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MANAGEMENT BRIEF

An Evaluation of Attractants to Increase Catch Rates and Deplete Age-0 Common Carp in Shallow South Dakota Lakes

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Abstract
Common Carp *Cyprinus carpio* is a highly invasive species that can alter shallow aquatic ecosystems from clear to turbid water. Although mechanical removals are commonly used to control abundance of adult Common Carp, harvest models suggest that removing age-0 Common Carp also reduces recruitment. Attractants often improve fisheries sampling and commercial harvest and may provide a tool to increase catch rates of age-0 Common Carp. However, techniques and attractants that target age-0 Common Carp have not been evaluated. Our objective was to compare catch rates and size distribution of age-0 Common Carp captured in cloverleaf traps with and without bait (fish meal or bloodworms) or light attractants. To assess whether trapping decreased the abundance of age-0 Common Carp, we also evaluated (1) the total number and proportion of age-0 Common Carp removed from the populations and (2) whether catch rates declined temporally as a result. Traps were fished in emergent vegetation for 5–6 nights in two shallow lakes in South Dakota during August 2010. Catch rates of age-0 Common Carp did not differ among attractants and the control. However, catch rates declined through time, and 3,102 age-0 Common Carp were removed from the two lakes. Depletion population estimates indicated at least 83% of age-0 Common Carp from Brant Lake and 21% (lower limits, 95% confidence intervals) of age-0 Common Carp from Whitewood Lake were removed, suggesting trapping may be successful at depleting abundance. Lighted traps caught larger age-0 Common Carp than did control traps or traps baited with bloodworms or fish meal. These results suggest that the attractants evaluated here do not increase catch rates of age-0 Common Carp. Nonetheless, cloverleaf traps may reduce abundance of age-0 Common Carp and have value in integrated management plans for this species.

The establishment and spread of invasive fishes can negatively affect food web dynamics, biodiversity, and water quality in freshwater ecosystems (Allan and Flecker 1993; Zambrano et al. 2001; Irons et al. 2007). One of the world's most successful freshwater invaders is the Common Carp *Cyprinus carpio*. Common Carp were introduced during the mid-1800s from the Ponto-Caspian region (Balon 1995) to North America for recreational and commercial purposes (Panek 1987; Kolar et al. 2010). Early maturation, fast growth, high reproductive potential, and ecological plasticity (Sivakumaran et al. 2003; Stecyk and Farrell 2007) are key characteristics that have allowed Common Carp populations to spread throughout the world and obtain extremely high densities in many systems (Harris and Gehrke 1997; Britton et al. 2007; Kolar et al. 2010). Establishment of Common Carp in lake ecosystems can result in an array of density-dependent negative effects that shift ecosystems from clear to turbid water (Parkos et al. 2003; Weber and Brown 2009). When Common Carp densities exceed a critical threshold (~100–250 kg/ha), populations can directly reduce macroinvertebrates, increase sediment suspension, and amplify nutrient availability through benthic foraging, resulting in bottom-up ecosystem effects (Barton et al. 2000; Parkos et al. 2003). Benthic foraging can also indirectly increase algal blooms and reduce aquatic macrophytes and the abundance of native fishes in shallow lake ecosystems (Schrage and Downing 2004; Miller and Crowl 2006; Weber and Brown 2011).

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Fisheries biologists are often interested in minimizing ecosystem effects of Common Carp by controlling abundance. Treating water bodies with piscicides can be an effective method of eradicating Common Carp in some situations (Marking 1992; Schrage and Downing 2004). However, chemical applications have negative effects on nontarget species, are cost-prohibitive in larger systems, and are typically used as a last resort for controlling undesirable fish species (Marking 1992; Kolar et al. 2010). Alternatively, mechanical removal may provide a species-selective approach and may be better suited for many management situations. Commercial harvest with large-mesh seines is a common technique for reducing abundance of adult Common Carp (e.g., Fritz 1987; Bajer et al. 2011; Colvin et al. 2012). However, seining is size-selective toward adult fish and consequently allows small Common Carp to persist. Integrated pest management strategies aim to use several techniques to target multiple life stages of a species (Brown and Gilligan 2014). Population models have shown that removals of age-0 Common Carp in concordance with adult removals (i.e., integrated Common Carp management) will likely provide faster and longer lasting results in decreasing overall abundance of Common Carp (Brown and Walker 2004; Weber et al. 2011; Colvin et al. 2012). Additional control options would be beneficial for managers, yet techniques to capture and remove age-0 Common Carp have not been evaluated.

Fisheries biologists have used an assortment of olfactory baits and optical attractants to increase catch rates of various species. When baiting nets is successful, the selected bait attracts additional fish that are unlikely to randomly encounter the trap and extends the time spent by individual fish inside the trap, resulting in increased catch rates (Flammang and Schultz 2007). For example, baiting hoop nets with cheese and soybean cakes increases catch rates of Channel Catfish *Ictalurus punctatus* (Gerhardt and Hubert 1989; Flammang and Schultz 2007) and adult Common Carp (Pierce et al. 1981). Common Carp possess exceptional olfactory sensitivity (Irvine and Sorensen 1993) and can quickly learn and recall the location of a food reward (Bajer et al. 2010). Many olfactory attractants have been used to bait adult Common Carp for recreational angling, including fish meal boilies (i.e., boiled paste fishing baits), sweet corn, bread crumbs, and various other baits (Arlinghaus and Mehner 2003). Small Common Carp feed primarily on detritus, zooplankton, and small chironomids (García-Berthou 2001; Howell et al. 2014), suggesting they may be attracted by these natural prey items. Common Carp have also been shown to readily consume fish meal pellets in aquaculture settings (Lam and Shephard 1988), which may also provide an economic and viable attractant in the wild. Beyond olfactory attractants, larval and juvenile fish of numerous species are positively phototaxic (Bulkowski and Meade 1983; Kelso and Rutherford 1996), and lighted traps have a positive effect on catch rates of Cyprinids in small streams (Floyd et al. 1984) and Percids in wetlands (Mangan et al. 2005).

Information regarding gears to capture age-0 Common Carp for mechanical removal is currently lacking but such details would benefit integrated pest management plans. The objectives of this study were to (1) compare catch rates and sizes of age-0 Common Carp captured among cloverleaf traps baited with olfactory (fish meal or bloodworms) and visual (light) attractants and (2) determine the feasibility of targeting and depleting (mechanical removal) age-0 Common Carp in shallow lakes by evaluating temporal variation in catch rates and the proportion of populations harvested. First, we hypothesized that olfactory and visual attractants would result in increased catch rates of age-0 Common Carp. Second, we hypothesized that the use of multiple consecutive trap net nights would deplete the abundance of age-0 Common Carp.

METHODS

This study took place in Brant and Whitewood lakes in eastern South Dakota, USA. Both are shallow lakes (Brant Lake: 420 ha, 3 m mean depth; Whitewood Lake: 1,893 ha, 1.3 m mean depth) with extensive backwater habitat and emergent and submerged vegetation (Figure 1). In addition to Common Carp, other fishes in these lakes are Walleye *Sander vitreus*, Yellow Perch *Perca flavescens*, Bluegill *Lepomis macrochirus*, Northern Pike *Esox lucius*, Black Crappie *Pomoxis nigromaculatus*, Green Sunfish *Lepomis cyanellus*, Black Bullhead *Ameiurus melas*, Bigmouth Buffalo *Ictiobus cyprinellus*, White Sucker *Catostomus commersonii*, and Fathead Minnow *Pimephales promelas*. Submerged and emergent vegetation in both lakes includes sago pondweed *Potamageton pectinatus*, cattails *Typha* spp., and bulrush *Scirpus* spp. Adult Common Carp make predictable movements into shallow, backwater embayments with vegetation for spawning (Bajer and Sorensen 2010; Taylor et al. 2012; Hennen and Brown 2014). In these embayments, abundance of age-0 Common Carp is higher within emergent vegetation (Weber and Brown 2012); thus, sampling targeted emergent vegetation in backwater habitats for this evaluation. Cloverleaf traps were selected for the study because of their simplicity, cost effectiveness, and minimal effort needed to set and retrieve the traps (20 s each; Mangan et al. 2005). Traps in this study were deployed and retrieved in less than 30 s. Additionally, these gears have successfully captured age-0 Common Carp in dense emergent vegetation (Weber and Brown 2012), where other gear (e.g., seines, mini-fyke nets) are difficult to use successfully.

Backwater habitats in each lake (Brant Lake: 52.5 ha, Whitewood Lake: 44.0 ha; Figure 1) were evenly split into four zones. Each night, four quartets of traps (quartet = four traps, one trap per attractant treatment and one empty control; 16 total traps) were randomly placed more than 25 m apart

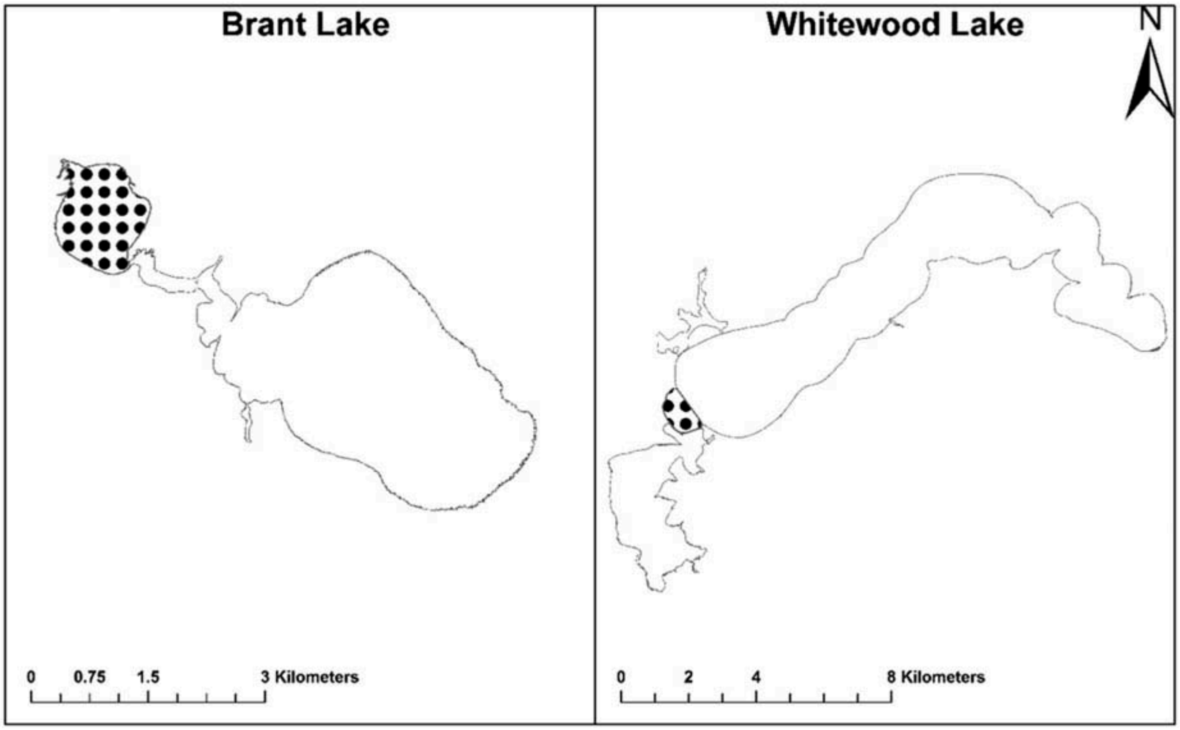

FIGURE 1. Brant Lake (left; 420 ha) and Whitewood Lake (right; 1,893 ha) in southeastern South Dakota. Age-0 Common Carp sampling areas are designated with dots (Brant, 53 ha; Whitewood, 44 ha).

within each zone of emergent vegetation in each lake. Traps were set around dusk, fished overnight, and retrieved the following morning after an approximate 12-h soak time. Cloverleaf traps were three-lobed (41 cm high, 50 cm diameter) and constructed of galvanized 6.4-mm-bar wire mesh with 12.7-mm-wide openings between lobes to allow for the entrance of juvenile fishes (Figure 2).

Results from use of three attractants were compared with that of a control trap having no attractant to assess the abilities of each approach to increase catch rates of age-0 Common Carp: Menhaden *Brevoortia tyrannus* fish meal (Omega Protein, Houston, Texas), bloodworms (frozen bloodworms, *Chironomus* spp.; Brine Shrimp Direct, Ogden, Utah), and cyalume glowsticks (15 cm, 4 lm, green Omniglow snaplight used for 12 h). One glowstick, or 100 g of either fish meal or bloodworms in mesh bags, was randomly selected and suspended in the center of a cloverleaf trap (Figure 2). Cloverleaf traps were fished in Brant Lake for 6 nights and in Whitewood Lake for 5 nights in August 2010. Captured individuals were identified to species, and age-0 Common Carp were measured for total length (mm) and then killed (250 mg/L MS-222). Age-1 Common Carp average 250 mm in eastern South Dakota (Weber et al. 2010), and age-0 Common Carp collected in fall are nearly exclusively shorter than 150 mm (Weber and Brown 2013). All Common Carp captured in this study were shorter than 130 mm and therefore were considered to be age-0.

Catch per unit effort (CPUE) was expressed as number of individuals captured per net night. Normality and homoscedasticity of age-0 Common Carp catch rate values and lengths were assessed a priori, using normal quantile and residual

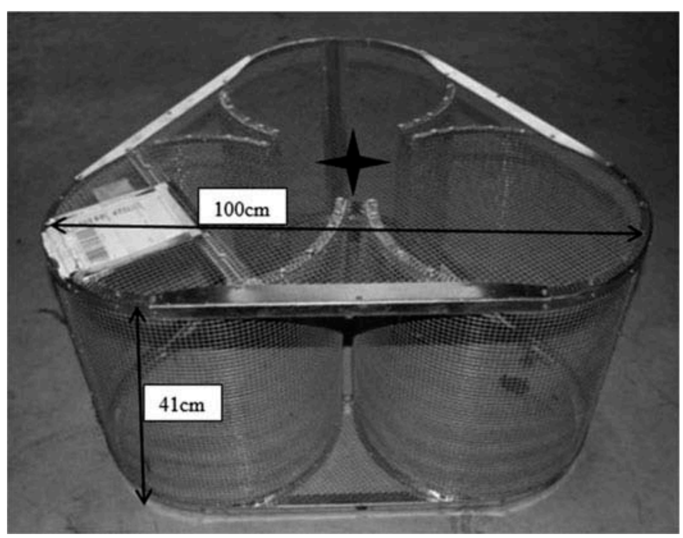

FIGURE 2. Cloverleaf trap used to sample age-0 Common Carp. A single glowstick or mesh bag with bait (bloodworms or fish meal) was hung from the top-center of the trap (star).

plots. Catch rates were ln(x + 1) transformed prior to analysis to normalize the data. Repeated measures analysis of variance (ANOVA) was used to evaluate differences in catch rates of age-0 Common Carp among attractants and through time, blocked by lake to remove between-system differences. The Leslie regression method (Leslie and Davis 1939) was used to calculate depletion population estimates for both lakes by plotting CPUE against cumulative catch. This method is commonly used to obtain depletion population estimates (Peterson et al. 1980; Hayes et al. 2007) and has been successfully applied to depletion estimates using minnow traps (He and Lodge 1990). Kolmogorov–Smirnov two-sample tests (K–S test) were completed to assess differences in length-frequency distributions of age-0 Common Carp captured among attractant treatments within each lake. Significance was determined at α = 0.05 for all analyses.

RESULTS

A total of 3,102 age-0 Common Carp were captured: 822 were removed from Brant Lake over 96 net nights and 2,280 were removed from Whitewood Lake over 80 net nights. Catch rates of age-0 Common Carp did not statistically differ among attractants (repeated measures ANOVA; $F_{9,164}$ = 2.19, P = 0.08; Figure 3). Mean CPUE values were numerically lowest for traps baited with fish meal (14.9 Common Carp per net night; SE = 3.76), intermediate for traps baited with bloodworms (17.3 Common Carp per net night; SE = 2.67) and the unbaited control (18.8 Common Carp per net night; SE = 2.85), and highest for lighted traps (20.4 Common Carp per net night; SE = 5.79). Catch rates of age-0 Common Carp were higher in Whitewood Lake (28.9 per net night; SE = 3.2) than in Brant Lake (8.5 per net night, SE = 1.9; repeated measures ANOVA, $F_{9,164}$ = 85.3, P < 0.01). Bycatch of additional species other than Common Carp were not numerically recorded, but anecdotally, Fathead Minnows contributed more than 90% of the nontarget catch; small Bluegill, Black Crappie, and Yellow Perch composed the remaining bycatch.

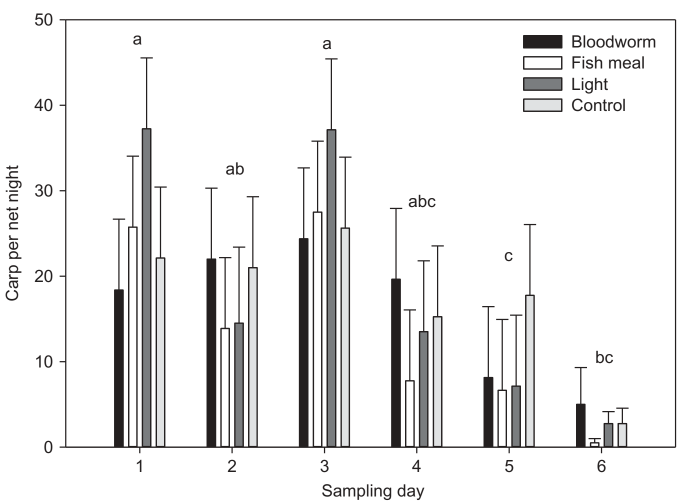

FIGURE 3. Mean catch per net night (CPUE; ±1 SE) of age-0 Common Carp collected in Brant and Whitewood lakes, South Dakota, with cloverleaf traps during August 2010. Letters represent differences in catch rates among sample days.

Although catch rates did not differ among treatments, age-0 Common Carp catch rates declined through time (repeated measures ANOVA; $F_{9,164}$ = 7.69, P < 0.01; Figure 3). An 89.5% decline in catch rates was observed between days 1 and 6, catch rates being higher on nights one (26.6 Common Carp per net night; SE = 5.66) and three (28.7 Common Carp per net night; SE = 7.10) than on nights five (9.9 Common Carp per net night; SE = 2.37) and six (2.8 Common Carp per net night; SE = 1.17). The depletion population estimate for Brant Lake was 879.4 age-0 Common Carp (95% CI: 764.8–995.1), indicating that 93.5% of age-0 Common Carp (95% confidence interval [CI]: 82.6%–107.5%) were removed from the lake. The depletion population estimate for Whitewood Lake was 5,759.6 age-0 Common Carp (95% CI: 712.9–10,705.5), indicating that 39.6% of age-0 Common Carp (95% CI: 21.3%–319.8%) were removed from the lake.

Total length of age-0 Common Carp captured in cloverleaf traps ranged between 35 and 126 mm (mean = 76 mm ± 1 SE) across treatments and lakes (Figure 4). Mean total length of age-0 Common Carp in Brant Lake was 78 mm (0.9 SE) in lighted traps, 75 mm (1.1 SE) with bloodworms, 74 mm (1.0 SE) in the control, and 73 mm (1.1 SE) with fish meal. Similarly, mean total length of age-0 Common Carp captured in Whitewood Lake was 80 mm (0.6 SE) in lighted traps, 75 mm (0.7 SE) in the control, 74 mm (0.7 SE) with bloodworms, and 73 mm (0.7 SE) with fish meal. Size distribution of age-0 Common Carp captured was associated with attractant type in both lakes. Traps in Brant Lake with glowsticks caught larger Common Carp than the traps baited with fish meal (K–S test; D = 0.21, P < 0.01), bloodworms (K–S test; D = 0.16, P < 0.01), or the control (K–S test; D = 0.17, P < 0.01). Likewise, traps in Whitewood Lake with glowsticks captured larger Common Carp than did traps baited with fish meal (K–S test; D = 0.26, P < 0.01), bloodworms (K–S test; D = 0.23, P < 0.01), or the control (K–S test; D = 0.19, P < 0.01).

DISCUSSION

Catch rates of age-0 Common Carp were not improved through the use of the type and quantity of attractants (fish meal, bloodworms, and light) selected for this study. Nonetheless, trapping may be an effective option for reducing abundance of age-0 Common Carp and may present a new tool for reducing recruitment. Age-0 Common Carp are too small to be captured by most mechanical removal techniques currently used to control populations. Adult Common Carp spawn in a predictable subset of available habitats (Bajer and Sorensen 2010; Taylor et al. 2012; Hennen and Brown 2014),

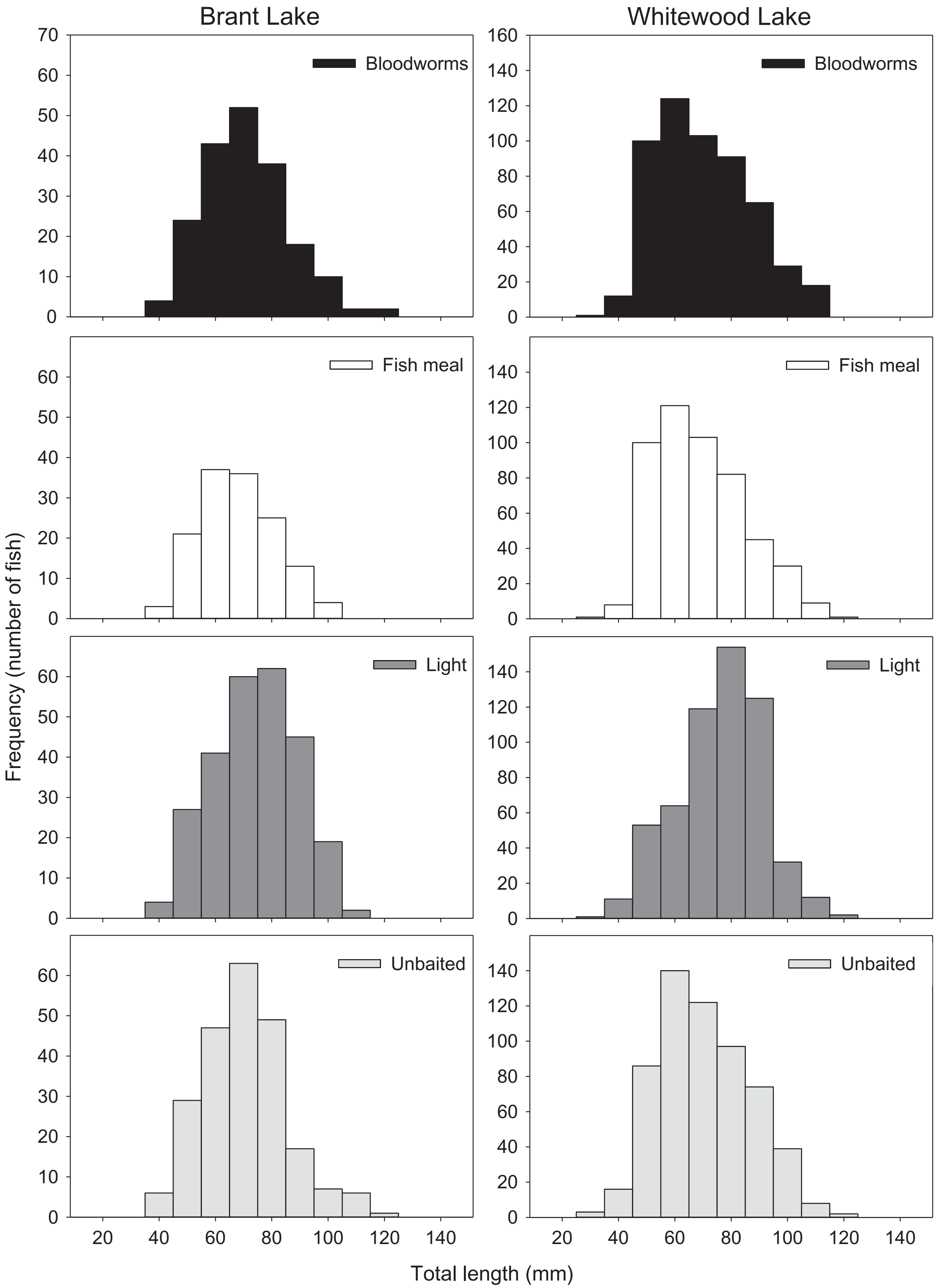

FIGURE 4. Length-frequency histograms for age-0 Common Carp captured in cloverleaf traps with control, bloodworms, fish meal, and glowsticks during August 2010 in lakes Brant (left) and Whitewood (right), South Dakota.

and juveniles appear to have specific microhabitat preferences within these areas (Weber and Brown 2012), making them relatively easy to target. However, the success of including cloverleaf traps in integrated Common Carp management plans depends on the traps' ability to efficiently capture and deplete age-0 Common Carp. Successful population depletions of a diverse array of taxa such as invasive crayfish (Hein et al. 2005), nonnative trout (Lamansky et al. 2009), Northern Pike (Jolley et al. 2008), and Sea Lamprey *Petromyzon marinus* (McLaughlin et al. 2007) have integrated passive trapping techniques. Our results indicate that abundance of age-0 Common Carp may be substantially reduced (approximate 90% reduction in catch rates following <100 net nights) using cloverleaf traps. Population estimates revealed 40% and 94% of age-0 Common Carp were removed from Whitewood and Brant lakes, respectively. Although large numbers of age-0 Common Carp reside in and can be targeted in specific microhabitats (e.g., emergent vegetation), our population estimates do not account for individuals occupying other habitats. Designated sampling areas of Common Carp spawning habitat were similar in size for both lakes (53 ha versus 44 ha), but total lake area was much smaller for Brant lake (420 ha) than for Whitewood Lake (1,893 ha). Greater total lake area and potentially higher total biomass of adult Common Carp may explain the higher catch rates of age-0 Common Carp in Whitewood Lake than in Brant Lake. We hypothesize that effort required to control age-0 Common Carp probably increases with lake area, but this should be evaluated in future work. Nonetheless, the small number of days required to reduce abundance of age-0 Common Carp in Brant Lake (6 d) and the simple design of cloverleaf traps makes it easy to set and retrieve a large number of traps, which is encouraging for helping manage recruitment in shallow lakes. This novel approach may allow managers to proactively and efficiently exploit a potentially vulnerable life stage of Common Carp in shallow lakes that previously received little attention.

Similar to previous studies on other species (Mangan et al. 2005), glowsticks tended to capture more age-0 Common Carp than other treatments did, but high variability in catches within treatments, a common issue with passive sampling gears (Hubert 1996), resulted in similar catch rates among attractants. Based on the highly sensitive olfactory system of Common Carp (Irvine and Sorensen 1993; Bajer et al. 2010) and results from Common Carp diet studies (García-Berthou 2001), we hypothesized that olfactory baits (fish meal and bloodworms, *Chironomus* spp.) would produce higher catches of age-0 Common Carp than the control traps would. Yet olfactory baits did not improve catch rates of age-0 Common Carp in this study. The quantity or type of attractant used may have produced these unexpected results. A 2–3-kg soybean cake or 2-kg waste cheese (Pierce et al. 1981; Flammang and Schultz 2007) was used to increase hoop net catches of several fishes in large rivers and impoundments. Utilizing only 100 g of the olfactory baits in this study may have influenced the effective range of these baits and ultimately related catch rates. Increasing the amount of fish meal or bloodworms may increase the time spent feeding by fish within the trap because baits would not diminish as quickly (baits were frequently entirely depleted when traps were retrieved), potentially resulting in higher capture rates. Similarly, using additional glowsticks or other light sources (e.g., light-emitting diodes) having greater lumen production may result in higher capture rates as identified in other studies (Gyekis et al. 2006). Finally, evaluations of alternative attractant types (e.g., soybean cake, waste cheese, other light sources) used in other studies (Pierce et al. 1981, 2006) or combining light and olfactory baits could possibly increase catch rates of age-0 Common Carp.

One potential benefit with the attractants evaluated is that cyalume glowsticks captured larger individuals than other attractants did. Though invertebrates were not sampled, light sources in other studies have concentrated aquatic macroinvertebrates, possibly improving foraging opportunities and drawing more fish toward the trap (Binion et al. 2011). Like many fishes, Common Carp undergo an ontogenetic diet shift from zooplankton to benthic invertebrates when reaching sizes between 40 and 150 mm (Britton et al. 2007; Weber and Brown 2013; Howell et al. 2014). Potential concentrations of benthic macroinvertebrates around traps containing glowsticks may have resulted in higher catch rates of larger age-0 Common Carp did other treatments. The ability to capture larger individuals may provide added benefit in controlling Common Carp recruitment. Overwinter survival of age-0 Common Carp is size-dependent in shallow South Dakota lakes, where the largest individuals are more likely to survive the winter and recruit to the adult population (Phelps et al. 2008). Thus, by selectively capturing larger age-0 Common Carp, glowsticks may be more effective at reducing recruitment and benefit integrated Common Carp management strategies in shallow lakes.

Fishing cloverleaf traps in predictable Common Carp spawning habitat offers a new tool for managers to include as a component of integrated Common Carp management plans or at least successfully assess abundance of age-0 Common Carp. Because of these traps' simplicity and their ability to effectively capture age-0 Common Carp, they may be used for early monitoring of Common Carp recruitment or even exploratory sampling regimes to search for exploitable backwater habitats. This selective, passive approach to capturing Common Carp could potentially provide a better alternative for reducing Common Carp abundance than such techniques as piscicides, water drawdowns, or fish barriers (Taylor et al. 2012), which may negatively influence native fish and other aquatic species. Furthermore, invasive populations are generally reproduction-regulated, where competition is strong among adults, and increases in adult mortality may increase reproduction (De Roos et al. 2007; Zipkin et al. 2009), furthering the need for integrative strategies that target early life stages. Our results indicate that managers could proactively exploit age-0 Common Carp in shallow lakes with cloverleaf traps to improve success of Common Carp control programs.

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