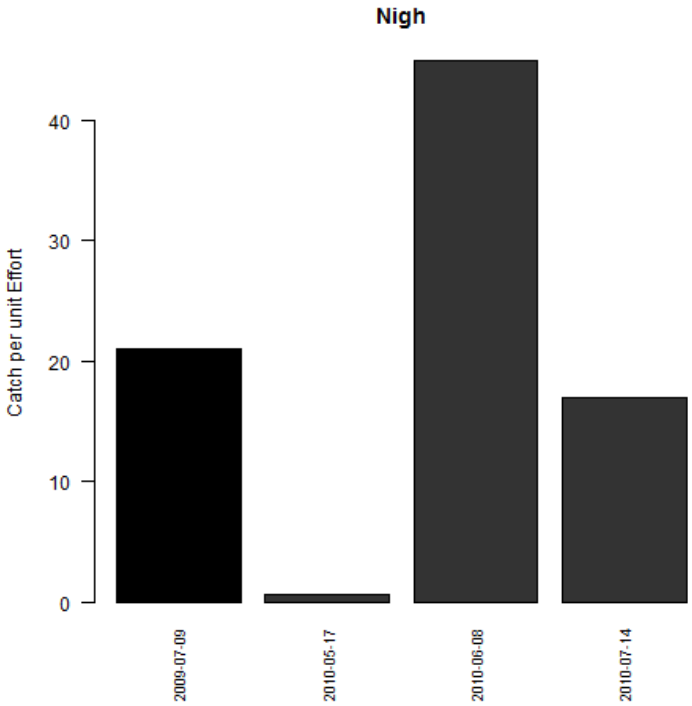

Figure 33. Catch per unit effort of all fishes at Nigh per sampling event.

Six species were detected at Nigh in 2009 and 2010. The most abundant species captured were GP (mean of 13 per haul) in 2009, and Central Mudminnow (mean of 14 (± 19) per haul) in 2010 (Figure 34). Green Sunfish was the most frequently detected species at Nigh, sampled in four sampling events and in both years. GP and Golden Shiner were the next most frequent, each sampled in three sampling events across both years.

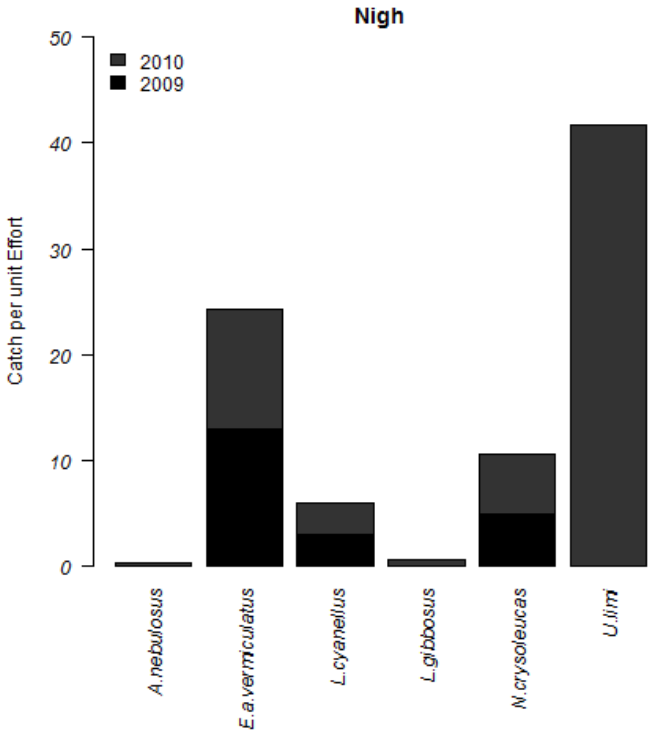

Figure 34. Catch per unit effort by species at Nigh

Stevensville

The mean CPUE at Stevensville was 47 (± 35) fishes (Table 3). The greatest mean number per haul was captured in 2010 (71 (± 7) fishes) and 2015 (71 fishes), while the lowest mean number captured per haul was in 2013 (24 (± 14) fishes). There was substantial variation in CPUE within years at Stevensville (Figure 35); the greatest variation was seen in 2009, with the largest and second smallest CPUE being caught in that year.

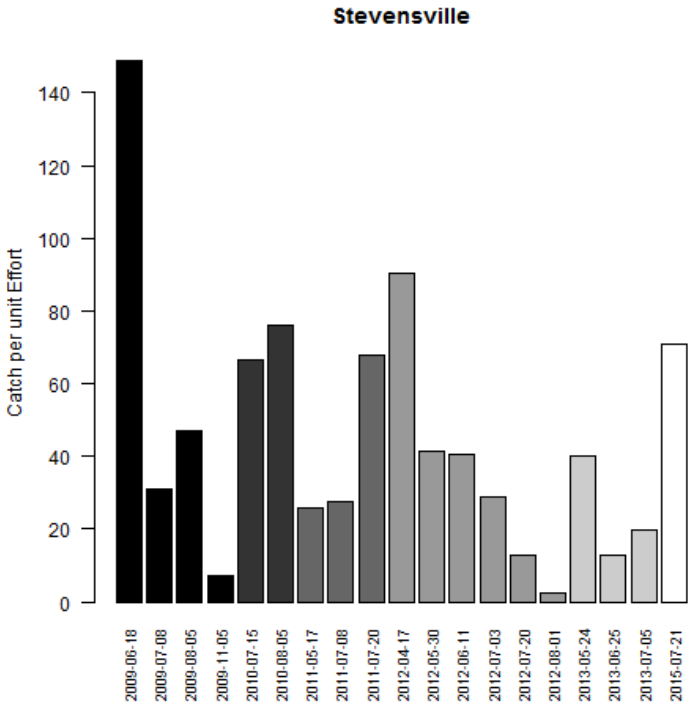

Figure 35. Catch per unit effort of all fishes at Stevensville per sampling event.

A total of 18 unique species were detected at Stevensville from 2009–2015 (Table 4). The most abundant species captured at Stevensville differed each year. In 2009, GP was the most abundant (mean of 50 (± 45) per haul) (Figure 36). Golden Shiner was the most abundant species in 2010 (mean of 36 (± 5) per haul), 2011 (mean of 19 (± 25) per haul), and 2015 (69 per haul). Emerald Shiner was the most abundant species in 2012 (mean of 36 (± 33) per haul) and 2013 (mean of 14 per haul). GP was the most frequently detected species at Stevensville, occurring in 94% of sampling events and all six years. Golden shiner was next, detected in 89% of sampling events across all years. Emerald Shiner was also detected regularly, 56% of events and four years.

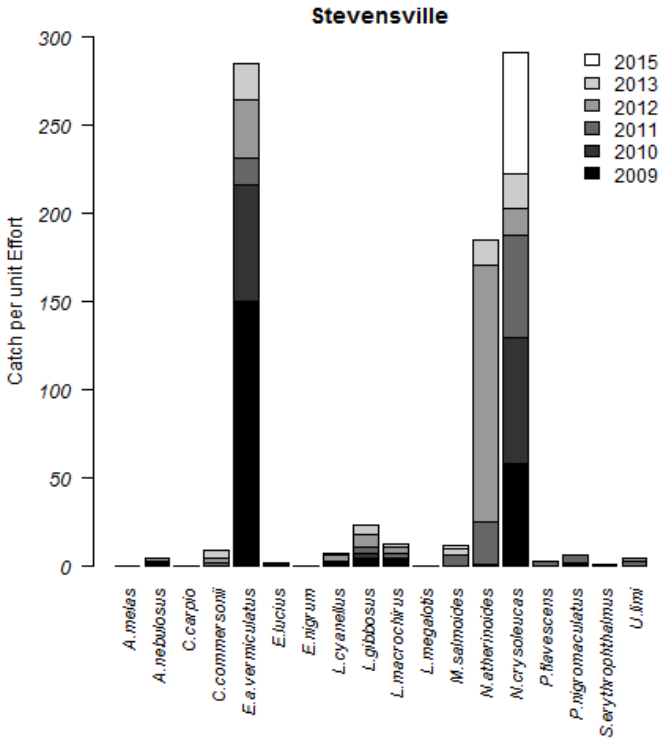

Figure 36. Catch per unit effort by species at Stevensville.

Winger

The mean CPUE at Winger was 28 (± 46) fishes (Table 3). The greatest mean number of fishes was captured in 2012 (56 (± 79) fishes per haul), while the lowest mean number of fishes captured was in 2011 (7 (± 6) fishes per haul). The variation in CPUE at Winger was relatively low within and between years, except in 2012 when there was substantial variation throughout the sampling season (Figure 37).

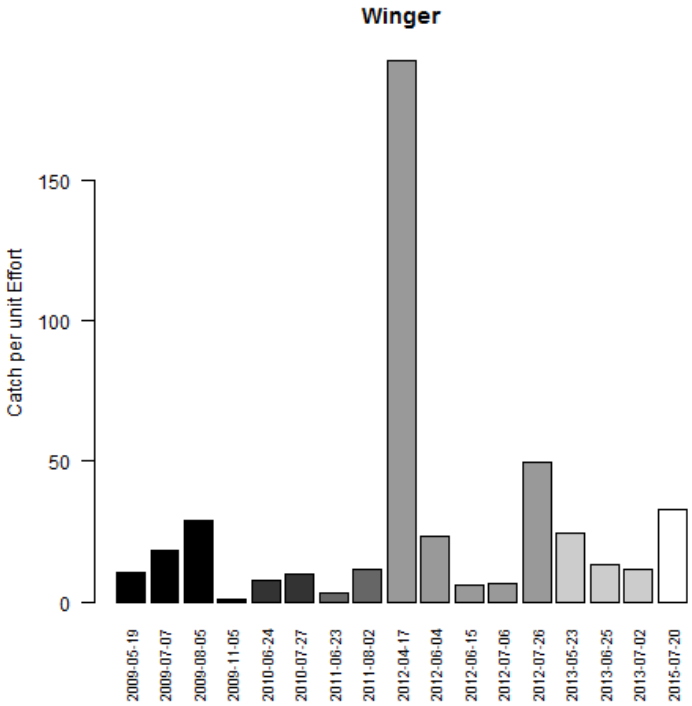

Figure 37. Catch per unit effort of all fishes at Winger per sampling event.

A total of 16 unique species were detected at Winger from 2009–2015 (Table 4). GP was the most abundant species captured in 2009 (mean of 6 (± 2) per haul), 2010 (mean of 6 (± 1) per haul), and 2011 (mean of 3 (± 4) per haul) (Figure 38). In 2012, Emerald Shiner was the most abundant species captured (mean of 45 (± 59) per haul). Golden Shiner was the most abundant in 2013 (mean of 7 (± 2) per haul) and 2015 (24 per haul). The most frequently detected species sampled at Winger was GP, occurring in 94% of sampling events and all six years. Golden Shiner was the next most frequently detected species, occurring in 88% of sampling events and six years. Central Mudminnow was detected 56% if the time, and in five years.

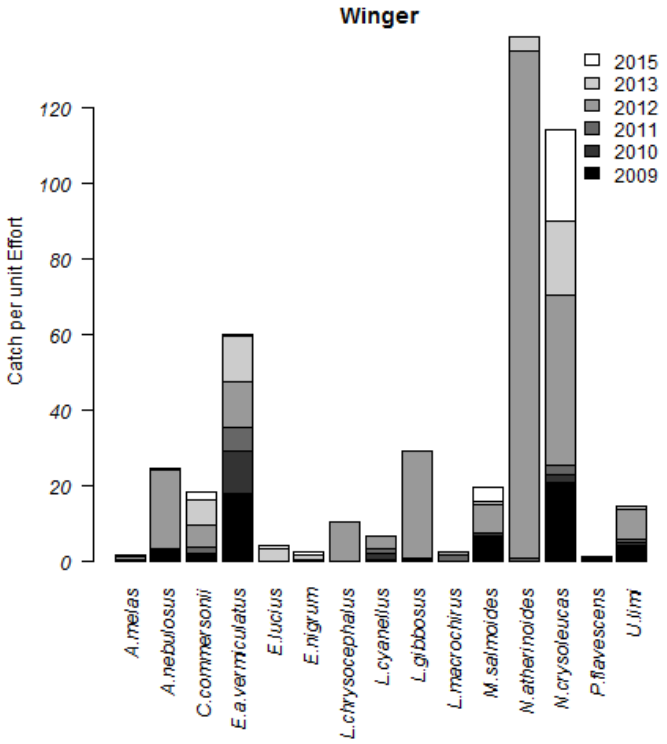

Figure 38. Catch per unit effort by species at Winger.

GRASS PICKEREL SAMPLING

A total of 4,971 GP were captured throughout the study, 2,019 GP were tagged with PIT tags, and 381 were recaptured with PIT tags. A total of 446 young-of-year (YOY) were captured. The abundance of GP declined substantially twice during this time; once after 2009 (mean number of GP captured per haul was 24.4 in 2009, 9.8 in 2010, 9.7 in 2011) and again after 2011 (mean of 3.7 in 2012, 2.2 in 2013 and 3.2 in 2015). The mean total length of all GP captured was 163 mm and the mean weight was 35.7 g. GP captured in 2015 were not checked for PIT tags or weighed. GP abundance data are summarized in Table 5 and body size data are summarized in Table 6.

The following parameters are summarized for each site:

- Relative abundance of GP;
- catch per unit effort of all GP, tagged GP and recaptured GP;
- mean total length (TL) of all GP captured;
- length frequency distribution (with Shapiro test of normality); and
- condition Index (length: weight relationship); fitted with a third order polynomial regression curve derived from all data. GP above the curve were in better condition than average.

Table 5. Standardized abundance of Grass Pickerel (GP) per year by site. Dash indicates sampling did not occur that year.

Site Name	Mean Relative Abundance (%) of GP						GP per haul						GP tagged per haul						GP recaptured per haul						YOY per haul					
Year	2009	2010	2011	2012	2013	2015	2009	2010	2011	2012	2013	2015	2009	2010	2011	2012	2013	2015	2009	2010	2011	2012	2013	2015	2009	2010	2011	2012	2013	2015
Ben's Place	-	-	36	47	100	33	-	-	3.4	6.6	2.5	1.0	-	-	2.8	1.6	0.0	0.0	-	-	0.0	0.1	0.0	0.0	-	-	0.4	1.0	0.5	1.0
Bertie	97	92	66	58	19	75	25.0	18.1	46.5	7.0	2.3	6.0	7.1	12.8	16.0	2.6	1.0	0.0	1.3	4.3	10.5	2.0	1.3	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Bertie ROW	-	-	-	4	-	-	-	-	-	2.0	-	-	-	-	-	1.0	-	-	-	-	-	0.0	-	-	-	-	-	0.0	-	-
Bowen	54	46	42	18	25	9	20.6	21.1	17.7	6.9	3.2	3.7	4.4	15.8	4.1	2.1	0.0	0.0	0.9	0.6	1.4	1.1	0.0	0.0	1.9	0.5	8.7	1.2	2.6	0.0
College	15	12	3	3	10	3	2.2	1.3	0.5	0.5	0.9	0.3	0.3	0.9	0.3	0.2	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.3	0.2	0.1	0.7	0.3
Eagle	19	15	27	3	2	25	5.3	3.4	5.7	0.6	0.7	3.5	2.8	2.9	1.8	0.4	0.2	0.0	0.2	0.2	0.3	0.1	0.0	0.0	0.1	0.2	3.3	0.0	0.4	0.5
Garrison East	82	89	49	30	14	6	57.3	25.7	10.7	7.6	2.1	6.0	9.8	21.7	5.8	1.7	0.4	0.0	2.5	2.8	1.6	0.2	0.1	0.0	0.7	0.9	0.7	0.5	1.1	1.0
Garrison West	35	8	8	4	1	5	5.3	1.9	2.3	0.7	0.3	3.0	1.2	1.3	1.4	0.0	0.1	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.1	0.3	0.9	0.0	0.0	0.0
Gorham	76	65	-	-	-	-	13.5	2.9	-	-	-	-	0.0	2.4	-	-	-	-	0.0	0.1	-	-	-	-	0.0	0.3	-	-	-	-
House	56	26	21	23	2	4	20.7	1.7	2.9	1.7	0.2	0.5	9.2	1.1	1.8	0.1	0.0	0.0	1.4	0.3	0.5	0.2	0.0	0.0	0.0	0.1	0.5	0.2	0.1	0.0
Nigh	62	16	-	-	-	-	13.0	3.8	-	-	-	-	0.0	2.8	-	-	-	-	0.0	0.1	-	-	-	-	0.0	0.9	-	-	-	-
Offline Pool 1	-	-	-	2	-	-	-	-	-	2.5	-	-	-	-	-	0.0	-	-	-	-	-	0.0	-	-	-	-	-	0.0	-	-
Offline Pool 2	-	-	-	0	0	0	-	-	-	0.0	0.0	0.0	-	-	-	0.0	0.0	0.0	-	-	-	0.0	0.0	0.0	-	-	-	0.0	0.0	0.0
Pool 2	-	-	-	12	2	7	-	-	-	3.5	0.7	6.3	-	-	-	0.2	0.7	0.0	-	-	-	0.0	0.0	0.0	-	-	-	0.2	0.0	0.7
Pool 3	-	-	-	2	3	7	-	-	-	1.0	0.0	4.3	-	-	-	0.5	0.0	0.0	-	-	-	0.0	0.0	0.0	-	-	-	0.0	0.0	0.0
Pool 4	-	-	-	13	3	4	-	-	-	2.5	0.7	2.7	-	-	-	0.2	0.7	0.0	-	-	-	0.0	0.0	0.0	-	-	-	0.0	0.0	0.0
Pool 5	-	-	-	-	-	0	-	-	-	-	-	0.0	-	-	-	-	-	0.0	-	-	-	-	-	0.0	-	-	-	-	-	0.0
Stevensville	69	46	13	26	34	0	45.6	32.8	5.1	5.4	6.9	-	12.0	23.2	1.3	2.3	0.6	-	3.6	5.5	0.4	0.8	0.3	-	0.0	0.3	2.3	0.6	3.8	0.0
Upstream of House	-	-	-	29	-	-	-	-	-	3.3	-	-	-	-	-	1.3	-	-	-	-	-	0.0	-	-	-	-	-	0.3	-	-
Winger	40	63	33	17	18	2	6.9	5.5	3.6	2.4	4.0	0.7	5.1	4.5	1.4	0.7	0.0	0.0	0.1	0.3	0.0	0.1	0.1	0.0	0.2	0.5	1.8	0.2	4.0	0.3

Table 6. Body size of Grass Pickerel per year by site. Dash (-) indicates sampling did not occur that year, asterisk (*) indicates Grass Pickerel were not captured. Weights were not recorded in 2015.

Site Name	Min TL (mm)	Max TL (mm)	Mean Total Length (mm)						Median Total Length (mm)						Mean Weight (g)				
			2009	2010	2011	2012	2013	2015	2009	2010	2011	2012	2013	2015	2009	2010	2011	2012	2013
Ben's Place	51	247	-	-	170	148	112	75	-	-	179	150	115	75	-	-	46.9	25.1	8.9
Bertie	73	266	160	180	192	191	195	190	160	180	190	195	199	193	27.5	40.8	49.9	42.7	50.7
Bertie ROW	157	225	-	-	-	182	-	-	-	-	-	181	-	-	-	-	-	26.8	-
Bowen	29	260	155	172	130	171	85	188	171	172	170	176	72	188	42.8	37.9	57.1	44.2	20.3
College	36	237	173	156	158	150	78	78	171	182	185	168	80	78	32.1	44.3	55.3	37.9	2.4
Eagle	19	245	167	184	126	198	109	176	168	190	85	195	83	193	34.3	46.8	61.1	49.5	22.0
Garrison East	21	276	165	181	179	155	117	180	161	185	190	150	77	197	33.1	44.6	44.6	32.4	51.6
Garrison West	25	246	154	167	146	159	170	191	157	184	178	155	144	187	21.6	43.1	50.9	24.1	34.2
Gorham	60	278	151	181	-	-	-	-	149	186	-	-	-	-	22.0	59.1	-	-	-
House	33	253	161	168	172	153	64	146	160	178	190	157	64	146	26.7	35.4	50.1	23.7	1.5
Nigh	46	239	193	158	-	-	-	-	194	178	-	-	-	-	42.0	43.9	-	-	-
Offline Pool 1	150	162	-	-	-	155	-	-	-	-	-	153	-	-	-	-	-	17.0	-
Offline Pool 2	*	*	-	-	-	*	*	*	-	-	-	*	*	*	-	-	-	*	*
Pool 2	61	243	-	-	-	161	216	181	-	-	-	165	216	191	-	-	-	24.0	65.0
Pool 3	165	249	-	-	-	217	179	202	-	-	-	212	179	205	-	-	-	68.3	43.5
Pool 4	151	236	-	-	-	170	198	207	-	-	-	166	198	207	-	-	-	29.9	35.5
Pool 5	*	*	-	-	-	-	-	*	-	-	-	-	-	*	-	-	-	-	-
Stevensville	26	256	167	168	129	167	103	-	165	165	130	182	97	-	26.6	33.9	40.2	38.3	16.7
Upstream of House	74	210	-	-	-	163	-	-	-	-	-	170	-	-	-	-	-	*	-
Winger	22	260	165	168	127	148	52	143	166	179	100	118	48	143	39.5	39.7	38.6	30.7	13.6

Ben’s Place

Approximately 2% of all GP captured in Beaver Creek were caught at Ben’s Place. GP made up a substantial proportion of the fish community in all years (Figure 39). It comprised at least 50% of the fish community on most sampling events in all years, except on three occasions.

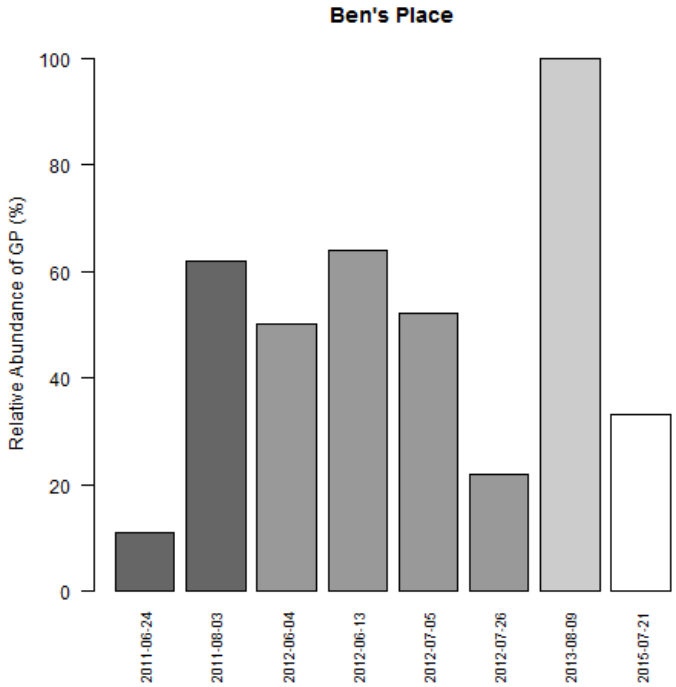

Figure 39. Relative abundance of Grass Pickerel at Ben's Place per sampling event.

Generally, few GP were captured per haul at Ben’s Place (i.e., approximately 5 or fewer), except one event in 2012 which yielded approximately 21 GP per haul (Figure 40). More than half of the individuals captured at Ben’s Place were tagged in 2011 and early 2012, but no individuals were tagged after July 2012. Only one individual was recaptured with a tag at Ben’s Place.

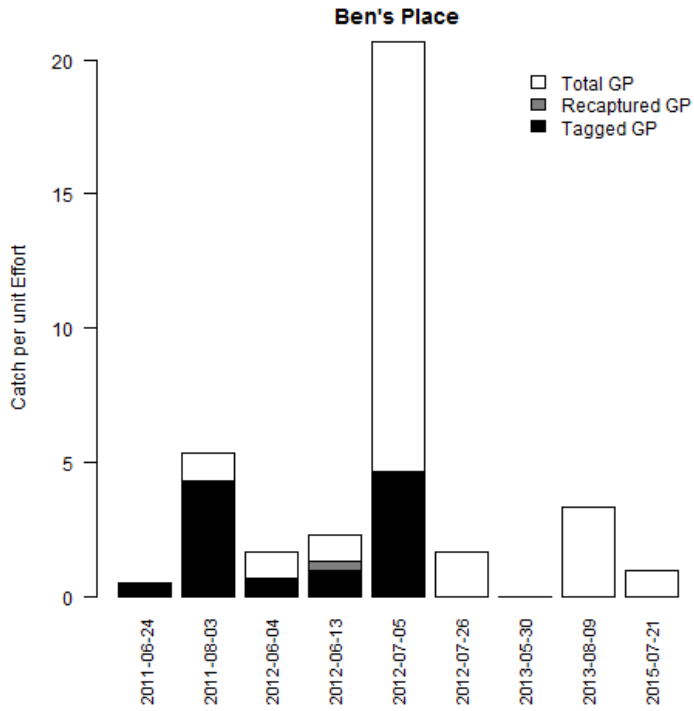

Figure 40. Number of Grass Pickerel captured per haul at Ben's Place per sampling event.

The mean TL of GP at Ben's Place was 147 mm. There was a significant difference in TL between years (χ^2 = 20.289, df = 3, p = 0.0001). TL generally declined from 2011–2015 (Figure 41).

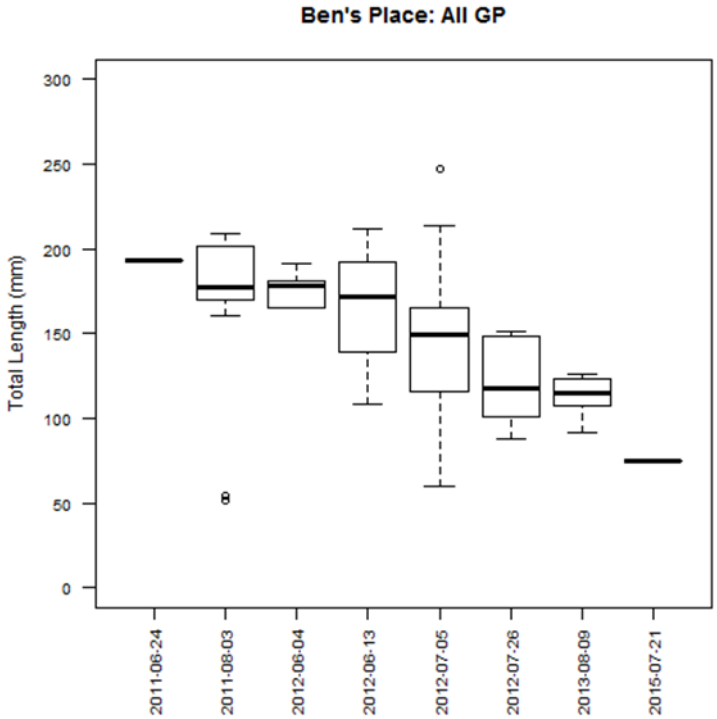

Figure 41. Total lengths of Grass Pickerel captured at Ben's Place per sampling event.

Lengths at Ben's Place were normally distributed around the mean (Figure 42).

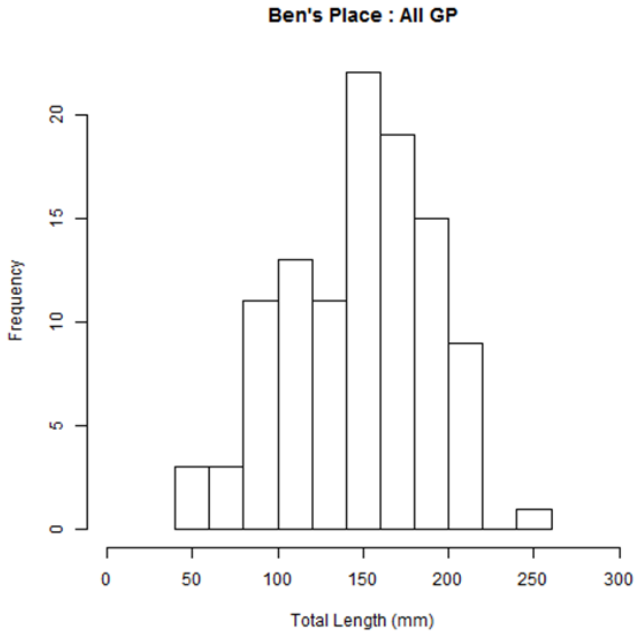

Figure 42. Length frequency distribution of Grass Pickerel captured at Ben's Place.

The length: weight relationship of GP captured at Ben's Place was consistent across all three years and GP were of approximately average size (Figure 43).

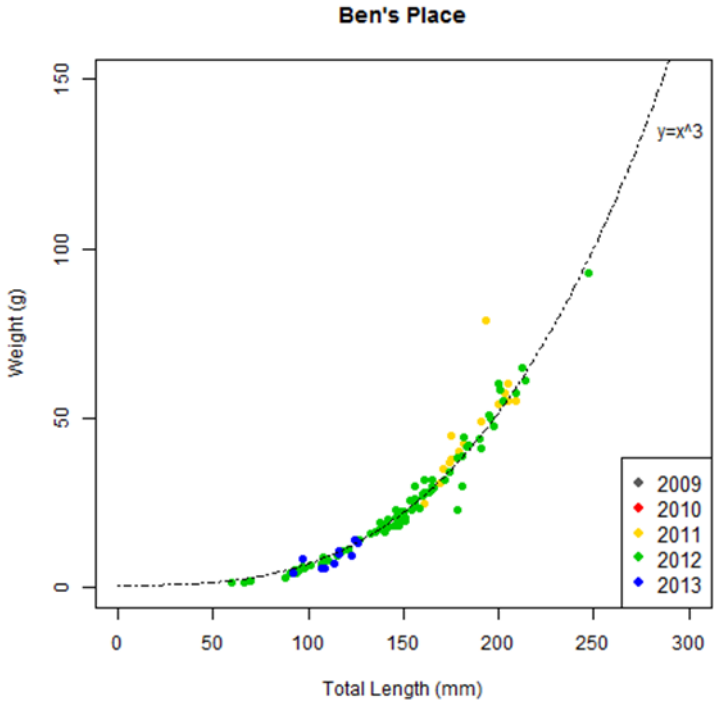

Figure 43. Body condition of Grass Pickerel captured at Ben's Place.

Bertie

Approximately 13% of all GP captured were caught at Bertie. GP was the most abundant species detected early on in this study (Figure 44). It made up at least 60% of the fish community from 2009–2011 and in the second half of 2012 and in 2015. The proportion of GP in the fish community increased throughout the season in 2012.

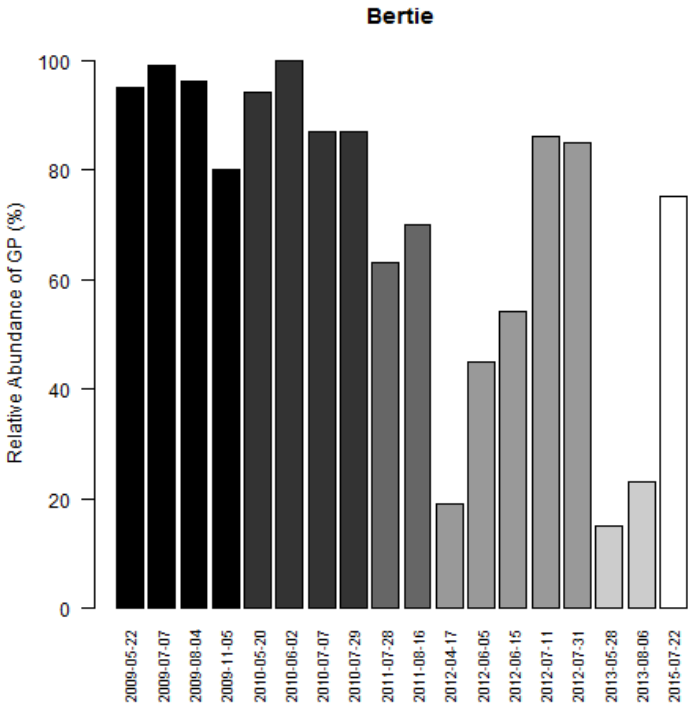

Figure 44. Relative abundance of Grass Pickerel at Bertie per sampling event.

There was a significant difference in the number of GP captured between years (χ^2 = 11.554, df = 5, p = 0.041). There were more GP detected in 2011 than 2012 or 2013. The CPUE of GP was relatively consistent in 2009 and 2012–2015, though greater in 2009 than the later years (Figure 45). The abundance of GP varied greatly in 2010 and 2011; increasing through the season in 2010. Almost all individuals caught on the first sampling event in 2009 were tagged, and no more were tagged that year. The majority of individuals captured in 2010, 2011, and early 2012 and 2013 were tagged. A few (i.e., approximately 1-10) tagged GP were recaptured at almost every sampling event in all years.

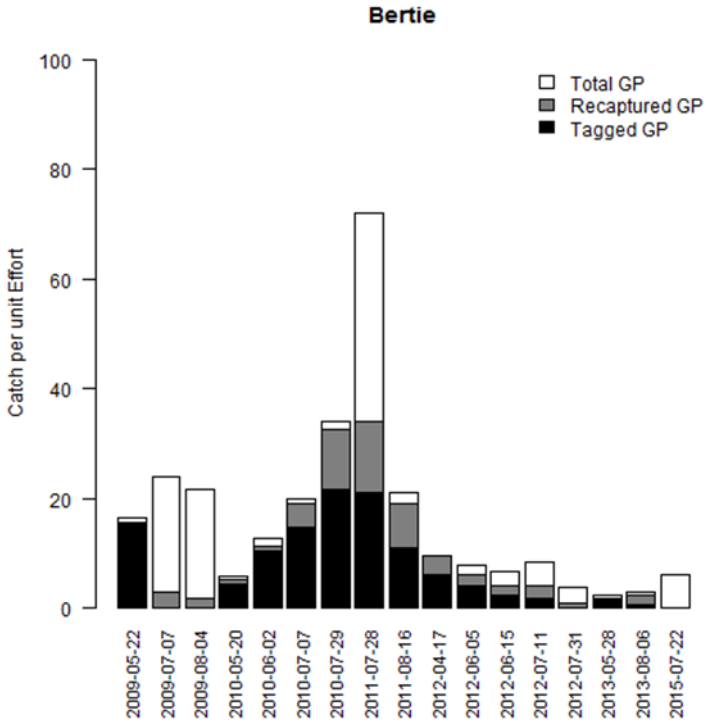

Figure 45. Number of Grass Pickerel captured per haul at Bertie per sampling event.

The mean TL of GP at Bertie was 176 mm. There was a significant difference in TL between years ($\chi^2 = 250.74$, df = 5, $p < 0.0001$). TL of GP captured at Bertie generally increased from 2009–2015, though there was some variation within years. The length of GP declined throughout the 2012 season (Figure 46). Generally only intermediate to large individuals were captured at Bertie.

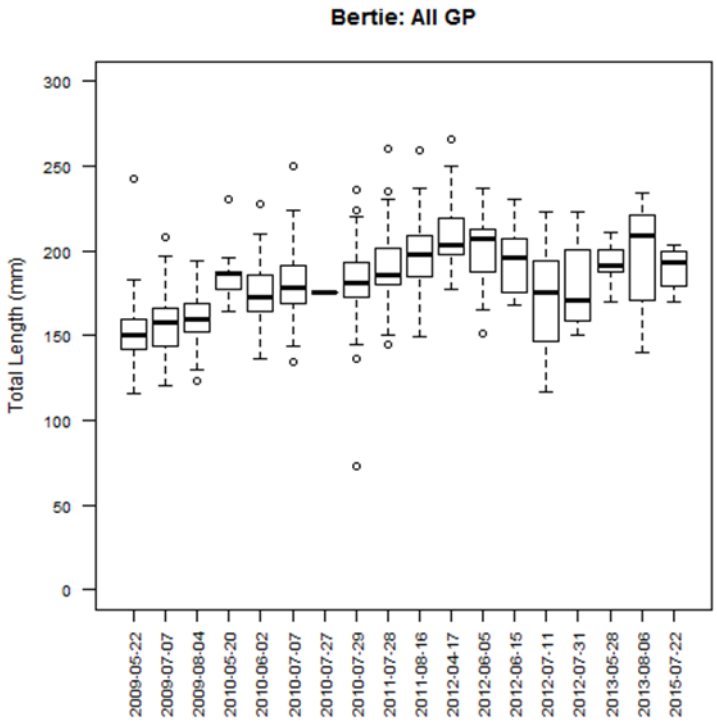

Figure 46. Total lengths of Grass Pickerel captured at Bertie per sampling event.

The length frequency distribution was significantly different from a normal distribution ($w = 0.99$, $p < 0.0004$) (Figure 47).

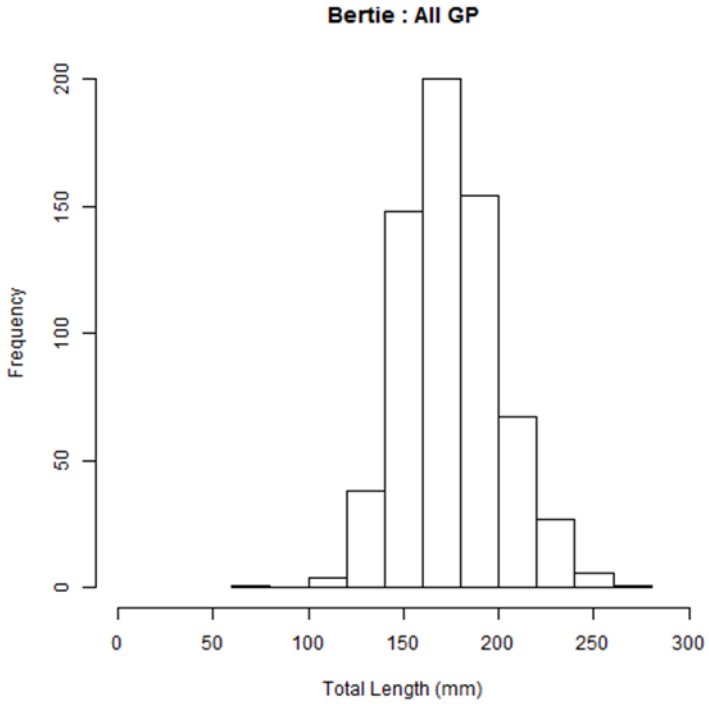

Figure 47. Length frequency distribution of Grass Pickerel captured at Bertie.

The length: weight relationship of GP captured at Bertie varied somewhat between years (Figure 48). GP caught in 2009 showed the greatest range in body condition. Individuals captured in 2011 weighed more than the average GP of the same length, while individuals captured in 2012 weighed less than the average for the same length.

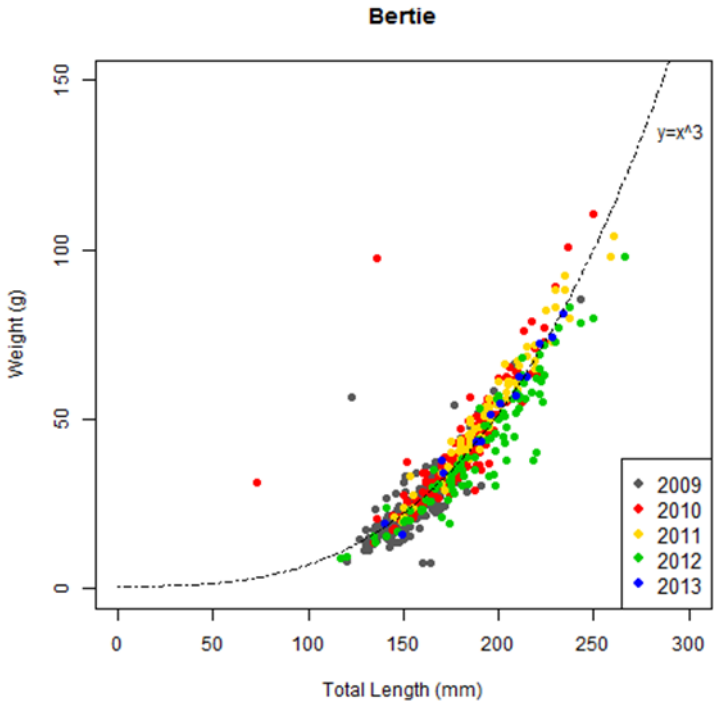

Figure 48. Body condition of Grass Pickerel captured at Bertie.

Bowen

Approximately 24% of all GP captured in Beaver Creek were caught at Bowen. The relative abundance of GP varied greatly within and between years (Figure 49). It was not detected at all during some sampling events, and made up as much as 75% of the fish community on others. The proportion of GP tended to increase throughout 2010, but decrease throughout 2012.

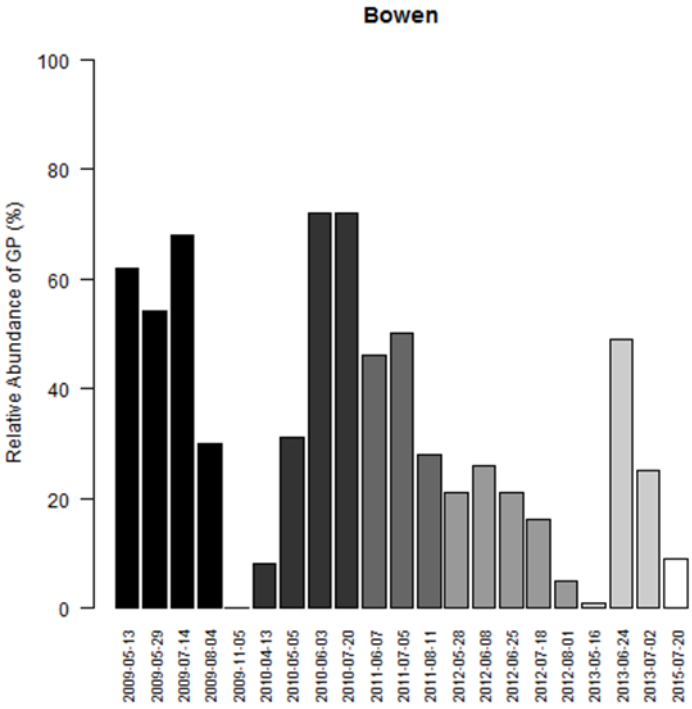

Figure 49. Relative abundance of Grass Pickerel at Bowen per sampling event.

The CPUE of GP was highly variable within and between years at Bowen; catches were generally higher, though more variable in 2009–2011 (Figure 50). The highest CPUE of GP was in 2010 and the lowest in 2013. Many GP were tagged early in 2009 and 2012, the majority of GP captured were tagged throughout 2010 and 2011, and no GP were tagged after June 2012. A few (i.e., approximately 2–3) tagged GP were recaptured per haul during most sampling events, except the first event in 2010 and all events after August 2012.

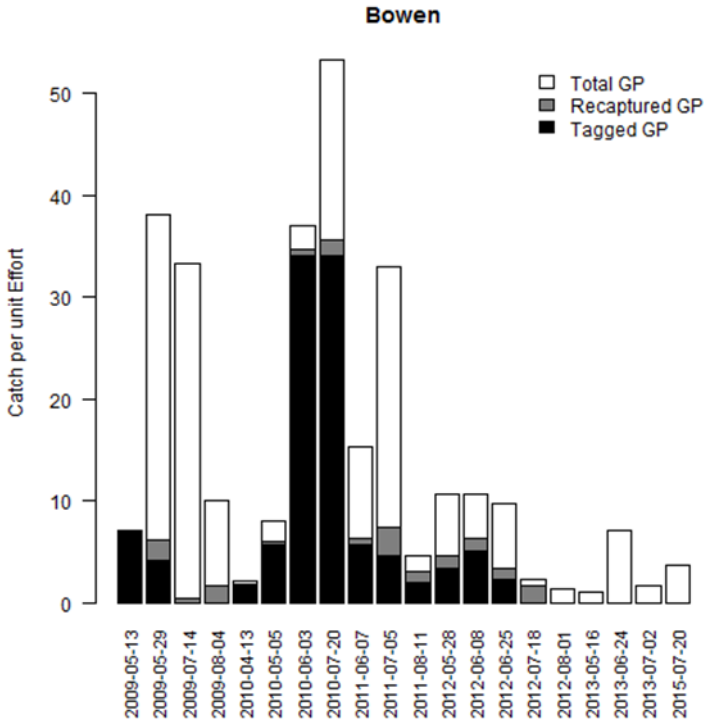

Figure 50. Number of Grass Pickerel captured per haul at Bowen per sampling event.

The mean TL of GP at Bowen was 156 mm. There was a significant difference in TL between years ($\chi^2 = 53.066$, df = 5, $p < 0.0001$). GP were longest in 2010 and shortest in 2011 and 2013. TL of GP varied greatly within and between years (Figure 51). GP of all size classes (29–260 mm) were captured at Bowen in all years.

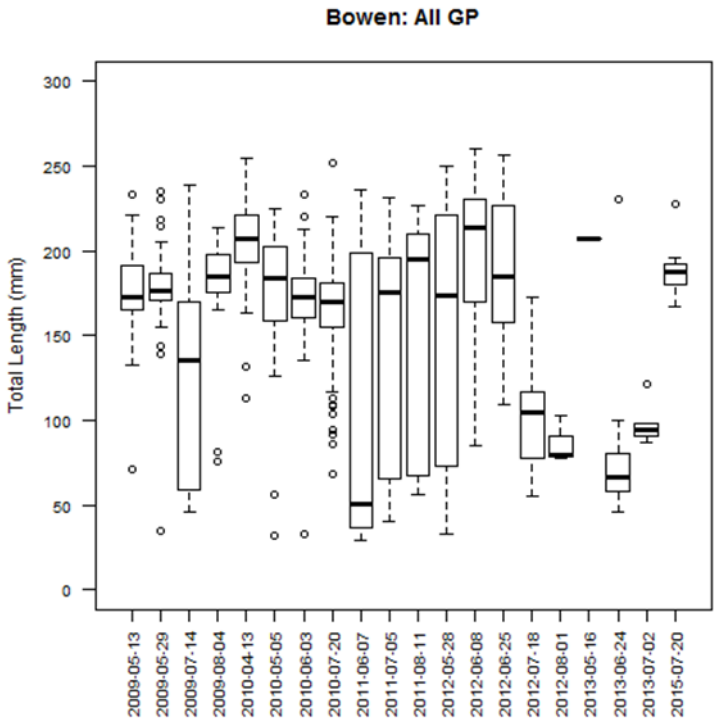

Figure 51. Total lengths of Grass Pickerel captured at Bowen per sampling event.

The length frequency distribution of GP at Bowen is bimodal (Figure 52), with peaks at approximately 50 mm and 175 mm, though the first peak is smaller.

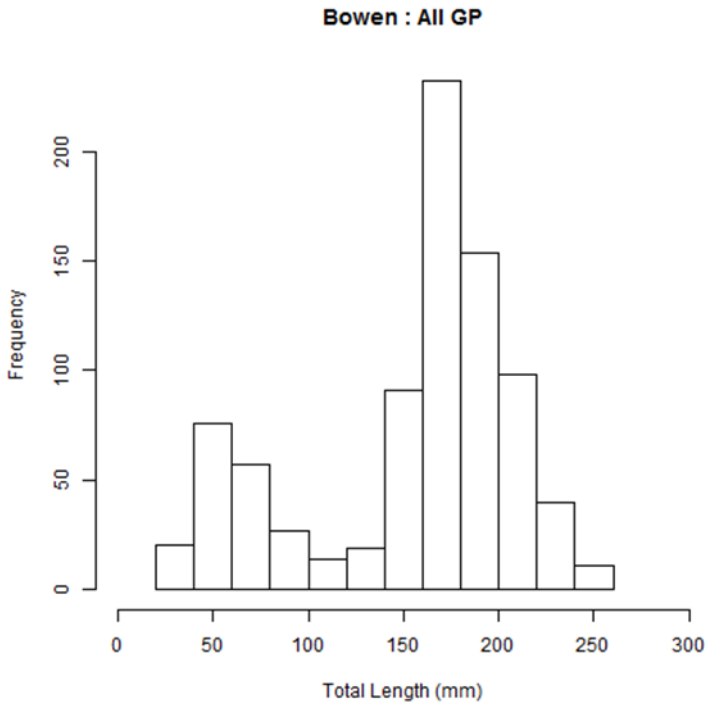

Figure 52. Length frequency distribution of Grass Pickerel captured at Bowen.

The length: weight relationship of GP captured at Bowen varied between years (Figure 53). Individuals captured in 2009 and 2011 appeared to be in better condition (i.e., weighed more) than GP of the same length from other years, while GP captured in 2012 were in poorer condition than GP of the same length in other years.

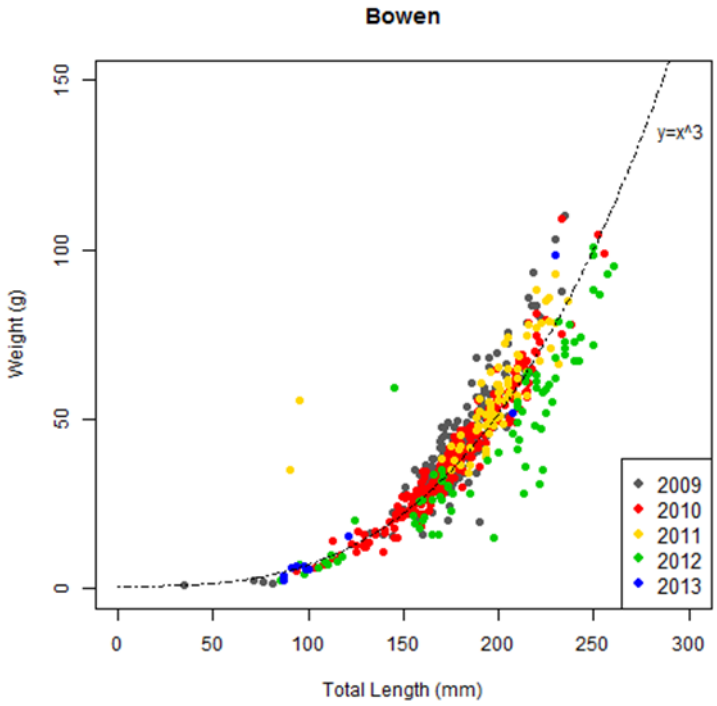

Figure 53. Body condition of Grass Pickerel captured at Bowen.

College

Approximately 2% of all GP captured were caught at College. The relative abundance of GP was generally low (Figure 54). It varied greatly within 2009 and 2010, sometimes GP was not detected and other times it made up almost 40% of the fish community. Relative abundance was generally more stable, around 0-10%, in 2011–2015.

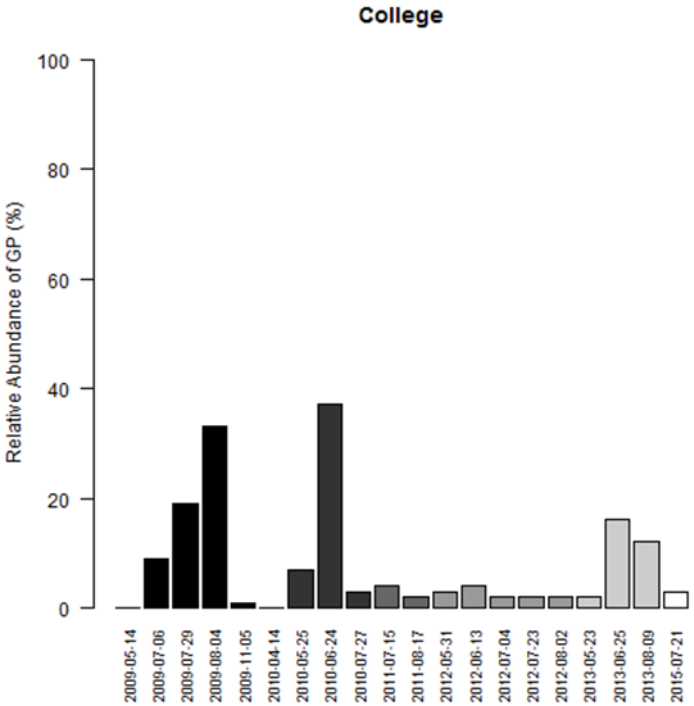

Figure 54. Relative abundance of Grass Pickerel at College per sampling event.

The CPUE of GP was generally low at College (always < 6 per haul), particularly after 2010 (Figure 55). GP were much more abundant in 2009 at College. GP were tagged in less than half of the sampling events when they were captured. When tagging occurred, all or the majority of GP captured were tagged. Tagging did not occur after July of 2012. Only one individual was recaptured with a tag at College; this was in 2010.

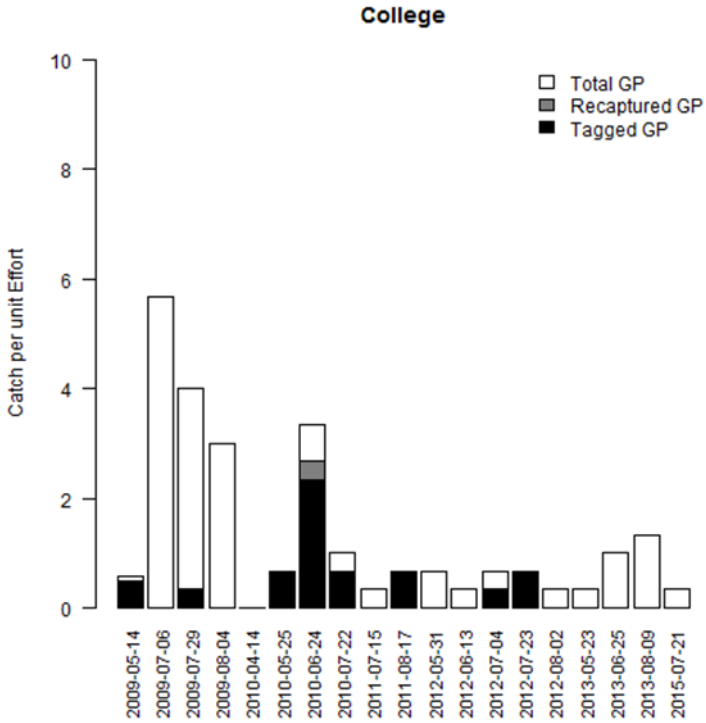

Figure 55. Number of Grass Pickerel captured per haul at College per sampling event.

The mean TL of GP at College was 157 mm. There was a significant difference in TL between years ($\chi 2 = 16.505$, df = 5, p = 0.006). TL of GP generally increased at College in 2009 and 2010, and then varied greatly within and between years after this time (Figure 56).

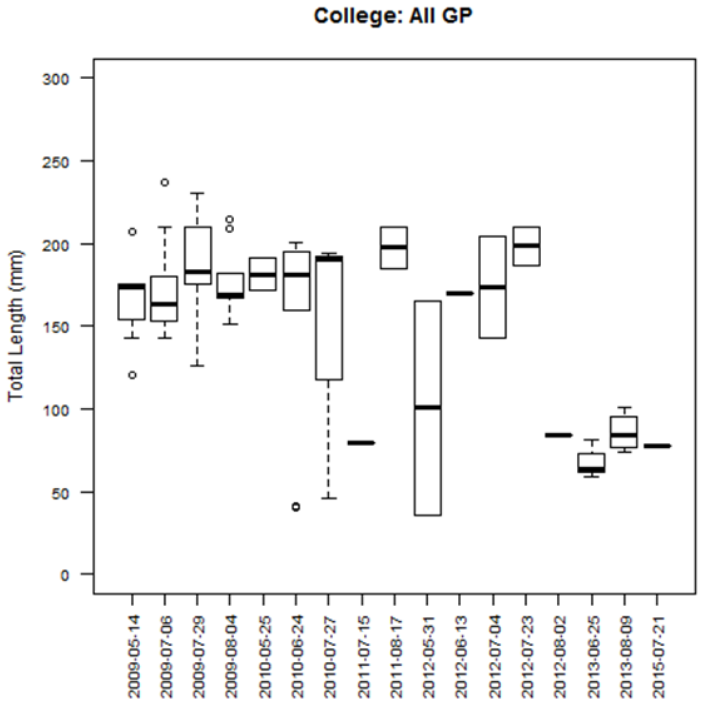

Figure 56. Total lengths of Grass Pickerel captured at College per sampling event.

YOY were not detected at College in 2009 or early 2010. The length frequency distribution of GP at College is bimodal, with a small peak occurring at approximately 75 mm and a larger peak at 175 mm (Figure 57).

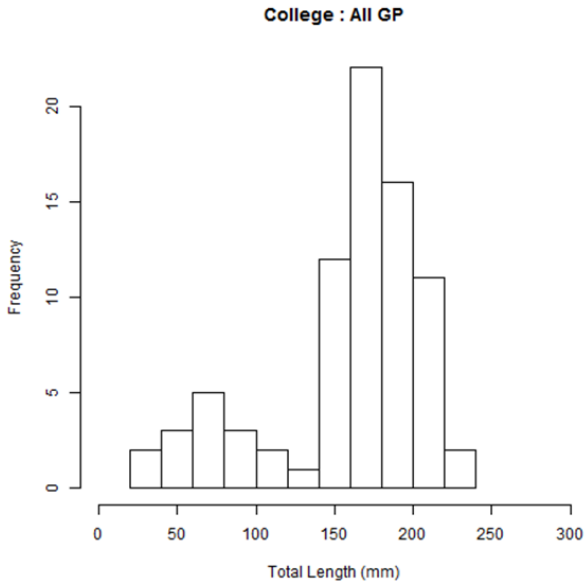

Figure 57. Length frequency distribution of Grass Pickerel captured at College.

GP captured at College showed a similar length: weight relationship in all years, except in 2009, when GP appeared to weigh less than GP of the same length in other years (Figure 58).

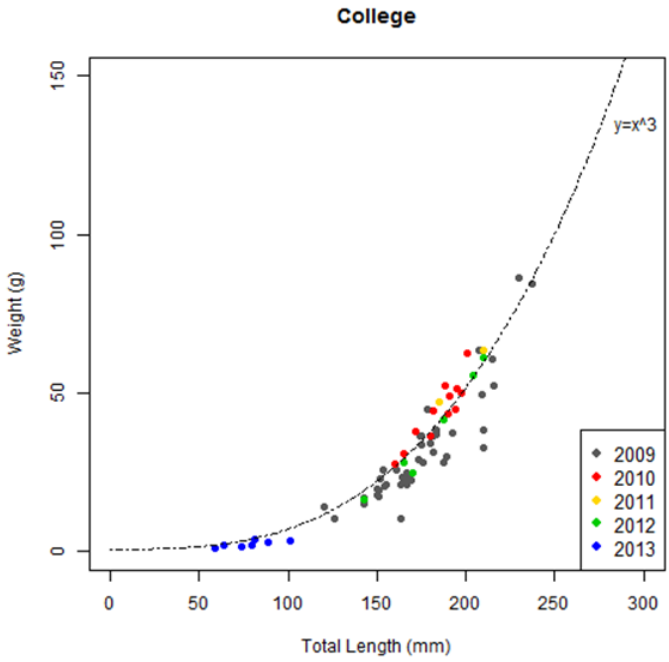

Figure 58. Body condition of Grass Pickerel captured at College.

Eagle

Approximately 6% of all GP captured were caught at Eagle. The relative abundance of GP varied greatly within and between years (Figure 59). It was generally low (i.e., < 20% of the fish community), but made up a greater proportion on one or two sampling events each year.

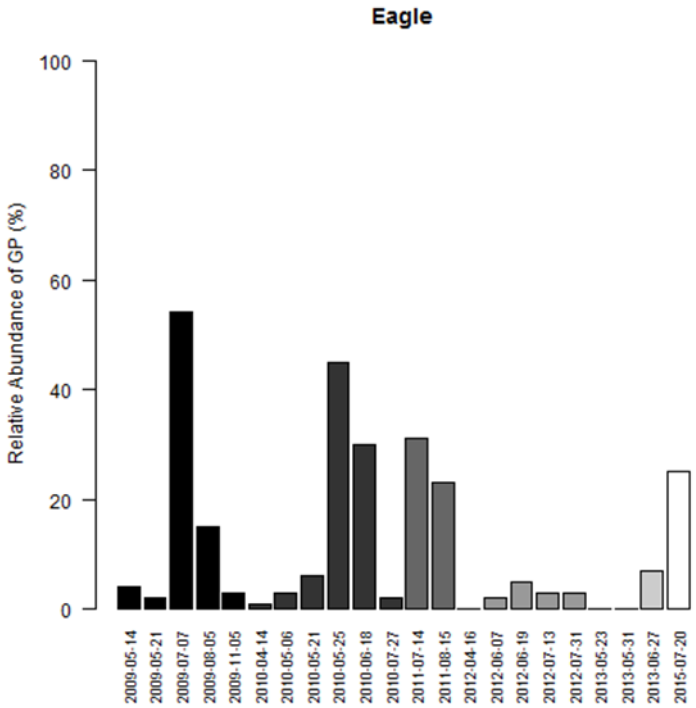

Figure 59. Relative abundance of Grass Pickerel at Eagle per sampling event.

There was a significant difference in the number of GP captured between years (χ^2 = 13.071, df = 5, p = 0.023). The CPUE of GP was generally low at Eagle (always < 9 per haul) but catches were variable within and between all years except 2012 when they were always low (Figure 60). GP were most abundant in 2009 and far less abundant in 2012 and 2013. Tagging occurred during all sampling events when GP were captured except for five, three of which were at the end of 2009. When tagging occurred, usually the majority of GP captured were tagged. Tagged GP were recaptured on seven sampling events from 2009–2012, usually only one to three individuals at a time.

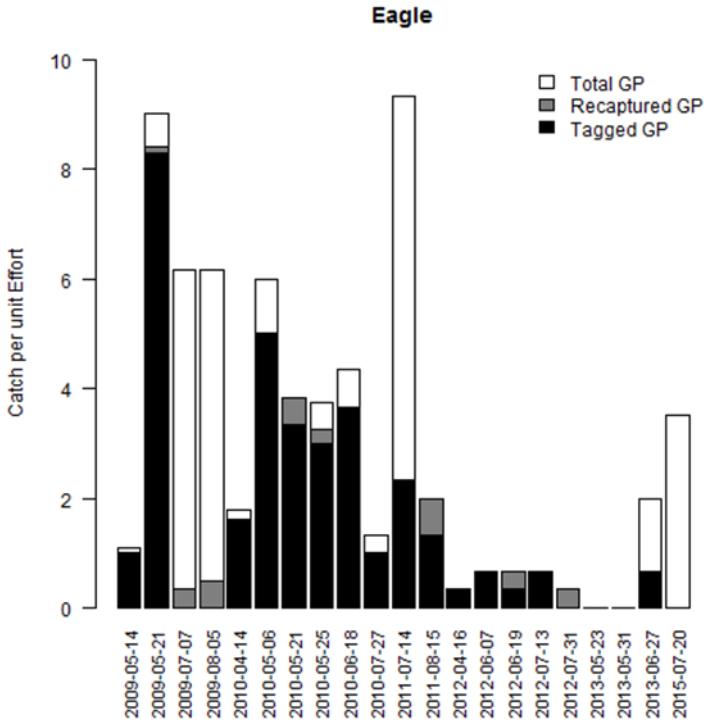

Figure 60. Number of Grass Pickerel captured per haul at Eagle per sampling event.

The mean TL of GP at Eagle was 167 mm. There was a significant difference in TL between years ($\chi^2 = 48.722$, df = 5, $p < 0.0001$). TL of GP generally increased at Eagle from 2009–2015, except for one sampling event in 2011 and one in 2013 when more small GP were detected (Figure 61). TL increased through the 2009 sampling season but was variable within all other years.

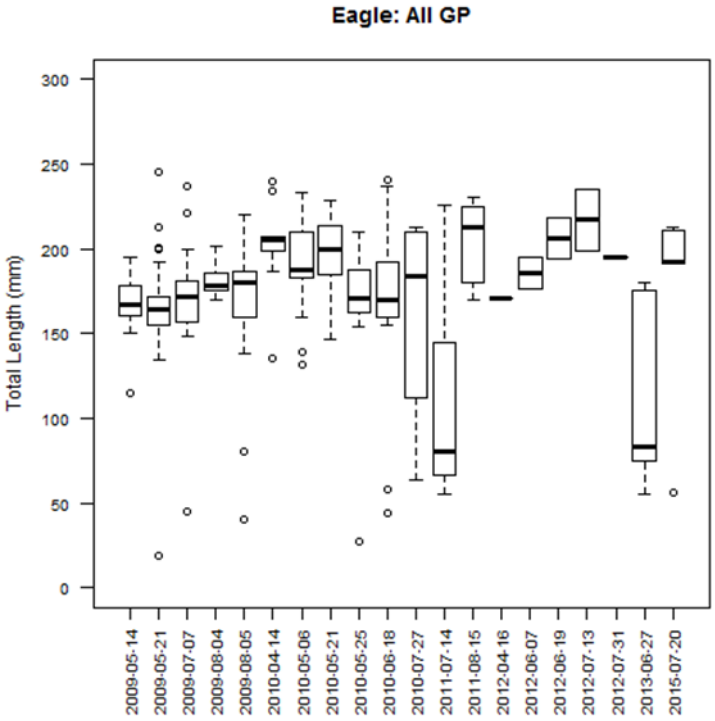

Figure 61. Total lengths of Grass Pickerel captured at Eagle per sampling event.

A wide range of size classes were consistently detected at Eagle (19–245 mm), except in 2012 when only larger individuals were detected. The length frequency distribution was bimodal at Eagle, with a small peak occurring at approximately 75 mm and a large peak at 175 mm (Figure 62).

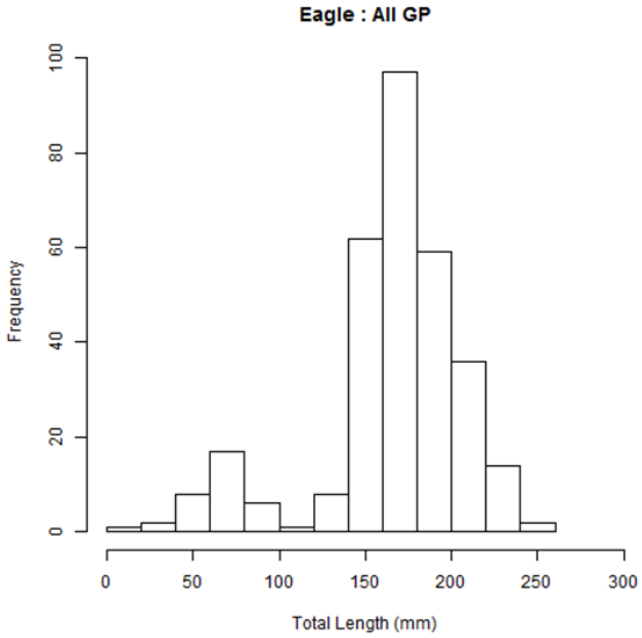

Figure 62. Length frequency distribution of Grass Pickerel captured at Eagle.

The length: weight relationship of GP captured at Eagle was consistent across all years and GP were of approximately average size (Figure 63). GP captured in 2009 showed the greatest variation in body size.

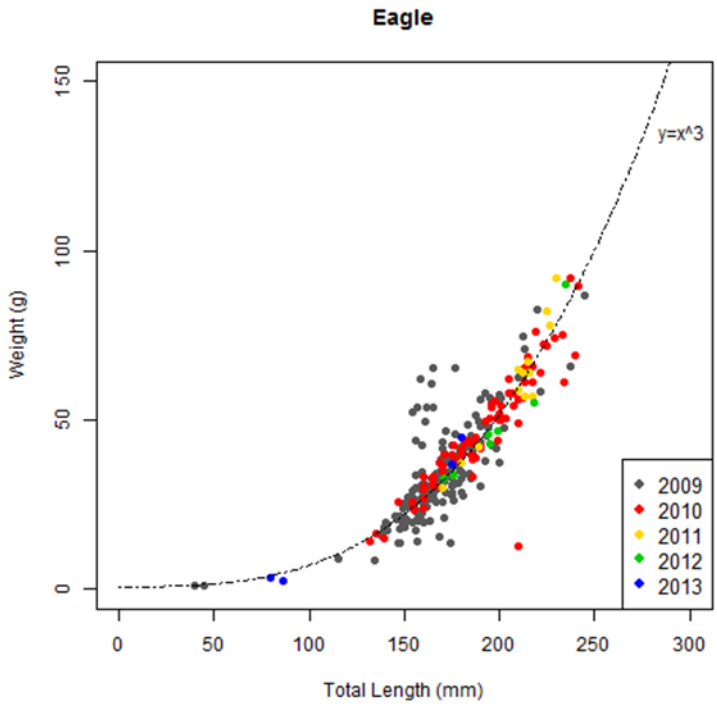

Figure 63. Body condition of Grass Pickerel captured at Eagle.

Garrison East

Approximately 20% of all GP captured in Beaver Creek were caught at Garrison East. The relative abundance of GP was generally high at this site, particularly early on in the study (Figure 64). GP made up at least 65% of the fish community in 2009 and 2010. The proportion of GP in the community declined after this, but it was still detected during every sampling event. Relative abundance declined throughout 2010 and 2011 and was variable within all other years.

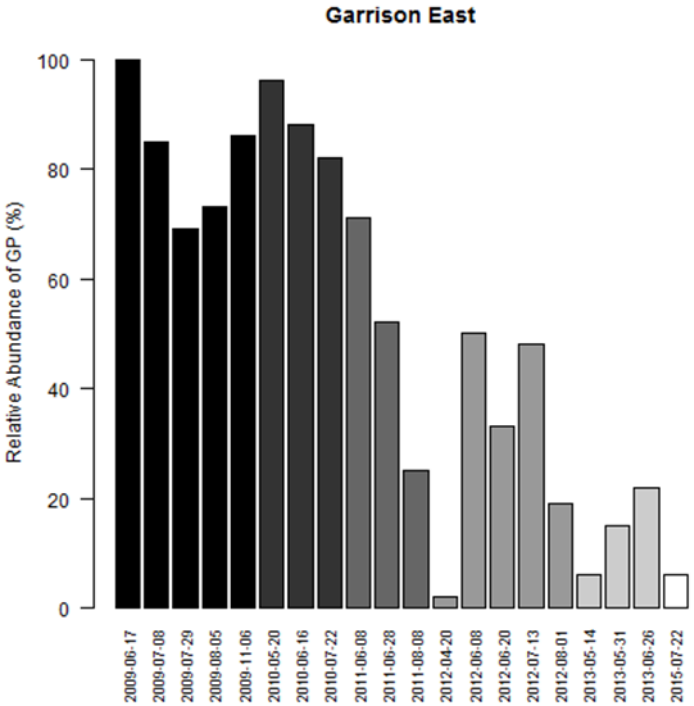

Figure 64. Relative abundance of Grass Pickerel at Garrison East per sampling event.

There was a significant difference in the number of GP captured between years (χ^2 = 14.161, df = 5, p = 0.015). The CPUE of GP was relatively high early in the study and generally declined from 2009–2015 (Figure 65). The number of GP increased throughout 2010 and decreased throughout 2011 and was variable in 2009 and 2012. Tagging occurred on the first and last sampling event in 2009; almost half of the GP captured were tagged on the first sampling event, and only one was tagged at the end. The majority of GP captured were tagged in both 2010 and 2011, and a few were tagged during all sampling events in 2012 and 2013. A few tagged GP (i.e., approximately 1–6) were recaptured during most sampling events 2009–2011, but none were recaptured after this.

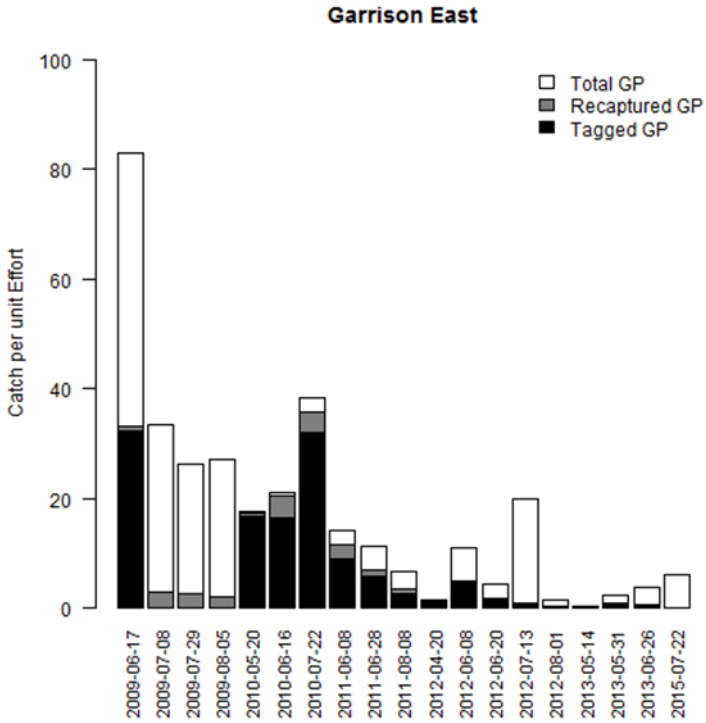

Figure 65. Number of Grass Pickerel captured at Garrison East per sampling event.

The mean TL of GP at Garrison East was 168 mm. There was a significant difference in TL between years ($\chi^2 = 105.01$, df = 5, $p < 0.0001$). Mean TLs were lowest in 2012 and 2013, and highest in 2010 and 2011. TL of GP generally increased from 2009–2011 but was highly variable within and between years after this time (Figure 66). A wide range of size classes (21–276 mm) was consistently detected at Garrison East.

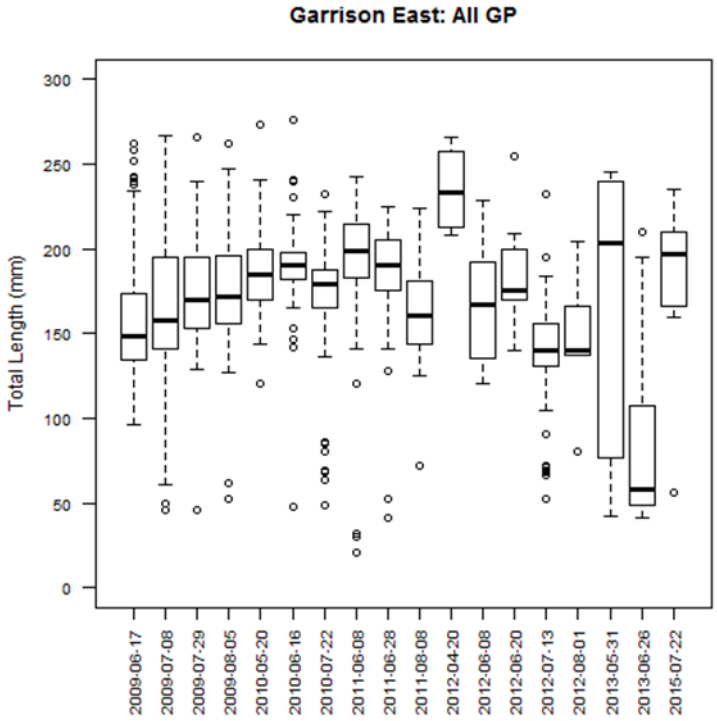

Figure 66. Total lengths of Grass Pickerel captured at Garrison East per sampling event.

The length frequency distribution of Garrison East is not normally distributed (Figure 67).

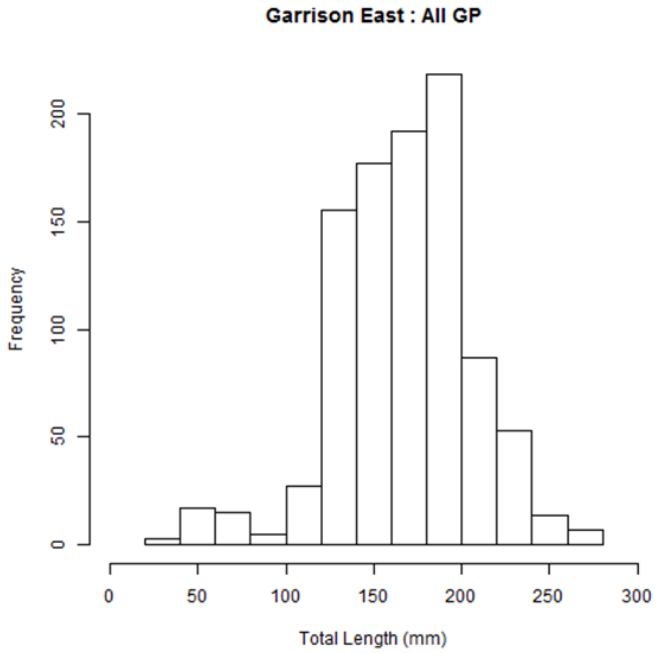

Figure 67. Length frequency distribution of Grass Pickerel captured at Garrison East.

The length: weight relationship of GP captured at Garrison East showed substantial variation within years (Figure 68). GP captured in 2009 showed the greatest variation in body condition. GP captured in 2010 appeared to be in slightly better condition than GP of the same length in other years, and GP in 2012 were in slightly poorer condition.

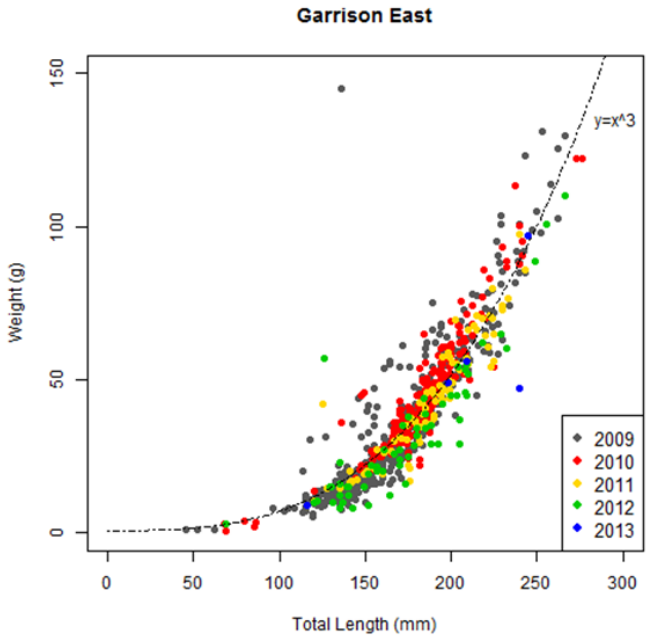

Figure 68. Body condition of Grass Pickerel captured at Garrison East.

Garrison West

Approximately 3% of all GP captured were caught at Garrison West. Relative abundance of GP was generally low at this site except early in 2009 (Figure 69). GP made up less than 20% of the fish community at most sampling events. During one sampling event in 2009, it made up nearly 70% of the fish community.

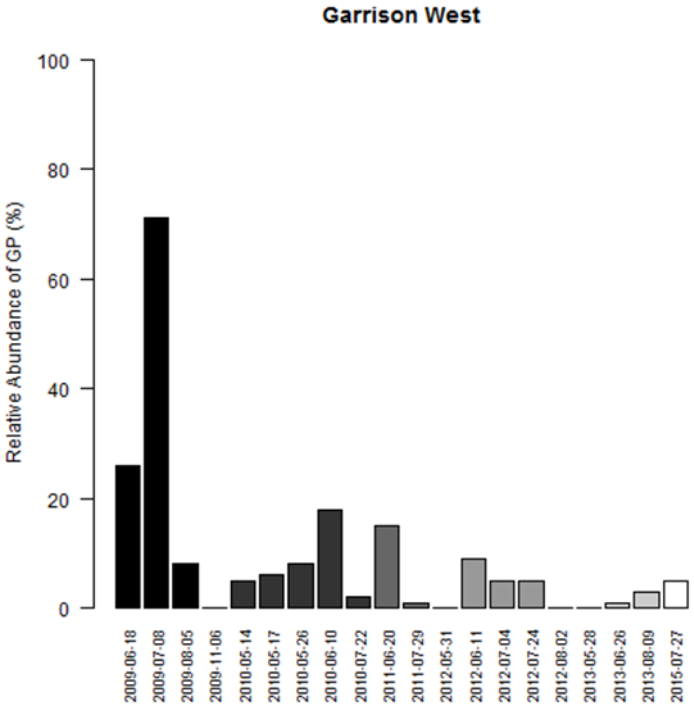

Figure 69. Relative abundance of Grass Pickerel at Garrison West per sampling event.

The CPUE of GP at Garrison West was consistently low (i.e., < 5 per haul) across all years, except for one sampling event in 2009 when approximately 13 GP were captured per haul (Figure 70). Catches of GP were highest in 2009 and lowest in 2013 and 2012. Tagging occurred during the first sampling event in 2009, 2011, and 2013, and three sampling events in 2010. The majority of or all of the GP captured were tagged during these events, except in early 2010 when less than half of the GP captured were tagged. GP were only recaptured with a tag in 2009 and 2010, and only one or two individuals each time.

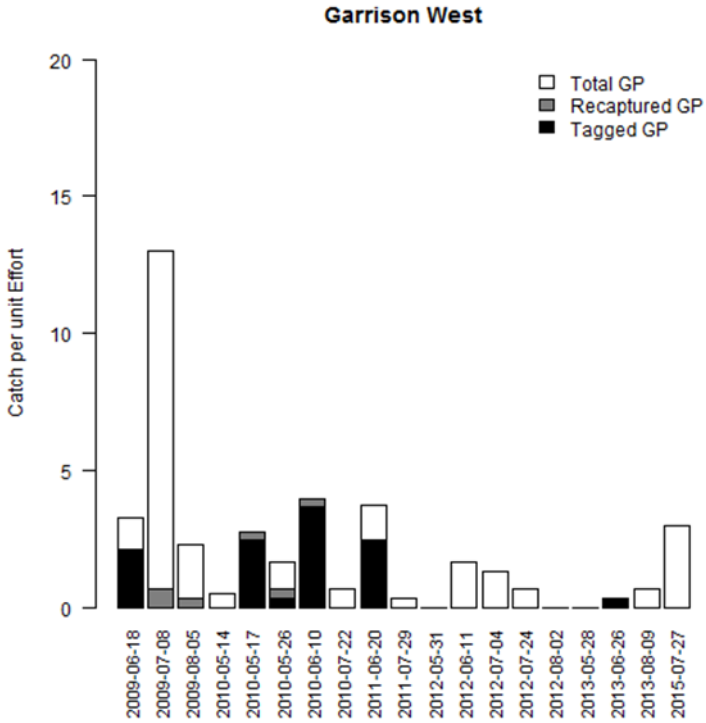

Figure 70. Number of Grass Pickerel captured per haul at Garrison West per sampling event.

The mean TL of GP at Garrison West was 159 mm. There was a significant difference in TL between years (χ^2 = 23.955, df = 5, p = 0.0002). Only larger individuals were detected at Garrison West 2012–2015. TLs of GP were highly variable within and between all years except in 2009 when TL increased through the season (Figure 71).

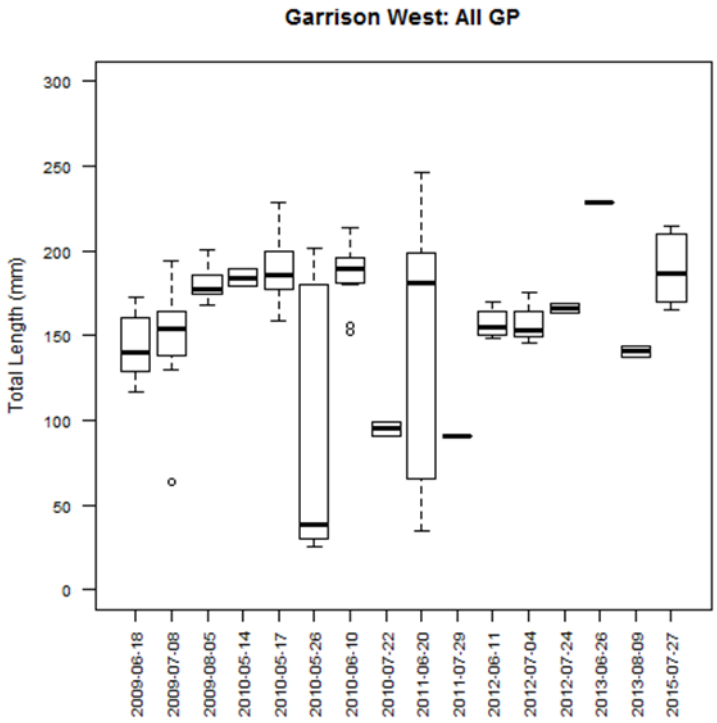

Figure 71. Total lengths of Grass Pickerel captured at Garrison West per sampling event.

The length frequency distribution at Garrison West is slightly negatively skewed (Figure 72).

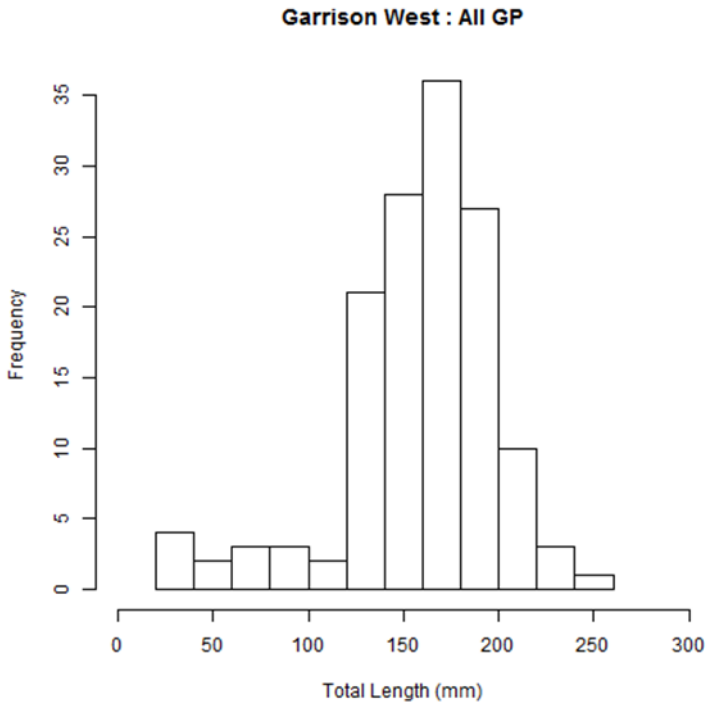

Figure 72. Length frequency distribution of Grass Pickerel captured at Garrison West.

GP captured at Garrison West generally fell below the cubic regression line in all years except 2010, suggesting GP at this site were of poorer condition than GP elsewhere in the creek (Figure 73).

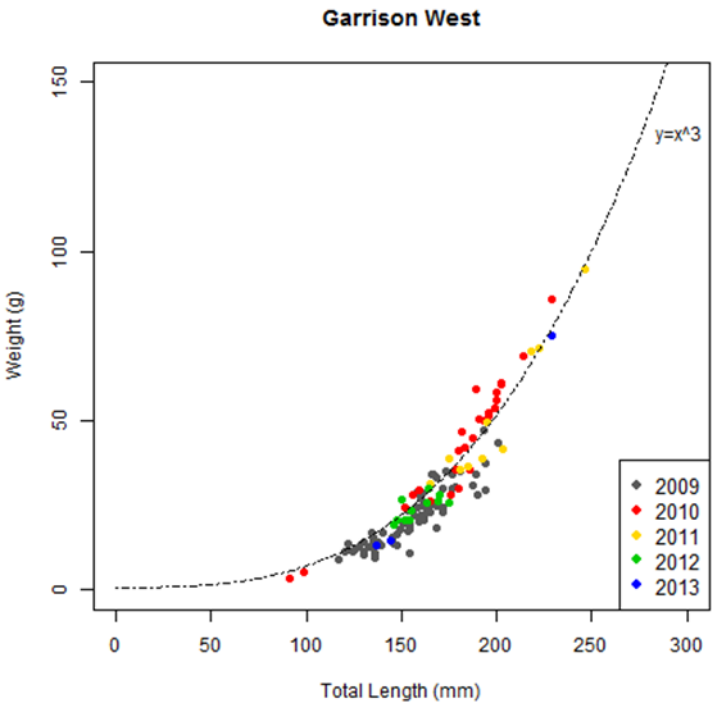

Figure 73. Body condition of Grass Pickerel captured at Garrison West.

Reconstructed Reach

The relative abundance of GP in Pool 4 was slightly higher in 2012 than 2013 and 2015, but was always less than 20% (Figure 74).

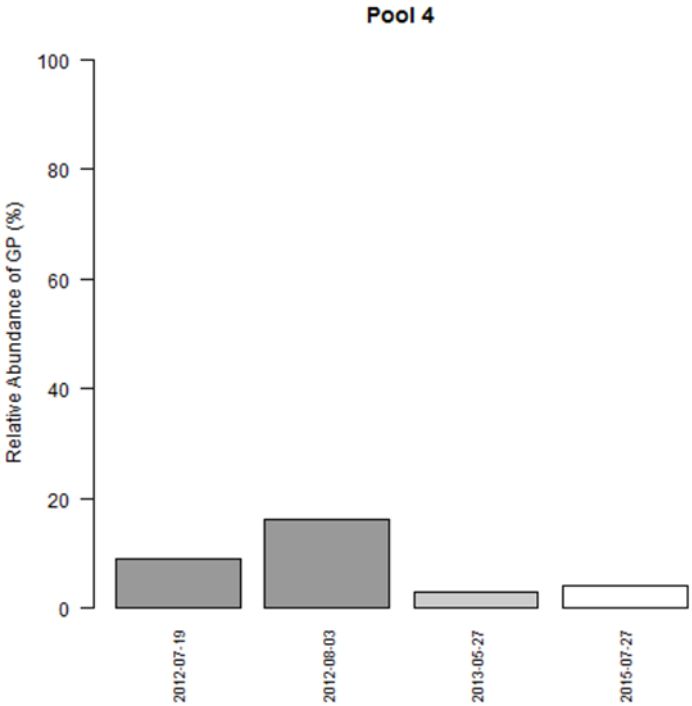

Figure 74. Relative abundance of Grass Pickerel at Pool 4 per sampling event.

One to four GP were captured per haul in Pool 4 in all years, one individual tagged in the second 2012 event, and both individuals captured in 2013 were tagged; no GP were recaptured with a tag (Figure 75).

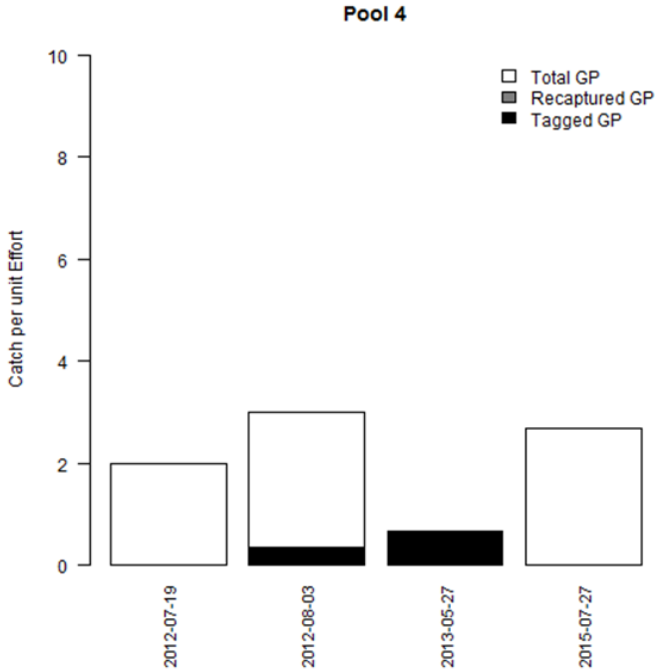

Figure 75. Number of Grass Pickerel captured per haul at Pool 4 per sampling event.

The mean TL of GP in Pool 4 was 187 mm; there was a significant difference between years (χ^2 = 9.9217, df = 2, p = 0.007) (Figure 76). GP captured tended to increase in length between 2012–2015.

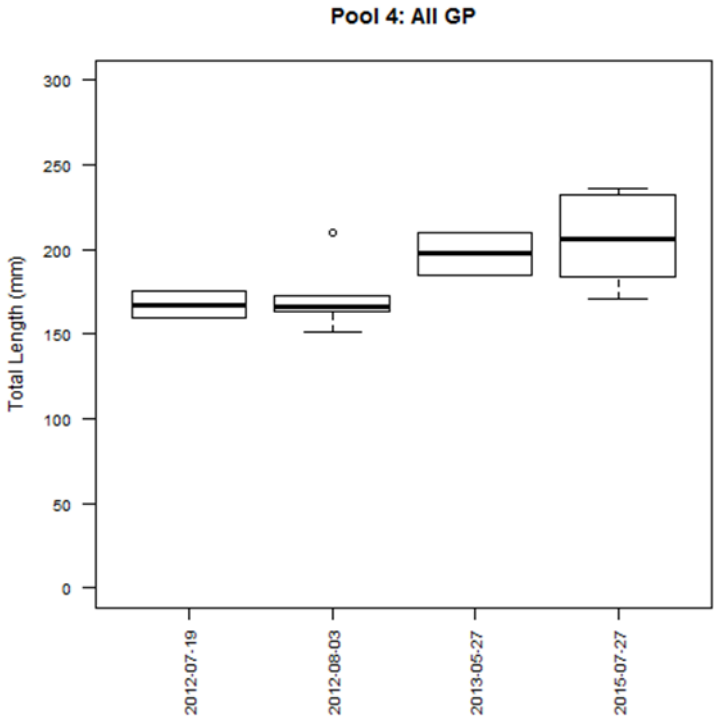

Figure 76. Total lengths of Grass Pickerel captured at Pool 4 per sampling event.

GP made up less than 5% of fishes captured in Offline Pool 1. Approximately two GP were captured per haul at Offline Pool 1, none were tagged or recaptured with a tag. The mean TL of GP was 155 mm.

GP made up around 5% of the fish community during most sampling events in Pool 3 (Figure 77).

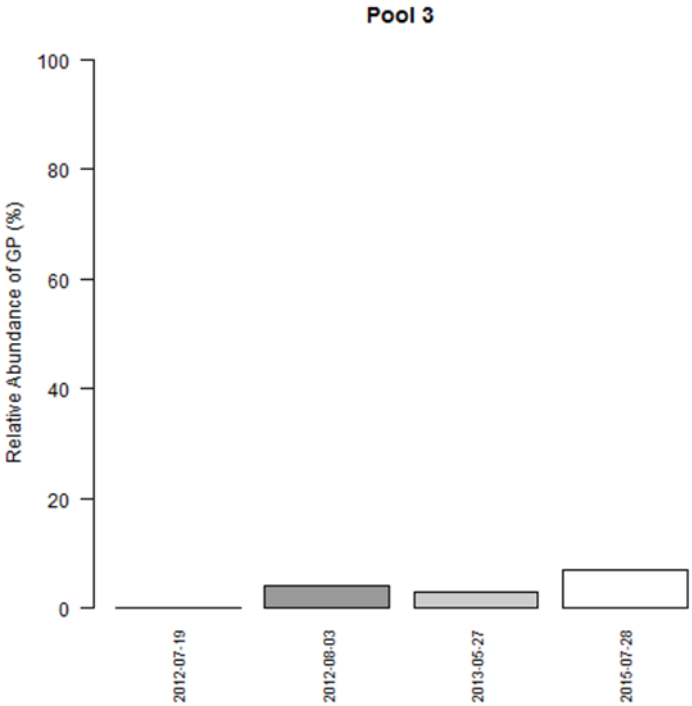

Figure 77. Relative abundance of Grass Pickerel at Pool 3 per sampling event.

One GP was captured per haul on both events in 2012, none in 2013 and approximately 4 per haul in 2015. One GP per haul was tagged during the second sampling event in 2012; no tagged GP were recaptured (Figure 78).

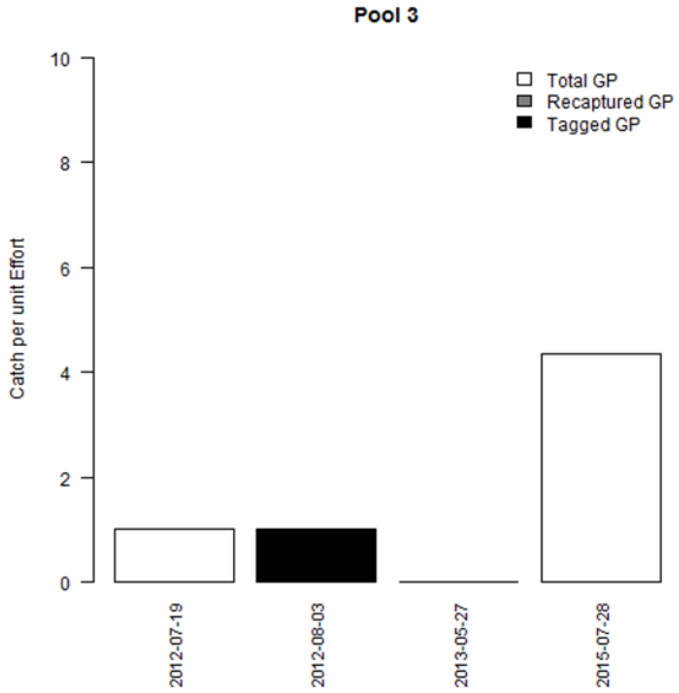

Figure 78. Number of Grass Pickerel captured per haul at Pool 3 per sampling event.

The mean TL of GP in Pool 3 was 203 mm, and lengths did not differ greatly as only larger individuals were captured (Figure 79).

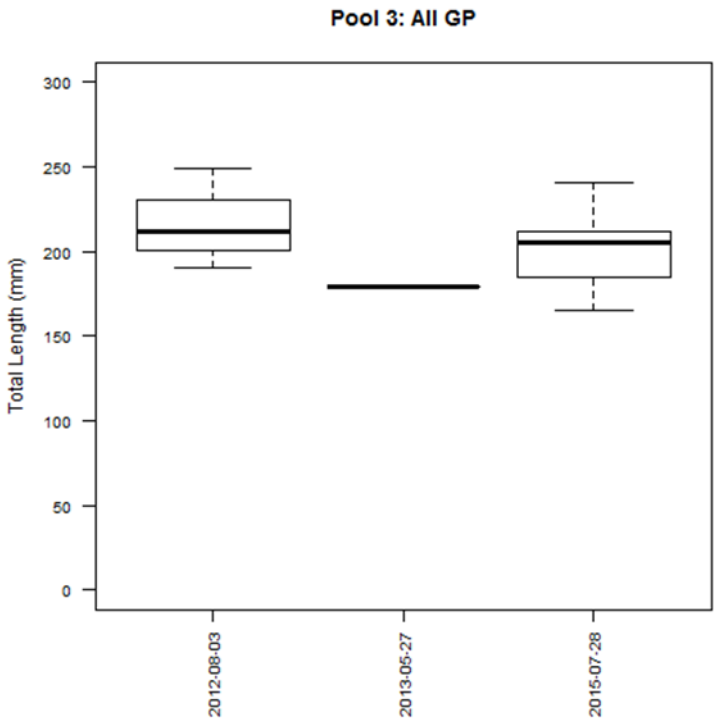

Figure 79. Total lengths of Grass Pickerel captured at Pool 3 per sampling event.

Relative abundance of GP in Pool 2 was relatively consistent (approximately 10%) across all sampling events, though it was slightly lower in 2013 (Figure 80).

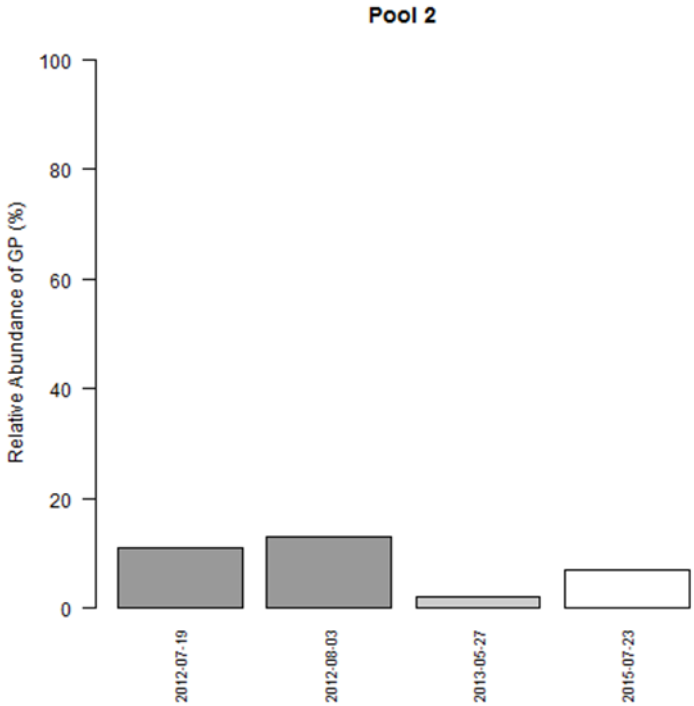

Figure 80. Relative abundance of Grass Pickerel at Pool 2 per sampling event.

The CPUE of GP declined from 2012–2013, but increased in 2015. One GP was tagged at the end of 2012, and two in 2013; none were recaptured with tags in Pool 2 (Figure 81).

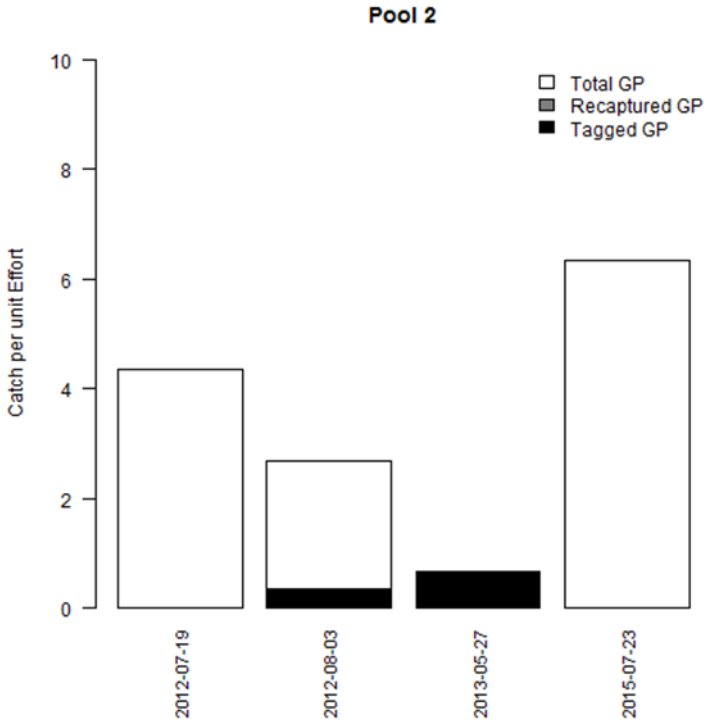

Figure 81. Number of Grass Pickerel captured per haul at Pool 2 per sampling event.

The mean TL of GP captured at Pool 2 was 155 mm; there was a significant difference between years (χ^2 = 7.3461, df = 2, p = 0.025) (Figure 82).

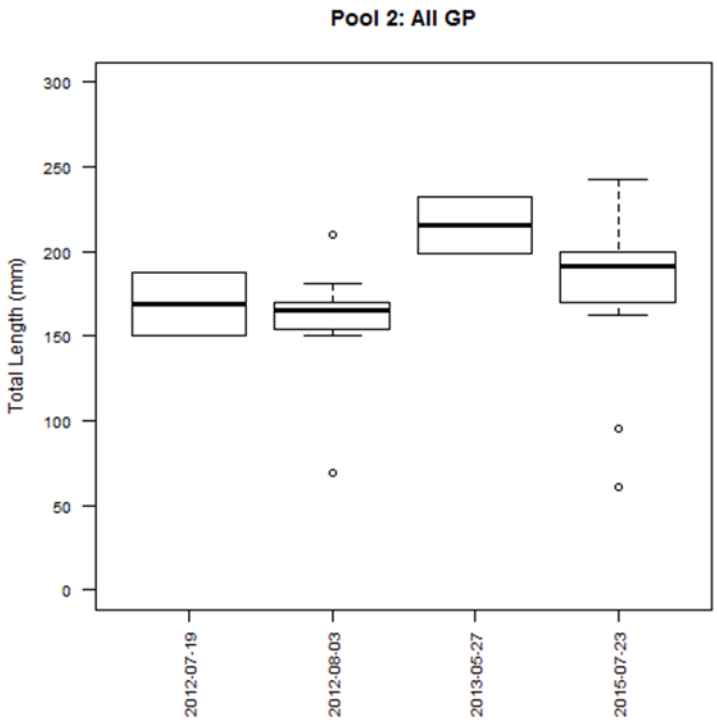

Figure 82. Total lengths of Grass Pickerel captured at Pool 2 per sampling event.

GP made up 29% of the fish community in the pool upstream of House. Approximately three GP were captured per haul, and almost half of these were tagged. The mean TL of GP was 163 mm at this site.

GP made up less than 5% of fishes captured at Bertie ROW. Approximately three GP were captured per haul; half of these were tagged and no tagged GP were recaptured. The mean TL of GP captured at Bertie ROW was 182 mm.

No GP were captured in Pool 5 or Offline Pool 2.

Most individuals captured in the reconstructed reach were from larger size classes (Figure 83).

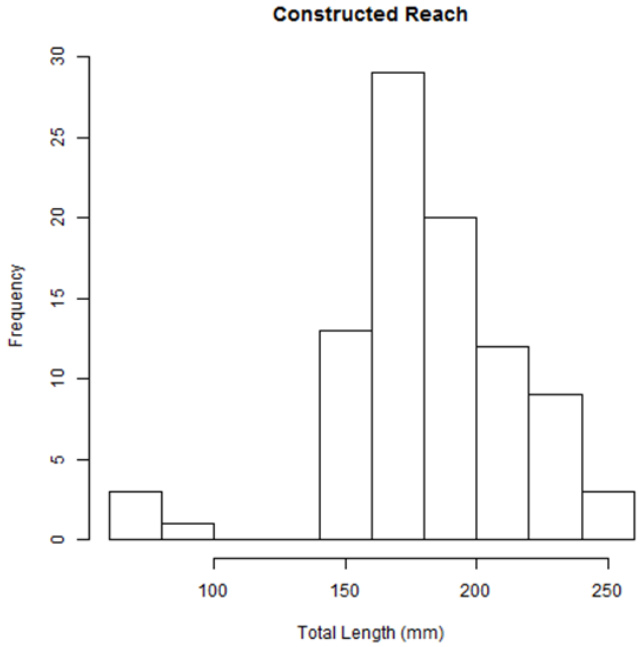

Figure 83. Length frequency distribution of Grass Pickerel captured in the reconstructed reach.

GP captured in the reconstructed reach appeared to be of equal body condition compared to the average in the creek in 2012 and 2013 (Figure 84).

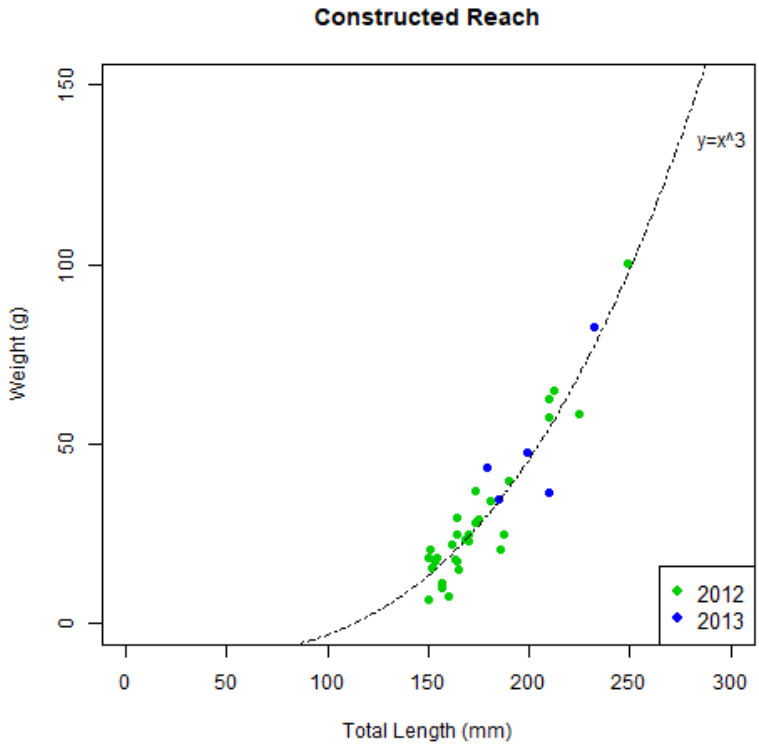

Figure 84. Body condition of Grass Pickerel captured in the reconstructed reach.

Gorham

Approximately 1% of all GP captured were caught at Gorham. The relative abundance of GP was consistently high (Figure 85), making up between 60–80% of the community both years that this site was sampled.

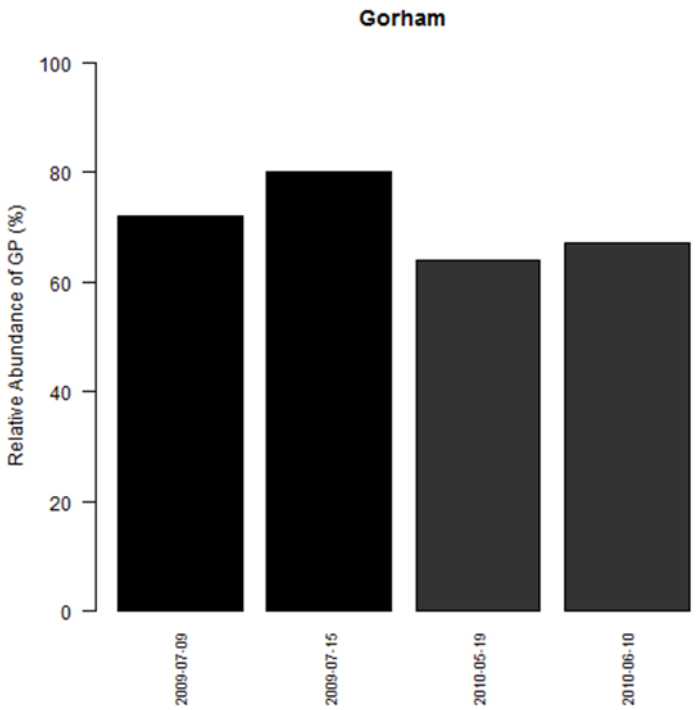

Figure 85. Relative abundance of Grass Pickerel at Gorham per sampling event.

The CPUE of GP was high during the first sampling event at Gorham (approximately 42 per haul), but declined to approximately 5 or fewer per haul after this (Figure 86). GP were only tagged in 2010, and only one individual was recaptured with a tag, this was at the end of 2010.

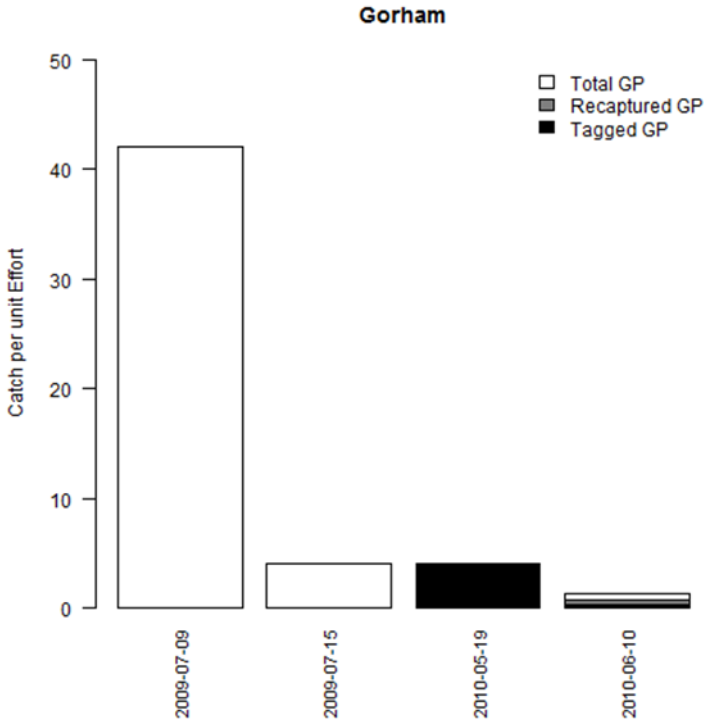

Figure 86. Number of Grass Pickerel captured per haul at Gorham per sampling event.

The mean TL of GP captured at Gorham was 159 mm. There was a significant difference in TL between years ($\chi^2 = 23.428$, df = 1, $p < 0.0001$). The longest GP captured in Beaver Creek was captured at Gorham (278 mm). TL was higher in 2010 than 2009. Mean TL increased through 2009 and early 2010, but smaller GP were detected later in 2010 (Figure 87).

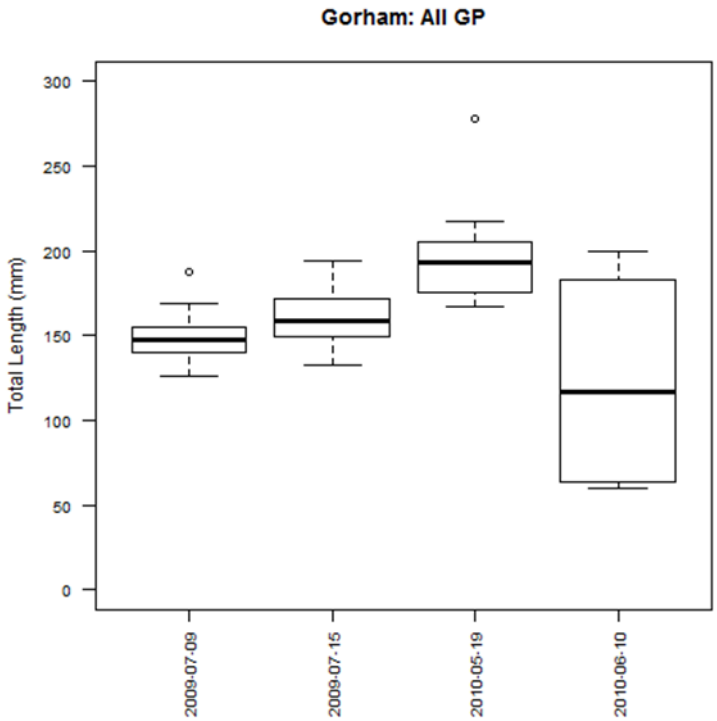

Figure 87. Total lengths of Grass Pickerel captured at Gorham per sampling event.

The length frequency differed significantly from a normal distribution at Gorham (w = 0.906, p < 0.0001) (Figure 88).

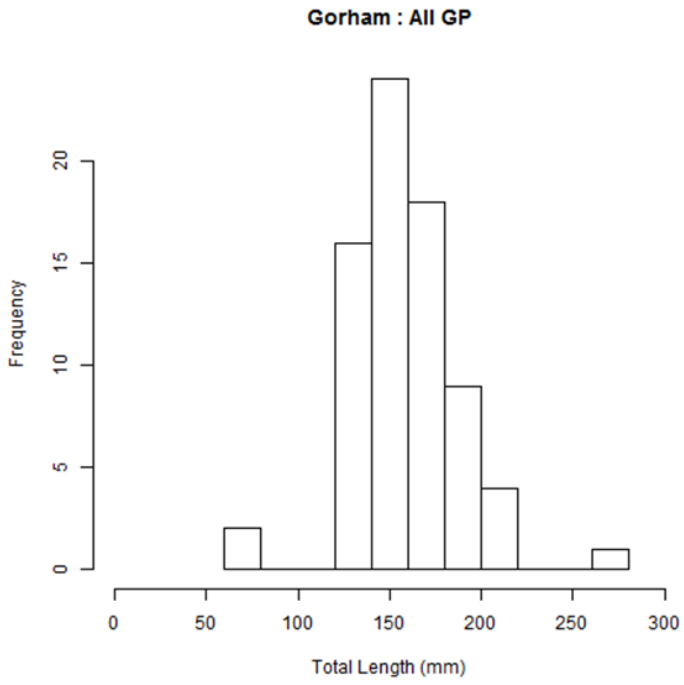

Figure 88. Length frequency distribution of Grass Pickerel captured at Gorham.

The length: weight relationship of GP at Gorham suggests variation in body condition within each year, particularly in 2010 (Figure 89). It is likely that many of the GP captured in 2009 were captured again in 2010 as the 2010 GP appear to represent the next size class.

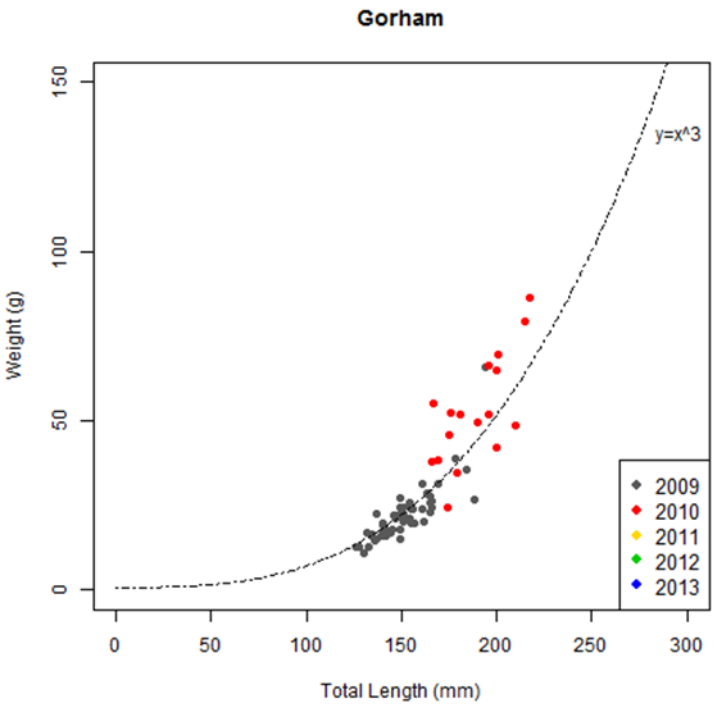

Figure 89. Body condition of Grass Pickerel captured at Gorham.

House

Approximately 6% of all GP captured in Beaver Creek were caught at House. The relative abundance of GP varied greatly within and between years at House (Figure 90). The relative abundance was most variable in 2009 and 2010, ranging between 5-70% of the community. Similarly, the variation in relative abundance was similar between 2011 and 2012; GP varying between 15% and 35% of the fish community. Relative abundance was consistently low in 2013 and 2015.

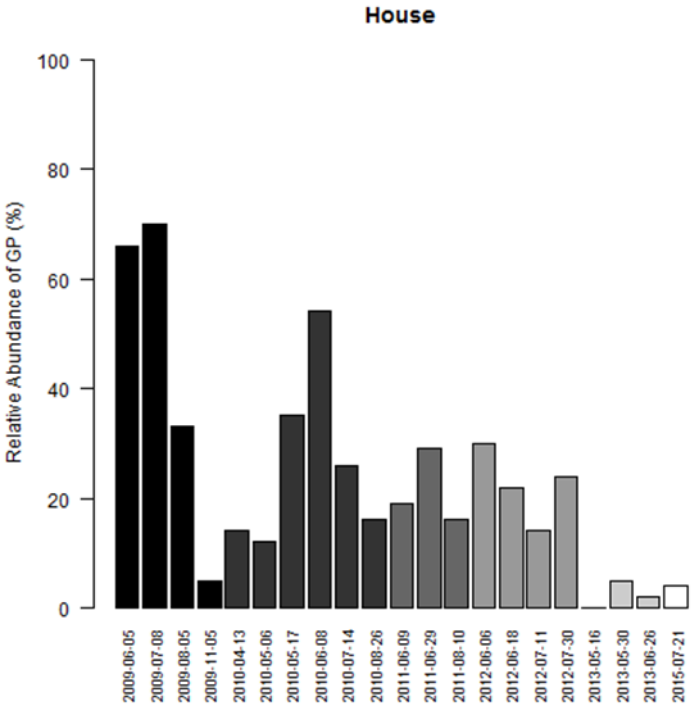

Figure 90. Relative abundance of Grass Pickerel at House per sampling event.

There was a significant difference in the number of GP captured between years (χ^2 = 14.416, df = 5, p = 0.013). Catches of GP were highest in 2009, though declined throughout the season, and remained relatively low (i.e., < 10 per haul) after 2009. Tagging of GP occurred on the first sampling event of 2009 and 2012, all but the last event in 2010, and all events in 2011. During tagging events, most or all GP captured at House were tagged. Tagged GP were recaptured during nine sampling events in 2009–2012; usually only one or two individuals were recaptured per sampling event, but approximately three were recaptured per haul in early 2009 (Figure 91).

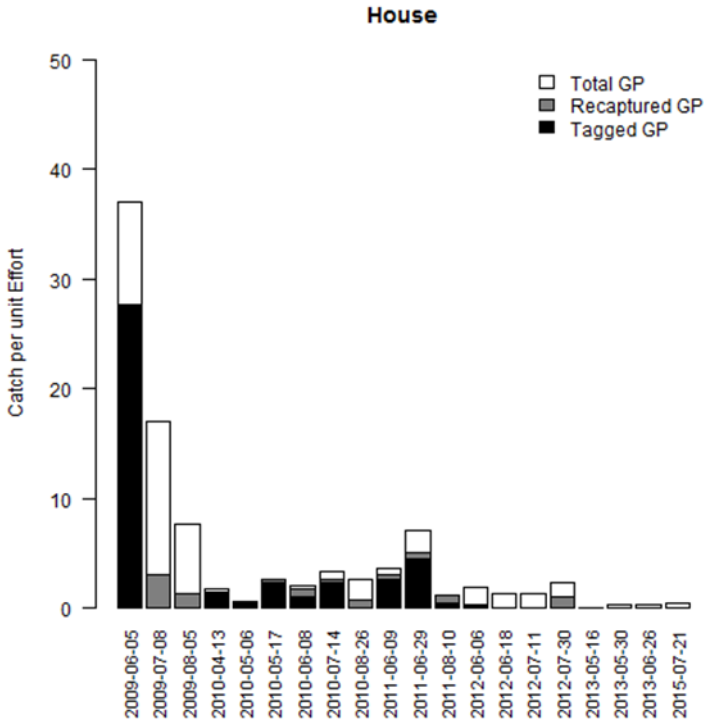

Figure 91. Number of Grass Pickerel captured per haul at House per sampling event.

The mean TL of GP at House was 162 mm. There was a significant difference in TL between years ($\chi^2 = 35.27$, df = 5, $p < 0.0001$). TL was highly variable within and between years at House and was lowest overall in 2013 (Figure 92). In 2009, TL generally increased through the season. Small size classes of GP were not detected at House in 2009 or early 2010.

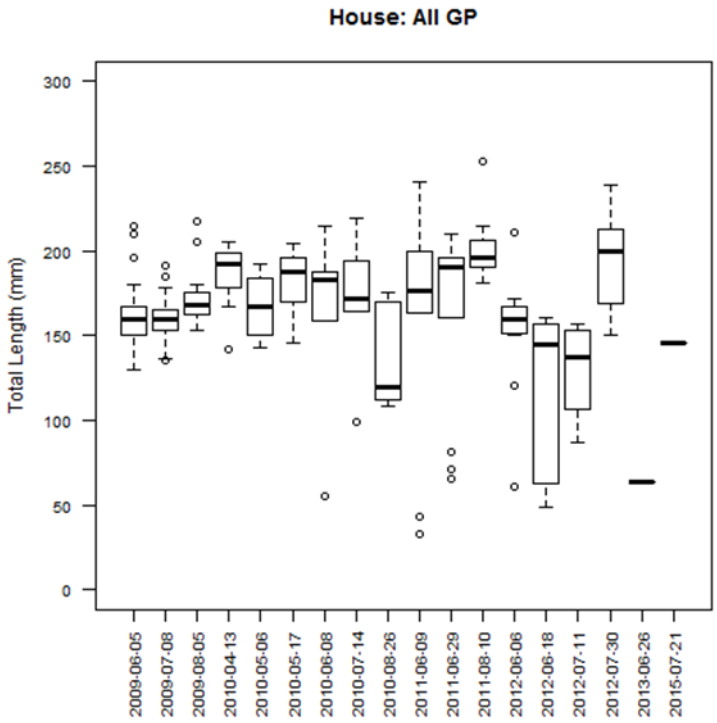

Figure 92. Total lengths of Grass Pickerel captured at House per sampling event.

The majority of GP captured at House were 140-180 mm TL and lengths were not normally distributed (Figure 93).

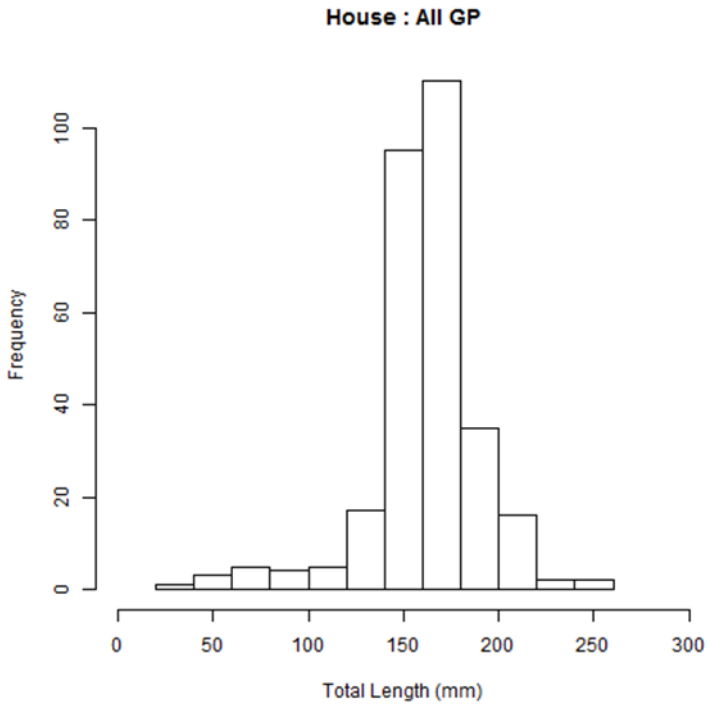

Figure 93. Length frequency distribution of Grass Pickerel captured at House per sampling event.

The length: weight relationship of GP at House was fairly consistent across all years (Figure 94). GP captured in 2012 generally appear in slightly worse condition than other years.

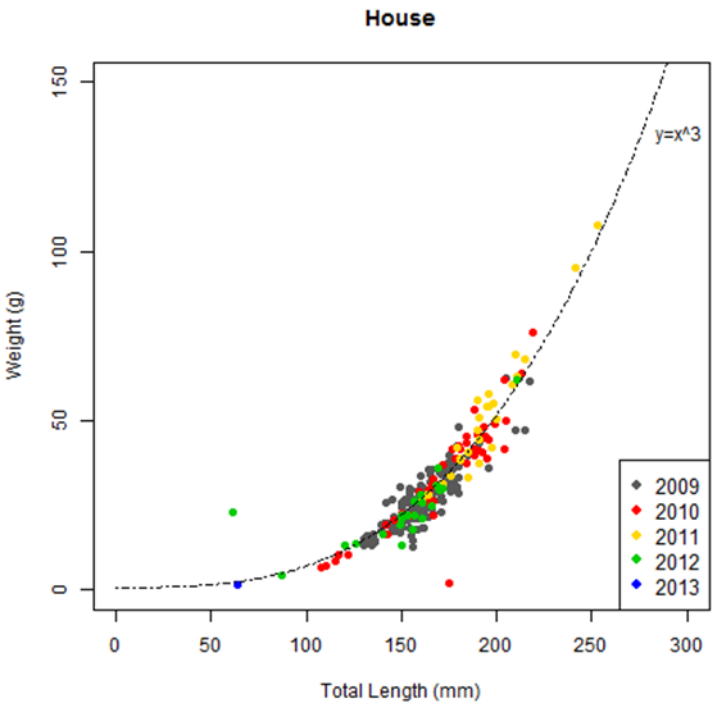

Figure 94. Body condition of Grass Pickerel captured at House.

Nigh

Approximately 1% of all GP captured were caught at Nigh. GP made up a large proportion of the fish community in 2009 (> 60%), but made up a smaller proportion in 2010 (Figure 95). The relative abundance of GP increased throughout the season of 2010.

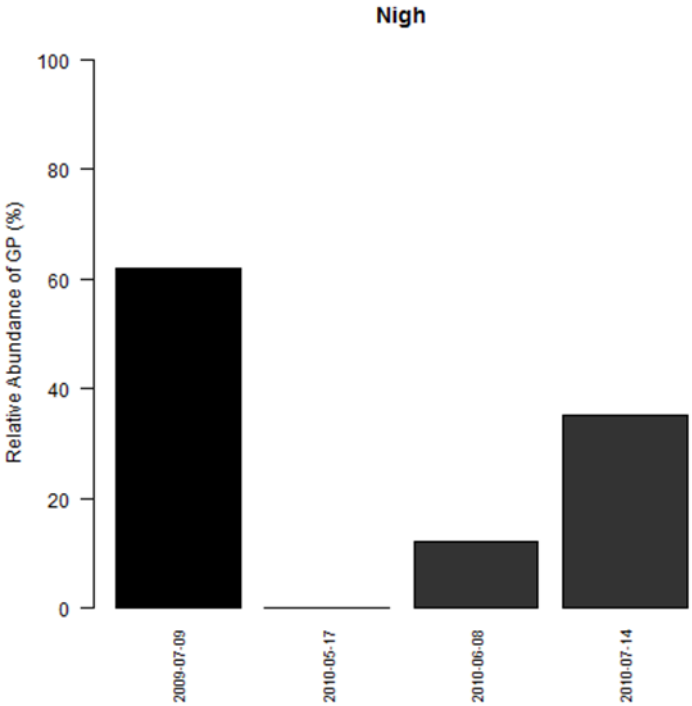

Figure 95. Relative abundance of Grass Pickerel at Nigh per sampling event.

The CPUE of GP varied within and between years at Nigh. It was higher in 2009 (approximately 13 per haul), while no GP were detected during the first sampling event in 2010 and approximately five were detected per haul in the last two sampling events (Figure 96). GP were only tagged during the last two events in 2010, and most GP captured were tagged. One individual was recaptured with a tag during the last sampling event of 2010 at Nigh.

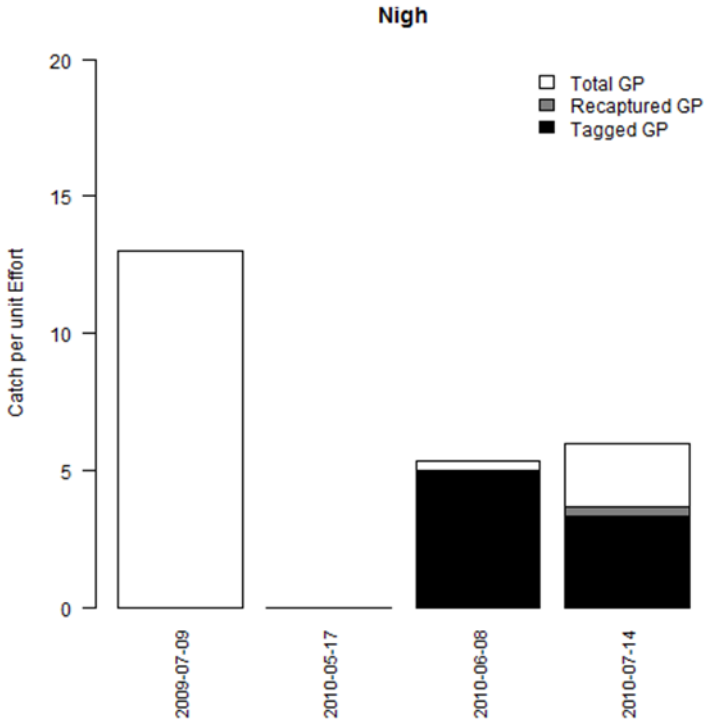

Figure 96. Number of Grass Pickerel captured per haul at Nigh per sampling event.

The mean TL of GP at Nigh was 168 mm. Mostly larger individuals were detected here, especially in 2009 (Figure 97).

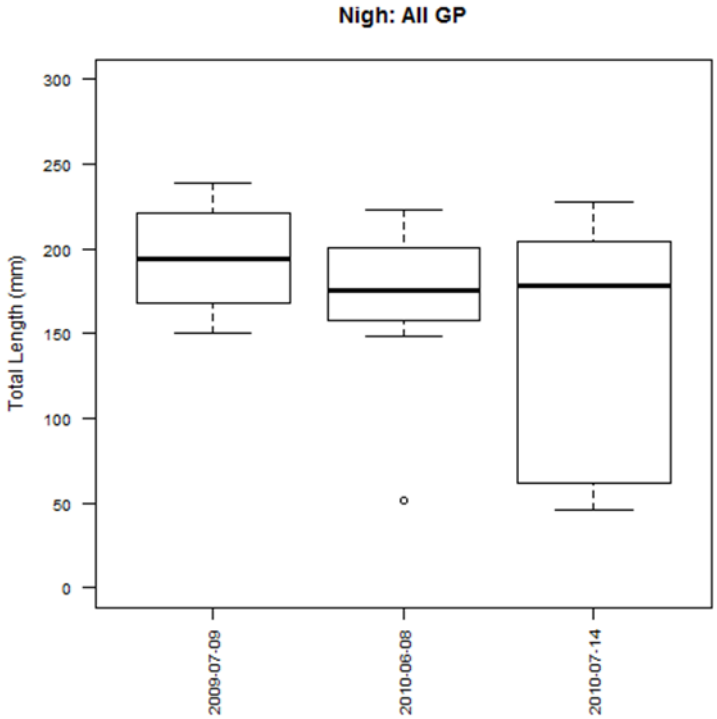

Figure 97. Total lengths of Grass Pickerel captured at Nigh per sampling event.

The length frequency distribution was bimodal, with one (smaller) peak occurring at 50 mm and the other at 190 mm (Figure 98).

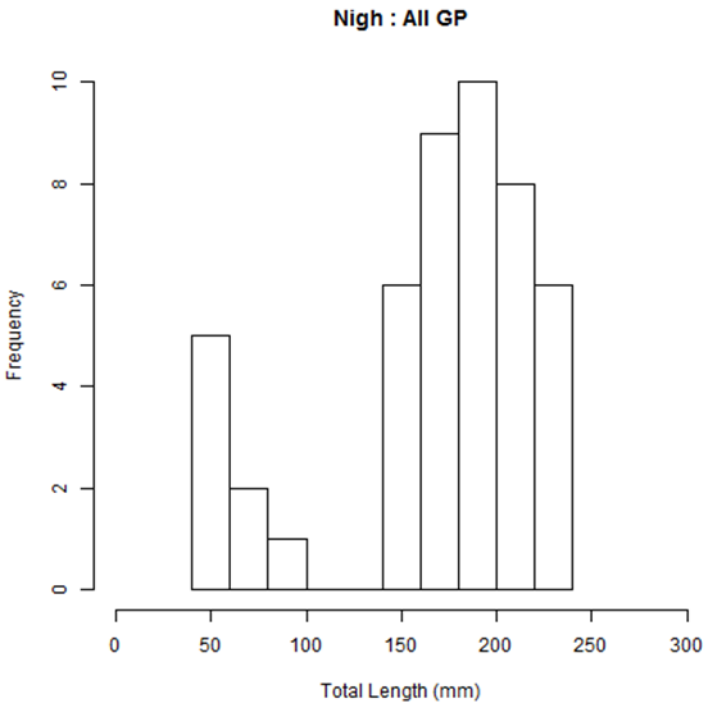

Figure 98. Length frequency distribution of Grass Pickerel captured at Nigh.

The length: weight relationship of GP captured at Nigh was variable within and between years (Figure 99). Generally, GP captured in 2009 appeared in slightly poorer condition, and GP captured in 2010 were in slightly better condition than the average.

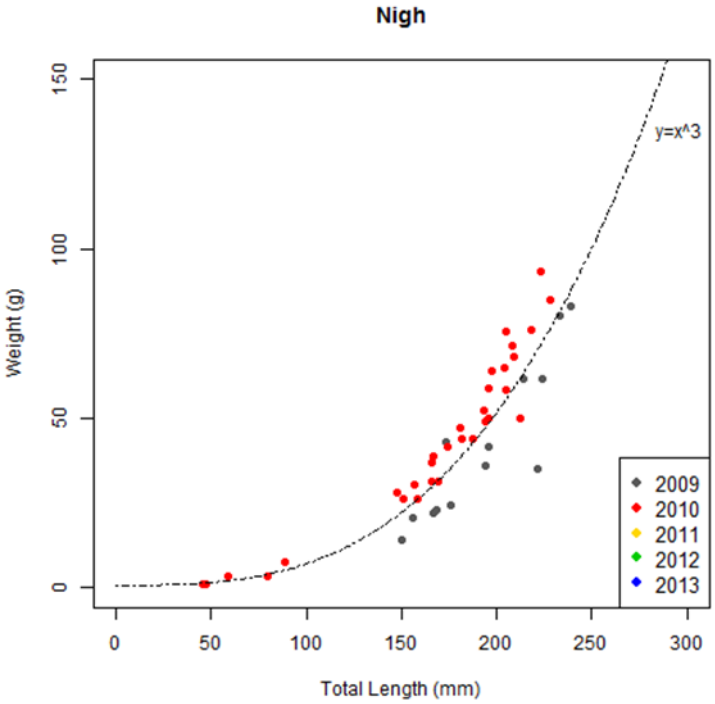

Figure 99. Body condition of Grass Pickerel captured at Nigh.

Stevensville

Approximately 15% of all GP captured were caught at Stevensville. The relative abundance of GP varied greatly within and between years (Figure 100). GP made up the majority of the fish community in 2009, though the relative abundance fluctuated throughout the year. The proportion of GP in the fish community was lower in 2011–2015 (i.e., always < 45%), and it was not detected in 2015 at this site. The relative abundance increased throughout 2012 and 2013.

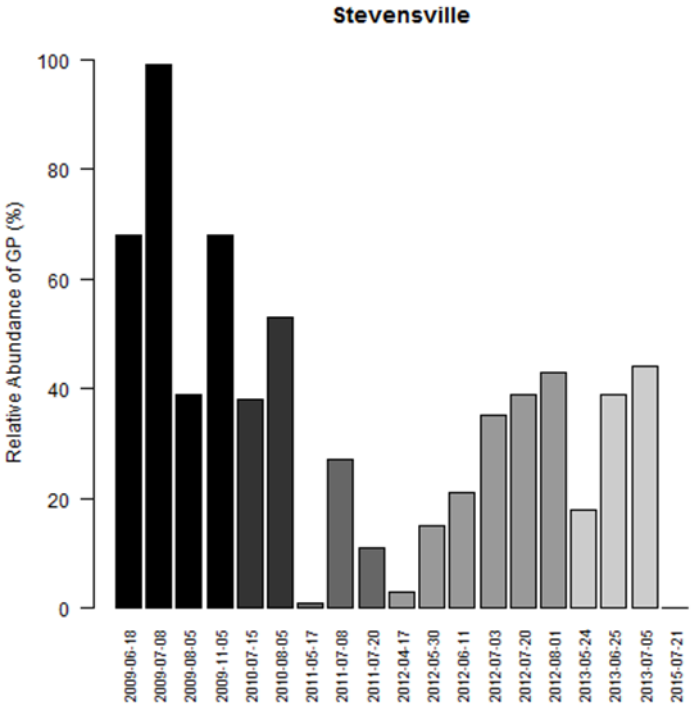

Figure 100. Relative abundance of Grass Pickerel at Stevensville per sampling event.

There was a significant difference in the number of GP captured between years at Stevensville (χ^2 = 10.143, df = 4, p = 0.038). The CPUE of GP was high in 2009 and 2010, reaching a maximum of over 100 GP per haul in early 2009, although the CPUE declined later that year (Figure 101). CPUE remained relatively low (i.e., < 10 per haul) in 2011–2015. GP were tagged during two sampling events in 2009, all events in 2010, the last two in 2011, and all but one event in both 2012 and 2013. Fewer than half of the GP captured were tagged during these events, except in 2010 when more than half of the GP captured were tagged. Tagged GP were recaptured on most events in all years sampled, ranging from one to ten individuals per event.

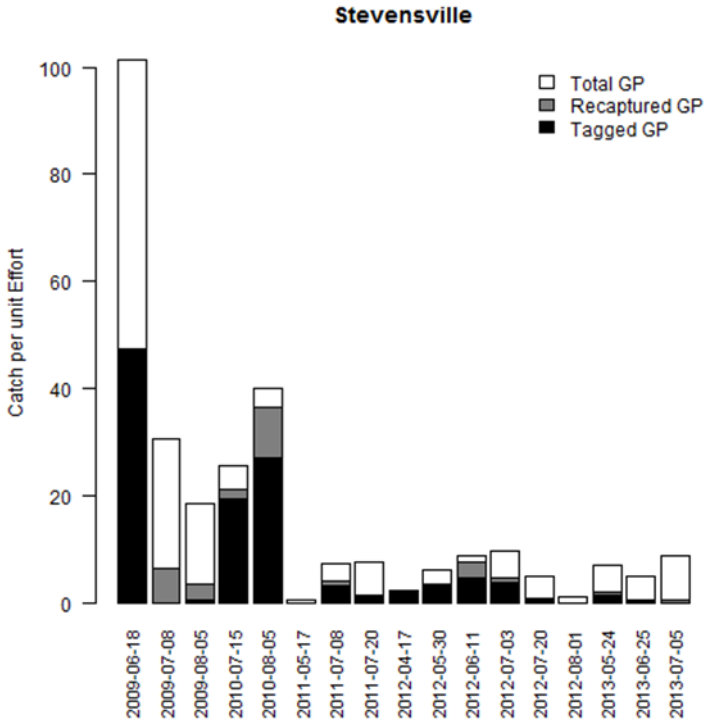

Figure 101. Number of Grass Pickerel captured per haul at Stevensville per sampling event.

The mean TL of GP at Stevensville was 160 mm. There was a significant difference in TL between years ($\chi^2 = 94.668$, df = 4, $p < 0.0001$). TLs were smallest in 2013 and 2011, but varied greatly within and between years at Stevensville (Figure 102). Lengths of GP tended to increase through 2009 and 2013 but decreased through 2011 and 2012. No YOY were detected at Stevensville in 2009.

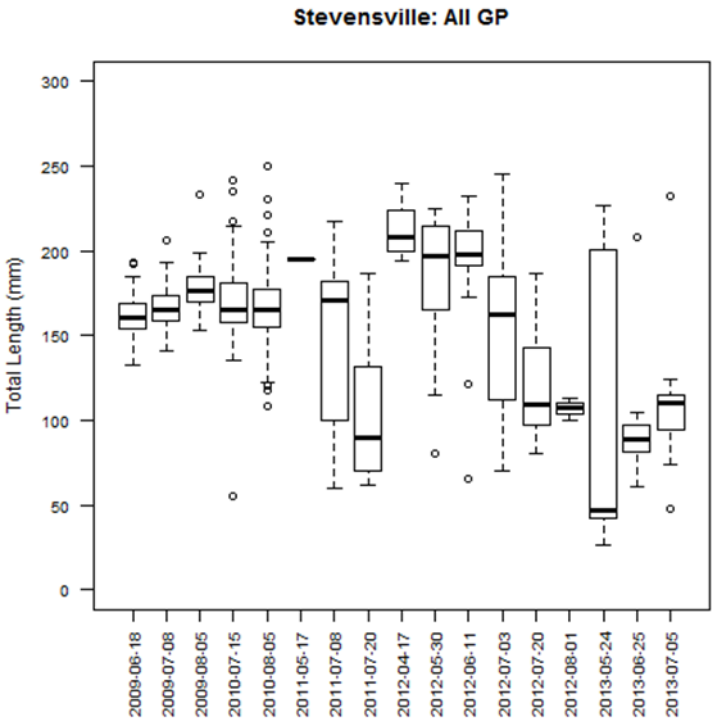

Figure 102. Total lengths of Grass Pickerel captured at Stevensville.

The length frequency distribution was slightly negatively skewed with most individuals ranging from 150–200 mm TL (Figure 103).

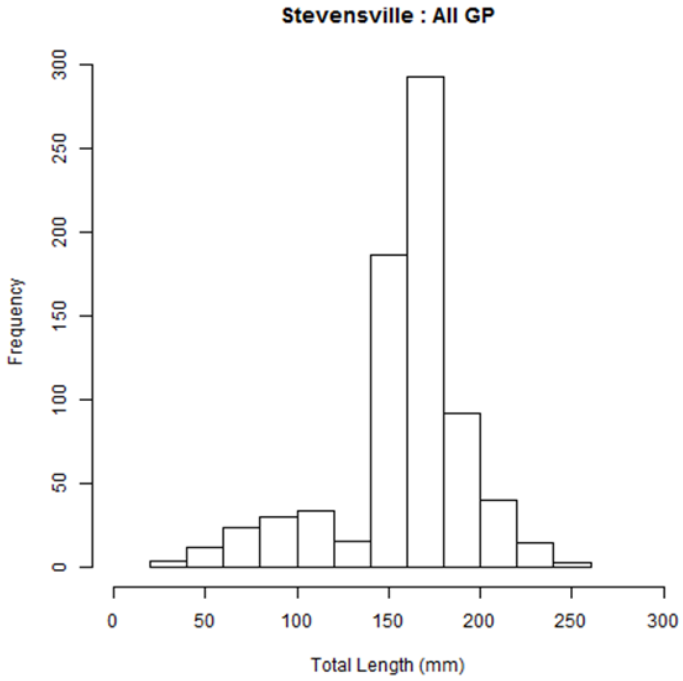

Figure 103. Length frequency distribution of Grass Pickerel captured at Stevensville.

The length: weight relationship of GP at Stevensville was fairly consistent across all years (with little variation around the cubic regression line), except 2009 (substantial variation around the line; Figure 104).

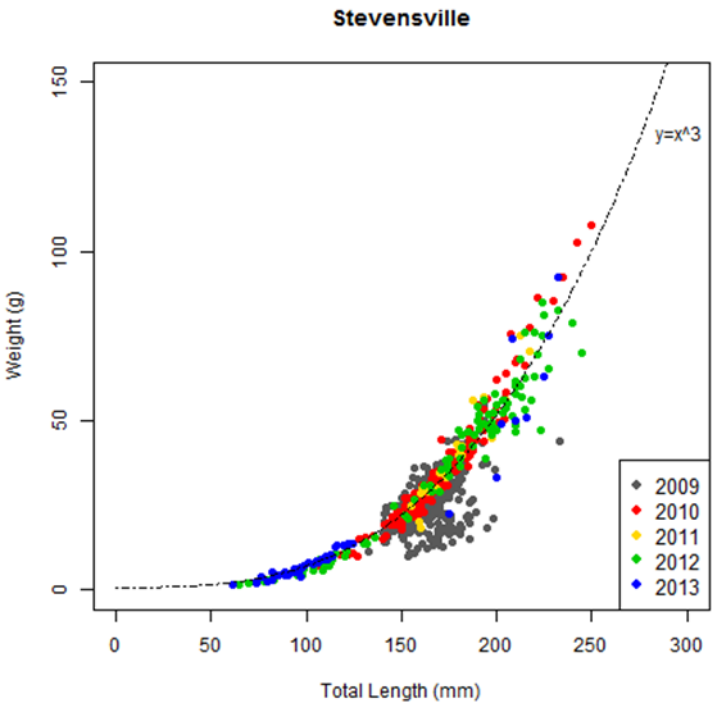

Figure 104. Body condition of Grass Pickerel captured at Stevensville.

Winger

Approximately 5% of all GP captured in Beaver Creek were caught at Winger. The relative abundance of GP was highly variable within and between years (Figure 105). Within the same year, GP were not detected during some sampling events, and made up the majority of the fish community during other sampling events. Relative abundance declined throughout the season in 2009, 2010, and 2013.

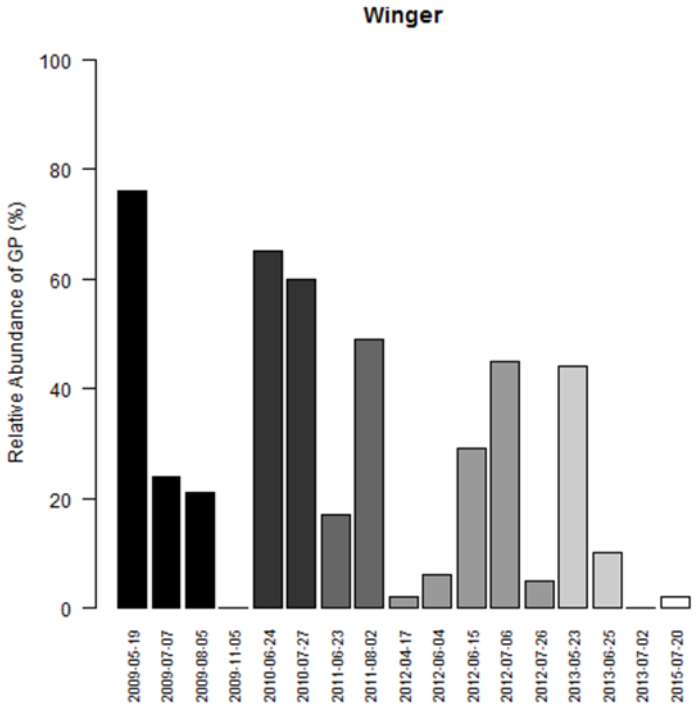

Figure 105. Relative abundance of Grass Pickerel at Winger per sampling event.

Catches of GP at Winger varied slightly within and between years (Figure 106), but ranged between 0 and 12 GP per haul. The number of GP declined each year. GP were tagged on six sampling events at Winger from 2009–2012. Tagged GP were recaptured during five sampling events across all years except 2011. Only one or two individuals were recaptured each time.

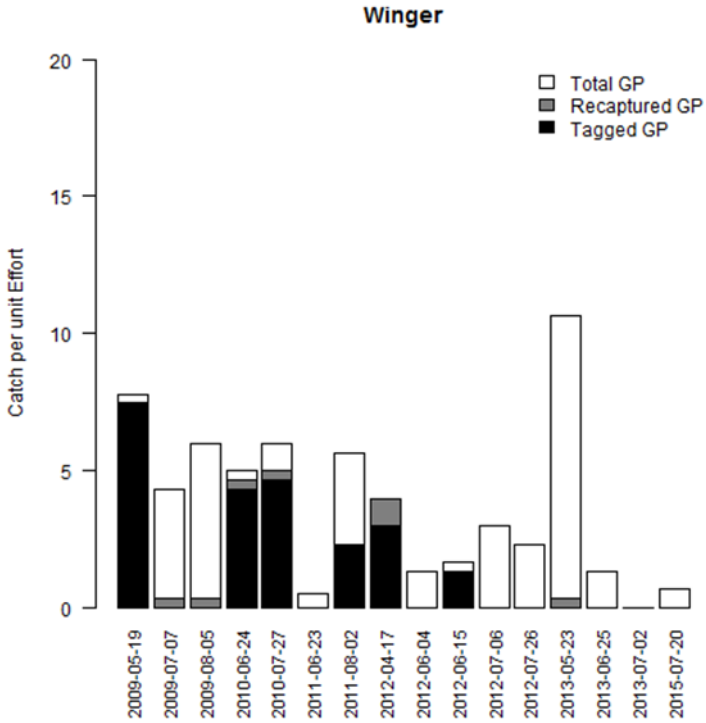

Figure 106. Number of Grass Pickerel captured per haul at Winger per sampling event.

The mean TL of GP at Winger was 144 mm. There was a significant difference in TL between years ($\chi^2 = 90.405$, df = 5, $p < 0.0001$). TLs varied greatly within and between years, but were smallest in 2013 (Figure 107). Lengths of GP tended to increase through 2009 and 2013 but decrease through 2011 and 2012.

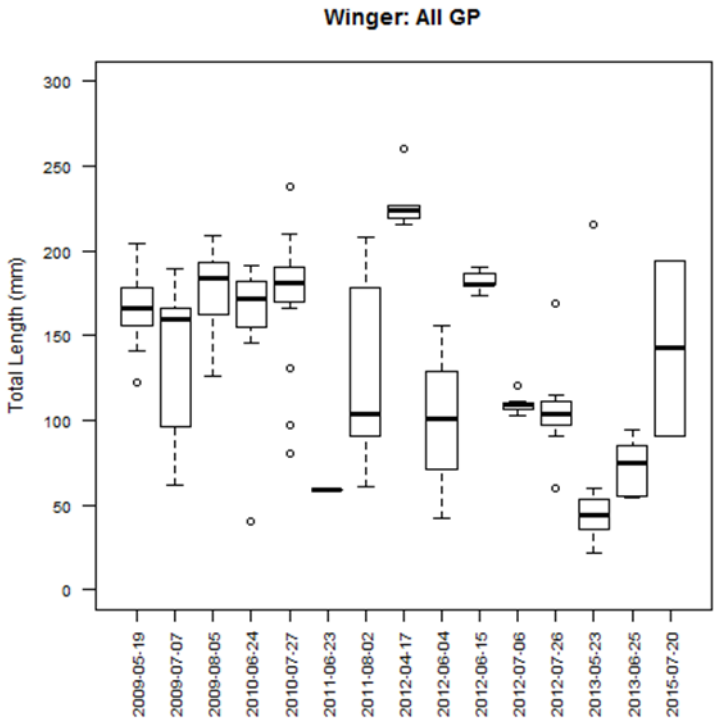

Figure 107. Total lengths of Grass Pickerel captured at Winger per sampling event.

A wide range of size classes were caught at Winger, with the majority being in the 150–200 mm TL range (Figure 108).

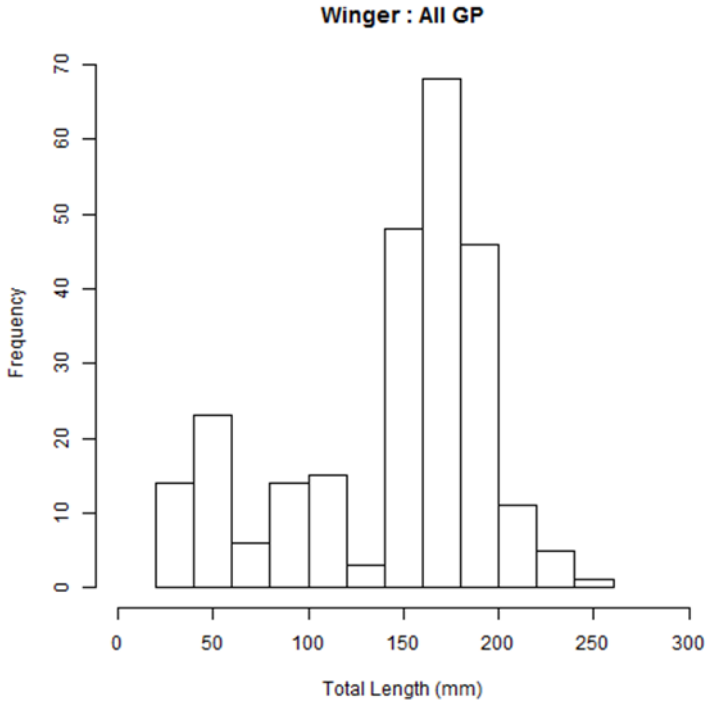

Figure 108. Length frequency distribution of Grass Pickerel captured at Winger.

GP captured at Winger tended to be of better body condition in 2009 and 2010 compared to the average in the creek, although more variable in 2009 (Figure 109). GP in other years were of approximately average body size.

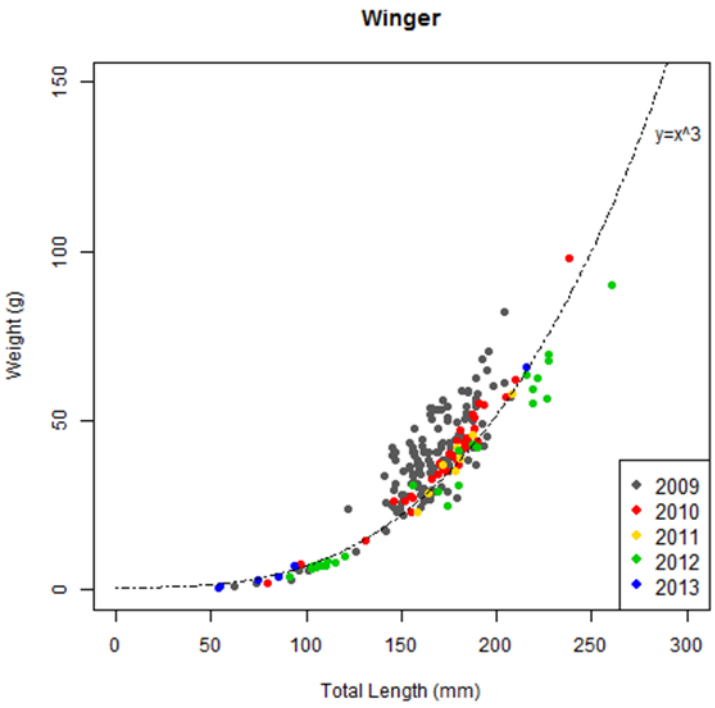

Figure 109. Body condition of Grass Pickerel captured at Winger.

Young-of-Year (YOY)

YOY GP were detected at all sites except in the reconstructed reach (where they were only found in Pool 2) (Figure 110). They were only detected at Garrison West in 2009–2011 (i.e., pre-reconstruction). YOY were detected at Winger in all six years, at Bowen and Garrison East in five of six years, and in all four years of sampling at Ben's Place. The most YOY were detected at Bowen, and the majority of them were detected in 2011 and 2009. YOY were also abundant at Stevensville and Winger. These three sites are closest to the confluence point of the east and west tributaries. YOY were most prevalent in the 2013 sample overall, this is also when adult GP were in lowest abundance.

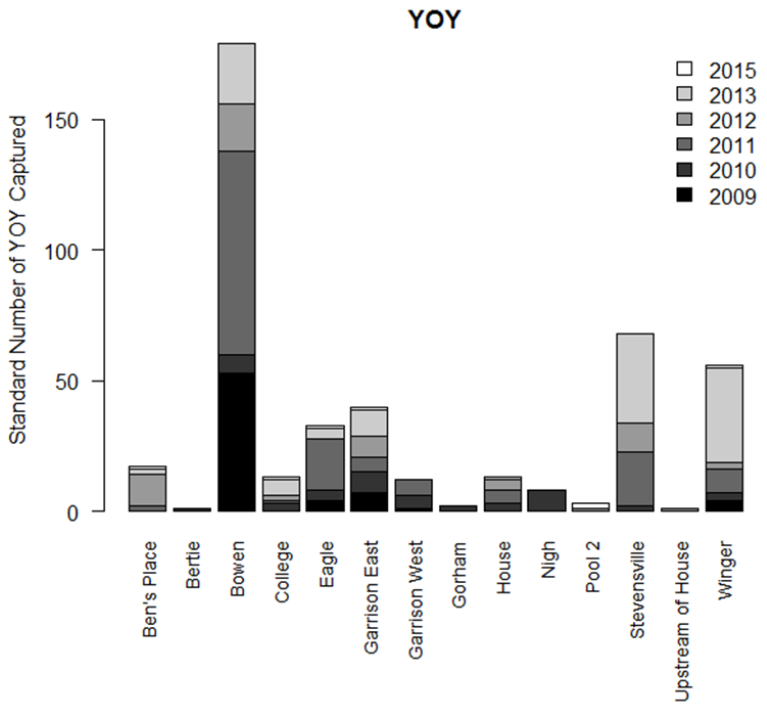

Figure 110. Abundance of young-of-year (YOY) Grass Pickerel captured in Beaver Creek per year by site.

Blue Grass Pickerel

In 2013, 19 GP were sampled that had blue colouration across their bodies (Figure 111). All of these GP were 84-124 mm in TL (likely year one age class/ 2012 year class). These GP were captured with other GP of the same size that were normal in colour. They were detected at Ben's Place, Stevensville and Bowen, three of the four sites closest to the tributary confluence.

Figure 111. Blue-coloured Grass Pickerel (top) and normal Grass Pickerel (bottom) captured at Bowen in 2013.

HABITAT ASSESSMENT

Habitat variables are summarized for each site per year. Water chemistry is summarized in Table 7. Dissolved oxygen, pH and turbidity were not measured in 2009 or 2010. Physical site measurements are summarized in Table 8, substrate in Table 9, aquatic vegetation in Table 10 and riparian vegetation in Table 11.

Table 7a and b. Mean air temperature and water chemistry per year by site.

a)

Site Name	Air Temperature (°C)						Water Temperature (°C)						Conductivity (µs/cm)					
	2009	2010	2011	2012	2013	2015	2009	2010	2011	2012	2013	2015	2009	2010	2011	2012	2013	2015
Ben's Place	-	-	23.6	21.2	24.1	23.0	-	-	21.7	18.3	18.9	20.1	-	-	956	1553	845	1076
Bertie	24.9	25.2	24.6	25.7	22.7	22.4	20.5	19.9	21.2	17.2	15.2	18.9	1365	1196	1546	1389	1267	1009
Bertie ROW	-	-	-	34.0	-	-	-	-	-	24.1	-	-	-	-	-	1788	-	-
Bowen	24.7	22.5	23.6	25.6	22.7	24.0	18.9	19.7	19.7	22.9	17.9	21.7	1030	1200	1086	1265	491	904
College	22.9	20.7	26.3	26.2	25.1	22.4	19.6	18.6	21.0	22.4	22.9	21.9	812	955	1572	1201	1218	839
Eagle	21.4	22.9	23.3	27.0	25.7	-	17.8	19.0	20.6	19.8	20.5	21.5	959	1016	1115	1122	785	833
Garrison East	24.1	24.8	27.8	25.4	21.7	-	20.1	21.1	21.5	19.9	16.6	19.1	1924	1721	1832	1667	1607	2036
Garrison West	23.0	24.2	31.2	27.1	18.7	30.0	20.3	18.0	22.1	26.6	16.7	20.8	958	528	900	1865	1004	868
Gorham	23.8	20.5	-	-	-	-	18.8	19.6	-	-	-	-	1462	460	-	-	-	-
House	23.1	19.1	23.7	23.3	24.4	28.6	21.3	17.3	20.9	18.0	17.2	23.1	1207	1063	740	1754	624	979
Nigh	22.7	22.7	-	-	-	-	18.9	15.9	-	-	-	-	1537	823	-	-	-	-
Offline Pool 1	-	-	-	28.9	-	-	-	-	-	24.7	-	-	-	-	-	972	-	-
Offline Pool 2	-	-	-	29.5	22.3	30.0	-	-	-	23.5	21.1	25.2	-	-	-	1982	725	1070
Pool 2	-	-	-	33.0	19.6	23.0	-	-	-	27.8	13.5	19.3	-	-	-	1554	745	861
Pool 3	-	-	-	30.2	27.9	27.1	-	-	-	26.5	14.1	22.2	-	-	-	1337	730	868
Pool 4	-	-	-	26.1	17.3	-	-	-	-	25.3	16.3	24.4	-	-	-	1111	7.57	925
Pool 5	-	-	-	-	-	29.8	-	-	-	-	-	20.9	-	-	-	-	-	892
Stevensville	20.7	25.6	22.9	23.5	19.7	30.9	19.4	24.0	18.2	20.5	19.1	21.5	981	1140	620	1243	698	972
Upstream of House	-	-	-	29.0	-	-	-	-	-	22.9	-	-	-	-	-	1127	-	-
Winger	20.3	28.2	26.9	21.6	24.8	30.1	18.2	23.7	21.9	18.4	19.8	21.0	1072	1168	866	1165	869	935

b)

Site Name	Dissolved Oxygen (mg/L)				pH				Secchi Depth (m)						Turbidity (ntu)			
	2011	2012	2013	2015	2011	2012	2013	2015	2009	2010	2011	2012	2013	2015	2011	2012	2013	2015
Ben's Place	3.8	6.4	4.5	2.4	7.8	7.3	8.1	7.7	-	-	0.31	0.34	0.46	0.44	61.4	17.2	25.7	11.5
Bertie	4.9	6.6	4.4	3.6	7.6	7.2	7.5	7.7	0.39	0.43	0.24	0.36	0.09	0.35	12.9	10.9	27.5	27.3
Bertie ROW	-	6.8	-	-	-	8.3	-	-	-	-	-	0.25	-	-	-	58.3	-	-
Bowen	6.4	7.7	6.2	3.7	8.0	7.6	7.7	8.0	0.40	0.31	0.31	0.19	0.32	-	49.1	25.8	17.3	4.7
College	6.3	8.4	6.8	4.5	8.3	7.9	7.9	8.2	0.28	0.28	0.30	0.38	0.26	0.55	130.6	13.5	16.8	5.6
Eagle	5.0	8.0	5.7	4.3	8.0	7.6	7.8	7.9	0.50	0.49	0.32	0.34	0.23	-	15.8	18.1	25.5	1.4
Garrison East	10.6	7.2	13.2	6.2	8.2	7.7	7.9	7.8	0.51	0.81	0.37	0.30	0.44	0.56	38.1	24.0	11.0	10.7
Garrison West	2.0	4.8	8.5	4.9	8.1	8.2	8.6	8.7	0.06	0.25	0.04	0.11	1.99	0.19	111.8	66.2	105.2	31.4
Gorham	-	-	-	-	-	-	-	-	0.18	0.11	-	-	-	-	-	-	-	-
House	7.5	9.8	8.5	5.8	8.4	8.0	8.1	8.0	0.06	0.32	0.08	0.22	0.16	0.07	94.2	57.8	79.3	53.7
Nigh	-	-	-	-	-	8.6	-	-	0.57	0.41	-	-	-	-	-	27.3	-	-
Offline Pool 1	-	6.5	-	-	-	-	-	-	-	-	-	0.22	-	-	-	-	-	-
Offline Pool 2	-	7.3	-	2.8	-	9.1	9.1	8.1	-	-	-	0.14	0.05	0.09	-	543.0	106.8	62.7
Pool 2	-	5.0	10.1	5.5	-	7.7	8.6	8.1	-	-	-	-	0.14	0.11	-	-	69.4	64.4
Pool 3	-	5.5	9.4	5.2	-	8.3	8.4	8.3	-	-	-	0.22	0.22	0.15	-	-	88.0	53.2
Pool 4	-	5.7	12.9	8.1	-	7.4	8.6	8.2	-	-	-	-	0.38	0.23	-	-	32.7	64.2
Pool 5	-	-	-	3.8	-	-	-	8.2	-	-	-	-	-	0.31	-	-	-	16.0
Stevensville	6.0	9.0	5.8	2.0	7.9	7.7	7.7	7.9	0.49	0.20	0.19	0.26	0.34	0.61	206.5	51.5	35.4	8.3
Upstream of House	-	6.6	-	-	-	8.3	-	-	-	-	-	0.23	-	-	-	40.0	-	-
Winger	5.5	7.8	7.0	4.9	7.8	7.5	7.8	7.7	0.35	0.37	0.14	0.43	0.40	-	77.1	22.0	20.4	7.2

Table 8. Physical site measurements per year by site.

Site Name	Mean Stream Width (m)						Maximum Sampling Depth (m)						Mean Channel Cover (%)					
	2009	2010	2011	2012	2013	2015	2009	2010	2011	2012	2013	2015	2009	2010	2011	2012	2013	2015
Ben's Place	-	-	5.5	6.53	7.25	10	-	-	1	0.7	0.93	0.64	-	-	10	13	5	20
Bertie	12	18.9	8	11.8	11	8	1.3	1.26	-	1.06	1.24	1.05	0	21	5	16	0	0
Bertie ROW	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	10	-	-
Bowen	10	8.33	18	4.93	10.8	4	1.3	1.19	0.79	0.78	0.93	0.86	13	1	8	29	57	10
College	16.5	13.4	9	9.98	10.3	12	0.89	0.87	-	0.81	0.89	1.01	35	24	33	75	47	50
Eagle	16.9	14.1	10	11.5	12	8	1.45	1.08	-	0.91	1.1	0.82	23	17	78	40	50	15
Garrison East	20	10.9	7.67	12.3	10	12	1.6	1.01	0.65	0.94	0.87	0.51	3	3	15	19	13	0
Garrison West	7.67	8.1	5.25	6.76	8.5	3	0.75	0.48	-	0.78	0.77	0.59	35	27	5	29	0	0
Gorham	4.5	3.1	-	-	-	-	-	0.66	-	-	-	-	40	18	-	-	-	-
House	6.95	7.55	8	7.75	9.5	10	0.71	0.74	0.56	0.55	0.79	0.49	37	5	5	42	13	5
Nigh	7	5.33	-	-	-	-	0.95	0.52	-	-	-	-	10	58	-	-	-	-
Offline Pool 1	-	-	-	9.6	-	-	-	-	-	1.2	-	-	-	-	-	30	-	-
Offline Pool 2	-	-	-	-	-	3	-	-	-	0.36	0.31	0.62	-	-	-	10	40	3
Pool 2	-	-	-	9.1	11	8	-	-	-	0.81	0.76	0.83	-	-	-	18	40	25
Pool 3	-	-	-	8.5	13	3	-	-	-	1.25	0.78	0.85	-	-	-	50	20	5
Pool 4	-	-	-	6.5	11	3	-	-	-	0.88	0.79	0.76	-	-	-	10	80	0
Pool 5	-	-	-	-	-	3	-	-	-	-	-	0.25	-	-	-	-	-	10
Stevensville	32.5	12.2	33.5	10.7	12.8	10	1.25	0.72	1	0.46	0.81	0.8	82	55	50	66	63	85
Upstream of House	-	-	-	3.5	-	-	-	-	-	-	-	-	-	-	-	90	-	-
Winger	13	13	7	7.94	9.83	6	0.6	0.71	1.45	0.53	0.97	0.69	40	25	35	50	35	10

Table 9. Mean percent composition of substrate types per year by site.

Site Name	Clay						Silt						Sand						Organic					
	2009	2010	2011	2012	2013	2015	2009	2010	2011	2012	2013	2015	2009	2010	2011	2012	2013	2015	2009	2010	2011	2012	2013	2015
Ben's Place	-	-	60	24	53	30	-	-	30	15	10	0	-	-	0	0	0	0	-	-	0	13	3	0
Bertie	17	0	0	10	25	20	3	13	0	20	10	0	0	0	0	0	0	0	10	21	23	41	45	0
Bertie ROW	-	-	-	40	-	-	-	-	-	40	-	-	-	-	-	0	-	-	-	-	-	20	-	-
Bowen	60	53	53	38	45	0	20	25	37	40	20	50	0	5	3	0	0	0	7	18	3	22	35	0
College	23	56	70	33	60	0	40	23	0	33	12	25	10	0	0	0	0	25	28	20	25	17	13	0
Eagle	26	53	78	49	53	0	43	19	13	36	20	65	4	0	0	0	0	25	28	12	5	10	17	0
Garrison East	3	13	17	24	24	0	50	18	33	28	39	70	23	28	18	0	0	20	10	23	13	28	29	0
Garrison West	0	59	75	28	55	0	35	11	0	28	0	100	3	9	3	0	5	0	12	6	0	42	18	0
Gorham	0	23	-	-	-	-	25	3	-	-	-	-	0	0	-	-	-	-	5	3	-	-	-	-
House	3	62	40	39	57	50	30	17	30	31	13	0	0	0	13	0	0	30	10	2	7	8	7	0
Nigh	0	35	-	-	-	-	60	12	-	-	-	-	0	10	-	-	-	-	10	13	-	-	-	-
Offline Pool 1	-	-	-	20	-	-	-	-	-	20	-	-	-	-	-	0	-	-	-	-	-	0	-	-
Offline Pool 2	-	-	-	20	40	10	-	-	-	20	10	60	-	-	-	0	0	30	-	-	-	0	30	0
Pool 2	-	-	-	55	90	0	-	-	-	35	0	100	-	-	-	0	0	0	-	-	-	10	10	0
Pool 3	-	-	-	35	70	5	-	-	-	35	0	80	-	-	-	0	0	10	-	-	-	10	10	0
Pool 4	-	-	-	45	65	0	-	-	-	40	0	40	-	-	-	0	0	0	-	-	-	15	15	0
Pool 5	-	-	-	-	-	0	-	-	-	-	-	10	-	-	-	-	-	0	-	-	-	-	-	0
Stevensville	0	3	7	38	45	10	40	10	42	21	8	0	0	18	3	0	0	20	13	13	20	0	10	0
Upstream of House	-	-	-	45	-	-	-	-	-	30	-	-	-	-	-	0	-	-	-	-	-	0	-	-
Winger	10	30	30	32	50	0	32	0	10	18	3	80	0	15	33	0	7	20	22	0	0	0	2	0

Table 9. Continued.

Site Name	Gravel						Cobble						Boulder						Bedrock					
	2009	2010	2011	2012	2013	2015	2009	2010	2011	2012	2013	2015	2009	2010	2011	2012	2013	2015	2009	2010	2011	2012	2013	2015
Ben's Place	-	-	0	49	35	70	-	-	0	0	0	0	-	-	10	0	0	0	-	-	0	0	0	0
Bertie	0	5	0	0	0	80	57	29	0	2	20	0	13	33	78	13	0	0	0	0	0	0	0	0
Bertie ROW	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-	0	-	-
Bowen	13	0	0	0	0	20	0	0	0	0	0	30	0	0	3	0	0	0	0	0	0	0	0	0
College	0	1	0	10	0	50	0	0	0	0	15	0	0	0	5	7	0	0	0	0	0	0	0	0
Eagle	0	5	0	0	10	0	0	0	0	0	0	10	0	11	5	5	0	0	0	0	0	0	0	0
Garrison East	7	17	18	16	8	10	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Garrison West	13	13	0	0	23	0	37	1	0	2	0	0	0	1	23	0	0	0	0	0	0	0	0	0
Gorham	0	30	-	-	-	-	70	43	-	-	-	-	0	0	-	-	-	-	0	0	-	-	-	-
House	0	4	0	0	0	0	53	5	0	0	0	20	0	2	10	5	0	0	0	0	0	0	0	0
Nigh	0	30	-	-	-	-	30	0	-	-	-	-	0	0	-	-	-	-	0	0	-	-	-	-
Offline Pool 1	-	-	-	60	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-	0	-	-
Offline Pool 2	-	-	-	30	0	0	-	-	-	0	0	0	-	-	-	0	0	0	-	-	-	30	20	0
Pool 2	-	-	-	0	0	0	-	-	-	0	0	0	-	-	-	0	0	0	-	-	-	0	0	0
Pool 3	-	-	-	0	0	5	-	-	-	0	0	0	-	-	-	0	0	0	-	-	-	20	20	0
Pool 4	-	-	-	0	0	10	-	-	-	0	0	0	-	-	-	0	0	0	-	-	-	0	20	0
Pool 5	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-	0
Stevensville	33	58	27	41	37	10	13	0	0	0	0	60	0	0	0	0	0	0	0	0	0	0	0	0
Upstream of House	-	-	-	0	-	-	-	-	-	25	-	-	-	-	-	0	-	-	-	-	-	0	-	-
Winger	0	25	8	9	23	0	37	25	0	13	3	0	0	5	20	20	0	0	0	0	0	0	0	0

Table 10. Mean percent composition of aquatic vegetation types per year by site.

Site Name	Open Water						Emergent Vegetation						Submerged						Floating					
	2009	2010	2011	2012	2013	2015	2009	2010	2011	2012	2013	2015	2009	2010	2011	2012	2013	2015	2009	2010	2011	2012	2013	2015
Ben's Place	-	-	45	10	58	95	-	-	5	24	20	0	-	-	0	16	23	5	-	-	50	50	0	0
Bertie	75	25	45	32	80	80	20	15	8	6	15	20	0	48	0	15	0	0	5	13	48	47	5	0
Bertie ROW	-	-	-	15	-	-	-	-	-	15	-	-	-	-	-	70	-	-	-	-	-	0	-	-
Bowen	10	86	85	54	40	80	20	11	7	19	32	5	70	3	8	27	28	15	0	0	0	0	0	0
College	70	92	85	17	55	80	0	3	8	30	22	10	25	4	3	44	20	10	5	2	5	9	3	0
Eagle	28	65	90	50	72	40	58	25	8	16	17	40	13	9	3	28	12	10	2	1	0	6	0	10
Garrison East	65	23	87	21	70	85	10	8	5	31	13	15	15	67	5	28	15	0	10	2	3	20	2	0
Garrison West	70	80	78	84	78	80	25	11	18	3	10	20	0	9	0	6	10	0	5	0	5	7	3	0
Gorham	40	88	-	-	-	-	60	13	-	-	-	-	0	0	-	-	-	-	0	0	-	-	-	-
House	-	59	73	31	78	10	-	30	12	20	10	10	-	9	15	32	12	80	-	2	0	18	0	0
Nigh	-	75	-	-	-	-	-	0	-	-	-	-	-	25	-	-	-	-	-	0	-	-	-	-
Offline Pool 1	-	-	-	15	-	-	-	-	-	10	-	-	-	-	-	60	-	-	-	-	-	15	-	-
Offline Pool 2	-	-	-	15	40	70	-	-	-	15	15	30	-	-	-	70	45	0	-	-	-	0	0	0
Pool 2	-	-	-	75	90	55	-	-	-	0	10	5	-	-	-	25	0	40	-	-	-	0	0	0
Pool 3	-	-	-	53	90	85	-	-	-	3	5	5	-	-	-	30	0	10	-	-	-	15	5	0
Pool 4	-	-	-	60	70	80	-	-	-	0	15	10	-	-	-	30	0	10	-	-	-	10	15	0
Pool 5	-	-	-	-	-	80	-	-	-	-	-	10	-	-	-	-	-	10	-	-	-	-	-	0
Stevensville	83	99	92	56	68	90	13	2	8	17	20	10	0	0	0	26	12	0	5	0	0	2	0	0
Upstream of House	-	-	-	50	-	-	-	-	-	0	-	-	-	-	-	50	-	-	-	-	-	0	-	-
Winger	70	94	90	53	57	30	10	3	5	22	20	10	10	3	5	7	23	60	10	1	0	18	0	0

Table 11. Mean percent composition of riparian vegetation types per year by site.

Site Name	Herbaceous						Shrubs						Deciduous					
	2009	2010	2011	2012	2013	2015	2009	2010	2011	2012	2013	2015	2009	2010	2011	2012	2013	2015
Ben's Place	-	-	75	70	73	10	-	-	0	13	13	0	-	-	25	17	15	90
Bertie	55	49	100	60	73	100	10	0	0	9	3	0	35	51	0	31	25	0
Bertie ROW	-	-	-	35	-	-	-	-	-	30	-	-	-	-	-	35	-	-
Bowen	67	72	77	70	47	20	3	0	0	6	7	0	30	28	23	24	47	80
College	40	61	80	38	28	80	5	13	0	21	12	0	55	26	20	41	60	20
Eagle	34	60	85	74	50	40	19	0	0	4	10	0	48	40	15	22	40	60
Garrison East	60	90	53	54	33	60	20	0	0	20	32	0	20	10	47	26	35	40
Garrison West	60	78	43	86	83	100	5	0	0	0	0	0	35	22	58	14	18	0
Gorham	35	95	-	-	-	-	50	0	-	-	-	-	15	5	-	-	-	-
House	-	55	70	62	47	95	-	0	0	18	13	0	-	45	30	20	40	5
Nigh	100	60	-	-	-	-	0	0	-	-	-	-	0	40	-	-	-	-
Offline Pool 1	-	-	-	80	-	-	-	-	-	0	-	-	-	-	-	20	-	-
Offline Pool 2	-	-	-	80	50	50	-	-	-	20	0	45	-	-	-	0	50	5
Pool 2	-	-	-	65	50	60	-	-	-	15	0	0	-	-	-	20	50	40
Pool 3	-	-	-	55	50	20	-	-	-	0	0	0	-	-	-	45	50	80
Pool 4	-	-	-	60	50	20	-	-	-	10	0	0	-	-	-	30	50	80
Pool 5	-	-	-	-	-	50	-	-	-	-	-	0	-	-	-	-	-	50
Stevensville	15	45	25	48	25	55	10	0	0	10	10	0	75	55	75	42	65	45
Upstream of House	-	-	-	50	-	-	-	-	-	0	-	-	-	-	-	50	-	-
Winger	0	50	38	44	22	55	20	0	0	20	48	0	80	50	63	36	30	45

SUMMARY

There were several trends that were noticeable throughout the study period. Eagle generally had the largest catches of fishes. Both College and Eagle had the greatest species diversity overall, with 31 species detected at each site. This may be because these sites are closest to the confluence with the larger Black Creek. Grass Pickerel were not evenly distributed through Beaver Creek; some sites always had higher abundances than others, specifically Bowen, Garrison East, Stevensville, and Bertie. Grass Pickerel were generally abundant through the east branch, and increased in abundance moving downstream towards the confluence in the west branch. Grass Pickerel abundance declined after 2009, and throughout the 2012 sampling season. The summer of 2012 was particularly warm and dry (Appendix C), and much of the creek dried up by the end of the summer leaving only small, isolated pools. Bertie generally had the largest Grass Pickerel. There were sites where YOY were more frequently detected; Bowen, Stevensville and Winger consistently yielded greater numbers of YOY suggesting spawning and or nursery habitat are better at these sites compared to others. Only three YOY were detected in the reconstructed section of the west branch after the works were conducted (i.e., after 2011); however they were infrequent in this reach beforehand as well. Body condition was variable between sites and over time, but was generally best in 2010, worst in 2012, and most variable in 2009.

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APPENDIX A. 2009 FALL SURVEY

Additional sampling was conducted in November 2009. These data are summarized separately here as there may be seasonal differences in fish community structure and habitat not accounted for in other years.

Sampling occurred at eight sites over two days (Table A1). The fish community was sampled with a 9.1 m seine net with 0.32 cm mesh on the bag and wings and three hauls were conducted at each site. A total of 320 fishes were captured representing 13 species; the catch per unit effort and number of species are summarized in Table A2. One-hundred and forty Grass Pickerel were captured, nine of which were tagged, and two were recaptured with a tag. The mean total length and weight of these Grass Pickerel was 185 mm and 37.6 g. The length frequency distribution of these Grass Pickerel was negatively skewed (Figure A1), and the body condition was slightly worse than average (Figure A2). Silt was the most common substrate type and sites were mostly open water with some emergent vegetation (Table A2).

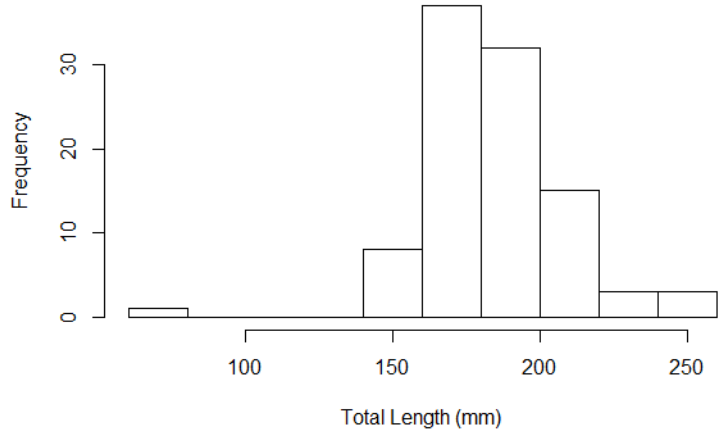

Figure A1. Length frequency distribution of Grass Pickerel captured during the fall 2009 at all sites.

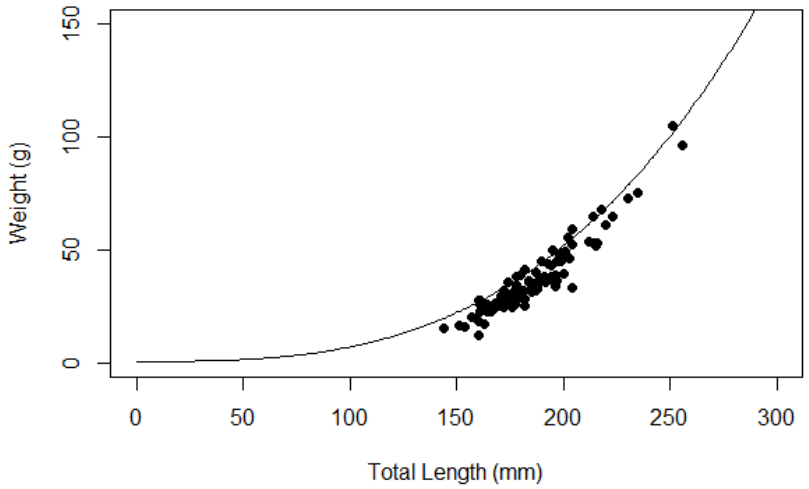

Figure A2. Body Condition of Grass Pickerel captured during the fall 2009 at all sites.

Table A1. Summary of sampling effort and fishes captured during the 2009 fall Grass Pickerel survey in Beaver Creek.

Site Name	Date	Effort (seine hauls)	Number of Fishes	Number of Species	Most Abundant Species	Number of GP	GP Tagged	GP Recaptured	Mean Total Length (mm)	Mean Weight (g)
Bertie	05/11/2009	3	70	4	Grass Pickerel	56	9	0	187	39.6
College	05/11/2009	3	78	9	Rock Bass	1	0	0	71	-
Eagle	05/11/2009	3	86	9	Striped Shiner	3	0	0	199	46.8
Garrison East	06/11/2009	3	74	3	Grass Pickerel	64	1	1	179	32
Garrison West	06/11/2009	3	26	6	Pumpkinseed	0	0	0	-	-
House	05/11/2009	3	20	4	Green Sunfish	1	0	0	160	18.5
Stevensville	05/11/2009	3	22	3	Grass Pickerel	15	1	1	201	46.4
Winger	05/11/2009	3	3	3	-	0	0	0	-	-

Table A2. Summary of habitat data (% composition of aquatic vegetation and substrate) recorded during the 2009 fall Grass Pickerel survey in Beaver Creek.

Site Name	Date	Open Water	Emergent	Submerged	Floating	Clay	Silt	Sand	Organic	Gravel	Cobble	Boulder
Bertie	05/11/2009	85	15	0	0	0	80	0	0	0	0	20
College	05/11/2009	90	10	0	0	30	0	40	30	0	0	0
Eagle	05/11/2009	60	40	0	0	20	50	0	30	0	0	0
Garrison East	06/11/2009	75	0	25	0	0	60	0	10	30	0	0
Garrison West	06/11/2009	70	30	0	0	0	40	40	0	20	0	0
House	05/11/2009	80	20	0	0	0	30	0	0	30	40	0
Stevensville	05/11/2009	60	20	20	0	10	20	0	10	60	0	0
Winger	05/11/2009	100	0	0	0	30	30	0	0	0	0	40

APPENDIX B. 2011 LARVAL SURVEY

Additional sampling was conducted in the spring of 2011 to target spawning and larval Grass Pickerel as part of an aging study. These data are summarized separately here as different gear types were used and there may be seasonal differences not accounted for in other years. Although this sampling targeted young-of-year Grass Pickerel, only four were detected.

Electrofishing was conducted using a Smith Root LR 24 Backpack electrofishing unit. Shocking occurred for approximately 1500 seconds per site sampled (Table B1). A total of 53 fishes were captured, representing seven species; 47 of these fishes were Grass Pickerel (Table B2). The mean total length of Grass Pickerel captured was 180 mm, and the length frequencies were close to a normal distribution (Figure B1). No Grass Pickerel were tagged at this time and one was recaptured with a tag at Bowen. The mean air and water temperatures during this survey were 18.6°C and 17.9°C, respectively (Table B3). The mean conductivity was 843 µs/cm. The mean dissolved oxygen was 10.6 mg/L. The mean pH was 7.8. The mean secchi depth was 0.3 m. The mean stream width was 7.0 m, and the mean channel cover was 21% of the sampling area. Clay and Silt were the dominant substrate types (Table B4). Open water and emergent vegetation types were most common, though submerged vegetation was prominent as well. No floating vegetation was recorded. Herbaceous vegetation was most common in the riparian zone at this time.

Quatrefoil plexiglass larval light traps were also set for approximately 5 hours each (Table B1). A total of 327 fishes were captured in the traps, representing eight species (Table B2). This included 311 Emerald Shiners and two Grass Pickerel. The mean air and water temperatures recorded were 17.5°C and 16.0°C, respectively (Table B3). The mean conductivity was 658 µs/cm. The mean dissolved oxygen was 9.3 mg/L. The mean pH was 7.7. The mean secchi depth was 0.2 m. The mean stream width was 14.9 m, and the mean channel cover was 13% of the sampling area.

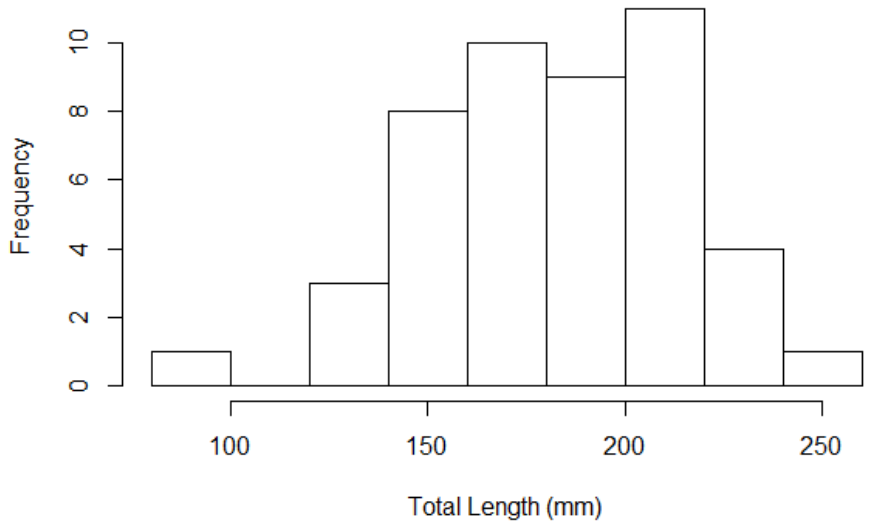

Figure B1. Length frequency distribution of Grass Pickerel captured by backpack electrofishing in spring 2011 at all sites.

Table B1. Summary of sampling effort employed in Beaver Creek during the spring 2011 Grass Pickerel larval survey. Gear types are backpack electrofishing (BPEF; a) and quatrefoil light traps (QLT; b).

a)

Site Name	Gear Type	Effort	Quantification of Effort	Amps (A)	Volts (V)	Power (watts)	Pulses/Second (Hz)
Ben's Place	BPEF	1504	seconds	0.95	140	NR	NR
Bertie	BPEF	1500	seconds	0.75	150	115	60
Bowen	BPEF	1503	seconds	1.1	110	NR	60
College	BPEF	1503	seconds	1.3	140	NR	60
Eagle	BPEF	1500	seconds	1.07	120	130	60
Garrison East	BPEF	1505	seconds	NR	NR	NR	NR
Garrison West	BPEF	NR	seconds	0.95	160	NR	NR
House	BPEF	1515	seconds	0.37	285	NR	60
Nigh	BPEF	1502	seconds	0.48	220	NR	NR
Winger	BPEF	2002	seconds	1.4	145	200	4

b)

Site Name	Gear Type	Effort	Quantification of Effort
Ben's Place	QLT	5	hours
Bertie	QLT	5	hours
Bowen	QLT	10	hours
College	QLT	4	hours
Eagle	QLT	NR	hours
Eagle	QLT	5	hours
Garrison East	QLT	5	hours
Garrison West	QLT	5	hours
Gorham	QLT	4	hours
House	QLT	5	hours
Nigh	QLT	4	hours
Nigh	QLT	4	hours
Stevensville	QLT	5	hours
Winger	QLT	5	hours

Table B2. Summary of fishes captured during the spring 2011 larval survey. Gear types are backpack electrofishing (BPEF) and Quatrefoil Light Traps (QLT).

Date	Site Name	Gear	Effort	Quantification of effort	Species	Number Captured
25/05/2011	Ben's Place	BPEF	1504	seconds	Grass Pickerel	3
17/05/2011	Bertie	BPEF	1500	Seconds	Grass Pickerel	3
12/05/2011	Bowen	BPEF	1503	Seconds	Grass Pickerel	7
12/05/2011	College	BPEF	1503	Seconds	Grass Pickerel	3
12/05/2011	College	BPEF	1503	Seconds	Pumpkinseed	1
12/05/2011	College	BPEF	1503	Seconds	Largemouth Bass	1
12/05/2011	College	BPEF	1503	Seconds	Logperch	1
13/05/2011	Eagle	BPEF	1600	Seconds	Grass Pickerel	6
26/05/2011	Garrison West	BPEF	NR	Seconds	Grass Pickerel	6
12/05/2011	House	BPEF	1515	Seconds	Grass Pickerel	10
12/05/2011	House	BPEF	1515	Seconds	Golden Shiner	1
12/05/2011	House	BPEF	1515	Seconds	Green Sunfish	1
12/05/2011	House	BPEF	1515	Seconds	Emerald Shiner	1
16/05/2011	Nigh	BPEF	1502	Seconds	Grass Pickerel	2
11/05/2011	Winger	BPEF	2002	Seconds	Grass Pickerel	7
16/05/2011	Ben's Place	QLT	5	Hours	Central Mudminnow	1
18/05/2011	Bertie	QLT	5	Hours	No fish captured	0
11/05/2011	Bowen	QLT	10	Hours	Emerald Shiner	5
24/05/2011	College	QLT	4	Hours	Emerald Shiner	105
24/05/2011	College	QLT	4	Hours	Emerald Shiner	45
24/05/2011	College	QLT	4	Hours	Central Mudminnow	1
13/05/2011	Eagle	QLT	NR	Hours	Pumpkinseed	3
13/05/2011	Eagle	QLT	NR	Hours	Emerald Shiner	93
13/05/2011	Eagle	QLT	NR	Hours	Spottail Shiner	2
13/05/2011	Eagle	QLT	NR	Hours	Yellow Perch	1
13/05/2011	Eagle	QLT	NR	Hours	Central Mudminnow	1

Date	Site Name	Gear	Effort	Quantification of effort	Species	Number Captured
19/05/2011	Garrison East	QLT	5	Hours	Emerald Shiner	3
19/05/2011	Garrison East	QLT	5	Hours	Central Mudminnow	5
16/05/2011	Garrison West	QLT	5	Hours	Emerald Shiner	1
17/05/2011	Garrison West	QLT	5	Hours	Grass Pickerel	1
24/05/2011	Gorham	QLT	4	Hours	Grass Pickerel	1
17/05/2011	House	QLT	5	Hours	Emerald Shiner	1
17/05/2011	House	QLT	5	Hours	Central Mudminnow	1
19/05/2011	Nigh	QLT	4	Hours	Emerald Shiner	3
19/05/2011	Nigh	QLT	4	Hours	Central Mudminnow	3
18/05/2011	Nigh	QLT	4	Hours	No fish captured	0
12/05/2011	Stevensville	QLT	5	Hours	Emerald Shiner	47
12/05/2011	Stevensville	QLT	5	Hours	Yellow Perch	2
17/05/2011	Winger	QLT	5	Hours	Emerald Shiner	2

NR indicates effort was not recorded.

Table B3. Water chemistry and physical habitat measurements recorded during the spring 2011 larval survey. Gear types are backpack electrofishing (BPEF) and Quatrefoil Light Traps (QLT).

Date	Site name	Gear	Air Temperature	Water Temperature	Conductivity	Dissolved Oxygen	pH	Secchi Tube (m)	Stream Width (m)	Channel Cover (%)
25/05/2011	Ben's Place	BPEF	27.9	22.23	1399	10.65	7.82	-	3	-
17/05/2011	Bertie	BPEF	11.4	12	735	10.85	7.8	0.485	6	20
12/05/2011	Bowen	BPEF	19.4	19.4	1089	7.92	7.66	0.398	14.8	10
12/05/2011	College	BPEF	21.7	18.61	1102	9.95	7.91	0.38	7	15
26/05/2011	Garrison West	BPEF	22.9	17.34	527	7.71	7.95	0.04	3	40
12/05/2011	House	BPEF	-	19.35	534	9.85	8.06	0.17	-	10
16/05/2011	Nigh	BPEF	8.9	11.1	240	11.52	7.87	0.08	-	40
11/05/2011	Winger	BPEF	18.2	22.9	1123	16.6	7.69	-	7.95	15
16/05/2011	Ben's Place	QLT	9.9	10.88	453	9.69	7.67	0.18	29.2	5
18/05/2011	Bertie	QLT	23.3	17.66	818	11.68	7.95	0.33	20	20
11/05/2011	Bowen	QLT	21.9	21.3	1049	7.7	7.7	0.6	14.3	0
24/05/2011	College	QLT	-	20.66	811	8.92	7.8	0.35	10.5	20
13/05/2011	Eagle	QLT	24.1	17.2	1014	8.08	7.6	0.58	20	10
12/05/2011	Eagle	QLT	18.8	18.28	973	7.39	7.65	-	20	10
19/05/2011	Garrison East	QLT	17.2	13.92	301	8.76	7.64	0.11	7	2
16/05/2011	Garrison West	QLT	10.3	10.47	520	11.23	7.76	0.203	13.6	-
24/05/2011	Gorham	QLT	20.9	18.97	1584	12.66	8.04	-	6.6	10
17/05/2011	House	QLT	10.6	11.14	329	10.33	7.77	0.09	-	2
18/05/2011	Nigh	QLT	23.3	18.62	212	8.23	7.7	0.06	8.6	2
19/05/2011	Nigh	QLT	17.2	14.04	264	8.75	7.59	0.1	2.5	30
12/05/2011	Stevensville	QLT	20.1	19.1	578	6.96	7.6	0.072	29	40
17/05/2011	Winger	QLT	10.1	11.26	311	9.28	7.55	0.23	12	15

Table B4. Percent composition of substrate recorded during the spring 2011 larval survey during backpack electrofishing sampling.

Date	Site name	Organic	Clay	Silt	Sand	Gravel	Cobble
25/05/2011	Ben's Place	10	10	80	0	0	0
17/05/2011	Bertie	15	0	80	0	0	5
12/05/2011	Bowen	0	70	20	0	10	0
12/05/2011	College	0	50	20	0	0	30
26/05/2011	Garrison West	70	0	20	10	0	0
12/05/2011	House	0	50	0	25	25	0
16/05/2011	Nigh	0	50	20	0	20	10
11/05/2011	Winger	0	0	90	10	0	0

Table B5. Percent composition of aquatic and riparian vegetation recorded during the spring 2011 larval survey during backpack electrofishing sampling.

Date	Site name	Emergent	Submerged	Open Water	Deciduous	Herbaceous
25/05/2011	Ben's Place	40	40	20	20	80
17/05/2011	Bertie	15	0	85	60	40
12/05/2011	Bowen	10	0	90	20	80
12/05/2011	College	5	0	95	50	50
26/05/2011	Garrison West	0	20	80	50	50
12/05/2011	House	90	0	10	50	50
16/05/2011	Nigh	10	0	90	40	60
11/05/2011	Winger	50	0	50	50	50

APPENDIX C. FORT ERIE CLIMATE DATA

Daily climate data were obtained from the Environment and Climate Change Canada Fort Erie climate station (42.88000, -78.97000) from 2006–2015. The daily mean air temperature in summer (Figure C1) was highest in 2012 and the total monthly precipitation in summer (Figure C2) was lowest in 2007 and 2012 compared to all other years 2006–2015 (Table C1). Although there was comparably little precipitation in the summers of 2007 and 2012, the air temperatures were substantially higher in 2012, likely resulting in greater evaporation. When looking at air temperature and precipitation through the whole year (Figures C3 and C4), 2012 was the hottest and driest of all years.

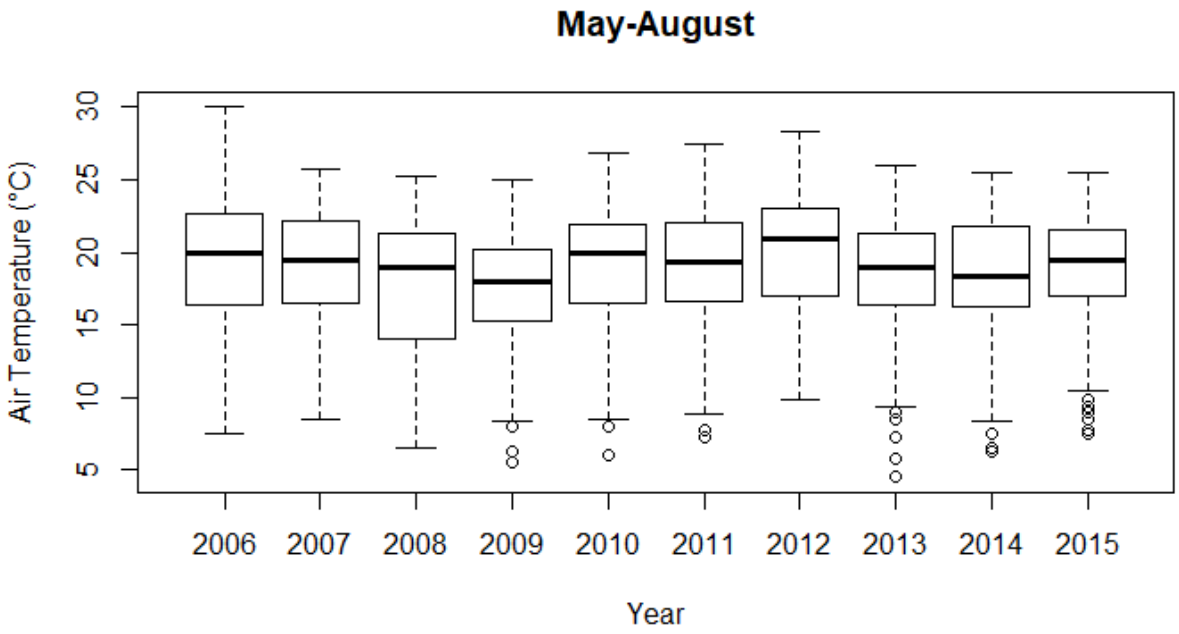

Figure C1. Daily mean air temperature (°C) in summer (May through August) Fort Erie, Ontario from 2006–2015.

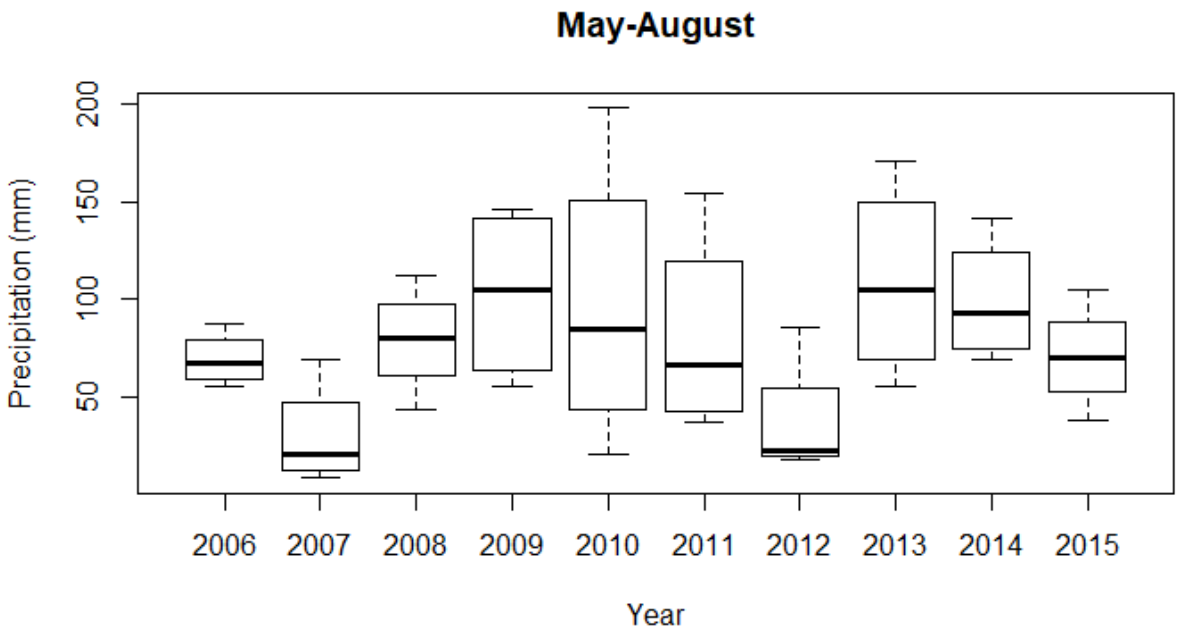

Figure C2. Total monthly precipitation (mm) in summer in Fort Erie, Ontario from 2006–2015.

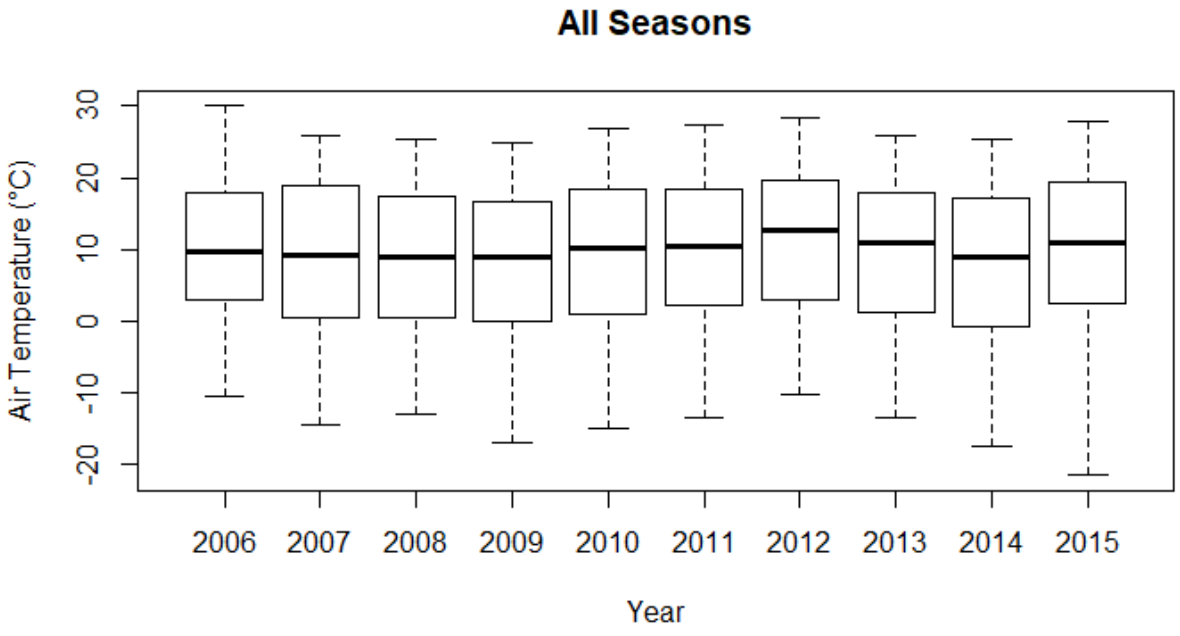

Figure C3. Daily mean air temperature (°C) in Fort Erie, Ontario from 2006–2015.

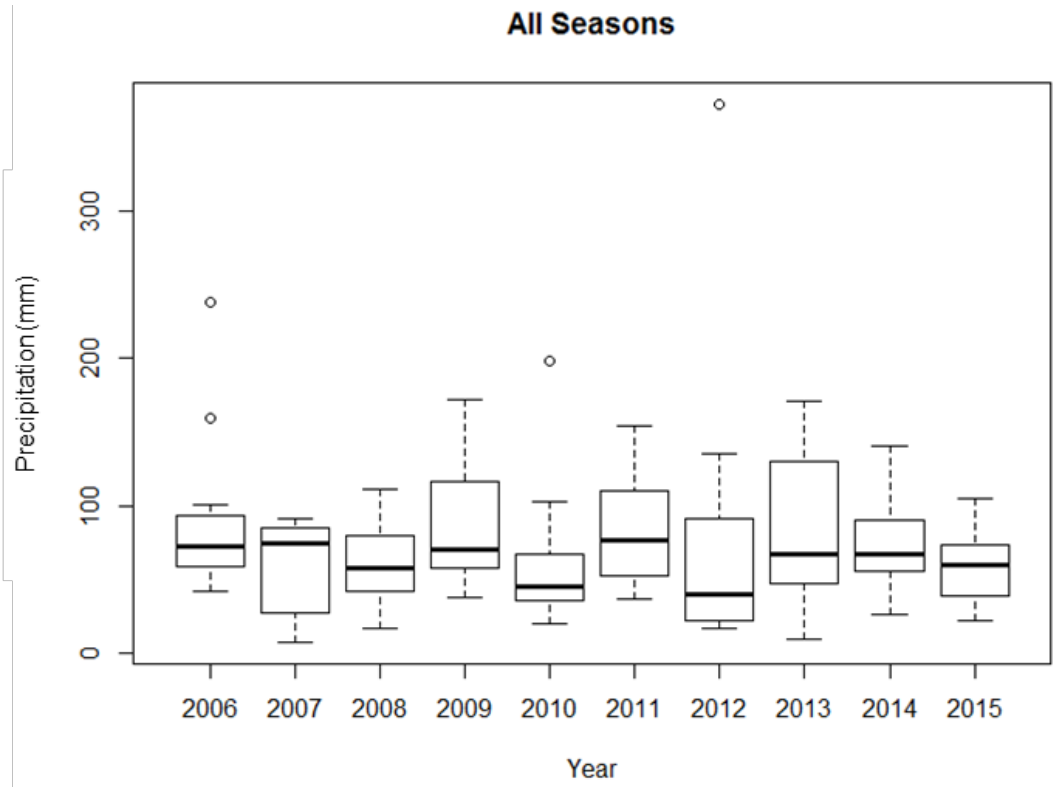

Figure C4. Total monthly precipitation (mm) in Fort Erie, Ontario from 2006–2015.

Table C1. Mean daily summer air temperature with standard deviation (SD) and mean total monthly summer precipitation with SD in Fort Erie, Ontario from 2006–2015.

Year	Mean Daily Summer Air Temperature (°C)	SD Daily Summer Air Temperature (°C)	Mean Total Monthly Summer Precipitation (mm)	SD Total Monthly Summer Precipitation (mm)
2006	19.2	4.6	69.2	13.5
2007	18.9	4.4	29.5	27.2
2008	17.6	4.9	78.8	28.2
2009	17.5	4.0	102.4	45.9
2010	19.1	4.5	96.8	75.5
2011	19.0	4.5	81.1	52.9
2012	20.0	4.0	37.1	32.6
2013	18.4	4.1	109.1	51.0
2014	18.2	4.3	99.1	32.0
2015	18.7	4.2	70.5	27.4