


Evaluation of Iowa’s Standard Fisheries Sampling Program

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Iowa Fisheries Research




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Executive Summary

Standardization of fisheries sampling gear and protocol is a necessary step to allow for accurate comparisons of results to be made across space or time, such as between lakes or between years as the same lake. Without standardization, two catch rates of a target species (e.g., Walleye) cannot be meaningfully compared. If valid comparisons cannot be made (e.g., Did Walleye catch-per-unit-effort decrease from Year 1 to Year 2?), then the appropriate management action cannot be determined. Gaps in Iowa's standard protocol could unknowingly cause biases in data. For example, seemingly minor differences within a single gear (e.g., net mesh size, mesh color) can drastically affect catch composition, length distribution, and catch rate. This study identified gaps in 5 of Iowa's fisheries standard sampling methods and provided Iowa DNR fisheries staff with recommendations to modify standard protocols.

Modified Fyke Nets

In Iowa, fisheries biologists routinely use modified fyke nets to capture structure-oriented fish species in deep lakes, reservoirs, and large rivers. However, differences in gear specifications such as trap dimensions, mesh size, throat size, and number of hoops across the state hindered data comparison. Of particular concern was the possibility of substantial escapement from certain modified fyke net designs. Whereas standard operating protocols have been developed for fisheries sampling in Iowa, they also did not completely align with newly established North American standards. Specifically, traditional Iowa fyke nets had two funnels with the rear funnel ending in a more restricted crowfoot-style throat. Newer Iowa fyke nets had two open funnels. Finally, North American standards demanded not only an open throat, but only one funnel. Conversion to the North American standard, although enhancing the defensibility of methods and shareability of data, was undesirable if the nets caught fewer fish or increased variability. Thus, we tested four modified fyke net designs for retention, catch efficiency, and catch precision; designs varied only in number of funnels and whether the cod end funnel ended in a restricted throat. Net design was a significant factor affecting both retention and catch efficiency, with the traditional Iowa net consistently capturing and retaining as many or more fish than other net designs. The number of net sets needed to capture 125 fish of each species and to achieve a target precision level was also calculated for each net design; two-funneled designs minimized the necessary number of net sets for Bluegill, crappie, and Redear Sunfish. Considerations for standard modified fyke net refinement include addition of a second funnel and restriction of the cod end throat. Work was published in the North American Journal of Fisheries Management.

Electrofishing Equipment

Iowa DNR electrofishing equipment was inventoried and evaluated for safety. Evaluations revealed multiple anode designs were used and wiring i.e., low voltage and high voltage current were used side by side in the same conduit. Following the equipment evaluations a workshop was held to discuss electrofishing equipment use and safety. During the workshop attendees had hands on experience measuring resistance, electrical fields, and calibrating control boxes.

Lastly, an evaluation of boat anodes and cathodes was completed. After mapping electrical fields for both covered and uncovered anode droppers it was deemed the uncovered droppers provided a desired electrical field output and cleaning 50% of the cathode from the bow working aft reduced resistance.

Gill Nets

The North American Standard experiment gill net contains 8 panels ranging from 19-64 mm. Larger-bodied fish species, such as Hybrid Striped Bass, Flathead Catfish, Blue Catfish, Walleye, Paddlefish, or Muskellunge, may not be effectively captured in these mesh sizes. Furthermore, multiple fisheries management teams within Iowa Department of Natural Resources use non-standard gill nets with mesh sizes greater than 64 mm on a regular basis due to the belief that the larger mesh facilitated capture of Walleye, Muskellunge, and Hybrid Striped Bass; conversion to the AFS standard experimental gill net alone would likely reduce their ability to capture larger-bodied individuals in managed fish populations and thereby inhibit effective fishery management. Thus, selectivity of the large-mesh add-on was considered important to guide decisions regarding adoption of the AFS standard. Therefore, we developed selectivity curves for mesh sizes in the AFS standard experimental gill net and its large-mesh add-on for Hybrid Striped Bass and White Bass. Selectivity was maximized for fish between 160 mm and 540 mm by the meshes available in the North American standard net. Models for the large-mesh add-on were less reliable due to high variance, but could be effective for fish over 690 mm. Although additional sampling with large-mesh panels is needed, we do recommend use of the North American Standard experimental gill net and its large-mesh add-on as a reasonable standard, as well as adjustment of catches based on known selectivity. Failure to recognize selectivity in catch can lead to misinterpretation of proportional size structure and changes in catch rates, as well as inhibiting comparisons among locations or over time if nets vary.

Non-Wadeable Rivers

Despite their importance to Iowa anglers, trend monitoring of interior river game fish populations has been lacking on many of Iowa's non-wadeable rivers for a variety of reasons. Among these reasons is the lack of a standardized sampling protocol for game fish sampling in these systems. Fisheries managers in Iowa expressed a need for such a protocol to ensure that comparable data can be collected for evaluation of long-term trends in game fish populations, as well as future evaluations of regulations or stocking regimens. Therefore, a standardized protocol was developed for sampling game fish populations at fixed sites on Iowa's non-wadeable interior rivers using boat electrofishing. This proposed protocol was developed based on previous research in Iowa, past experience, methods used in surrounding states, and other literature. This protocol will serve as a starting point to allow fisheries managers to monitor temporal trends in relative abundance and size structure of non-wadeable river game fish populations more effectively, and can be refined in the future as additional information becomes available.

Rotenone Application

Complete and selective fish renovations (biomanipulation) involve the eradication or partial removal of a fish population or community from the treated water, respectively. These treatments are accomplished with the use of rotenone which is recognized as the most environmentally benign of the commonly used fish poisons (piscicides or ichthyocides). We developed a formal set of guidelines based on peer-reviewed literature, established safety expectations, and staff experience to standardize and formalize the process by which Iowa Department of Natural Resources (DNR) conducts rotenone-based fishery renovations. The Iowa DNR is recognized as one of the most prolific users of rotenone in fisheries management, and our staff have accrued substantial knowledge regarding the implementation and execution of fish renovation and biomanipulation plans with the use of rotenone. The basis of the guidelines is the American Fisheries Society's Standard Operating Manual and product label. While certain procedures and methods listed within the manual are required, other portions are generalized suggestions, often aimed at new users of these products. Given the high level of use and considerable experience of DNR staff, many of the suggested procedures used elsewhere could be streamlined and expedited, while remaining true to label requirements. Thus, the guidelines were developed to explore those portions of the manual that are most relevant to Iowa DNR fisheries staff and to serve as a quick reference guide for the use of rotenone in Iowa.

Management Highlights

- Modified fyke nets should be standardized across the state for targeting panfish in lentic waters as a 3'x6' frame net with two funnels including a restricted throat on the cod end. This design consistently caught and retained as many or more Bluegill, crappie, and Redear Sunfish than other designs. Be aware that this design does not perfectly align with the North American Standard. When ordering replacement modified fyke nets, the following specifications should be used:

    Nets should be constructed with two rectangular 3' x 6' cold roll steel (5/16" diameter) frames with center braces that are 2' apart with inwards mesh trap that tapers from the first frame to the second frame ending in a 4" diameter opening, and four 30" diameter fiberglass hoops spaced 2' apart with two mesh funnels. The first funnel should start at the first hoop and end with a square throat attached to the second hoop. The second funnel should start at the third hoop and end with a crowfoot-style throat just past the fourth hoop, with the crowfoot stretching taut when the net is set. Nets should include a purse string closure on the cod end. Knotless nylon netting (1/2" bar measure) with black asphalt-type coating should be used for both the fyke and lead. The lead should be 50-100' long, 3' tall, and hung on a 0.33 ratio with a 3/8" foam core line on the top and 30 pound lead core line on the bottom.
- Incorporate Missouri Department of Conservation guidelines to wire electrofishing boats and AFS standard electrofishing equipment setup into Iowa DNR standard electrofishing protocol document.
- Make ETS control boxes the standard control box.
- Collect R_{100} data on each electrofishing boat when the boat hull is clean. Each year prior to using the boat for the first time R_{100} measurements should be collected. When the R_{100} levels increase 50% of the boat hull should be

cleaned starting at the bow. The R_{100} values can be calculated using ambient water conductivity and the peak volt and amp reading from the control box meters.

- Clean boat hulls using a soft wire brush attached to an angle grinder. If aluminum is being removed from the boat hull use a finer wire brush.
- Check resistance levels throughout the entire electrical system annually and maintain levels below 0.8 Ω.
- The North American Standard experimental gill net should be adequate for Hybrid Striped Bass sampling if the fishery is composed of fish less than 540 mm in total length. However, it is probable that the large-mesh add on would be wise to incorporate into standard sampling for Hybrid Striped Bass fisheries as populations can exceed that length. By utilizing the add-on, in combination with the standard net, the Iowa DNR can successfully monitor Hybrid Striped Bass fisheries while harmonizing with national sampling standards. These nets may not be appropriate for more targeted sampling such as Walleye broodstock collection. However, use of varying mesh sizes hinders any data comparison between different offices or among different nets. Furthermore, selectivity can affect calculations of proportional size structure, and catches should be adjusted based on mesh sizes used. Note the impact of each mesh size on fish selectivity, and consider future large-mesh net designs which could be acceptable and appropriate statewide for sampling large-bodied fishes including Walleye, Muskellunge, Blue Catfish, and Hybrid Striped Bass.
- A standard Rotenone Application Guide has been developed for use in complete renovations and selective treatments. It includes extensive detail for each step of the process, as well as a review of the chemical's history, toxicity, and required training for application. Use this guide as a resource to plan rotenone treatments.

Suggested citation format, American Fisheries Society Style Guide:

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Modified Fyke Net Evaluation

Results from the modified fyke net evaluation conducted during Project 7046 appeared in an article titled "Comparison of panfish catch and retention by four modified fyke net designs" that was published in the North American Journal of Fish Management. This article is included as part of this report as it covers this work in its entirety. When referencing this information, it should be cited as:

Krogman, RM. 2019. Comparison of panfish catch and retention by four modified fyke net designs. North American Journal of Fisheries Management 39:1277-1287.

COMPARISON OF PANFISH CATCH AND RETENTION BY FOUR MODIFIED FYKE NET DESIGNS

Abstract

Modified fyke nets are commonly used across the U.S. for sampling littoral fish communities, including crappies *Pomoxis* spp., Bluegill *Lepomis macrochirus*, Redear Sunfish *L. microlophus,* and other panfish, and are recommended for standard sampling in all lentic waters. Traditional modified fyke nets in Iowa differed from the American Fisheries Society standard in two primary ways: throat configuration and number of funnel-shaped throats. Given the historical datasets derived from traditional modified fyke nets and the reticence to convert to a net design with lesser catch rates, a formal evaluation of net designs was needed. Four combinations of throat configuration (square or restricted) and number of throats (one or two) were included in this study. To examine retention, all four net designs were stocked with fish and checked for retained fish the following day, enabling calculation of probability of retention and relative risk of escape. To examine catch efficiency and precision, nets were deployed in 13 southern Iowa lakes and reservoirs. Catch rates were compared using generalized linear mixed models predicting catch with net design. Net design was a significant factor affecting both retention and catch efficiency, with the traditional Iowa net consistently capturing and retaining as many or more fish than other net designs. The number of net sets needed to capture 125 fish of each species and to achieve a target precision level was also calculated for each net design; two-funneled designs minimized the necessary number of net sets for Bluegill, crappie, and Redear Sunfish. Considerations for standard modified fyke net refinement include addition of a second funnel and restriction of the cod end throat.

Introduction

Modified fyke nets are a common passive entrapment gear used for sampling littoral fish communities, especially structure-oriented and mobile species. In North America, modified fyke nets are a standard gear for targeting a variety of centrarchids, percids, esocids, and ictalurids in small and large lentic waters (Miranda and Boxrucker 2009; Pope et al. 2009), and have been shown to be especially effective for sampling crappie *Pomoxis* spp. (Bennett and Brown 1969; Boxrucker and Ploskey 1989; McInerny 1989; Miranda et al. 1991). In a comparison of seven sampling methods in Iowa lakes and reservoirs, Fischer and Quist (2014) found modified fyke nets maximized detection probabilities for Common Carp *Cyprinus carpio*, Bigmouth Buffalo *Ictiobus cyprinellus*, Black Bullhead *Ameiurus melas*, Yellow Bullhead *A. natalis*, Northern Pike *Esox niger*, Muskellunge *E. masquinongy*, Pumpkinseed *Lepomis gibbosus*, Orangespotted Sunfish *L. humilis*, Bluegill *L. macrochirus*, and crappie. The gear has since become an established method for targeting crappies and other panfish in standard sampling by the Iowa Department of Natural Resources.

Specifications for modified fyke nets have been refined over time, with initial descriptions defining the lead(s) and modification of the first hoops to rectangular frames (Hubert 1983) and more recent descriptions defining net material and coating, mesh size, frame and hoop size, size of openings, and season and timing of deployment (Bonar et al. 2009). Catch rate, species composition, and size distribution in entrapment gears can be affected by varying specifications including frame and hoop size (Gritters 1997; Fischer et al. 2010; Fischer and Quist 2014; Flammang et al. 2016), throat size (Shoup et al. 2003), mesh size (Grinstead and Gomez 1972; Willis et al. 1984; McInerny 1989; Besler et al. 1999; Jackson and Bauer 2000; Shoup et al. 2003; Schultz and Haines 2005; Fischer et al. 2010), set time and duration (Grinstead 1970; Schorr and Miranda 1990; Breen and Ruetz 2006; Bonds et al. 2009; Neely and Dumont 2011), set location and orientation (Schorr and Miranda 1996; Bonds et al. 2009), and season (McInerny 1989; Miranda et al. 1991; Schultz and Haines 2005; McInerny and Cross 2006; Flammang et al. 2016). Setting nets in tandem, with multiple cod ends in which fish may be captured, may increase catch rates (Walker et al. 1996; Bonds et al. 2009). Catch can also be affected by dynamic characteristics such as fish density or presence of predators in the net (Breen and Ruetz 2006; McInerny and Cross 2006; Smith et al. 2016).

The standard modified fyke net suggested by Bonar et al. (i.e., the AFS design; 2009) differed substantially from the modified fyke net traditionally used in Iowa by natural resource agency professionals and commercial fishers. Primary differences included overall size, number of funnel-shaped throats in the hoop portion of the net, and restriction of the cod end throat. Traditional Iowa modified fyke nets varied frequently in dimensions but typically had two funnels, with restriction on the cod end throat. Following several evaluations of net frame and mesh sizes in which larger modified fyke nets outperformed the "mini-fyke" in catch rates for target species (Gritters 1997; Fischer et al. 2010; Flammang et al. 2016), the Iowa Department of Natural Resources internally standardized the mesh, frame, and hoop size for sampling lentic waters. However, these nets still had two funnels rather than one (cf. the AFS design), more similar to commercial and agency fishing nets which had been used in the past (e.g., in IA, MN: McInerny and Cross 2006; Great Lakes: Uzarski et al. 2017). Additionally, doubt remained whether the newly adopted nets could catch more fish than a net with a restricted throat, another characteristic of commercial fishing nets and traditional Iowa nets. A restricted throat, also known as a "finger throat" or "crowfoot-style throat," tapers toward the cod end, promoting unidirectional movement into the cod (Figure 1; Hubert et al. 2012). Recent work has shown how important specification of throat configuration can be, as it affects retention of target species in a 24-hour period (Smith et al. 2016). Escapement of fish from entrapment-type nets is a long-established issue (Hansen 1944 cited in Patriarche 1968), and restriction of the cod end throat has been shown to reduce escapement in modified fyke nets and hoop nets (Porath et al. 2011; Smith et al. 2016). Furthermore, doubt remained whether a second shift to the AFS design would yield similar or higher catch rates and precision of target sportfish species.

Therefore, the objective of this study was to examine several modified fyke net designs which differed in number of funnels and throat configuration, and identify the design with highest retention, catch rate, and precision of target species, including White Crappie, Black Crappie, Bluegill, and Redear Sunfish *L. microlophus*.

Methods

Data collection

Four modified fyke net designs were deployed over three years (2015, 2016, and 2018) and differed in two specifications: number of funnel-shaped throats and throat configuration (Figure 2). The American Fisheries Society (AFS) standard design defined by Bonar et al. (2009) had a single 203-mm square throat (AFS-A design) and was deployed during 2015 and 2018. An altered AFS design was identical except the throat was restricted (AFS-B design); the AFS-B design was deployed during 2016 and 2018. Modified fyke nets traditionally used in Iowa had two funnels, with the first starting on the first fyke net hoop and the second starting on the third hoop (Hubert et al. 2012). The Iowa-A design had two 203-mm square throats, whereas the Iowa-B design had a restricted second throat. Both Iowa designs were deployed all years. Restricted throats were created by cutting the lines pulling the mesh funnel open as a square and attaching longer lines which are pulled taut with purse string closure of the net. All modified fyke net designs had 3'x6' traps, were constructed of knotless mesh, and otherwise matched the standard specifications established by Bonar et al. (2009).

In September 2015, three net designs (excluding AFS-B) were tested for fish retention in a southern Iowa reservoir. Each net was "stocked" with up to 10 individuals per species which had been captured by a previous netting effort. For the AFS design, all individuals were placed in the cod end. For the Iowa design, up to 5 individuals of each species were placed between the first and second throats (i.e., the "front end") and up to 5 individuals of each species were placed in the cod end. Each stocked fish was marked with a unique fin clip identifying its net and position of stocking (i.e., front or cod end). Clips include top caudal (stocked into AFS-A net), anal (AFS-B net), left pectoral (front keep of Iowa-A net), left pelvic (cod end of Iowa-A net), right pectoral (front keep of Iowa-B net), and right pelvic (cod end of Iowa-B net). Nets were placed in sets of three at 6 sites around the reservoir, with net order randomized, and fished overnight, encompassing two crepuscular periods. Paired nets at a site were set approximately 20-30 m from each other. Nets were checked for marked fish the following morning, and each retained individual's net position was recorded. Results from 2015 led to the decision to alter the AFS-A design by restricting the throat and repeating retention tests (i.e., the AFS-B design). In September 2016, three net designs (excluding AFS-A) were tested at 8 additional sites at 2 southern Iowa reservoirs. In September 2018, all four net designs were tested again at the same reservoirs (Table 1). To avoid excessive netting stress and avoid bias from using net-captured fish that may be more susceptible to retention, each net in 2016 and 2018 was "stocked" with fish which had been captured via electrofishing or short-set nets earlier that day. Again, stocked fish were marked with a unique fin clip identifying net and position of stocking. All species were present in each reservoir, yielding information on Redear Sunfish, Bluegill, and crappie (White Crappie and Black Crappie combined). Crappies were combined because they are managed jointly in Iowa.

For catch rate comparisons, modified fyke nets were deployed during fall 2015, 2016, and 2018. The AFS-A design was deployed in 2015 in one reservoir and three reservoirs in 2018. The AFS-B design was deployed in 2016 in two reservoirs and three reservoirs in 2018. During 2015 and 2016, AFS-style nets were set alongside Iowa-style nets each time; and in 2018, all four net designs were tested concurrently. Iowa-A and Iowa-B designs were deployed in an additional 10 lakes and reservoirs in 2016 to elucidate potential differences in catch rate based on 2015 results. Locations sampled ranged in size from 10 to 4,450 ha and were distributed throughout southern Iowa. All sampling was conducted between late September and early November. Nets were set in a random order, fished overnight encompassing two crepuscular periods, and checked the following morning. Fish were identified to species and enumerated. Net sets used for retention testing were not used for catch rate comparisons, thereby excluding stocked fish from all catch rate calculations.

Data analysis

For retention testing, dead fish found in their original stocking location were discounted from the starting sample size, and all nets with a starting sample size less than 2 of a species were excluded from chi-square analysis due to inadequate sample size. To ensure marked fish were not transfers from a similar net design at a different site, marked fish lengths were compared to length measurements from the previous day's stocking. Fish with the appropriate batch mark and length for a particular net/location were assumed to have been stocked into that net, rather than escaping from another net of the same design and being recaptured. This assumption was necessary due to the use of batch marks but was considered acceptable because of the low likelihood of a fish of identical length and mark moving between widely dispersed sites across the reservoir.

Probability of escape was calculated as the proportion of individuals which escaped the net; inversely the probability of retention was calculated as the proportion of individuals which did not escape the net. Probability of escape of a species by each net design was tested overall using the general association Cochran-Mantel-Haenszel statistic (CMH), a form of chi-square test for stratified *n*-way tables in which sites were considered strata ($\alpha = 0.05$; FREQ procedure in SAS). The CMH test is designed to identify consistent differences in probability based on a given factor (e.g., net design) in the presence of site-level variability in central tendency. Lake and year were part of the site definition in this analysis. Significant overall CMH tests were followed by pairwise comparisons between net designs for each species ($\alpha_{\text{corrected}} = 0.05$). In addition to the CMH test, the Mantel-Fleiss criterion (MF) was examined for comparison validity; the CMH results are considered valid when the MF value is greater than or equal to 5 (Mantel and Fleiss 1980). The relative risk of fish escapement by net design was calculated between each pair of net designs. Finally, probability of escape by species and net design was calculated for visual interpretation.

Fish movement within nets was compared for Iowa designs by calculating the proportion of fish which moved between the front and cod ends or escaped after 24 hours, by species. Standard deviations and confidence limits were calculated for each proportion, and a Pearson test for differences between two probabilities was used to identify differences between Iowa-A and Iowa-B nets ($\alpha = 0.05$).

Finally, catch efficiency was compared among net designs by modeling catch of stock-length fish using a generalized linear mixed model, calculating species-specific catch rates, calculating minimum sample sizes to catch at least 125 fish of each species, and calculating sample sizes to achieve a target precision level. Mixed models (family = Poisson) were developed using catch/net-night of a single species as the response variable, net design as a fixed effect, and site nested within lake and year as random effects. Each model was tested against an intercept-only null model using a likelihood ratio test to ensure the model including net design was useful (Zuur et al. 2009). For models in which net design had a significant effect (Type III test of fixed effects), least-square mean catch rates (fish/net-night) and confidence intervals were calculated, and pairwise comparisons were made using the Tukey-Kramer test ($\alpha_{\text{corrected}} = 0.05$). The minimum sample size needed to sample 125 individuals from each species was calculated as 125 divided by the mean catch rate by each net design, rounded up to the nearest integer (recommended minimum number of fish to calculate a

Proportional Stock Density: Quist et al. 2009). Lower and upper estimates were based on the 95% confidence interval of catch rate, with the upper limit indicating the highest catch rate likely from a given net and the lower limit indicating the lowest catch rate likely from a given net. Finally, the number of samples required to achieve target coefficients of variation of 0.20 and 0.30 was calculated for each net design, by species group, as:

$$n = \left[\mathrm{SD}/\left(\mathrm{CV} * \widehat{\mathrm{CPUE}}\right)\right]^2$$

where SD = standard deviation, CV = target coefficient of variation, and $\widehat{\mathrm{CPUE}}$ = mean catch rate. In data summaries, Iowa-A and Iowa-B designs were collectively referred to as "Iowa designs," AFS-A and AFS-B designs as "AFS designs," Iowa-A and AFS-A as "A designs," and Iowa-B and AFS-B designs as "B designs."

Results

A total of 280 Bluegill, 399 Redear Sunfish, and 452 crappie were included in retention tests; 112 fish were discounted from the starting sample size due to mortality overnight. A total of 75 unique nets were stocked for retention testing. Overall, net designs had different retention rates for each fish species (Bluegills: CMH = 36.1414, df = 3, p-value <0.0001; Crappie: CMH = 8.0177, df = 3, p-value = 0.0456; Redear Sunfish: CMH = 14.3573, df = 3, p-value = 0.0025; Figure 3). Pairwise comparisons indicated that Bluegill were 2 to 7 times more likely to escape from A designs than B designs (Table 2). Redear Sunfish were 2.6 times more likely to escape from A designs than the Iowa-B design. Despite a significant overall test, pairwise comparisons for crappie lacked adequate consistency among strata to make clear conclusions.

Migration after 24 hours between sections of the Iowa nets also differed between the Iowa-A and Iowa-B designs (Figure 4). The Iowa-B design retained a significantly greater proportion of Bluegill (p-value = 0.047) and marginally greater proportions of Redear Sunfish (p-value = 0.074) and Crappie (p-value = 0.098) in the cod end than the Iowa-A design. Likewise, the Iowa-A design allowed significantly greater proportions of crappie and Redear Sunfish to move from the cod end to the front section (Crappie p-value <0.001; Redear Sunfish p-value = 0.04). Similar to CMH results, the Iowa-A design allowed a significantly greater proportion of Bluegill to escape p-value = 0.012) and a marginally greater proportion of Redear Sunfish to escape (p-value = 0.059) than the Iowa-B design.

The assumption that fish with the appropriate batch mark were not transfers from another net of the same design was not entirely true; fifteen fish were identified as certain transfers from another net of similar design (6 crappie, 6 Redear Sunfish, and 3 Bluegill). These fish represented 1.3% of the crappie tested, 1.5% of the Redear Sunfish tested, and 1.1% of the Bluegill tested; all were removed from the dataset prior to the chi-square analysis. One crappie and 1Redear Sunfish stocked into AFS-A nets were recaptured in Iowa-A nets, and 2 crappie stocked into AFS-A nets were recaptured in Iowa-B nets. Two crappie and one Redear Sunfish stocked into Iowa-A nets were recaptured in Iowa-B nets, and one Redear Sunfish stocked into an Iowa-B net was recaptured in an Iowa-A net. AFS-style nets never recaptured fish from a different net design. In addition, one fish's mark could not be identified because its tail had been eaten. All remaining fish were identified as the fish stocked the day before based on their length and mark.

A total of 2,566 Bluegill, 3,124 crappie, and 1,618 Redear Sunfish were included in catch efficiency and precision tests. Bluegill and crappie were present in all study locations; Redear Sunfish were present in 6 of the 13 lakes and reservoirs. All models with net design performed significantly better than an intercept-only (i.e., null) model (Bluegill $\chi^2 = 36.16, \text{p-value} < 0.0001$; Crappie $\chi^2 = 33.05, \text{p-value} < 0.0001$; Redear Sunfish $\chi^2 = 6.76, \text{p-value} = 0.0093$). Net design was a significant factor affecting Bluegill catch rate ($\mathrm{F} = 12.51$, df $= 3, \text{p-value} < 0.0001$), with the Iowa-A and Iowa-B designs catching more Bluegill than both AFS designs (Figure 5). Net design was also a significant factor affecting crappie catch rate ($\mathrm{F} = 11.03$, df $= 3, \text{p-value} < 0.0001$), with the Iowa-A, Iowa-B, and AFS-B designs catching more crappie than the AFS-A design. Finally, net design was a marginally significant factor affecting Redear Sunfish catch rate ($\mathrm{F} = 2.27$, df $= 3, \text{p-value} = 0.0836$). Number of samples (net sets) required to obtain 125 stock-length individuals of each species were minimized for Bluegill and crappie using the Iowa-B design, whereas the number of net sets required for 125 Redear Sunfish was minimized using the Iowa-A design (Table 3). The same net designs were likewise appropriate for achieving target measures of precision.

Discussion and Management Implications

Modified fyke nets with two funnels including a restricted throat on the cod end (the Iowa-B design) consistently caught and retained as many or more Bluegill, crappie, and Redear Sunfish than other net designs. Movement within two-funneled nets indicated that fish tended to be retained in their net sections or moved further into the net, with less forward movement/escapement in the Iowa-B net compared to the Iowa-A net. Porath et al. (2011) found similar improvement in fish retention in the cod end for Channel Catfish in hoop nets with restricted throats. Alteration of the AFS-A net to a restricted throat (i.e., AFS-B design) increased crappie catch rates; these findings are similar to those of Smith et al. (2016). Smith et al. (2016) observed over four times greater catch rates of stock-length Black Crappie in AFS nets with restricted throats than unrestricted throats; in this study crappie catch was over two times greater in AFS-B nets than AFS-A nets. Similar to Smith et al. (2016), this study never observed greater mean catch rates of stock-length fish in unrestricted nets (A designs) than restricted nets (B designs). Throat restriction appeared to be particularly important for Bluegill and Redear Sunfish retention; this was also reflected in both species' net movement tendencies. Crappie retention was affected by net design as well and deserves additional study.

An additional funnel enhanced catch rate and reduced the minimum sample size (number of net sets) needed to precisely characterize fish populations. Longer nets with two funnels (Iowa designs) captured as many if not more stock-length Bluegill and crappie than the AFS designs with one funnel. As such, longer nets also minimized the number of net sets required to capture 125 stock-length fish, and were comparable to the sample sizes estimated by Fischer et al. (2010). This study found lower minimum sample sizes for capturing 125 individuals in Iowa-B nets than determined for 100 individuals by Flammang et al. (2016). This difference likely resulted from unique analytical approaches, with the estimates of Flammang et al. (2016) being more precautionary in terms of potential workload. Koch et al. (2014) found lower minimum sample sizes in AFS standard nets than this study for capturing 100 Bluegill or crappie in small to medium-sized reservoirs in Kansas. However, the authors noted high variability in catch rates for both species, and the estimated sample sizes reported here for AFS-A nets fall within the 10^{th} and 90^{th} percentiles reported by Koch et al. (2014). Given the wider confidence intervals around AFS-style net sample sizes, minimum sample size recommendations should be treated conservatively. Rather, precision should be considered using coefficient of variation as a metric of net performance. Notably, the AFS-B net captured similar numbers of crappie and had similar sample size estimates as the Iowa designs for a target number of fish captured; however, precision-based sample sizes differed.

More detailed models could be developed if fish were marked individually, rather than batch-marked in treatment groups (e.g., Porath et al. 2011). This would allow for better tracking of individual movements within and across nets, which could improve estimates of escapement. Similar to the findings of Smith et al. (2016), the assumption that fish with expected marks were from a particular net did not always hold true, indicating that fish did actively escape and become recaptured in other nets. This could have caused escapement from those nets to be slightly underestimated. Although fish movement did occur a few times during the study, differences found between net designs were not dependent on this source of variability as those fish were identified using length data and removed from retention analyses. Again, two-funneled net designs caught all of the fish which were known to have been stocked in different nets. In addition to marking fish individually, a valuable improvement for future studies would be to collect the fish for escapement tests using alternative gears or methods; initial overnight net sets were overly stressful to the fish and could have biased results by including fish with stronger net-seeking behaviors.

This study did not examine stocking density as a factor affecting fish retention or catch rate. Smith et al. (2016) found that Black Crappie escapement from unrestricted modified fyke nets increased with conspecific stocking density ranging from 0 to 17 fish per net, whereas Breen and Ruetz (2006) found that escapement for several species from unrestricted modified fyke nets decreased with increasing fish densities up to 60 fish per net. Porath et al. (2011) found that throat restriction in hoop nets reduced escapement of Channel Catfish at densities varying from low to high. The current study only examined lower stocking densities (0 to 10 fish of a single species per net) in order to avoid excessive stress associated with high stocking densities. Furthermore, fish were distributed as equally as possible among nets in a single lake or reservoir to ensure each net had an adequate number of fish for statistical testing. Future studies could further examine the effect of conspecific stocking densities for a wider variety of species including percids and esocids. However, the importance of conspecific stocking density may be outweighed by the importance of net specifications such as throat type when ultimately explaining catch rates in modified fyke nets (Smith et al. 2016). This study also did not examine the relationship between total length and catch rate in different net designs for Bluegill, crappie, or Redear

Sunfish. However, Smith et al. (2016) found that nets with restricted throats captured larger Black Crappie and Bluegill. McInerny and Cross (2006) found differential catchability in modified fyke nets of Black Crappie by length group, with smaller individuals having lower catchability; the authors did not determine whether this difference was due to a difference in initial catch or in escapement. If size-specific escapement from modified fyke nets does occur, it could affect size-based indices such as Proportional Size Distribution and should be recognized as a source of potential bias in modified fyke net specifications. Future research on modified fyke net specifications should focus on the importance of fish size and density on probability of escape and catch.

The results of this study indicate the need to continue studying and refining the specifications of the standard modified fyke net (Bonar et al. 2009). This study concluded that optimal catch and retention for crappie, Bluegill, and Redear Sunfish may be achieved with a net that includes two funnels, with the first funnel starting on the first hoop and ending with a square throat on the third hoop and the second funnel starting on the third hoop and ending with a restricted throat. That said, catch efficiency, precision, and retention are just some of many important attributes that should be considered in establishing a standard; other considerations include catchability (Fischer et al. 2010) and representativeness of the true population's characteristics (McInerny 1988; Besler et al. 1998; Shoup et al. 2003; McInerny and Cross 2006). Given the potentially widespread adoption of the specifications set forth by Bonar et al. (2009), addition of the restricted throat alone could significantly improve catch rate depending on target species (crappie: Smith et al. 2016, this study). However, addition of a second throat improved catch rates too, especially for *Lepomis* spp., and improved precision. More research is needed to determine the importance of throat configuration and number of throats on more species of interest outside the Midwest, and to determine appropriate conversion formulas from one gear configuration to another. Fisheries sampling efforts using any modified fyke net design should at least include reporting of the throat configuration and number of throats in the sample metadata and associated publications, allowing for valid comparisons among studies to be made (Shoup et al. 2003; Porath et al. 2011; Smith et al. 2016).

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Table 1. Reservoir locations, dates, and number of sites examined during modified fyke net retention tests.

Reservoir	Date Stocked	Date Sampled	Sites
Lake Ahquabi	9/28/15	9/29/15	6
	9/11/18	9/12/18	3
	9/12/18	9/13/18	3
Williamson Pond	9/12/16	9/13/16	3
	9/19/16	9/20/16	3
	9/9/18	9/10/18	2
West Lake Osceola	9/27/16	9/28/16	2
	9/24/18	9/25/18	3
	9/25/18	9/26/18	3

Table 2. Pairwise comparisons of fish escapement between modified fyke net designs, by species. Abbreviated headings are defined as k = number of sites, CMH = Cochran-Mantel-Haenszel test for general association (all df = 1), MF = Mantel-Fleiss criterion, and Relative risk = relative risk of fish escapement for first net compared to second net (95% confidence interval).

Comparison	k	CMH	p-value	MF	Relative risk
			Bluegill		
AFS A vs. Iowa A	19	0.6649	0.4148	7.6052	1.2568 (0.6928 - 2.2799)
AFS A vs. Iowa B	17	7.0578	0.0079	3.6331	2.0237 (1.2243 - 3.3450)
AFS B vs. Iowa A	19	27.3340	<0.0001	14.2483	0.1367 (0.0479 - 0.3899)
AFS B vs. Iowa B	18	4.8820	0.0271	5.6638	0.2220 (0.0443 - 1.1118)
Iowa A vs. Iowa B	12	11.3209	0.0008	16.8747	2.3367 (1.3560 - 4.0268)
AFS A vs. AFS B	18	12.0605	0.0005	13.0190	3.6859 (1.5502 - 8.7639)
			Crappie		
AFS A vs. Iowa A	23	1.0641	0.3023	12.7357	1.4080 (0.7307 - 2.7130)
AFS A vs. Iowa B	24	3.9277	0.0475	18.0316	1.7731 (0.9935 - 3.16146)
AFS B vs. Iowa A	22	0.2666	0.6057	2.4172	1.4604 (0.3524 - 6.0522)
AFS B vs. Iowa B	23	0.4857	0.4859	4.0184	0.6542 (0.1981 - 2.1599)
Iowa A vs. Iowa B	17	1.7731	0.1830	16.3642	0.6687 (0.3670 - 1.2187)
AFS A vs. AFS B	23	4.6653	0.0308	3.2397	9.2808 (0.7438 - 115.8082)
			Redear Sunfish		
AFS A vs. Iowa A	15	0.8267	0.3632	19.4354	0.7782 (-.4547 - 1.3319)
AFS A vs. Iowa B	15	7.3480	0.0067	15.1739	2.6066 (1.2399 - 5.4795)
AFS B vs. Iowa A	13	2.9663	0.0850	5.3095	0.3744 (0.1152 - 1.2169)
AFS B vs. Iowa B	14	0.0036	0.9523	3.0749	0.9601 (0.2524 - 3.6518)
Iowa A vs. Iowa B	11	8.5079	0.0035	14.8198	2.6899 (1.3417 - 5.3931)
AFS A vs. AFS B	15	0.5939	0.4409	3.9457	1.6240 (0.4707 - 5.6039)

Table 3. Sample size (number of net sets), by species, required for four modified fyke net designs to capture 125 fish (n125) with 95% confidence interval (minimum based on upper limit; maximum based on lower limit), and to achieve coefficients of variation of 0.20 ($n_{CV0.30}$) and 0.30 ($n_{CV0.30}$).

Net Design	n_{125}	n_{125} 95% CI	$n_{CV0.20}$	$n_{CV0.30}$
		Bluegill		
AFS A	51	29 - 90	427	190
AFS B	44	24 - 80	349	155
Iowa A	17	12 - 23	31	14
Iowa B	9	7 - 13	18	8
		Crappie		
AFS A	38	24 - 61	170	76
AFS B	13	8 - 20	46	21
Iowa A	11	8 - 14	15	7
Iowa B	8	6 - 10	12	5
		Redear Sunfish		
AFS A	25	14 - 44	104	46
AFS B	51	26 -100	436	194
Iowa A	18	11 - 29	50	22
Iowa B	21	13 - 33	57	26

A

B

Figure 1. A square throat (A) and a restricted throat (B) on a modified fyke net.

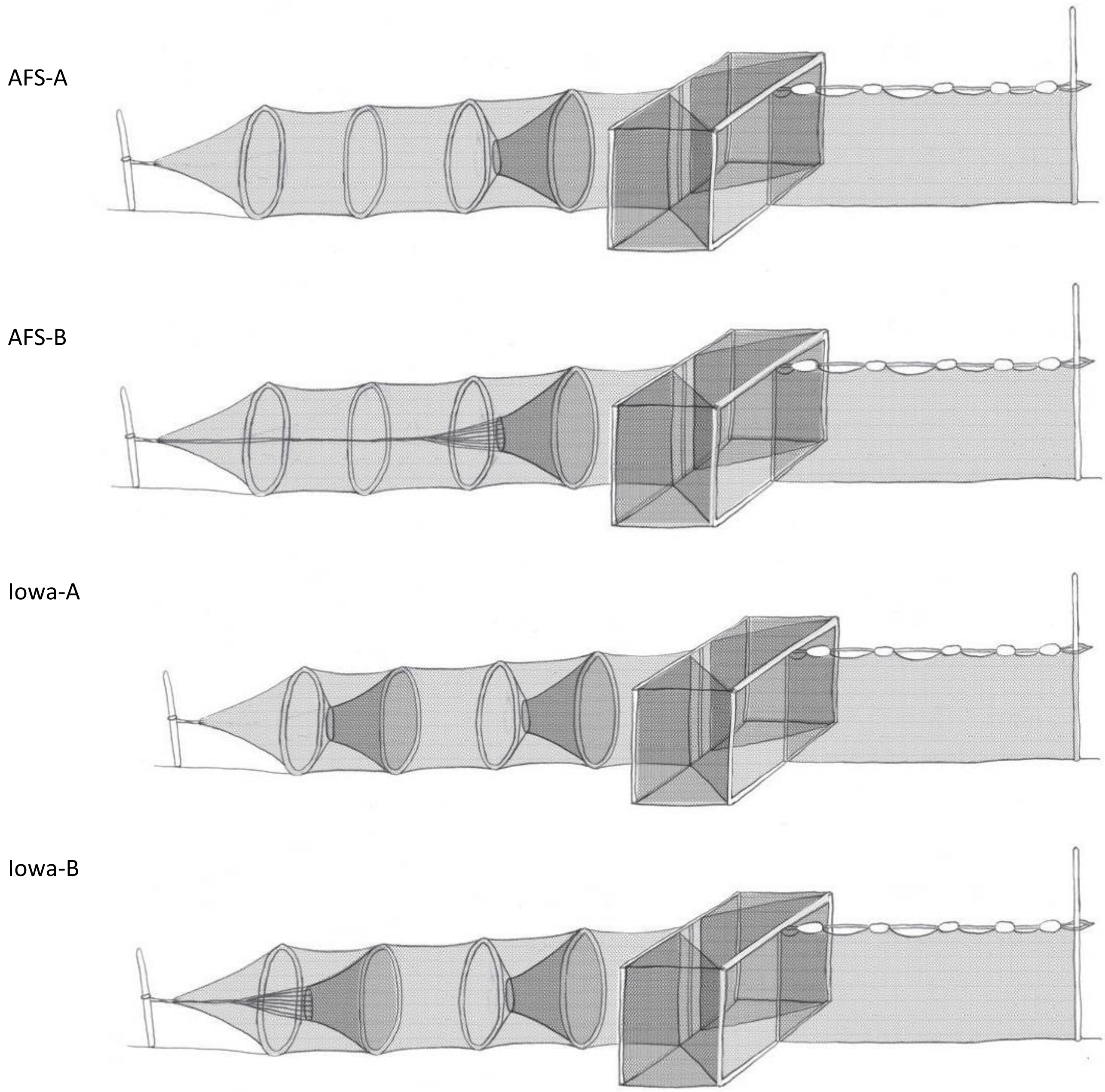

Figure 2. Visual representation of an American Fisheries Society standard modified fyke net (AFS-A), an altered AFS modified fyke net with a restricted throat (AFS-B), an Iowa modified fyke net with two square throats (Iowa-A), and an Iowa modified fyke net with one square throat and one restricted throat (Iowa-B).

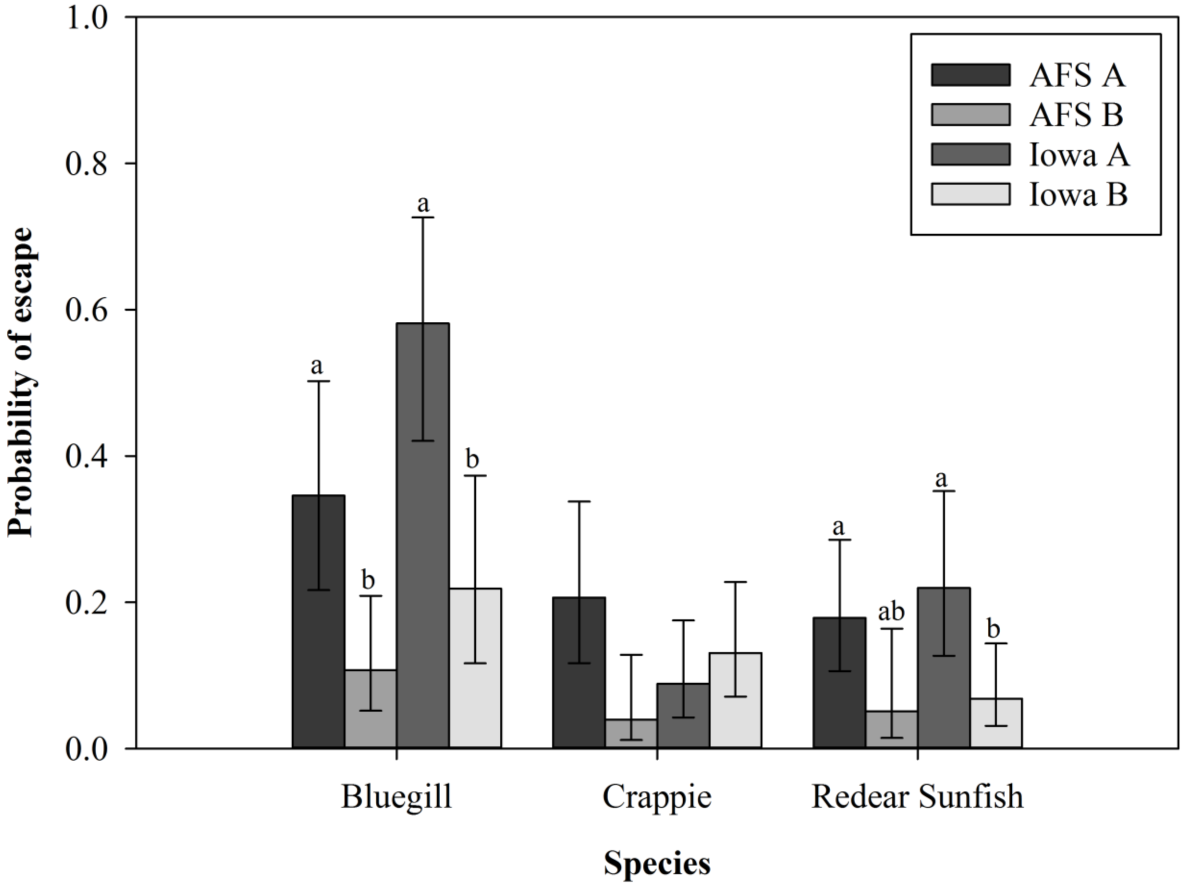

Figure 3. Probability of fish escape from four modified fyke net designs, by species. 95% confidence intervals are shown. Significant differences between nets are indicated by letters within each species group.

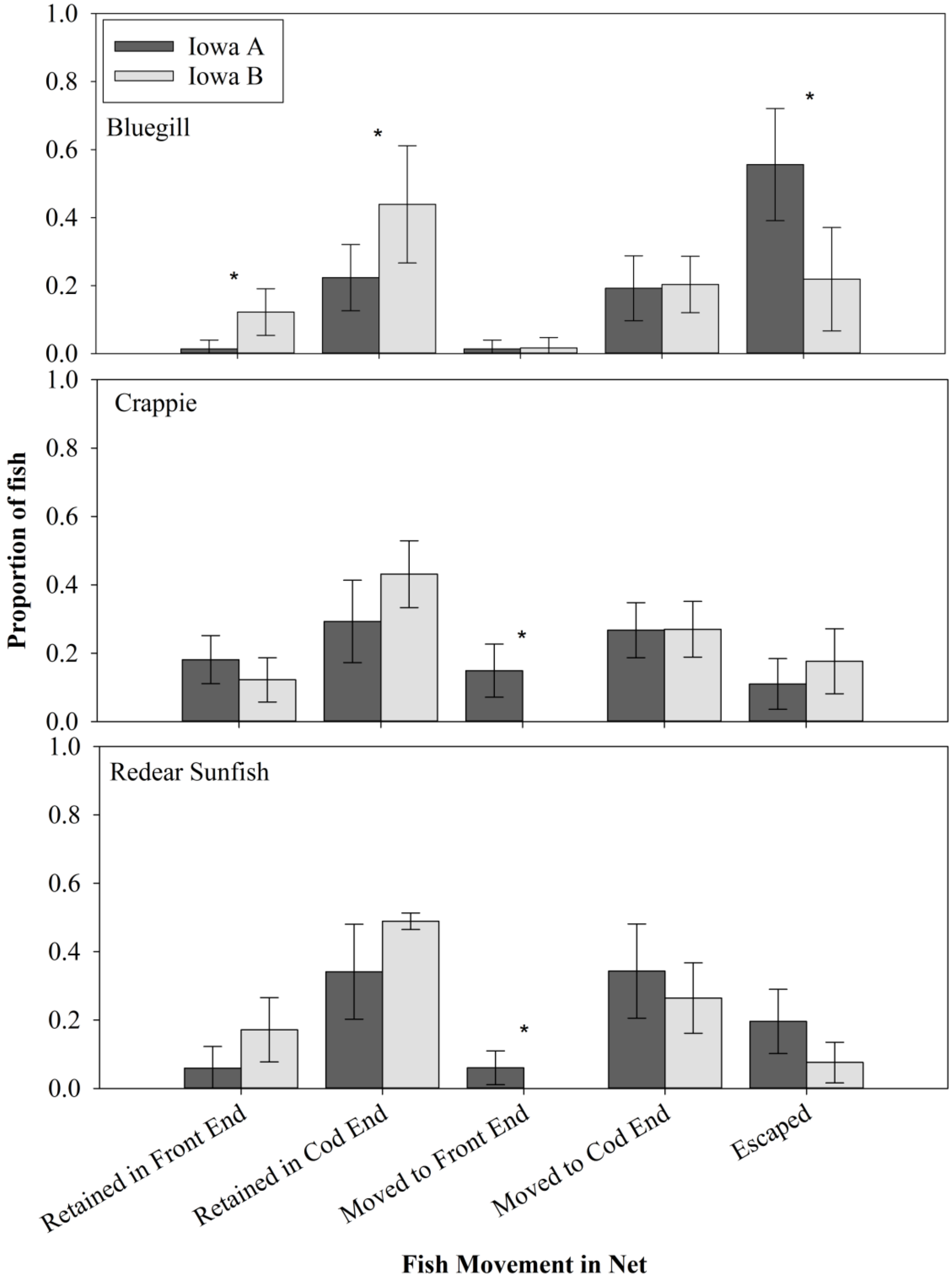

Figure 4. Proportion of fish retained, migrated, and escaped from the front and cod ends of two modified fyke net designs, by species, after 24 hours. 95% confidence intervals are shown. Significant differences between nets are indicated by an asterisk.

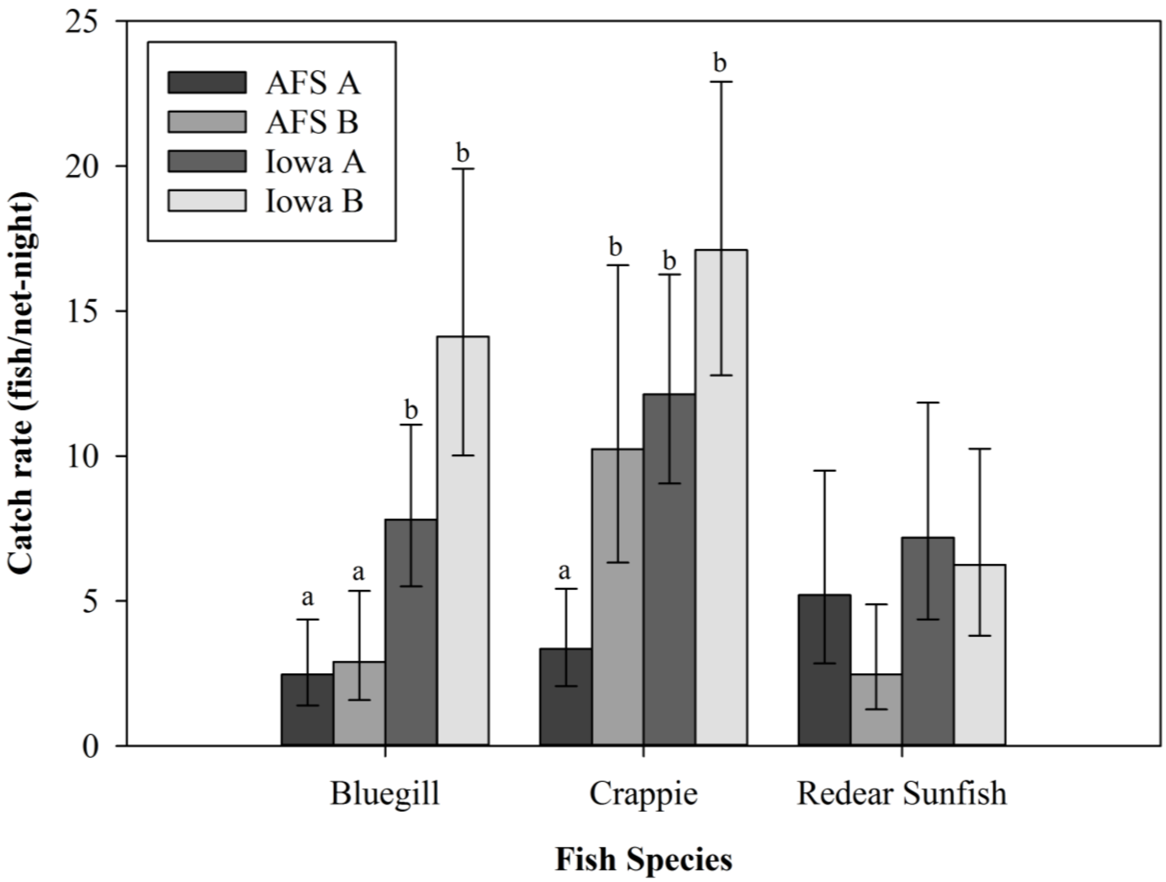

Figure 5. Mean catch rate by four modified fyke net designs, by species. 95% confidence intervals are shown. Significant differences between nets are indicated by letters within each species group.

Electrofishing Equipment Evaluations and Standardization

Introduction

Boat electrofishing is used by fisheries managers to collect a wide range of fishes from lentic and lotic systems. An appropriately timed electrofishing survey can provide a sample for assessing important population parameters, including abundance, size and age structure, and growth data (Coble 1992; Miranda et al. 1996; Reynolds and Simpson 1978). Short- and long-term management goals are implemented from information collected during these surveys (Tyszko 2017). The Iowa DNR, like most state fisheries management agencies, has a standard sampling program for lentic systems to allow for statewide comparison of fisheries data. Without standardized equipment and methods, fish can be injured and statistical variation between surveys can be large. Boat electrofishing is an important component of that standard sampling program, and the Iowa DNR has been gradually working towards standardization of this gear since 2011. Additional work needed to standardize electrofishing equipment was noted by Bruce (2018).

Electrofishing surveys are especially onerous to standardize because there are numerous factors to consider, including: environmental, human influence, and equipment. Because the boat is in motion, changing environmental conditions during a survey affect how electricity moves through the water, eliminating the ability to have a completely standardized survey; however, uncontrollable variables will always exist, so the goal should be controlling as many variables as possible. Some human influences can be managed through training - but not all - and there will always be variables such as vision prohibiting complete standardization between dip netters. Equipment is one variable where standards can be setup and applied to all boats. Burkhardt and Gutreuter (1995) explained 14.9% of night catch variation by standardizing power applied to the water.

In the 1950's, research was underway to refine boat electrofishing equipment and methods (Haskell 1954; Witt and Campbell 1959). Kolz (1989) proposed the power transfer theory of electrofishing; and Kolz and Reynolds (1989) demonstrated it. Several years later, the power transfer model was tested by Dolan and Miranda (2003). In 2009, AFS recognized the need for standard sampling methods and published a book "Standard Methods for Sampling Freshwater Fishes in North America"; using these methods, managers can compare survey data at multiple spatial scales (i.e., county, state, or nationwide). This study examined additional methods to standardize electrofishing equipment.

Methods

In 2017 an electrofishing equipment and safety workshop was presented in Milford, IA. At least one person from every Iowa DNR fisheries field station attended. Lectures discussed electrofishing theory, safety, how to setup an electrofishing boat, and methods used to diagnose problems with boats. The last day of the workshop consisted of four hands on stations: boat information, voltage field gradients, resistance, and calibration. Boat length and width, number of electrodes, diameter and length of each anode dropper, diameter of each anode array, and the orientation of the anode arrays to the front of the boat were measured for nine setups (Table 4).

Table 4. Boat setup specifications for 9 electrofishing boats evaluated as part of an electrofishing workshop.

Boat ID	Boat Hull		Anode Array Diameter (in)	Anode Droppers			Anode Array Orientation in Front of Boat		Control Box Model
	Length (in)	Width (in)		Diameter (in)	Length (in)	Total Number	Center to Center (in)	Center to Boat Hull (in)	
1A	192	67	36	0.5	3 to 5	16	70	129	MBS 1D
2A	198	72	33	0.1875	19	12	95	97	GPP 5
3A	192	68	36	0.5	6.25	16	76	101	MBS 1D
4A	194	60	37	0.25	24	12	91	108	MBS 1D
5A	192	60	36	0.25	18	16	75	91	MBS 1D
6A	170	62	3	0.375	7	14	74	108	MBS 1D
7A	212	60	36	0.1875	18	12	62	123	MBS 1D
8A	192	56	42	0.75	1 to 6	14	79	110	VVP15B
9A	232	72	38	1.0	10	8	84	106	MBS 1D

After the electrofishing workshop was presented additional work to further standardize electrofishing gear was deemed necessary. Anode configuration was evaluated prior to testing boat hull resistance, system resistance, and mapping electrical fields for five Iowa electrofishing boats. Two anode configurations were used in Iowa, covered and uncovered droppers. After the anode configurations were evaluated all boats were converted to use uncovered anode droppers based on results from the anode evaluation. Five boats were selected to measure boat hull resistance, system resistance, and voltage gradients in the electrical fields (Table 5). Boat hull resistance measurements were collected from both dry and wet hulls with the boat sitting on the trailer and out of the water. A Fluke 124 Oscilloscope was used to measure resistance in ohms(Ω), an overload(OL) value was displayed if the resistance measurement on the oscilloscope is greater than 40 Ω. An area was cleaned on the gunnel of each boat and a 2.54 cm by 2.54 cm by 0.635 cm block of aluminum was pressed to the hull of each boat. The positive end of the Fluke meter probe was pressed against the aluminum block holding it to the hull. The negative end was pressed against the cleaned gunnel and the resistance measurement was recorded. Resistance values were recorded for 10 random locations on the boat hulls below the water line. Positively charged ion buildup was quantified by cleaning a 225 cm^2 area on the starboard side of the boat below the waterline amidships. Boat hulls were scrapped using a 2 cm wide wood chisel and loosened deposits were collected on a sheet of paper below the scrapped area. Deposits were placed on a digital scale and measured to one hundredth of a gram.

System resistance was measured after boats were anchored and the sampling grid was deployed. Ambient water conductivity and water temperature were measured prior to applying power to the water. Miranda (2009) provided standardized peak power settings based on ambient water conductivity and water temperature. After volts and amps were set on the ETS Control Box to achieve the required power setting system resistance was calculated and using the follow equation:

$$R = \frac{V}{A}$$

where R is resistance, V is peak volts, and A is peak amps. Although all field tests were completed on the same lake ambient water conductivities were different for each field test. Boat system resistance values were standardized (R_{100}) prior to analysis using the following equation:

$$R_{100} = \frac{R_s * Ca}{100}$$

where R_{100} is standardized resistance value, R_s is measured system resistance, and Ca is ambient water conductivity. These values were compared to weighed material from the boat hulls.

Electrical field measurements were also collected using a Fluke 124 Oscilloscope. A voltage gradient probe (VG) and sampling grid were fabricated to guide electrical field data collection (Figure 6 and Figure 7). The grid size and sampling depths were designed to mimic a typical fish collection area in front of the boat during an electrofishing survey. Transects were spaced 0.914 m apart, set perpendicular to the bow and sampling points were spaced 0.457 m apart on each transect (Figure 6). Electrical field intensity was measured using a voltage gradient probe at two predetermined depths, 0.457 m and 1.372 m for each point along the four transects totaling 44 sample points per depth plane for a total of 88 sample points per survey. Collecting a sample at each point consisted of slowly turning the probe clockwise and recording the highest value, V/cm, displayed on the oscilloscope. Voltage gradients are affected by water conductivity and need to be standardized prior to comparing survey results. Voltage gradient measurements for all surveys were standardized by water conductivity and fish conductivity, 100 µS/cm and 115 µS/cm, using the equation:

$$VG_s = \frac{VG_m(VG_t + Fc)}{(Fc + Ca) * (Fc/VG_t)}$$

where VG_s is the standardized voltage gradient, VG_m is the measured voltage gradient, VG_t is the target voltage gradient, Fc is the standard fish conductivity, and Ca is the measured ambient water conductivity for each survey. Voltage gradients, pre- and post-cleaning, were analyzed for each boat using a Wilcoxon Signed Rank test, P values <.05 were considered significant. Shaded contour maps were created to visually represent the electrofishing fields at each measured depth.

Table 5. Boat hull and Anode array measurements for 4 bare aluminum hull boats and 1 painted aluminum boat hull used to evaluate boat hull resistance, system resistance, and electrical field voltage gradients post hull cleaning. *Boat has a painted aluminum hull.

Boat ID	Hull Length (cm)	Hull width (cm)	Hull to Anode Center (cm)	Ring Center to Center (cm)	Ring Diameter (cm)	Dropper Length (cm)	Dropper Diameter (cm)	Number of Droppers
1	493	152	249	188	91	61	0.635	6
2	488	168	274	244	91	61	0.635	6
3	488	152	244	203	91	61	0.635	6
4	488	152	191	224	107	46	0.953	6
5*	386	107	224	152	61	61	0.635	6

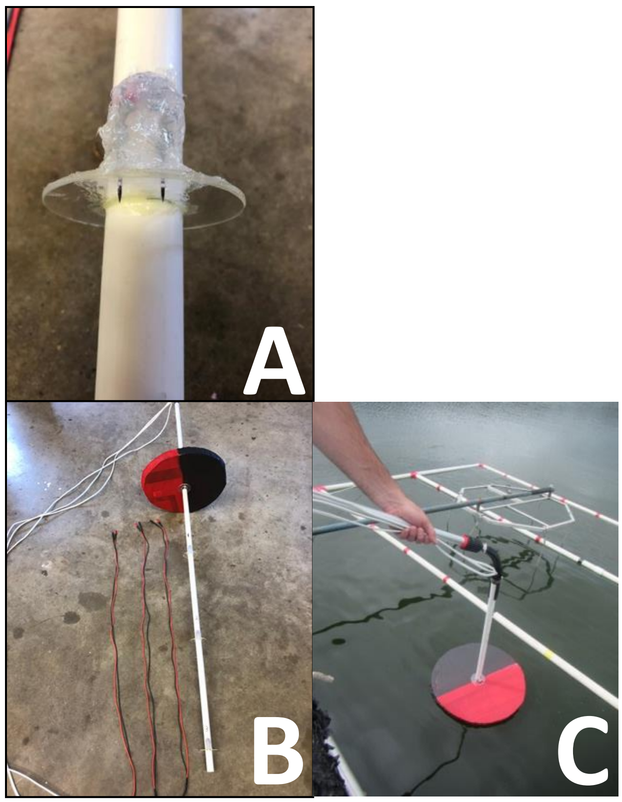

Figure 6. Gradient probe used to measure field intensity at .457m and 1.372m below the water surface: (A) gradient probe points spaced 1 cm apart to collect field intensity at each depth; (B) floating disc attached to gradient probe and three leads for oscilloscope attachment; (C) floating gradient probe with rubber hose attached to extendable pole used to rotate the probe at each sampling location while standing in the boat.

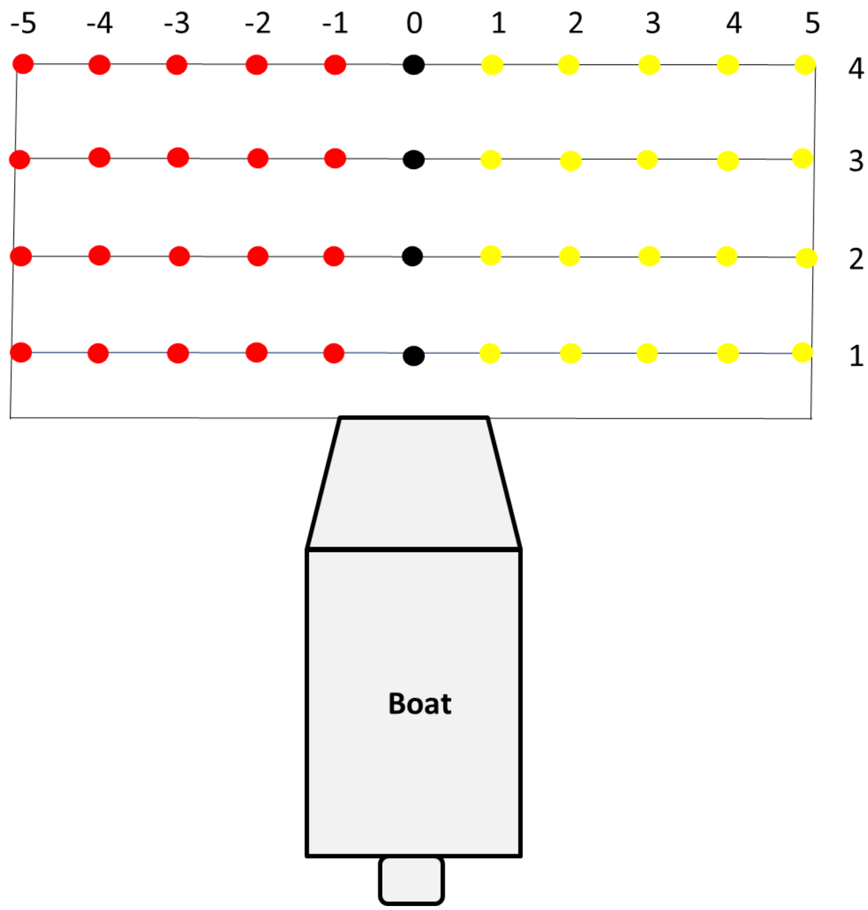

Figure 7. Electrofishing field sampling grid constructed of 2" PVC pipe and anchored using ropes that would not interfere with the electrical current in the water. Each transect is spaced 1 meter apart and sample locations on each transect are space 18".

Results

The workshop held in 2017 provided Iowa DNR staff with the information necessary to safely work with electrofishing equipment and provided the methodology to further standardize Iowa's electrofishing fleet. The calibration station results showed ETS control boxes provide accurate peak amp and volt metering. The voltage field gradient station provided information about the two anode dropper configurations used in Iowa, covered and uncovered. Voltage gradients were measured for both configurations (**Figure 8**). Voltage gradients for boat 4A produced an exponential curve, voltage decreased as distance from the anode increased. Boat 1A produced a bell shaped curve, voltage gradients increased from 50 cm to 70 cm and then decreased as distance from the anode increased.

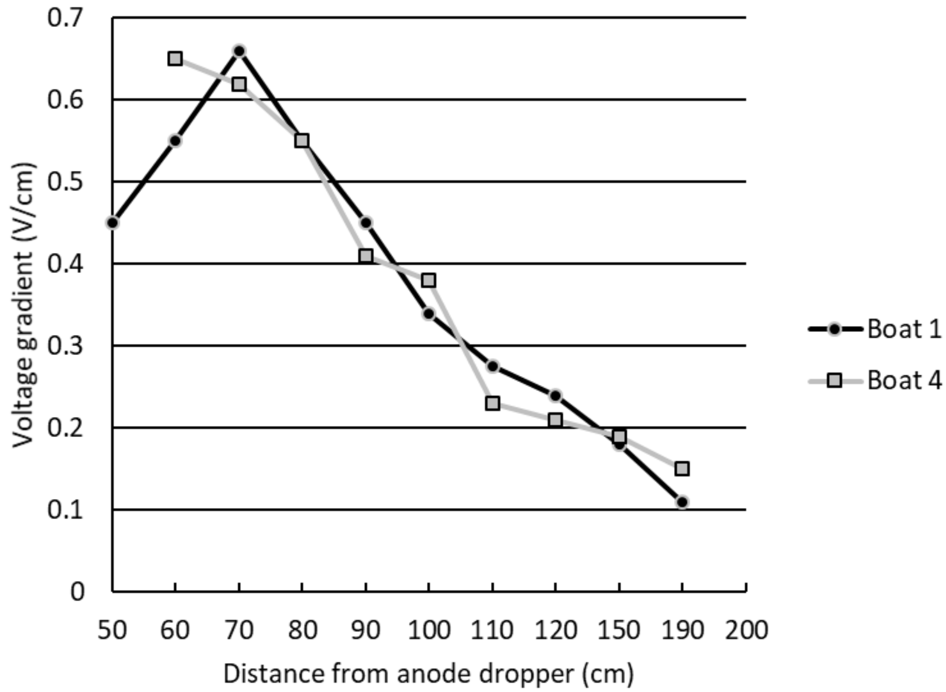

Figure 8. Lateral voltage gradients for two electrofishing boats; Boat 1 used covered droppers whereas Boat 4 did not use a sheath to cover the anode dropper.

Cleaning boat hulls reduced hull resistance for all boats. Pre-cleaning measurements for all boats were OL and therefore not measurable, post cleaning measurements were .4 Ω. Measured ionic buildup on each boat hull was between .98 g and 2.52 g with boat 4 having the greatest amount of buildup (Table 6). System resistance (R_{100}) decreased for boat 4 after both 25% and 50% of the hull was cleaned; mixed results were recorded for boats 1, 2, 3 and 5 (**Table 7**).

Table 6. Weighed amount of ionic buildup on boat hulls from a 225 cm2 area from the starboard side of boat amidships.

Boat ID	Boat Name	Weight (g)	Cleaned Area (cm^2)
1	Cold Springs Management	0.98	225
2	Mount Ayr	0.82	225
3	Lake View	1.15	225
4	Cold Springs Research	2.52	225
5	Cold Springs Pond	NA	NA

Table 7. Percentage of cleaned boat hull, ambient water conductivity, control box meter settings, measured boom amp values, and calculated resistance values for 5 electrofishing boats.

Boat	Cathode Type	% Hull Cleaned	Ca (µS/cm)	Peak Volts (V)	Peak Amps (A)	Stbd (A)	Port (A)	Rs	R_{100}
1	Alum Hull	0	227	191	17	3.24	3.91	11.2	25.5
1	Alum Hull	25	215	195	16.5	3.49	3.68	11.8	25.4
1	Alum Hull	50	206	204	15.2	3.2	3.9	13.4	27.6
2	Alum Hull	0	210	236	13.2	0.41	6.57	17.9	37.5
2	Alum Hull	25	215	235	13.6	0.38	4.44	17.3	37.3
2	Alum Hull	50	201	244	12.5	0.4	6.21	19.5	39.2
3	Alum Hull	0	208	225	14	2.51	3.51	16.1	33.4
3	Alum Hull	25	197	242	13	2.8	3.4	18.6	36.7

Boat	Cathode Type	% Hull Cleaned	Ca (µS/cm)	Peak Volts (V)	Peak Amps (A)	Stbd (A)	Port (A)	Rs	R_{100}
3	Alum Hull	50	198	230	13.5	2.3	1.9	17.0	33.7
4	Alum Hull	0	325	195	17.7	3.91	4.46	11.0	35.8
4	Alum Hull	25	290	185	18.8	3.8	4.3	9.8	28.5
4	Alum Hull	50	186	211	14	2.81	3.91	15.1	28.0
5	Painted Hull	0	270	220	14	1.63	1.3	15.7	42.4
5	Painted Hull	25	310	220	16	3.86	3.57	13.8	42.6
5	Skirt	0	270	180	15	1.8	1.3	12.0	32.4

Electrical field voltage gradient measurements were significantly different between pre and post cleaning at the deeper depth plane of 1.37 m (Table 8). Boat 3 showed a significant difference between pre and post cleaning at both depth planes. Boat 5 exhibited significantly electrical field measurements for both depth planes when 25% of the boat hull was cleaned. The skirt that was attached prior to cleaning the hull on boat 5 showed no significant change at either depth plane.

Table 8. Depth plane, percent of cleaned hull, and P values for significance of difference between voltage gradients for 44 points on each depth plane between surveys for each boat.

Boat ID	Depth (m)	Percent Clean	N	P Value
1	0.457	25	44	0.17
1	1.37	25	44	<.001
1	0.457	50	44	0.071
1	1.37	50	44	<.001
2	0.457	25	44	0.102
2	1.37	25	44	<.001
2	0.457	50	44	0.255
2	1.37	50	44	<.001
3	0.457	25	44	<.001
3	1.37	25	44	<.001
3	0.457	50	44	<.001
3	1.37	50	44	<.001
4	0.457	25	44	0.478
4	1.37	25	44	<.001
4	0.457	50	44	0.659
4	1.37	50	44	<.001
5	0.457	25	44	<.001
5	1.37	25	44	<.001
5	0.457	0% Clean, Skirt	44	0.268
5	1.37	0% Clean, Skirt	44	0.112

Voltage gradient contour maps were created for each survey to visually demonstrate how cleaning the hull of a boat can affect the size, location, and intensity of the associated electrical field. As the percentage of cleaned hull increased for Boat 1 the voltage intensity also increased (Figure 9). Boat 2 showed a decrease in voltage intensity as the hull was cleaned (Figure 10). This boat also had an issue with the starboard anode. The shaded contour map was only able to display voltage gradients for the port side anode array. Boat 3 shows a decrease in field intensity as the boat hull is cleaned from 25% to 50% (Figure 11). Boat 4 exhibits an increase in field intensity and movement of the field anterior to the bow as the boat hull is cleaned (Figure 12). The field intensity for boat 5 moves from the bow to the the anode array when the hull is cleaned 25% (Figure 13). The electrical field for boat 5 also moves towards the anode array with the addition of the cathode skirt.

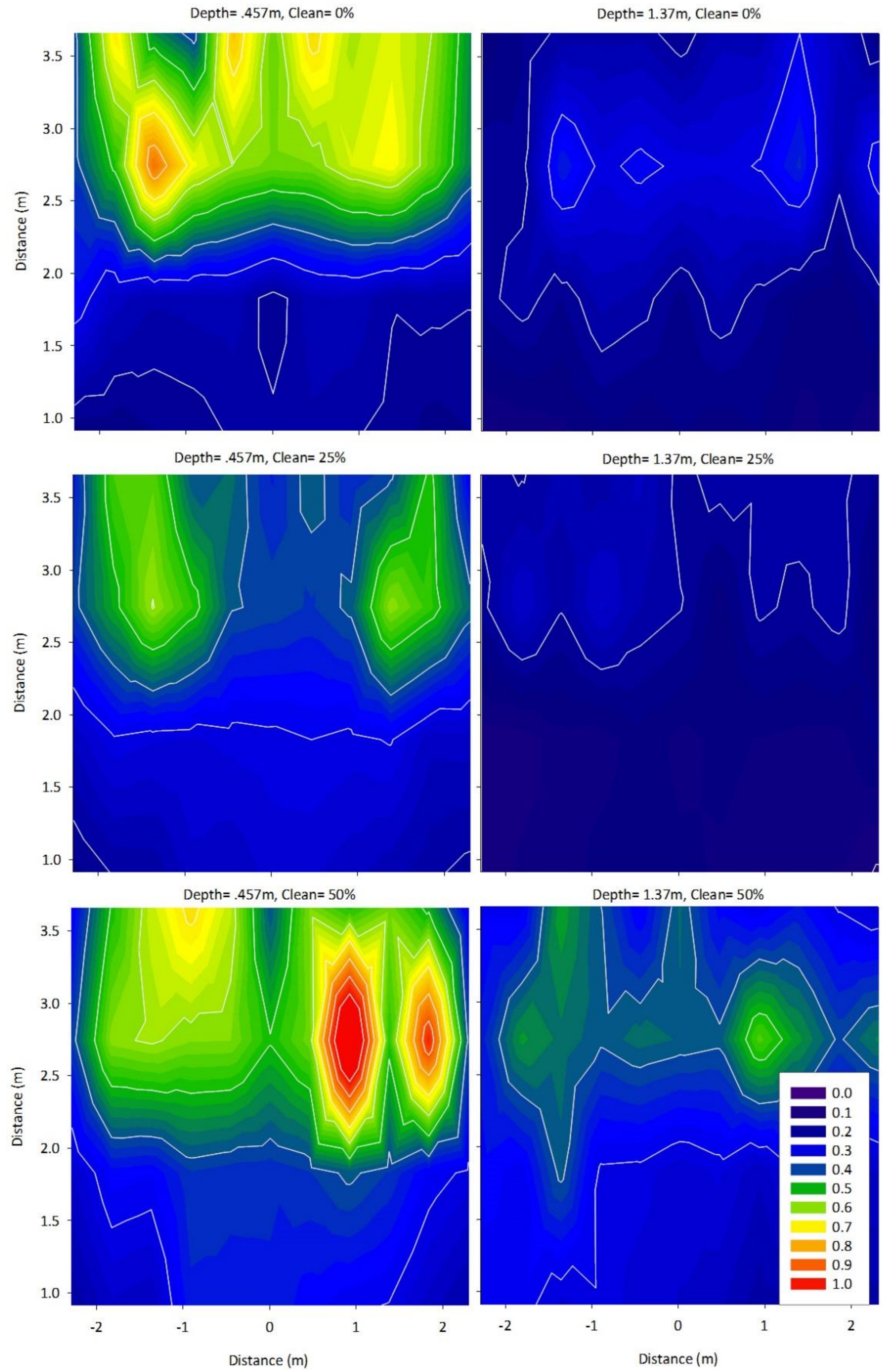

Figure 9. Contour maps of Boat 1 at two depth planes, .457 m and 1.372 m, for pre clean, 25% clean, and 50% clean hull surveys. The vertical axis represents the distance in (m) in front of the boat starting at the waterline and the horizontal axis is the distance in (m) to the left and right of center on the bow of the boat. Contour labels are represented as V/cm.

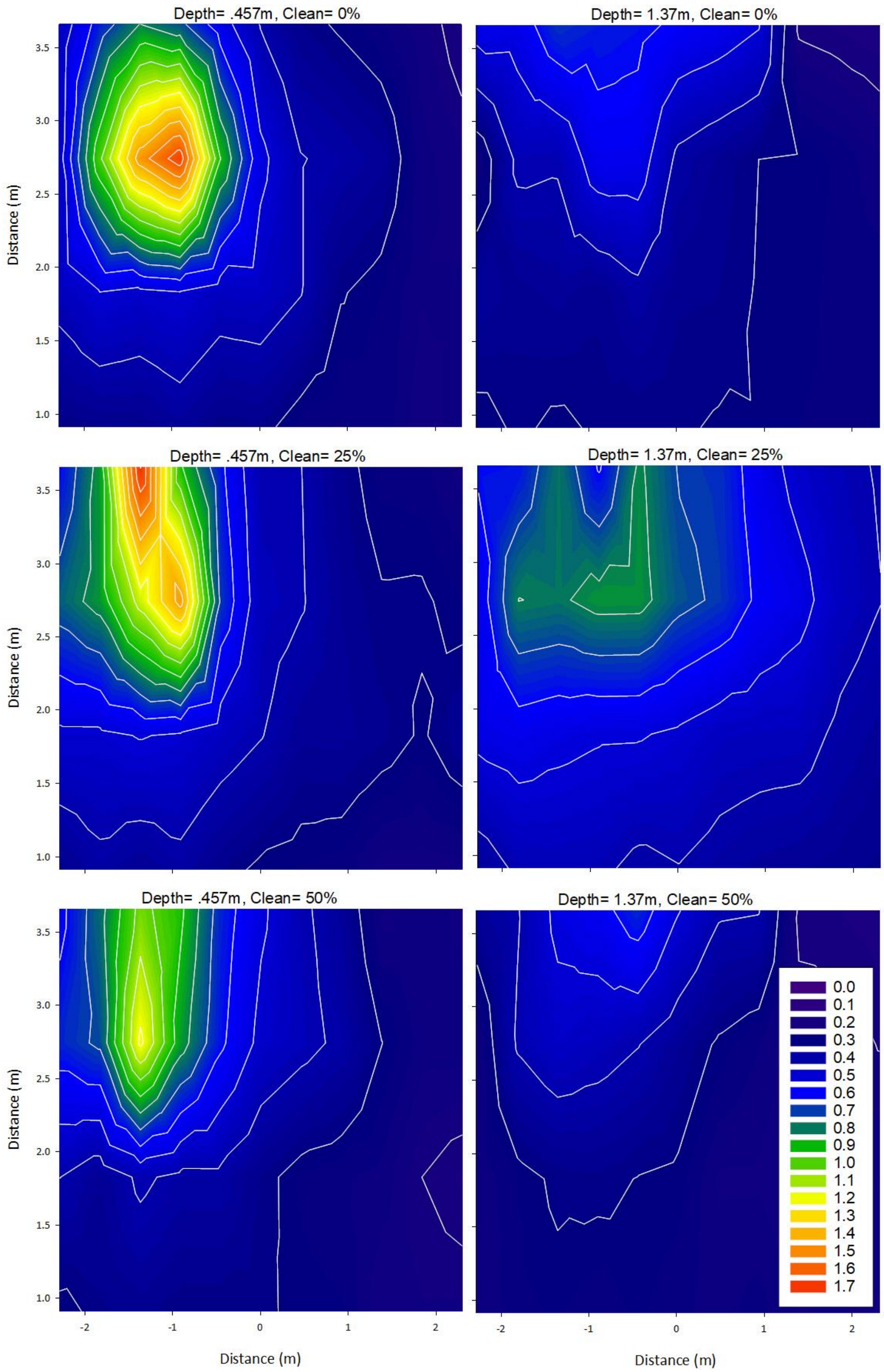

Figure 10. Contour maps of Boat 2 at two depth planes, .457 m and 1.372 m, for pre clean, 25% clean, and 50% clean hull surveys. The vertical axis represents the distance in (m) in front of the boat starting at the waterline and the horizontal axis is the distance in (m) to the left and right of center on the bow of the boat. Contour labels are represented as V/cm.

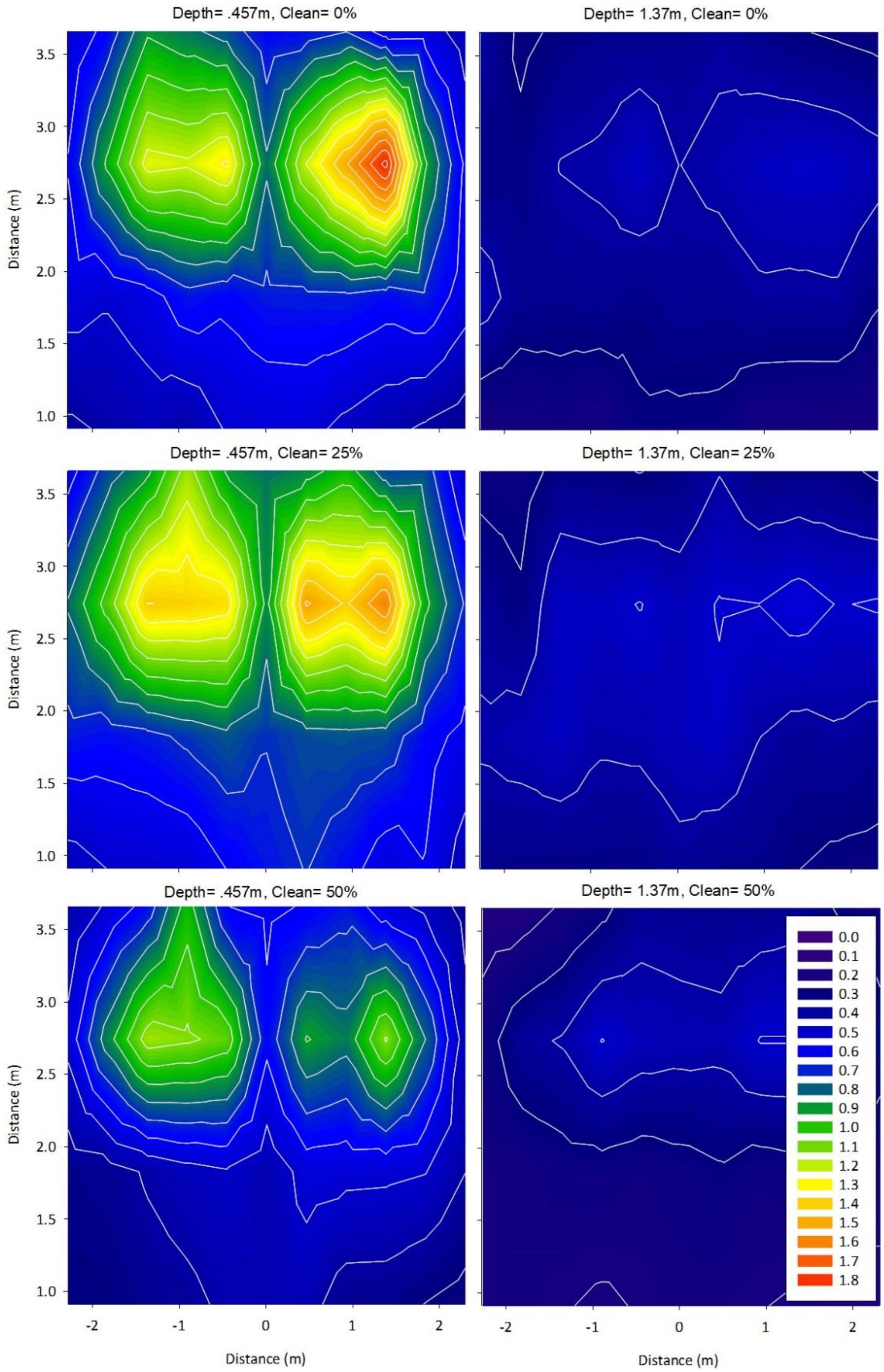

Figure 11. Contour maps of Boat 3 at two depth planes, .457 m and 1.372 m, for pre clean, 25% clean, and 50% clean hull surveys. The vertical axis represents the distance in (m) in front of the boat starting at the waterline and the horizontal axis is the distance in (m) to the left and right of center on the bow of the boat. Contour labels are represented as V/cm.

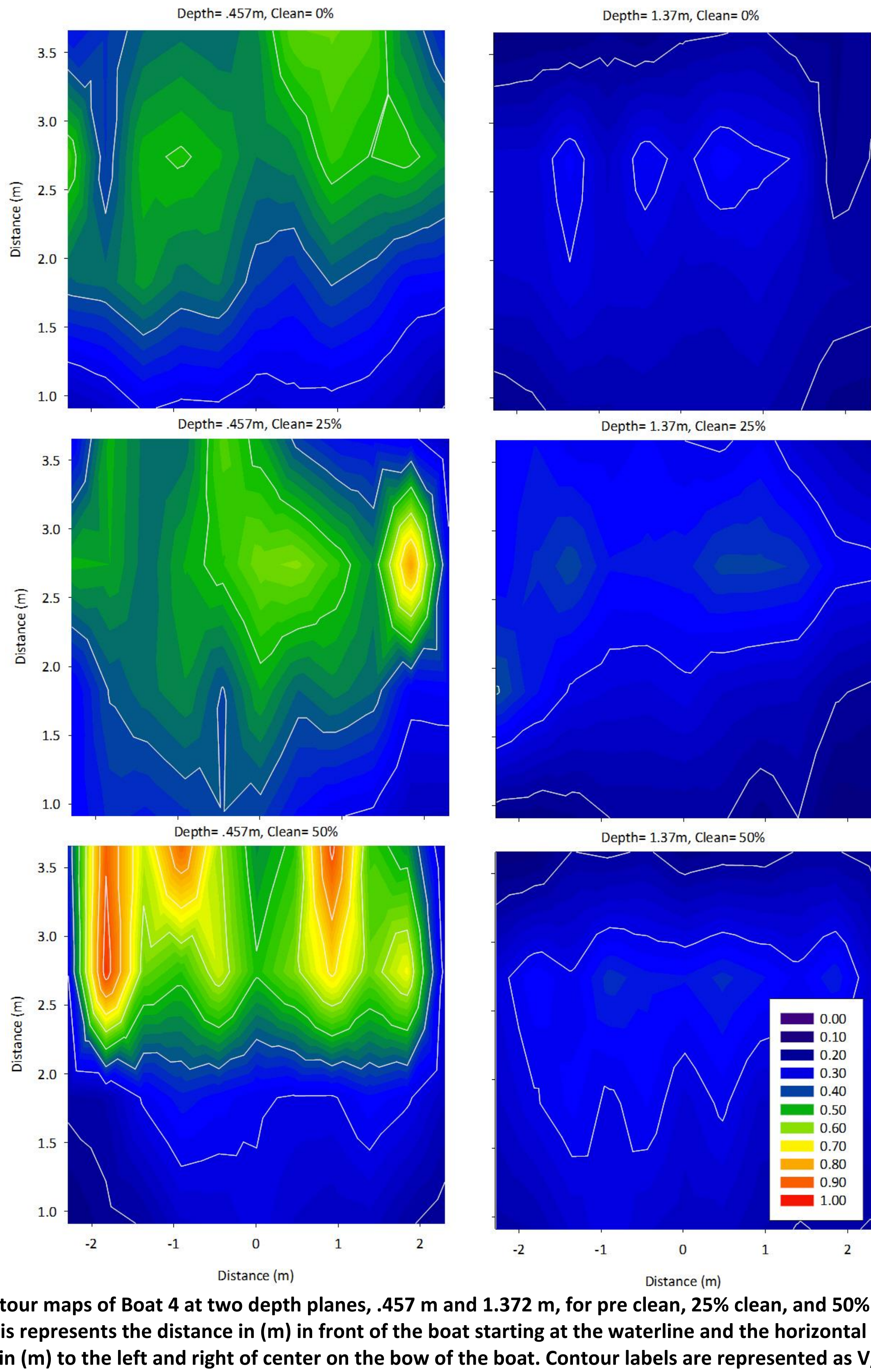

Figure 12. Contour maps of Boat 4 at two depth planes, .457 m and 1.372 m, for pre clean, 25% clean, and 50% clean hull surveys. The vertical axis represents the distance in (m) in front of the boat starting at the waterline and the horizontal axis is the distance in (m) to the left and right of center on the bow of the boat. Contour labels are represented as V/cm.

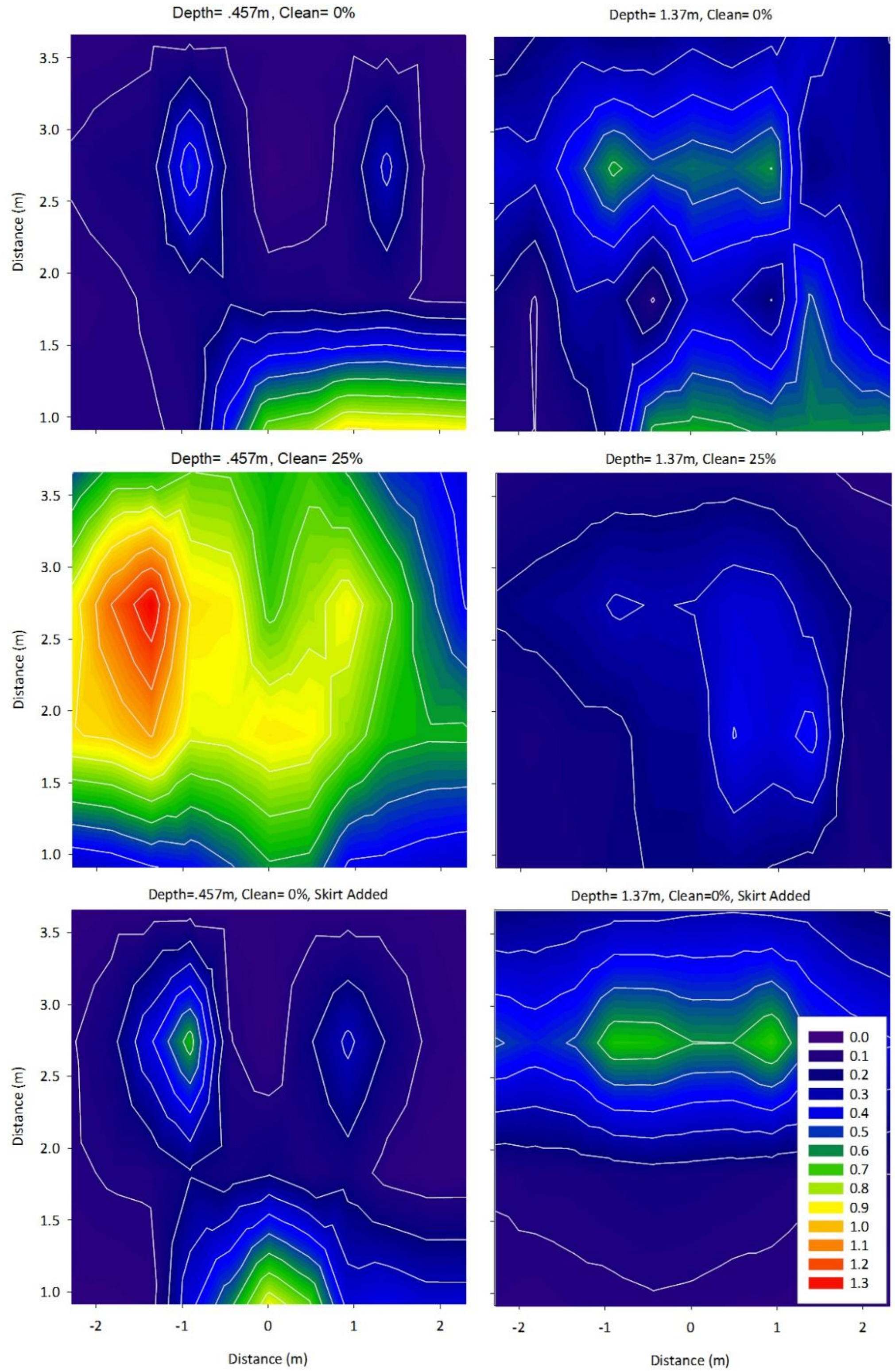

Figure 13. Contour maps of Boat 5 at two depth planes, .457 m and 1.372 m, for pre clean, 25% clean, and 50% clean hull surveys. The vertical axis represents the distance in (m) in front of the boat starting at the waterline and the horizontal axis is the distance in (m) to the left and right of center on the bow of the boat. Contour labels are represented as V/cm.

Discussion

Standardizing an electrofishing fleet is important for two reasons. First, the process provides methodology to make sure every boat is operating safely at peak performance. Second, data collected from two different boats that are standardized will have less variation. During the electrofishing workshop calibration station ETS control boxes were noted to accurately provide peak amp and volt metering. This is important to calibrate and monitor system resistance in electrofishing boats. Most of Iowa DNR fisheries teams have started using this control box manufacturer. The standard

AFS anode array consists of two rings with 6 evenly spaced droppers made of stainless steel cable 4.8 mm to 6.4 mm in diameter (Miranda and Boxrucker 2009). Iowa electrofishing boats used the AFS standard design and a nonstandard configuration. Instead of completely exposed steel cable droppers below the surface of the water a sheath was used to increase or decrease the amount of exposed stainless steel cable. This covered dropper produced a bell shaped curve in the voltage gradient profile for boat 1 which is not optimal for electrofishing. As fish approach the anode array the voltage gradient increases but near the anode array the gradient weakens and this could allow approaching fish to escape before capture. Boat 4 showed a preferred exponential curve that increases power as distance to the anode dropper decreases; as fish approach the anode array they are more likely to be affected by the electrical field and captured.

Standardized electrofishing setups in Iowa use aluminum boat hulls as the cathode. Cathodes gain material, positively charged Ca and Mg ions, over time while the electrofishing field is energized. The buildup of these materials on the cathode inhibit the transfer of electricity from water to cathode or in this case the boat hull. If materials build up on electrical system components the ability for power to pass through the system is inhibited causing resistance. When resistance increases current or amps decrease causing a reduction in power. To improve the passing of current through a system the circuitry is cleaned. Two things may be expected to change after cleaning a boat hull. The resistance may decrease and the electrical field may change.

Post cleaning analysis of all five boat hulls documented a reduction in resistance, unmeasurable readings pre clean and 0.4 ohms or less for all boat hulls post cleaning. Resistance values of 0.4 to 0.8 ohms are acceptable values in electrofishing setups (Dean and Reynolds 2017). These low resistance values were obtained by cleaning the boat hull with a soft wire wheel attached to an angle grinder. Cleaning the hulls with a wire wheel was a low cost and efficient methods compared to washing boat hulls with corrosive chemicals that were more expensive and required added personal protective equipment. Because we were unable to quantify the level of resistance on the boat hulls using an oscilloscope we cleaned a 225 cm^2 area on the four bare aluminum boat hulls. The scraped material for Boat 4 weighed 2.5 times more than the material collected from Boat 1 (**Table 6)**. System resistance and R_{100} values for Boat 4 were reduced after 25% of the hull was cleaned and further reduced after 50% of the hull was cleaned (**Table 7**). This information suggests the buildup of materials on the cathode increases system resistance. Calculated R_{100} values also increase with buildup of material on the hull of Boat 4. To help standardize power output for electrofishing boats R_{100} can be monitored. If R_{100} values increase the resistance is increasing and 50% of the boat hull should be cleaned to improve standardization with the rest of the electrofishing fleet.

The other possible change to an electrofishing boat after cleaning the hull is an alteration in the electrical field. Using a grid pattern to map electrical field voltage gradients can show the changes in an electrical field after the hull is cleaned. An ideal electrical field has an outside edge intensity of 0.1 V/cm, warm and cool water fish exhibit taxis when the electrofishing field reaches this level. As a fish approaches the center of the anode the intensity should steadily increase. Boat 3 illustrated an ideal electrical field using the AFS standard setup design. Boat 2 had the same setup design but there was an issue with the starboard side anode, therefore only the port side anode is producing a visible electrical field (**Figure 10**). The problem was high resistance in the boat electrical system caused by a loose wire. Periodical resistance testing should be part of an electrofishing boat maintenance schedule. Boat 4 showed the most improvement in the electrical field arrangement (**Figure 12**). As the hull was cleaned the field moved away from the bow. Movement away from the bow provides netters with more time to collect fish. Boat 4 also had the most buildup of material on the hull by 2.5 times compared to the other boats.

Electrofishing surveys are affected by the equipment used to collect fish. The anode and cathode are two major components in an electrofishing setup. Standardizing these two pieces of equipment for an entire fleet will reduce variability in data collection and analysis between surveys. Maintenance is the final step in standardizing electrofishing equipment. Added resistance in a system due to loose wires, corrosion, or ionic buildup on the cathode should be monitored and issues should be addressed prior to completing additional surveys.

Management Highlights

- Incorporate Missouri Department of Conservation guidelines to wire electrofishing boats and AFS standard electrofishing equipment setup into Iowa DNR standard electrofishing protocol document.

- Make ETS control boxes the standard control box.
- Collect R_{100} data on each electrofishing boat when the boat hull is clean. Each year prior to using the boat for the first time R_{100} measurements should be collected. When the R_{100} levels increase 50% of the boat hull should be cleaned starting at the bow. The R_{100} values can be calculated using ambient water conductivity and the peak volt and amp reading from the control box meters.
- Clean boat hulls using a soft wire brush attached to an angle grinder. If aluminum is being removed from the boat hull use a finer wire brush.
- Check resistance levels throughout the entire electrical system annually and maintain levels below 0.8 Ω.

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Selectivity of the AFS standard gill net with large mesh addition for Hybrid Striped Bass and White Bass

Experimental gill nets are used to sample fish in small and large lentic waters, including lakes and reservoirs in Iowa. A standard experiment gill net was defined by Bonar et al. (2009), detailing not only overall net size but also specific mesh sizes for a set number of panels. In addition, the authors recognized the possibility that biologists would want to target fish that were generally smaller or larger than the standard set of mesh sizes would typically catch, and therefore designed two additional specifications for small-mesh and large-mesh add-ons. The standard experiment gill net contains 8 panels ranging from 19-64 mm (Bonar et al. 2009). Larger-bodied fish species, such as Hybrid Striped Bass, Flathead Catfish, Blue Catfish, Walleye, Paddlefish, or Muskellunge, may not be effectively captured in these mesh sizes. In fact, experiments in Kansas indicated that large-mesh gill nets with mesh sizes ranging from 25-127 mm captured fish greater than 700 mm in length while the AFS standard net caught almost none, when the two net designs were fished concurrently (N. Kramer, Kansas Department of Wildlife and Parks, personal communication). Furthermore, multiple fisheries management teams within Iowa Department of Natural Resources use non-standard gill nets with mesh sizes greater than 64 mm on a regular basis due to the belief that the larger mesh facilitated capture of Walleye, Muskellunge, and Hybrid Striped Bass; conversion to the AFS standard experimental gill net alone would likely reduce their ability to capture larger-bodied individuals in managed fish populations and thereby inhibit effective fishery management. Thus, selectivity of the large-mesh add-on was considered important to guide decisions regarding adoption of the AFS standard. Therefore, our objective was to develop selectivity curves for mesh sizes in the AFS standard experimental gill net and its large-mesh add-on for Hybrid Striped Bass and White Bass.

Methods

Intensive gill netting for Hybrid Striped Bass and White Bass was conducted at Lake MacBride in October 2018 and 2019 and in Red Rock Reservoir in May 2019. White Bass were included in this evaluation because their body shape is so similar to Hybrid Striped Bass at smaller sizes; we believed both species would be captured equally effectively in a given mesh size. Gill nets were deployed at sampling locations across each lake and allowed to soak for approximately 4 hours. Nets were fished once during the day and once in the evening, with evening soak times overlapping the crepuscular period in hopes of maximizing catch rates. Captured fish were measured (total length in mm) and weighed (g), and the mesh size in which they were caught was recorded. In addition, mesh-specific data collected in 2013 were included to further supplement the dataset.

Data for the standard AFS gill net and the large mesh add on were modeled separately because sampling conducted in 2013 did not include use of the large mesh add on. Capture probabilities of mesh sizes were calculated for 20 mm length groups using a normal scale model, a normal location model, and a log normal model (Model equations can be found in Table 9). The model with the lowest deviance value was deemed the best fitting model to our data. Parameter estimates for each model type were also calculated (Table 10). Analysis was completed using the "select_Millar" and "gillnetfit" functions in the TropFishR package of R Studio Statistical software.

Table 9. Equations and model parameters (constants) for the three selectivity models used in R Studio. Equations relate mesh size j (denoted as m_j) with the number of fish of length l captured in that mesh size. All other symbols within an equation represent constants.

Model (constants)	Selection Curve Equation
Normal Scale (k_1, k_2)	$\exp\left(-\frac{(l - k_j \times m_j)^2}{2{k_2}^2 \times {m_j}^2}\right)$
Normal Location (k, σ)	$\exp\left(-\frac{(l - k \times m_j)^2}{2\sigma^2}\right)$
Log Normal (μ, σ)	$\frac{m_j}{l \times m_1}\exp\left(\mu - \frac{\sigma^2}{2} - \frac{\left(\log(l) - \mu - \log\left(\frac{m_j}{m_1}\right)\right)^2}{2\sigma^2}\right)$

Table 10. Model parameters, deviance, and degrees of freedom for three gill net selectivity models (Normal Scale, Normal Location, and Log Normal) estimated using the SELECT (share each length class's catch total) method.

Model	Parameter 1	Parameter 2	Deviance	Degrees of Freedom
Normal Scale	$k_1 = 238.36$	$k_2 = 3846.21$	615.56	194
Normal Location	$k = 216.88$	$\sigma = 89.51$	552.31	194
Log Normal	$\mu = 5.13$	$\sigma = 0.26$	455.38	194

Results and Discussion

A total of 392 hybrid striped bass and white bass were collected across 156 gill nets. Total sample size when including historical data was 480 fish. Mean size of fish captured ranged from 164 mm to 509 mm in the AFS standard experimental gill net (Table 11) and ranged up to 690 mm in the large-mesh add-on (Figure 14). A 2018-2019-only model (excluding historical data) was developed to visualize the selectivity of all mesh sizes including the large-mesh add-on (Figure 15). Unfortunately, all three large meshes had low catches overall, and the mesh-specific models had very high variance. Thus, additional modeling was completed for only the standard mesh sizes.

Table 11. Mean total length (TL) and standard error for hybrid striped bass and white bass captured in each mesh size of the AFS standard gill net.

Mesh Size (in)	Sample Size (n)	Mean TL (mm)	Standard Error (±)
0.75	69	164	7.29
1.00	84	222	7.28
1.25	124	263	5.15
1.50	72	341	8.86
1.75	31	374	16.14
2.00	47	279	12.65
2.25	23	368	25.65
2.50	15	509	22.73

Instead, models were run using only data from the standard AFS gill net (Table 12); this allowed incorporation of historical data which benefited the model fit. Each model approach was parameterized using these data (Table 9; Table 10). Deviance values indicated that the log normal model had the best fit to the data and was the most appropriate model for estimating gill net selectivity for hybrid striped bass and white bass in Iowa (Figure 16). Selectivity was maximized for fish between 160 and 540 mm by the meshes available in the AFS standard net (Table 13).

We concluded that the AFS standard experimental gill net should be adequate for Hybrid Striped Bass sampling if the fishery is composed of fish less than 540 mm in total length. However, fish captured from medium-sized reservoirs during Study 7043 do exceed this length by the age of 5, so it is probable that the large-mesh add on would be wise to incorporate into standard sampling for Hybrid Striped Bass fisheries. By utilizing the add-on, in combination with the standard AFS net, the Iowa DNR can successfully monitor Hybrid Striped Bass fisheries while harmonizing with national sampling standards.

Due to sampling seasons overlapping with other studies, the selectivity sampling was limited to focus on Hybrid Striped Bass and White Bass. Additional sampling could occur in the future targeting Walleye, Muskellunge, and Blue Catfish. Walleye broodstock, especially females, can easily exceed 540 mm, and monitoring of broodstock populations may be improved with use of large-mesh nets. In fact, larger mesh sizes are already used at Rathbun Reservoir, the primary Walleye broodstock lake; however, the selectivity of those nets is undetermined. Muskellunge are often caught in lower numbers, so selectivity modeling may be difficult; nonetheless larger meshes would likely be beneficial for capturing such large-bodied fish. Finally, Blue Catfish are a relatively novel lake species in Iowa, having been stocked in reservoirs only recently to provide trophy fishing. Although this species is native to Iowa, it is typically found in rivers and associated oxbows. Monitoring of new fisheries in Three Mile Lake and elsewhere may benefit from more targeted sampling as these fish get older and exceed the limits of the standard gill net.

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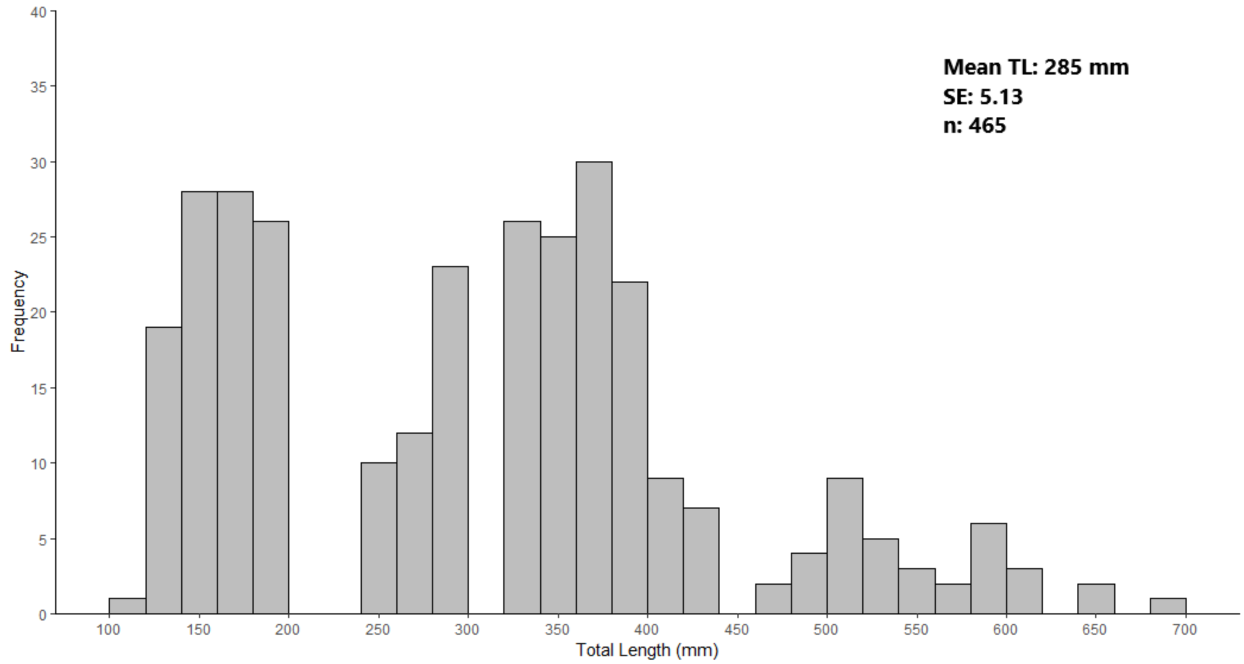

Figure 14. Length-frequency of hybrid striped bass and white bass captured using AFS standard experimental gill nets in 2013 and 2018-19.

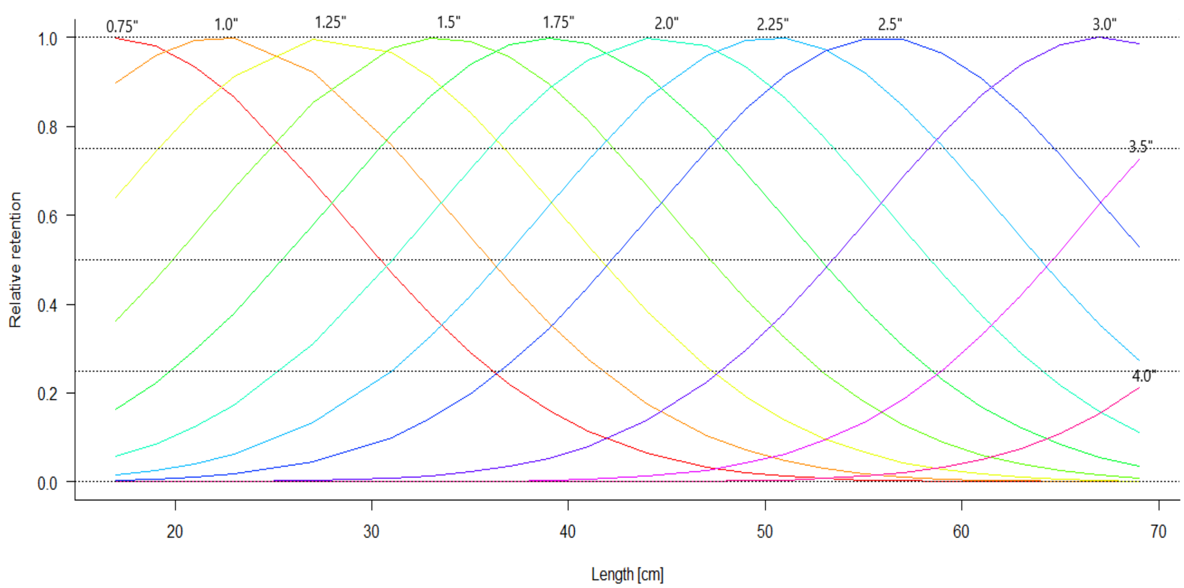

Figure 15. Selectivity curves for the eleven mesh sizes of the AFS standard gill net for hybrid striped bass and white bass.

Table 12. Count matrix based on 20 mm length bins for each mesh size in the AFS standard gill net.

Length Bin (mm)	Mesh Size (mm)							
	19	**25**	**32**	**38**	**44**	**51**	**57**	**64**
100	1	0	0	0	0	0	0	
120	16	0	0	1	0	0	0	0
140	29	0	0	0	0	0	0	0
160	18	9	0	0	0	0	0	0
180	1	22	0	0	2	0	0	0
200	0	23	26	0	0	2	4	0
220	0	19	43	0	0	1	1	0
240	0	1	8	1	0	1	0	0
260	0	2	6	2	0	1	0	0
280	0	0	10	8	0	1	1	1
300	2	2	9	19	2	3	2	0
320	0	3	9	15	1	4	3	0
340	1	1	4	6	10	1	1	0
360	0	0	3	10	8	8	2	0
380	0	0	3	3	3	12	1	0
400	0	0	1	0	1	4	1	2
420	0	0	1	1	1	3	1	0
460	0	0	0	0	0	1	1	0
480	0	1	0	0	0	1	1	1
500	0	0	1	1	1	2	0	4
520	0	0	0	2	0	0	2	1
540	1	0	0	1	0	0	0	1
560	0	0	0	0	0	1	0	0
580	0	0	0	2	0	0	1	4
600	0	0	0	0	1	0	1	1
620	0	0	0	0	0	0	0	0
640	0	1	0	0	0	0	0	0
660	0	0	0	0	1	0	0	0
680	0	0	0	0	0	1	0	0

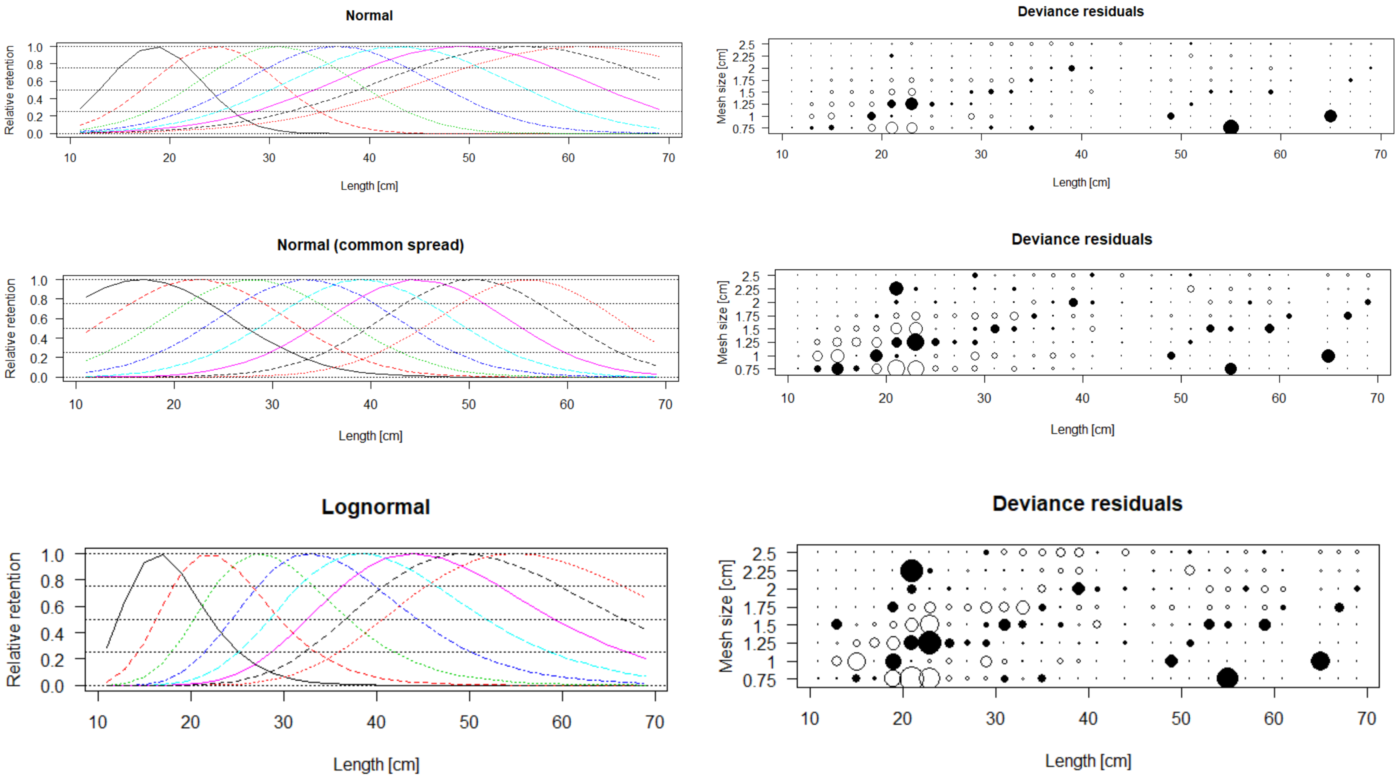

Figure 16. Selectivity curves and residuals for hybrid striped bass in Iowa calculated using the Normal (top), Normal (common spread) (middle), and Log Normal (bottom) models. In the deviance residual plots, filled circles represent positive residuals and open circles represent negative residuals. The area of the circle is proportional to the square of the residuals.

Table 13. Capture probability of length bins for each mesh size. Capture probabilities were calculated using the log normal model. Length bins are 20 mm, and an asterisk (*) denotes where a gap in length bin order occurs due to no fish captured in the subsequent length bin (Example: No fish were captured in the 440 mm length bin)

Length Bin (mm)	Mesh Size (mm)							
	19	25	32	38	44	51	57	64
100	0.28	0.02	1.5^-3	9.4^-5	5.7^-6	3.8^-7	2.7^-8	2.2^-9
120	0.65	0.12	0.01	1.2^-3	1.1^-4	1.0^-5	1.0^-6	1.1^-7
140	0.93	0.32	0.06	8.5^-3	1.0^-3	1.3^-4	1.7^-5	2.3^-6
160	0.99	0.60	0.17	0.03	5.9^-3	9.6^-4	1.5^-4	2.5^-5
180	0.85	0.85	0.35	0.09	0.02	4.4^-3	8.7^-4	1.7^-4
200	0.63	0.98	0.57	0.21	0.06	0.01	3.5^-3	8.1^-4
220	0.42	0.98	0.78	0.37	0.13	0.03	0.01	2.9^-3
240	0.25	0.87	0.93	0.55	0.24	0.08	0.02	8.5^-3
260	0.15	0.71	0.99	0.73	0.38	0.16	0.06	0.02
280	0.08	0.54	0.97	0.88	0.54	0.26	0.11	0.04
300	0.04	0.39	0.89	0.97	0.70	0.39	0.18	0.08
320	0.02	0.27	0.76	0.99	0.83	0.53	0.28	0.13
340	0.01	0.18	0.63	0.97	0.93	0.67	0.40	0.21
360	6.3^-3	0.12	0.50	0.90	0.98	0.79	0.52	0.30
380	3.2^-3	0.07	0.38	0.80	0.99	0.89	0.65	0.40
400	1.6^-3	0.04	0.28	0.68	0.96	0.96	0.76	0.51
420*	5.7^-4	0.02	0.17	0.52	0.86	0.99	0.90	0.68
460	2.0^-4	0.01	0.10	0.37	0.73	0.96	0.98	0.83
480	1.0^-4	6.8^-3	0.07	0.29	0.63	0.91	0.99	0.90
500	5.1^-5	4.1^-3	0.05	0.22	0.53	0.84	0.99	0.95
520	2.6^-5	2.4^-3	0.03	0.17	0.44	0.76	0.96	0.99
540	1.3^-5	1.4^-3	0.02	0.13	0.36	0.67	0.91	0.99
560	6.7^-6	8.8^-4	0.01	0.09	0.30	0.59	0.85	0.98
580	3.4^-6	5.2^-4	0.01	0.07	0.24	0.50	0.78	0.96
600	1.7^-6	3.1^-4	7.2^-3	0.05	0.19	0.43	0.70	0.91
620	9.2^-7	1.8^-4	4.8^-3	0.03	0.15	0.36	0.63	0.86
640	4.7^-7	1.1^-4	3.2^-3	0.02	0.11	0.30	0.55	0.80
660	2.5^-7	6.7^-5	2.1^-3	0.02	0.09	0.25	0.48	0.73
680	1.3^-7	4.0^-5	1.4^-3	0.01	0.07	0.20	0.42	0.66

Development of proposed non-wadeable river sampling protocol for Iowa

The following proposed standard sampling protocol was developed for Iowa rivers based on previous research in Iowa, past experience, methods used in surrounding states, and other literature. Prior to development, the Non-Wadeable Standardized Sampling Committee assessed past and current non-wadeable river sampling efforts in Iowa, as well as perceived future needs for fish population data on non-wadeable rivers through questionnaires and meetings. A primary need identified in this process was the establishment of a standardized protocol for sampling game fish populations at fixed sites on Iowa's non-wadeable interior rivers using boat electrofishing. Such a protocol would allow fisheries managers to monitor temporal trends in relative abundance and size structure of non-wadeable river game fish populations more effectively. Consultation with biologists in other states, and a search of the literature and online resources on non-wadeable river sampling revealed that many standardized sampling protocols existed for fish community sampling for biocriteria monitoring purposes. However, few standardized protocols existed for monitoring game fish population trends on non-wadeable rivers in the Midwestern US. Such protocols were found for Wisconsin (Wisconsin Department of Natural Resources 2020) and Tennessee (Tennessee Wildlife Resources Agency 2005) and were used in the development of the proposed protocol for Iowa. Information gained from previous research in Iowa (Gelwicks 2001, Gelwicks 2013, Gelwicks and Steuck 2011), and past experience of the Iowa DNR Interior Rivers Research Team was also used to develop this protocol.

Gelwicks, GT 2001. Evaluation of fingerling walleye stockings among interior Iowa rivers. Iowa Department of Natural Resources, Federal Aid to Fish Restoration Completion Report Stream Fisheries Investigations, F-160-R, Study 7005, Des Moines.

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PROPOSED PROTOCOL FOR SAMPLING NON-WADEABLE RIVERS IN IOWA

Introduction

Interior rivers and streams provide a substantial and wide diversity of fishing opportunities for Iowa anglers. In the most recent survey of Iowa anglers, interior rivers and streams were the most commonly fished type of water body for 21% of anglers (Duda et al. 2008). The popularity of rivers and streams is largely due to the fact that interior rivers and streams are the most abundant and locally accessible water resource available to Iowa anglers. The state of Iowa has 27,290 miles of perennial streams [Iowa Department of Natural Resources (DNR) 2016], including over 3,400 miles that can be considered non-wadeable, interior rivers (Neebling and Quist 2010). Non-wadeable rivers are defined as any river that cannot be sampled safely or effectively using sampling methods typically used in wadeable streams (Neebling and Quist 2010). In Iowa, these rivers are generally 5th order or greater but also include some 4th order streams.

Despite their importance to Iowa anglers, trend monitoring of interior river game fish populations has been lacking on many of Iowa's non-wadeable rivers for a variety of reasons. One reason identified in the Iowa DNR Walleye Management Plan (Gelwicks et al. 2019) is the lack of a standardized sampling protocol for game fish sampling in these systems. Such a protocol is needed to ensure that comparable data will be available for evaluation of long-term trends in game fish populations, as well as future evaluations of regulations or stocking regimens. The purpose of this document is to establish a standardized protocol for sampling game fish populations at fixed sites on Iowa's non-wadeable interior rivers using boat electrofishing. The use of fixed sites limits the influence of river and site level variables, and allows managers to monitor temporal trends in relative abundance and size structure of game fish populations more effectively.

Site selection

Sites should be selected that can be reliably accessed and effectively sampled during normal summer low-flow conditions on an annual basis. Other considerations for site selection may include: angling pressure, habitat quality, proximity to stocking locations (i.e. walleye fingerling stocking site), special regulations or regulation changes, or information requests from the public. Site selection should be coordinated with other management teams which share fisheries management responsibility for a given river.

Sample site length and number of sampling runs will vary among sites due to river size and local abundance of target species. Sample site length should be at least 1 mile. If an adequate sample of individuals of the targeted species is not collected in a 1-mile reach, it may be necessary to extend the sample site length. Crews should be able to be complete sampling at a site in one day, including travel time. Sampling runs should be approximately evenly distributed in sample sites, but may need to be adjusted due to local habitat conditions and fish abundance.

Site selection and sample site length may require some adjustment after initial sampling efforts. However, site locations and site lengths should remain fixed during future sampling after these adjustments have been made.

Site characteristics

Once site selection has been completed, the following information should be determined for the database:

- River name
- Description of site location (i.e. access area/boat ramp name, nearest bridge crossing)
- County
- GPS coordinates most upstream point (UTM Zone 15N or LatDD/LongDD WGS84 datum)
- Site length
- Drainage area
- HUC12 number
- Stream order
- Major drainage basin (Mississippi of Missouri)

Targeted species

Primary game fish species targeted by this protocol include: Walleye, Smallmouth Bass, Channel Catfish, and Northern Pike. Effectiveness of this electrofishing protocol for sampling Channel Catfish in rivers that remain turbid throughout the sampling season will likely be limited, and other protocols may need to be developed for these systems. Although some Flathead Catfish may be sampled using electrofishing settings describe in this protocol, methods described in Gelwicks and Steuck (2011) should be followed to effectively sample Flathead Catfish populations in interior rivers. Secondary species and hybrids targeted by this protocol include, but are not limited to: Rock Bass, Largemouth Bass, White and/or Black Crappie, Bluegill, White Bass, and Wiper.

A list of non-game species present at a site may also be recorded. A species must be netted, examined, and positively identified before adding it to the list in order to reduce misidentifications of similar species. A waterproof fish key is useful for identifying difficult non-game species in the field.

Equipment
Standard equipment is a boat mounted, pulsed DC electrofishing unit. Preferred set up is a 16 ft, flat bottom, aluminum boat with a 40/60 or larger jet outboard motor. Propeller driven outboards may be used where they can be operated effectively to sample the majority of habitats during normal summer low-flow conditions at a site. If sampling during higher than normal flows is necessary to allow use of propeller driven outboards, sampling effectiveness will be greatly reduced. An ETS MBS-1DP electrofishing unit powered by a 5000 W or larger generator should be used to supply pulsed DC output with a frequency of 60 HZ and duty cycle of 25%. The anodes consist of two booms with rings from which 12 cylindrical (6 each), 1/4 - 3/8 inch-diameter droppers are suspended. During operation, 12-24 inches of the droppers should be exposed underwater and the boat should serve as the cathode.

Sampling season and conditions
Sampling for trend monitoring of game-fish populations should be conducted between mid-July and mid-October. This has historically been a time of generally stable to falling river levels. Fish movement in rivers is also generally reduced during this period as most species have completed their movements to and from spawning areas and have not yet moved to overwintering areas. If young of the year (YOY) Walleye are being targeted, sampling should be conducted in late-September or early-October to be make sure that these fish have had enough time to grow and recruit to boat electrofishing gear. It should be noted that sampling in October should cease when water temperatures drop below 50^{o} F, since this will cause most fish to move to deep overwintering areas and reduce sampling effectiveness. Sampling during periods of extremely high water temperatures should also be avoided due to increased sampling mortality, especially when sampling Walleye. Sites should be sampled as close as possible to the same time period during each sample year. Sampling should be conducted in the daytime during normal summer low flow conditions. Sampling may be conducted during slightly higher flow conditions if water clarity permits.

Sampling
Sampling should be conducted with a crew of 2-3 people. One or two netters should net stunned fish using a dipnet with 0.5 inch (square) mesh. Electrofishing should begin at the most upstream point of the sample site and proceed downstream. The boat should be operated at a speed that allows most stunned fish to rise to the surface before the boat moves over top of them, or out of the netter's reach. This is generally about the same speed as the river's current velocity. On smaller rivers, it may be possible to follow the thalweg and sample all available habitats. It may be necessary on larger rivers to sample one shoreline downstream for a distance, and then run upstream and follow the other shoreline downstream. The boat should be maneuvered in and out of available cover (i.e. log piles), and care should be taken to sample both shallow and deep habitats, as different species and sizes of fish occupy different habitats.

Sample information
For each sample, the following information should be recorded (see Appendix A):

- Date (date on which sample conducted)
- River
- Site location description (i.e. access area/boat ramp name, nearest bridge crossing)
- Sample type (Targeted Single Species, Game Fish Only, Game Fish plus Non-game Presence)
- Survey Crew (names of persons conducting the sample)
- Number of netters
- Weather conditions

- Water temperature
- Secchi
- Conductivity
- River Stage and Discharge at nearest gaging station (can be obtained from USGS site)
- Electrofishing settings (frequency, duty cycle, amps, volts)
- Shocking time (shocker on time recorded at end of each run)
- GPS location (starting point and end of each run to obtain distance sampled for each run)
- Comments (could be related to habitat, gear efficiency, etc.)

Fish information

Game fish information should be separated by runs (see Appendix B). Circle selected units and record length and weight for individual primary game fish species. Record length (weight optional) for secondary game fish species. Comments field can be used to record marks/recaptures if applicable or notes on fish condition. Record list of non-game species collected if applicable (Appendix C).

References

Duda, MD, T Beppler, SJ Bissell, A Criscione, B Hepler, JB Herrick, M Jones, A Lanier, A Ritchie, CL Schilli, and T Winegord. 2008. Iowa Angler Survey. Responsive Management, Harrisonburg, Virginia.

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Iowa Department of Natural Resources. 2016. Ambient water monitoring strategy for Iowa: 2016-2021. Iowa Department of Natural Resources, Des Moines, IA.

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Appendix A. Form 542-0830

Iowa DNR Non-Wadeable Electrofishing Datasheet

Date: ________________ Site Code: ____________________________

River: ____ County: ____________________________

Location Description: ____

Start Point: UTM X ____________ Y _____________ End Point: UTM X ________________ Y ____________________

Survey Type: ☐ Game Fish

☐ Game Fish Plus Single Species

River Stage: ___________ feet Discharge: ___________ cfs. @ gauge location: __________________________

Flow Conditions: ☐ low ☐ normal ☐ high

Gear: ____________________________ Volts: _________ Amps: _____________ Power: ______________________

Duty Cycle: 25% Frequency: 60 pps

Conductivity: _____________ µS/cm Water Temp: ___________ °F Secchi: ____________ inches

Weather Conditions: ____

Survey Quality: ____

Survey Crew: ____ Number of netters: ☐ 1 ☐ 2

Additional Comments: ____

____

Total Distance Sampled: ______________ m Total Effort: _____________ sec.

Run #1 Start Waypoint: ______________ UTM X ______________ Y ______________

End Waypoint: ______________ UTM X ______________ Y __________ Distance _________ m Effort __________ sec.

Run #2 Start Waypoint: ______________ UTM X ______________ Y ______________

End Waypoint: ______________ UTM X ______________ Y __________ Distance _________ m Effort __________ sec.

Run #3 Start Waypoint: ______________ UTM X ______________ Y ______________

End Waypoint: ______________ UTM X ______________ Y __________ Distance _________ m Effort __________ sec.

Run #4 Start Waypoint: ______________ UTM X ______________ Y ______________

End Waypoint: ______________ UTM X ______________ Y __________ Distance _________ m Effort __________ sec.

Run #5 Start Waypoint: ______________ UTM X ______________ Y ______________

End Waypoint: ______________ UTM X ______________ Y __________ Distance _________ m Effort __________ sec.

Run #6 Start Waypoint: ______________ UTM X ______________ Y ______________

End Waypoint: ______________ UTM X ______________ Y __________ Distance _________ m Effort __________ sec.

Appendix B. Form 542-0831

Iowa DNR Non-Wadeable Electrofishing Game Fish Datasheet

Date: ______________ Site Code: ______________________

River: ______________________________________ County: ______________________

Units for lengths and weights: ☐ mm ☐ inches / ☐ g ☐ lb

Species: ______________________________

Run #	Length	Weight	Comments

Species: ______________________________

Run #	Length	Weight	Comments

Appendix C. Form 542-0832

Iowa DNR Non-Wadeable Electrofishing Non-Game Fish Species List

Date: ______________ Site Code: __________________________

River: ____ County: __________________________

Non-Game Species	Comments

Development of Rotenone Application Guidelines

Complete and selective fish renovations (biomanipulation) involve the eradication or partial removal of a fish population or community from the treated water, respectively. Renovation projects are commonly completed in cooperation with local partners and other public agencies, as well as with the Iowa Department of Natural Resources (DNR) Lake Restoration Program which utilizes an ecosystem-based approach to lake and water quality improvement. These treatments are accomplished with the use of rotenone which is recognized as the most environmentally benign of the commonly used fish poisons (piscicides or ichthyocides). Rotenone is a natural organic pesticide product isolated from certain subtropical and tropical members of the pea family found in South America and Southeast Asia. Rotenone is one of four approved piscicides in the United States, two of which target lamprey and the third (antimycin) has greater restrictions and less documentation of its effects. Up to 30 different piscicides have been used in the US since the 1930s, including chlorinated hydrocarbons, organophosphates, copper, and ammonia, but most of these chemicals had greater toxicity to humans and waterfowl or were persistent in the environment. In contrast, rotenone is highly specific to fish and degrades quickly once applied. Its effects and chemical properties are well-documented, allowing appropriate safety and usage guidelines to be established.

The following guidelines were developed based on peer-reviewed literature, established safety expectations, and staff experience to standardize and formalize the process by which Iowa Department of Natural Resources (DNR) conducts rotenone-based fishery renovations. The Iowa DNR is recognized as one of the most prolific users of rotenone in fisheries management, and our staff have accrued substantial knowledge regarding the implementation and execution of fish renovation and biomanipulation plans with the use of rotenone. The basis of the guidelines is the American Fisheries Society's Standard Operating Manual and product label. While certain procedures and methods listed within the manual are required, other portions are generalized suggestions, often aimed at new users of these products. Given the high level of use and considerable experience of DNR staff, many of the suggested procedures used elsewhere could be streamlined and expedited, while remaining true to label requirements. Thus, the guidelines were developed to explore those portions of the manual that are most relevant to Iowa DNR fisheries staff and to serve as a quick reference guide for the use of rotenone in Iowa.

This document was structured to provide additional background information to staff on rotenone, its effectiveness, and public and worker safety, as well as specific procedures on the complete renovation and selective renovation / biomanipulation of fish communities in Iowa water bodies. Sections include history, toxicity, basic steps for a rotenone application, specific recommendations for complete renovations, specific recommendations for selective treatments, and training and safety requirements.

Through careful review of, and familiarity with, this and other reference documents, the Iowa DNR will remain one of the most effective users of this important fishery management tool, which will in turn pay dividends to Iowa anglers.

ROTENONE USER GUIDE

Preface

The Iowa Department of Natural Resources (DNR) is recognized as one of the most prolific users of rotenone in fisheries management, and DNR Fisheries staff have accrued substantial knowledge regarding the implementation and execution of fish renovation and biomanipulation plans with the use of rotenone. The DNR has a long-standing history of safe and successful use of this pesticide.

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) is a United States Federal law that regulates user compliance with pesticide labeled rules of use, including the use of rotenone. In addition to the rotenone label, the American Fisheries Society Rotenone Standard Operating Procedures Manual (AFS SOP Manual[1]) provides a more comprehensive source on the use of rotenone, safety, public concerns, and a host of other information that biologists will find useful. These documents together form the basis for the continued use of rotenone on an international basis and serve as a comprehensive source of information for a variety of applications of various products.

While certain procedures and methods listed within the AFS SOP Manual are required, other portions are generalized suggestions, often aimed at new users of these products. Given the high level of use and considerable experience of DNR staff, many of the suggested procedures used elsewhere can be streamlined and expedited, while remaining true to label requirements. The following document has been developed to explore those portions of the AFS SOP Manual that are most relevant to Iowa DNR fisheries staff and to serve as a quick reference guide for the use of rotenone in Iowa. We also incorporate information gained from decades of rotenone use in Iowa. This document is structured to provide additional background information to staff on rotenone, its effectiveness, and public and worker safety, as well as specific procedures on the complete renovation and selective renovation / biomanipulation of fish communities in Iowa water bodies. This document is not meant to be the sole source of information for all renovations, but rather is prepared as a companion to the aforementioned documents and summarizes portions of applicable AFS SOP Manual sections as they relate to rotenone use in Iowa. Through careful review of, and familiarity with, all of these documents, the Iowa DNR will remain one of the most effective users of this important fishery management tool, which will in turn pay dividends to Iowa anglers.

Introduction

Complete and selective fish renovations (biomanipulation) involve the eradication or partial removal of a fish population or community from the treated water, respectively. Renovation projects are commonly completed in cooperation with local partners and other public agencies, as well as with the Iowa Department of Natural Resources (DNR) Lake Restoration Program which utilizes an ecosystem-based approach to lake and water quality improvement. These treatments are accomplished with the use of rotenone which is recognized as the most environmentally benign of the commonly used fish poisons (piscicides or ichthyocides).

In response to recent public concerns about large-scale rotenone use in fisheries management, the American Fisheries Society established a rotenone stewardship program to provide advice on the safe use of rotenone and to encourage good planning and public involvement in rotenone use (Finlayson et al. 2010). Use of rotenone as a piscicide for fisheries management is still common in the United States and Canada and represents a considerable proportion of total rotenone consumption, worldwide (Finlayson 2000).

While this document is aimed at providing needed information for the completion of fish renovations and low-concentration selective treatments in Iowa waters, DNR staff is encouraged to review the AFS SOP Manual and to be familiar with the product labels. The reader will observe that this document often makes note that the reader may seek additional information in the AFS SOP Manual. That document is organized into multiple SOPs, each with a specific number. This document and additional useful references are available at:

[1] References herein refer to the 2018 AFS SOP Manual, 2nd Edition. If you are using the 1st Edition, note that section numbers changed slightly (e.g,. Section 3.0 is now Section 3.1).

- AFS SOP Manual, or "Planning and Standard Operating Procedures for the Use of Rotenone in Fish Management"
- Rotenone Stewardship Program Website
- Summary of the Federal Insecticide, Fungicide, and Rodenticide Act

Important note for readers: Throughout this document we refer to "rotenone". This reference is specifically to the concentration of active ingredient. Where we refer to "formulation" we are typically discussing the 5% liquid product (usually Prenfish, CFT Legumine, or Chemfish Regular). For the reader's information and as an example, when treating water at 4ppm of 5% rotenone formulation it equates to 200 ppb (200 µg/L, 0.2 ppm) rotenone.

Historic Use of Rotenone

Rotenone is a natural organic pesticide product isolated from certain subtropical and tropical members of the pea family found in South America and Southeast Asia. The use of rotenone by man may be ancient, as early explorers noted Peruvian natives using crude extracts of the Cubé plant to stun fish for capture and eventual consumption. In the early 1900s, botanists exploring Peruvian jungles searching for new and useful plants of potential commercial value exported large quantities of plant roots and extracts to the US for use as insecticides on food crops. The major active ingredient of the extracts was rotenone. Rotenone has been used commercially as a garden insecticide since the middle 1800s and is still widely used as a natural botanical insecticide.

Rotenone is one of four approved piscicides in the United States, two of which target lamprey and the third (antimycin) has greater restrictions and less documentation of its effects. Up to 30 different piscicides have been used in the US since the 1930s, including chlorinated hydrocarbons, organophosphates, copper, and ammonia, but most of these chemicals had greater toxicity to humans and waterfowl or were persistent in the environment. In contrast, rotenone is highly specific to fish and degrades quickly once applied. Its effects and chemical properties are well-documented, allowing appropriate safety and usage guidelines to be established.

The use of rotenone as a fish management tool has been wildly recognized. Rotenone enables fish and wildlife agencies to target certain sensitive fish populations or to eradicate entire fish communities with minimal impact to non-target wildlife. Application purposes may include sport fish restoration, native fish restoration, undesirable fish removal, elimination of certain fish diseases or parasites, or fish sampling. Although other approaches such as electrofishing and gill netting can be useful in controlling fish populations, they do not eradicate fish (Finlayson 2000).

Use of Rotenone in Iowa

Rotenone has been used for fishery management in Iowa since the product became available on the market in the 1930s. Complete renovations are the most common, but low-concentration selective treatments are becoming more common due to recent research indicating its effectiveness for targeting sensitive and undesirable species. Complete renovations including watershed treatments are often undertaken as part of a comprehensive lake restoration project. Low-concentration selective treatments have been used to remove entire populations of undesirable fishes and biomanipulation has been used to decrease overall fish densities in slow-growing gamefish populations. For example, these methods have been used to improve population structure in Bluegill. The illegal introduction of Gizzard Shad, Yellow Bass, or other undesirable species has resulted in a renewed interest in selective treatments of fish communities. For instance, Gizzard Shad are not a preferred component of the fish community in most constructed lakes in Iowa. Gizzard Shad have been directly and indirectly implicated in declines in abundance and quality of several gamefish populations in constructed lakes (DeVries and Stein 1990). In eutrophic constructed lakes and reservoirs, Gizzard Shad can attain high biomass and often dominate the fish assemblage (Stein et al. 1995; Gido 2001). Overpopulation of Gizzard Shad leads to competition with other species during early life history stages (Garvey and Stein 1998; Aday et al. 2003; Schaus et al. 2010). Gizzard Shad abundance has also been correlated with increased turbidity (Miller 1960; Aday et al. 2003; Schaus et al. 2010). At high abundance, Gizzard Shad can have strong ecosystem effects (e.g., alter zooplankton and phytoplankton assemblages, bioturbation and nutrient loading). Thus, Gizzard Shad are commonly targeted for removal or control at low abundances (e.g., Flammang 2014, Catalano and Allen 2009). Finally, Iowa DNR staff used rotenone to evaluate fish community composition and biomass in coves, a common research application during the 1960s through the 1980s. Through such evaluations, staff was able to identify management goals for predator species such as Largemouth Bass and Walleye.

Rotenone Manufacturers and Available Products
Since 2007, registered use of rotenone as a piscicide is available in three commercial liquid 5% formulations: Prenfish™ Toxicant Liquid E.C. (EPA Reg. No. 655-422), TIFA™ Chemfish Regular Toxicant Liquid (EPA Reg. No. 82397-1), and Prentox CFT Legumine™ Fish Toxicant (EPA Reg. No. 655-899). Of these three, Prenfish and Chemfish Regular are most commonly used in Iowa. CFT Legumine™ has been utilized in Iowa but has been shown to be difficult to apply in cold conditions, and costs approximately twice that of the other two formulations. Rotenone is also manufactured as a powder, but the Iowa DNR does not use this formulation.

The current chemical labels and Safety Data Sheets (M)SDS are part of the legal documentation for the chemical's use:

- Prenfish Toxicant Liquid Label and (M)SDS
- Chemfish Regular Toxicant Liquid Label and (M)SDS
- Prentox CFT Legumine Fish Toxicant Label and (M)SDS

Toxicity of Rotenone
While rotenone is not highly toxic to humans, mammals, or birds if ingested orally, rotenone is highly toxic to fish. Rotenone is effective at interrupting mitochondrial electron transport which hinders the utilization of oxygen in respiratory organs, leading to cell death and eventually to the death of the organism. Because the respiratory mechanism of fish is directly linked to water through the gills, rotenone may pass directly into the bloodstream of fish.

Toxicity to Humans and Other Mammals
Most mammal species are relatively resistant to rotenone. Rotenone is much less toxic to mammals (and birds) because the typical route of ingestion is through the gut, where much of the compound is broken down to less toxic components before toxic quantities can enter the bloodstream. Rotenone ingestion through inhalation results in higher toxicity, as there is a more direct pathway into the bloodstream. Although no fatalities have ever resulted from normal rotenone use, product labels require respiratory protection while spraying concentrated formulations containing rotenone for piscicidal applications.

The Iowa DNR's obligation to comply with the Occupational Safety and Health Administration (OSHA) Respiratory Protection Standard, 29 CFR 1910.134 requires fit testing of a NIOSH approved particulate respirator with any R or P filter with NIOSH approval prefix TC84A. This tight-fitting face piece respirator is to be worn when spraying rotenone formulation (see product label for specific guidance on respirator prefix need; Figure 17). As per OSHA's Respiratory Protection Standard (29 CFR 1910.134), respirator use training must completed annually. The policy further requires fist testing to be required annually, or at least prior to any fish renovation project. All applicators who will apply rotenone using a sprayer, either powered or backpack, must complete a fit test if one has not been performed within the last year. It is the responsibility of the project supervisor (biologist) to ensure all applicators who will use spray equipment, are notified of the need for respirator fit testing. See "Annual Requisite Training for Rotenone Applicators" for a check list of training and testing requirements and details for applicators.


Figure 17. Rotenone applicator undergoing fit testing for the P-95 respirator.

Despite these requirements for respirator training and fit testing, the risk of rotenone inhalation is very low. Worker exposure has been monitored during field applications in both California (Vasquez et al. 2012) and Iowa (Flammang 2015), and no detectable levels of rotenone were observed in either case. No fatalities in humans have been reported in response to normal use of rotenone products. Non-lethal symptoms have been reported in humans following prolonged occupational exposure to rotenone dusts during large-scale fisheries applications of powdered product (Pintler and Johnson 1958). Headaches, sore throats and other cold-like symptoms were reported due to inhalation of dusts. Contact symptoms included sores on mucous membranes, skin rashes and irritation of the eyes.

Once rotenone is diluted in the water column, the risk of ingestion via inhalation is insignificant because of the very low concentrations of rotenone added to the water and the low probability of humans, mammals, or birds aspirating sufficient quantities into the lungs. The amount of water that would have to be aspirated into the lungs would cause drowning long before any toxic dose could be delivered.

Because rotenone is so highly specific and highly toxic to fish, only very small quantities are needed to kill target fish. The amount of rotenone applied to a water column to achieve the desired degree of toxicity depends on several factors: temperature, hardness, pH, the amount of organic material (either dissolved or particulate), and the amount of sunlight that penetrates the water. Typically, the concentration of rotenone for piscicidal application ranges from 20-200 ppb (µg/L) rotenone. In context, the maximum labeled dosage is 200 ppb (200 µg/L, 0.200 ppm) rotenone. This would be the equivalent of less than 2.5 oz. of rotenone formulation placed in an Olympic-size swimming pool. For the average adult human to obtain a lethal dose of rotenone from drinking treated water (at the maximum allowable treatment level), this person would have to consume 100,000 liters (more than 26,000 gallons) of water in one sitting. To compare against a point of reference, the lethal dose of caffeine is estimated to be 192 mg/kg; which approximates drinking 80 - 100 cups of coffee in rapid succession. It is probably more feasible to die from caffeine poisoning from drinking too much coffee than from drinking rotenone-treated water at piscicidal concentrations.

<u>Rotenone Residues in Poisoned Fish</u>

Indigenous peoples of Southeast Asia and South America have used rotenone products for centuries to harvest fish for human consumption (Leonard 1939; Ray 1991). Concentrations of rotenone in fish filet are generally far below 1 ppm, whereas the level considered safe for human consumption has been estimated at 10 ppm (Lehman 1950). On the basis of measured concentrations of rotenone in fatally-poisoned carp filets, and assuming that all rotenone in the meal were absorbed, an adult human would need to eat approximately 22,000 pounds of fish in one sitting to receive a fatal dose. However, at present, all rotenone formulation labels preclude the legal consumption of fish removed as a result of rotenone application.

Potential Pathogenic, Teratogenic, Carcinogenic and Anti-cancer Effects of Rotenone

Rotenone has been shown to display no carcinogenic, mutagenic, teratogenic (disturbs the development of an embryo or fetus), or reproductive negative effects (Ling 2003). Rotenone has recently been reported to cause effects in rats similar to those of Parkinson's disease, but those studies are not considered to be applicable to humans (Finlayson et al. 2012). Recent research has revealed that rotenone may be an effective agent against certain types of cancers by its ability to inhibit cellular respiration. Rotenone was effective at low concentrations at killing mouse liver cancer cells and human epithelial breast cancer (Fang and Casida 1999).

Toxicity to Aquatic Invertebrates and Amphibians

Rotenone effects on aquatic invertebrates and amphibians have been reviewed recently. Cladoceran and copepod zooplankton and some species of mayfly and caddisfly are all sensitive to rotenone concentrations at piscicidal concentrations. Protozoans, rotifers, zooplankton eggs, fish eggs, amphibian eggs, and amphibian adults all exhibit a high level of tolerance to rotenone at piscicidal concentrations. Negative impacts to most taxa are short-term, and populations recover relatively quickly. Larval amphibians show sensitivities similar to the most resistant fish species (Hamilton 1941; Chandler 1982).

Toxicity to Birds

Birds are extremely unlikely to be affected by normal fisheries management use of rotenone. Like mammals, the most likely route of ingestion is through the gut, where much of the compound is broken down before entering the bloodstream. Rotenone poisoning as a result of consuming poisoned fish is highly unlikely due to the low levels of rotenone in fish tissue, rapid degradation of rotenone products, and poor absorption of rotenone products in the guts of birds (Ling 2003).

Toxicity to Fish

Despite fish being generally susceptible to rotenone toxicity, different species demonstrate variable tolerances to specific treatment concentrations. This variability in tolerance is important for multiple reasons. In cases of whole lake renovations, biologists must select an application concentration sufficient to eliminate the most resistant species. In most Iowa applications, this species is Black Bullhead, which is one of the most tolerant species (Figure 18). AFS SOP Manual 5.1 describes the need for bioassays using site water (or water of similar quality) and target species of similar (and maximum) sensitivity. Thus, Black Bullhead are a useful surrogate given their ubiquitous nature in Iowa water bodies and the highly organic nature of Iowa lakes. In Iowa, the need for site specific bioassays may be superseded by a relatively few number of bioassays demonstrating the consistent need for high levels of treatment. One bioassay completed in Iowa is presented in detail below and can be referenced for rotenone application planning. However, project leaders should consider additional bioassay work (AFS SOP Manual 5.1) on, at least, a more regional basis within the State.

A second treatment alterative often used in Iowa is the low-concentration treatment or "selective treatment". For selective treatments, biologists attempt to reduce or remove certain less tolerant species or improve quality of overabundant and slow-growing populations of gamefish by removing a portion of the population. For instance, Gizzard Shad and Yellow Bass often constitute undesirable components of Iowa fish communities. The selective removal of these species is possible due to their relatively low rotenone tolerance compared to other species (Figure 18). However, some gamefish species, such as Muskellunge or Walleye, also have a low tolerance to rotenone and will be eliminated by such treatments. Thus, biologists should weigh the loss of these fisheries before undertaking such applications. It is possible to impact population structure of species such a Bluegill through low-concentration treatments, but biologists are cautioned that such treatments may also impact Largemouth Bass density, the top-level predator of most lentic Iowa systems. Methods for selective treatments appear later in this document and a detailed discussion of selective treatments is available (Flammang 2014).

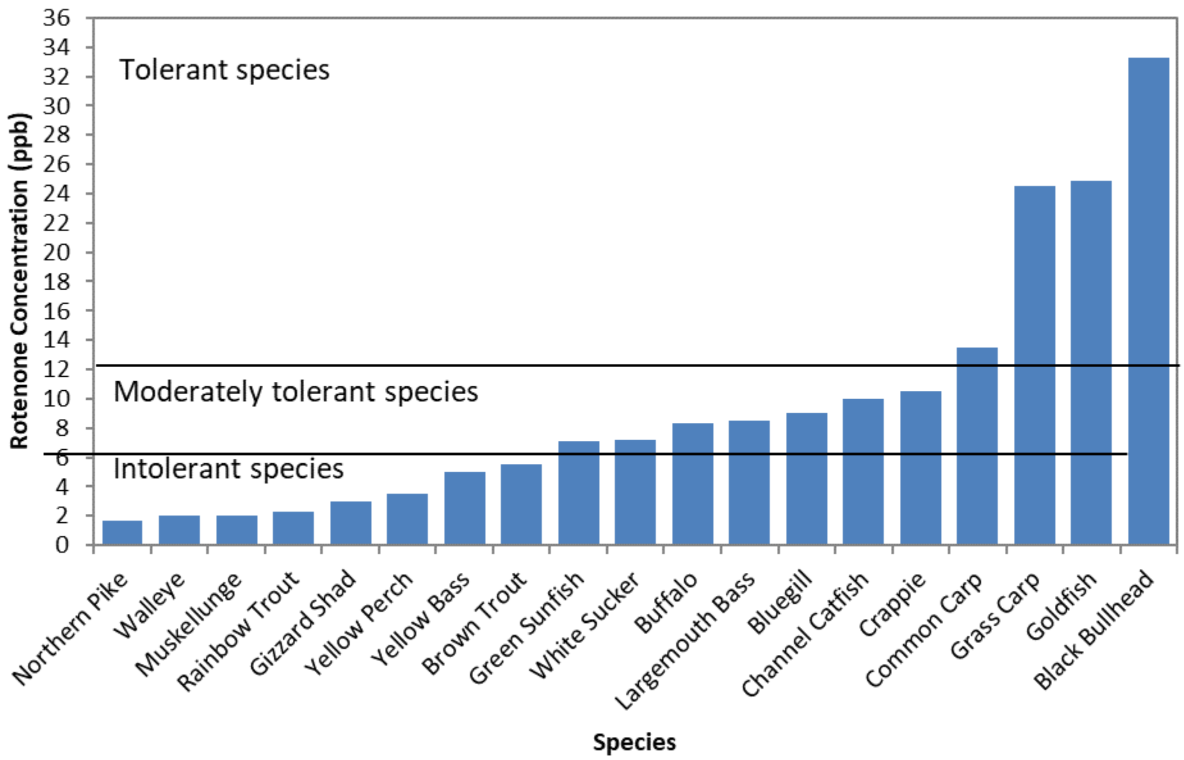

Figure 18. Median lethal concentration (LC50) values for 96 h exposure of fish commonly observed in Iowa systems. Reference lines indicative of rotenone tolerance are shown at 6 ppb and 12 ppb (µg/L).

Basic Steps for Rotenone Applications

Fish renovations in Iowa are an important management tool. A renovation, whether complete or selective, is typically applied when other methods of fish community manipulation are ineffective. For example, complete physical removal of Common Carp through aggressive harvest is not feasible in most lakes. Rotenone applications for fish renovation occur in five stages:

1. Preliminary planning
2. Intermediate planning
3. Final planning
4. Treatment(s)
5. Review and wrap-up

In Iowa, these steps are often considered as one continuous plan, steps often overlap, and the process expedited, especially when cooperation among partners and user groups is high. A generalized planning timeline is available in Appendix B.

Preliminary Planning

Preliminary planning includes identifying the project need, identifying stakeholders, surveying the project area, and establishing interagency and partner responsibilities. Early planning ensures consistent project direction, improved communication with partners and proper dissemination of information to the public. Preliminary planning typically begins as soon as the project is considered for implementation. The following are key points to be considered in any renovation plan.

<u>Statement of Need</u>

It should be obvious to the biologist whether a lake is in need of renovation due to the established fish sampling protocols and declining pubic use. Several reasons for renovation include low catch rates of game fish, a high standing stock of rough fish, an unbalanced game fish population composed of a high percentage of stunted or slow-growing panfish or the introduction of injurious species such as Yellow Bass, White Perch, Common Carp, Asian Carp, or Black Bullhead. The statement of need summarizes the current state of the project area and supports the need for rotenone treatment with data describing fish populations and / or water quality. Statements should provide insight into declines in angling quality or other needs requiring the renovation of the fish community. Data should include, at a minimum, indices of abundance and composition of the fish community as well as recent environmental changes (e.g., water quality changes). Low catch rates of sportfish (e.g., less than 0.5 fish/angler hour or survey catch rates below a predetermined goal) for several years in a row or high numbers of stunted panfish may be indicative of a degraded fishery. Data reflecting biomass are often useful, particularly for injurious species such as Common Carp which are better represented by biomass than abundance. Excessive biomass (e.g., greater than 150 lb/ac) may indicate the need for renovation. A comprehensive population assessment may be needed, at times incorporating abundance and biomass estimates, or at least indexing abundance against historic datasets. In addition, trends in angler use are important for documenting both economic and recreational need for the project.

A statement regarding expected project outcomes should be included, including an overview of lake restoration activities, fish restocking, and a timescale for the subsequent developing fishery. Typically, renovations are part of a comprehensive ecosystem / lake restoration project managed by the Iowa DNR and cooperating agencies. However, even if renovation does not include large-scale restoration activities within the watershed, in-lake treatments of injurious fishes such as Common Carp will result in water quality improvements. The biologist should be prepared to address potential ecosystem changes, specifically the reestablishment of aquatic vegetation upon the elimination of Grass Carp and/or Common Carp. Outlining reasonable expectations of a successful project early can help establish trust and support from stakeholders. In addition, development of the statement of need should include consideration of alternative management options. While there are typically reasonable explanations as to why these techniques are not considered viable, the introduction of these alternatives can be valuable when discussing the process with the public. For instance, regulation adjustment, predator stocking, or mechanical removal have consistently been shown to be ineffective toward improving the fish community structure.

Following are examples of statements of need:

- From 1999 to 2005 Largemouth Bass biomass at Hawthorn Lake decreased from 49 lbs/acre to just 7 lbs/acre, while Common Carp Biomass increased to nearly 400 lbs/acre. Mean secchi transparency decreased from 32 inches to just 12 inches in this same time.
- Yellow Bass density at Three Mile Lake increased dramatically from 2005 to 2015. Electrofishing catch rates changed from 2 fish / hour in 2005 to more than 300 per hour in 2015. Meanwhile, Bluegill catch declined by 90% and Black Crappie catch by 75% in this same time.

A management biologist's intent to renovate a lake, encapsulated by the statement of need, should be reviewed by the district supervisor prior to any other outreach. The supervisor should be informed of the problem as well as any steps taken prior to identifying the need for chemical renovation with rotenone.

<u>Public and Media Involvement</u>

Communication with the public and media is essential beginning early in the planning process. Assistance and guidance can and should be obtained from the Iowa DNR Fisheries Bureau Information Specialist, who can assist with press releases, public meeting announcements, and fielding questions from the public.

Identify and contact key individuals, groups and agencies that use the water body as early as possible, in advance of the project implementation. The goal of engaging the public is to achieve consensus, and seek resource user buy-in. Informing the public of the project usually involves at least one public meeting where the project is presented with an emphasis on both the problem and the solution, while allowing for public comments. Public meetings will set the tone for the project and help develop a timeline that will be sufficiently long to address all objectives while ensuring the project moves forward. An oral presentation with visual aids is usually prepared for the public and defines the problem, develops a "statement of need" and lists alternatives to correcting the problem, nontechnical information on rotenone, an explanation and schedule for the proposed project and restocking efforts, funding mechanisms, and anticipated benefits to the resource and the public (including economic benefits if available). A successful public engagement process includes convincing the public there is a problem, convincing the public that you are the one to solve it, convincing the public your approach is reasonable, and finally listening and responding to the public's concerns.

Typical concerns include the use of chemicals and the killing of fish. These concerns can result from the public's lack of understanding or disagreement with the project's purpose(s), environmental tradeoffs created by the project (e.g., changes in vegetation growth post renovation), and the management decisions leading to the project. The use of chemicals can and should be justified for each project and may include the following reasons: 1) ineffectiveness of alternatives (e.g., mechanical removal of common carp by electrofishing), 2) targeted efficiency of rotenone toxicity to fish, 3) timeliness (e.g., coordination with a drawdown), and 4) safety of the selected rotenone formulation (e.g., rapid breakdown in the environment).

The killing of fish can be addressed through 1) demonstrating the need to eliminate injurious fish, 2) implementing the Promiscuous Fishing rule, 3) conducting a fish rescue or fish salvage operation prior to rotenone application, 4) assuring the public of restocking and presenting restocking plans, and 5) ensuring fishery development after restocking. Other concerns may include presence of dead fish, impact of chemicals on public health and the environment, or animal welfare, and liability and property damage. These concerns generally can be addressed through education of the public.

Additional public meetings may be necessary or desirable to ensure public support of the project and the dissemination of accurate information as determined by the project leader. Public notification of meetings should occur at least 14 days in advance of the meeting. The public is interested and involved in the project as indicated by their attendance to these meetings. Interest may be affected by proximity to and size of population centers, the extent of the treatment, or the types of aquatic uses of the waterbody. Be prepared to face opposition early and prevent it if possible by working early and often with stakeholders. Potential or realized conflicts with user groups should be discussed internally with your supervisor in order to develop the most effective response to these concerns.

Local media must be kept informed throughout the entire process to maintain public confidence and to avoid confusion and rumor. Work with the Fisheries Bureau Information Specialist to provide media with details as appropriate through the process. Especially important is a press release with final details of the project before project implementation, including a summary of the project, name and concentration of piscicide, any public or water use restrictions, posting procedures, anticipated length of time the project area will be affected, and contact information for questions.

Intermediate Planning: Logistics

Mapping of Lake and Watershed

All lakes are mapped with a Biosonics single beam DT-X mapping system. Survey data are collected and edited using Biosonics Visual Acquisition and Habitat software applications. Lake volumes are calculated using the 3D Analyst extension in ArcGIS 10.5. Lakes greater than 20 acres are typically subdivided into zones, each corresponding to 20 to 75 surface acres for individual treatment (Figure 19). Individual volume estimates from each zone are calculated and appropriate rotenone needs can be identified. Lake volume should be calculated at each one-foot contour interval to ensure the appropriate amount of chemical can be estimated at any drawdown level. An Excel spreadsheet is available to assist in these calculations. The number of zones indicates the minimum number of boats needed to conduct the treatment. In addition to the acre-feet of water in the lake pool to be treated, the surface area of mudflats to be sprayed, surface area of marsh/wetland/ephemeral pools to be sprayed in the watershed, and the miles of stream to be treated should be quantified. Assistance with lake mapping can be obtained from the Cold Springs Research Team.

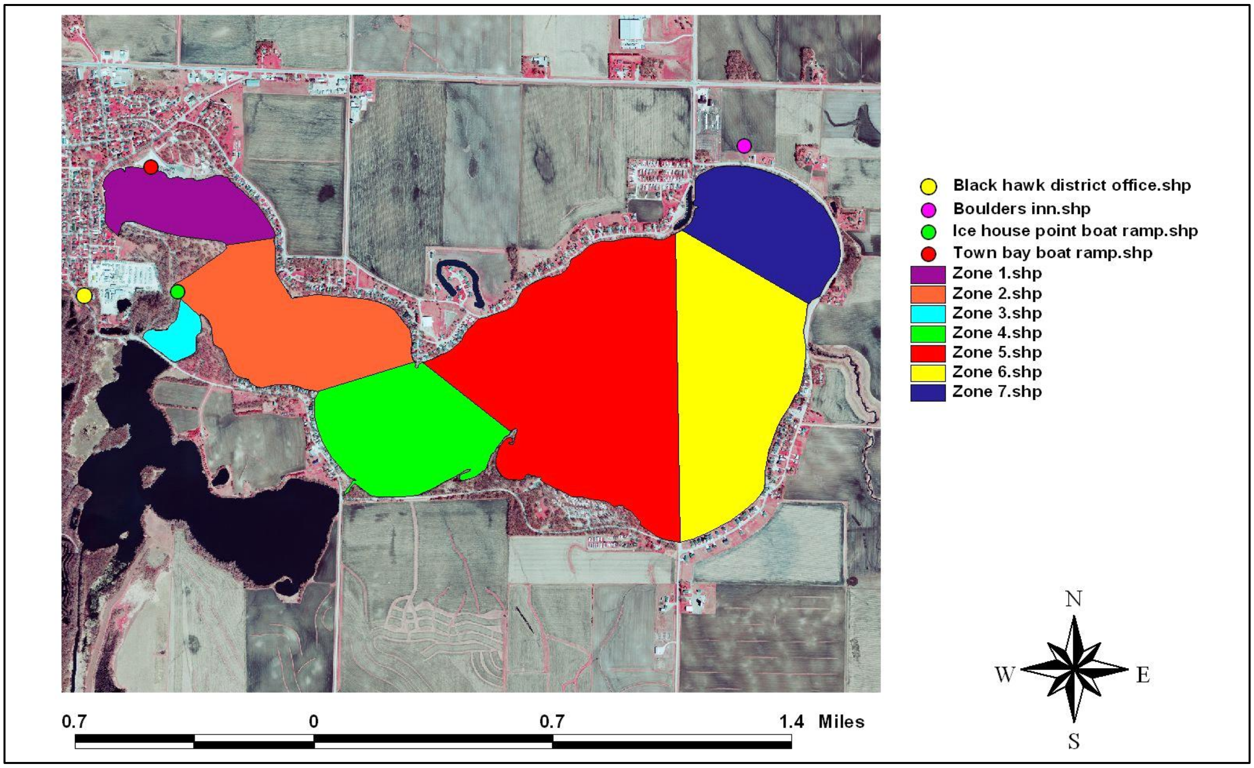

Figure 19. Typical lake section map with multiple rotenone application zones indicated.

Barriers, Ownership, and Obstructions

Indicate and describe the watershed and define ownership of all lands, including ponds and wetlands. The Iowa DNR Water Monitoring and Watershed Atlas is a good place to start when attempting to define watershed boundaries for any State-owned lake. For additional assistance project leaders should consider contacting the Iowa DNR GIS Section.

Project leaders should consider the possibility that ponds within the watershed may contain the same undesirable species as the lake you are treating. This is most possible for ponds near the lake, especially those with open spillways. These ponds should be sampled with electrofishing or seining, as appropriate. The collection of injurious species will necessitate the renovation of these systems prior to lake treatment. As these water bodies often are located on private land, coordination with the landowner will be required. If the landowner desires, restocking should be provided by the DNR following completion of the project. Identify all inflows and subdivide watershed streams accordingly for drip station or backpack sprayer application (Figure 20).

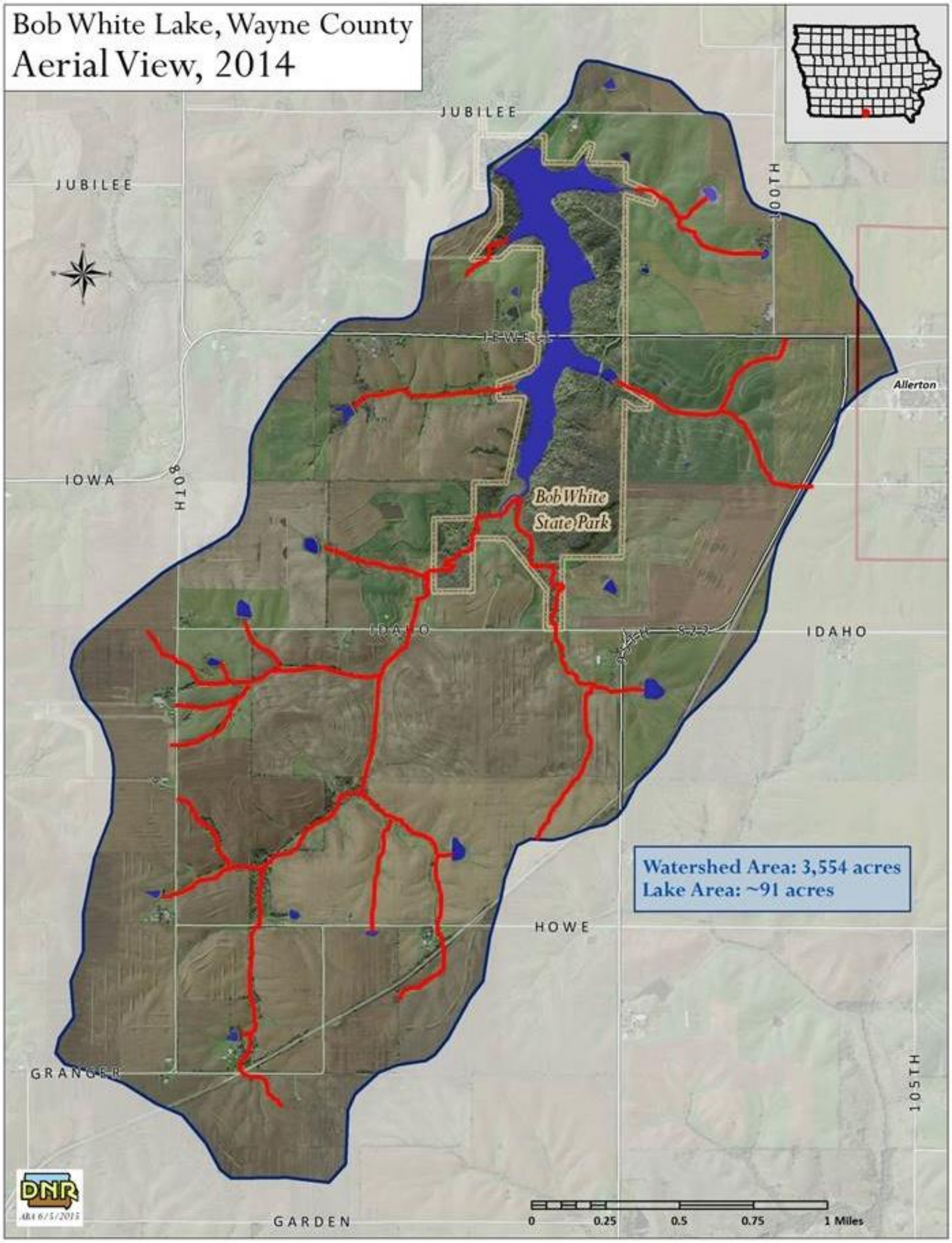

Figure 20. Typical watershed map describing the watershed boundary, watershed drainages (red), and ponds and wetlands (blue).

<u>Determination of Required Treatment Concentration</u>

The terminology associated with rotenone concentration is sometimes confused among users. The rotenone formulations typically used in Iowa (e.g. Prenfish, Chemfish Regular, CFT Legumine) are 5% liquid formulations. Typically, we refer to this undiluted product as “rotenone formulation.” Formulations are commonly acquired in 30-gallon drums by the Iowa DNR. When discussing “rotenone” in application situations, we are typically referring to “active ingredient” which is the portion of the formulation that makes up the various rotenoids which, together, make up rotenone. For instance, treating at 4 ppm 5% rotenone formulation (Prenfish, CFT Legumine, or Chemfish Regular) equates to 200 ppb (200µg/L or 0.200 ppm) rotenone in treated water.

The amount of rotenone administered to a water column to achieve the desired degree of toxicity to fish depends on several factors: temperature, hardness, pH, the amount of organic material (either dissolved or particulate), and the amount of sunlight that penetrates the water (Finlayson 2010). Typically, the concentration of rotenone for piscicidal application ranges from 20-200 ppb (µg/L). Iowa waters are typically highly organically enriched and thus, rotenone renovations require greater application rates to achieve project goals. Table 14 demonstrates formulation and active rotenone equivalents in concentration, as well as the quantity of water in acre-feet treated per gallon of rotenone formulation. This table is adapted from the label of all common 5% liquid formulations and is a general guide for whole lake renovations in most Iowa aquatic systems.

Table 14. Treatment concentrations of formulation and active chemical for treatment of Iowa lakes.

Type of Use	Formulation (ppm)	Rotenone (ppb or µg/L)	Acre-feet / gallon	Gallons / acre-foot
Normal (not typical for Iowa)	0.5-1.0	25-50	6.0-3.0	0.17-0.33
Tolerant Species (not typical for Iowa)	1.0-3.0	50-150	3.0-1.0	0.33-0.98
Tolerant Species in Organic Waters (**Typical for Iowa**)	2.0-4.0	100-200	1.5-0.75	0.65-1.30

Need for Bioassay

In accordance with the AFS SOP Manual, it is suggested the certified applicator conduct bioassays using water of "similar quality" to test those species to be eliminated, to ensure over-application does not occur. Detailed guidance for bioassays can be found in the AFS SOP Manual 5.1. The target rotenone concentration for any lake or pond renovation will be at least twice the Minimum Effective Dosage (MED; 100% target fish mortality), up to the maximum labeled application rate of 200 ppb active rotenone. Given the ubiquitous nature and high tolerance of Black Bullhead in Iowa, they are a suitable target species for analysis for most treatments.

Black Bullhead sensitivity to rotenone was evaluated at the Rathbun Fish Culture Research Facility during late summer 2015. The water used in this bioassay (from Rathbun Lake) was filtered to remove most suspended organic content; dissolved and particulate organic matter reduces the effectiveness of rotenone by binding with and neutralizing rotenoid compounds. In reality, this water was likely lower in organic content than most Iowa lakes, thereby lowering the quantity of rotenone required to eliminate Black Bullhead in this bioassay.

The MED for Black Bullhead in filtered Rathbun Lake water was 4.0 ppm rotenone formulation, or 200 ppb active rotenone (Figure 21). Bioassay methods (AFS SOP Manual 5.1) require this value to be multiplied by at least a factor of two, indicating a concentration of 8.0 ppm rotenone formulation (or 400 ppb active rotenone) should be used to eliminate Black Bullhead. Because this bioassay was conducted with a representative species (a potentially injurious, highly tolerant fish which is very common in Iowa) in typical Iowa water which was filtered, it is likely that most rotenone applications in Iowa should be treated with a concentration of at least 8.0 ppm rotenone formulation (label requirements limit rotenone formulation application to a maximum of 4.0 ppm without Special Local Need [SLN 24(c)] designation). The water quality parameters of water used in this project were likely typical of many Iowa lakes, especially impoundments of southern Iowa. However, project leaders are encouraged to complete additional bioassay efforts, especially if the productivity of the system to be treated is unknown.

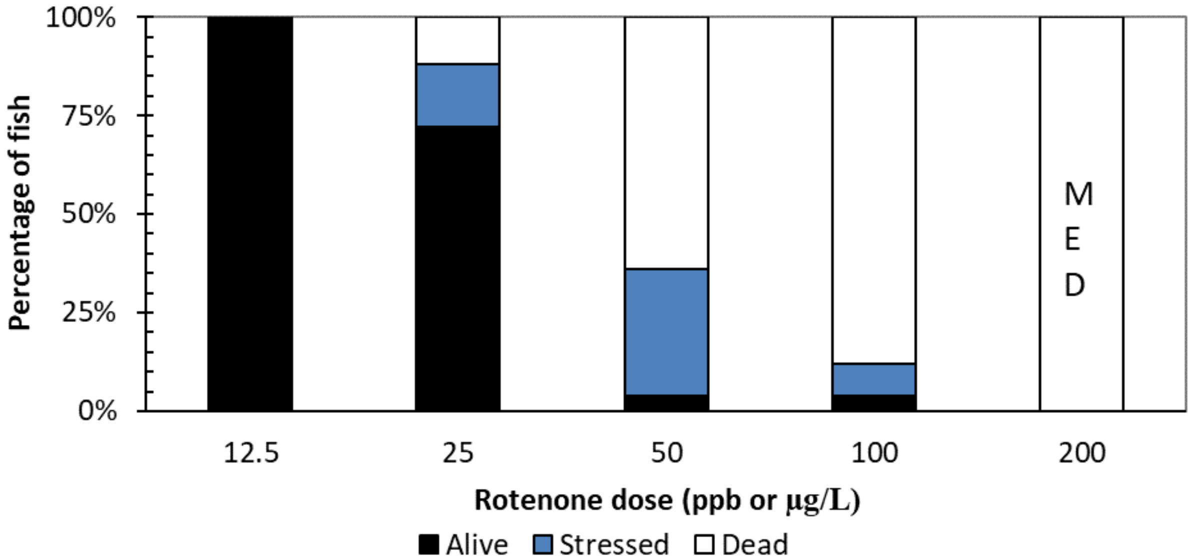

Figure 21. Determination of minimum effective dose (MED) for Black Bullhead for rotenone renovations in Iowa, using 25 test fish exposed to rotenone concentrations between 12.5 and 200 ppb (µg/L).

Special Local Need Designation for Increased Application Rates, Aerial Applications, and other off-label uses

When label requirements may interfere with the overall success of the renovation project, the applicator may apply for a Special Local Need designation, or SLN 24(c). For instance, applicators may need to apply at concentrations over the label allowance due to the established need to remove tolerant species such as Black Bullhead, or they may wish to apply undiluted rotenone with an aerial sprayer (airplane or helicopter) to eliminate fish from areas which cannot be safely traveled by foot or boat.

The first step in application for the SLN 24(c) is to contact the registrant (either Central Garden and Pet, formerly Envincio, formerly Prentiss, and TIFA Worldwide) who will be familiar with the regulatory needs of the product. The applicant (Iowa DNR Fisheries) will inform the registrant of their specific wishes to apply “off-label”. If the registrant approves, the applicant will contact the Iowa Department of Land Stewardship (IDALS) which will submit an application to the U.S. Environmental Protection Agency (EPA). The point of contact with IDALS is:

Dr. Gretchen Paluch
Public Service Manager 1
Iowa Department of Agriculture and Land Stewardship
Pesticides Section
502 East 9th St.
Des Moines, IA 50319
(515) 281-8590
gretchen.paluch@iowaagriculture.gov

When applying for the SLN 24(c) designation, it may be helpful to complete additional bioassays with site water to strengthen the application to EPA. Otherwise, regional bioassays on Black Bullhead will likely provide sufficient justification for treatment within label limits.

Estimation of total rotenone formulation needed

Weeks, months, or even years prior to treatment; applicators should estimate rotenone needs for budgetary purposes. Calculate all pesticide needs for both the lake and watershed components for the treatment at the expected required dosage. A spreadsheet is available to assist in these calculations. In most cases, a treatment concentration of at least 4.0 ppm formulation will be required to eliminate the most tolerant species in Iowa. Volume calculations should reflect the anticipated lake drawdown elevation. Estimates of need should include a buffer of up to 10% to accommodate issues with drawdown and watershed treatment. You must ensure sufficient rotenone is ordered and will be delivered by the needed date. Manufacturers may require substantial lead time for the manufacture of orders of 300 gallons or more.

Project Timing

Rotenone projects can be completed at various times of the year but are most common in the late summer or early fall. Temperature and contact time are the two main variables that significantly affect toxicity. The time required to cause 100% mortality decreases approximately 2 to 4-fold for each five-degree rise in temperature (Gilderhus 1972). Thus, summer treatments are the most toxic to fish. In addition, summer flowage in the watershed is often at a low and precipitation chances reduced, which is often desirable when renovating lakes. By ensuring minimal inflow and reducing the potential for storm water capture, the chances of an unwanted discharge of rotenone-laced water can be reduced. One disadvantage to summer treatment is the impact treatments may have on non-angler recreational use of parks and recreation areas. This issue can often be alleviated by delaying treatment until after Labor Day.

Logistics and Budget

Determine all personnel, rotenone, material, and equipment (including special items) costs for the treatment activities as well as funding mechanisms for these efforts. First, summarize the methods of application for different parts of the treatment area (e.g., main lake, mudflats, and streams). Based on mapping, divide the watershed into sections which can be completed by a single person/team in 1-2 days. As a general guide, a recommended number of staff needed for various responsibilities is included here (Table 15). All applicators must wear appropriate PPE for their duties and, while most Iowa applicators are certified applicators, at least one applicator must be up-to-date on requisite Category 5 (See AFS SOP Manual 3.1). In addition to application crews, you will also need a designated project leader who typically serves as the communications officer.

Table 15. General recommendations for minimum staff needed for rotenone applications.

Duty	Area Covered	Staff Needed
Supervising project	-	1 certified applicator
Applying rotenone in-lake	10-40 acres (200 acre-feet)	1 certified applicator, 1+ crew
Applying rotenone on streams	1 mile	1 certified applicator / mile
Applying by aerial sprayer	Indeterminate	1 certified applicator, 1+ crew

Personal Protective Equipment

All mixers, loaders, applicators, and other handlers must wear, at a minimum, the following personal protective equipment (PPE):

- Coveralls, over long-sleeved shirt and long pants (Tyvek jumpsuits over normal attire are allowed).
- Chemical-resistant gloves
- Chemical-resistant footwear plus socks
- Protective eyewear
- P (or R)-95 Respirator (see Toxicity to Humans and Other Mammals)

The use of the respirator is only required during actual application (Respirators must be NIOSH approved particulate respirator with an N, R or P approved prefix - see label for product specific guidance). Applicators are allowed to remove the mask, even when inside the treatment area, if they are not actively spraying.

Exception: waterproof waders may be worn in place of coveralls, chemical-resistant apron and chemical-resistant footwear.

Application Equipment

A variety of equipment may be used in a complete renovation. Planning can help you identify not only how many boats are needed, but what size and what application system each boat will use. First, size each boat as appropriate for their role in the application. Small boats, canoes, kayaks, or air boats may be necessary where water is shallow. Large boats are appropriate for open water sections of the lake. Aerial application (either helicopter or fixed wing) may be beneficial over mud flats with pools.

Boat and Application Equipment
Boat operators must wear a PFD. Additionally, each boat should have GPS and sonar capabilities. Push poles are often useful in shallows.

Semi-closed application system - The semi-closed probe system allows for the transfer of rotenone formulation concentrate directly from the drum to the pumping device with the use of a suction hose connected to an intake manifold affixed to the inlet end of the pump (usually 1 ½" to 3" pump). The rotenone concentrate is diluted and mixed in the pump head (at a minimum dulution rate of 10:1) and discharged to site water, below the surface, without applicator contact. Attach a valve at the distal end of the liquid rotenone concentrate intake suction hose (i.e., ½ or 1½ inch diameter). The valve controls the rate of liquid rotenone flow into the water intake. The probe is inserted through a foam or rubber ring or gasket into the bung hole of the drum. The addition of a large valve in the water intake line, before the pump, provides for an additional level of control in application rates. The applicator may partially close this valve to increase the negative pressure on the rotenone line, increasing the application rate if so desired. Application is below the water surface. A photo of assembled systems is shown in Figure 22.

Venturi Boat-Bailer Systems - This system consists of a reservoir and a delivery system for the application of diluted liquid rotenone (10:1 dilution) to standing waters (Figure 23). The mix tank suction hose is the same as used by semi-closed systems.

Hand-directed nozzle - Semi-closed systems can be equipped with a spray nozzle when treating shallow waters. When applicators shift from underwater application to spraying, each boat occupant must wear the appropriate respirator.

When completed, rinse the system thoroughly with raw treated water that is drawn into the operating pump.

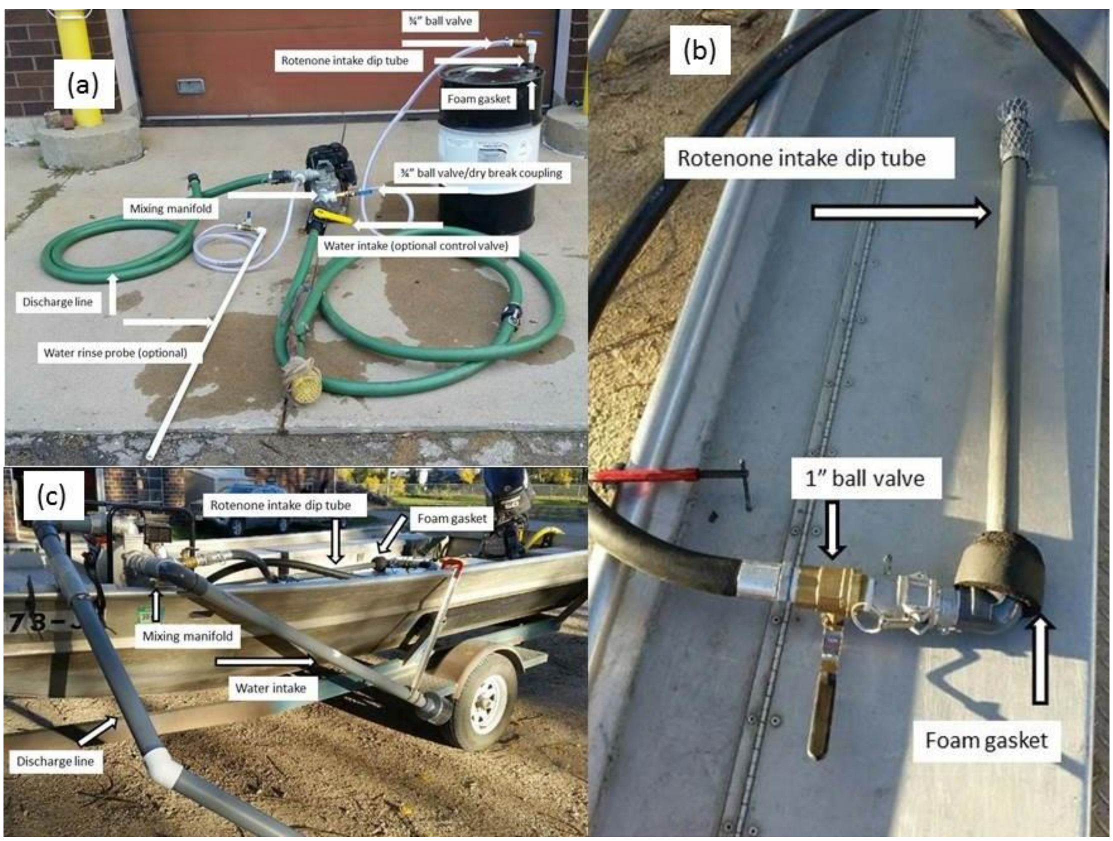

Figure 22. Assembled semi-closed application systems with flexible (a) and fixed intake and outlet lines (c) and close of up of fixed line dip tube (b).

Figure 23. System for liquid rotenone application using a Venturi system on small boat with outboard motor. Note mixing tank for diluted formulation.

Drip Stations

Construction - Drip cans consist of a reservoir and a delivery apparatus for the application of rotenone to flowing waters (Figure 24). The reservoir can be any size, made from any material but typically plastic or metal in construction. The delivery system provides regulated flow of rotenone to the stream for maintaining a constant concentration of rotenone.

Operation - usually undiluted 5% rotenone formulation is applied continuously in small amounts for extended periods of time when treating flowing waters.

Placement of Application Sites - Rotenone drips are usually applied for a period of 4 to 8 hours to flowing water; however, longer duration is acceptable. Multiple application sites are necessary along the length of the treated water to maintain the desired rotenone concentration. Application sites are generally spaced at no more than 1/2 to 2 miles apart; depending on water flow travel-time, stream gradient, solar radiation, turbidity, and other factors affecting rotenone degradation. For tributaries with high flows, stations should be located in closer proximity to one another.

Quantity of Rotenone - For flows over 25 ft^3/s, it is usually desirable to treat using undiluted rotenone formulation. For flows less than 25 ft3/s, it is usually desirable to treat using diluted (usually 10:1) formulation.

Labeling - All service containers, backpack sprayers, and drip stations must be properly labeled. Label requirements include the product name, name of responsible party (Iowa DNR) with address, label signal word (either “Danger” or “Warning”).

Figure 24. Typical drip stations used in Iowa.

Sprayers
Follow label requirements for PPE for mixers, loaders, applicators and other handlers. All must wear chemically resistant gloves and footwear (or waders), goggles, coveralls, and an R or P prefix respirator during spraying (see label for specific guidance on respirator section). A number of sprayer types are available (Figure 25). The style of sprayer used is often determined by the quantity of chemical to be applied. As a general rule, gas powered sprayers are preferred for treatment areas greater than 5 acres. Battery-operated units are useful in smaller areas and backpack units are commonly used in lake drainages when walking downstream. All sprayers must be labeled as previously outlined under drip stations.

The amount of undiluted rotenone formulation required is added to the tank directly from a service container for flowing water. For standing waters, make a dilute rotenone solution by partially filling the tank with water, adding the predetermined quantity of undiluted rotenone liquid to the tank, then filling the tank to the desired volume. When filled, it is recommended that the tank is diluted to not more than 10% rotenone formulation. Undiluted rotenone formulation may be applied to flowing waters. For additional information, AFS SOP Manual 8.1 addresses additional issues associated with operation of semi-closed application systems for liquid rotenone formulation, AFS SOP Manual 11.1 addresses the use of drip stations, while AFS SOP Manual 12.1 outlines the use of sprayers.

Figure 25. Typical sprayer types including gas powered, battery-powered ATV and backpack sprayers used for difficult to reach locations during rotenone applications.

<u>Other Useful Items</u>

Additional items to be on-site include:

- Bung wrench for opening drums
- Extra buckets

- Spare PPE
- First Aid kit(s)
- Bottled water
- Two-way radios and/or cell phones
- Life jackets and other boat safety items for boat crews

Intermediate Planning: Permitting and Laws

Interagency responsibilities

Contact all government agencies at the local, county, state, or federal level that might have plans, permits, authorities, or responsibilities affected by the treatment. These include state and county parks, DNR Environmental Protection, and DNR law enforcement. Include local governments (counties, cities, water supply boards, and conservation districts, where appropriate). Discussions with local resource managers are an integral part of any renovation plan. Local buy-in will assist in ensuring a strong level of public trust in the project. In addition, local cooperators are often an integral part of securing funding for such projects.

Internal Review and Approval

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) is a United States Federal law that regulates user compliance with pesticide labeled rules of use, including the use of rotenone. FIFRA guidelines require the applicator to maintain certain records for all controlled use pesticide applications. The applicator is required to maintain the following information for each application of rotenone. All records need to be maintained for a period of at least 3 years post-application.

- ☐ Date of the application
- ☐ Tradename of the product applied
- ☐ Concentration targeted by the applicator
- ☐ Temperature (air and water), wind direction and speed (measure multiple times during the day)
- ☐ Start and end time of the application
- ☐ Specific site of application (lake name)
- ☐ What applicator is treating (all fish or selected species)

Permits from the Water Quality Section of the DNR are required for application of rotenone to Class C - Drinking Water Supplies. These are waters which are used or can be used as a raw water source of potable water. A complete list of Class C lakes is available (Table 16). Rotenone application above 40µg/L is precluded by EPA in active water supplies. Not all Class C waterbodies are active water supplies. For those water bodies that are actively utilized for municipal or private water, an alternative water supply must be secured by the controlling authority until rotenone concentrations fall below 40µg/L. In addition, wells within a designated distance of a treated Class C lake may need to be located and reported to local municipal water supply managers in order to prevent contamination of the drinking water of local residents or facilities (See AFS SOP 16.1 for additional information). Low-concentration selective applications are well below this threshold; however, it is imperative that the controlling authority and the public be included in this decision-making process prior to treatment. There are no National Pollution Discharge & Elimination System (NPDES) permits required for rotenone application.

The Iowa DNR's Water Resource Section requires a water release permit be completed prior to drawdown of lakes. A written letter explaining the purpose, extent, and duration of the drawdown must be submitted and will serve as the application.

Table 16. Class C water supply lake designations.

County	Waterbody Name
Adair	Greenfield Lake
	Nodaway Lake County Park (Ken Sidey Nature Area)
	Orient Lake R.A.
Adams	Binder Lake
	Lake Icaria County R.A.
	West Lake Corning (a.k.a. Corning Reservoir)
Appanoose	Lower Centerville Reservoir
	Mystic Reservoirse
	Upper Centerville Reservoir (Lelah Bradly Park)
Cerro Gordo	Clear Lake State Park
Clarke	West Lake (Osceola)
Davis	Lake Fisher Park
	Lake Wapello State Park
Decatur	Home Pond
	Lake LeShane
	Little River Watershed R.A. Lake
	Nine Eagles State Park Lake
Dickinson	Big Spirit Lake S.G.M.A.
	Silver Lake S.G.M.A.
	West Okoboji S.G.M.A
Emmet	Iowa Lake S.G.M.A.
Henry	Geode Lake State Park
Jasper	Rock Creek Lake State Park
Jefferson	Fairfield Municipal Reservoir #1
	Fairfield Municipal Reservoir #2n
	Walton Reservoir
Lucas	Ellis Lake
	Morris Lake
	Red Haw Lake State Park
Madison	Cedar Lake (a.k.a. Winterset City Reservoir)
Mahaska	Lake Keomah State Park
Monroe	Albia City Reservoir
Montgomery	Viking Lake State Park
Polk	Dale Maffitt Reservoir
	Des Moines Water Works Recharge Basins
Poweshiek	Diamond Lake County Park
Ringgold	Loch Ayr Reservoir
Shelby	Prairie Rose Lake State Park
Taylor	Bedford Impoundment
	East Lake (Lenox)

Fish Rescue and Removal of Fishing Limits

The prospect of wasting fish in a treatment may prompt public concern. Consider the viability of a pretreatment salvage operation. In most situations, there are very low numbers of Largemouth Bass or other predator fish that can be moved to nearby lakes and provide a valuable function. This is particularly true for adult Largemouth Bass which may serve as broodstock for other recently renovated water bodies, or Channel Catfish which might replace semi-annual maintenance stockings in area lakes. In addition to the biological value, this activity does enhance public relations between the public and the Iowa DNR. Care should be taken to ensure that no injurious or invasive species are transported in these operations.

Liberalization of fishing regulations can also effectively address concerns over wasting fish and can improve public support. Iowa's Promiscuous Fishing Rule (IAC 571-84.1(481A)) allows for this activity. Under Promiscuous Fishing, angling regulations including bag and length limits, method of take and the number of rods that can be used at one time are relaxed. Anglers are allowed to use any technique or gear, other than explosives, chemical or stupefying substances that can be used to harvest fish that would otherwise be wasted. Commonly, promiscuous fishing entails the use of nets and seines to capture fish. A positive public relations image and a reduction in fish cleanup are advantages of promiscuous and liberalized fishing. Relaxed fishing regulations prior to the renovation are to be coordinated with the local conservation officers, pertinent resource managers and supervisors. Promiscuous fishing is typically opened two to three months before scheduled renovation Anglers are required to have a valid fishing license in their possession. Promotion of promiscuous or liberalized fishing activities should be accomplished with the help of the Fisheries Bureau Information Specialist.

Disposal of Dead Fish

The Iowa DNR does not typically recover dead fish from the treatment area. However, in cases where high-use areas are impacted or if safety reasons dictate, fish pickup is sometimes performed. Have adequate resources available for the collection of dead fish. Do not offer or provide dead fish for human consumption because no tolerance for rotenone in fish flesh for human consumption has been established. Additionally, there are other public health issues (e.g., flies and *Salmonella*) associated with decaying flesh.

Collect fish during and after standing water treatments by crews in boats and/or walking the shore with dip nets. Because most fish carcasses sink, the collection of dead fish is limited. Bradbury (1986) reported that only about 30% of the dead fish could be recovered from treated lakes in Washington. Pick up fish for two to five days depending on water temperature.

If fish disposal is necessary, multiple outlets are available. One option to consider before disposal at a sanitary landfill would be the DNR's Iowa Waste Exchange program. This service is used to identify potential end users that could utilize the euthanized fish (e.g., rendering facilities, animal shelters, cattle/swine feed operations, turtle growers). While these options may take some upfront planning and time, they could result in significant cost savings over transport and disposal at a sanitary landfill. Additional options allowed within the Iowa Administrative Code (IAC) are as follows:

1. **567 IAC 113 Sanitary Landfills:** Final disposal at the permitted sanitary disposal facility (i.e. landfill). Should first coordinate with the landfill operations manager prior to delivery (daily cover at the landfill would minimize odor and landfills are lined to collect leachate).

2. **567 IAC 105 Composting:** Composting should be done pursuant to 567 IAC 105.3. Contact local DNR Field Office in advance for compliance assistance.

3. **567 IAC 121 Land Application of Wastes:** If dead fish were land applied, the following should be considered: land apply at agronomic rates, maintain separation distances of 200' from property line, stream, lake, pond, sink hole, or tile line surface intake or 500' from ground water well, at a rate of no more than 2 tons per acre, mechanically incorporated into the soil within 48 hours of application.

Permitting for disposal must be completed before treatment begins.

Post-application Stocking Plans
Most, but not all, complete renovation projects will be followed with an effort to restock the treated waterbody. Develop a restocking plan based on the proposed treatment date, management objectives, and expected rotenone degradation or deactivation time. The restocking effort should be consistent with the current DNR Fisheries stocking guidelines and should be completed by November in the year prior to the treatment to be included with the annual stocking request. The request should include fish needed for restocking of private waters which are treated as part of the project.

Public resistance to a treatment may be due to an unwillingness to accept lost fishing opportunities or the loss of quality-sized fish. In such cases, there may be a demand for recapture of fish previously salvaged from this water body and temporarily relocated to another water body. Channel Catfish and Largemouth Bass are examples of fish that can be easily returned after temporary relocation to another area water body. Restocking can usually be performed within 2 - 3 weeks, post-treatment. However, in the absence of post-treatment rotenone testing by the University of Iowa Hygienic Laboratory (UHL), staff may wish to test the lake with caged sentinel fish placed in the lake for 24 h. The survival of these fish for that period will ensure the survival of the stocked product. See AFS SOP Manual 14.1 for additional details on the use of sentinel fish.

Fish renovation is a time-tested and efficient fisheries management technique in Iowa. Response of fish populations in a new-lake situation is predictable and should succeed in producing excellent results within two or three years.

Final Planning

Storage and Transportation of Rotenone
Original and Service Containers - Rotenone formulation typically comes from the manufacturer in large 30-gallon drums. Do not open pesticide containers until ready for use. Rotenone formulation may be transferred from drums to small service containers which can be any secure and operational storage container except those of a type commonly used for food, drink or household products. Service containers must provide (1) the name and address of the person or firm responsible for the container, (2) the identity of the pesticide in the container, and (3) the signal word that appears on the label of the original container (i.e., “Danger” for Prenfish and Chemfish Regular). These same labeling rules apply to any container with undiluted product, including sprayers and drip stations.

Guidelines for Long-term Storage Facilities - The designated long-term storage facility for the Iowa DNR is at the Boone Wildlife Research Station. Long-term storage should be considered for any chemical that will not be applied within the current open-water season. Specific design of long-term storage facilities can be found in AFS SOP Manual 4.1

Guidelines for Project Site - Acceptable storage enclosures include closed vehicles, trailers, buildings, fenced enclosures and other locations that reduce the likelihood of public contact. Metal containers with screw type bungs and/or secured and locked valves and sealed five-gallon containers are also acceptable storage enclosures and may be located outside the previously described requirements. Note that the product label has important instructions for use and is considered part of the product; in other words, the label must be present at the project site.

Transportation
State Exemption: The federal codes regulating transport of hazardous materials exempts state agencies from many of the requirements regarding hazardous materials training, license endorsements and placarding. However, piscicides should not be carried in the same compartment as passengers, food, or feed. Transportation containers should be secured in place. Prior to transport, the applicator or vehicle driver must ensure that pesticide containers are properly labeled. Shipping papers, emergency response phone numbers, and (M)SDSs should be present in the vehicle when transporting rotenone.

Spill Prevention and Containment
Site spills may be associated with improper storage or accidents during handling and transport. The storage of rotenone materials at the project location may be in a location that is graded to allow drainage to the project water body in case of an accidental spill. Containers of rotenone liquid may be set on a plastic barrier, concrete ramp, or other impermeable surface sloped toward the project water body. A small spill of rotenone can then be rinsed into the treated water.

Staging

Arrangements should be made with park managers or rangers to have areas on-site in which to securely store chemical and stage the project. Drums of rotenone formulation need to be delivered to boat ramp areas for loading into boats. Persons participating in watershed treatment should ensure they collect required chemical and equipment to treat selected zones. In addition, remember to stay hydrated, watershed treatments are commonly strenuous and often occur during warm periods.

Placarding Treatment Areas

Applicators must post publically accessible sections of the treatment area with placards (see Appendix A) that inform the public of the application of the pesticide and the need for specialized PPE within the treatment zone. Do not allow recreational access (e.g., wading, swimming, boating and fishing) within the treatment area while rotenone is being applied or while placards remain.

If treatment concentrations are less than 90 ppb (µg/L), placards can be removed immediately upon completion of treatment. Applicators should consider quantitative analysis of rotenone concentration through an approved laboratory to ensure the concentration is below threshold levels prior to removal of placards. Water samples for the UHL should be collected for analysis using a Kemmerer bottle suspended under the water surface or by submerging the sample bottle a few inches below the surface. Before taking a sample, the collection device is triple-rinsed with water from sampling depth.

Water samples can be processed at the University Hygienic Laboratory (UHL) in Coralville, Iowa. Approximately two weeks prior to treatment applicators should contact UHL to inform them of the need for analysis and to request sample bottles. The contact at UHL is:

Client Services Program Manager
State Hygienic Laboratory
U of I Research Park
2490 Crosspark Rd
Coralville, IA 52241-4721
Tel: 319-335-4500
Fax: 319-335-4555

Alternatively, sentinel fish (i.e. game fish such as Largemouth Bass or Bluegill) placed in enclosed cages in the treated water body, that survive for 24 h indicate that rotenone levels are below signage thresholds and placards may be removed (See AFS SOP Manual 14.1 for additional discussion on the use of sentinel fish).

Safety Plan Compilation

By this point in the planning process, most items needed for a safety plan have been completed and need only be compiled for reference during project implementation. Components of a safety plan are:

- ☐ Definition of a command structure, with a single Project Supervisor
    - Providing contact information for all teams
- ☐ Reducing and mitigating chemical exposure
    - Ensuring staff are appropriately trained for their respective duties
    - Providing all necessary PPE
    - Providing a wash station
    - Identifying emergency medical care options
    - Maintaining appropriate documents including (M)SDSs and labels
- ☐ Addressing general safety hazards
    - Preparing for illness, heat exhaustion/stroke, and other hazards
    - Ensuring a first aid kit and staff trained in First Aid/CPR are completed
- ☐ Restricting access to the treatment area

- Restricting public access to treatment areas through placarding and other communications
    - Ensuring worker re-entry requirements are met including PPE as appropriate
- ☐ Proper chemical handing, storage, and spill mitigation
    - Providing secure on-site storage for chemical
    - Cleaning up and reporting spills

Project Implementation and Management

The last stage before treatment is to finalize plans for all operations associated with the project. Depending on the size of the project, the preceding steps will likely be sufficient to facilitate a successful application. Specific final implementation steps are outlined later in this document in either the “Complete Renovation” or “Low-Concentration Selective Treatment” sections. In addition, the AFS SOP Manual is available where more detail is required.

Complete Renovations - Specific Guidance

Complete renovations are needed when a lake’s fish community is dominated by undesirable fish populations (e.g., Common Carp, Gizzard Shad, Black Bullhead, or Yellow Bass) and cannot be effectively managed by mechanical removal, biological manipulation, or other methods. The recreational fishery typically suffers as a direct result of “rough fish” dominance via interspecific competition, predation, or habitat alteration. Complete renovations often coincide with lake drawdowns which reduce the treatment area and volume, therefore the amount of chemical needed.

Complete renovations differ from selective treatments in several ways: 1) elimination of all fish from the lake requires higher treatment rates and thus more chemical, 2) elimination of all fish from the watershed requires additional personnel, planning, and equipment, and 3) higher treatment rates require elevated safety actions. Watershed-level treatments are often necessary to minimize risk of re-introduction of “rough fish” but require much more coordination and collaboration with private landowners.

Preliminary Planning for Complete Renovations

As aforementioned, public meeting(s) are an important step in developing local support for any renovation. An important part of fostering this relationship is to provide succinct and easily understood information to the public. At a minimum, the biologist should deliver the following information for complete renovations:

- Why must the fishery be renovated? *Determined by biologist*
- Why is rotenone the only likely option for this fishery? *See Statement of Need on Page 52*
- What is rotenone? *See Introduction on Page 47*
- Is rotenone safe for the public and our environment? *See Toxicity to Humans and Other Mammals on Page 49*
- How long will the proposed rotenone treatment take? *Determined by biologist*
- Does rotenone kill “everything”? *See Toxicity of Rotenone on Page 49*
- Will wildlife that eat the dead fish be harmed? *See Rotenone Residues in Poisoned Fish on Page 50*
- What will become of the dead fish? *See Disposal of Dead Fish on Page 65*
- What is the budget for this project? *Determined by biologist*
- How long will it take for quality angling to return? *Determined by biologist*
- What is the overall timeline for the project? *Determined by biologist and partners*

Intermediate Planning for Complete Renovations

Mapping of Lake and Watershed

Specific procedures for lake mapping were described previously. For complete renovations, the watershed requires detailed mapping and watershed application requires additional staff and equipment. Chemical needs in the lake may require dividing the lake into sections to allow multiple teams to apply chemical simultaneously or conducting two-tier applications is often required. Chemical needs can be reduced by coordinating application with a lake drawdown. These specific instructions are detailed below.

Watershed Treatment

The number of persons required to treat the watershed is determined by the length of stream to be treated, the amount of flow in the watershed, and the terrain surrounding the streams. Typically, one applicator carrying a standard backpack sprayer will treat no more than one mile of continuous stream. The strenuous nature of these applications and the required PPE make additional application problematic for many individuals. Backpack application is recommended, even if drip stations are utilized, to ensure complete coverage of areas out of the direct current of the flowage. Drip stations can be used to treat water entering the treatment area and to ensure a lethal concentration of rotenone is maintained in the watershed for at least 4 to 8 hours. Backpack and drip station applicators may apply undiluted rotenone to flowing water.

To plan a watershed treatment, first subdivide the watershed into treatment sections and assign personnel. Determine application method for each section. Application options include:

- Drip stations, placed every ~1/2 to 2 miles between stations depending on stream flow and travel time.
- Backpack sprayers - This option is used to treat hard-to-reach areas not effectively treated with drip stations. Potential sites include deep pools, eddies, or stream stretches that are excessively distant from drip stations.
- Both drip stations and backpack sprayers to ensure complete coverage

Flow rates in the watershed should be surveyed within 48 hours of treatment to assess final chemical needs for watershed treatment. If exceedingly high flows have resulted from recent precipitation, it may be desirable to temporarily delay the application.

Pond and Wetland Treatment

Watershed ponds that contain injurious fishes must be renovated prior to or during the lake renovation. To ensure that no reinvasion occurs, wetlands with direct connection to the treatment water body should be treated concurrently with the lake. Ponds within the watershed are typically treated with a small boat and a semi-closed or spray application system (Figure 26). Also note that all pond outflows (e.g., plunge pools) should be treated to ensure they do not become deep water refugia for target fishes.

Figure 26. Example of small craft and application equipment for watershed and pond treatments.

Lake Treatment

Section the lake, calculate lake treatment section volumes, and assign application accordingly. Typically lake sections are no more than 40 acres in size and contain no more than 250 acre-feet of water. Boats should utilize a semi-closed application system (Figure 22). Undiluted rotenone is lifted from the barrel and mixed internally with the pump. The use of a GPS tracking system ensures the even distribution of chemical in the treatment zone. Figure 27 pictures a typical GPS track from an application. Applicators should maintain an even and safe speed. While the use of a Venturi boat bailer system is allowed, it is not recommended as the use of this system requires the application of diluted formulation (minimum dilution 10:1), thus increasing the time needed for application.

Determine if two-tier application is necessary. Typically deep water pumping is not required in Iowa treatments performed during the spring, summer or fall. The most typical impediment to mixing is the onset of a thermocline; however, given the hypoxic or anoxic nature of the metalimnion and hypolimnion of Iowa lakes during these periods, this zone is not a practical refuge. That said, applicators may wish to utilize deep water application in zones 20 feet or more in depth, particularly if no thermocline exists. Rotenone needs can be calculated based on estimates of volume of water deeper than 20 feet. Application will utilize the semi-closed pumping system described previously; with a weighted diffusion nozzle (Figure 28) suspended at approximately the 20-foot depth contour.

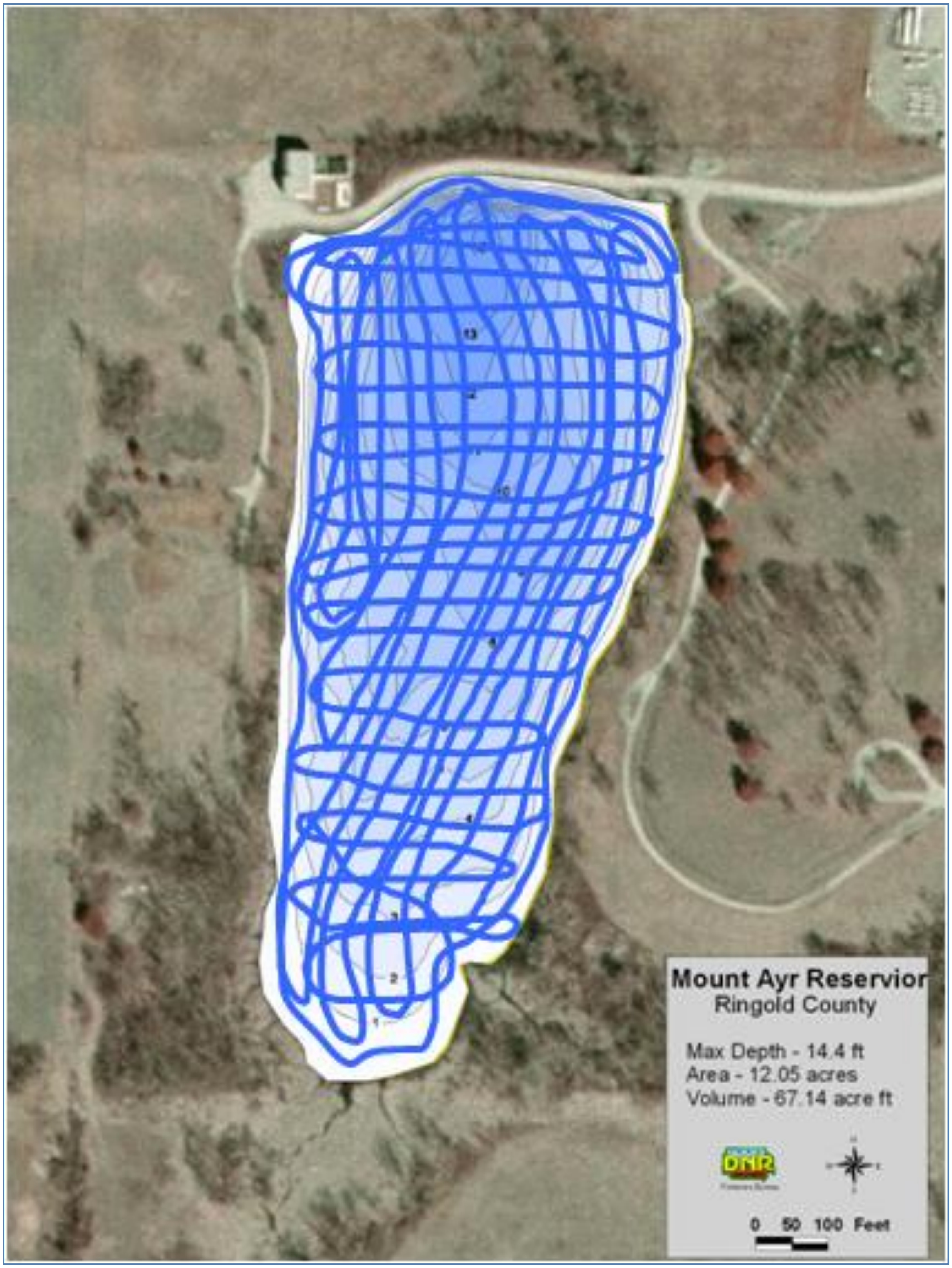

Figure 27. Typical GPS track during rotenone applications. Applicators should travel the perimeter of the application zone first to establish the limits of their site.

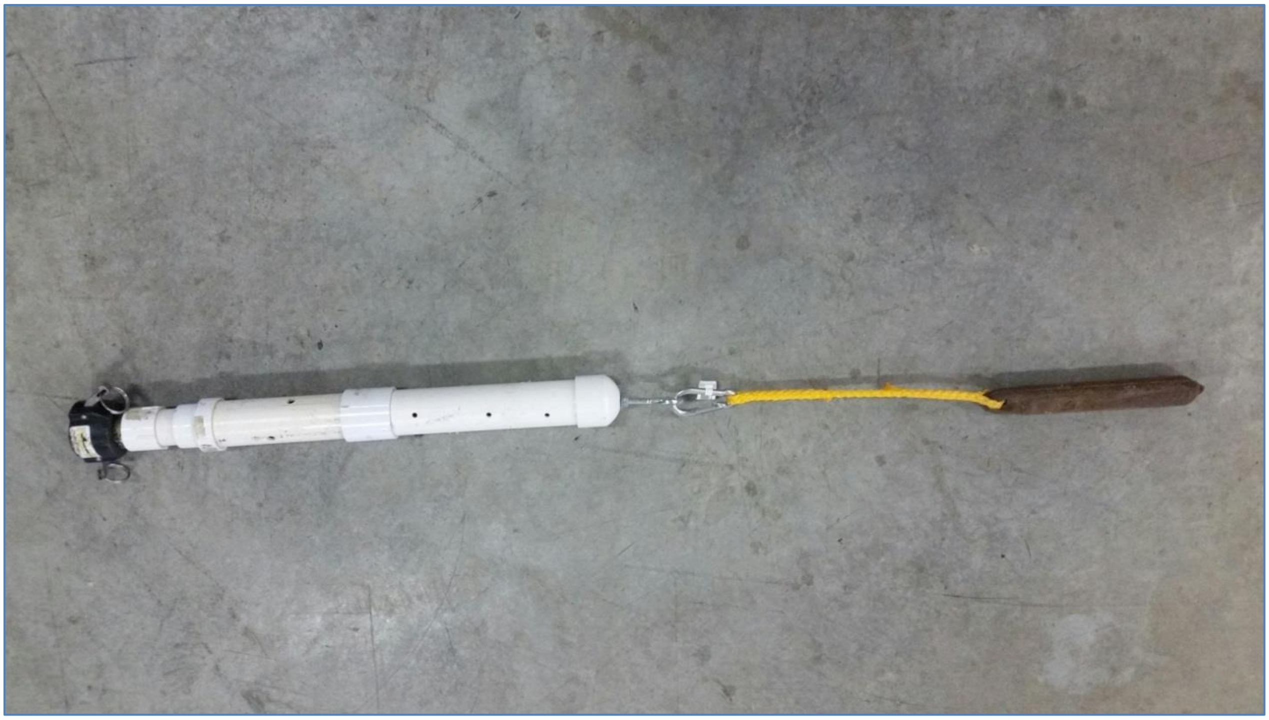

Figure 28. Example of a weighted diffusion nozzle used for deep water application.

Lake Drawdown

Lake drawdown is an important step to ensure that treated water does not escape the system and cause fish mortality below the treatment area. If releases occur, a detoxification system will be required below the treatment area. Furthermore, drawdown reduces water volume to be treated, reducing both chemical cost and the risk of untreated refugia (e.g., deep holes).

In cases where no outlet control structure is available, summer or fall treatments are especially helpful as water levels often fall below normal pool elevations. Alternatively, pumping or siphoning may be useful in reducing pool elevations. Attention to weather forecasts and a substantial lake drawdown can ensure that detoxification below the treatment area will not be required. In addition, if heavy rains occur beyond 48 h post treatment in summer or fall it is likely that remaining rotenone levels in the treated water will be below levels that will result in downstream fish mortality. It is imperative that the final pool elevation be determined prior to treatment to ensure an accurate calculation of water volume for the proper treatment concentration.

Downstream Deactivation

Because the half-life of rotenone in the water column may be longer than what is needed to remove undesired fish, potassium permanganate is sometimes used to neutralize the piscicidal effects of rotenone in flowing water. However, in Iowa, rotenone is rarely, if ever used, in flowing systems, except for tributary streams of renovated lakes. In cases of whole-lake renovations, lakes are typically “drawn down” to some degree to reduce the cost of rotenone required, and to provide a buffer from post-treatment inflows resulting from precipitation events. If rain events result in the outflow of water from a treated lake within the first 48 h of treatment, it may be necessary to treat outflowing water with potassium permanganate to ensure downstream fish kills do not result. Specific methods of potassium permanganate application can be found on the rotenone label and AFS SOP Manual 7.1. However, all steps possible should be taken to reduce the need for deactivation through the reduction in pool elevation and closure of outlet structures prior to lake treatments. Attention to weather forecasts can greatly reduce the chances of such treatments being necessary. If heavy rains occur beyond 48 h post treatment in summer or fall, it is likely that remaining rotenone levels in the treated water will be below levels that will result in downstream fish mortality.

Required Permits

As described previously, no active water supply can be treated with rotenone concentrations in excess of 40µg/L rotenone. If treatment concentrations exceed 40µg/L, an alternative water source must be identified for use for as long as concentrations remain above this threshold. Typical complete renovations treat above this benchmark and require a permit through the Water Use Section of the Iowa DNR if the target water is a Class C Water Supply Lake. No additional permitting is required as long as application remains within labeled limits.

Final Planning for Complete Renovations

Placarding Treatment Areas

For complete renovations in Iowa, maximum rotenone concentrations within the label parameters are often up to 200 ppb (µg/L). Thus, placards should remain at the water line (at all access points or for high use areas every 250 feet) until rotenone concentrations decline to ≤ 90 ppb (µg/L) or for 14 days post application, whichever comes first. Typically, renovations in Iowa are performed in late summer or early fall when water temperatures are 60° - 80°F. Under these temperature conditions, rotenone concentrations decline quickly. Based on past Iowa lake treatments of 200 ppb (µg/L) rotenone, placards can be removed when concentrations are 45% of the treatment concentration, or approximately 2 days post treatment (Figure 29); however, project supervisors should consider quantitative analysis of rotenone concentration through the UHL to ensure the concentration is below threshold levels.

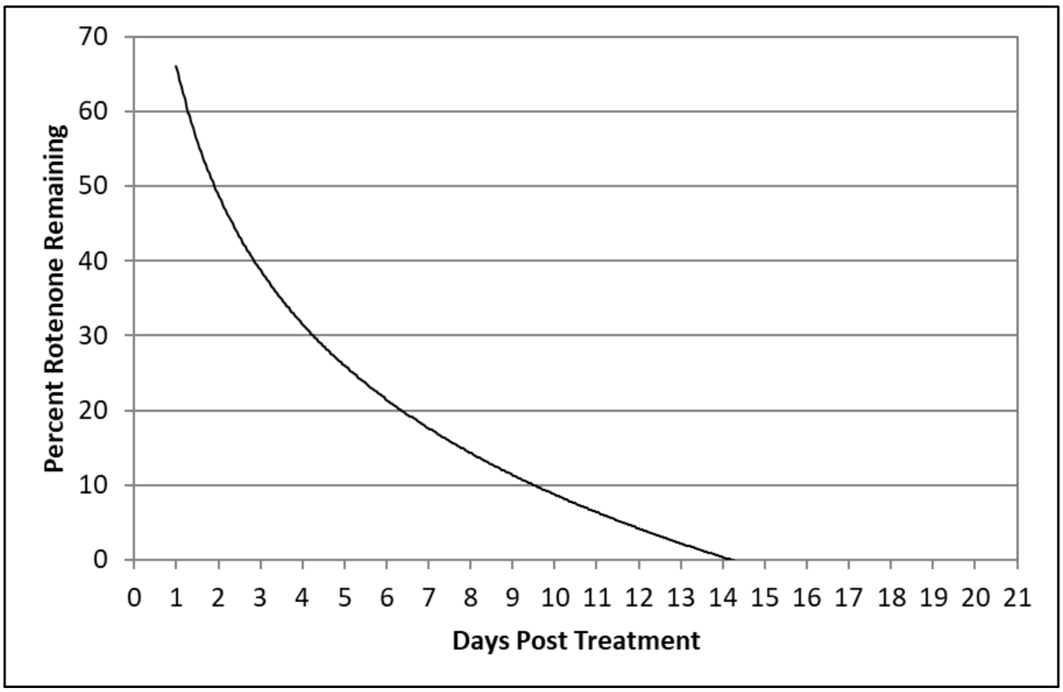

Figure 29. Decline in rotenone concentration from treatment level at "x" days post treatment. All data are derived from complete lake renovations at treatment levels of at least 200 ppb (µg/L) and water temperatures were between 60º and 80ºF.

Documentation to Have On-Hand

The following documentation is helpful, if not required, to have on-hand during treatment:

- ☐ Chemical product labels
- ☐ Chemical (M)SDSs
- ☐ AFS SOP Manual
- ☐ Emergency contact information and medical care notice
- ☐ Detailed watershed and lake maps
- ☐ Extra public notices for posting around the treatment area

Treatment

On the date of treatment, begin with a team meeting and provide an overview of the treatment plan, crew assignments, and safety guidelines. All placarding should be in place, and access to the treatment area should be limited to assigned staff with appropriate training and PPE. Remind the team of who is the project coordinator. By default, this individual is in possession of important documentation and will handle safety concerns. Make sure the chain of command is clearly communicated to everyone. Review the (M)SDS, product label, and SOP with applicators, and demonstrate the appropriate use of PPE and application equipment. It may be helpful to review the annual training requirements at this time, including the following:

- Rotenone health effects
    - The four routes of exposure
    - Explain potential exposure side effects
    - Ways to clean PPE
- Emergency first aid and where to go for treatment
- PPE
    - What PPE are required
    - How to properly wear
- Pesticide safety
    - Meaning of safety statements on label
    - General safety rules
- Access to (M)SDS

Keep track of rotenone quantities applied to avoid over treatment. Total amount of rotenone applied to the stream or lake from all applications (i.e., drip cans, and undiluted rotenone application) should not exceed the quantity needed for the desired treatment rate.

<u>Review and Wrap-up</u>

<u>Re-entering the Treatment Area</u>

For applications that result in concentrations greater than 90ppb (µg/L) active rotenone, handlers re-entering treated water, must wear, at a minimum, the following PPE:

- ☐ coveralls over long-sleeved shirt and long pants (Tyvek or rain gear)
- ☐ chemical-resistant gloves
- ☐ chemical-resistant footwear plus socks
- ☐ chemical-resistant apron

No respirator is required when reentering after applications is complete.

Exception: waterproof waders may be worn in place of coveralls, chemical-resistant apron and chemical-resistant footwear.

Duration of PPE requirements for persons re-entering treated water corresponds to duration of placarding requirements (i.e. PPE requirements end when placards are removed).

<u>Water Monitoring</u>

As aforementioned, applicators must monitor rotenone concentrations and maintain placarding until concentrations fall below 90 ppb (µg/L), or until 14 days have passed. Methods for monitoring rotenone concentration include 1) exposing sentinel fish to treated water, 2) conducting quantitative analysis, or 3) waiting the requisite number of days post-application.

Sentinel fish may be placed in a cage in treated water. Placarding may be removed if sentinel fish survive for 24 hours. Experience suggests that most treatments will detoxify sufficiently to remove placarding within 48 hours of treatment (Figure 29). For additional information on the use of sentinel fish, review AFS SOP Manual 14.1.

<u>Pesticide Container Disposal</u>

Product labels direct applicators to triple rinse each empty container. Render all plastic and metal containers unusable by puncturing or crushing them. Recycle plastic containers or deposit the empty container in a licensed sanitary landfill.

Metal drums are subject to a Code of Federal Regulations (CFR) exemption under the Resource Conservation and Recovery Act (RCRA). Therefore 40 CFR 261.4(a)(13) excludes Scrap Metal from regulation if recycled. Thus, metal drums may be disposed of for scrap metal as appropriate.

Disposal of Dead Fish
Collection of dead fish may be necessary in high-use areas or if there are safety concerns regarding the excessive presence of decaying fish. Inform the public that all rotenone formulation labels preclude the legal consumption of fish removed as a result of rotenone application.

Restocking Fish
Restocking can usually be performed within 2 - 3 weeks, post-treatment. However, in the absence of post-treatment rotenone testing by UHL, staff may wish to test the lake with caged sentinel fish placed in the lake for 24 h (See AFS SOP Manual 14.1 for additional details). The survival of these fish for that period will ensure the survival of the stocked product.

Biological Monitoring
Biological monitoring can help not only gauge success in a renovation, but also assure stakeholders of the project area's resilience to treatment. Specifically, fish sampling for multiple years following project implementation can provide data regarding fishery development, guiding the public's expectations after sportfish are restocked.

Selective Treatments - Specific Guidance
Rotenone tolerance varies among fish species (Figure 1). This variability allows for the selective eradication or biomass reduction of some species, with relatively minor impacts on other populations, allowing for the biomanipulation of important sport fisheries in Iowa waters. Low concentration selective rotenone treatments are an important tool wielded by Iowa DNR Fisheries staff for the management of Iowa water bodies.

Biologists have successfully employed this differential tolerance to the elimination of various invasive or injurious fishes (Bowers 1955; Flammang 2014). For example, Gizzard Shad and Yellow Bass are sometimes illegally introduced to Iowa lakes and are not a preferred component of thefish community. Both species have been effectively eliminated at various levels of rotenone treatment in field trials, while gamefish populations have been relatively unaffected (Flammang 2014). Eradication efforts are most often successful when there is considerable separation of rotenone tolerance between target and non-target species, whereas biomanipulation efforts are aimed at the reduction of target species abundance, but not elimination.

Preliminary Planning for Selective Treatments
Public and Media Involvement
An important part of fostering this relationship is to provide succinct and easily understood information to the public. This may be accomplished through public meetings. Project leaders should coordinate with the Fisheries Bureau Information Specialist to develop press releases that will inform and educate the public about project goals. Partners must be informed of important biological, ecological, and water quality impacts of the injurious species. At a minimum, the biologist should deliver the following information for selective treatments, via written or verbal format:

- Why must the population in question be targeted?
- Why is rotenone the only likely option for this fishery?
- What is rotenone?
- Is rotenone safe for the public and our environment?
- How long will the proposed rotenone treatment take?
- How much rotenone will be used and how does this compare to complete renovations?
- Will game fish be impacted?
- How long will the lake be closed to angling?
- What will become of the dead fish?

Timeline and Statement of Need

As with complete renovations, discussions with local resource managers are an integral part of any selective treatment. One of the initial points of discussion would be to identify the problem and determine if selective treatment is an option. The presence of quality Walleye or Muskellunge populations would likely preclude the immediate use of selective treatments, unless the Department and the public are prepared for the entire loss of these populations. Alternatively, the low-concentration treatment might be delayed to a time when these populations have declined naturally in the face of the cessation of maintenance stockings.

Intermediate Planning for Selective Treatments

Lake Mapping

A high degree of accuracy in bathymetric mapping and lake volume calculation is required to achieve successful selective treatments. In some cases the margin of error can be narrow. Excessive rotenone concentration will result in high non-target mortality, whereas insufficient treatment may fail to affect the target population to the desired degree. Bathymetric measurements of lakes should be collected using georeferenced sounding hardware (e.g., a Biosonic DT-X system utilizing a 430 kHz transducer and Trimble GPS receiver with sub-meter accuracy). ArcGIS, Surfer, or similar software package capable of analyzing the post-processed sounding data is used to calculate volume and lay out application areas. The lake should be subdivided into zones, each corresponding with 5-20 surface acres for individual treatment. In addition, zones should be subdivided further into shallow (<20 ft) and deep (>20 ft) zones. A typical lake map developed for a selective treatment is pictured in Figure 30.

Watershed Treatment

Watershed treatment is typically unnecessary unless the watershed is large, flowing, and has substantial pooling and inflow at time of application. Watershed application should be completed using diluted formulation with a minimum dilution of 10:1. Drip stations provide more consistent treatment if flowing. Backpack systems may be employed in standing streams at the same dilution.

Pond and Wetland Treatment

Watershed ponds and wetlands will be treated if they contain target species. In most cases, the complete renovation of these systems is preferred, followed by a restocking program. Wetlands with direct attachment to the treated waterbody must be treated concurrently with the lake.

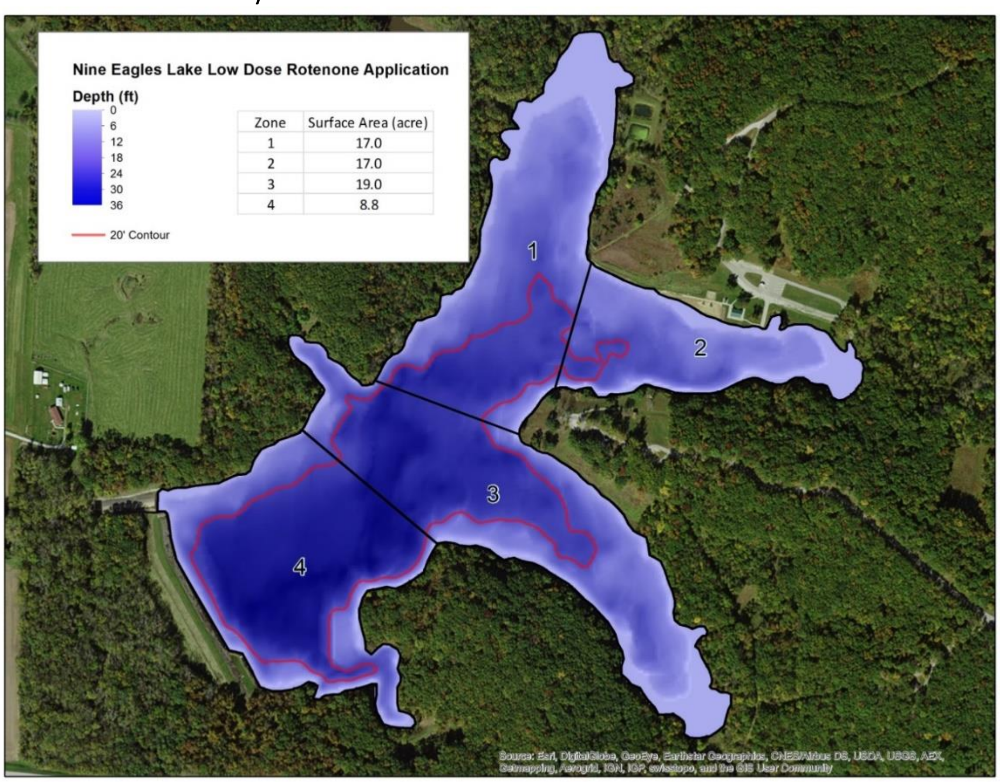

Figure 30. Typical lake zone map for selective treatments.

Lake Drawdown

It is imperative that the final pool elevation be determined prior to treatment to ensure the target treatment concentration is attained. Typically lake drawdown is not required with low-concentration treatments, unless applicators wish to expose hazards such as tree stumps to improve applicator safety. Usually one to two feet of exposure will be sufficient.

Analytical Determination of Rotenone Formulation Concentration

The level of differential rotenone tolerance is relatively small across fish species; therefore, the actual rotenone concentration of the formulation used in selective renovations should be analytically confirmed. The concentration of rotenone has been found to vary plus/minus 20% from the labeled 5% active ingredient (Flammang 2014). Concentrations vary among manufacturers, lots, or dates of manufacture. Also, rotenone concentration has been observed to vary over time in the original container, especially once opened. This variability may have negative effects on the success of selective renovations by causing non-target mortality (due to higher-than-expected concentration) or failure to affect the target species to the degree wanted (due to lower-than-expected concentration). Applicators should have stock rotenone assessed by a third party laboratory prior to use. (See ASF SOP Manual 16.1 for more information on analytical chemistry). Make sure the undiluted formulation is well mixed before sampling for analysis (AFS SOP Manual 16.1) and toxicological (AFS SOP Manual 5) testing. In addition to the analytical confirmation of rotenone content, it may be useful to conduct bioassays with the target species life-cycle stage targeted using the site water.

Pre-use determination of active rotenone should be assessed analytically by reverse-phase high-pressure liquid chromatography (HPLC) with UV absorption detection (Warner et al. 1982). An independent laboratory should be utilized to perform this analysis to evaluate stock rotenone concentration prior to treatment. Rotenone concentration can be evaluated by:

CIA Labs
1717 Commercial
PO Box 3022
Saint Joseph, MO 64503
816-232-8007

From this analytical determination, we can calculate nominal dosages more accurately, thus facilitating the highest level of accuracy possible for determining application rates. A spreadsheet is available to assist in these calculations.

Determination of Treatment Concentration

The use of standard petroleum-based formulations (e.g. Prenfish or Chemfish Regular) is recommended to improve mixing during cool water applications. Rotenone concentrations for selective treatments are typically 3-10% of concentrations used for complete fish removal (Table 17). The amount of rotenone administered to a water column to achieve the desired degree of toxicity to fish depends on the species of fish to be treated. Typically, concentrations will not exceed 8.0 ppb (µg/L) (Flammang 2014). The variability in tolerance among species allows for this level of selectivity (Table 18). For a more detailed review of target mortality and suggested dosages, see Flammang (2014).

Table 17. Typical treatment concentrations of formulation and rotenone for use in complete fish removal and selective treatment.

Type of Use	Formulation (ppm)	Rotenone (ppb or µg/L)	Acre-feet / gallon	Gallons/ acre-foot
Normal	0.5-1.0	25-50	6.0-3.0	0.17-0.33
Tolerant Species	1.0-3.0	50-150	3.0-1.0	0.33-1.00
Tolerant Species in Organic Waters	2.0-4.0	100-200	1.5-0.75	0.67-1.33
Selective Treatment	0.003-0.15	6-30	50.5-10.1	0.0198-0.099

Table 18. Suggested target concentrations for selective rotenone treatment based on species targeted.

Suggested Target Concentrations	Special Notes	Active Rotenone Concentration (ppb or µg/L)
Walleye Removal		3.0-5.0
Gizzard Shad Removal		5.0-8.0
Yellow Bass Removal		6.0-8.0
Bluegill population structure biomanipulation	Multiple treatments may be required	8.0-9.0
Grass Carp reduction	Multiple treatments	7.0-10.0

Gizzard Shad Removal: We suggest a target concentration of 8.0 ppb (µg/L) for all field trials aimed at eliminating Gizzard Shad. This has resulted in 100% success in all field and static pond trials.

Yellow Bass Removal: We suggest a target concentration of 8.0 ppb (µg/L) for all field trials aimed at eliminating Yellow Bass. This has resulted in 100% success in all field and static pond trials.

Bluegill population Structure Manipulation: Managers interested in reducing high-density bluegill populations may consider multiple concentrations of rotenone. However, we suggest initial attempts should be conservative. A treatment of 8.0 ppb (µg/L) will reduce bluegill density by 30-40% and will likely have desirable impacts on Bluegill growth and size structure in the years immediately following treatment. A treatment of 9.0 ppb (µg/L) will have a greater impact but may result in heavier than intended mortality of Bluegill and other species, including Largemouth Bass, the top-level predator in most Iowa systems.

Grass Carp Reduction: Managers interested in affecting macrophyte communities may consider the use of low-concentration rotenone for partial removal of Grass Carp. We recommend a treatment concentration of 8.0 ppb (µg/L), which will result in a reduction in Grass Carp density of 30% - 50%. Applicators may wish to utilize mechanical removal of stressed Grass Carp during selective treatment. Typically Grass Carp exhibit stressed behavior and appear at the surface of the water; however, often these fish recover and survive (Flammang 2014). Project supervisors may wish to investigate the use of extraordinary including the use of bowfishing equipment or potentially the use of shotguns for the removal of these fish. However, project supervisors must determine what requirements are needed for personnel to participate (i.e. gun training) in such an effort and what site specific requirements might exist (i.e. proximity to habitation, etc.). Multiple treatments may be necessary over multiple years to allow for the restoration of the desired aquatic macrophyte community.

Largemouth Bass Preservation: Largemouth Bass are the primary predator in most Iowa lakes. It is recommended that treatment levels not exceed 9.0 ppb (µg/L) to ensure sufficient predator density in post-treatment environments.

Logistics and Budget

Equipment and Application

Typically spray application is not required for selective treatments. Application should be accomplished with a pumped ATV system (Figure 31) that applies chemical from a mixing tank under the surface of the water from a boat. Alternatively, a semi-closed application system as described previously may be utilized for selective treatments, assuming that operators are able to calibrate applications to specific and dilute concentrations applied in an even distribution. The terminal end of any application equipment may be attached directly to the lower unit of the boat motor so the rotenone solution is applied directly in front of the prop wash. Treatments usually are performed in the late fall or spring when water temperatures are <55°F. Applicators are encouraged to take advantage of stable and comfortable weather conditions during this time frame as there is no noticeable benefit for delaying treatments until extreme cold. Applications can be made as long as the lake remains ice-free;

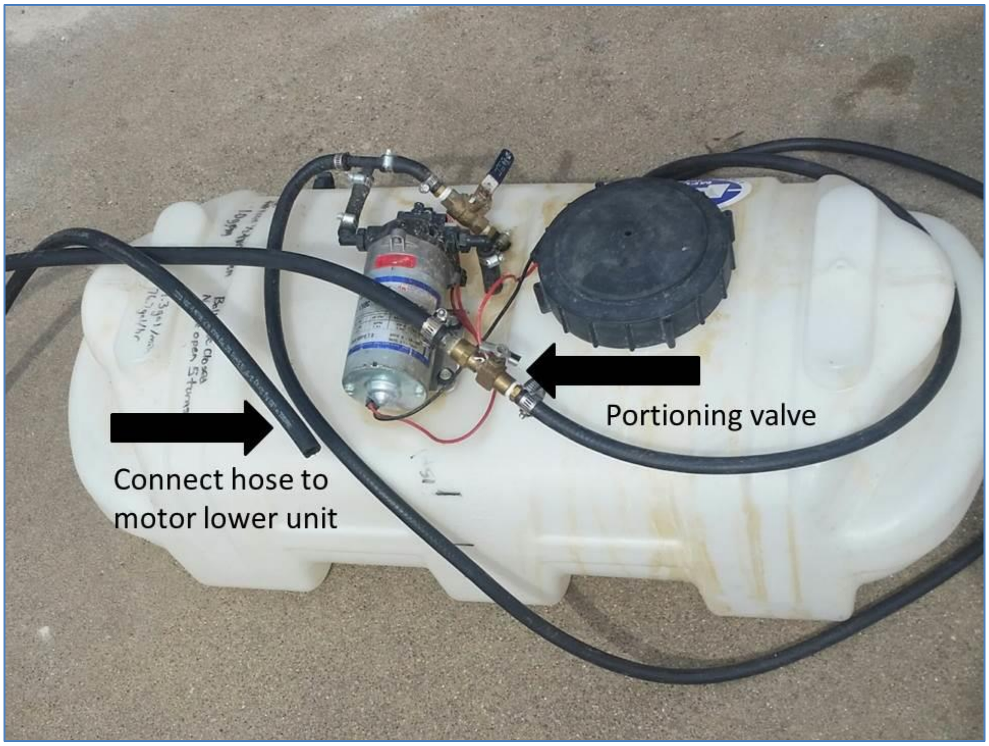

Figure 31. Assembled ATV applicator system.

All sections, either surface or deep, should be applied concurrently. Rotenone is applied over a 4-6 h time period for each section. Pumps should be calibrated to deliver approximately 0.25 to 1.0 gallons of diluted rotenone solution / minute. Total formulation need for each section should be divided by the anticipated number of tank fills to occur over the 4-6 hour application period. Rotenone concentration within the sprayer tank will not exceed 10% and the solution should be well-mixed prior to application. Table 19 presents an example of the parsing of rotenone by zone for a typical selective kill in a relatively small impoundment.

Table 19. Lake volume and rotenone needed for elimination of Gizzard Shad at a treatment rate of 8.0 ppb (µg/L).

Zone	Acre Feet	Rotenone at 5.64% (assayed; ml)	Quantity of rotenone per tank (5 fills in 5 hours; mL)
Zone 1 < 20’	105.58	18,474	3,695
Zone 1 > 20’	29.54	5,169	1,034
Zone 2 < 20’	49.52	8,665	1,733
Zone 2 >20’	8.15	1,426	285
Zone 3 <20’	112.53	19,690	3,938
Zone 3 > 20’	35.70	6,247	1,249
Zone 4 < 20’	154.63	27,057	5,411
Zone 4 > 20’	65.42	11,447	2,289

A boat-mounted or handheld GPS must be used to monitor the application coverage route. Transect spacing should be narrowed as the application progresses. Given sufficient time, applicators may wish to run additional transects perpendicular to the first. Each zone’s surface area will be covered several times and application speed should be sufficient (2-5 mph) to minimize localized “hot spots” that may occur if application speed is too slow. A graphic description of a “typical” GPS track recorded during an application is pictured in Figure 32.

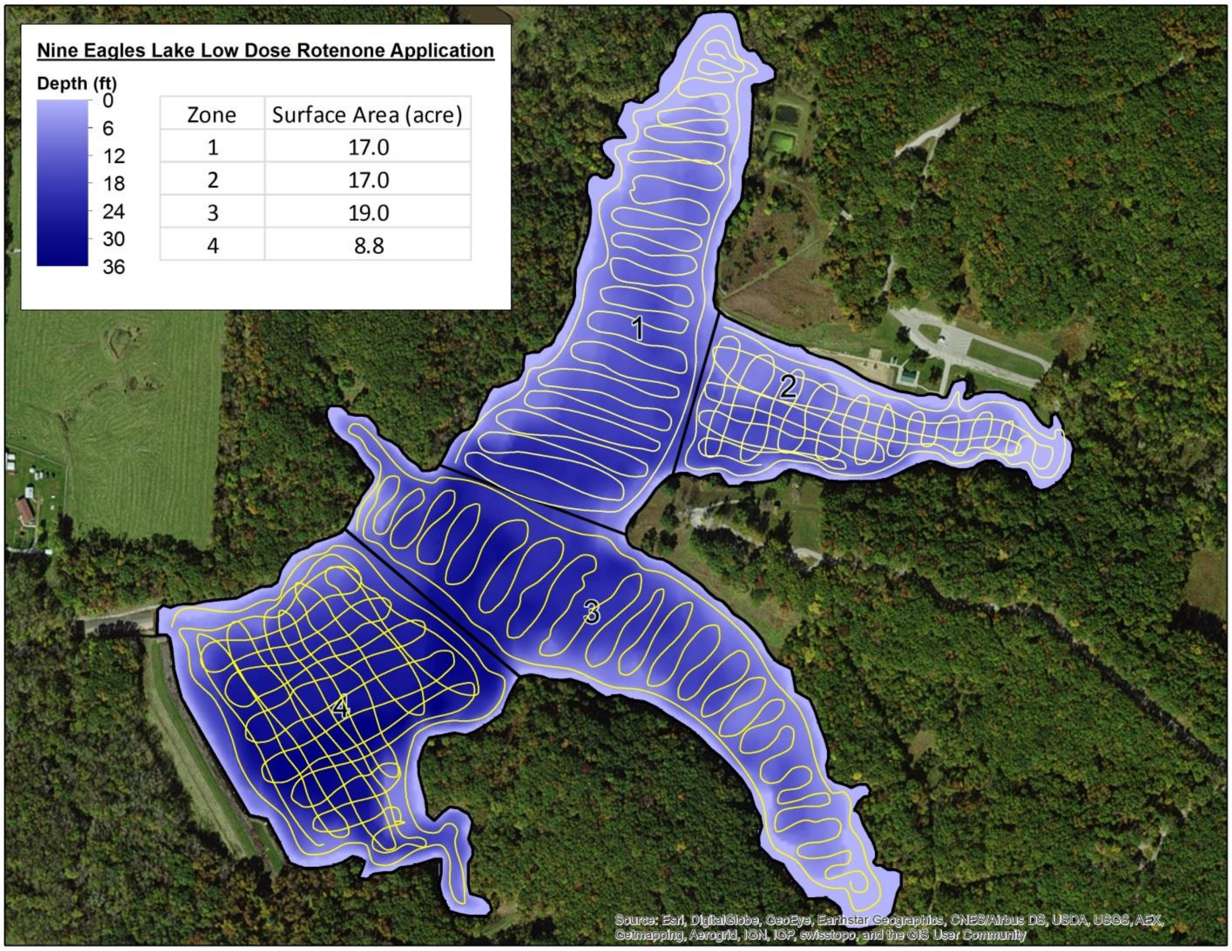

Figure 32. Typical GPS track of application path for low-concentration rotenone.

Deep-water application should be used in lake zones where water depth exceeds 20 feet. This will reduce the likelihood of over-application at the surface. Application will be similar to the method described previously; however, the terminal end of the apparatus will be fitted with a weighted nozzle to diffuse applied material (Figure 28) that trails the boat at the appropriate depth. Deep water applications are typically performed at approximately ½ speed due to the use of the suspended application hose and zone size is usually smaller than surface zones, due to the reduced application speed.

Required Permits

Permits from the Water Quality Section of the DNR are required for application of rotenone to Class C - Drinking Water Supplies. These are waters which are used or can be used as a raw water source of potable water. A complete list of Class C lakes is available (Table 3). Not all Class C waterbodies are active water supplies. Low concentration treatments are never applied above the 40 µg/L threshold for water supply lakes and thus, public consumption of water from treated sources is allowed by EPA and requires no permit. However, it is imperative that Iowa DNR Fisheries actively engage municipal and rural water providers to supply sufficient information to the public to support this application and to alleviate fears from water customers.

Final Planning for Selective Treatments

Placarding Treatment Areas

Low concentration selective treatments performed in Iowa are always below the threshold requiring placarding (90 ppb [µg/L]) post application. Therefore, placards are required during the application; however, may be removed immediately upon completion of the application.

Downstream Deactivation
Chemical deactivation will not be required as concentrations will be insufficient to cause downstream mortality. However, an attempt to contain the treated water and minimize outflow should be made. This can be done through lake drawdown or the placement of sandbags placed in the lake outlet.

Documentation to Have On-Hand
The following documentation is helpful, if not required, to have on-hand during treatment:

- ☐ Chemical product labels
- ☐ Chemical (M)SDSs
- ☐ AFS SOP Manual
- ☐ Emergency contact information and medical care notice
- ☐ Detailed watershed and lake maps

Treatment
On the date of treatment, begin with a team meeting and provide an overview of the treatment plan, crew assignments, and safety guidelines. All placarding should be in place, and access to the treatment area should be limited to assigned staff with appropriate training and PPE. PPE requirements are the same as outlined for complete renovations. The use of the respirator is not required unless spraying. See the rotenone formulation for specific guidance on respirator selection. The project coordinator should remind the team he or she has important documentation relevant to the application such as (M)SDS and product labels and if there are safety concerns, they are the proper contact. Review the (M)SDS, product label, and SOP with applicators, and demonstrate the appropriate use of PPE and application equipment.

Additional Notes
Drinking Water Supply
As per label "Drinking Water Monitoring" under "Directions for Use" and AFS SOP Manual 16.0, applications of rotenone greater than 40ppb (µg/L) rotenone in active water supplies require the user to be advised against consumption of the water. Selective treatments will not exceed 15 ppb (µg/L) and should therefore be safely under this threshold. Cooperation with any water provider is imperative to ensure accurate dissemination of information to the public.

Re-entering the Treatment Area
Duration of PPE requirements for persons re-entering treated water corresponds to duration of placarding requirements (i.e. PPE requirements end when placards are removed, in this case immediately upon completion of the application). Thus, PPE is not required immediately following application.

Water Monitoring
Monitoring should not be necessary following a low-concentration treatment. However, to ensure rotenone levels are at or near the target concentration, you may want to collect a sample for laboratory analysis.

Pesticide Container Disposal
Product labels direct applicators to triple rinse each empty container. Render all plastic and metal containers unusable by puncturing or crushing them. Recycle plastic containers or deposit the empty container in a licensed sanitary landfill. Metal drums are subject to a Code of Federal Regulations (CFR) exemption under the Resource Conservation and Recovery Act (RCRA). Therefore 40 CFR 261.4(a)(13) excludes Scrap Metal from regulation if recycled. Thus, metal drums may be disposed of for scrap metal as appropriate.

Disposal of Dead Fish
Fish quantities will likely be insufficient to require pickup. The effective treatment of grass carp may require fish removal due to their sometimes large size.

Biological Monitoring

Biological monitoring can help not only gauge success in a low-concentration selective renovation, but also assure stakeholders of the project area's resilience to treatment. Long-term sampling of the fish communities for multiple years following project implementation can provide data regarding fishery development and elimination of target fish populations, guiding the public's expectations.

Annual Requisite Training for Rotenone Applicators

While all Iowa DNR Fisheries staff receive annual pesticide applicator training to maintain their pesticide applicator's certification, annual training on the specific use of rotenone is also required. Employees must receive the following information in this training:

- Chemicals in product
- Knowledge of the health effects of rotenone
- Knowledge of how chemical exposure makes you feel
- Routes of exposure
- Proper use of PPE
- First aid and health warnings
- Pesticide safety (explaining meaning of safety statements on label)
- Review of label
- Access to (M)SDS (Where to find it, etc.)
- Directions for applying

Rotenone use training is available by annual review of an informational PowerPoint.

Paper records must be maintained to show internal training has been completed. A completion of training record must be completed annually and sent to Jay Rudacille. This form can be found on the Intranet under "Fisheries."

In addition, appropriate respirator training must be completed at least annually. Respirator fit testing will be completed by all applicators who will utilize spray equipment for rotenone formulation. If fit testing has not been completed within the last year the applicator must be refitted. Each fisheries management district will identify one individual who will conduct fist testing as needed. Each regional supervisor can provide the contact information for this individual. It is the responsibility of the project supervisor (biologist) to ensure all persons who will apply rotenone with spray equipment are properly fit tested. Each of these persons is to contact their respective designated fit tester to arrange this procedure well in advance of the fish renovation. Note: fit testing is not required for support personnel or persons utilizing semi-closed application systems.

Training Checklist

- ☐ Pesticide Applicator Certification, Aquatic Certification (Annual)
- ☐ Rotenone Training Review (Annual)
- ☐ Respirator Training (Annual)
- ☐ Respirator Fit Testing (For persons using spray equipment, to be completed prior to the application, unless fit testing was completed within the last year. It is the responsibility of the project supervisor (biologist) to ensure all spray applicators are properly fit tested)
- ☐ Respirator Medical Evaluation (One time review of medical status, no additional evaluations required unless any of the following apply)
    - employee reports medical signs or symptoms related to ability to use respirator
    - physician or other licensed health care professional (PLHCP), program administrator, or supervisor recommends reevaluation
    - Information from the respirator program, including observations made during fit testing and program evaluation, indicates a need
    - Change occurs in workplace conditions that may substantially increase the physiological burden on an employee

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Appendix A

DANGER/PELIGRO

DO NOT ENTER WATER/NO ENTRE AGUA:

Pesticide Application / Rotenone

Fish Eradication

Start Date _________Start time _______

End Date_ _________End time ________

Recreational access (e.g., wading, swimming, boating, fishing, etc.) within the treatment area is prohibited while rotenone is being applied.

Do not swim or wade in treated water while placard is displayed.

Do not consume dead fish from treated water.

Iowa Department of Natural Resources
Insert Address
Insert Phone Number

Appendix B

Planning Timeline