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MANAGEMENT BRIEF

A Comparison between Conventional Boat Electrofishing and the Electrified Dozer Trawl for Capturing Silver Carp in Tributaries of the Missouri River, Missouri

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Abstract
Silver Carp *Hypophthalmichthys molitrix* are elusive fish that can be difficult to capture with conventional management tools. New tools must be developed to help increase the capture of Silver Carp, thereby improving the understanding and management of the species. An electrified dozer trawl was developed in an attempt to increase the capture of Silver Carp while reducing the amount of sampling effort needed to successfully assess a population and inform management actions. We compared Silver Carp catch rates, sample run time, and Silver Carp length frequency distributions from the electrified dozer trawl with those from conventional boat electrofishing. Silver Carp capture was greater and sample time was shorter for the electrified dozer trawl compared to conventional boat electrofishing. Length frequency distributions were similar between gears. The electrified dozer trawl can shorten sample run times and potentially improve Silver Carp capture, thus facilitating management. Use of the electrified dozer trawl should be expanded beyond Missouri River tributaries to further understand the gear's potential for sampling Silver Carp in a diverse array of environments.

Proper management actions for a fishery require agencies to accurately and successfully capture targeted species. This can be difficult when targeting highly elusive species, such as the Silver Carp *Hypophthalmichthys molitrix* (Conover et al. 2007; Klumb 2007; Hayer et al. 2014). Silver Carp pose a major threat to the native biota found in river basins (Kolar et al. 2007; Phelps et al. 2017) and also threaten the biodiversity of the Laurentian Great Lakes. The ability to capture invasive species like the Silver Carp is essential for understanding their distribution, life history characteristics, biology, and population dynamics (i.e., recruitment, growth, and mortality) and ultimately for effectively monitoring, managing, and eradicating these fish.

Conventional boat electrofishing has proven effective at capturing multiple fish species in a variety of habitats (Reynolds and Kolz 2012); however, it has been difficult to capture Silver Carp due to their elusive behavior (Bouska et al. 2017). Environmental factors, like water clarity, can have a negative influence on the ability of netters to capture fish (Pygott et al. 1990; Zalewski and Cowx 1990; Hayes et al. 1996; Bayley and Austen 2002; Reynolds and Kolz 2012; Lyon et al. 2014). Furthermore, conventional boat electrofishing has a bias toward large-bodied fish and may overrepresent larger fish while underrepresenting smaller-sized fish (Chick et al. 1999; Dolan and Miranda 2003; Ruetz et al. 2007). The combination of a low success rate due to low visibility in water, a bias toward large fish, and the elusiveness of Silver Carp can lead to high variability in abundance estimates and misrepresentation of size structure. These inaccuracies make it difficult to understand current Silver Carp population assessments and could lead to the mismanagement of the population. Nevertheless, monitoring efforts for Silver Carp typically use conventional boat electrofishing methods. Improving catch rates over a large size range with an effective method would provide crucial information to managers for population status and trend assessments.

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Recent interest has developed in the modification of push trawls for Silver Carp capture due to their ability to capture a large size range of fish over diverse habitats in flowing systems (Hayes et al. 1996; Herzog et al. 2005; Reeves 2006; Drews et al. 2016). Trawls are active sampling techniques that can sample a diverse array of fish species and lengths by adjusting the mesh size and targeting benthic or pelagic habitats. They have proven to be effective at capturing fish in a variety of environments, including rivers (Herzog et al. 2005; Gosch et al. 2015) and lakes (Hayes et al. 1996; Allen et al. 1999) and in shallow (Herke 1969; Rogers 1985; Herzog et al. 2005; Sechler et al. 2012) and pelagic (Michaletz et al. 1995) locations. Freedman et al. (2009) electrified a Missouri trawl (Herzog et al. 2005) to increase the total numbers of fish, species, and large-bodied fish captured relative to a non-electrified Missouri trawl. Additionally, the fixed net of a trawl limits the biases associated with the clarity and turbidity of a water body. An electrified push trawl could provide an opportunity to exploit the advantages of both conventional boat electrofishing and push trawls and to limit the bias associated with each gear independently. This combination of gears would allow for accurate assessments of many fish species, including the Silver Carp, in both lentic and lotic systems, which previously has been difficult to achieve.

Our goal was to determine whether Silver Carp catch rates and sampling time could be improved through sampling with an electrified dozer trawl compared to conventional boat electrofishing in several tributaries of the Missouri River, Missouri. These comparisons were made for catch rates (fish/200 m), sample run time (h), and size structure (length frequencies). Identifying a gear that can effectively sample Silver Carp will allow managers to assess the relative abundance and size structure of a population in a timely manner to make appropriate management decisions.

METHODS

Gears.— The electrified dozer trawl is a conical net attached to a rigid frame that is pushed in front of the boat (Figure 1). The attached frame is 2.13 m wide × 0.91 m high. The net has 38-mm body mesh at the opening, decreasing to 6-mm mesh at the cod end. The 1.83-m-long net extends under the boat. A modified boom extends in front of the dozer frame with three cable anode droppers. Electrofishing settings were continuous through a run at 30 Hz and a 15% duty cycle on a 42-A Midwest Lakes Electrofishing System (MLES) Infinity box. Amperes were adjusted based on site water ambient conductivity and Silver Carp behavioral response using guidance from Miranda (2009). The speed of the boat was standardized to 4.5 km/h (3.0 mi/h). The trawl frame was fully submerged in the water to sample the top 0.91 m of the water column.

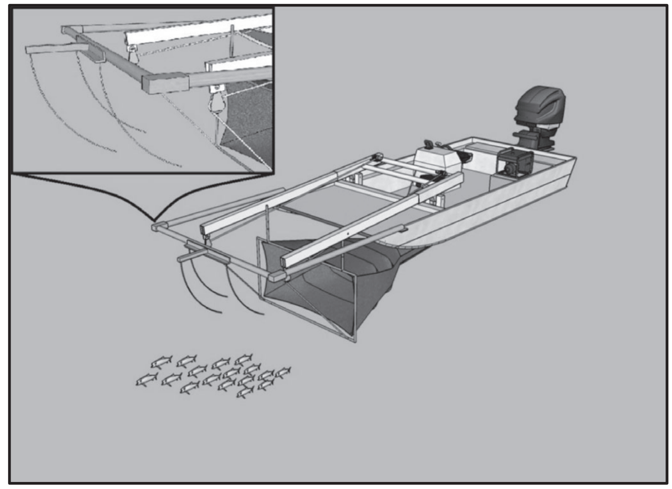

FIGURE 1. Schematic of an electrified dozer trawl design.

The conventional boat electrofishing setup consisted of two spider arrays with six anode droppers, each attached to a boom extending approximately 1.5 m in front of the boat (Miranda 2005). Two crew members on the bow utilized a 406- × 610-mm dip net with 6-mm mesh to capture fish. Electrofishing settings were continuous through a run at 30 Hz and a 15% duty cycle on a 42-A MLES Infinity box. Like the dozer trawl, amperes for the boat electrofisher were adjusted based on site water ambient conductivity and Silver Carp behavioral response using guidance from Miranda (2009). The speed of the boat was targeted for around 1.6 km/h (1.0 mi/h) or adjusted to give dipnetters the greatest potential for success.

Sampling design.— Eight tributaries of the Missouri River were each sampled one time between May and October 2016 (Figure 2). Current velocities in tributaries were low (<0.1 m/s), with depths ranging from 0.61 to 31.50 m and ambient conductivity ranging from 195 to 865 μS/cm. Initial sampling in each tributary commenced near the tributary mouth and progressed upstream.

Each sampling run was 200 m in distance, and time (s) was recorded. In small tributaries, we started sampling at the confluence, moving upstream along a single shoreline using one of the two sampling gears. The next 200-m sampling run was completed with the other sampling gear, and we continued to alternate gears among sampling runs. We allowed for 200-m buffers between sampling runs. This process was then completed on the opposite shoreline, starting with whichever gear was not used on the first sampling run along the first shoreline. After sampling of the confluence was completed, these gears alternated sampling runs upstream to minimize the potential effect of disturbance. Larger tributaries (i.e., wetted width >25 m)

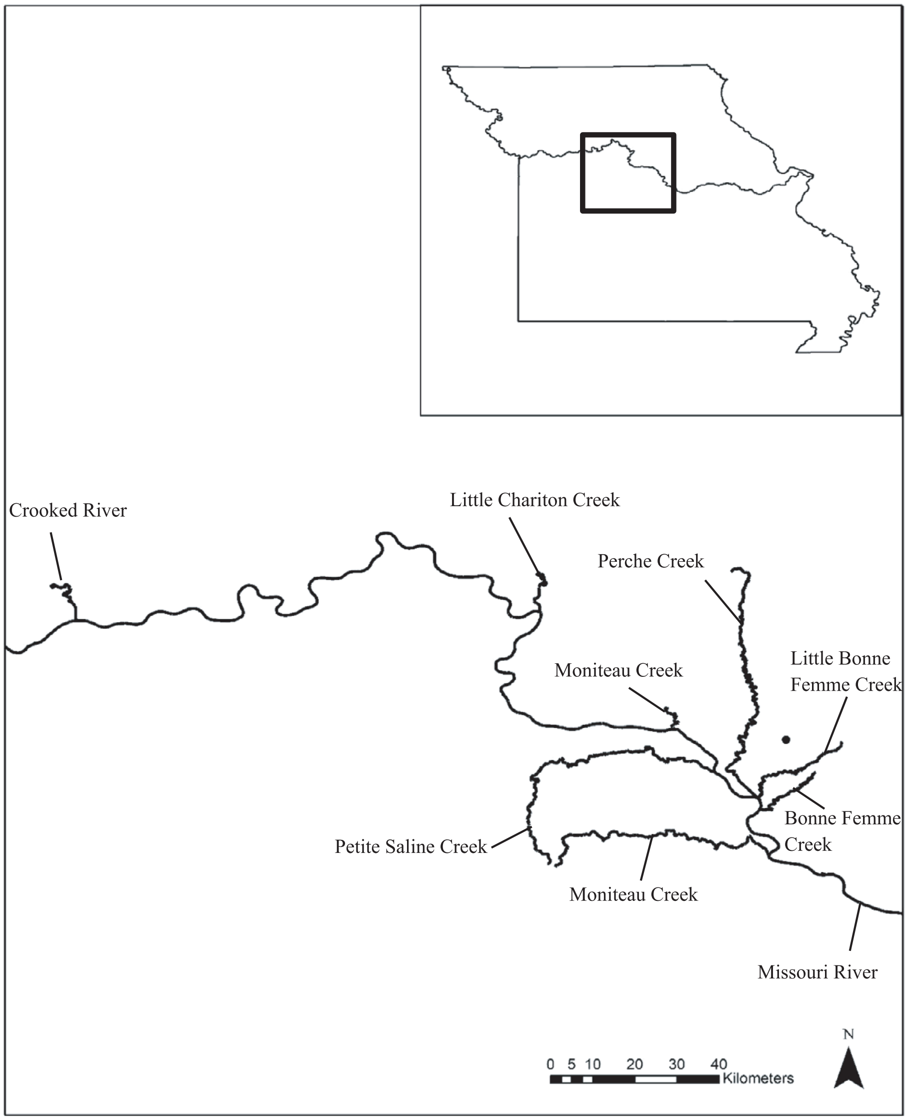

FIGURE 2. Missouri River, Missouri, tributaries that were sampled for Silver Carp during May–October 2016. The dot indicates where the city of Columbia is located.

were sampled similarly except at the confluence. The confluence for larger tributaries was sampled by both gears simultaneously on opposite shorelines. Tributaries were only sampled once. Habitat parameters (i.e., open water, near shore, and combined) were randomly assigned for each sample run. For the purposes of this study, open water was defined as greater than 10 m from the shoreline, and near shore was defined as less than 10 m from the shoreline. A combined habitat was assigned to transects that crossed between both open-water and nearshore habitats. Open-water sample runs were directed upstream and parallel to the bank in a straight transect. Nearshore sample runs were directed upstream along the contour of the bank. Four sample runs for each gear were targeted in each tributary, and more sample runs were added when time allowed.

All captured fish were identified to species and enumerated. The TLs (mm) of all Silver Carp were measured. Individual fish that were not identified in the field were preserved in formalin and taken back to the laboratory for identification. In the event that a large sample was collected, a random subsample was taken and extrapolated to represent the sample.

Data analysis.— All analyses were performed in R (R Development Core Team 2013). Silver Carp catch rates (fish/200 m) and size distributions were evaluated for both gears. We used the “lmer” function in the lme4 package (Bates et al. 2015) to run a linear mixed-effects model to determine differences in catch rate and sample run time for the fixed effects (gear and habitat) and their interaction. Random effects were tributary and month. Differences in length frequency distributions between gears within tributaries and habitats sampled were determined using nonparametric Kolmogorov–Smirnov tests with a Bonferroni correction. An ANOVA with a post hoc Tukey's multiple comparison test was conducted on all significant fixed effects and interactions. Statistical significance for all analyses was declared at $\alpha = 0.05$.

RESULTS

Overall, 101 electrified dozer trawl sample runs and 98 conventional boat electrofishing sample runs were conducted. Conventional boat electrofishing captured 905 Silver Carp, while the electrified dozer trawl captured 1,560 Silver Carp. Additionally, another 5,898 and 965 larval bigheaded carp *Hypophthalmichthys* spp. that were not identified to species were captured by the electrified dozer trawl and conventional boat electrofishing, respectively. Larval fish that were only identified to genus were not included in further analysis. Quantile–quantile plots for catch rate and sample time were normally distributed.

Silver Carp catch rates between the electrified dozer trawl and conventional boat electrofishing differed in only one of the seven tributaries. A linear mixed-effects model identified a significant difference in Silver Carp catch rates between gears (mixed model: $F = 9.33$, df = 1, $P < 0.01$; Table 1). Silver Carp catch rates obtained when using the electrified dozer trawl were greater than those obtained from conventional boat electrofishing (ANOVA: $F = 8.89$, df = 1, $P < 0.01$; Figure 3).

A linear mixed-effects model for sample run time found that the interaction between gear and habitat was significant (mixed model: $F = 29.59$, df = 2, $P < 0.01$; Table 1). Electrified dozer trawl sample run time was nearly half as long as the run time with conventional boat electrofishing for combined habitat (ANOVA: $F = 240.70$, df = 1, $P < 0.01$), littoral habitat (ANOVA: $F = 295.70$, df = 1, $P < 0.01$), and pelagic habitat (ANOVA: $F = 202.30$, df = 1, $P < 0.01$; Figure 4).

TABLE 1. Linear mixed-effects model for Silver Carp catch rate and sample run time in Missouri River tributaries during May–October 2016. Both main effects (gear and habitat) and interactions were tested. The random effects were month and tributary.

Effect	*F*	df	*P*
Silver Carp catch rate			
Gear	9.33	1	<0.01
Habitat	2.08	2	0.13
Gear × Habitat	2.06	2	0.13
Sample run time			
Gear	434.70	1	<0.01
Habitat	74.48	2	<0.01
Gear × Habitat	29.60	2	<0.01

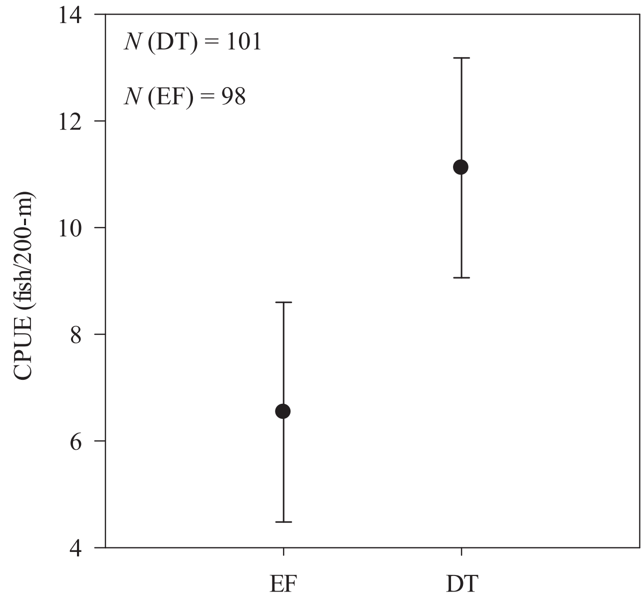

FIGURE 3. Total number of sample runs (N) and mean (±SE) Silver Carp CPUE (fish/200 m; circles) for conventional boat electrofishing (EF) and the electrified dozer trawl (DT) in Missouri River tributaries during May–October 2016 (sample run distance = 200 m). Significant differences were found between gears (ANOVA: $F = 8.89$, df = 1, $P < 0.01$).

Silver Carp ranged from 11 to 820 mm TL for conventional boat electrofishing and from 10 to 864 mm TL for the electrified dozer trawl. The mean length (±SE) of Silver Carp captured via conventional boat electrofishing was 353.07 ± 8.19 mm, and the mean TL for those captured by the electrified dozer trawl was 393.46 ± 6.91 mm. Data were pooled for each gear because no differences in length frequency were found in all comparisons of tributaries and habitats (Kolmogorov–Smirnov test: $P > 0.05$). Once data were combined, no differences were found in Silver Carp length frequency distributions between gears (Kolmogorov–Smirnov test: $D = 0.11$, $P = 0.50$; Figure 5).

DISCUSSION

Our results suggest that both conventional boat electrofishing and the electrified dozer trawl have the capability to capture Silver Carp in Missouri River tributaries. The electrified dozer trawl was capable of capturing a greater number of Silver Carp in less sample run time than conventional boat electrofishing. Several factors could account for these differences between the gears. Conventional boat electrofishing relies on the ability of the dipnetters to successfully see and net the fish, but

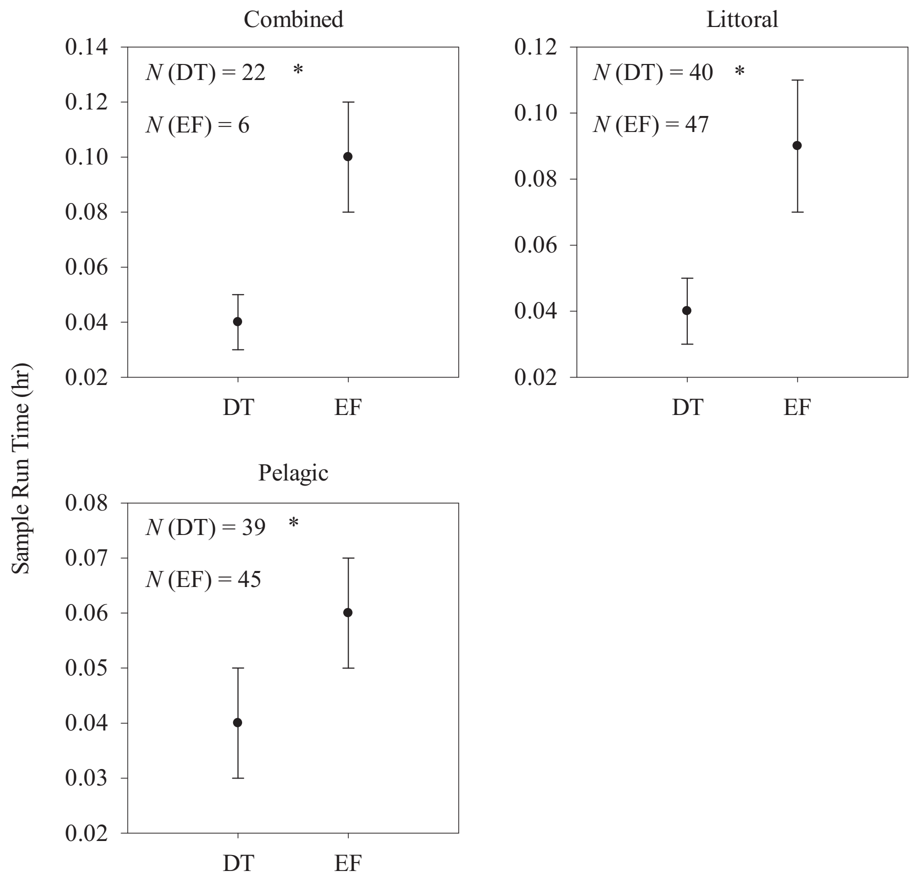

FIGURE 4. Total number of sample runs (*N*) and mean (±SE) Silver Carp sample run time (h; circles) in all habitats (littoral, pelagic, and combined) sampled by the electrified dozer trawl (DT) and conventional boat electrofishing (EF) in Missouri River tributaries during May–October 2016. Differences between gears and habitats are indicated by asterisks (ANOVA: $P < 0.05$).

speed and water clarity limit the dipnetters' ability to accomplish these tasks (Bayley and Austen 2002; Reynolds and Kolz 2012; Lyon et al. 2014). The speeds used in conventional boat electrofishing tend to be slower to give dipnetters a higher probability of netting fish. When dipnetters are not needed, such as with the use of the electrified dozer trawl, it allows the boat speed to be increased, which could limit Silver Carp elusiveness. Although water clarity was not measured in this study, netting the fish during conventional boat electrofishing may have been more difficult when water clarity was low. The electrified dozer trawl does not rely on water clarity to function; therefore, it is not influenced by water clarity as much as conventional boat electrofishing. Finally, the electrified dozer trawl's frame is nearly eight times larger than the two dip nets. The ability of the electrified dozer trawl to safely use a larger net would give it a larger area for capturing Silver Carp.

Six times more larvae of bigheaded carp *Hypophthalmichthys* spp. were captured with the electrified dozer trawl compared to conventional boat electrofishing. The capture of small individuals belonging to *Hypophthalmichthys* spp. was a central objective of the 2017 Asian Carp Monitoring and Response Plan (ACRCC 2017) for the Illinois River. Conventional boat electrofishing can be biased toward large fish (Chick et al. 1999; Dolan and Miranda 2003; Ruetz et al. 2007), making it difficult to capture these smaller *Hypophthalmichthys* individuals. Some of this bias could be associated with the dipnetters unintentionally targeting larger fish or with human error. The electrified dozer trawl does not require dipnetters, thereby limiting any bias associated with human error. The electrified dozer trawl could serve as a tool to help achieve the objective of the 2017 Asian Carp Monitoring and Response Plan (ACRCC 2017) in capturing and better understanding smaller bigheaded carp.

The ability of the electrified dozer trawl to sample a large array of habitats within lotic systems demonstrates its versatility. The electrified dozer trawl was used near shore and in the open water but did not incur a decrease in Silver Carp catch rate. It should be noted that the ability of the electrified dozer trawl to effectively sample within larger systems, like the Missouri River, is likely different from its sampling ability in these smaller tributaries.

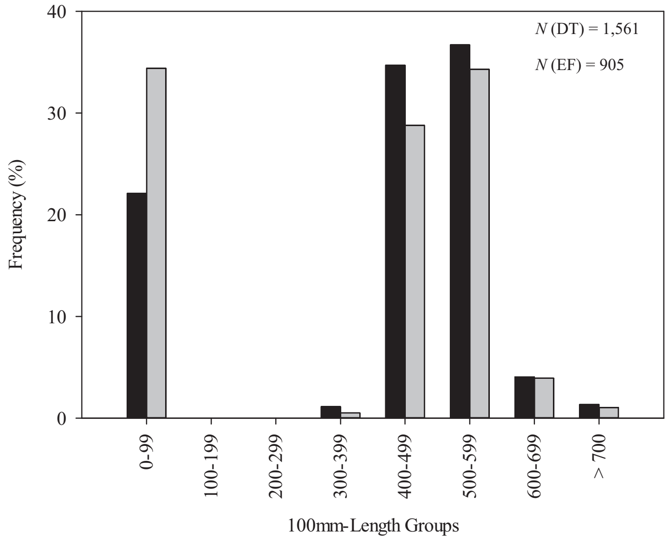

FIGURE 5. Length frequencies (100-mm TL groups) and total catch (N) of Silver Carp obtained with the electrified dozer trawl (DT; black bars) and conventional boat electrofishing (EF; gray bars) in Missouri River tributaries during May–October 2016. No significant differences were found between the two gears (Kolmogorov–Smirnov test: $D = 0.11$, $P = 0.50$).

Future sampling evaluation within larger systems and diverse habitats is needed; however, within this study, the potential for the electrified dozer trawl to sample a variety of habitats was indicated. This is important due to the relative unknowns that surround Silver Carp habitat use at different ages and different sizes (DeGrandchamp et al. 2008; Calkins et al. 2012).

Management of a species through time requires confident, consistent sampling in a cost-effective way. Our results suggest that both conventional boat electrofishing and the electrified dozer trawl are capable of capturing Silver Carp over a large size range in Missouri River tributaries. The size overlap between these gears could provide opportunities for the two gears to be used interchangeably in a Silver Carp management plan. Given that many management plans for Silver Carp have historically used conventional boat electrofishing (ACRCC 2017), it would be crucial to maintain these long-term data sets. It is possible that data collected by the electrified dozer trawl could be applied or compared to historical data collected via conventional boat electrofishing, leaving the integrity of the long-term data sets intact.

Although not assessed in this paper, the ability of the electrified dozer trawl to capture multiple fish species could provide another tool for assessing fish communities or other fish species. Nearshore habitats can be sampled through its adaptable frame design while also allowing users to take advantage of flowing-water areas, which many times are avoided due to the inability to sample effectively (Dauble and Gray 1980; Grossman and Ratajczak 1998). Additionally, turbid waters associated with many streams and rivers can restrict the ability of conventional boat electrofishing (Bayley and Austen 2002; Reynolds and Kolz 2012; Lyon et al. 2014). The replacement of dipnetting with a trawl net eliminates the bias associated with limited clarity and allows for consistent sampling in a diverse array of turbid systems. This versatility suggests that the electrified dozer trawl has the potential for use as an additional tool in fish community assessments or in sampling other fish species found within an array of habitats.

Limitations exist with all gears, and those limitations should be recognized so that appropriate management decisions can be made. The electrified dozer trawl lacks the ability to specifically target certain species; therefore, bycatch will be associated with sampling efforts when using this gear. Structure found within the water can be problematic if not appropriately navigated. The frame's design allows robustness to limit risk, but obstructions to the gear can slow sampling efforts. Efforts to navigate these structures should be emphasized to minimize the amount of sampling time lost due to repairs.

Invasive species like the Silver Carp constitute a growing threat throughout the United States, and new technologies to manage and control these species will need to be developed for fisheries managers. The goal of this study was to determine whether the electrified dozer trawl could be a useful tool for capturing Silver Carp based on catch rates and sample run time. Currently, the conventional methods used to monitor and manage Silver Carp could be improved with the addition of the electrified dozer trawl. The increased catch rates and diverse range of habitats that can be sampled with an electrified dozer trawl give managers an effective tool for capturing Silver Carp. The electrified dozer trawl would allow agencies to sample Silver Carp populations in a reduced amount of time relative to conventional boat electrofishing without increasing sampling bias; use of this gear would help agencies to maintain confidence in population assessments and thus make appropriate management decisions.

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