EVALUATION OF A COMMON CARP (*Cyprinus carpio* L.) EXCLUSION AND TRAPPING DEVICE FOR USE IN AQUATIC PLANT FOUNDER COLONY ESTABLISHMENT

Paul Edwin Williams, B.S.

Thesis Prepared for the Degree of

MASTER OF SCIENCE

UNIVERSITY OF NORTH TEXAS

May 2008

APPROVED:

Paul F. Hudak, Major Professor
Kenneth L. Dickson, Committee Member
Gary O. Dick, Committee Member
Art Goven, Chair of the Department of Biological Sciences
Sandra L. Terrell, Dean of the Robert B. Toulouse School of Graduate Studies

Williams, Paul Edwin. Evaluation of a Common Carp (*Cyprinus carpio* L.) Exclusion and Trapping Device for Use in Aquatic Plant Founder Colony Establishment. Master of Science (Environmental Science), May 2008, 50 pages, 12 tables, 21 figures, references, 34 titles.

The focus of this study was to design and evaluate a trapping system that would reduce populations of common carp within water bodies in conjunction with establishment of native aquatic macrophytes founder colonies. A pond study and field study were conducted. A pond study was performed at the Lewisville Aquatic Ecosystem Research Facility, located in Lewisville, Texas, followed by a field study within a constructed wetland located in southern Dallas, Texas. For the pond study, twelve funnel traps were constructed (four reps of each type: control, dual-walled and ring cage). Two anti-escape devices were tested with funnels including steel fingers and hinged flaps. Ring cage and dual-walled treatments were planted using native pondweeds, while controls were left unplanted (additional bait and a drift fence scenarios were also tested). Common carp were introduced into the study pond. Chi-square statistical analyses were utilized and showed ring cage treatments using fingers as well as the use of a drift fence to be most effective. Following completion of the pond study, the two most effective treatments (controls and ring cages) were tested within the Dallas, Texas wetland; no carp were caught during the field test.

ACKNOWLEDGEMENTS

I would like to thank my committee members Dr. Paul Hudak, Dr. Gary Dick and Dr. Ken Dickson. I would also like to thank Dr. Michael Smart, director of the Lewisville Aquatic Ecosystem Research Facility, for funding this project. Thanks also goes out to everyone who helped in any way, including, Matt Spickard, Josh Troegle, Nathan Harms, any LAERF interns or past employees, Dian Smith, Julie Nachtrieb, Cindy Black, Chetta Owens and the LAERF lab. Lastly, I would like to thank my wife Lynde, my parents David and Sue, Brother Matthew and every family member for all they have ever done.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Common carp (*Cyprinus carpio* L.), also known as European, king, German, mirror or leather carp (Figure 1), were first introduced into the United States sometime around the 1830's to 1840's from their native China. By 1880, the U.S. Fish Commission had distributed more than 12,000 to persons in 25 states and territories (Steiner, 2000). Since this introduction, lake managers have been trying to find ways to rid our water bodies of these pests. Although introduced to create new game fisheries, recreational exploitation of the species was never realized in the U.S., and subsequent spread to most large lake, rivers, and reservoirs has resulted in water resource management problems, including increased turbidity and damage to aquatic plant beds. This increase can lead to an increase in nutrients into the water column. Common carp can also reduce diversity of sport fish, if populations are left unchecked, due to their ability to eliminate aquatic macrophytes. With these two problems at the focal point, a study was designed and implemented in an attempt to reduce the negative impacts of the invasive common carp.

The study was conducted at the U.S. Army Engineer Research and Development Center's Lewisville Aquatic Ecosystem Research Facility (LAERF), located in Lewisville, Texas. Of the many focuses of LAERF, one of the main goals is to establish native aquatic macrophytes within water bodies in order to enhance habitat; carp often hinders these efforts. This project focused on development of an exclusion and trapping system for reducing common carp densities in areas undergoing aquatic macrophyte restoration.

Objectives

The objectives of my research was to test exclosure designs that permit establishment of founder colonies of native aquatic plants while at the same time trap common carp. Eradication of carp is not likely with this system, but trapping may result in reduced carp densities in areas immediately surrounding the founder colonies, potentially resulting in more rapid spread.

Figure 1. Common carp (*Cyprinus carpio*); Photo credit: Shedd Aquarium, http://www.sheddnet.org/).

The study addressed the following hypotheses:

a. Ho: Common carp traps using fingers, on the end of the funnels, will not show statistical significance between control, dual-walled and ring cage treatments.

  H_1: Common carp traps using fingers, on the end of the funnels, will show statistical significance between control, dual-walled and ring cage treatments.

b. Ho: Common carp traps using flaps, on the end of the funnels, will not show statistical significance between control, dual-walled and ring cage treatments.

  H_1: Common carp traps using flaps, on the end of the funnels, will show statistical significance between control, dual-walled and ring cage treatments.

c. Ho: Common carp traps, that are baited, will not show statistical significance when comparing control, dual-walled and ring cage treatments that are not baited.

  H_1: Common carp traps, that are baited, will show statistical significance when comparing control, dual-walled and ring cage treatments that are not baited.

d. Ho: Common carp traps, connected to a drift fence, will not show statistical significance when comparing control, dual-walled and ring cage treatments not connected to a drift fence.

  H_1: Common carp traps, connected to a drift fence, will show statistical significance when comparing control, dual-walled and ring cage treatments not connected to a drift fence.

CHAPTER 2

CHARACTERISTICS AND BIOLOGY

Cyprinus carpio is a member of the Cyprinidae and is closely related to common goldfish (*Crassius auratus*) (Curtin, 2001). A hardy species, common carp thrive under harsh conditions including low dissolved oxygen, high turbidity, and in areas having substrates contaminated with pesticides, heavy metals, and/or excess nutrients (Webb and Morrison, 2004).

Common carp superficially resemble wild goldfish, but are distinguishable by fleshy barbells on each side of the mouth and larger size at maturity. The common carp is a scaled fish, having a lengthy dorsal fin along the back. According to the State of Pennsylvania (2006), common carp has an olive-brown to reddish-brown back with coloration on the sides of silvery-bronze, brass, or olive-gold. The underbelly is always a yellowish tone, while anal and caudal fins show a hint of red-orange coloration.

Common carp are found in a large array of aquatic habitats ranging from highly polluted and turbid systems to clear, clean streams and rivers. Ponds, reservoirs, and lakes with substrates ranging from mud, sand or gravel also serve as habitat for this fish. Common carp are usually found in freshwater systems, but have the ability to tolerate salinities of 14 ppt. (Crivelli, 1981).

The species is omnivorous and feeds from both bottom sediments and surface waters. Their diet includes a wide variety of aquatic plants, algae, plankton, insects and their larvae, benthic invertebrates, and small fish. Bottom feeding is achieved by disturbing sediments with the snout, then sucking in dislodged food and sediments; turbidity is often increased when the fish blows the unwanted sediment out (Steiner, 2000). Pharyngeal teeth are located in the throat and are used to crush food items. Senses of taste and smell are highly developed and may be used to locate food (Steiner, 2000).

Spawning (Figure 2) occurs in shallower areas of the littoral zone and usually includes multiple males and a single female (Morrison and Webb, 2004). Temperatures required to induce spawning are usually between 15 to 28 degrees Celsius (Morrison and Webb, 2004). In the U.S., spawning takes place from March through July, but has been observed as late as November (Wang, 1986).

Figure 2. Common carp spawning activity in shallow water; Photo credit: Auburn University, **http://www.ag.auburn.edu/fish/**).

From 36,000 to 2,000,000 adhesive eggs may be deposited in a single spawning season by each female (National Sea Grant, 1999). Eggs are typically deposited among submersed plants, tree roots, roots of undercut banks, leaf litter, and/or logs in a mass or singularly (Wang, 1986). Eggs are generally round to oval and either clear or tinted yellow. Eggs are abandoned by the female and hatch in 3 to 5 days after being laid.

Common carp grow rapidly (Table 1) and reach 10 to 13 centimeters in length within the first year of life (Steiner, 2000). Juveniles are used as baitfish and are frequently transported/spread to other water bodies (Chick et al., 2002). Common carp have been reported to live up to 20 years and reach a maximum weight of 60 pounds, though most fall between 1 and 10 pounds (Wang, 1986).

Table 1. Attributes of carp as an invasive species (derived from Koehn, 2004).

Attribute	Details
Invasion history, widespread distribution and abundance	Introduced and established throughout Europe, Asia, Africa, North, South and Central America, Australia, New Zealand, Papua New Guinea and some islands of Oceania
Wide environmental tolerances	Temperature tolerance ranges from 2 to 40.6 °C, salinity tolerances up to about 14 ‰ (0.4 seawater salinity), pH from 5.0 to 10.5, and dissolved oxygen levels as low as 0.4 mg/L (Dunham et al, 2002)
Early sexual maturity	Males at 1 year, females at 2 years
Short generation time	2–4 years
Rapid growth	Hatching of eggs is rapid (2 days at 25 °C) and newly hatched carp grow very rapidly
High reproductive capacity	Highly fecund broadcast spawners with egg counts as high as 2 million per female
Broad diet	Omnivore/detritivore
Gregariousness	A schooling species
Possessing natural mechanisms of dispersal	A mobile species with fish moving between schools. Dispersal can also occur with downstream drift of larvae. Rates of transfer can be affected by conditions such as flooding
Commensal with human activity	Bred as an ornamental (koi) and aquaculture species, used as bait and sought by some anglers

Negative Impacts of Common Carp

Common carp were introduced into the United States (from Europe) around 1831 as a sport and food fish (Murdock, 2004). By 1880, the U.S. Fish Commission had distributed more than 12,000 in 25 states and territories (Steiner, 2000). Since these early introductions, common carp have spread into every major water body in the continental U.S., legally and/or illegally

(USGS, 2005). Although heavily utilized as a food fish in many countries, common carp are mainly looked upon as nuisance trash fish in the U.S. The species was probably the earliest fish to be introduced on a wide scale, and is the most frequently reported nuisance fish in the U.S. (Miller and Crowl, 2006).

Feeding and spawning activities can be accounted for as two of the leading behavioral activities which lend themselves to the negative reputation of the common carp. The species has been implicated in widespread degradation of numerous aquatic habitats and is considered responsible for increasing incidents of blue-green algal blooms, causing declines in native fish populations, increasing turbidity, damaging stream banks, and significantly reducing aquatic vegetation (Lowry et al., 2005). Reduction in aquatic plant biomass has been attributed to consumption and uprooting by common carp, both of which may lead to increased turbidity and re-suspension of pollutants and nutrients (Murdock, 2004). Elimination of aquatic macrophytes by common carp has also been implicated as harmful to desirable fisheries, with loss of structural habitat and degradation of water quality associated with plant biomass reduction both linked to decreased fishery diversity (Bonneau et al., 1995). Overall, higher densities have greater impacts on plant communities, benthic invertebrates, and water quality (Miller & Crowl, 2006).

Management Strategies

Methods to control common carp have been attempted by water resource managers, including netting, electro-fishing, poisoning, trapping, daughterless carp technology, electrical and non-electrical barriers, and introduction of predators. Descriptions of these methods are reviewed below.

Netting methods that have been used include gillnets, trap nets and seine nets. A main advantage of netting is cost effectiveness (Bonneau et al., 1995), but netting has only been moderately effective in reducing pre-reproduction populations. Furthermore, netting has been shown to have negative effects on other fish, turtles, aquatic birds, macrophytes, and other species (Lowry et al., 2005). Targeting common carp with larger mesh size has been somewhat effective in reducing non-target species impacts, but netting remains marginally ineffective as a tool for managing common carp populations.

Electro-fishing is another alternative: fish are stunned and netted, with the catch then held for disposal (Pinto et al., 2005). This method is effective at culling out target fish, leaving other species to recover. Another advantage of electro-fishing is its effectiveness on all size classes of common carp. However, large-scale electro-fishing requires large capital cost and a great deal of manual labor, making it logistically impractical for managing common carp in larger systems (Lowry et al., 2005).

Chemical control has also been attempted on common carp, with rotenone, a natural fish toxicant, the most commonly used product. This toxicant works by biochemically inhibiting oxygen use by fish (Bonneau et al., 1995). Unfortunately, rotenone cannot be applied selectively, and rates required to kill common carp cause complete fish kills in treated areas. Baits laced with rotenone have also been attempted (Bonneau, 1996). The idea is to feed common carp untreated bait (floating pellets designed specifically for carp attraction) for a period of time, then switch to treated baits to achieve a kill. Ingestion does not always result in mortality, however, and common carp that have been sickened once by treated bait will not feed on baits again.

Trapping of common carp has also been attempted. According to Lowry et al. (2005), trapping is the most cost-effective compared to other methods in use: "The challenge is to develop a trap design that would mitigate the capture and fishing mortality of by catch species".

Trapping systems designed for use in Lakes Crescent and Sorell Australia have been in place for ten years or more and have proven to be highly successful in common carp management (Tasmanian Inland Fisheries Service, 2005). 7,778 total carp have been captured in Lake Crescent and only a few of females are thought to remain. This view is accepted since no females were trapped in 2005, and there was no evidence of spawning activity during that year. Similar results have occurred in Lake Sorell, where 2,358 carp have been trapped since 1995. In 2005, only a single mature female was trapped and no spawning activity was observed.

Trapping has also been attempted in Bowman-Haley Reservoir in North Dakota, with traps designed to capture common carp and other undesirable species as they move upstream for spawning (Bonneau et al., 1995). Overall, around 907,185 kilograms (one ton/surface area) of rough fish have been removed since 1994 (Berard, 2006 – personal contact).

Another trap system (Figure 3) was designed and tested in New South Wales, and will be made available for commercial removal of common carp in Australia (Lowry et al., 2005).

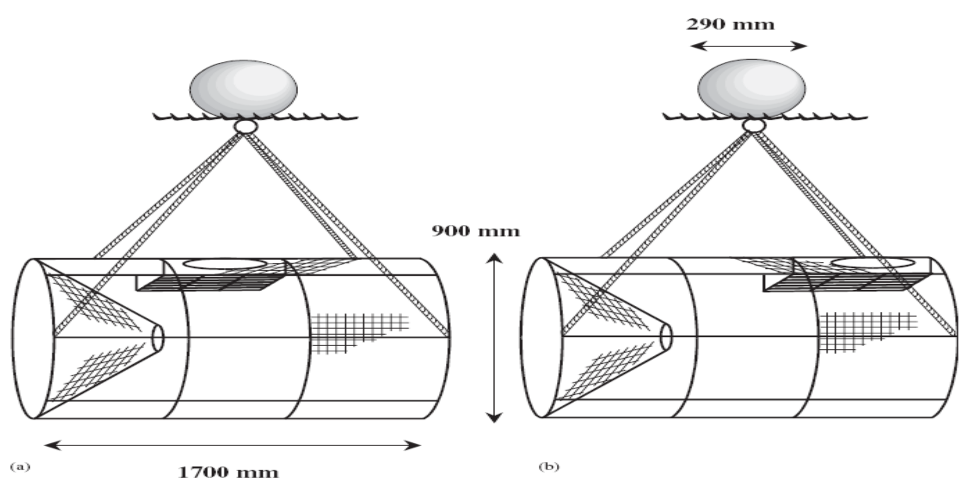

Figure 3. (New South Wales common carp trap designs; Photo credit: Lowry et al., 2005).

Cylindrical funnel traps (commercial common carp traps) were retrofitted with turtle release devices and suspended above substrates with floats. Two designs were constructed; each having the same turtle release device, but with different placement. 120 common carp were used in this study with an 88% capture rate, with only 14 total carp escaping after being trapped. Final analysis of the study showed a turtle release rate of 77% with no significant differences between the two designs. In field use these traps are set onto creek bottoms and a bait (information as to what type is restricted) is used as an attractant.

Introduction of "daughterless" carp is a proposed practice for management of nuisance common carp populations. The idea behind this approach is to release genetically engineered fish that produce only male offspring (Erdmann, 2004). Eventually (over several decades), it is theorized that as existing females die off, only males will remain in the population, leading to eradication of the species within that particular water body. Due to concerns regarding release of genetically modified organisms into natural environments, the Australian government is not expected to make a final decision on application of this technology until at least 2009 (Parliament of Australia, 2004). Literature seems to indicate that if this technology makes it out of the lab the first permitted trial will take place in Murray River, Australia (Murray-Darling Basin Commission, 2002). Unless proven highly effective and safe, it is unlikely that this technology will reach the U.S.

Re-introduction or increase of predator species populations has been used with limited success in reducing densities of common carp. Northern pike (*Esox lucieus)* populations have been enhanced through stocking in hopes that these predators will impact common carp (Galbraith, 1996; Webb and Morrison, 2004). Unfortunately, common carp usually overwhelm predator species due to rapid reproduction and growth rates, resulting in too many and too big of fish for predators to consume (Koehn, 2004).

Barriers preventing common carp movement from one water body to another, or to limit access to areas within a water body, have been used with some success. Two types of barriers, structural and electrically charged, are described below.

Structural barriers have been used in Hamilton Harbor, Canada and in Australia. In Hamilton Harbor, a fishway (barrier) was constructed in three sections: 1) the first section was designed to allow any species except common carp to pass into Cootes Paradise (Figure 4), with six chambers (each 1.2 meters wide) designed to trap carp attempting to pass through; chambers are periodically raised for carp removal; 2) the second section made use of 5-cm wide grates, which deterred movement of larger common carp not trapped in the first section; grates were removed in September to allow carp to leave the marsh during fall migration back into the harbor; 3) the third section was designed as a one-way corridor, which allowed all fish, including common carp, to move from Cootes Marsh into Hamilton Harbor (Webb and Morrison, 2004). Prior to 1997 (the year the project became operational), there were an estimated 70,000 mature carp within this Cootes Paradise. In a 2003 survey, under 1000 remained and presently it is estimated that 95% of all carp have been excluded from the harbor (Royal Botanical Gardens, 2006).

Figure 4. Cootes Paradise, Canada fishway; Photo credit: McMaster University.

The Australian project makes use of a barrier to prohibit migration upstream in Murray River, with a vertical step system, trap, and control gate utilized in combination (Figures 5 and

6). This system takes advantage of the tendency of fish to swim upstream: because native species travel along the bottom of the fishway (barrier) and common carp use the upper levels of the water column, common carp were lured towards the trap system by piped-in flowing water near the surface, inducing them to jump towards the flow and into traps (Kelly, 2004). The latest data indicates common carp populations have been stabilized, with the fishway capturing approximately 90 percent of target species that enter (Parliament of South Australia, 2004).

Figure 5. Murray River, Australia common carp barrier; Photo credit: Environmental Waikato.

Figure 6. Murray River, Australia common carp trap system; Photo credit: Environmental Waikato.

Electrically charged barriers have been tested in Illinois to halt the movement of common carp and other non-native fish into Lake Michigan from the Mississippi River basin. "The idea is that as fish pass through the barrier, they feel increasing levels of electricity, which leads them to turn around" (Chick and Pegg, 2004). Observational data reported indicate only two attempted passes by common carp through the barrier were successful, out of 381 observed. Successful passes were accounted for by a single small common carp, which passed through twice.

Another common carp removal methodology is being tested at Lake Sorell, Tasmania. Scientists are running a net system across two areas of the lake, effectively cutting it into three sections. Each section is within the main seasonal migration route for common carp. Passive chain-link traps will then be set within both barrier sections in hopes of capturing this invasive fish (Tasmanian Inland Fisheries Service, 2005).

Overall, experiments of methods to control common carp have experienced both positive and negative results. At best, however, current methodologies are expensive and labor intensive, and achieve only modest success. Because eradication of common carp is not likely in larger systems, a refocused goal of reducing carp densities may be a more realistic approach to managing this nuisance species. Additionally, localized management may prove beneficial in reducing herbivory pressures on efforts to establish aquatic vegetation when hindered by carp populations.

Common Carp and Aquatic Plant Restoration

Aquatic plant community enhancement has gained favor in recent years as a means of improving habitat for fish and other wildlife, water quality, and reducing erosion. Unfortunately, common carp often hamper aquatic plant establishment efforts by feeding directly on newly establishing plants and degrading water quality (Smart et al., 1998). Reductions in common carp numbers, at least locally, might enable project managers to achieve earlier and greater successes when attempting to establish native vegetation. According to McMaster University (Webb and

Morrison, 2004), any common carp control measure should only be viewed as a means to "kick start" a restoration project. The final goal is one that ends with a self-sustained, stable, balanced, and diverse ecosystem (Webb and Morrison, 2004).

Large-scale lake restoration is generally impractical due to high costs and logistics. Instead, recent efforts have focused on establishing founder colonies, which serve as propagule sources for natural spread in the water body. "The founder colony approach involves the establishment of small colonies of several aquatic plant species by planting transplants or robust propagules" (Smart et al., 1998).

Two major obstacles have been identified when attempting to establish founder colonies: water level fluctuations and herbivory (Smart et al., 1996). Common herbivores encountered in aquatic plant establishment projects have included fish that uproot and/or consume vegetation (such as common carp), turtles, crayfish, nutria, beaver, deer, and insects (Smart et al., 1998). Herbivory has the potential to devastate a planting site in a short amount of time.

Most aquatic plant establishment efforts use exclosures to protect initial plantings of macrophytes from large herbivores. Various materials and scales have been used, with the most successful being relatively small cages constructed from PVC-coated (poly vinyl chloride) welded-wire, with meshes ranging from 1-in x 1-in to 2-in x 4-in (nominal sizes); two main types of cages are used, a cylindrical ring cage and a rectangular box referred to as a tray cage (Smart et al., 1997). Larger exclosures, including fenced off coves and shorelines have had successes protecting new plantings but require high maintenance. Larger exclosures are prone to breaches, especially when water levels rise and permit entry by common carp and other herbivores: falling water levels often leave fish and turtles trapped inside exclosures, resulting in damage to founder colonies (Smart et al., 1998). To address this problem, herbivore release devices have been installed, but these are largely untested and their efficacy is unknown (Dick, personal communication). Field observations suggest that herbivores, especially common carp and turtles, key in on founder colony exclosures. These increased densities may result in higher breach rates, negatively impacting plant establishment efforts. A methodology specifically designed to reduce herbivore densities may further protect plants.

A founder colony is considered to be established once plants persist for more than one growing season. Once well established, founder colonies are capable of producing enough propagules to overwhelm herbivores, and significant spread to other areas of a water body has been reported (Smart et al., 1998). However, the process may take years, with variable lengths of time probably due to a combination of fluctuating water and herbivory inhibiting full-season growth of founder colonies. Additional methodologies designed to improve founder colony establishment may expedite spread and merit investigation. However, the process may take years, with variable lengths of time probably due to a combination of fluctuating water and herbivory inhibiting full-season growth of founder colonies.

CHAPTER 3

STUDY AREA

The Lewisville Aquatic Ecosystem Research Facility (LAERF) consists of 55 experimental ponds and is located below the dam at Lewisville Lake, Texas, a Corps of Engineers reservoir that serves as flood control and municipal water supply for the City of Dallas and other communities in the area (Figure 7). LAERF supports studies in biology, ecology, and management of aquatic plants (Smart et al., 1995), with aquatic habitat restoration a major focus of this facility.

Figure 7. Aerial view of the Lewisville Aquatic Ecosystem Research Facility – Lewisville, Texas.

Generally, LAERF ponds are rectangular and cover surface areas ranging from 0.17 to 0.32 hectares (0.42 to 0.79 acres) (Smart et al., 1995). The ponds were constructed in the 1950's with the berms and bottoms made from local clay and overlaid with topsoil (Smart et al., 1995). On average, pond substrates consist of 28 percent sand, 33 percent silt, and 38 percent clay particles, with nutrients and organic matter content favorable towards growth of macrophytes (Smart et al., 1995).

According to Smart et al. (1995), the ponds have developed a characteristic aquatic flora that persists as seeds/spores in the sediment, including muskgrass (*Chara vulgaris*), American pondweed (*Potamogeton nodosus*), horned pondweed (*Zannichellia palustris*) and southern naiad (*Najas guadalupensis*).

CHAPTER 4

MATERIALS AND METHODS

The goal of this study was to evaluate a stratagem that would reduce common carp effects often associated with the establishment and spread of native aquatic plants, through the use of founder colonies. Exclosures normally used to protect aquatic plants from herbivores were modified to permit both growth of plants and trapping of common carp. These exclosures were expected to serve as protective barriers for plants which in turn served as bait to attract the fish into containment areas. One-way entry funnels had been previously tested and showed that common carp were trappable using this method. Successful funnel designs were then integrated into exclosure/traps which were then tested in pond and field scenarios.

In spring 2006, twelve common carp exclosures were constructed on the approximate 0.9-m depth contour of a 0.58-hectare (1.43-acre) surface area pond at LAERF (Figure 8). Exclosures measured 1.3-m tall x 3-m x 3-m, and were made from eight steel T-posts (2-m, #125 grade) and, 2-in x 4-in mesh (nominal size), PVC-coated welded-wire. This mesh size was deemed adequate to prevent movement by common carp measuring 25-cm or greater in total length. Wire was attached to each T-post using three aluminum fence ties, one each at the top, middle, and bottom. Upon completion of the walls, T-posts were driven into the sediment (with a T-post driver) to deter common carp from easily "digging" under walls. Exclosures were then modified to serve as traps, with four replicates of each of three types built. The trap types included 1) dual-walled, 2) ring cage, and 3) control (Figure 9).

The dual-walled treatment was designed as a trap (1.68-m^2) built within a larger exclosure (3-$m^{2)}$, with a single funnel installed (on the deepest side) to permit entry from outside the exclosure to inside the trap. Plants were placed between the walls of the exclosure and trap, resulting in 1.32-m^2 of plants growing along the entire outer perimeter of the exclosure (Figure 9). Common carp encountering this exclosure might therefore feed along the perimeter as plants grew through the mesh of the outer wall, eventually being directed into the funnel and trap.

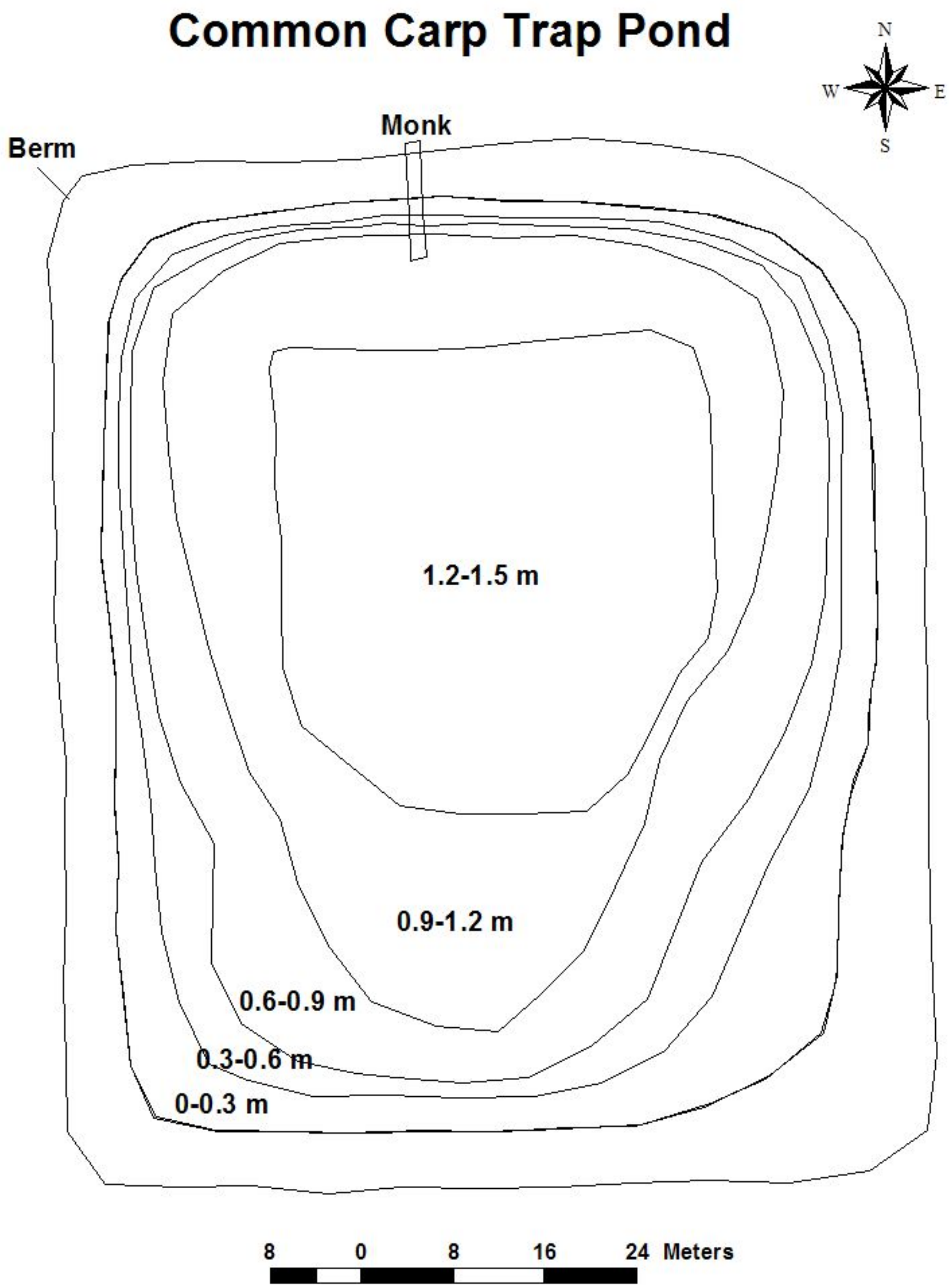

Figure 8. Common carp trap study pond at LAERF.

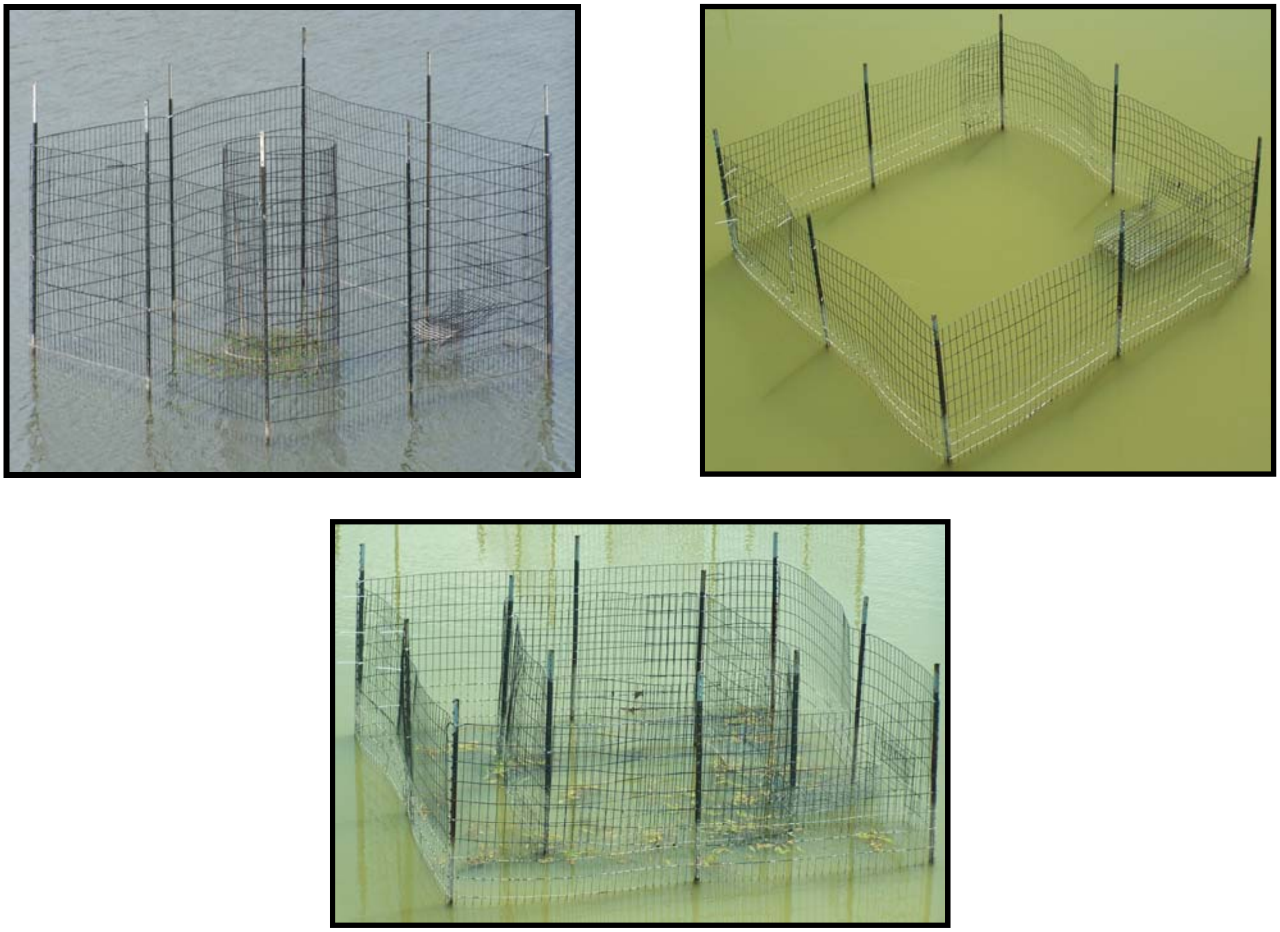

Figure 9. Common carp trap designs: top left ring cage design, top right control design and bottom dual-walled design.

The ring cage treatment consisted of a wire-mesh, 0.97-m diameter by 1.22-m tall cylinder placed in the center of a trap to serve as protection for plants. Although plants could grow out of the ring cage and into the trap area, it was anticipated that trapped fish would prevent this from occurring. A single funnel (on the deepest side) permitted entry into the exclosure. Plants were not in contact with the trap wall in this treatment, but it was assumed that common carp might be attracted to them by scent, sight, or other means and try to gain entry by swimming the perimeter of the trap.

The control treatment consisted of an unplanted exclosure and single funnel. Substrates were covered with geotextile landscape fabric to discourage plant growth. A single funnel was installed on the deepest side. This treatment assumed that plants did not attract common carp, but capture was still possible by the exclosure walls serving as drift fences.

Trap funnels had been previously tested in a pond at LAERF to ensure that common carp would pass through them (Dick, unpublished data). Cylindrical funnels (18-in diameter entry x 10-in diameter exit x 30-in long) constructed from 1-in hexagonal mesh PVC-coated steel wire were tested in enclosures (each measuring 2-m x 2-m x 1.25 m) constructed in a LAERF pond. Steel wire "fingers" (16 ga., 18-in length) were attached to the smaller opening of one funnel to serve as an escape deterrent; a 2-in x 4-in (nominal size) PVC-coated wire mesh, hinged "flap" was attached to the smaller opening of the second; no return-barrier structure was attached to the third. Fingers were the most effective of the three, with six of six fish moving into the trap but unable to escape after 24 hours. While no fish were able to escape the flap funnel, only five of six initially passed through; the flap may have deterred movement to some degree. Fish were able to move freely in or out of the funnel with no return-deterrent. It was decided to include fingers in the trapping study to prevent escape of common carp between sampling dates.

Because of the difficulty in constructing cylindrical funnels from the materials that were available, square funnels were constructed from 1.5-in (nominal size) mesh, PVC-coated 14 gauge steel welded-wire and measured 46-cm x 46-cm by 92-cm. Tops and bottoms were attached to provide a 46-cm x 46-cm entry opening and centered 23-cm x 46-cm exit opening, and wire fingers were attached to prevent escape by captured fish (Figure 10). Funnels were fastened to exclosures with cable ties, and a wire mesh cover was attached over the large opening to prevent entry by common carp when desired.

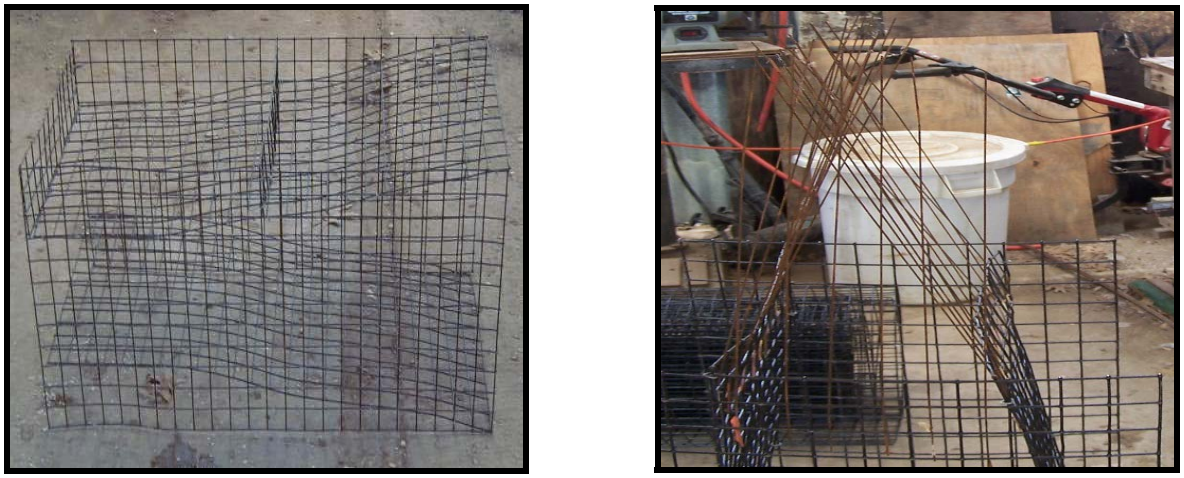

Figure 10. Common carp funnel without fingers pictured at left, fingers pictured at right.

Upon completing trap construction, water from Lewisville Lake, Texas was added to the pond to equal a depth of 1.59-m at the pond outlet. In early June 2006, 50 adult common carp (minimum 35-cm total length) were collected from other LAERF ponds and released into the study pond. After release, the fish were given approximately three months to equilibrate to the environment of the study pond. During this period, common carp activity in the pond maintained high turbidities (a mean of 22.0 ntu averaged from three samples) and minimized establishment of volunteer aquatic vegetation from seeds.

Since the study pond was relatively devoid of aquatic plants (especially the species to be used in this study) it was decided to introduce them from the LAERF aquatic macrophyte culturing area. Initial plantings of exclosures were conducted in early August, 2006, with two species chosen for the project: American pondweed (*Potamogeton nodosus)* and Illinois pondweed (*Potamogeton illinoensis).* Both species are perennial submersed aquatic plants and are native to the Texas bioregion. These two species were chosen due to field observations that indicated a strong possibility of common carp targeting them as a food source (Dick, personal communication, 2006)

Dual-walled traps were planted between the inner and outer walls with a mature nursery-grown potted (4-in diameter, nominal size) American pondweed plant at each of the four corners and one mature nursery-grown potted (4-in diameter, nominal size) Illinois pondweed plant at the midway point of each wall, totaling eight potted plants. Exclosures in ring cage treatments were each planted with two American pondweed and two Illinois pondweed potted plants. Control treatments were left unplanted. At that point, the plants were allowed to take hold and grow for four weeks. Re-plantings were needed as necessary to ensure the presence of macrophytes in target areas. At the time of plantings, re-plantings and growth periods the funnel openings were closed off to prevent entry by common carp.

On September 8, 2006 the first sampling of traps was undertaken. Dip nets (85-cm by 90-cm and 90-cm deep) were used to collect fish, with one person standing outside of each exclosure, dragging the net from the far wall towards them. Difficulties using this sampling method were encountered, including the possibility that fish were avoiding capture by dip net and interference by and damage to the funnel and fingers. Turbidity was also a limiting factor, while using this sampling method, since any trapped fish could not be verified visually. Common carp or non-target animals caught were recorded and released back into the study pond (Appendix). Prior to annual plant senescence, I was able to gather data on a total of five runs, a seven day time period between samplings. In this study, a run is defined as being the term used for an individual sampling period.

A partial drawdown of the study pond was conducted on February 28, 2007 in order to perform a visual inspection of the physical condition of the traps and funnels (Figure 11). Water levels were only lowered enough for this inspection, leaving a large enough volume so as to not be harmful to the fish.

Figure 11. LAERF study pond at drawdown February, 2007.

Upon inspection, it was decided that several changes/ repairs were necessary in order to continue the experiment the following spring. These changes included closing gaps between exclosure walls and pond bottom, replacement of funnel fingers with another escape-prevention method, control treatment plant barrier modification, redesign of funnel attachments, and repositioning of two traps that had originally been installed at slightly higher elevation than other traps.

Repair of trap walls consisted of moving gravel to fill in a few small gaps between the wall bottom and pond bottom. This precaution was needed to reduce potential escape by captured common carp. Geotextile barriers in control treatments had shifted due to gases trapped beneath them and were remedied by adding anchors (concrete pavers and 1/2-in (nominal size)) steel rebar (Figure 12).

Figure 12. Control exclosure during repairs February, 2007.

Because of sampling difficulties with the original design, all twelve common carp trap funnel openings were refitted to allow for their removal during sampling. The larger opening was modified to measure 46-cm x 51-cm, with 65-cm x 15-cm flanges. This allowed each funnel to be firmly attached with cable ties to the exclosure during trapping periods, but be easily removed during data collection. Wire-mesh bracing was also added to each funnel to prevent sagging (Figure 13).

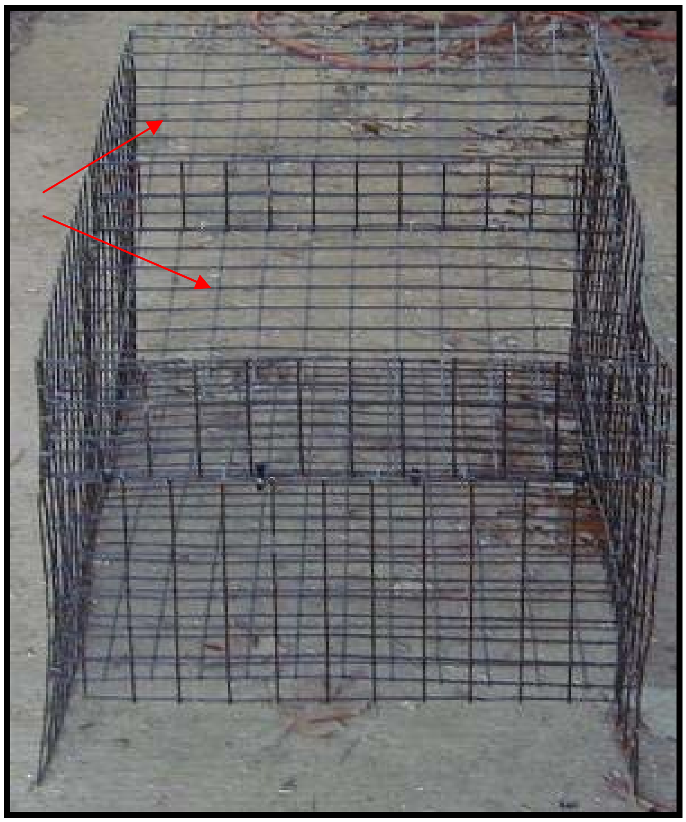

Figure 13. Funnel design with braces indicated by red arrows.

Although attaching fingers to the small opening of funnels was shown to be the most effective means of capturing and retaining common carp, after five collection periods many of the steel fingers were severely damaged and no longer functional. Some had been bent out of place by the sweeping motion made while using the dip nets, while others had simply deteriorated to the point of being ineffective at keeping trapped common carp from escaping.

Although hinged flaps were not thought to be as effective in trapping common carp, I decided to conduct an additional test to verify whether they might serve as a substitute for fingers. This test was conducted in April, 2007 and took place within a concrete raceway at LAERF (Figure 14).

Figure 14. Top pictures showing front (left) and back (right) of funnel, bottom picture shows entire raceway.

The raceway measured 6.1-m in length, 0.91-m wide, with a maximum possible depth of 63.5-cm. A 2-in x 4-in mesh (nominal size) 41-cm tall by 31-cm wide PVC-coated welded-wire flap was loosely attached with cable ties to the top of the small opening of the funnel, resulting in a hinged, one-way door. The idea behind this flap was that common carp could easily push through when entering the trap, but could not return through the funnel after the flap was closed. The funnel was placed in the center of the raceway and secured using cinder blocks. Water level was maintained at a depth of 46-cm, which came up to the top of the funnel opening. Three common carp approximately 36-cm and one measuring approximately 50-cm in length were placed in the portion of the raceway faced by the larger opening. The fish were left overnight and all had moved through the funnel by morning. The test was reset the next morning, with all fish moving through within forty-five minutes. These two tests indicated that common carp will move freely through funnels with hinged flaps, so it was then decided that hinged flaps would be used to replace fingers in the study pond.

An additional modification involved relocation of two traps (one ring cage treatment and one control) to more suitable elevations. Both were initially constructed approximately 20 cm shallower than other traps, potentially affecting the outcomes of trapping common carp (Figure 15). Because American pondweed had become the dominant vegetation in all planted traps during the previous summer (Illinois pondweed had not persisted in any of the traps), the relocated ring cage trap was planted with six American pondweed plants in spring 2007; supplemental planting of the other ring cage and dual-walled traps with American pondweed was also undertaken at that time, with plants added to protected areas that were devoid of vegetation.

Figure 15. Relocation of two exclosures to more suitable depths was necessary during a partial drawdown of the study pond during winter 2007.

Uncertainties about the effectiveness of sampling with dip nets while standing outside exclosures led to a decision to use a seine style device that was made from 1.5-in mesh PVC-coated steel wire (3.35-m x 0.91-m) with wooden shovel handles attached to each end. An opening was cut into each cage on the side opposite the funnel to allow entry for the two persons needed to work the device. This "door" measured 51-cm high by 91.5-cm wide and was cut from the top down so when opened the bottommost portion would still be above the water line. Five cable ties were used to hinge the bottom and two were used on each side.

In order to conduct sampling, the funnel was first removed and replaced by a 0.92-m long by 0.61-m tall by 0.61-m wide collection box constructed from 1.5-in mesh PVC-coated welded-wire. After entering the trap through the rear panel, the seine net device was dragged towards the front portion of the trap by a person at each end. Any trapped fish or other animals were then corralled through the opening and into the collection box and data collected (Figure 16).

Figure 16. Collection box in use.

After modifications to the traps/ exclosures were completed, the pond was refilled to its desired depth (1.59-m) and data collection resumed during the summer of 2007. Three collections were made from June 11th to June 25th, 2007, with one week occurring between each. Fish collected during each sampling period were returned to the study pond.

Overall numbers of common carp collected during each run were deemed low (less than or equal to 18% estimated population in the study pond). For this reason, traps were baited with dry dog food in an effort to increase trapping efficacy. Dry dog food is one of the preferred sources of attractants (bait and chum) used for common carp (Carp Anglers Group, 2003). A nylon hose bag was filled with 654-g of dry dog food and placed near the center of two of each treatment and held to the bottom using a single steel ground staple. The dry dog food used had a composition equaling 21% crude protein, 12% moisture, 8% crude fat and 6% crude fiber. Of this dry dog food composition, the ten most prevalent ingredients include: ground yellow corn, wheat middlings, meat & bone meal, corn gluten, animal fat, calcium carbonate, salt, yeast, brewers dried grain and dried whey. After the first week, fish were harvested and bait was removed from these treatments. A fresh batch was then placed into each previously un-baited rep of the three treatments.

For the final two weeks (July 16th through July 30th) of the pond study, a drift fence constructed from 1.5-in mesh PVC-coated welded-wire was added to evaluate whether numbers being caught could be increased by guiding fish towards the traps. The first week it was attached to and ran the length of the six traps on the eastern side of the pond (total drift fence length was 90-m). Traps were checked, and then the drift fence was moved to the remaining six traps for one week.

On September 26th, 2007 the study pond was drained down to a manageable depth at which the contents could be counted without harm to fish. This final count accounted for 76 common carp and 1 Largemouth bass. Successful reproduction, in 2006, was deemed the reason for a higher population of carp than stocking rate and the bass had more than likely come from Lewisville Lake through the input pipes while adding lake water to the pond.

In addition to the pond study, a field test was set up in a man-made wetland located in southern Dallas, Texas. This wetland, known as Dallas Floodway Extension Cell D, is part of an ongoing habitat enhancement project by the United States Army Corps of Engineers for the city of Dallas, Texas. The floodway extension project and is located adjacent to Interstate highway 45 and Overton road in Dallas, TX. This location was chosen for the field study due to its close proximity to LAERF as well as having a visual confirmation of a population of common carp at an unknown density. Eight traps were built along the western shore of the wetland, four each of the most successful treatment in the pond study (ring cage), and four controls. The traps were constructed (identically to the pond study) along a depth contour of approximately 46-cm. The order of the traps was randomly selected using the numbers in a hat method. Each ring cage treatment was planted, in a cluster formation, with six nursery-grown potted (4-in diameter, nominal size) American pondweed plants. No baits (other than plants) or drift fences were tested in this trial. Following a 1 month period of construction and planting, sampling was begun. The same sampling techniques used in the LAERF pond study (removal of funnel, collection box and seine net device) were used here as well (Figure 17). This field study lasted for three weeks and consisted of three repetitions.

Figure 17. Data collection at Cell D in southern Dallas, TX.

CHAPTER 5

RESULTS AND DISCUSSION

Plants persisted in protected areas throughout this study. Pondweeds between the inner and outer walls of the dual-walled treatment showed one hundred percent coverage, with no signs of herbivory. Native macrophytes (growing inside the exclosure) within ring cage treatments also showed one hundred percent coverage rate with no noticeable herbivory. Control treatments proved efficient in deterring all plant growth.

Chi-square (X^2) goodness-of-fit analysis[1] was used in order to ascertain the normality of distributions of common carp caught within the three treatments tested within this study. This goodness-of-fit test is used when looking for differences in count/ enumerated data, which relates directly with the data in this study (i.e. the amount of common carp caught within different trap types). This test is a variance of Pearson's chi-square, and is used in order to determine if one distribution conforms to another. Chi-squared was chosen, in part, because this study needed to compare catch distributions between treatment types. Chi-square [$X^2 = \sum$ (observed data - expected data)^2 /expected data)] was used to compare differing parameters tested within common carp traps. The variables compared in this study include: ring cage, control and dual-walled using fingers; ring cage, control and dual-walled using flaps, ring cage, ring cage, control and dual-walled using bait as an attractant and ring cage, control and dual-walled using a drift fence in an attempt to guide common carp towards traps. All parameters were tested for normality and found to be non-normally distributed.

[1] Chi-square (X^2) goodness-of-fit analysis was deemed to be the most appropriate statistical test. There were three variables indicating the need for a 3X2 contingency test; as 2X2 statistical tests were not applicable, such as Yate's correction test for continuity and Kolmogorov-Smirnov goodness of fit.

Table 2. Common carp catch September 2006 through July 2007, RC: ring cage, C: control, DW: dual-walled.

DATE	RC 1	C 2	DW 3	RC 4	RC 5	C 6	C 7	DW 8	DW 9	RC 10	C 11	DW 12	COMMENTS
9/8/2006	0	0	0	0	0	9	0	0	0	0	0	0	using fingers
9/19/2006	0	0	0	0	0	0	1	0	0	0	0	0	using fingers
9/26/2006	0	0	0	0	0	1	0	0	0	0	0	0	using fingers
10/17/2006	0	0	0	0	0	0	0	0	0	0	0	0	using fingers
11/27/2006	0	1	0	0	0	0	1	0	0	0	0	0	using fingers
6/11/2007	0	0	0	0	0	0	1	0	0	0	0	0	using flaps
6/18/2007	1	0	1	0	0	0	0	0	0	2	0	0	using flaps
6/25/2007	0	0	0	0	0	0	0	0	0	0	0	0	using flaps
7/2/2007	0	0	0	0	0	0	1	0	0	1	0	0	first and third treatments baited
7/9/2007	1	0	0	0	0	0	0	0	0	0	0	0	second and fourth treatments baited
7/16/2007	1	0	0	2	0	0	0	0	0	0	0	0	drift fence on traps 1-6
7/23/2007	2	0	0	0	0	0	0	0	0	4	0	0	drift fence on traps 7-12

Funnels Using Steel Fingers

Data were collected once a week for five weeks from traps using funnels with steel fingers. At the end of this period, 13 common carp had been captured in control treatments and none in the ring cage or dual-walled treatments (Figure 18).

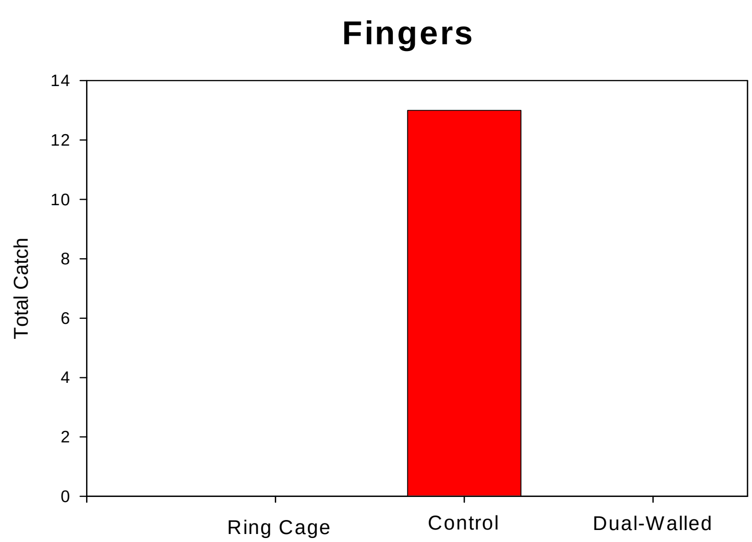

Figure 18. Total catch within control (13), ring cage (0), and dual-walled (0) treatments making use of steel fingers attached to funnel ends within common carp traps.

Using an alpha value of 0.05, chi-square analysis was run on these five repetitions to compare the effective difference between the three treatments (Table 3). The test showed a significant difference ($p = 0.0000022$), with control traps catching more fish than either of the two planted treatments. This indicated that plants were not attracting common carp, and why fish were captured by control traps was unclear. Since nine target fish out of thirteen were caught in a single run, and those were taken in a single trap, it could be explained by a group following a single lead fish into the trap. Males may have been chasing a female in an effort to spawn. It is conceivable that a female wanted to spawn over the geotextile fabric, or may have entered the trap in an attempt to elude the males. Also, sampling technique may have played a role. The control traps were the easiest to sample (no internal cages to deal with) and visually clearer (no disturbed substrates). The results may have indicated a better sampling success rather than greater efficacy by control traps.

Table 3. Chi-squared test for common carp trap with fingers ($\alpha = 0.05$).

	CONTROL	DUAL-WALLED	RING CAGE
OBSERVED FREQUENCY	13	0	0
EXPECTED FREQUENCY	4.333	4.333	4.333

OVERALL CHI-SQUARE	26.002
P-VALUE	0.0000022
DEGREES OF FREEDOM	2

Funnels Using Hinged Flaps

Data were collected once a week for three weeks using hinged flaps in place of the steel fingers. At the end of the three-week period one common carp was captured in the control and dual-walled treatments, while three were caught by the ring cage treatments (Figure 19).

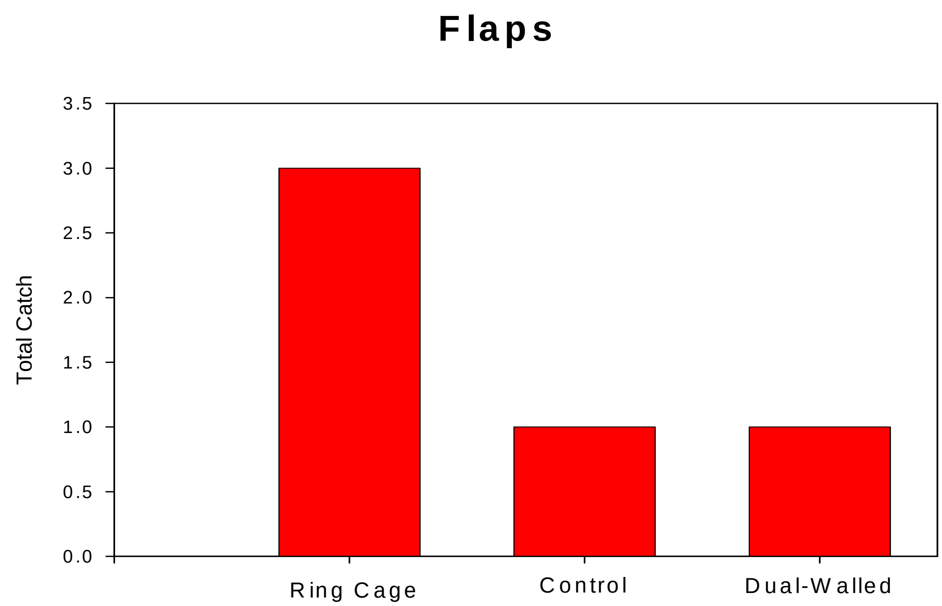

Figure 19. Total catch within control (1), ring cage (3), and dual-walled (1) treatments making use of a PVC-coated wire mesh flaps attached to funnel ends within common carp traps.

Using an alpha value of 0.05, chi-squared analysis was run on these three repetitions to compare the effective difference between the three treatments (Table 4). The test shows no significant difference ($p = 0.4493$) between the three treatments. The lack of significance could be explained by the common carp not having a strong enough incentive to enter one trap type over another. Potentially, food sources outside of the treatments could have been plentiful enough not to have to enter in search of a meal.

Table 4. Chi-squared test for common carp trap with flaps ($a = 0.05$).

	CONTROL	DUAL-WALLED	RING CAGE
OBSERVED FREQUENCY	1	1	3
EXPECTED FREQUENCY	1.667	1.667	1.667

OVERALL CHI-SQUARE	1.600
P-VALUE	0.449
DEGREES OF FREEDOM	2

Funnels Using Flaps and Baited

Data were collected once a week for two weeks while baiting half of each treatment with 454-g of dry dog food. Two common carp were captured within the ring cage non-baited treatment and a single fish in the control baited treatment, while no carp were caught within the dual-walled treatment type (Figure 20) during that period.

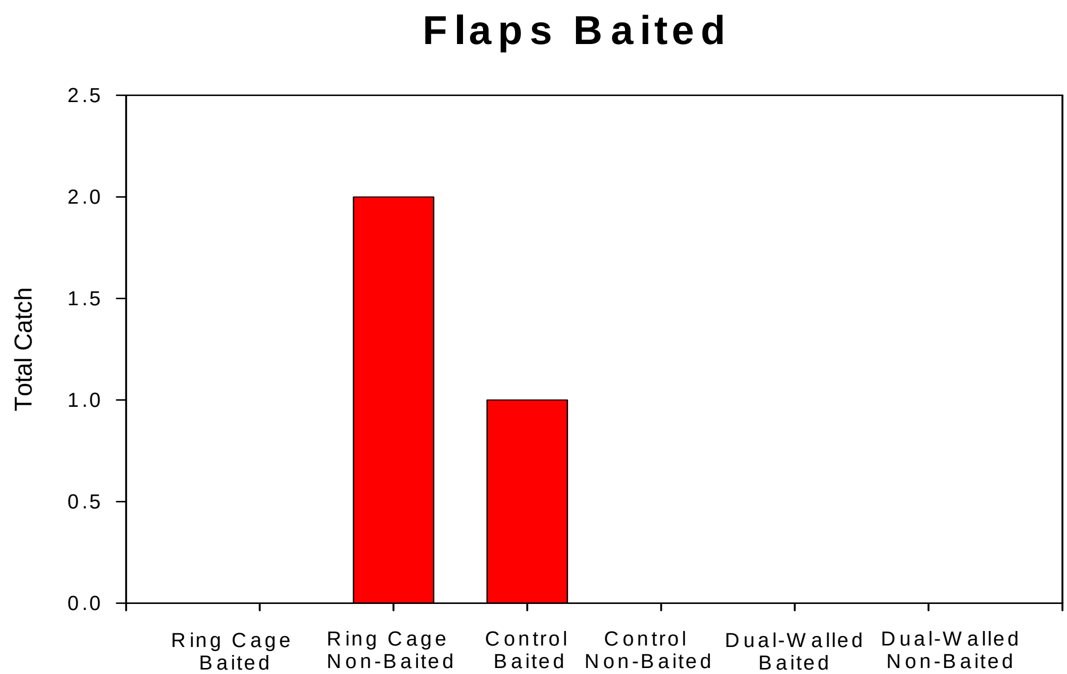

Figure 20. Total catch within baited and non-baited treatments, while also using flaps attached to funnel ends within common carp traps; ring cage non-baited (2), control baited (1) and none were captured within the other treatment types.

Using an alpha value of 0.05, chi-square analysis was run on the two repetitions to compare the effectiveness between the six treatments (Table 5). The test shows no significant difference ($p = 0.2206$). This outcome could possibly be explained by the common carp not being able to hone in on the specific source of the bait, since it had no effect upon capture rates. The lack of significance found is a bit confusing given the fact that common carp anglers tout dry dog food as an effective bait, as well as chum source (Carp Anglers Group, 2003). Capture appeared to remain a random event or triggered by some other factor not evaluated in this study.

Table 5. Chi-squared test for common carp traps baited vs. non-baited (a = 0.05).

	CB	C	DWB	DW	RCB	RC
OBSERVED FREQUENCY	1	0	0	0	0	2
EXPECTED FREQUENCY	0.5	0.5	0.5	0.5	0.5	0.5

OVERALL CHI-SQUARE 7.000
P-VALUE 0.2206
DEGREES OF FREEDOM 5

With the same statistical criteria, chi-square was used to evaluate each individual treatment type as well. Control baited versus control was run first (Table 6) and showed no significant difference between treatments (p = 0.3137).

Table 6. Chi-squared test for common carp traps control baited vs. control (a = 0.05).

	CB	C
OBSERVED FREQUENCY	1	0
EXPECTED FREQUENCY	0.5	0.5

OVERALL CHI-SQUARE 1.000
P-VALUE 0.3137
DEGREES OF FREEDOM 1

Dual-walled baited was then run against dual-walled treatment (Table 7). Since no target fish were captured at all there was no significant difference (p = 1.0000).

Table 7. Chi-squared test for common carp traps dual-walled baited vs. dual-walled (a = 0.05).

	DWB	DW
OBSERVED FREQUENCY	0	0
EXPECTED FREQUENCY	0	0

OVERALL CHI-SQUARE 0.000
P-VALUE 1.000
DEGREES OF FREEDOM 1

Lastly, ring cage baited was statistically compared to the ring cage treatment (Table 8). After running chi-squared analysis, there was determined to be no statistical difference (p = 0.1573) between the two treatment types. Once again, this low catch rate could be explained by the food not being a preferred source or not leaving a strong enough trail to be a worthy attractant. The only definitive conclusion that can be made is that baiting the traps, with dry dog food, had no positive impact on the overall effectiveness of this study.

Table 8. Chi-squared test for common carp traps ring cage baited vs. ring cage (a = 0.05).

	RCB	RC
OBSERVED FREQUENCY	0	2
EXPECTED FREQUENCY	1	1

OVERALL CHI-SQUARE	2.000
P-VALUE	0.1573
DEGREES OF FREEDOM	1

Funnels Using Flaps and a Drift Fence

Data were collected once a week for two weeks after installing a drift fence set to potentially direct common carp towards the funnel-side of one half of all traps, alternated at the end of the first week. At the end of the two weeks, nine common carp were captured (Figure 21). Treatments having ring cages were solely successful, with the ring cage with drift fence tallying a total of seven common carp while two were collected from ring cage treatments not having a drift fence attached. Not a single target fish was caught within the control or dual-walled treatments having or not having a drift fence attached.

Using an alpha value of 0.05, chi-squared analysis was run on the two repetitions to compare the effective difference between treatment types (Table 9). The test shows significant difference (p = 0.00008) between the treatments. This overall significance can be visually detected and attributed to the ring cage treatments having a drift fence attached. A total of six out of the seven common carp were trapped within ring cage treatments that were at bends in the drift fence. This finding lends credit to the idea that the angle of attachment of the drift fence to these specific traps could have resulted in directing the fish more effectively towards traps at the apex of the fence.

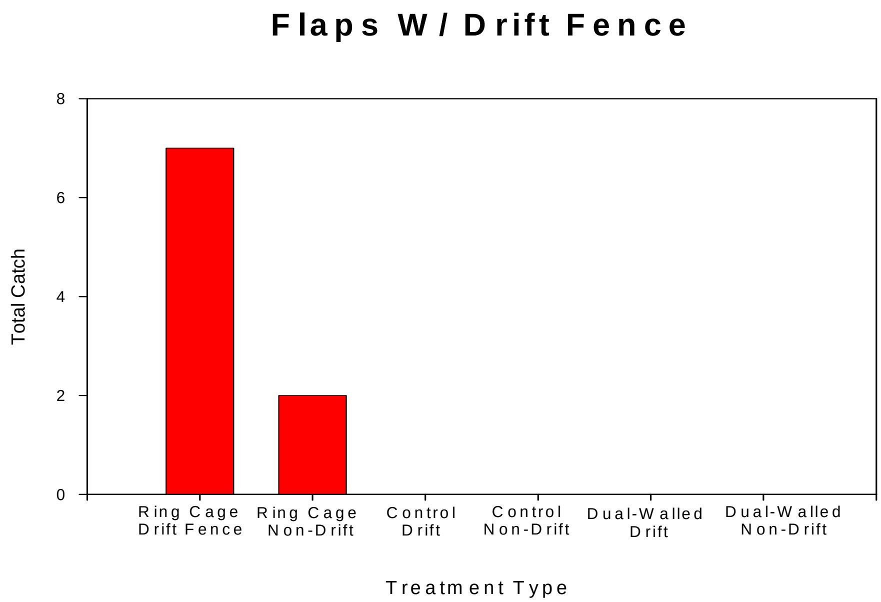

Figure 21. Total catch within control, ring cage, and dual-walled treatments making use flaps attached to funnel ends and having a drift fence attached to one half of all treatments for two weeks; ring cage with drift fence (7), ring cage without drift fence (2) and none were captured within the other treatment types.

Table 9. Chi-squared test for common carp traps using flaps and drift fence attached to half of the traps (a = 0.05).

	CDF	C	DWDF	DW	RCDF	RC
OBSERVED FREQUENCY	0	0	0	0	7	2
EXPECTED FREQUENCY	1.5	1.5	1.5	1.5	1.5	1.5

OVERALL CHI-SQUARE 26.334
P-VALUE 0.00008
DEGREES OF FREEDOM 5

The treatments were then broken down to control drift fence vs. control, dual-walled drift fence vs. dual-walled, and ring cage drift fence vs. ring cage. All were statistically compared using chi-squared and an alpha value of 0.05. The reps between control drift fence and control were compared first (Table 10) and since no target fish were captured within either, no significant difference could be determined.

Table 10. Chi-squared test for common carp traps using flaps and drift fence attached half of the traps, comparing control treatments (a = 0.05).

	CDF	C
OBSERVED FREQUENCY	0	0
EXPECTED FREQUENCY	0	0

OVERALL CHI-SQUARE	0.000
P-VALUE	1.000
DEGREES OF FREEDOM	1

Dual-walled drift fence was then compared to dual-walled using chi-squared analysis. As was the case with between the control treatments, no common carp were captured within the dual-walled treatments either. With this being the case, no statistical difference could be found ($p = 1.0000$) as shown in table 11.

Table 11. Chi-squared test for common carp traps using flaps and drift fence attached to half of the traps, comparing dual-walled treatments (a = 0.05).

	DWDF	DW
OBSERVED FREQUENCY	0	0
EXPECTED FREQUENCY	0	0

OVERALL CHI-SQUARE	0.000
P-VALUE	1.000
DEGREES OF FREEDOM	1

Ring cage treatments were the last to be compared during the use of drift fencing (Table 12). As previously mentioned, all nine total common carp were caught within this type of treatment, seven within a drift fence leading them towards the trap openings and two without. After running chi-squared analysis no significant difference could be inferred (p = 0.0954). However, visually studying the total catch data leads one to believe there is a meaningful difference. This difference could possibly be explained in stating that the drift fence simply allowed the target species to find entrance into the ring cage treatments most efficiently, possibly due to angle changes at the fence bends (where the vast majority of common carp were captured).

Table 12. Chi-squared test for common carp traps using flaps and drift fence attached to half of the traps, comparing ring cage treatments (a = 0.05).

	RCDF	RC
OBSERVED FREQUENCY	7	2
EXPECTED FREQUENCY	4.5	4.5

OVERALL CHI-SQUARE	2.778
P-VALUE	0.0954
DEGREES OF FREEDOM	1

In summary, the LAERF pond study included five sampling periods which made use of funnel fingers, three using funnel flaps, two using bait as an attractant and two utilizing a drift fence in an attempt to increase catch amounts of common carp within trap types. After statistical analysis (using chi-square goodness-of-fit), the results showed significance between treatments using fingers (due to catches within controls) and the use of a drift fence (ring cage treatments). No significant difference could be found among the treatments using flaps or when bait was used to attract common carp.

Following the pond study, a field study was set up in an artificial wetland located in the southern portion of Dallas, Texas. Control and ring cage treatments were installed at the site and three sampling periods were conducted. There was no statistical analysis run on this portion of the study since no common carp were captured within any trap treatment. Interestingly, the traps did show promise since they captured ten Red-eared slider turtles (*Trachemys scripta elegans*) over the sampling period (Appendix). This species of turtle has proven to be a substantial hindrance in the effort to establish founder colonies of native aquatic plants and any potential method to reduce their numbers, within a water body, could prove beneficial in future restoration efforts.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

This study's main objective was to develop and test a trap system which would reduce common carp (*Cyprinus carpio*) densities in the vicinities of native aquatic plant restoration efforts, which in turn could increase the growth and spread potential of native aquatic macrophytes. A pond study was conducted at the Lewisville Aquatic Ecosystem Research Facility, Lewisville, Texas to test devices designed to both capture common carp and protect founder colonies of native aquatic plants. Twelve traps were constructed in a study pond, with four replicates of each type: control, ring cage, and dual-walled. Common carp were introduced into the pond and data was collected periodically over two plant growing seasons.

The common carp traps were built using PVC-coated 2-in x 4-in (nominal size) mesh welded-wire supported by a T-post frame. Funnels were then constructed as an entry way into the traps; each was fitted with devices made from steel fingers and then later with a hinged flap to prevent escapes. Native aquatic plants, American and Illinois pondweed, were planted and protected within dual-walled and ring cage treatments to serve as founder colonies and bait for common carp. Controls were left unplanted. Additional tests using dry dog food as bait and installation of a drift fence to direct common carp into traps were tested as possible tools for increasing catch rates.

Upon completion of common carp trap tests within the LAERF study pond, a field study was constructed in order to further test these traps. The field study was performed within a wetland located within southern Dallas known to support a population of common carp. Ring cage treatments were deemed statistically more effective than the dual-walled treatments in the study pond and were logistically much simpler to construct, so these were tested and compared with unplanted controls. Four of each treatment was constructed at this site and sampling conducted on a weekly basis for a period of three weeks.

The presence of macrophytes in the traps did not appear to affect trapping rates of common carp in this study. The use of dry dog food as bait was ineffective at increasing common carp capture rates as well. Placements of bait near the outer portion of the trap wall (instead of the center of each trap) or nearer each funnel could prove beneficial. The use of different baits, such as dough type, corn, and commercial carp baits could be tested in future studies as well as attempting to use other types of native aquatic plants. I speculate that the common carp may not have actually been tempted by the type of attractants which were used and could actually have sought out benthic organisms as a food source. If this is the case, this behavior could explain why these traps were not as effective as it was originally hoped. More behavioral research and/or study is needed (including sight, scent and telemetry responses) to justify this possible theory.

One thought is to set up a controlled experiment which involves being able to study the feeding behavior of this fish type. A single or several potted aquatic plants could be placed within a fish raceway type enclosure. The "leafy" portion of the plant would be protected from consumption while allowing the carp access to the sediment and root matter. Another plant set could be set up protecting the benthic portions, but allowing the fish the ability to consume the leafy matter in order to compare feeding preferences.   A "Pavlov" type study is also recommended. Such a study would eliminate any food source other than what was being offered to the common carp. This action would get them to get used to this type of feed, eventually leading to this food source being used as bait within a pond study. The smaller scale study could be set up in a fenced off area of the larger pond.

Capture rates from the study pond were statistically compared using chi-squared analysis. This analysis showed that control treatments with funnel fingers, showed to be most effective, but was probably due to spawning activity. No effective difference was found among treatments using hinged flaps. The repetitions making use of a drift fence increased catches, especially within the ring cage treatments. Angles within the fence could help explain increases in capture rates only within those traps. More work using drift fences is recommended in finding ways to get common carp to enter traps. This could include testing specific angles as the drift fence attaches to the trap treatments, as well as evaluating if where the drift fence is joined to the traps could have an impact upon catch amounts.

Other limitations should be mentioned and possibly addressed in any future continuation of this study. Repetitions, of each of the three treatment types, could be increased within the pond study. This increase would increase the strength of any future statistical analysis conducted. The use of only one study pond could have been seen as a limiting factor in the statistical outcomes and should be increased for any future testing of common carp trapping.

Any further testing should also consider time of year with this type of study. The outcome could possibly be improved upon if sampling periods ran for an entire twelve month period. This increase in sampling period would cover the entire spring and fall spawning periods of common carp, which could be of help in understanding what role these activities play in the capture of this fish.

The inability to identify common carp which had previously been trapped was another limiting factor within this study. There was no way to tell if common carp which had been captured were ever recaptured or if they tended to avoid the traps after initial trapping. Tagging of first time captured common carp would account for the void in data not obtained during the initial study. Tagging methods could include notching a fin upon initial trapping or actually tagging/banding a fin. All aforementioned limitations and recommendations should be considered for any future pond and/or field studies which address trapping of common carp.

Lastly, I would like to include a few more recommendations to possibly enhance future research. I feel more work with water level fluctuations could have a positive benefit. Sampling could be added into a time period where water levels are increased from what was used in the LAERF pond study. Several new levels could be undertaken and statistically analyzed against one another. Knowing better what depths to set the water level above the funnels could be beneficial. Also, new funnel designs should be created and experimented with in order to improve the prospect of future success in trapping of common carp. Such modifications might include turning funnels on their sides; this change would make the openings narrower but taller, which could possibly enhance trapping effect.

Other ideas for future consideration might include reducing littoral zone vegetation as well as attempting to reduce turbidity within the study pond. A reduction in littoral vegetation could be accomplished through periodic herbicide treatments, which would reduce the amount of vegetative food source available to the common carp. This in turn could lead to a better understanding of any significance possibly gained by using aquatic vegetation as an attractant within planted traps. A better visual analysis would be quite beneficial in any future study as well. Turbidity proved a deterrent in any effort to visually identify any common carp which were left, within any trap, after netting or seine fencing was employed to free any trapped fish. LAERF has a concrete lined pond which could be used in any future study that might allow for increased clarity and perhaps more precise data collection.

Testing of common carp traps within an actual lake is a future scenario worthy of mention. Several traps would have to be created and implemented at any given site. These traps would presumably be constructed from the same materials used in the above study, though difficulties not experienced in the LAERF pond study nor the field study would need to be addressed. Fluctuations of water levels and potential damage from floating debris and/or from human influences are the two main difficulties foreseen.

In order to get around issues involving water level fluctuations, two rows of traps could be set up one at a predetermined depth and another set deeper or shallower depending upon typical fluctuation data. This would allow for at least one set of traps to be operational in most foreseeable events. Trap damage by floating debris and/or human activity could be addressed by implementing a frequent monitoring system (personal) where damage traps would be reported for repair in between sampling periods if necessary.

APPENDIX

TYPED DATA SHEETS OF TURTLE CATCH WITHIN POND STUDY AND FIELD STUDIES FROM SEPTEMBER 8, 2006 THROUGH OCTOBER 15, 2007

LAERF Pond study turtle catch.

Trap #	1	2	3	4	5	6	7	8	9	10	11	12	Comments
Date	*RC*	*C*	*DW*	*RC*	*RC*	*C*	*C*	*DW*	*DW*	*RC*	*C*	*DW*	
9/8/2006	0	0	0	0	0	0	0	0	0	0	0	0	FINGERS
9/19/2006	0	1	0	0	0	0	2	0	1	0	1	1	FINGERS
9/26/2006	0	0	0	1	0	0	1	0	0	5	0	0	FINGERS
10/17/2006	0	0	0	0	2	1	0	0	0	5	3	0	FINGERS
11/27/2006	0	0	0	0	0	1	1	0	0	3	0	0	FINGERS
6/11/2007	0	0	0	0	0	0	0	0	0	1	0	0	FLAPS
6/18/2007	1	0	0	0	0	0	0	0	0	0	0	0	FLAPS
6/25/2007	0	1	1	0	0	0	0	0	0	0	0	0	FLAPS
7/2/2007	1	0	0	0	0	0	0	0	0	0	0	0	1,2,3,4,6,8 BAITED
7/9/2007	0	0	1	0	1	0	0	0	0	0	0	0	5,7,9,10,11,12 BAITED
7/16/2007	0	1	1	1	0	0	0	0	0	0	0	1	1-6 DRIFT FENCE
7/23/2007	0	1	0	1	0	0	0	0	0	2	1	0	7-12 DRIFT FENCE

DFE Cell D field study turtle catch.

Trap #	1	2	3	4	5	6	7	8
Date	*RC*	*C*	*RC*	*RC*	*C*	*C*	*RC*	*C*
10/1/2007	1	0	0	0	0	0	1	0
10/8/2007	0	1	0	0	1	0	2	0
10/15/2007	1	1	0	0	0	0	0	0

REFERENCES

Australian Inland Fisheries Service. 2004. Carp Management Program <http://www.ifc.tas.gov.au/carpup.html>. Accessed 2005 November 22.

Bonneau, J., D. Scarnecchia, and E. Berard. North Dakota Outdoors. 1995. Less Carping at Bowman-Haley Reservoir <http://www.und.nodak.edu/org/ndwild/carp.html>. Accessed 2005 November 22.

Carp Anglers group Forum. 2003. Cat/Dog Food as Bait? <http://www.carpanglersgroup.com/forum/lofiversion/index.php?t2672.html>. Accessed 2008 January 29.

Chick, J.H. and M. Pegg. Illinois-Indiana Sea Grant. 2002. Sea Grant Research Shows Electric Barrier May Stop Asian Carp <http://www.scienceblog.com/community/older/2002/D/20024331.html >. Accessed 2005 December 2.

Crivelli, A.J., 1981. The Biology of the Common Carp, *Cyprinus carpio* L. in the Camargue, Southern France Journal of Fish Biology 18(3): 271-290.

CSIRO Marine Research and Murray-Darling Basin Commission. 2002. Carp Management in the Murray Darling Basin: Daughterless Carp Technology <http://www.marine.csiro.au/LeafletsFolder/pdfsheets/Daughterless_carp_13may02.pdf> Accessed 2006 March 24.

Curtin, C.B. McGraw-Hill Access Science. 2001. Carp <http://www.accessscience.com>. DOI 10.1036/1097-8542.110800. Accessed 2005 December 2.

Diggle, J. 2005. Inland Fisheries Service Annual Report 2004-05 Tasmania Inland Fisheries Service. p.1-37.

Doyle, R.D., R.M. Smart, and K. Bickel. 1997. Establishment of Native Aquatic Plants for Fish Habitat: Test Plantings in Two North Texas Reservoirs Journal of Lake and Reservoir Management 13(3): 259-269.

Dunham, R.A., N. Chatakondi, A. Nichols, T.T. Chen, D.A. Powers, and H. Kucuktas. 2002. Survival of F2 Transgenic Common Carp (Cyprinus carpio) Containing pRSVrtGH1 Complementary DNA When Subjected to Low Dissolved Oxygen Journal of Marine Biotechnology 4(3): 323-327.

Environmental Protection Agency. 2006. Great Lakes Contaminated Sediments <http://www.epa.gov/glnpo/sediments.html>. Accessed 2006 March 24.

Graham, K.J., Lowry, M.B. and Walford, T.R. 2005. Carp in NSW: Assessment of Distribution, Fishery and Fishing Methods NSW Department of Primary Industries – Fisheries Final Report, Series No. 72, p. 88.

Kelly, K., 2003. Investigations into the Application of Australian Methods for the Control and Management of Carp (*Cyprinus carpio*) in New Zealand Environment Waikato Technical Report TR04/03. p. 45.

Koehn, J. D. 2004. Carp (*Cyprinus carpio*) as a Powerful Invader in Australian Waterways Journal of Freshwater Biology, 49:882-894.

Lowry, M.B., B.C. Pease, K. Graham, and T.R. Walford. 2005. Reducing the Mortality of Freshwater Turtles in Commercial Fish Traps Aquatic Conservation: Marine and Freshwater Ecosystems 15: 7-21.

Miller, S.A. and T.A. Crowl. 2006. Effects of Common Carp (*Cyprinus carpio*) on Macrophytes and Invertebrate Communities in a Shallow Lake Journal of Freshwater Biology 51(1): 85-94.

Murdock, G. Bell Museum of Natural History. 2004. Invasive Carp Threaten Native Species, Boaters <http://bellmuseum.org/invasive_carp.html>. Accessed 2005 December 2.

National Sea Grant and Geographic Education Alliances. 1999. <http://iisgcp.org/EXOTICSP/carp/htm>. Accessed 2005 December 2.

Parliament of Australia Senate Committee. 2004. Inquiry into the Regulation, Control and Management of Invasive Species and the Environment Protection and Biodiversity Conservation Amendment (Invasive Species) Bill Chapter 4 <http://www.aph.gov.au/senate/committee/ecita_ctte/invasive_species/report/c04.htm>. Accessed 2006 March 24.

Parliament of South Australia. 2004. Examination of Lock and Weir No. 9 Official Hansard Report. House Of Assembly Public works Committee. p. 1-11.

Pinto, L., N. Chandrasena, J. Pera, P. Hawkins, D. Eccles, and R. Sim. 2005. Managing Invasive Carp (Cyprinus carpio L.) for Habitat Enhancement at Botany Wetlands, Australia Aquatic Conservation: Marine and Freshwater Ecosystems 15: 447-462.

Pipalova, I. 2002. Initial Impact of Low Stocking Density of Grass Carp on Aquatic Macrophytes Journal of Aquatic Botany 73(1): 9-18.

Royal Botanical Gardens. 2004. The Fishway <http://www.rbg.ca/pages/visit_fishway.html>. Accessed 2006 April 6.

Smart, R.M., G.O. Dick, and R.D. Doyle, 1998. Techniques for Establishing Native Aquatic Plants Journal of Aquatic Plant Management 36:44-49.

Smart, R.M., J.D. Madsen, J.R. Snow, G.O. Dick, and D.R. Honnell. 1995. Physical and Environmental Characteristics of Experimental Ponds at Lewisville Aquatic Ecosystem Research Facility Miscellaneous Paper A-95-2, U.S. Army Engineer Research and Development Center, Vicksburg, MS. p. 1-21.

Smart, R.M., R.D. Doyle, J.D. Madsen, and G.O. Dick, 1996. Establishing Native Submersed Aquatic Plant Communities for Fish Habitat American Fisheries Society Symposium, 16:347-356.

Steiner, L. 2000. Pennsylvania Fishes. Pennsylvania: Pennsylvania Fish and Boat Commission. 170pp.

USGS – Upper Midwest Environmental Sciences Center. 2005. Asian Carp <http://www.umesc.usgs.gov/invasive_species/asian_carp.html>. Accessed 2005 December 2.

Wang, J.C. 1986. Fishes of the Sacramento-San Joaquin Estuary and Adjacent Waters, California: A Guide to Early Life Histories California Department of Water Resources, California Department of Fish and Game, U.S. Bureau of Reclamation, and U.S. Fish and Wildlife Service, Technical Report 9 (FS/B10-4ATR 86-9). P. 806.

Webb, L. and T. Morrisson. McMaster University. 2004. Common Carp in Hamilton Harbor < http://www.science.mcmaster.ca/Biology/Harbour/CARP/CARP.HTM>. Accessed 2005 November 10.

Wilcox, D. U.S. Army Corps of Engineers, St. Paul District. Minnesota. Invading Asian Carp Pose Unusual Threat <http://hq.usace.army.mil/cepa/pubs/may04/story9.htm>. Accessed 2005 December 2.

Yahoo News. 2005. Czech Carp Competes for a Place at the Christmas Table <http://news.yahoo.com/s/afp/20051222/1f_afp/afplifestyleczech_05.htm>. Accessed 2005 December 23.

Zar, J. 1999. Biostatistical Analysis Fourth Edition. New Jersey: Prentice Hall. 663pp.