Rathbun Lake Habitat Assessment

Study 7037 Completion Report
Federal Aid to Sport Fish Restoration

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Period Covered: 1 July 2010 – 30 June 2015
Iowa Department of Natural Resources
Chuck Gipp, Director

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COMPLETION REPORT

LARGE RESERVOIR FISHERIES INVESTIGATIONS

Study 7037. Rathbun Lake Habitat Assessment

Job 1. Literature review of issues associated with aquatic habitat establishment and assessment, and associated changes in fish populations

Job 2. Identify at least three coves in Rathbun Lake that can be classified as ecologically important habitats (based on findings of Mitzner 1995 and/or visually) capable of providing important fish spawning and nursery habitat, and three control coves

Job 3. Assess alteration of littoral physiochemical characteristics in the three shoreline stabilization areas and three control areas

Job 4. Assess alteration of littoral zooplankton and macroinvertebrates in the three shoreline stabilization areas and three control areas

Job 5. Assess zooplankton and ichthyoplankton composition at six historical Rathbun Lake sites

Job 6. Examine the effects of shoreline stabilization on densities, growth rates, and diets of age-0 Largemouth Bass and crappie

Job 7. Completion report, management guidelines, and publication of results

Period Covered: 1 July 2009 – 30 June 2015

Prepared by: _____ June 30, 2015
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CONSERVATION AND RECREATION DIVISION
Iowa Department of Natural Resources
Chuck Gipp, Director

Executive Summary

Rathbun Lake is the second-largest waterbody and fourth-most popular recreational fishery in Iowa (Duda et al. 2011). The reservoir brings $64.2 million in total expenditures and 495 jobs to the area and attracts almost 306,000 households annually for recreation (Herriges et al. 2011). Anglers typically target White Crappie *Pomoxis annularis* and Black Crappie *P. nigromaculatus*, as well as Walleye *Sander vitreus*, Channel Catfish *Ictalurus punctatus*, and White Bass *Morone chrysops* (M. Flammang, Iowa Department of Natural Resources, personal communication). The reservoir supports an essential broodstock Walleye population used by Rathbun Fish Hatchery to stock fry and fingerling Walleye statewide. In addition, the reservoir provides flood control and serves as the water supply for the hatchery and Rathbun Regional Water Association, affecting 70,000 people in 18 counties of southeast Iowa and northeast Missouri.

Despite its importance in recreation and water supply, Rathbun Lake is subject to numerous habitat-related stressors and threats. It suffers from high turbidity which stems from watershed runoff, wave action and shoreline erosion (Mitzner 1991), and is experiencing sedimentation at an extremely rapid rate. Work has been ongoing in the watershed to reduce external sediment loading, but little had been done prior to this study to protect the shoreline and improve fish spawning and nursery habitat, particularly that of crappie. On top of these serious habitat limitations more common to Iowa reservoirs, adult Zebra Mussels *Dreissena polymorpha* were detected in Rathbun Lake in October 2007. Zebra Mussels presented an entirely new suite of threats to the reservoir, with implications for the plankton and fish communities, water quality, and use as a water supply. This study was initiated in 2009 to investigate these habitat issues by characterizing the role of shoreline stabilization in structuring littoral communities in Rathbun Lake and characterizing the plankton community and any effects had from Zebra Mussel infestation.

Major findings from this research were as follows:

- Riprap treatment of cove shorelines yielded few detectable differences in water quality, zooplankton communities or fish communities in Rathbun Lake. The substantial sampling efforts expended during data collection and laboratory analysis imply a massive investment of time and resources required to achieve statistically significant results, an investment which may not be feasible within the limitations of state agency resources. This limitation should be considered before entering into future habitat evaluations.

- Specific zooplankton taxa including *Daphnia* spp., cyclopoid copepods, calanoid copepods, and certain rotifers such as *Hexarthra* spp. and *Trichocerca* spp. were somewhat more abundant in treatment coves than in control coves. In contrast, other rotifers including *Asplanchna* spp., *Filinia* spp., and *Mytilina* spp. were less abundant. These community changes imply a change in water quality, especially turbidity, despite the statistically insignificant difference in water quality parameters between treatments.

- Specific fish taxa including White and Black Crappies and Largemouth Bass *Micropterus salmoides* were somewhat more abundant in treatment coves than in control coves, and

age-0 White Crappie and Gizzard Shad, specifically, were much more abundant in treatment coves than in control coves. These community changes imply a change in habitat quality and/or forage availability.

- Despite weak statistical support, these comparisons between treatment and control coves appeared to be ecologically meaningful. Shoreline stabilization appeared to have some effects at a local level, specifically on crappies which were the focus of this part of the study. Enhancement of the Rathbun Lake crappie fishery could benefit even more from additional bank stabilization with riprap in other strategically placed areas.

- The current zooplankton and ichthyoplankton communities did not differ substantially from historical data collected during the 1990s at fixed sampling sites located throughout the reservoir. Although Zebra Mussels have been detected in Rathbun Lake, the current-day plankton community was believed to represent a reasonable baseline to which future samples can be compared.

- No short-term directional trends were detected in either zooplankton or ichthyoplankton from 2010 to 2013. This further supports the use of current-day data as a baseline. If Zebra Mussels do infest the reservoir at a detectable level in the future, the effects on the plankton community can be measured in relation to data from 2010 to 2013.

Suggested citation format, American Fisheries Society Style Guide:

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STUDY 7037

Rathbun Lake Habitat Assessment

OBJECTIVE

By 2015, characterize the role of shoreline stabilization in structuring littoral assemblages in Rathbun Lake, and assess current density and species composition of ichthyoplankton in Rathbun Lake to document potential changes in ichthyoplankton following Zebra Mussel establishment in Rathbun Lake.

JOB 1

Literature review of issues associated with aquatic habitat establishment and assessment, and associated changes in fish populations

OBJECTIVE

Perform a literature review relative to aquatic habitat establishment assessment and associated changes in fish populations and compile historical data known to impact this relationship.

JOB 2

Identify at least three coves in Rathbun Lake that can be classified as ecologically important habitats (based on findings in Mitzner 1995 and/or visually) capable of providing important fish spawning and nursery habitat, and three control coves.

OBJECTIVE

Identify coves as sampling sites.

JOB 3

Assess alteration of littoral physiochemical characteristics in the three shoreline stabilization areas and three control areas.

OBJECTIVE

Assess dissolved oxygen, conductivity, temperature, and turbidity in habitat areas.

JOB 4

Assess alteration of littoral zooplankton and macroinvertebrates in the three shoreline stabilization areas and three control areas.

OBJECTIVE

Determine zooplankton and macroinvertebrate species diversity and density.

JOB 5

Assess zooplankton and ichthyoplankton composition at six historical Rathbun Lake sites.

OBJECTIVE

Determine changes in composition between 1984 – 1998 period and current.

JOB 6

Examine the effects of shoreline stabilization on densities, growth rates, and diets of age-0 Largemouth Bass and crappie.

OBJECTIVE

Assess any changes in Largemouth Bass and crappie populations.

JOB 7

Completion report, management guidelines, and publication of results.

OBJECTIVE

Compile, analyze, and publish results in federal aid reports, peer-reviewed and lay journals as appropriate.

STUDY 7037 COMPLETION REPORT
FISHERIES RESEARCH

STATE:	Iowa	**TITLE**:	Changes in zooplankton and fish communities in coves following riprap stabilization of the shoreline in a southeast Iowa reservoir (Rathbun Lake, Appanoose County)
JOBS:	1-4, 6-7		

The following chapter has been formatted for submission to North American Journal of Fisheries Management, a peer-reviewed journal of the American Fisheries Society, as a manuscript entitled:

Changes in zooplankton and fish communities in coves following riprap stabilization of the shoreline in a southeast Iowa reservoir (Rathbun Lake, Appanoose County)

Abstract – Rathbun Lake is the second-largest body of water and the fourth-most popular fishery in Iowa, providing opportunities for White Crappie *Pomoxis annularis*, Black Crappie *P. nigromaculatus*, Walleye *Sander vitreus*, Channel Catfish *Ictalurus punctatus* and White Bass *Morone chrysops*. Despite the crappie fishery's popularity, crappie populations in Rathbun Lake are limited by a paucity of quality spawning and nursery habitat; shoreline habitat is highly degraded and turbidity is high throughout much of the reservoir. In an effort to reduce shoreline erosion and improve habitat quality for crappies, riprap was installed on the shoreline at six treatment sites located in the best available crappie habitat. Six control sites were also identified in the best available crappie habitat but were not riprapped. Water quality, zooplankton, macroinvertebrates, and fish communities were monitored from 2010 to 2013 at each site. Water quality was compared between treatments using a multivariate dispersion test and a multivariate analysis of covariance (MANCOVA) with reservoir conditions (e.g., pool elevation) as covariates. Zooplankton and fish communities were compared between treatments using MANCOVAs with water quality and reservoir conditions as covariates. The macroinvertebrate community was not compared between treatments because catch rates were extremely low. There was no detectable difference in water quality between treatments, but certain zooplankton taxa sensitive to water quality did appear to change; specifically larger-bodied cladocerans and copepods tended to increase in density in treatment coves and smaller-bodied cladocerans and rotifers tended to decrease. The fish community was even more variable, and no difference could be detected between treatments; however, visual comparison of catch rates implied possible positive effects on crappies and Largemouth Bass *Micropterus salmoides* in treatment coves. Furthermore, length frequencies of Age-0 fish differed between treatments for White Crappie, Bluegill *Lepomis macrochirus*, Largemouth Bass, White Bass, and Gizzard Shad *Dorosoma cepedianum*. Despite a lack of statistical support, shoreline stabilization with riprap did appear to affect the reservoir community to some degree and could benefit important recreational fish species if completed in more locations throughout Rathbun Lake. However, the limited ability to measure effects of shoreline stabilization efforts should be recognized prior to conducting the work, as said effects may be a poor measure of success.

Introduction

Rathbun Lake is the second-largest body of water in Iowa, attracting almost 306,000 households annually for recreation (Herriges et al. 2011). The lake brings $64.2 million in total expenditures and 495 jobs to the area (Herriges et al. 2011), and is the fourth-most popular waterbody in the state for fishing (Duda et al. 2008). Anglers typically target White Crappie *Pomoxis annularis* and Black Crappie *P. nigromaculatus*, as well as Walleye *Sander vitreus*, Channel Catfish *Ictalurus punctatus*, and White Bass *Morone chrysops* (M. Flammang, Fisheries Management Biologist, Iowa Department of Natural Resources, personal communication).

Despite the crappie fishery's popularity, crappie populations in Rathbun Lake are limited by a paucity of quality spawning and nursery habitat. The reservoir has approximately 150 miles of shoreline, 61 of which were designated as adequate crappie habitat based on substrate firmness, wind direction, velocity and duration (Mitzner 1995). High quality habitat was even less common. This is a common problem in reservoirs, especially those with frequent or untimely water level fluctuations (Maceina and Stimpert 1998; Sammons et al. 2002). Mitzner (1991) demonstrated that density of age-0 crappies in Rathbun Lake increased linearly with reservoir water storage and that floodwater storage was the most importance factor affecting age-0 crappie abundance. Increases in water levels during spawning can make higher quality habitat available, such as by inundating terrestrial vegetation along an otherwise barren shoreline (Dagel and Miranda 2012).

Figure 1-1. Shoreline near Honey Creek Resort, Rathbun Lake, prior to riprap installment.

The second most important factor affecting age-0 crappie abundance was turbidity, which was inversely related to abundance (Mitzner 1991). Turbidity in Rathbun Lake stems from three major sources: watershed runoff, wave action and shoreline erosion, and resuspension of bottom sediments (Mitzner 1991). Total sediment delivery from the watershed was estimated at 377,308 tons in 2010 (Downing and Balmer 2011), which is matched by nearly the same from internal loading by shoreline erosion and sediment resuspension in the reservoir (U.S. Army Corps of Engineers, unpublished data). Resulting sedimentation is currently occurring at a rate that is up to three times faster than anticipated when the reservoir was built.

Work has been ongoing in the watershed to reduce external sediment loading, primarily via a grassroots partnership called the Rathbun Land and Water Alliance (www.rathbunlandwateralliance.blogspot.com). However, little had been done to protect the shoreline from further erosion within the lake prior to this study (Figure 1-1). It was surmised that riprap protection of twelve

priority shorelines could reduce up to 50,000 tons of sediment per year. Stabilization of the shoreline, accompanied by reduced turbidity and other water quality improvements, may in turn benefit fish such as crappie by providing improved habitat. Therefore, the objective of this study was to assess the effects of shoreline stabilization with riprap on water quality and fish, macroinvertebrate and zooplankton communities in Rathbun Lake.

Methods

Study Location

Rathbun Lake is an 11,000-acre flood control and water supply reservoir located in southeast Iowa. The watershed is 354,062 acres, yielding a relatively low watershed area:surface area of 32:1. Land use is dominated by row crop agriculture and livestock production. Control and treatment sites were selected from shoreline areas identified as quality crappie habitat by Mitzner (1995; Figure 1-2). Treatment sites were stabilized with riprap in spring 2011 to protect the shoreline from further erosion and provide rocky substrate for fish spawning and nursery habitat. Control sites were not altered and were generally highly eroded mudflats with silt substrate.

Data Collection

Sites were monitored between July and September from 2010 to 2013. Monitoring included measuring water quality, sampling zooplankton (which began in 2011), sampling macroinvertebrates, and sampling fish. Each site was sampled at least four times per summer. Water quality was measured at the surface using a YSI 556; parameters included water temperature (degrees Celsius), dissolved oxygen (mg/L), specific conductivity (µS/cm), pH, and total dissolved solids (g/L).

Zooplankton were sampled by pulling a Wisconsin plankton net (80-micron mesh) concurrently with the larval fish tow. Samples were preserved with 3-5% formalin solution and stored in glass jars until laboratory processing. Zooplankton samples were processed by examining three 1-mL subsamples in a Sedgewick-Rafter cell using a compound microscope set at 40X-100X. Zooplankton were identified to various taxonomic levels using the taxonomic key of Pennak (1978). Copepod crustaceans were identified to order or identified as nauplii; cladocerans and rotifers were identified to genus. Total number per liter water volume was calculated for each taxon for each sample.

Macroinvertebrates were sampled with a Ponar dredge in a randomly selected location within the site area. Samples were preserved with 3-5% formalin solution until laboratory processing. Macroinvertebrates were identified to family (Merritt and Cummins 1996) and enumerated.

Fish were sampled using a benthic otter trawl with 6.3-mm delta outer mesh and 34.9-mm bar inner mesh (Herzog et al. 2005). Trawl towlines were 38.1 m long for a maximum effective depth of 5.4 m with a 7:1 drop ratio. Additional information on trawl design was described by Herzog et al. (2005). Trawls were towed perpendicular to the shoreline for 3 minutes at approximately 2.0 km/h.

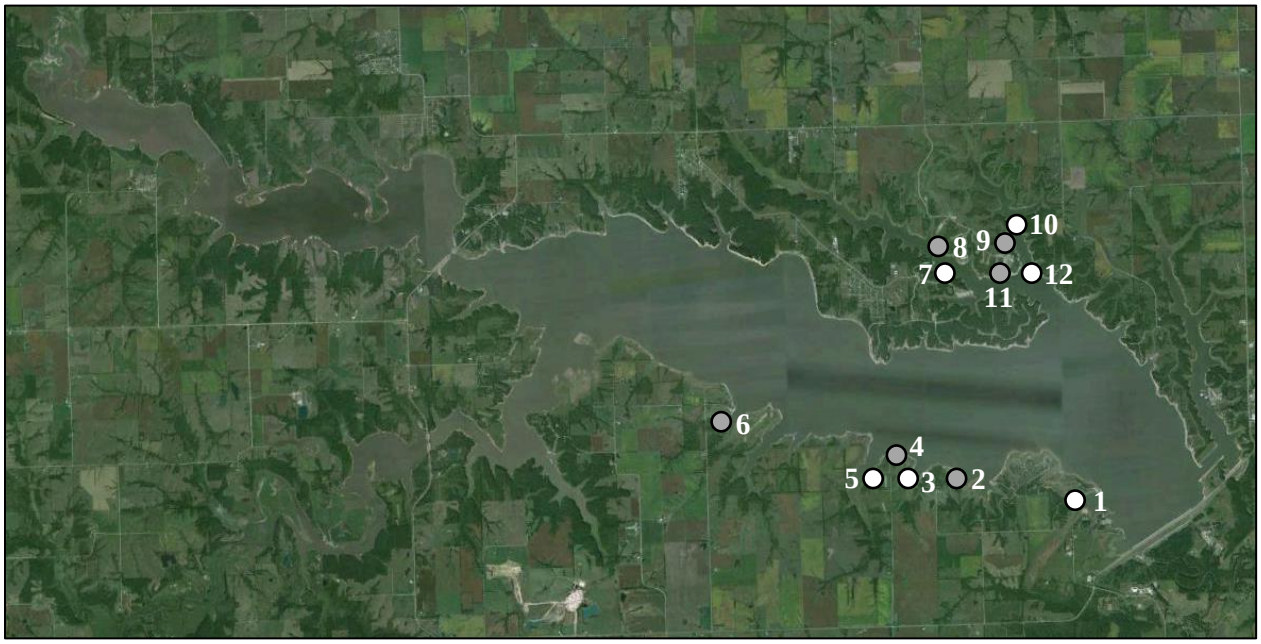

Figure 1-2. Rathbun Lake, Iowa. Control site = open circle, Treatment site = shaded circle

Daily reservoir condition data were obtained from the Rathbun Office of the U.S. Army Corps of Engineers (Natisha Stansberry, U.S. Army Corps of Engineers, unpublished data). Variables included daily pool elevation, discharge rate, and total precipitation over the previous three days. On dates when data were not collected, values were interpolated using the nearest dates with data available. All variables were used as reservoir condition covariates during analysis.

Data Analysis

Water quality parameters were tested for differences in multivariate dispersion between treatments (PERMDISP routine; PRIMER, Inc.), indicating whether water quality parameters were more extreme or variable in one treatment versus the other. A permutational multivariate analysis of covariance was conducted on normalized data comparing treated and control coves (PerMANCOVA, PRIMER, Inc.). The PerMANCOVA included four factors: Year, Date, Treatment, and Site. Each site was a treatment site or control site, making Site a nested random-effect factor within Treatment. Sites were visited multiple times each year, resulting in a repeated-measures design with Date nested as a random effect within Year. As is typical with repeated-measures studies, there were no true replicates, so the highest-level interaction was removed from the PerMANCOVA during analysis. The number of frost-free days at the time of sampling (FFD) and reservoir conditions were used as covariates. Due to the inclusion of covariates, the pseudo-F and p-values from Type I sums of squares are presented in the Results. If the main test was significant, pairwise comparisons were made to identify where differences occurred.

Zooplankton density was transformed using a fourth root transformation to reduce the influence of the most abundant taxa on

subsequent analyses. First, the zooplankton community was examined as a whole by creating a similarity matrix with the Bray-Curtis similarity index. A PerMANCOVA was applied to the matrix using the design described above and FFD, water quality parameters, and reservoir conditions as covariates. The dates 9/21/11 and 8/10/12 were excluded due to missing values for water quality parameters. If the main test was significant for fixed effects, pairwise comparisons were made to identify where differences occurred. Second, zooplankton data were used to calculate several additional metrics including the zooplankton ratio (i.e., ratio of Calanoida abundance to the combined abundance of Cladocera and Cyclopoida: Gannon and Stemberger 1978), Shannon diversity index, and the complement of Simpson's index representing overall taxon diversity and evenness (Pielou 1969). Each metric was submitted to PerMANCOVA separately. If main tests were significant, pairwise comparisons were made to identify where differences occurred. Third, zooplankton taxon was added to the analysis as a factor, allowing the identification of individual taxa responsive to treatment. The PerMANOVA included five factors: Year, Date, Treatment, Site, and Taxon. Again, Date was nested within Year and Site was nested within Treatment. Taxon was considered a fixed effect with no nesting. The similarity matrix was created using fourth root-transformed relative abundance only with Euclidean distance. If the main test was significant, pairwise comparisons were made to identify where differences occurred. Additionally, densities for each taxon were graphed by treatment as boxplots for visual interpretation.

Due to extremely low catch of macroinvertebrates, macroinvertebrate community composition is presented but not compared among sites, treatments or years. The community sampled was assumed to represent the current status of the Rathbun Lake macroinvertebrate community as a whole.

Fish data from otter trawls were used to compare fish community composition, length distribution, and catch rate between treatments. First, the fish community was examined as a whole by creating a similarity matrix with the Bray-Curtis similarity index. A PerMANOVA was applied to the matrix using the design described above for zooplankton. If the main test was significant for fixed effects, pairwise comparisons were made to identify where differences occurred. Following overall community tests, fish species was again added as a fixed factor to the PerMANOVA. Second, length frequency histograms were generated for each taxon by treatment, and Kruskal-Wallis tests were applied to identify differences between treatments for each taxon. Next, median lengths were calculated for taxa with significant Kruskal-Wallis tests. Finally, length frequency was examined with only the smallest group of fish within each species (assumed to be Age-0). In most cases, this included all fish less than 100 mm; for Largemouth Bass this included all fish less than 120 mm. Kruskal-Wallis tests were repeated, and median Age-0 lengths were presented for fish species with significant differences.

Results

Water quality dispersion did not differ between treatment and control sites, indicating that one was no more or less stable than the other (F = 0.135, p-value = 0.738). Similarly, cove treatment was not a significant factor in the PerMANCOVA (Pseudo-F = 1.596, p-value = 0.217), indicating no detectable differences in water quality between treatments (Table 1-1).

Changes in the Zooplankton Community

Zooplankton communities as a whole did not differ between treatments based on Bray-Curtis similarity (treatment factor Pseudo-F = 0.506, p-value = 0.927), Shannon diversity (treatment factor Pseudo-F = 1.311, p-value = 0.232), or Simpson index (treatment factor produced a negative sum of squares). Likewise, the zooplankton ratio did not differ between treatments (treatment factor Pseudo-F = 0.966, p-value = 0.428). Rather, zooplankton communities were most influenced by environmental factors such as reservoir pool elevation (Pseudo-F = 41.971, p-value = 0.001), number of frost-free days at the time of sampling (Pseudo-F = 25.430, p-value = 0.001), water temperature (Pseudo-F = 3.939, p-value = 0.009), and dissolved oxygen (Pseudo-F = 5.450, p-value = 0.007). Notably, zooplankton communities differed between years (Pseudo-F = 3.139, p-value = 0.009), with 2012 differing from 2013 in pairwise comparisons (p-value < 0.006). Much of this difference appeared to be in the densities of copepod nauplii and Rotifera, which may have been related to the individual identifying zooplankton each year. When these very small-bodied taxa were excluded, zooplankton communities appeared to be much more similar among years, dominated by Calanoida early in the summer and an increasing number of Cladocera later in the summer (Figure 1-3). Although treatment still had no effect following the removal of small-bodied taxa from analysis (Pseudo-F = 0.991, p-value = 0.48), the difference between years was also no longer significant (Pseudo-F = 1.532, p-value = 0.186).

When taxon was added to the PerMANOVA as a fixed factor, the interaction between taxon and treatment was marginally statistically significant (Pseudo-F = 1.452, p-value = 0.056). Despite a lack of statistical support, visual interpretation of zooplankton density boxplots by treatment implied that some taxa may be affected by treatment (Figure 1-4). Notably, large-bodied cladocerans and copepods tended to increase in density in treatment coves, whereas small-bodied cladocerans and many Rotifers tended to decrease in density in treatment coves.

Table 1-1. Water quality characteristics in coves at Rathbun Lake during summer, 2011-2013.

Parameter		Minimum	Q1	Median	Q3	Maximum
Temperature	°C	18.18	24.45	26.32	28.29	29.62
Dissolved oxygen	mg/L	2.39	5.06	6.53	8.25	12.76
Specific conductivity	µS/cm	0.01	0.20	0.21	0.24	0.47
pH		6	7	8	8	8
Total dissolved solids	g/L	0.01	0.13	0.14	0.15	0.31

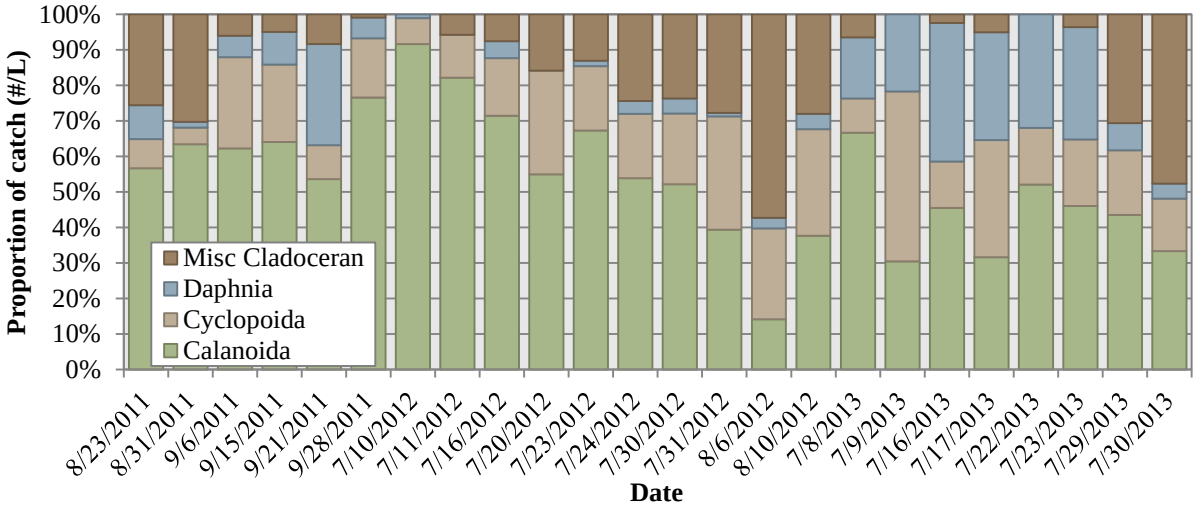

Figure 1-3. Catch composition (based on density averaged across sampling sites) of zooplankton from Rathbun Lake, Iowa, sampled during summer 2011-2013.

Macroinvertebrate Community

The macroinvertebrate community was sparse throughout the reservoir, with many samples yielding zero catch. Overall, Chironomidae (Diptera) dominated the macroinvertebrate community, followed by Ephemeroptera and Oligochaeta (Figure 1-5). Other taxa were represented by only one sampled individual.

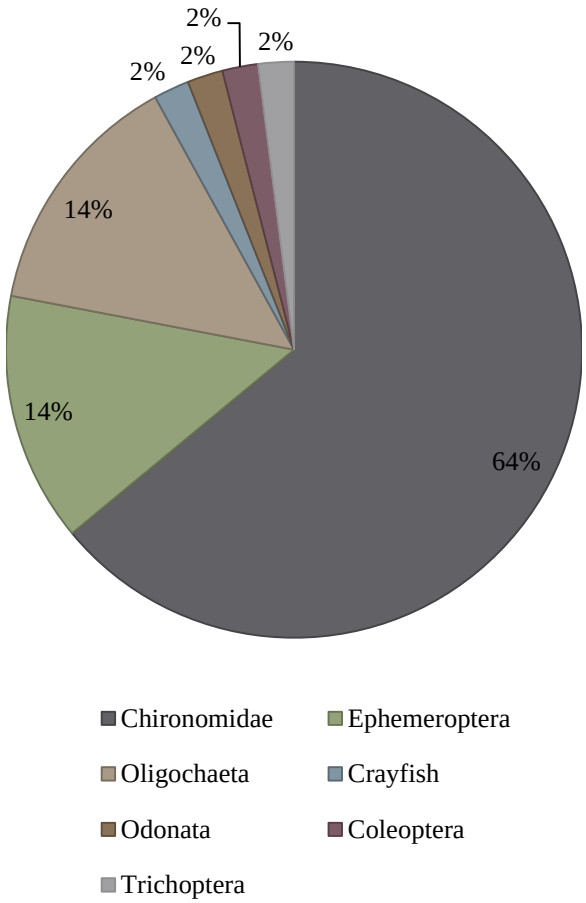

Figure 1-5. Macroinvertebrate community composition in Rathbun Lake, Iowa, sampled with a Ponar dredge from 2011-2013.

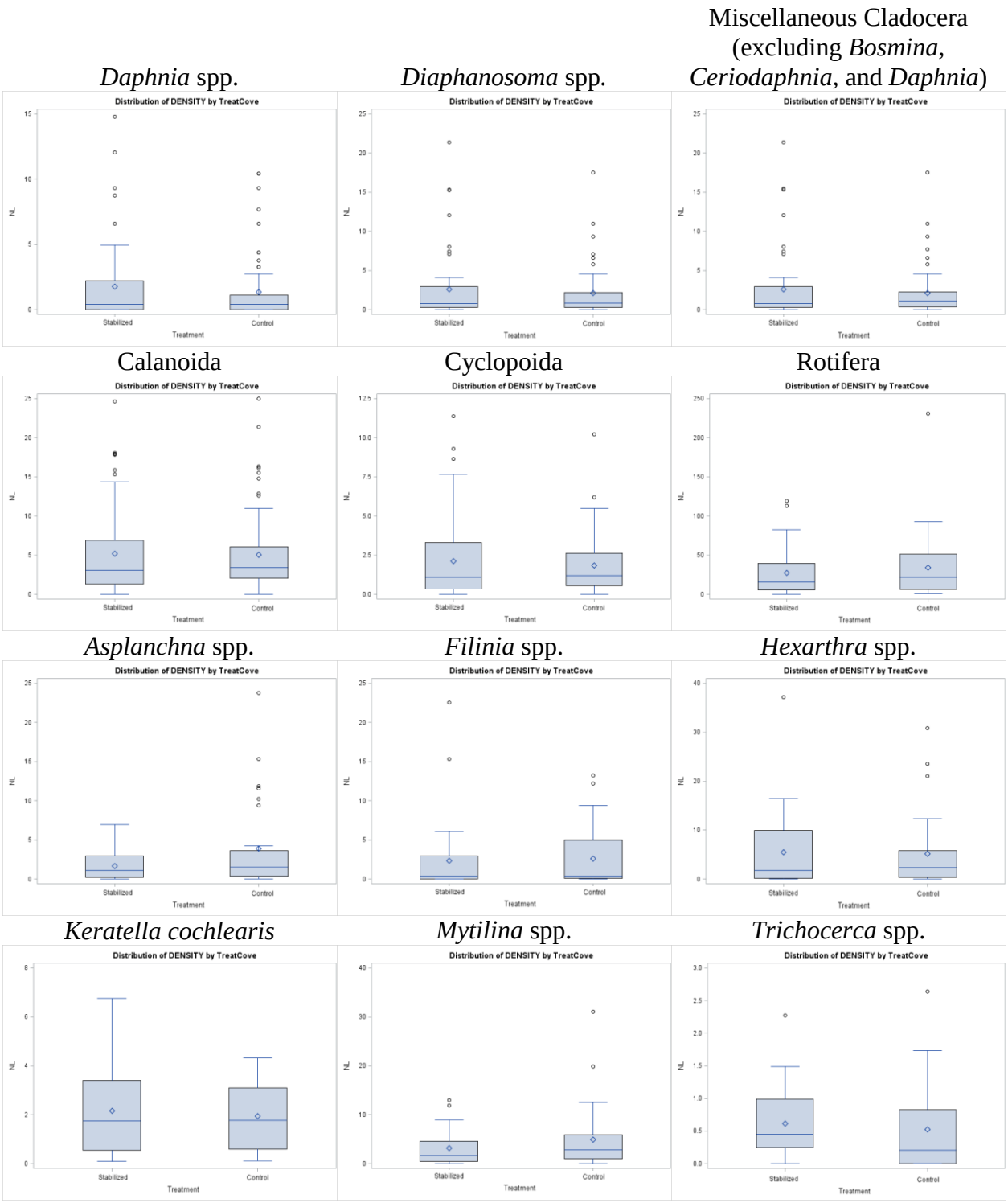

Figure 1-4. Distribution of density for selected zooplankton taxa in control and treatment coves in Rathbun Lake, Iowa, from 2011-2013.

Changes in the Fish Community

The fish community overall did not differ between treatments, but rather between years (Pseudo-F = 3.683, p-value = 0.029), between sites (Pseudo-F = 3.162, p-value = 0.001), and between samples within years (Pseudo-F = 3.346, p-value = 0.001). When fish taxon was added to the PerMANOVA as a fixed factor, the interaction between taxon and treatment was not significant (Pseudo-F = 0.902, p-value = 0.649). Again, despite a lack of statistical support, visual interpretation of catch rate boxplots by treatment implied that some species may be affected by treatment despite a lack of statistical significance (Figure 1-6). Notably, larval *Lepomis* species appeared to decrease overall in catch rate in treatment coves, while larval *Pomoxis* species appeared to have reduced variability in treatment coves. White Crappie, Black Crappie, and Largemouth Bass appeared to increase in catch rate in treatment coves, whereas Bluegill and White Bass appeared to decrease.

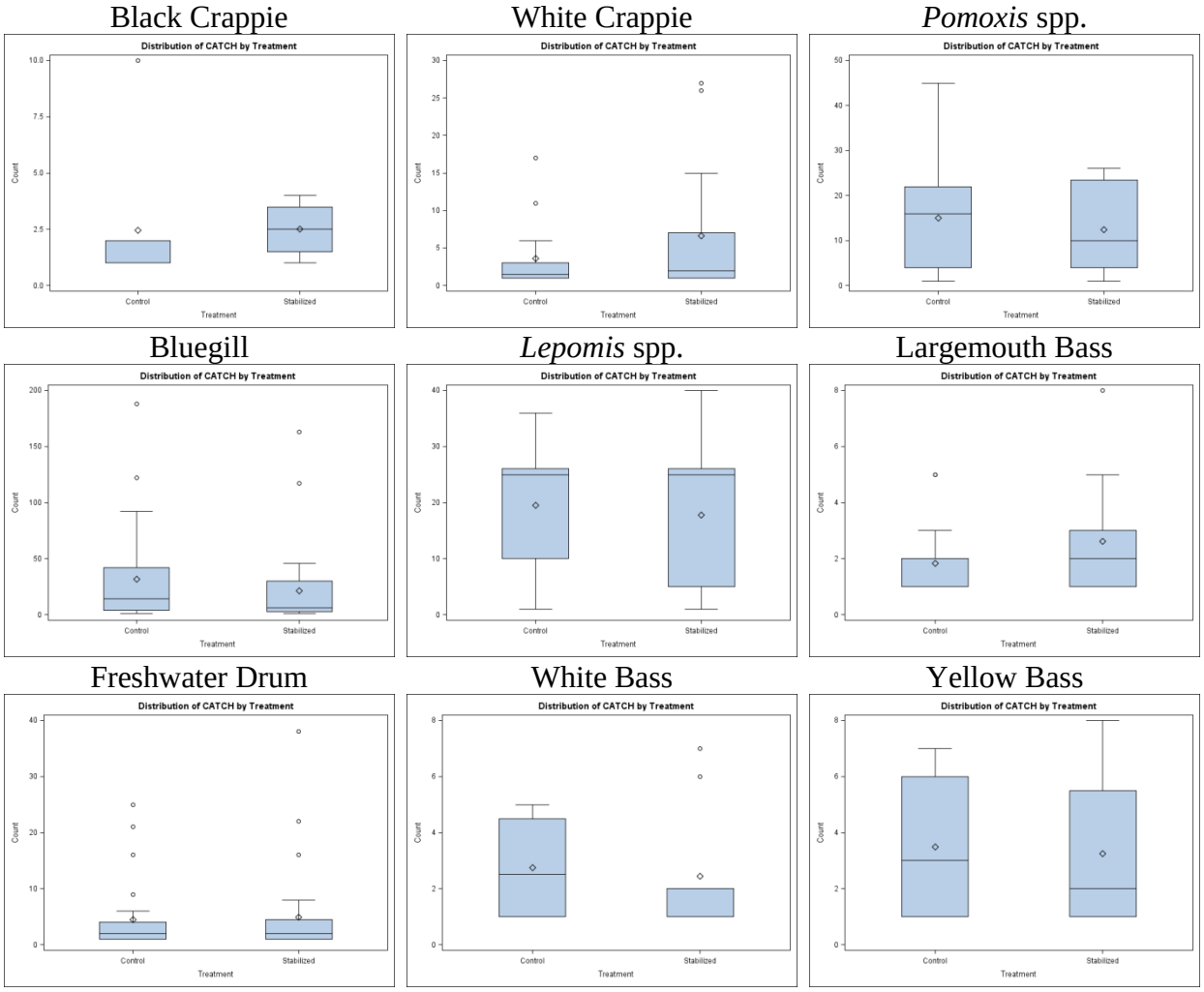

Figure 1-6. Distribution of catch rate for several fish taxa captured in control and treatment coves in Rathbun Lake, Iowa, from 2010-2013.

Length frequency distributions differed between treatments for some fish species (Table 1-2). Larger crappies which could be identified to species differed in length distribution between treatments, with Black Crappies having a greater median total length in treatment sites and White Crappies having a greater median total length in control sites. White Crappie had a wider range of total length in treatment sites than in control sites, potentially reflecting positive effects of shoreline stabilization through both increased Age-0 fish catch and increased adult catch (Figure 1-7). A difference was not observed for larval *Pomoxis* spp. Similarly, Bluegill differed in length distribution between treatments with Bluegill having a greater median total length in control sites; this difference was not observed for larval *Lepomis* spp. Largemouth Bass, White Bass, Gizzard Shad *Dorosoma cepedianum*, and Freshwater Drum *Aplodinotus grunniens* also had higher median total lengths in control sites than in treatment sites. Similar to White Crappie, high Age-0 Gizzard Shad catch in treatment sites resulted in a lower median length for Age-0 fish, but may still have reflected positive effects of shoreline stabilization due to increased Age-0 catch (Table 1-3). Other Age-0 fishes which showed significant differences in length frequency included Bluegill, Largemouth Bass and White Bass.

Table 1-2. Comparison of length distribution and median length (mm) for fish taxa captured with a benthic otter trawl in control and treatment coves at Rathbun Lake, Iowa, from 2010-2013.

Taxon	**Control**		**Treatment**		**Kruskal-Wallis Test**	
	N	Median TL	N	Median TL	Chi-square	P-value
Pomoxis spp.						
Black Crappie	22	51.5	10	157.5	3.910	0.0480
White Crappie	50	52.5	93	33.5	17.084	<0.0001
Pomoxis, unidentified	284		199		0.001	0.9804
Lepomis spp.						
Bluegill	1071	27.5	701	23.5	17.452	<0.0001
Lepomis, unidentified	664		480		1.370	0.2419
Other species						
Largemouth Bass	31	65.5	34	53.5	5.928	0.0149
Walleye	5		5		0.044	0.8340
Yellow Perch*	83		1		83.000	<0.0001
White Bass	22	45.5	22	38.5	6.209	0.0127
Yellow Bass	14		13		0.466	0.4947
Channel Catfish	14		19		1.236	0.2663
Gizzard Shad	11	37.5	74	23.5	14.379	0.0001
Freshwater Drum	131	43.5	139	39.5	3.797	0.0514
Common Carp*	3		4		0.500	0.4795
Bluntnose Minnow	496		393		0.058	0.8101

* Sample size too low for meaningful interpretation; corresponding figure and medians not presented.

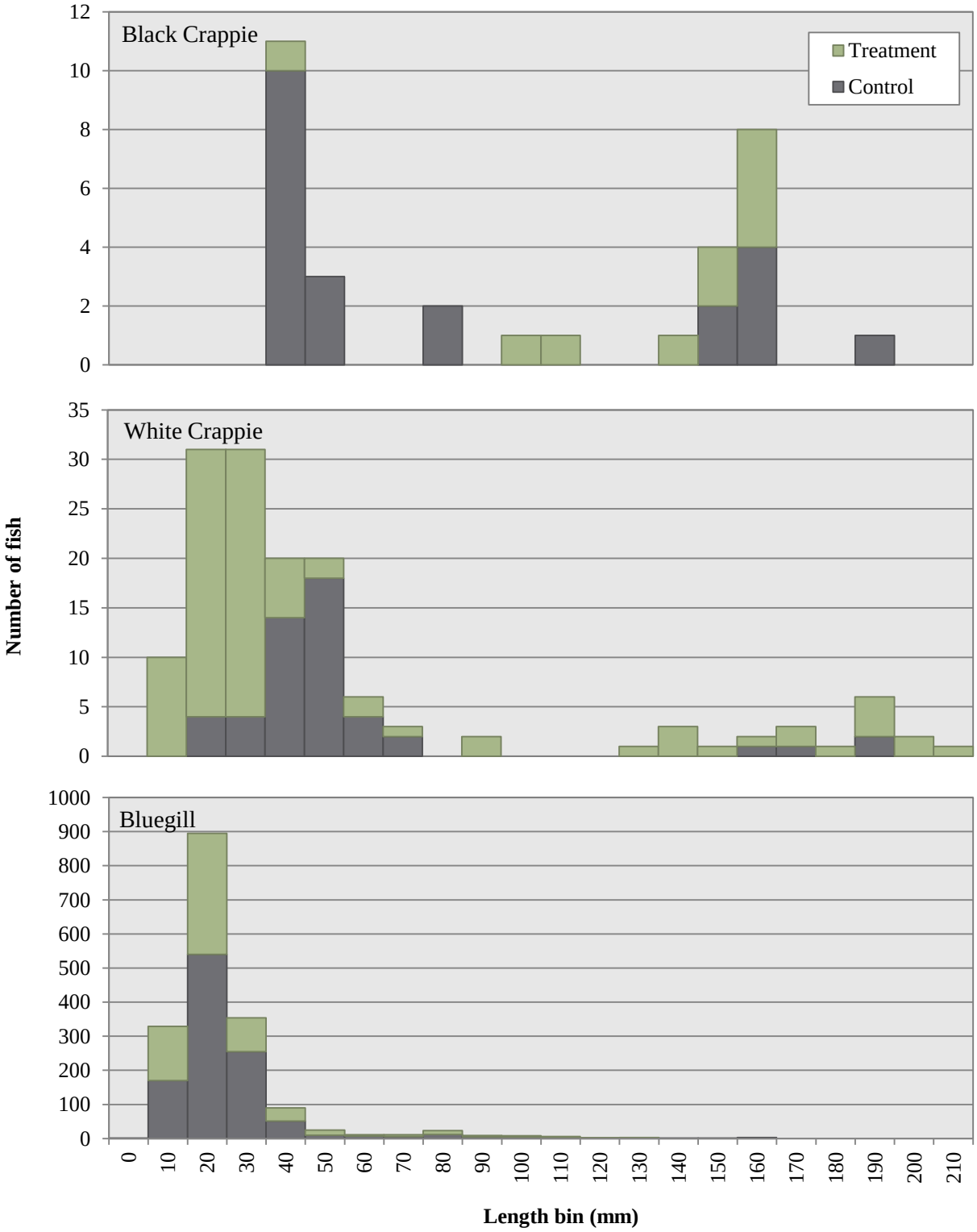

Figure 1-7. Length frequency distributions of selected fish species captured with benthic otter trawls in treatment and control coves of Rathbun Lake, Iowa.

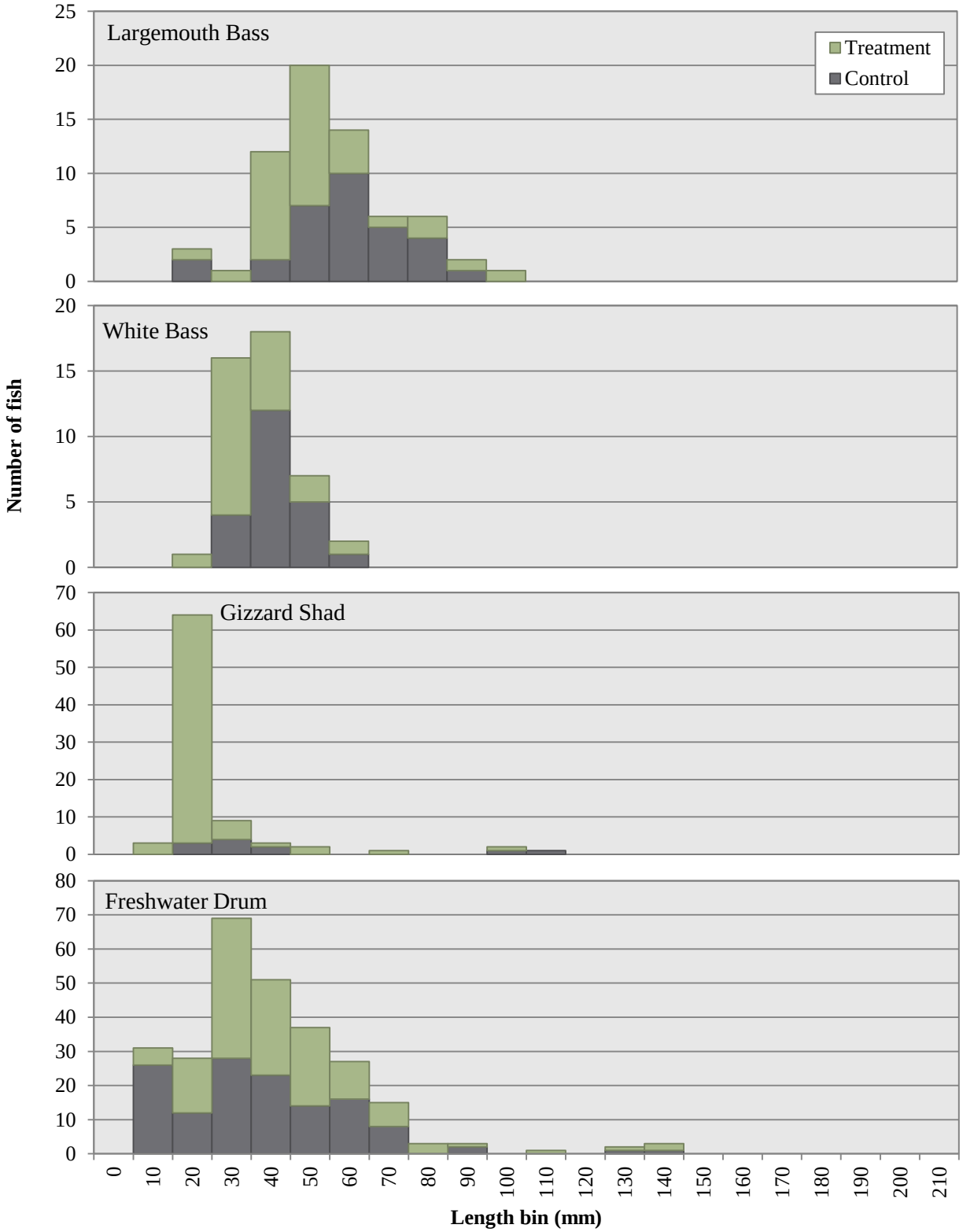

Figure 1-7. Continued.

Table 1-3. Comparison of Age-0 length distribution and median length (mm) for fish taxa captured with a benthic otter trawl in control and treatment coves at Rathbun Lake, Iowa, from 2010-2013.

Taxon	**Control**		**Treatment**		**Kruskal-Wallis Test**	
	N	Median TL	N	Median TL	Chi-square	P-value
Pomoxis spp.						
Black Crappie	15		1		0.976	0.3232
White Crappie	46	51.5	77	31.5	38.469	<0.0001
Pomoxis, unidentified	284		199		0.001	0.9804
Lepomis spp.						
Bluegill	1,057	27.5	691	23.5	18.549	<0.0001
Lepomis, unidentified	662		477		1.174	0.2787
Other species						
Largemouth Bass	31	65.5	34	53.5	5.928	0.0149
Walleye	2		1		0.500	0.4795
Yellow Perch*	83		1		83.000	<0.0001
White Bass	22	45.5	22	38.5	6.209	0.0127
Yellow Bass	14		12		1.180	0.2773
Channel Catfish	4		2		0.221	0.6386
Gizzard Shad	9	37.5	73	23.5	10.620	0.0011
Freshwater Drum	129		135		3.297	0.0694
Common Carp*	2		0			
Bluntnose Minnow	496		393		0.058	0.8101

*Sample size too low for meaningful interpretation; corresponding medians not presented.

Discussion

Riprap treatment of cove shorelines yielded few detectable differences in water quality, zooplankton communities or fish communities in Rathbun Lake. Despite weak statistical support, several comparisons between treatment and control coves appeared to be potentially ecologically meaningful.

First, specific zooplankton taxa including *Daphnia* spp., cyclopoid copepods, calanoid copepods, and certain rotifers such as *Hexarthra* spp. and *Trichocerca* spp. were somewhat more abundant in treatment coves than in control coves. In contrast, other rotifers including *Asplanchna* spp., *Filinia* spp., and *Mytilina* spp. were less abundant in treatment coves. Large-bodied cladocerans such as *Daphnia* spp. have been documented to feed less efficiently in turbid water but also find refuge from zooplanktivorous predators (Gardner 1981; Arruda et al. 1983; McCabe and O'Brien 1983). In a highly turbid system like Rathbun Lake, the small (statistically insignificant) difference made in turbidity due to shoreline stabilization apparently favored large-bodied cladocerans in treatment coves; this was corroborated by a simultaneous reduction in most rotifers which is supported by the literature (Gilbert 1988; Cuker and Hudson 1992). Unlike smaller-bodied cladocerans, large-bodied cladocerans such as *Daphnia* spp. can cause high rotifer mortality at densities as low as 1 individual per liter (Gilbert 1988); this study documented densities between 0 and 5 individuals per liter in treatment coves. The increase in *Hexarthra* and *Trichocerca* spp. in treatment coves was also supported by the

literature; both genera are greatly reduced in turbid water (Miracle et al. 2007). In the absence of cladocerans, such as may occur in highly turbid systems, tolerant rotifers such as *Keratella cochlearis*, *Brachionous calyciflorus*, and *Polyarthra vulgaris* can dominate the zooplankton community (Kirk and Gilbert 1990).

Second, specific fish taxa including White and Black Crappies and Largemouth Bass were somewhat more abundant in treatment coves than in control coves. Age-0 White Crappie and Gizzard Shad, in particular, were relatively more abundant in treatment coves than in control coves. As implied by zooplankton results, riprap treatment may have reduced suspended sediments or altered other water quality parameters at a level below detection. This seemingly minor difference may have been enough to influence nesting site selection by adult fishes even if all sites had water quality parameters within a suitable range (e.g., Phelps et al. 2009). High turbidity in Rathbun Lake between 1980 and 1983 was associated with reduced age-0 crappie catch (Mitzner 1991). Another possibility is that increased crustacean zooplankton densities in treatment coves provided better forage for zooplanktivorous and larval piscivorous fishes, indirectly leading to increased catch rates for those fish species (White Crappie: Sammons et al. 2001). Crappies and Largemouth Bass would additionally find more adequate forage with high age-0 Gizzard Shad availability during subsequent shifts to piscivory throughout the summer.

Although crappies do tend to aggregate near riprap, they do not typically prefer riprap for nesting sites. A previous study at Rathbun Lake indicated that the substrate firmness associated with the highest age-0 crappie catch was 4 inches of penetration (whereas riprap is 0 inches; Mitzner 1991). Black Crappie adults in two South Dakota lakes tended to nest in the most protected areas available regardless of substrate firmness (Pope and Willis 1997). Black Crappie in a small urban lake preferentially nested on clay or sand substrates in lieu of gravel (but hard rock or riprap substrates were not available in that study; Phelps et al. 2009). Therefore, the riprap treatment may have affected crappie catch rates through aggregation rather than increasing crappie production. The reduction in Bluegill catch rate in treatment coves was somewhat unexpected, as Bluegill typically prefer harder substrate to muck or silt substrate, but treatment coves also lacked other preferred Bluegill habitat components including aquatic vegetation and gravel (Gosch et al. 2006). Age-0 Bluegill typically require vegetation to avoid predation (Mittelbach 1981). However, the reason for control coves providing better habitat than treatment coves in this study remains unknown. In any case, differences in substrate firmness between treatment and control coves did not appear to be the driving factor effecting differences in these species' catch rates.

Age-0 White Bass catch rates were also reduced in treatment coves. Diet overlap with age-0 piscivores such as Walleye has been demonstrated (Beck et al. 1998), and White Bass may have been outcompeted in treatment coves of Rathbun Lake. However, this explanation seems unlikely, as crappies are more gape-limited than either Largemouth Bass or White Bass (Michaletz 1997). Age-0 White Bass consumed adult copepods and small-bodied cladocerans (e.g., *Bosmina*, *Diaphanosoma*) and avoided *Daphnia* in a Kansas reservoir (Quist et al. 2002); this further obscures the reason for

any reduction of White Bass in treatment coves as treatment coves tended to have more copepods and *Diaphanosoma* than control coves. Understanding of the effect of shoreline stabilization with riprap on White Bass could be important to managing the recreational fishery if White Bass are an important component, as is somewhat the case at Rathbun Lake. White Bass compose a part of the recreational catch each year, but crappies and Walleye are considerably more important in Rathbun Lake.

Management Implications and Recommendations

This study entailed a substantial amount of field work during data collection and laboratory work during sample processing and still failed to detect many of the changes expected from improved fish habitat. This implies a massive investment of time and resources required to achieve statistically significant results. Monitoring habitat projects in a large reservoir like Rathbun Lake to measure "success" (e.g., of brush piles, shoreline armoring, or artificial structures) simply may not be feasible within the limitations of state agency resources. This limitation should be considered before entering into future habitat evaluations. Alternative study designs or locations could also be considered to enhance the statistical rigor of the study and to eliminate confounding factors wherever possible.

The ecological significance of this study may be more important than the statistical significance of its results. Shoreline stabilization appeared to have some effects on water quality and the zooplankton and fish communities at a local level, although most differences were not statistically significant. Riprap treatment appeared to benefit crappies, which were the primary focus of the study. Enhancement of the Rathbun Lake crappie fishery could benefit even more from additional bank armoring with riprap in other strategically placed areas (see Mitzner 1995). The entire shoreline of Rathbun Lake is publicly held, increasing the ability of resource managers to identify and address issues. The reservoir is operated by U.S. Army Corps of Engineers, and much of the land is managed cooperatively between the Corps and the Iowa Department of Natural Resources. Continuation of agency partnerships could greatly benefit the recreational fishery at Rathbun Lake.

Acknowledgments

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STUDY 7037 COMPLETION REPORT
FISHERIES RESEARCH

STATE:	Iowa	**TITLE**:	Monitoring of the zooplankton and ichthyoplankton communities of a large southeast Iowa reservoir (Rathbun Lake, Appanoose County) following detection of Zebra Mussels
JOBS:	5, 7		

The following chapter has been formatted for submission to Lake and Reservoir Management, a peer-reviewed journal of the North American Lake Management Society, as a manuscript entitled:

Monitoring of the zooplankton and ichthyoplankton communities of a large southeast Iowa reservoir (Rathbun Lake, Appanoose County) following detection of Zebra Mussels

Abstract – Rathbun Lake is the second-largest waterbody and fourth-most popular recreational fishery in Iowa. The reservoir was exposed to Zebra Mussels *Dreissena polymorpha* in 2007, and follow-up monitoring detected low densities of Zebra Mussel veligers beginning in 2008. The potential for successful Zebra Mussel establishment in Rathbun Lake appeared to be high given its environmental conditions, and the potential effects had implications for the reservoir as a fishery, broodstock source, and water supply. The objectives of this study were to compare the zooplankton and ichthyoplankton communities in Rathbun Lake to historical data and establish a baseline condition and to identify any subsequent changes that may be related to Zebra Mussel infestation. Zooplankton and larval fish were collected from fixed historical sites from 2010 to 2013 and compared to historical zooplankton (1995-1998) and ichthyoplankton (1993-1999) datasets collected with the same methods. Time periods were compared using multivariate analysis of covariance with reservoir conditions (e.g., pool elevation) as covariates. Current-day zooplankton and ichthyoplankton samples were used to test short-term directional trends from 2010 to 2013. Jonckheere-Terpstra tests were conducted by site for major taxa, with the assumption that density/catch rate would change directionally over time if Zebra Mussel infestation was actively altering the system during the study. Zooplankton communities did not differ between time periods when small-bodied taxa were excluded, but rather were most influenced by the number of frost-free days at the time of sampling. Ichthyoplankton communities did differ between time periods, among sites and among years within time periods, and week of the year was a highly significant covariate affecting fish community composition. The most notable differences between historical and current-day samples were the reduced percent composition of Walleye and increased percent composition of *Lepomis* spp. No short-term trends in zooplankton or ichthyoplankton were detected, and Zebra Mussels have not been detected in the reservoir since 2011. Generally, zooplankton and ichthyoplankton did not differ substantially from historical samples, and current-day samples were believed to represent a reasonable baseline to which future samples can be compared if Zebra Mussels do successfully establish in Rathbun Lake.

Introduction

In October 2007, adult Zebra Mussels *Dreissena polymorpha* were found attached to the side of a boat in a Rathbun Lake marina. Iowa Department of Natural Resources (DNR) staff did not find adults in follow-up surveys but did collect very low numbers of veligers in water samples from 2008 to 2011 (K. Bogenschutz, Iowa DNR, personal communication). Although the effects of Zebra Mussels have been thoroughly investigated in the Great Lakes (e.g., Schloesser and Nalepa 1994; Trometer and Busch 1999; Ackerman et al. 2001) and in large rivers (e.g., Caraco et al. 1997; Ricciardi et al. 1997; Jack and Thorp 2000), the effects are lesser known in large reservoirs. However, the potential for successful Zebra Mussel establishment in Rathbun Lake appeared to be high based on waterbody size and depth, hardness, and temperature (Strayer 1991).

Zebra Mussels typically impact the aquatic community through competition for food resources with native mussels (Schloesser and Nalepa 1994; Caraco et al. 1997; Parker et al. 1998; Baker and Levinton 2003), selective feeding of phytoplankton and photosynthetic bacteria (Vanderploeg et al. 2001), physical interference of feeding by native mussels (Haag et al. 1993; Parker et al. 1998), alteration of nutrient cycling (Mellina et al. 1995) and nutrient ratios (Nicholls et al. 1999), and alteration of water column stratification (Ackerman et al. 2001). It was suspected that, were Zebra Mussels to successfully colonize Rathbun Lake, they would have similar effects in the reservoir as those observed in the Great Lakes and large rivers. With their ability to attain high densities quickly, Zebra Mussels may rapidly exert a bottom-up influence on aquatic food webs, affecting zooplankton and both planktivorous and larval fishes that are dependent on zooplankton as a food source. The presence of adult Zebra Mussels in the Ohio River negatively affected cladocerans including *Bosmina* and *Diaphanosoma*, the copepod *Diacyclops*, and certain rotifer species including *Polyarthra vulgaris* and *Keratella crassa* (Jack and Thorp 2000). The authors suspected Zebra Mussels altered the zooplankton community through both indirect pathways (e.g., competition for food resources) and direct pathways (e.g., predation, especially on smaller-bodied zooplankton). Zooplanktivorous fish such as Gizzard Shad *Dorosoma cepedianum* may decline as food sources are reduced, in turn causing a decline in piscivorous fishes which are often important sport fish species. Gizzard Shad are key components of White Crappie *Pomoxis annularis* and Walleye *Sander vitreus* diets (Momot et al. 1977; Pflieger 1997), both important sport fish species in Rathbun Lake. Age-0 Gizzard Shad abundance during the summer and fall is a key determinant of recruitment, growth and condition of sport fishes in reservoirs, and food deprivation during the larval stage may lead to reduced recruitment, stunted growth and reduced overwinter survival (Garvey et al. 1998). Similarly, direct competition between Zebra Mussels and sport fish species prior to the onset of piscivory could lead to food deprivation, if zooplankton abundance was reduced (Sammons et al. 2001). In addition to being one of the premier crappie fisheries in the state, Rathbun Lake is a major Walleye broodstock lake for Iowa DNR hatcheries. Any detrimental effects to Walleye recruitment and growth in Rathbun Lake may affect brood fish collections and, hence, the Walleye stocking program for the state.

Zebra Mussels are highly efficient colonizers, attaching to any hard substrate including native mussel shells. They have been known to establish densities of 1,500-4,000 individuals/m^2 in large rivers (Ricciardi et al. 1997). This can physically inhibit native mussel filtration and feeding (Parker et al. 1998). For the same reason, Zebra Mussels can also interfere with water supplies by clogging intakes and pipelines (Elliott et al. 2005). Therefore, they pose a serious risk to the Rathbun Regional Water Association, which provides water to more than 70,000 people in 18 counties in southeast Iowa and northeast Missouri. The reservoir also provides water to the largest hatchery in Iowa, the DNR's Rathbun Fish Hatchery. Rathbun Fish Hatchery grows fish for stocking across the state and has also inherited increased costs due to the requirements of water treatment for Zebra Mussel infestation. This is to mitigate the possibility of spreading Zebra Mussels through stocking fish raised in water potentially infested with Zebra Mussel veligers (Horvath et al. 1996).

When this study began, Zebra Mussels had been detected during isolated sampling events but had not appeared to successfully establish any colonies. The objectives of this study were therefore two-fold: 1) to compare zooplankton and ichthyoplankton communities in Rathbun Lake to historical data and establish a baseline condition, and 2) to identify any subsequent changes that occurred in the plankton community due to Zebra Mussel infestation.

Methods

Study Location

Rathbun Lake is an 11,000-acre flood control and water supply reservoir located in southeast Iowa. Typical discharge rates ranged from 25 to 1,500 cfs during 2010-2013, with a maximum capacity of 5,000 cfs. The water residence time is approximately 43.5 days. Historical fixed sampling sites were located throughout the reservoir in both openwater and tributary arms (Figure 2-1) and were sampled at the surface. Some sites were also sampled at the subsurface and are labeled "A" (surface) and "B" (subsurface). Sites 5 and 6 were added in 2012 and Site 10 was added near the location where Zebra Mussel veligers had been detected in the Buck Creek tributary arm and sampled from 2010-2011.

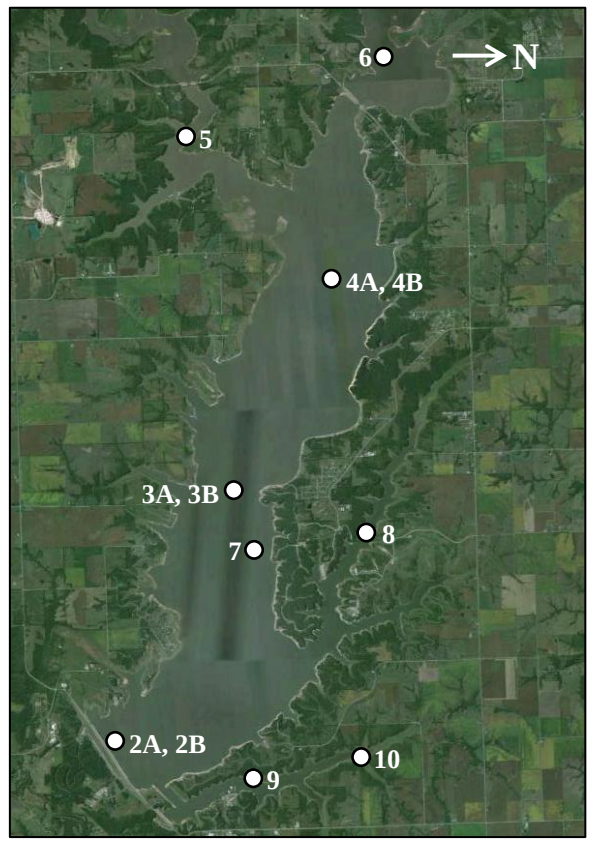

Figure 2-1. Rathbun Lake, Iowa. Sites are shown including surface samples (A) and subsurface samples (B). Sites 5, 6, and 10 were not sampled historically. From: Mitzner (1995)

Data Collection

Sites were sampled for fish and zooplankton between May and July from 2010 to 2013. Sites 5 and 6 were added in 2012. Each site was sampled at least 11 times per summer, with an average of 17 times per summer. Monitoring included measuring water quality, sampling zooplankton, and sampling ichthyoplankton. Water quality was measured at the surface using a YSI 556; parameters included water temperature (degrees Celsius), dissolved oxygen (mg/L), specific conductivity (µS/cm), pH, and total dissolved solids (g/L).

Zooplankton were sampled by pulling a Wisconsin plankton net (80-micron mesh). Samples were preserved with 3-5% formalin solution and stored in glass jars until laboratory processing. Zooplankton samples were processed by examining three 1-mL subsamples in a Sedgewick-Rafter cell using a compound microscope set at 40X-100X. Zooplankton were identified to various taxonomic levels using the taxonomic key of Pennak (1978). Copepod crustaceans were identified to order or identified as nauplii; cladocerans and rotifers were identified to genus. Total number per liter water volume was calculated for each taxon for each sample.

Fish were sampled using a meter net towed behind the boat for approximately ten minutes at 3.2 km/h along a predetermined transect. Samples were taken during the daytime only after unsuccessful nighttime sampling (results not presented). The boat speed and tow time were combined to calculate a known sampled volume of water. For subsurface samples, a depressor board was used to hold the net deeper in the water column. After the net was retrieved, each sample was poured into a quart jar with a resulting approximate total concentration of 3-5% formaldehyde for transport and storage.

Historical data were obtained from Iowa Department of Natural Resources' Large Impoundments Research archives (published in part by Mitzner [1995]). Zooplankton and larval fish were sampled using the same methods as described above. Zooplankton data were obtained from 1995-1998, providing the most recent four years of data available. Zooplankton were only identified to a few, specific taxonomic levels in historical datasets (i.e., *Bosmina*, *Ceriodaphnia*, *Daphnia*, Copepoda, nauplii, and Rotifera). Larval fish data were obtained from 1993-1999, providing the most recent seven years of data available.

Daily reservoir condition data were obtained from the Rathbun Office of the U.S. Army Corps of Engineers (Natisha Stansberry, U.S. Army Corps of Engineers, unpublished data). Variables included daily pool elevation, discharge rate, and total precipitation over the previous three days. Water temperature was not used because it was not collected by the Corps prior to the 2000s. On dates where data were not collected, values were interpolated using the nearest dates with data available. All variables were used as reservoir condition covariates during analysis.

Data Analysis

To determine whether current day samples were similar to historical samples, both zooplankton and larval fish communities were compared between the 1990s and 2010s using permutational multivariate analyses of covariance (PerMANCOVAs).

Zooplankton density was transformed using a fourth root transformation to reduce the

influence of the most abundant taxa on subsequent analyses. The zooplankton community was examined as a whole by creating a similarity matrix with the Bray-Curtis similarity index. Several date-site combinations were excluded due to complete lack of zooplankton capture, which resulted in an undefined similarity matrix (5/10/96 Site 3, 5/16/96 Site 9, 5/5/97 Sites 3 to 9, 5/7/97 Sites 2 and 9, 5/8/97 Sites 3 to 9, and 5/28/13 Site 9). A PerMANCOVA was applied to the matrix using the design described above and FFD and reservoir conditions as covariates. The PerMANCOVA was applied using Sample Date nested within Year, nested within Time Period and Site as a fixed factor. Due to the inclusion of covariates, the pseudo-F and p-values from Type I sums of squares are presented in the Results. If the main test was significant for fixed effects, pairwise comparisons were made to identify where differences occurred.

Larval fish catch rate was transformed using a fourth root transformation to reduce the influence of the most abundant taxa on subsequent analyses. The larval fish community was examined as a whole by creating a similarity matrix with the Bray-Curtis similarity index. Numerous date-site combinations were excluded due to complete lack of fish capture, which resulted in an undefined similarity matrix; however, nearly 800 records were still available resulting in no concerns regarding sample size. A PerMANCOVA was applied to the matrix using the design described above and FFD and reservoir conditions as covariates. The PerMANCOVA was applied using Sample Date nested within Year, nested within Time Period and Site as a fixed factor. Due to the inclusion of covariates, the pseudo-F and p-values from Type I sums of squares are presented in the Results. If the main test was significant for fixed effects, pairwise comparisons were made to identify where differences occurred.

Current-day samples were also used to test short-term trends in zooplankton and ichthyoplankton communities, specifically abundance of the more common taxa. Jonckheere-Terpstra tests were conducted by site, with ordered alternatives defined by year. Only taxa and sites sampled at least three years were tested. It was expected that trends in abundance (indexed by density) would change directionally (either up or down) over time if Zebra Mussel infestation was actively altering the system during the study. Monte Carlo simulation was used to calculate one-sided p-values.

Results

Comparison to Historical Data

Zooplankton communities as a whole did differ between historical and current time periods (Pseudo-F = 3.4628, p-value = 0.026). However, much of this difference appeared to be in the densities of copepod nauplii and Rotifera, which may have been related to the individual identifying zooplankton each year. When these very small-bodied taxa were excluded, zooplankton communities appeared to be much more similar among years (Pseudo-F = 0.43044, p-value = 0.9; Figure 2-2). Rather, zooplankton communities were most influenced by the number of frost-free days at the time of sampling (Pseudo-F = 4.7193, p-value = 0.037), and there was significant variation among years within time periods (Pseudo-F = 13.546; p-value = 0.001). Additional date-site combinations had to be removed to perform this follow-up analysis (6/16/96 Site 8, 7/6/95 Sites 7 to 9, 7/11/95 Sites 2 to 9, 7/20/95 Sites 2, 3 and 8, 6/7/12

Sites 2 to 7, 6/11/12 Sites 3 and 4, 6/14/12 Sites 5 and 8, 6/18/12 Sites 7 and 8, 6/21/12 Sites 3 and 6, 6/25/12 Sites 4, 7 and 8, and 6/28/12 Sites 5, 7 and 9). Overall, the zooplankton community was very similar between historical and current time periods.

Because historical samples were aggregated into higher-level taxonomic groups, it is difficult to characterize the zooplankton community with adequate detail; given the results above, the current zooplankton samples can characterize the Rathbun Lake community and represent that of the past. A total of 25 zooplankton taxa were found in Rathbun Lake between 2010 and 2013 (Table 2-1). The most abundant group was Rotifera, followed by Copepoda and associated nauplii. Among the cladocerans, *Daphnia* was most common.

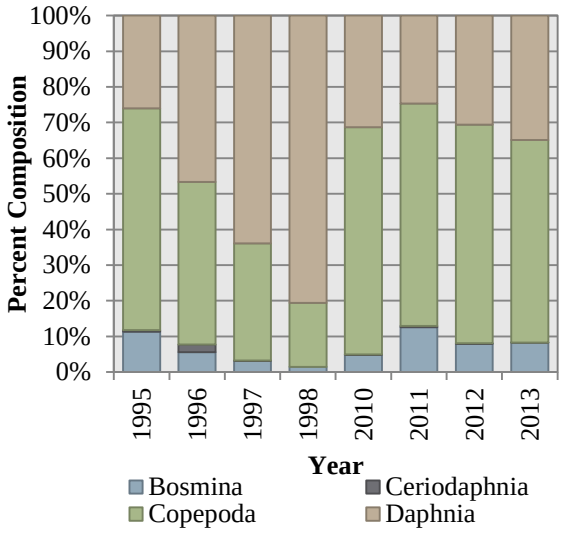

Figure 2-2. Percent composition by major zooplankton taxa sampled from Rathbun Lake, Iowa, from 1995-1998 and 2010-2013. Rotifers were excluded due to inconsistencies in sample collection and analysis.

Specific years within time periods did differ (Pseudo-F = 13.546, p-value = 0.001). The years 1996 and 1998 differed (Pseudo-F = 4.2948, p-value = 0.004), 2011 differed from 2013 (Pseudo-F = 2.4798, p-value = 0.005), and 2012 differed from both 2011 (Pseudo-F = 7.5229, p-value = 0.001) and 2013 (Pseudo-F = 3.0346, p-value = 0.004). The year 2012 also had numerous zero-catch samples, which may have been related to ongoing drought that affected Iowa that year.

Table 2-1. Zooplankton taxa found in Rathbun Lake, Iowa, between 2010 and 2013.

Taxon	
Cladocera	
	Bosmina
	Ceriodaphnia
	Chydorus
	Daphnia
	Macrothricidae
	Scapholeberis
Copepoda	
	Calanoida
	Cyclopoida
	Nauplius
Rotifera	
	Asplanchna
	Euchlanis
	Keratella
	Lecane
	Lepadella
	Momommata
	Monostyla
	Platyias
	Squatinella
	Synchaeta
	Testudinella
	Trichotria
	Other (Unidentified rotifer)
Hydracarina	
Ostracoda	

Despite substantial variability, zooplankton community composition changed throughout the summer in a similar pattern each year, with cladocerans and copepods peaking earlier and rotifers peaking later (Figure 2-3). *Ceriodaphnia* tended to appear before *Bosmina*, whereas *Daphnia* and Copepoda both peaked early and slowly declined throughout summer (Figure 2-4). Mean densities are presented averaged across sites because, according to PerMANCOVA, site was not a significant factor affecting zooplankton communities (Pseudo-F = 1.2263, p-value = 0.212).

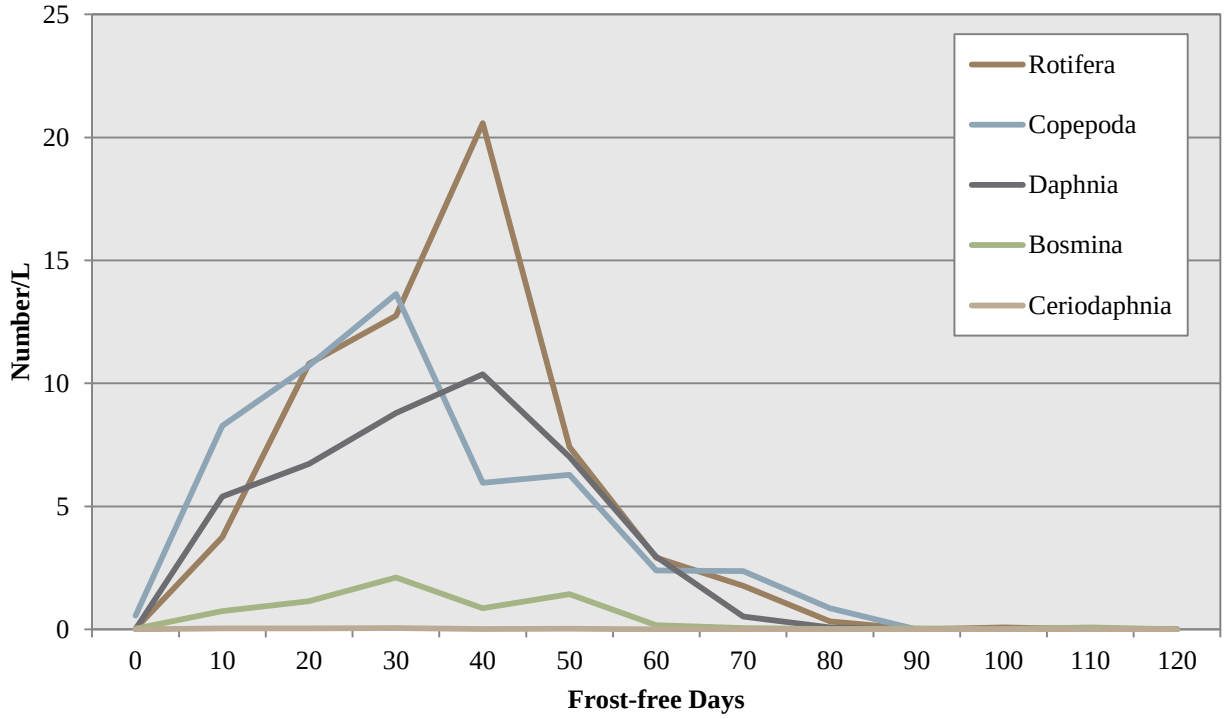

Figure 2-3. Zooplankton densities by frost-free day, averaged across all years (1995-1998, 2010-2013) and sites at Rathbun Lake, Iowa. Rotifera are included despite inconsistencies in sample collection and analysis.

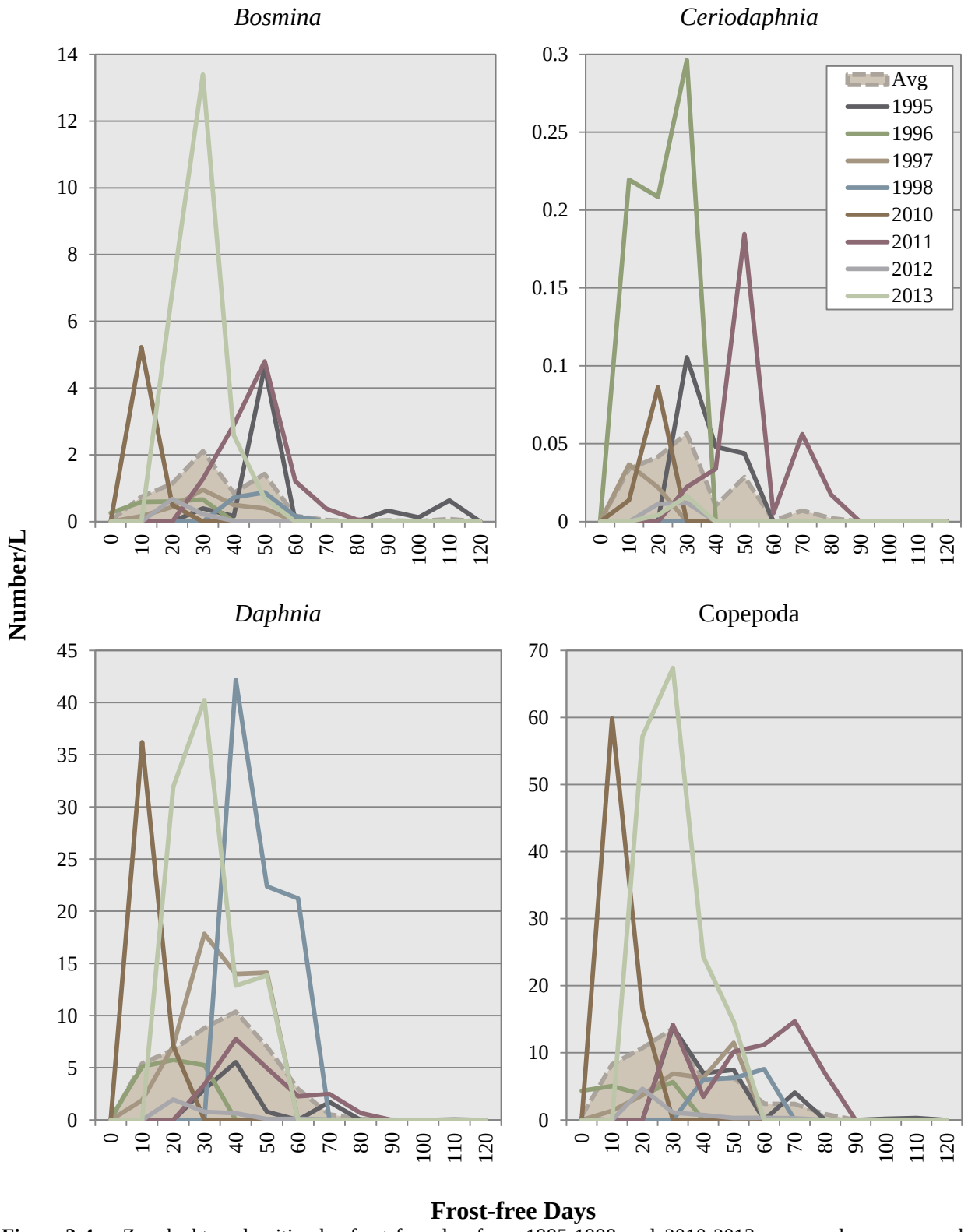

Figure 2-4. Zooplankton densities by frost-free day from 1995-1998 and 2010-2013, averaged across sample sites. The average trend across years is shown with a dashed line.

Larval fish communities as a whole also differed between historical and current time periods (Pseudo-F = 4.2259, p-value = 0.008) despite significant variation explained by sites (Pseudo-F = 1.9808, p-value = 0.002) and years within time periods (Pseudo-F = 4.2468, p-value = 0.001; Figure 2-5). The week of the year was also a highly significant covariate (Pseudo-F = 40.599, p-value = 0.001). Because of this, additional results for larval fish are presented by week and site.

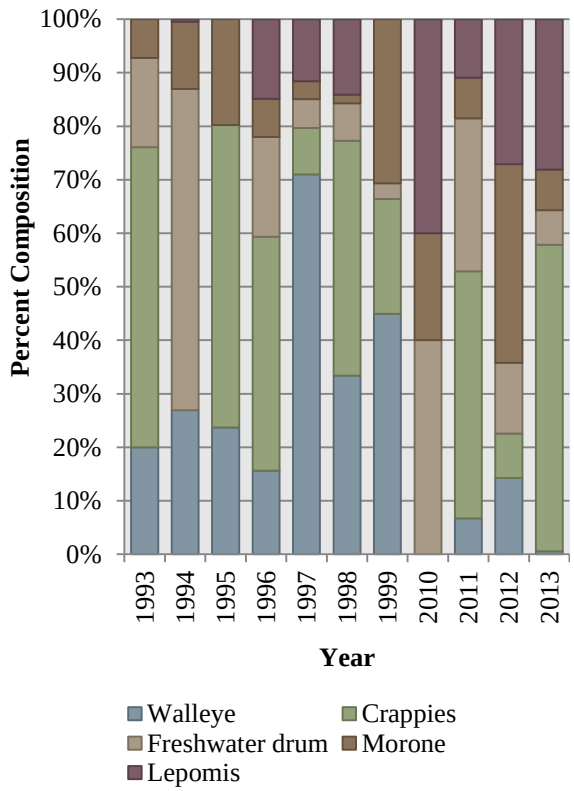

Figure 2-5. Percent composition by major fish taxa sampled from Rathbun Lake, Iowa, from 1993-1999 and 2010-2013. Gizzard Shad were excluded because their abundance masked trends in other taxa.

Although high variability among years within time periods makes statistical testing difficult, larval fish community composition did appear to change, specifically Walleye. During the 1990s, Walleye typically composed between 20 and 70% of the larval fish community (excluding Gizzard Shad); during the 2010s, Walleye composed between 0 and 15% and did not appear in samples during two of four years. Gizzard Shad were excluded from this comparison due to extremely high variability in catch which masked trends in other taxa. *Lepomis* spp. typically composed between 0 and 15% of the larval fish community in the 1990s, whereas they composed between 10 and 40% during the 2010s. These changes may reflect larger fishery changes, and coincide with known declines in the Rathbun Lake Walleye population (M. Flammang, Iowa Department of Natural Resources, personal communication). Similar trends were not observed for other major taxa.

Despite substantial variability, larval fish community composition changed throughout the summer in a similar pattern each year (Figure 2-6). Typically, Walleye peaked early in summer, followed by White Bass and crappie, and lastly Bluegill and other *Lepomis* spp. (Figure 2-7). Freshwater Drum peaked very late in the summer, whereas Gizzard Shad dominated the larval fish community for the majority of the summer. Sites also showed significant differences in the larval fish community. Generally, mean catch rates were higher for Walleye at Site 7, for crappies at Sites 8 and 9, Freshwater Drum at Site 4, *Morone* spp. at Site 6, and *Lepomis* spp. at Site 8 (Figure 2-8). Historical catch rates tended to be higher than current catch rates regardless of taxon. Again Gizzard Shad were excluded due to their extremely high abundance.

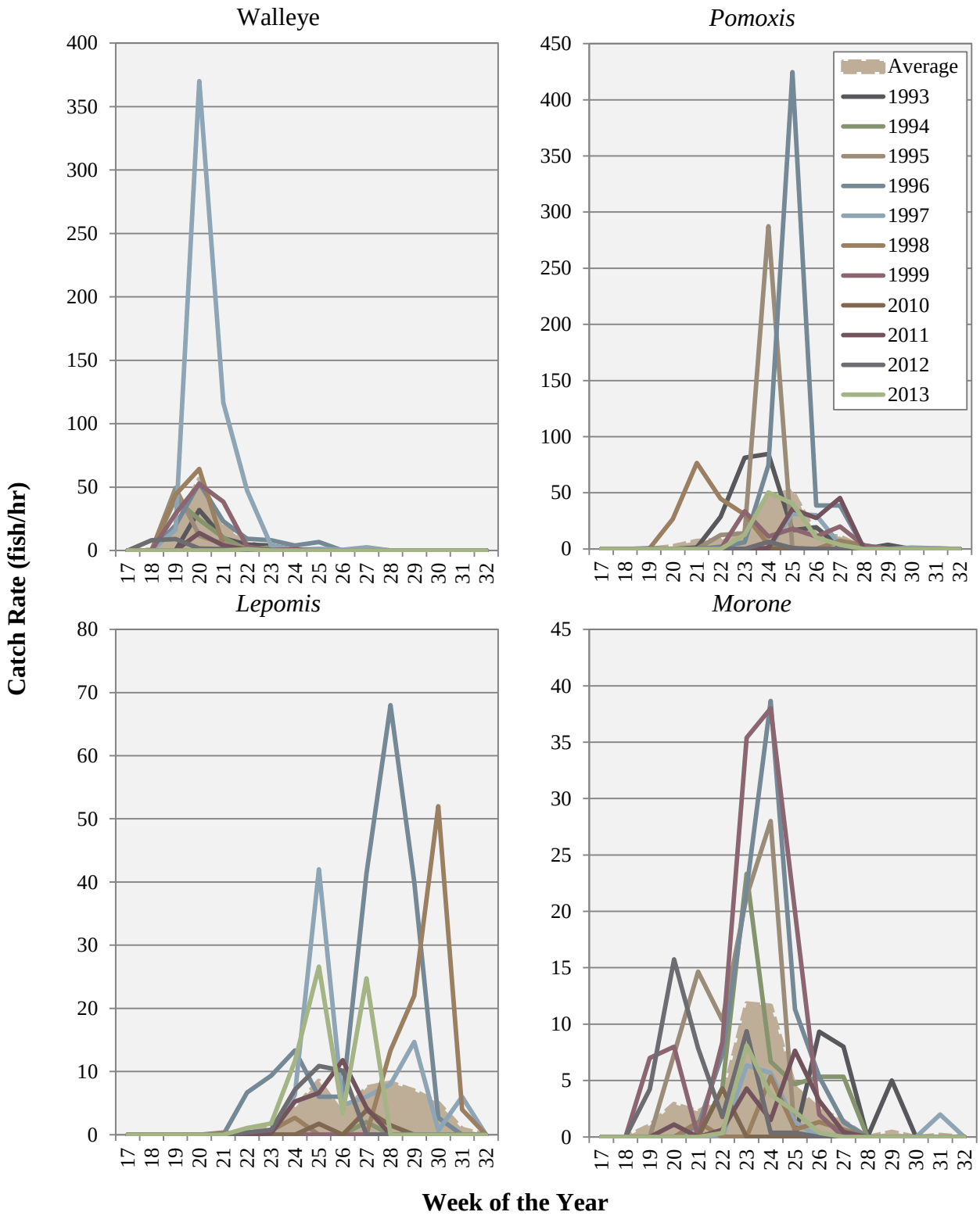

Figure 2-6. Larval fish densities by frost-free day from 1995-1998 and 2010-2013, averaged across sample sites. The average trend across years is shown with a dashed line.

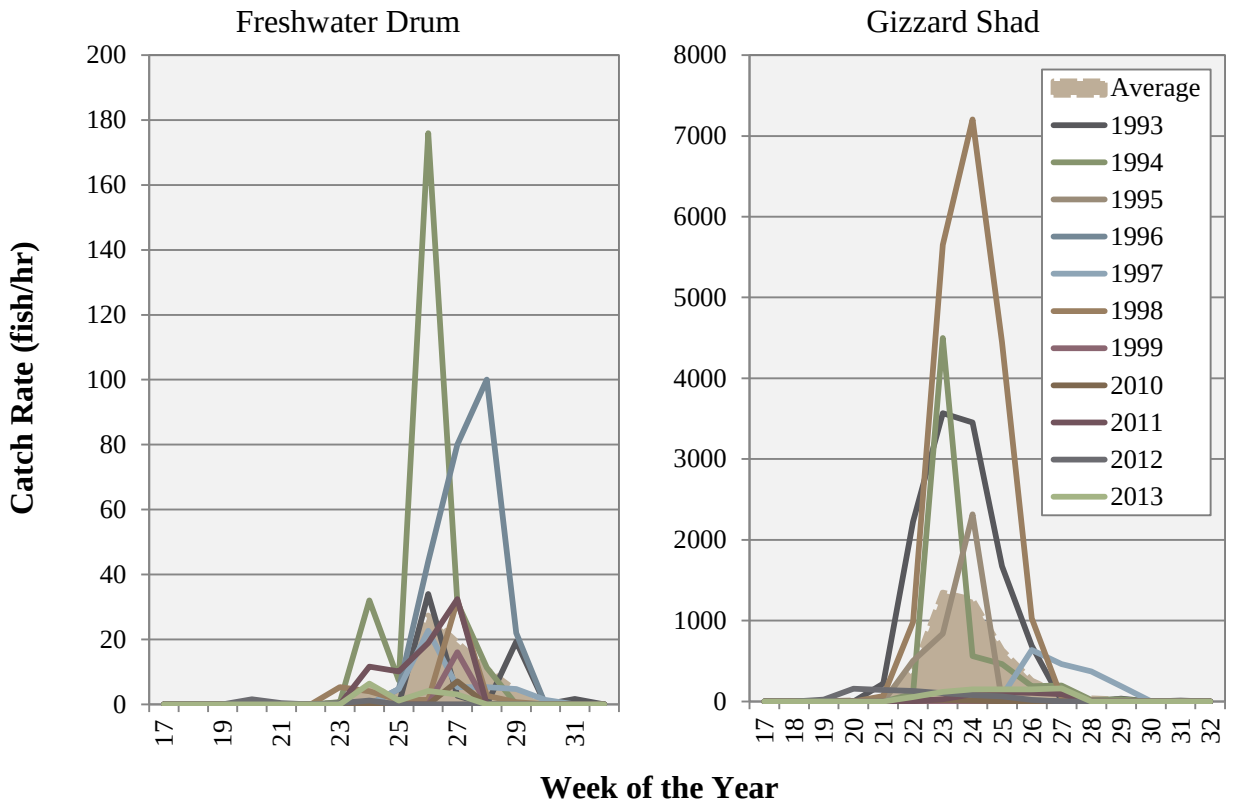

Figure 2-6. Continued.

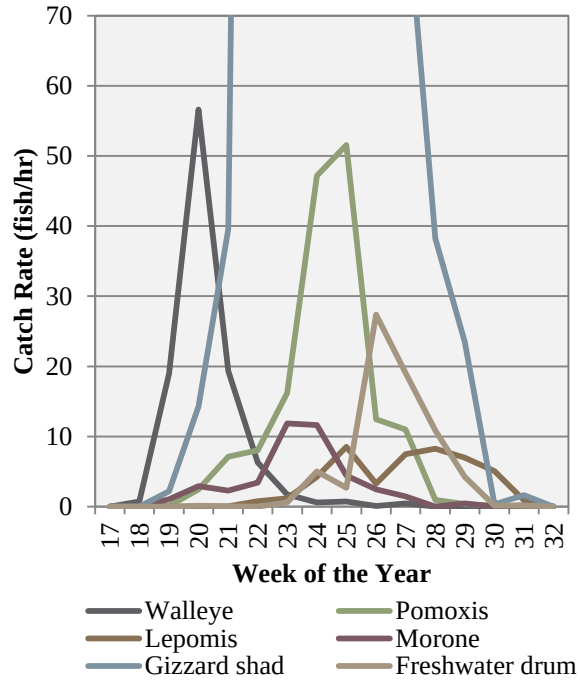

Figure 2-7. Larval fish densities by week, averaged across all years (1993-1999, 2010-2013) and sites at Rathbun Lake, Iowa. Gizzard Shad catch rates exceeded 1,000 fish/hr in mid-summer and were cut off to allow examination of other taxa.

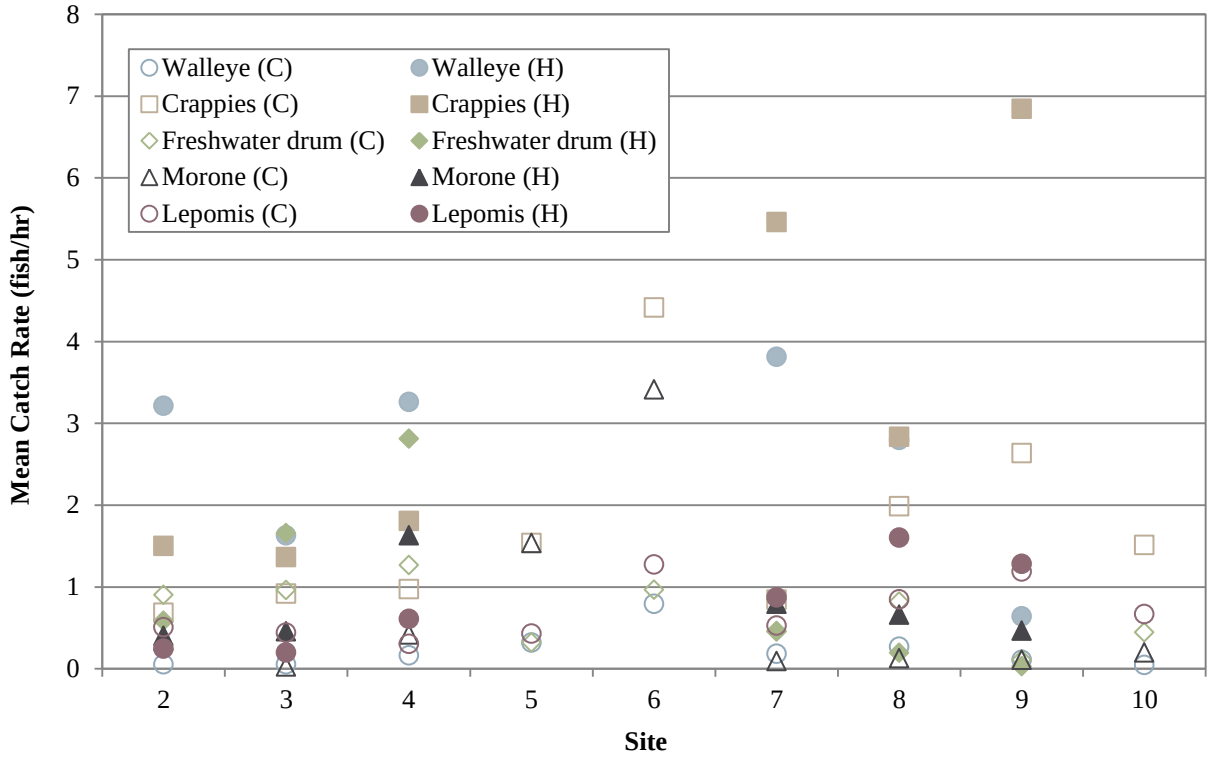

Figure 2-8. Mean catch rate of larval fishes historically (H) and currently (C) at fixed sampling sites in Rathbun Lake, Iowa.

A total of fifteen species and a hybrid were collected between 2010 and 2013, as well as a number of larval fishes which could not be identified beyond genus (Table 2-2). The most abundant group was Gizzard Shad, followed by *Pomoxis* spp. and Walleye.

Recent Community Shifts

Major zooplankton and ichthyoplankton taxa generally did not display a directional trend in density over time in any site (Table 2-3). Only *Bosmina* and Gizzard Shad plankton showed even marginally significant temporal trends, and only at single sites. This implied that the current plankton community in Rathbun Lake is not only stable, but is not likely shifting directionally in response to Zebra Mussel occurrence.

Discussion

The most recent detection of Zebra Mussel veligers was in June 2011 by the Iowa DNR's Aquatic Nuisance Species program (K. Bogenschutz, Iowa DNR, personal communication). Locations near Buck Creek and the dam are sampled each summer from May to August as part of the program. No adults have been found on settlement samplers or in dive surveys, and no veligers were detected until June 2015, indicating a Zebra Mussel population of very low densities.

The potential for Zebra Mussels to infest Rathbun Lake may be limited by the reservoir's habitat conditions, specifically its substrate and water quality. Decreasing

Table 2-2. Fish taxa found in Rathbun Lake, Iowa, between 2010 and 2013.

Species Name	Common Name
Centrarchidae	
Lepomis macrochirus	Bluegill
Lepomis microlophus	Redear Sunfish
Lepomis spp.	Sunfish, unidentified
Micropterus salmoides	Largemouth Bass
Pomoxis annularis	White Crappie
Pomoxis spp.	Crappie, unidentified
Clupeidae	
Dorosoma cepedianum	Gizzard Shad
Cyprinidae	
Cyprinus carpio	Common Carp
C. carpio × *Carassius auratus*	Hybrid, Common Carp × Goldfish
Hybognathus hankinsoni	Brassy Minnow
Ictiobus cyprinellus	Bigmouth Buffalo
Notropis atherinoides	Emerald Shiner
Notropis spp.	Shiner, unidentified
Ictaluridae	
Ictalurus punctatus	Channel Catfish
Pylodictis olivaris	Flathead Catfish
Moronidae	
Morone chrysops	White Bass
Morone mississippiensis	Yellow Bass
Percidae	
Sander vitreus	Walleye
Sciaenidae	
Aplodinotus grunniens	Freshwater Drum

substrate size resulted in lower Zebra Mussel densities in the St. Lawrence and Hudson rivers and Oneida Lake, Canada (Mellina and Rasmussen 1994). In that study, substrate size explained more variability in Zebra Mussel densities than any other factor. Furthermore, like many Iowa waters, Rathbun Lake receives high levels of phosphorus and nitrate from external and internal sources, which has been associated with reduced numbers of Zebra Mussels in other lentic systems (Ramcharan et al. 1992). High inorganic suspended sediment levels could also reduce Zebra Mussel feeding efficiency and subsequently growth at levels as low as 1 mg/L (Madon et al. 1998); inorganic suspended sediment concentrations in Rathbun Lake typically range from 2-10 mg/L (M. Balmer, Lake Monitoring Program, Iowa Department of Natural Resources, unpublished data). Despite the lack of evidence of Zebra Mussel impacts on the Rathbun Lake plankton community, Zebra Mussels are still present in the reservoir, but likely in low numbers often falling below detection levels.

Nonetheless, the current zooplankton and ichthyoplankton communities did not differ significantly from historical data, and the current-day samples were believed to represent a reasonable baseline to which future samples can be compared. Furthermore, no temporal trend was detected from 2010 to 2013 in either zooplankton or ichthyoplankton data. If Zebra Mussels do infest the reservoir at a detectable level in the future, the effects on plankton communities can be measured in relation to 2010-2013 data.

Table 2-3. Results of Jonckheere-Terpstra tests for a directional trend in zooplankton densities (n/L) and ichthyoplankton catch rates (n/*f*) at fixed sites in Rathbun Lake, Iowa, from 2010-2013. Test statistics are shown with one-sided p-values in parentheses. Results are presented only for taxa sampled at least three years between 2010 and 2013.

Site	Zooplankton				Ichthyoplankton		
	Bosmina	*Daphnia*	Calanoida	Cyclopoida	Gizzard Shad	*Lepomis*	*Pomoxis*
2	211.000 (0.0484)	311.000 (0.3827)	314.000 (0.4005)	298.000 (0.2845)	254.000 (0.0125)	15.000 (0.2093)	7.500 (0.5245)
3	277.000 (0.2291)	354.000 (0.4664)	350.000 (0.4414)	319.000 (0.2118)	250.500 (0.1125)	4.500 (0.0252)	-
4	334.000 (0.1385)	372.000 (0.2501)	362.000 (0.1932)	333.000 (0.0783)	413.500 (0.0653)	11.500 (0.5542)	4.000 (0.1727)
7	241.000 (0.0902)	364.000 (0.2752)	374.000 (0.3485)	289.000 (0.0202)	239.000 (0.0233)	1.000 (0.5011)	2.000 (0.6208)
8	222.000 (0.0223)	312.000 (0.0576)	363.500 (0.2933)	330.000 (0.1153)	322.500 (0.0578)	27.000 (0.4276)	1.000 (0.3311)
9	190.500 (0.0123)	315.500 (0.1167)	353.000 (0.4192)	364.500 (0.3978)	239.500 (0.2144)	45.500 (0.2354)	7.000 (0.0517)

Management Implications and Recommendations

Continued monitoring of Rathbun Lake for Zebra Mussel veligers and adults is recommended, as the reservoir has been exposed to both life stages in the past. If Zebra Mussels do successfully establish colonies, a follow-up investigation of their effects in the reservoir may be required. As stated above, the information collected during this study can provide a baseline for what the zooplankton and ichthyoplankton communities looked like prior to widespread infestation. In addition to guiding management of Rathbun Lake specifically, research on Zebra Mussel effects in large reservoirs would represent a significant contribution to the invasive species literature, which currently lacks this information.

An additional concern identified during sampling of the larval fish community was the reduced catch rates of Walleye during the 2010s. In comparison to the 1990s, recent catch rates were greatly reduced with years of zero catch. This finding corroborates suspicions of very poor recruitment which has contributed to multiple years of small Walleye year-classes (M. Flammang, unpublished data). This may threaten the health of the broodstock and hinder the success of the Iowa DNR's Walleye stocking program.

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