

A pilot project for designing a novel fish barrier to deter movement of carp between lakes

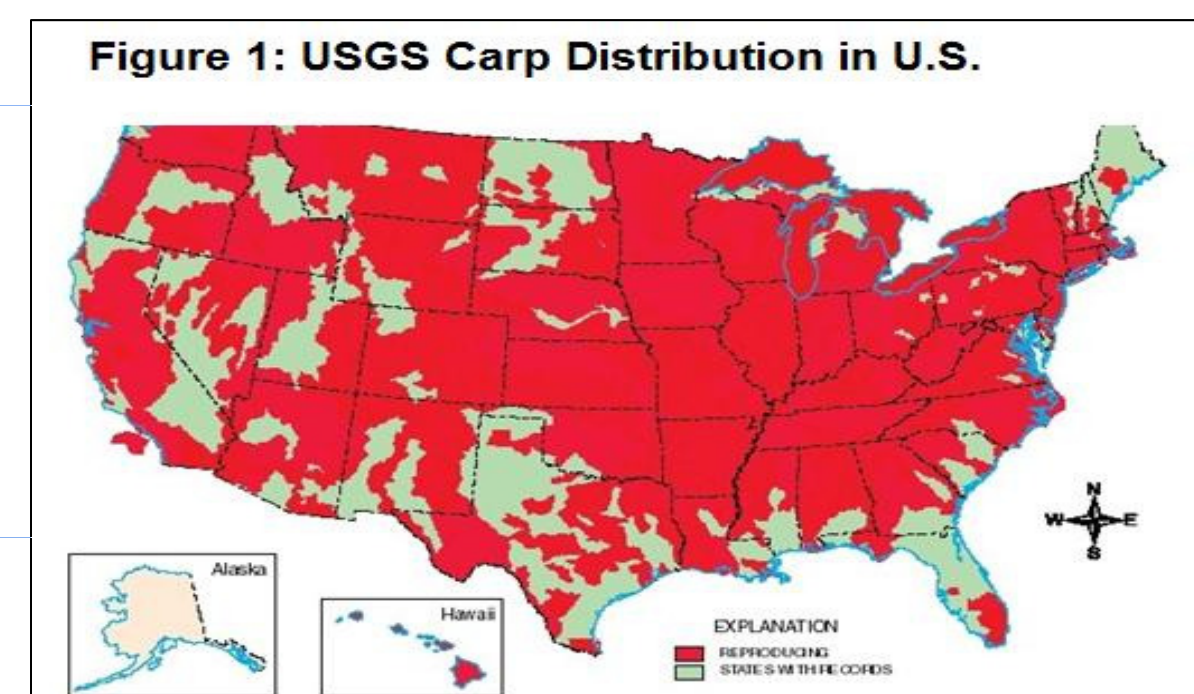
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Introduction

The common carp, *Cyprinus carpio L.*, is among the most invasive freshwater fish. It has been dispersed to every inhabited continent, with serious ecological, economic, and social impacts on natural systems [6,3]. Common carp (hereafter 'carp') originate from Eurasia and were introduced and stocked in the United States as a food source in the late 1800s at the request of the U.S. Fish Commission. Fisheries have been inundated with carp due to their ability to carry over a million eggs, spawn multiple times per year, migrate between interconnected water bodies, and inhabit polluted and unpolluted freshwater systems [1].

Carp are now prevalent in the Midwest [7,8,5] as a result of their ability to migrate between lakes that are suitable for overwintering and shallower lakes used as spawning and nursery habitats [1]. Their proliferation can be controlled at the links between these lake systems.

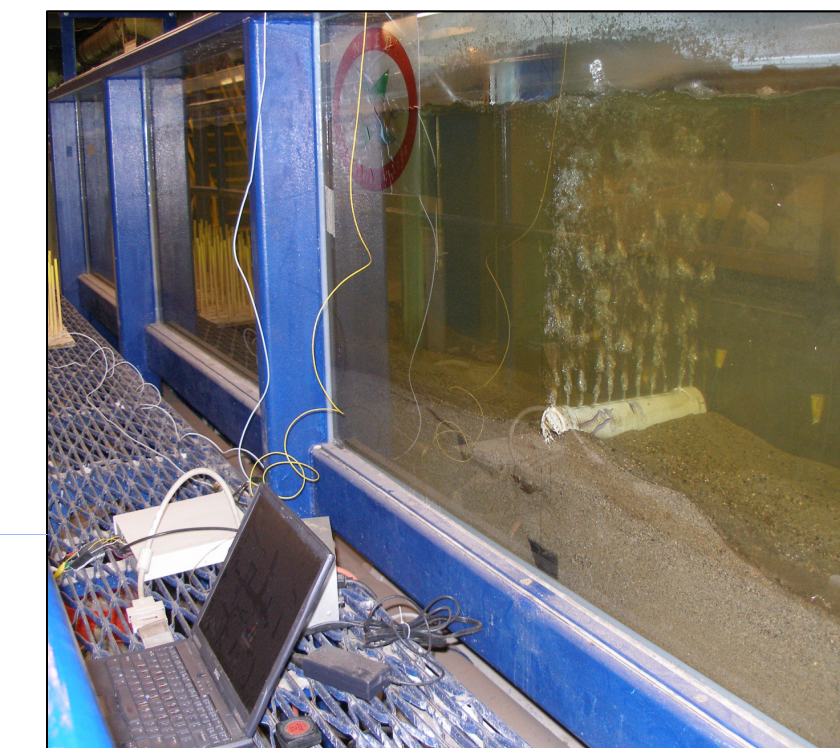
The intent of this project is to conduct flume studies aimed at designing and testing a novel fish barrier capable of limiting carp movement, therefore reducing carp abundance and the negative effects associated with their presence.



Project Goals and Details

Overall Goals

- 1) Construct a simple forced air bubble curtain in a flume comprised of readily available materials.
- 2) Utilize sound recording equipment to measure the acoustical output of the bubble curtain.
- 3) Perform a cursory analysis of the acoustical output to infer if sound is detectable by carp.
- 4) Perform a rudimentary behavioral study to observe juvenile carp's response to the bubble curtain. Report on barrier effectiveness.



Sound recording set-up



Juvenile carp tested

Project Details

- Bubble curtain constructed out of PVC pipe with forced air controlled by an air pressure gage.
- 3-D sound measurements recorded with a hydrophone at St. Anthony Falls Lab.
- Behavioral studies on juvenile carp conducted at University of Minnesota's Aquaculture Center.
- Barrier effectiveness reported based on number of fish crossing barrier location with barrier off versus on. Each trial conducted for two hours and included five fish.

Acoustic Measurements

3-D measurements of sound generated from a bubble curtain were recorded. A submersible hydrophone connected to a data acquisition card converted the disturbance of sound pressure and particle velocity generated from the bubble curtain to a digital signal. A Fast Fourier Transform analysis converted the time domain signal to a frequency domain signal with a minimum resolution of 2 Hz and a frequency range set within the spectrum of carp hearing. Fish should be able to hear sounds 20 to 30 decibels above background levels [4], which is most distinct nearest the barrier location. Recorded frequencies were found to be within the critical range of carp (300 to 500 Hz). Reference decibel calculations were based on maximum Power Spectral Density (PSD) values recorded at the exact locations when the barrier was off and on.

Figure 4 – dB values when Barrier is On

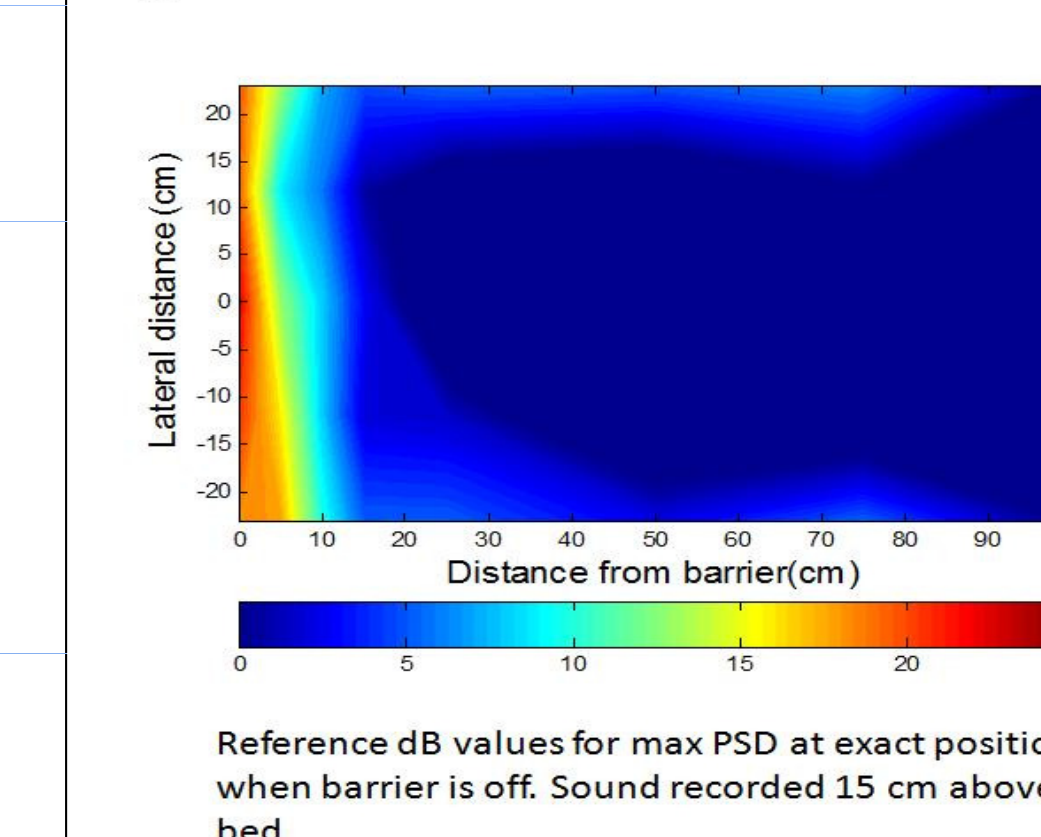
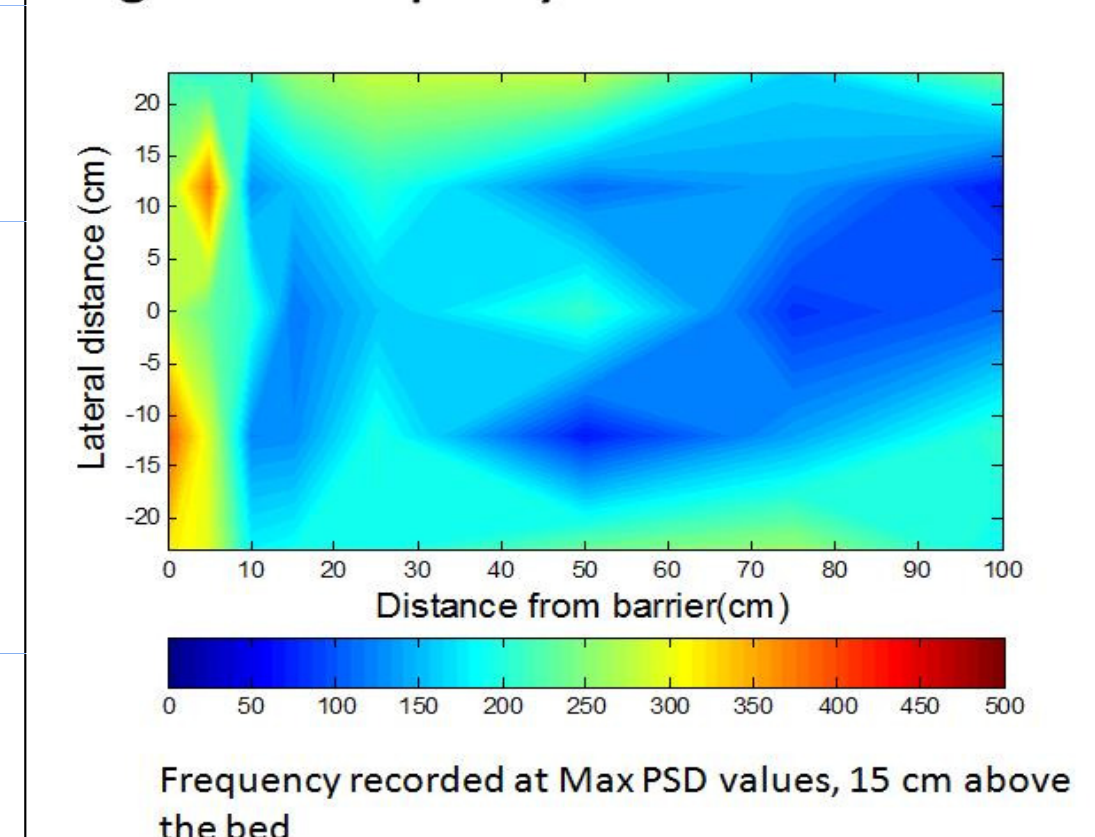


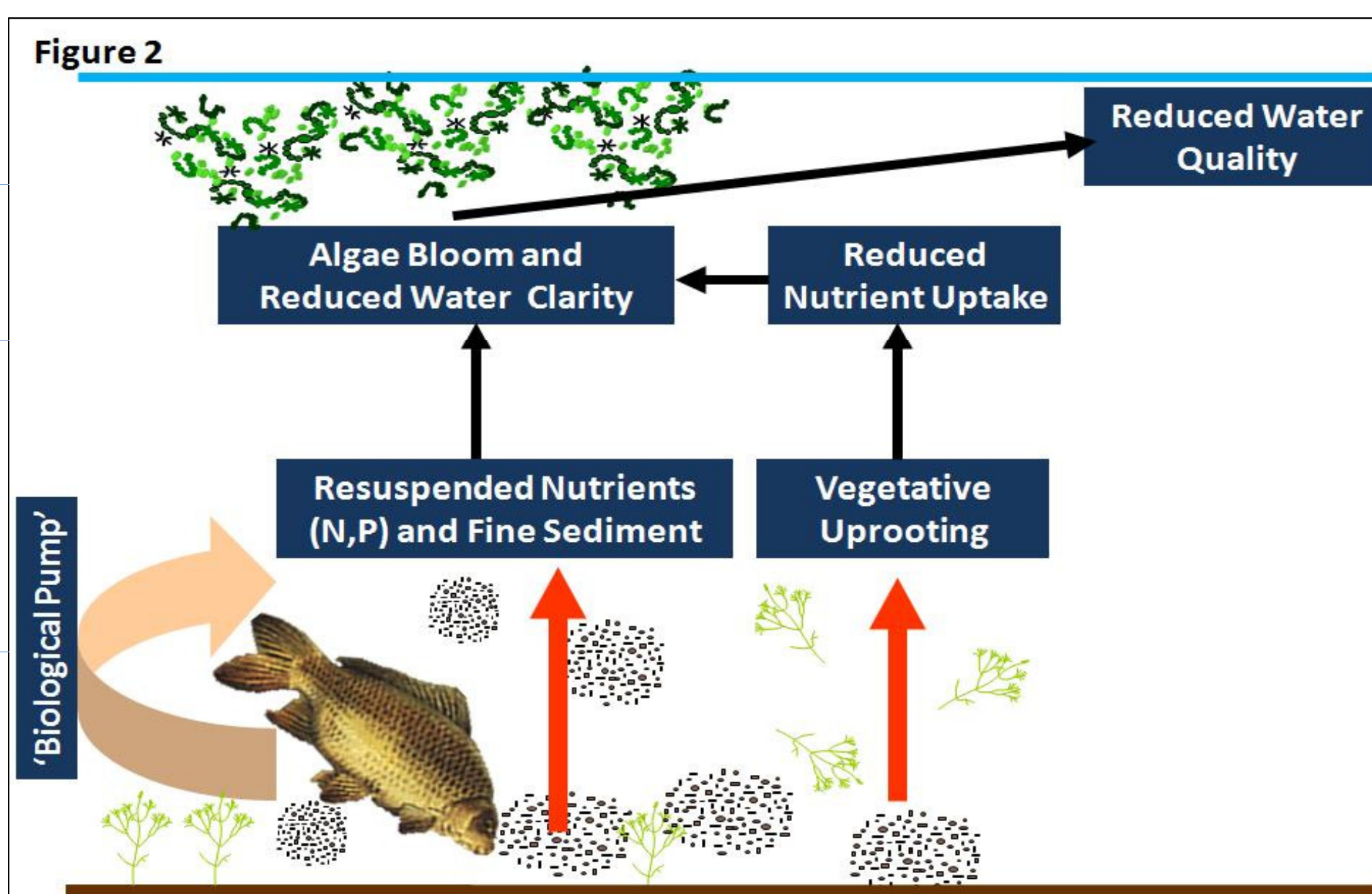
Figure 5 – Frequency when Barrier is On



Water Quality Effects

The need for carp management is spurred by the damaging effects on water quality, aquatic plant communities, and spawning and nursery areas for native fish. Their benthic feeding behavior results in the removal of rooted vegetation and increases turbidity and internal phosphorous loading as depicted in Figure 2 [10].

The relationship between carp presence and environmental degradation to lake ecosystems is alarming. For example, Bajer et al's 2009 study of two newly restored Midwestern lakes found that a carp biomass density of 100 kg/ha (well below common densities in Midwestern lakes) reduced vegetative cover and waterfowl population numbers by 50%. Therefore, for restoration efforts it is essential to prioritize carp management.

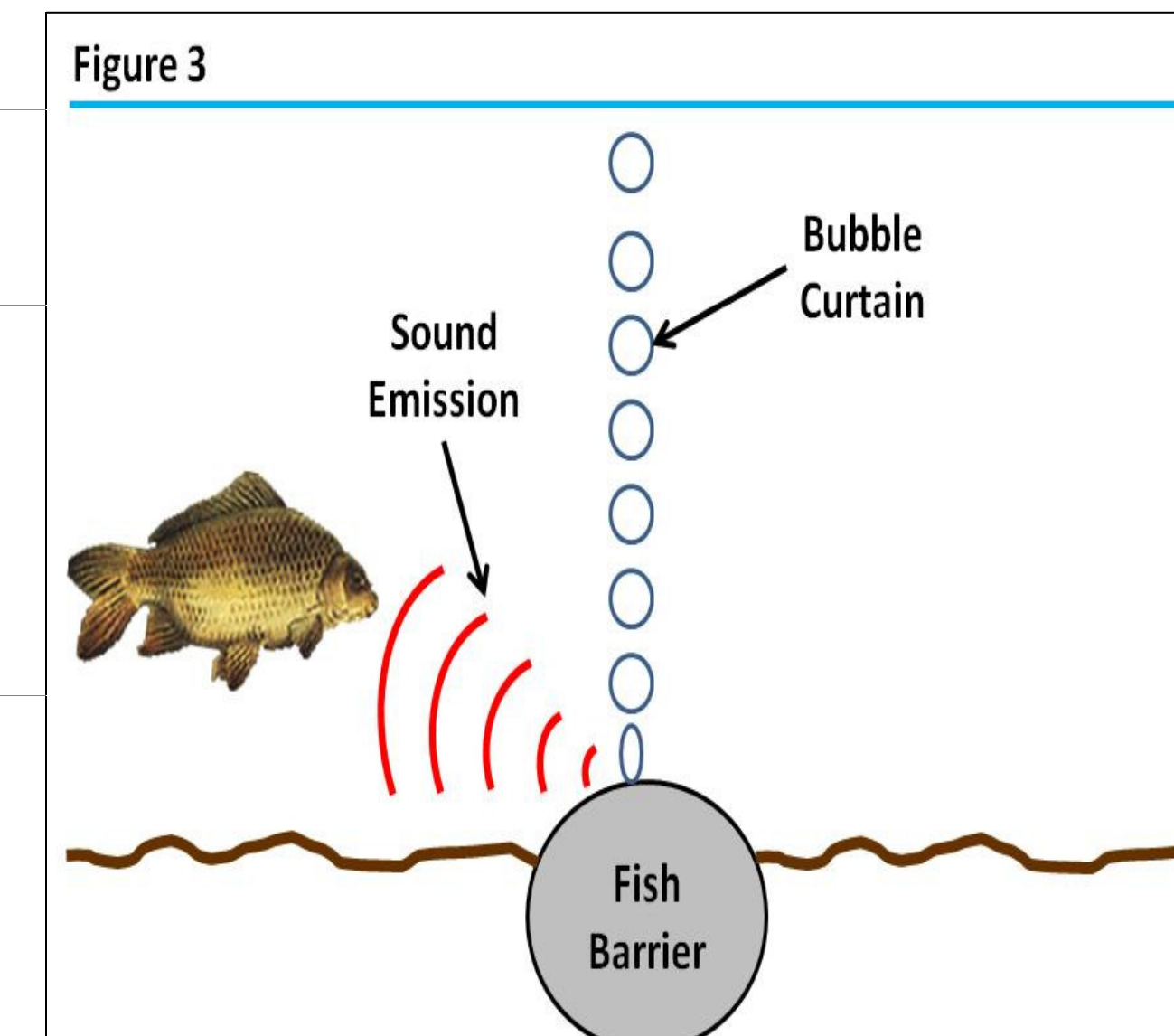


Targeting a Sensory System

Carp are considered *hearing specialists* when compared to many Midwestern fish (e.g. northern pike and sunfish) that are classified as hearing generalists. Hearing specialists have an enhanced auditory system capable of detecting and localizing sound at lower auditory levels and have the ability to detect sound within a broader frequency range. This ability is most likely related to the presence of the Weberian ossicles which connects the swim bladder to the inner ear [9]. This connection enhances sound pressure detection, one of the two main components of a sound signal. The other property, disturbance of the hydrodynamic field, is detected by the stimulus of the lateral line.

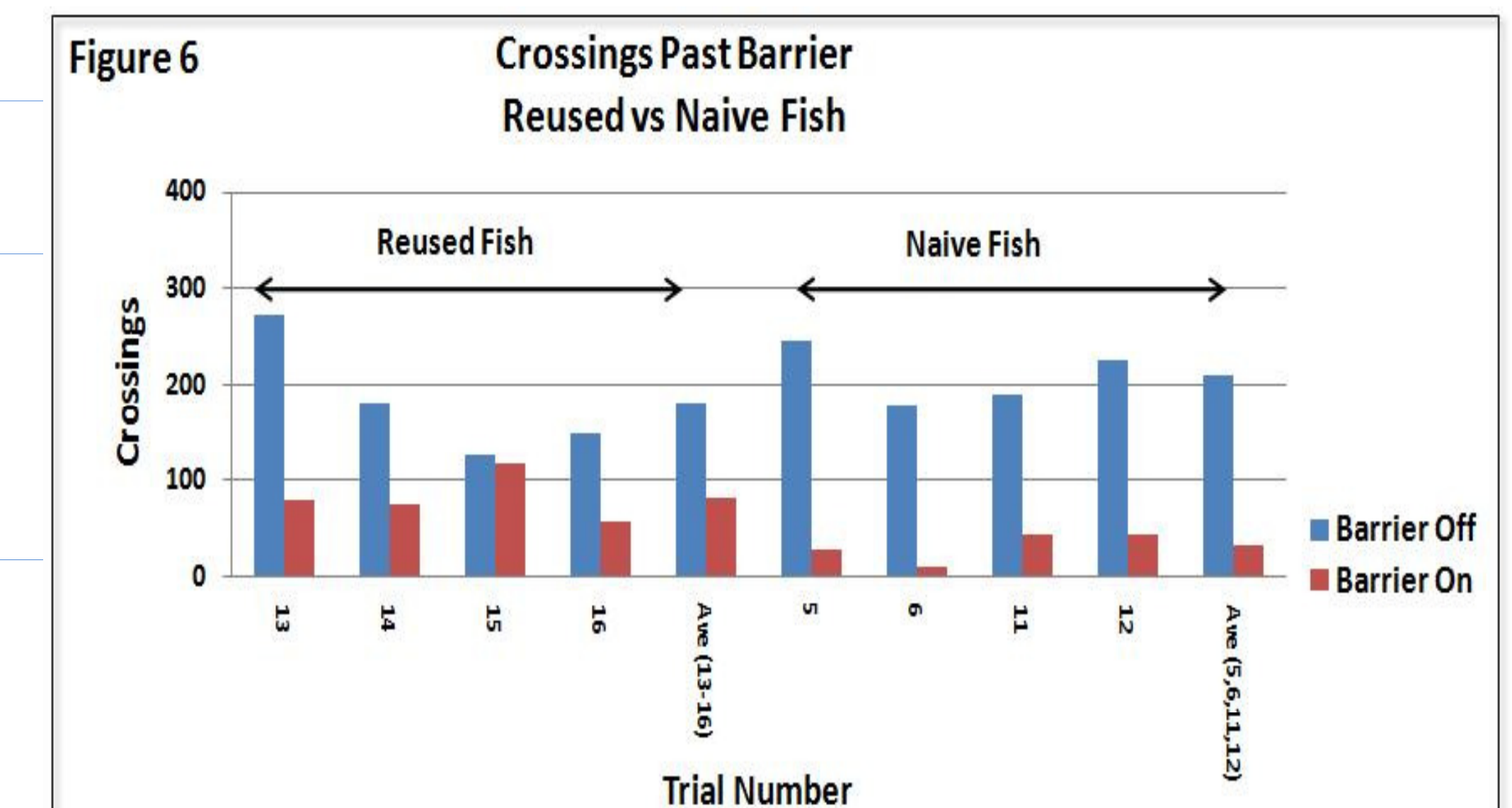
Since carp are hearing sensitive, it is reasonable to design a barrier that targets their auditory sensory system. This design could therefore be species-specific by deterring carp and allowing passage of other species insensitive to a certain auditory range.

The idea of investigating the effectiveness of a simple forced air bubble curtain was proposed because bubble curtains are well known for producing sound. Furthermore, construction and field installation could be simple and economically feasible. Bubble curtains may also be effective for triggering a response from other sensory systems, (e.g. sight and touch).



Behavioral Study

Experiments were conducted to test barrier effectiveness and determine the desired location of fish within the flume. Approximately 100 juvenile fish were subjected to a two row barrier under nocturnal conditions. An infrared sensitive video camera monitored the movement of fish within the flume. In separate trials, both naive and reused fish were tested. On average the barrier was **85% effective for naive** and **50% effective for reused** fish. In addition to tracking the flux of fish passing across the barrier, the position of each fish was monitored as a way to hypothesize if sound or other disturbances may have contributed to the observed behavior. Interestingly, it was found that carp congregated closer to the bubble curtain when the barrier was on. This may indicate that other carp sensory mechanisms (e.g. lateral line) or properties of the bubble curtain (e.g. recirculation current) are playing a role in barrier performance.



References

1. Bajer P. G. and P. Sorensen. 2009. Recruitment and Abundance of an Invasive Fish, the Common Carp, is Driven by its Propensity to Invade and Reproduce in Basins that Experience Winter-time Hypoxia in Interconnected Lakes. *Biol. Invasions*.
2. Bajer P. G., G. Sullivan and P. Sorensen. 2009. Effects of a Rapidly Increasing Population of Common Carp on Vegetative Cover and Waterfowl in a Recently Restored Midwestern Shallow Lake. *Hydrobiologia*, 632:235-245.
3. Fletcher A., A. Morison and D. Hume. 1985. Effects of Carp, *Cyprinus carpio L.*, on Communities of Aquatic Vegetation and Turbidity of Waterbodies in the Lower Goulburn River Basin. *Australian Journal of Marine and Freshwater Research*, 36:311-327.
4. Higgs D.M., L.Zhongmin, D.A. Mann. 2006. Hearing and Mechanoreception. In *The Physiology of Fishes*. (ed. Evans, D.H. and J.B. Claiborne). Boca Raton, FL, 3rd ed. 389-428.
5. Koehn J.D. 2004. Carp (*Cyprinus carpio*) as a Powerful Invader in Australian Waters. *Freshwater Biology*, 49:882-894.
6. McCrimmon H. 1968. Carp in Canada. *Bulletin of the Fisheries Research Board of Canada*, 165:1-93.
7. Neess J.C., W.Helm, and C. Threinen. 1957. Some Vital Statistics in a Heavily Exploited Population of Carp. *J Wild Manager*, 21:279-292.
8. Panek F.M. 1987. Biology and Ecology of Carp. In: Cooper E.L. (ed) *Carp in North America*. American Fisheries Society, Bethesda.
9. Popper A.N. 1972. Pure Tone Auditory Thresholds for the Carp, *Cyprinus carpio*. *Journal of the Acoustical Society of America*, 52(6) Part 2, 1714-1717.
10. Shapiro J.C. and D. Wright. 1984. Lake restoration by biomanipulation: Round Lake, Minnesota, the first two years. *Freshwater Biology*, 14: 371-383.
11. Sorensen, P.W. 2006. Biology and Management of the Common Carp. Minnesota Valley Wildlife Refuge. Bloomington, Minnesota.

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