3-11-2013

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Fisheries managers applied rotenone to Mormon Island West in August of 2010 to renovate a fish community that was hypothesized to be unbalanced (i.e., dominated with gizzard shad and common carp) based on standardized survey results. We estimated species-specific biomass following the lake renovation to provide a baseline biomass estimate for a sand pit lake and to evaluate the effectiveness of standardized sampling gears. Gizzard shad (*Dorosoma cepedianum*) were abundant in all sampling gears, but mostly stock-size (>175 mm total length) and larger individuals were caught in gill and trap nets and sub-stock (≤175 mm total length) individuals were caught with boat electrofishing. The abundance of common carp (*Cyprinus carpio*) found after rotenone application was better represented from boat electrofishing sampling than gill nets. The total biomass found in Mormon Island West at the time of lake renovation was 982.1 kg/ha with 90% of that biomass composed of gizzard shad and common carp. The priority management species of largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), and channel catfish (*Ictalurus punctatus*) comprised only 3% of the total biomass. Overall, this lake appears to have been a good candidate for a rotenone treatment as other management approaches were not likely to correct the existing imbalances.

Key words: sand pit, biomass, common carp, gizzard shad, Nebraska, rotenone, standardized sampling, electrofishing, gill nets, trap nets

Introduction

Fisheries managers have used rotenone for over 100 years (Solman 1950, Kiser *et al*. 1963). The product rotenone is derived from the natural toxic properties from the roots of several different derris plant species that are located in tropical regions (Ling 2002). The toxins work by blocking mitochondrial electron transport at the cellular level (Singer and Ramsay 1994). These properties have been useful to fishery professionals for: control of undesirable fish; eradication of harmful exotic fish; target treatment of nuisance fish species; quantification of populations; assessment of sampling methodologies; elimination of competing species in aquaculture ponds; treatment of drainages prior to impoundment; eradication of fish to control disease; restoration of threatened or endangered species; and assessment of specific habitat treatments (McClay 2000, Ling 2002).

Rotenone use was widespread in the early 1990s as 77% of states and 62% of federal and state agencies reported use (McClay 2000). The most prevalent use for rotenone applications in lentic waters was reported as maintenance of sport fisheries (McClay 2000). The essence of this use was to re-set fish communities that were not balanced or dominated by non-desirable species. Subsequent to this time, the use of a piscicide and concerns of potential impacts to non-target components of the aquatic community were questioned and many entities have limited the use of rotenone.

The Nebraska Game and Parks Commission (NGPC) periodically apply rotenone to renovate communities composed of non-desirable fish species. Numerous articles have been written surrounding the use of rotenone, but most are dated. These articles outline fish communities in various waters, as well as breadth of potential impacts stemming from rotenone applications (Peterson et al. 2011). The choice to conduct a rotenone application is largely driven by previous experience with the application of this piscicide, knowledge of the water body and available funding. Formal decision criteria have not been developed by NGPC largely because case study information is lacking. We decided to use a planned rotenone event at Mormon Island West as a case study to: qualify the species-specific biomass observed in a management lake reclamation project; review the effectiveness of standardized gear at assessing populations of various species in sand pit waters; and develop a reference for biomass potential from sand pit waters in South-central Nebraska. The product from this work should provide support for aquatic managers when determining if renovation of an aquatic community is necessary.

Study Site

Mormon Island West covers 17.0 ha and has a maximum depth of 7.3 m. The lake is considered a sand pit and is located at 40.8233459 latitude and -98.3678404 longitude. This lake is owned and managed by the NGPC as part of the Mormon Island State Recreation Area. The NGPC has established largemouth bass (*Micropterus salmoides*), channel catfish (*Ictalurus punctatus*) and bluegill (*Lepomis macrochirus*) as the species they prioritize in this water, which were referred to as priority management species.

Additional species stocked in the waterbody were walleye (*Sander vitreus*), grass carp (*Ctenopharyngodon idella*), and white crappie (*Pomoxis annularis*). Species found in the lake but not intentionally introduced included common carp (*Cyprinus carpio*), gizzard shad (*Dorosoma cepedianum*), white bass (*Morone chrysops*), yellow perch (*Perca flavescens*), black crappie (*Pomoxis nigromaculatus*), and tiger muskie (*Esox masquinongy* X *E. lucius*).

Methods

Standardized sampling scheduled for every 5 years was conducted in May of 2002 and 2007. Each sampling event consisted of boat electrofishing, experimental gill nets, trap nets, and Secchi depth. Electrofishing was conducted with pulsed DC standardized at 40% duty cycle and square wave-form pulse rate of 80 Hz. Electrofishing efforts began approximately 30 minutes after sunset and were conducted at four standardized locations. Effort was recorded to the nearest second and catch per unit effort was standardized as the number of fish per species caught in one hour of electrofishing. Gill nets were 45.6 m long and 1.8 m deep, with 6 7.6-m panels consisting of 1.9, 2.5, 3.2, 3.8, 5.1 and 7.6 cm bar mesh and were fished at two NGPC standardized locations. Gill nets were set in the afternoon and pulled the following morning for an effort of one gill net-night, which was approximately 16 hours of soak time. Trap nets used for standardized surveys were a 1.27 X 0.86 m frame with 2.5-cm stretch mesh for the lead and double throated trap. Trap nets were set perpendicular to shore with a single lead line and frames which were extended to approximately 1 m of depth. Trap nets were set at the four different NGPC standardized locations in the afternoon and pulled the next morning. Effort was considered one trap net-night, which was approximately 16 hours of soak time.

Rotenone Event

Rotenone application on Mormon Island West occurred on August 23, 2010. A total of 450 gallons of PrenFish 5% liquid rotenone were applied with four separate boats to achieve a minimum of 3 ppm rotenone concentrate. Longer tubing was used to introduce 165 gallons of the applied rotenone to deeper water. Surface water temperature at the time of application was 26.7˚C.

Fish Biomass Estimate

The timing and location of this rotenone application necessitated that dead fish were removed and buried at an on-site trench. The planned clean-up effort allowed us to design a four tiered approach to estimating biomass of the fish community which included counting fish salvaged prior to renovation, at the trench site, on the shoreline and floating on the lake. Biomass estimates from each method of counting were added to provide an overall biomass estimate for the lake at the time of the renovation.

Salvage Effort Biomass – Six separate efforts were conducted to remove existing sportfish from Mormon Island West prior to the rotenone event. Trap nets were used on June 22, June 23 and August 7, while boat electrofishing was conducted on July 16, August 4 and August 5. Fish were enumerated by species and were assigned to 25 mm length categories based on relative length frequency distributions during the rotenone event. Biomass of fish salvaged was calculated by multiplying the number of fish per 25 mm category by the mean weight for that length category taken from fish collected at the rotenone event.

Counting Trench Site Fish – Fish carcasses were removed for 48 hours following the rotenone application, which encompassed three work days. Dead fish were placed within the frontloader of a tractor or the bed of a side-by-side all-terrain vehicle and transported to the trench site. A plastic tub was also used to transport fish carcasses on a single occasion. Four staff stationed at the trench site sub-sampled the fish biomass by counting individual fish in ≥10% of the container specific loads. Container specific loads were sampled as processers were available throughout the entire 48 hour removal period. In total, 6 of the 57 tractor loads placed in the trench site and 2 of the 17 side-by-side all-terrain vehicle bed loads and the single tub load were counted in full, so that total biomass removed could be extrapolated.

Sub-sampling procedures included recording the species and total length to the nearest 25-mm length group. The mean number and weight of each fish species was determined by 25-mm length group for fish >75 mm for each type of hauling container. Weight (g) was recorded for up to 10 individuals per 25-mm length group for each species to determine a mean weight per length group. Smaller length (≤75 mm TL) bluegill, yellow perch, crappie spp., and gizzard shad precluded individual mass measurements, so instead ten taxa-specific batch weights of at least 25 individual fish were used to determine a mean weight per fish. All weights were collected within the first 24 hours following the rotenone event as the integrity of this measurement may be compromised thereafter.

Shoreline Counts – Prior to renovation, the shoreline of Mormon Island West was marked with orange paint to distinguish 20 sections (approximately 100 m in length). We randomly selected 20% of the sections (4/20) to be sub-sampled 48 hours post rotenone application (i.e. once counting had ceased at the trench). The shoreline was defined as 3 m on either side of the waters edge. All fish within this area were enumerated by species and assigned to a length category of ≤ or > 75 mm for bluegill, yellow perch, crappie spp. and gizzard shad; ≤ or > 125 mm for largemouth bass. Fish above the minimum length designation were partitioned into specific 25-mm length categories based on the trench site relative frequency. Total number of fish per 25-mm length group was rounded to the nearest whole fish.

Biomass along the shoreline was estimated using length-specific mean weights established from the trench site. These length-specific mean weights were multiplied by the total number of fish per length group. Species-specific biomass was estimated for each of the four counted sections and a mean species-specific biomass per section was then estimated. Mean species-specific biomass per section was then multiplied by 20 and summed to provide the shoreline biomass estimate. Variability surrounding each of the four sections was used to determine the species-specific shoreline biomass standard error.

Transect Counts – To select transect locations the lake was viewed as a circle and due North was represented by 0 degrees. Prior to renovation four randomly generated numbers were selected between 0 and 359. Each number selected was plotted on the edge of the lake and a transect was drawn to the number 180 degrees from the starting location.

Similar to shoreline counts, transect counts were initiated 48 hours after rotenone application once trench site counts had ceased. Each transect was counted once and began 3 m from the edge of the water. Fish within a canoe paddle distance from each side of the boat, as well as in the path of the boat were counted. Collected fish were enumerated by species and assigned a length group as defined for shoreline count procedures. The estimated width for each transect was 6 m and total distance covered was 413 m, 422 m, 495 m and 524 m, respectively.

Biomass estimates for transects were accomplished in a similar manner as described for shoreline counts, except biomass was estimated per square meter of surface area rather than distance of shoreline. The resulting species-specific biomass estimate per square meter was then extrapolated to the lake surface area that was not included as part of the shoreline sampling. Variability surrounding each of the four transect counts was used to determine the species-specific transect biomass standard error. The four estimates of fish biomass (salvage, trench site, shoreline, and lake transects) were summed to estimate total fish biomass.

Results

The fish community changed between 2002 and 2007 standardized samples. The relative abundance of all management priority fish for this lake decreased (Table 1), with the decrease in largemouth bass warranting concern. A notable development was the introduction of gizzard shad to this system and the presence of multiple year-classes. Catch of common carp were similar from gill net samples, but a greater observed presence of carp prompted the collection of this species with electrofishing samples. The result was approximately 3 times more common carp than largemouth bass from the standardized locations during 2007. Water quality also changed during this time as Secchi disk readings decreased from 168 cm in 2002 to 91 cm in 2007. Priority management species comprised 3.1% or 30.8 kg/ha of the 982.1 kg/ha total fish biomass of which 14 kg/ha or 25.7 fish/ha were quality size or larger (Table 2). Gizzard shad that entered the system sometime between 2002 and 2007 comprised 55% of the available fish biomass (Table 2). Common carp had the second greatest biomass accounting for 35% of the available fish biomass (Table 2). Sampling efforts following the rotenone event indicated that a complete kill was obtained, so the fish biomass estimate is considered to be for the entire community.

Table 1. Species-specific relative abundance for catch per hour of boat electrofishing, catch per night of trap netting and catch per night of gill netting found at Mormon Island West, Nebraska during the 2002 and 2007 standardized samples.

Year of Sample		2002	2007
Species	Gear	CPUE	CPUE
Largemouth Bass	Electrofishing	108.0	24.7
Bluegill	Trap Nets	16.0	12.5
Crappie Spp.	Trap Nets	6.0	0.0
Channel Catfish	Gill Nets	21.0	16.5
Common Carp	Gill Nets	0.5	0.5
Common Carp	Electrofishing	N/A[a]	70.9
Gizzard Shad	Gill Nets	0.0	81.0[b]
Gizzard Shad	Electrofishing	0.0	500+[cd]
Gizzard Shad	Trap Nets	0.0	130.0[e]
Walleye	Gill Nets	0.0	8.5[f]

[a] Common carp were observed but not collected or recorded on the data sheet
[b] 90% of collected gizzard shad were stock size or larger
[c] Number is based on data sheet comment that reports thousands of shad observed
[d] The note indicated that these were mostly young of the year fish
[e] All of these were stock or larger size gizzard shad
[f] Started stocking advanced fingerlings after 2002

Discussion

Application of rotenone can be controversial and has led to adverse public reaction in multiple states (McClay 2000), therefore the decision to proceed with this management action is considered to be a "last resort" option. A review of available literature has not shared any documented conditions that led managers to decide that a

Table 2. Species-specific estimates of total count with associated mean standard error from trench count, shoreline count, and water transect count estimates, biomass, biomass of quality or larger size fish, and density of quality or larger size fish found from the salvage efforts, trench counts, shoreline counts, and transect counts conducted at Mormon Island West, Nebraska during the summer of 2010.

Species	Estimated Total Count (number /ha)	Estimated Biomass (kg/ha)	Estimated Biomass of Quality Fish (kg/ha)	Estimated Number of Quality Fish (number/ha)
Gizzard Shad	4,887.1 ± 51.8	545.9	261.6	859.1
Largemouth Bass	13.4 ± 0.3	5.7	2.6	6.6
Grass Carp	2.0 ± 0.5	22.6	N/A	N/A
Common Carp	86.2 ± 1.1	345.0	345.0	90.5
White Bass	128.5 ± 1.5	10.0	1.8	4.0
Walleye	5.0 ± 0.3	1.1	0.4	0.6
Yellow Perch	103.5 ± 1.8	3.3	0.4	2.6
Crappie Spp.	414.9 ± 3.8	19.8	4.9	15.5
Bluegill	2,275.2 ± 22.4	18.8	3.3	16.6
Channel Catfish	15.8 ± 0.3	9.9	8.1	2.5
Total	7,919.2	982.1		

rotenone application was necessary. The NGPC has no established criteria as a threshold for initiating a renovation rather they rely on experience of managers with past rotenone events and available funds to drive the use of this management tool. Review of this particular rotenone event was intended to offer a case study that can be shared to assist aquatic managers in the future. The authors understand that justification of a management action is subjective and individualized, but knowing how standardized survey results link to the distribution of various fish species in a water body can assist managers with these subjective decisions.

In Mormon Island West, gizzard shad were not present in 2002 standardized samples, but were the most prevalent species in all gears during 2007 samples. Disparity of gizzard shad sizes captured were noted with passive gears catching stock (>175 mm total length) and larger sized fish and the active gear capturing age-0 gizzard shad. The presence of common carp in experimental gill nets was inconsequential in both samples (0.5 per net-night) however a high relative abundance during 2007 boat electrofishing suggested carp biomass may be high. Clark et al. (1991) found gill netting was more effective for sampling common carp than trap netting, but used a single mesh and larger mesh sized gill nets. Our results suggest that boat electrofishing may be a more effective manner to assess the relative abundance of common carp than gill net sampling, but additional work would need to be conducted to substantiate this observation. Standardized sampling gears established for sportfish populations seem to be efficient (i.e. high catchability) as the number of largemouth bass, bluegill, channel catfish, walleye, and white bass sampled were disproportionately larger in the standardized gear compared to the percent composition of the lake by biomass (Tables 1 and 2). It is important to remember that the actual rotenone was three years after the sample, so fish populations may have changed during this timeframe.

Biological control is an alternative to rotenone application, but may not have been appropriate for this situation. By 2010, rough fish (gizzard shad, common carp and grass carp) comprised 93% of the fish biomass in the lake, while non-priority management species comprised over 96% of the fish biomass. Johnson *et al.* (1988) used bioenergetics models to calculate the impact of stocking five piscivorous fish species into an Ohio Reservoir. The stocked piscivorous fish were predicted to consume 20% of the 73 kg/ha annual shad production in this reservoir (Johnson *et al*. 1988). For comparison, an assumed gizzard shad introduction in 2003 (since none were present in 2002 sampling) would equate to a conservative 68 kg/ha biomass increase per year assuming no mortality. The annual gizzard shad production would be greater with mortality or a more recent introduction. Regardless of the introduction date, annual gizzard shad production of this magnitude suggests effective top-down biological control methods would not be effective.

The total fish biomass of 982.1 kg/ha found in this sand pit was similar to other bodies of water that are considered more productive. The 55% of standing biomass composed of gizzard shad was slightly higher than the 45% found by Jenkins (1967) in southern ponds. The 546 kg/ha of gizzard shad biomass estimate was less than the maximum reported biomass for this species of 1,236 kg/ha found by Schoonover and Thompson (1954), similar to the 417 kg/ha estimated in an Ohio reservoir (Schaus *et al*. 1997) and more than the 43 kg/ha found in Texas coves (Bettoli *et al*. 1993). Biomass of common carp (345 kg/ha) was less than those found in a North Dakota reservoir which supported 1,157 kg/ha of fish that were 90% carp (Bonneau 1999), but greater than two South Dakota lakes (103 and 177 kg/ha) comprised of >90% carp (Schoenebeck et al. 2012). A palustrine wetland in South Dakota had an estimated 2,409 kg/ha of just common carp prior to a winterkill event (Clark 1990). Other lakes reported similar biomass of common carp, but there communities were dominated by centrarchids (105-804 kg/ha) (Reynolds and Simpson 1978) or black bullheads (*Ameiurus melas*) (238 kg/ha) (Blaser 1985).

Removal of gizzard shad and common carp from Mormon Island West should benefit the fishery. The densities of gizzard shad observed in this lake exceeded the densities DeVries and Stein (1992) hypothesized to regulate food webs via middle out control. Removal of gizzard shad has been shown to immediately increase recruitment of largemouth bass and bluegill, as well as increase bluegill growth (Kirk *et al*. 1986; Aday *et al*. 2003). Elimination of the rough fish population will free up available nutrients for priority management species, however the total biomass of Mormon Island West following the renovation will likely not exceed the levels reported here. Introduction of rough fish typically increases fish biomass as there is utilization of detritus and organic nutrients. An example comes from Swan Lake, Iowa that was managed for largemouth bass, channel catfish, and panfish. Swan Lake had 571 kg/ha of which 96% were primary management species prior to carp introduction (Hill 1999). After 6 years of common carp present, Swan Lake fish biomass increased to 757 kg/ha while the percent of primary management species declined to 34% (Hill 1999).

Estimates of fish biomass in this study may be conservative. Biomass estimates would likely be higher if carcass losses due to terrestrial scavengers were quantified. A more probable source of bias would be the underestimation of fish biomass if only a percentage of fish were detected. Although not quantified, fish detection may have been <100% if a portion of the biomass remained submersed, thus underestimating fish biomass. Managers believed that more channel catfish were present in the lake than were recorded at the rotenone event. It is possible that channel catfish remained at the bottom during the 3 days of collection, but sampling efficiency of rotenone was reported by Bayley and Austen (1990) to be similar for all species and species types.

The assessment of a rotenone event at Mormon Island West has provided some valuable background information surrounding what led to the management decision to rotenone this lake, the potential biomass of a South-central Nebraska sand pit and how estimates of fish biomass in a sand pit compares to other water bodies. Future efforts surrounding rotenone applications on sand pits should attempt to; get pre- and post-data on angler success, include standardized sampling that targets rough fish populations, as well as work to get more timely information from standardized surveys surrounding the rotenone application. As such, the decision to rotenone a body of water and the actual application do encounter a time lag because of the money needed and the requirements of an environmental assessment and public review. Avoidance of time gaps in decision making will allow for more appropriate use of rotenone in management actions. We believe this article has established a base to build information from surrounding this management option for smaller waterbodies in Nebraska.

Acknowledgments

We thank T. Anderson, D. Schumann, C. Uphoff, and S. Warner who assisted with fish collection, identification, measuring and the data collection effort. Special thanks to B. Eifert and B. Newcomb with the Nebraska Game and Parks Commission for keeping us informed of the rotenone renovation and providing us historical management information. We thank the Mormon Island State Park Staff for their assistance during this project. We also thank the University of Nebraska at Kearney and the Nebraska Game and Parks Commission for technical support.

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