Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2014 Work Plan

Date of Report: 1/15/2014

Date of Next Status Update Report: 1/15/2015

Date of Work Plan Approval:

Project Completion Date: 6/30/2017

Does this submission include an amendment request? No

PROJECT TITLE: Bioacoustics to Detect, Deter, and eliminate Silver Carp

Project Manager: Allen F. Mensinger

Organization: University of Minnesota Duluth

Mailing Address: Biology Department, 1035 Kirby Drive

City/State/Zip Code: Duluth, MN 55812

Telephone Number: (218) 726-7259

Email Address: amensing@d.umn.edu

Web Address: www.d.umn.edu/biology

Location: Statewide

Total ENRTF Project Budget:		
	ENRTF Appropriation:	**$262,000**
	Amount Spent:	**$0**
	Balance:	**$262,000**

Legal Citation: M.L. 2014, Chp. 226, Sec. 2, Subd. 04b

Appropriation Language:
$262,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota-Duluth to develop bioacoustic technology for detection and early warning systems, capture and elimination methods, and deterrent systems for silver carp. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

I. PROJECT TITLE: Bioacoustics to detect, deter and eliminate flying carp

II. PROJECT STATEMENT:

The Asian silver carp, one of four invasive carp species, is migrating north via the Mississippi River and threatening native fish in Minnesota rivers and lakes by outcompeting them for food supplies. Additionally, its unique jumping ability places recreational boaters in danger of being injured during collisions with airborne fish. However, this jumping ability is a weakness that can be exploited to detect, manage and control fish populations. The goals of this project are:

1) use the sound that stimulates jumping to develop early warning and detection systems

2) develop management techniques using sound to exhaust the fish on the surface or to herd the fish into shallow waters for capture and removal

3) use sound to deter or repel fish from moving through strategic waterways

In the previous year, we have made two significant findings: 1) determined the sound that initiates jumping in wild silver carp in the Illinois River; 2) successfully used this sound to repel carp in experimental outdoor ponds at the USGS Upper Midwest Environmental Science Center (UMESC) in LaCrosse, Wisconsin. This proposal would allow us to develop bioacoustic (sound) technology to combat the silver carp. The most effective sound that influences carp behavior is of relatively high frequency and is outside the hearing range of most native and game fishes. Our first goal is to develop remotely operated buoys with underwater speakers and above water video cameras to stimulate carp jumping to ascertain if an early detection or identification system can be developed. Our second goal is to develop a mobile sound system to stimulate continuous jumping for exhausting the fish on the surface and/or use sound to herd the fish into shallow water or nets for easy capture. Finally, we will test the efficacy of using sound to repel carp from specific areas. All the proposed studies will take place in large, secured (caged) outdoor experimental ponds at the USGS UMESC in LaCrosse, Wisconsin or on populations of wild carp in the Illinois River near Havana, IL. Both sites provide access to fish in outdoor locations where they behave naturally, allow large scale trials that cannot be replicated in indoor facilities and pose no danger of silver carp being released in MN waters.

III. PROJECT STATUS UPDATES:

Project Status as of 1/15/2015:

Project Status as of 7/15/2015*:*

Project Status as of 1/15/2016:

Project Status as of 7/15/2016:

Project Status as of 1/15/2017:

Overall Project Outcomes and Results:

IV. PROJECT ACTIVITIES AND OUTCOMES:

Activity 1: Early warning and detection system development
Description:

One of the challenges in assessing the silver carp invasion is to accurately census the population and to identify the vanguard of new invasion fronts. Carp have been documented to avoid traps and nets which make using traditional fisheries census techniques challenging. Although environmental DNA analysis can confirm the presence of carp DNA at low concentrations in the water, it cannot pinpoint the source of the DNA (ie live carp v

vs bird fecal material) or the number and age of the carp. The silver's carp unique jumping ability could be used to develop early warning systems by stimulating the carp to jump and determine the number and composition of the population in the area. Preliminary trials have indicated that individual carp can be stimulated to jump and they do not have to occur in high densities to exhibit this behavior. Therefore, detection systems could be used both to census established populations as well as early warning systems when small numbers of carp first enter an area.

Silver carp of different size and age classes will be maintained in large, secured outdoor tanks at the UMESC facility in Lacrosse, WI which has a captive silver carp population. The carp are viewed remotely with overhead cameras to monitor their normal swimming patterns and their response to sound and/or vibrational stimulus. Underwater speakers will be mounted throughout the tanks and the carp response to complex sound, primarily underwater recordings of boat motor sound will be played through the speakers. The swimming and jumping behavior of the carp will be observed in response to sound stimulus. Preliminary trials have shown that silver carp will rapidly swim away from this type of sound. Other fish behavior such as jumping and schooling will be noted. Various sound frequencies and intensities will be tested to determine the optimal sound that causes the fish to move away from the sound source. As fish behavior is related to age (size), density and temperature, the sound will be tested on both juvenile and adult fish at different temperatures and densities.

We will develop a remotely operated, early warning buoy equipped with video cameras, underwater speakers, vibrational stimulus and hydrophones for the field deployment. This buoy will be designed to stimulate carp jumping behavior in the field. It will be programmed or remotely operated to play sound stimulus at random times during the day and the number of fish jumping will be recorded by the video cameras.

To test the buoy, prior to field deployment, trials will be conducted in a ½ acre pond to create more natural conditions and determine the stimulus range. The pond is equipped with fish tracking systems and underwater cameras which will allow us to monitor fish position and behavior underwater. We will the optimal stimulus that was developed in the smaller tanks to stimulate carp jumping which will be recorded by the video cameras on the buoy. The number of carp jumping and the range of the stimulus will be determined

We will then travel to Havana, IL to test the system on wild populations of carp in the Illinois River. The buoy will be floated into areas of varying carp concentrations and remotely operated to trigger various stimuli to detect the carp. Prior to or after buoy deployment, we will determine the carp concentration in the area by passing through with motor boats and/or electrofishing boats. We will compare its effectiveness in areas of high and low carp concentration to determine its effectiveness as a detection system.

Summary Budget Information for Activity 1:

ENRTF Budget: $96334
Amount Spent: $ 0
Balance: $96334

Activity Completion Date: 6/30/2017

Outcome	Completion Date	Budget
1. optimal stimulus, small outdoor tank trials	12/31/14	$32,334
2. buoy construction, ½ pond trials	12/31/15	$32,000
3. buoy testing, Illinois River	12/31/16	$32,000

Activity Status as of 1/15/2015

Activity Status as of 7/15/2015

Activity Status as of 1/15/2016

Activity Status as of 7/15/2016

Activity Status as of 1/15/2017

Final Report Summary:

ACTIVITY 2: Bioacoustical movement of carp

Description: We have determined that carp will swim away from complex sounds such as underwater recordings of outboard boat motors. Commercial fishermen already use crude sound stimulus (banging on the sides of their boats) to concentrate fish and herd them into nets. It is anticipated that multiple arrays of underwater speakers could herd and/or concentrate the fish into shallow water for capture. We will develop underwater speaker arrays drive and/or herd fish into specific areas of the tanks or use the speakers in the field to drive the fish into nets. As both species of carp exhibit sound aversion, we will employ this technology on both silver and bighead carp. The goal is reduce or eliminate already established populations by concentrating the fish for easy capture and removal

Additional, we plan to take advantage of the silver carp's unique jumping ability and use this behavior against the fish. Aerial jumps are energetically expensive for fish, and even salmon that migrate hundreds of miles upstream, need to rest before jumping successive water falls. If carp are stimulated to jump repeatedly, it may be possible to exhaust them to the point where they will float on the surface and can be easily netted and removed.

The initial trials will be conducted in large, outdoor concrete ponds on the campus of the USGS facility in LaCrosse, WI. Silver carp of different size and age classes will be maintained in large, secured outdoor tanks at the UMESC facility in Lacrosse, WI which has a captive silver carp population. The carp will be viewed remotely with overhead cameras to monitor their normal swimming patterns and their response to sound and/or vibrational stimulus. Underwater speakers will be mounted throughout the tanks and the carp response to complex sound, primarily underwater recordings of boat motor sound will be played through the speakers.

The swimming behavior of the carp will be observed in response to sound stimulus. Preliminary trials have shown that silver carp will rapidly swim away from this type of sound. Different sound frequencies, vibrations and intensities will be tested with the underwater speakers. Preliminary trails indicated playbacks of underwater boat noise is an effective stimulus to displace and move carp. In contrast to Activity 1, multiple speakers (4 to 5) will be placed strategically in the tank to herd the fish into designated areas. As the fish will be viewed remotely with the overhead cameras, different speakers or combinations of speaker can be activated to drive the carp into designated areas of the tank or stimulate jumping to the point of exhaustion.

Trials will move then to the ½ acre pond described in activity 1 to create more natural conditions. Speaker arrays consisting of multiple speakers will be suspended from boats and used to herd the carp into specific areas of the tank. To concentrate them in one area, it is anticipated that two or three arrays will be operating simultaneously. Fish position will be monitored either by jumping or underwater cameras. Trials will be conducted with 25 to 50 fish and the accuracy to technique evaluated based on the number of fish that can concentrated into the designated areas. Small boats with outboard motors may also be used in the pond to move or herd carp into designated areas.

Once the methodology has been optimized, field trials will be conducted on the Illinois River. The field trials will use underwater speakers and/or motor boats to drive the carp into nets or shallow water for capture. All trials may be augmented by electroshocking as electric current has been noted to produce herding behavior similar to sound in field trials. Additionally, before and after carp movement and capture, electroshocking can used to census the river population to test the efficacy of the procedures.

Summary Budget Information for Activity 2: **ENRTF Budget: $ 86,583**
Amount Spent: $ 0

Balance: $ 86,583

Activity Completion Date: 6/30/2017

Outcome	Completion Date	Budget
1.Bioacoustic movement, outdoor tank trials	12/31/14	$ 29,583
2. develop speaker array, bioacoustic outdoor pond trials	12/31/15	$ 29,000
3. Field trials, Illinois River	06/30/17	$ 28,000

Activity Status as of 1/15/2015

Activity Status as of 7/15/2015

Activity Status as of 1/15/2016

Activity Status as of 7/15/2016

Activity Status as of 1/15/2017

Final Report Summary:

ACTIVITY 3: Carp deterrence

Description: One of the key strategies for integrated invasive species management is to deter fish from entering areas in which they have been eliminated or from invading new areas. Permanent barriers are expensive to maintain and interfere with commercial ship traffic and native fish movement. The aversion of carp to complex sounds has the potential to provide an environmentally friendly barrier that will not impact ship or native fish movement. We have determined that pure tones (same sound frequency) that normally are used for fish behavior and/or deterrent barriers is ineffective in deterring carp movement, however silver carp will readily swim away from complex sounds (playbacks of outboard motor noise). These preliminary experiments indicate that sound either alone or as part of a combined light and bubble barrier, may provide a cost effective and environmentally friendly barrier to silver or bighead carp migration or repel them from breeding areas.

Carp have specific tank locations either associated with three dimensional structures, sunlight or feeding location at which they prefer to reside. The first series of experiments in outdoor concrete tanks will identify the tank locations and use underwater speakers to deter the carp from these locations. Sound intensity, frequency, duration will be varied and the length of time that fish stay away from the location will be monitored to gain an understanding of how effective sound is as a deterrent.

We will then divide the tank into two sections with an expandable barrier/divider that will allow us to regulate the opening between the two sections of the tank. Three dimensional structures (i. e. milk crates) will be placed in one half, shade cloth erected over the same area to minimize light levels and all feeding will transpire in this section which will make this portion the “preferred” section for the carp to inhabit. We will then use sound from the underwater speakers submerged in the tank to drive the fish from the preferred section to the other half of the tank. Additional speakers will be positioned near the opening in the barrier to repel fish that attempt to return to the preferred half. The width of the barrier opening will be gradually expanded to determine how effective sound can be in larger passageways.

The same experiments will be performed in the large ½ acre pond described for previous activities. Again, a preferred location will be established and then sound used to displace the carp out of this area. Additional speakers will be place at the barrier openings and use to repel fish that try to return to the original location. The opening in the barrier will be gradually expanded to determine the effective width of the deterrent system.

Field trials will be conducted in a large sand pit (5 mile length) that parallels the Illinois River. Carp will be herded or netted to the narrow end of the sand pit and a barrier placed across the pit. An opening will be made in the barrier and underwater speakers placed to at the opening to enable use to use sound to deter the carp from leaving the terminal end of the sand pit and migrating back into the main channel. The barrier opening will be gradually widened to determine the effectiveness of the underwater sound in deterring carp from entering large channels.

Summary Budget Information for Activity 3:

ENRTF Budget: $ 79,083
Amount Spent: $ 0
Balance: $ 79,083

Activity Completion Date: 6/30/2017

Outcome	Completion Date	Budget
1. Outdoor tank deterrent trials	12/31/14	$ 27,083
2. Outdoor pond deterrent trials	12/31/15	$ 26,000
3. Sandpit trials	12/31/16	$ 26,000

Activity Status as of 1/15/2015

Activity Status as of 7/15/2015

Activity Status as of 1/15/2016

Activity Status as of 7/15/2016

Activity Status as of 1/15/2017

Final Report Summary:

V. DISSEMINATION:

Description: All results of the study will be published in peer reviewed publications. Mensinger and the graduate student will present the results at the appropriate state, regional and national meetings. Mensinger will develop a web page that will contain information, pictures and video of the experiments and results to provide wide dissemination. The USGS will also place information and material about the project on their web site. Mensinger also will be available to consult (at no charge) for the appropriate end users of this technology such as local, state and federal agencies including the MN DNR for the duration of the grant. Mensinger will develop a web page that will have video of carp jumping behavior and the sound deterrent experiments. The web page will also provide updates on the progress of the experiments and incorporate appropriate tables and graphs.

Status as of 1/15/2015

Status as of 7/15/2015

Status as of 1/15/2016

Status as of 7/15/2016

Status as of 1/15/2017

Final Report Summary:

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget Overview:

Budget Category	$ Amount	Explanation
Personnel:	$ 195,400	Salary is budgeted for the Principal investigator (0.55 FTE total for three years) , two graduate students (3.25 FTE total for three years) and two undergraduate students (0.49 FTE total for three years) for the project
Professional/Technical/Service Contracts:	$ 9,000	Funds are budgeted for boat rental and fuel expenses from the Illinois Natural History Survey
Equipment/Tools/Supplies:	$25,500	Funds are budgeted to build the early warning system and the sound arrays for carp movement and deterrence
Other: Travel to LaCrosse WI and Havana, IL	$32,100	Out of state travel is necessary to combat the invasive carp before they become established in MN. The outdoor tank and pond studies will take place in LaCrosse, WI and the field trials will take place in Havana, IL. Rates are based on University of MN travel plan rates
TOTAL ENRTF BUDGET:	**$262,000**	

Explanation of Use of Classified Staff: N/A

Explanation of Capital Expenditures Greater Than $5,000: N/A

Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation:
4.29

Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation:

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
Non-state			
Integrated Biological Sciences graduate program (cash)	$ 9,516	$0	The Integrated Biological Sciences graduate program will provide summer salary match for the graduate student budgeted in the project (pending)
UMD (cash)	8,400	0	Undergraduate research opportunities grants from UMD to further support undergraduate research in this proposal (pending)
UMD (cash)	5,500	5,500	Pilot grants were obtained from UMD to support preliminary data collection
Mensinger Salary (In-kind)	79,324	0	Two months of academic year salary will be provided as in kind support for the proposal (secured)

USGS (In-kind)	10,000	0	Access to silver and big head carp, outdoor tank and pond use (secured)
TOTAL OTHER FUNDS:	**$117,650**	**$11,500**	

VII. PROJECT STRATEGY:

A. Project Partners:

1) Professor Allen Mensinger of the University of Minnesota Duluth will supervise all aspects of the project. He and UMD will receive $253,000 from the appropriation

2) Mark Gaikowski, USGS, Lacrosse Wisconsin. The PI will work closely with Mark Gaikowski throughout the project. The USGS is providing the outdoor tanks and ponds, fish and support personnel at no cost to the grant. Mensinger and Gaikowski will develope the experimental protocols, train the students, analyze the data and be responsible for dissemination of the work. Mr. Gaikowski will not receive any funds from the appropriation.

3) Illinois Natural History Survey. The INHS will provide boats and personnel for the field trials planned in Havana, IL. The grant includes boat rental charges to partially offset the cost of the equipment and fuel. The INHS will receive $9,000 from the appropriation.

B. Project Impact and Long-term Strategy:

Since their introduction in the southeastern US, silver and bighead head carp have migrated north into the upper Mississippi Valley and pose severe ecological consequences to native Minnesota fish. Currently, the only barriers to carp are large dams or expensive electrical barriers. Based on the carp's avoidance or jumping to boat motors, we propose to use bioacoustics to 1) develop early warning systems 2) herd carp for capture and 3) develop acoustical deterents. As the sound stimulus is well above the hearing threshold of most native fish, it is unlikely to harm the native population. Bioacoustical deterrence is inexpensive, environmentally friendly and portable and can be used both in small streams and larger lakes.

The strategy is to develop bioacoustic early warning and deterent systems and perform controlled tests in outdoor tanks and ponds to develop the optimal sound intensities and frequencies for carp management. The equipment will be then field tested on wild carp population in the Illinois River. The technology will be made available to interested management agencies as part of an integrated pest management strategy for controlling carp.

C. Spending History: M.L. 2010 Chp. 362, Sec. 2, Subd 6d. – Bioacoustic traps for Management of Round Goby. This project was related to sound work on invasive species and much of the hardware will be used for the carp study.

Funding Source	**M.L. 2008 or FY09**	**M.L. 2009 or FY10**	**M.L. 2010 or FY11**	**M.L. 2011 or FY12-13**	**M.L. 2013 or FY14**
LCCMR			175,000		

VIII. ACQUISITION/RESTORATION LIST: N/A

IX. VISUAL ELEMENT or MAP(S):

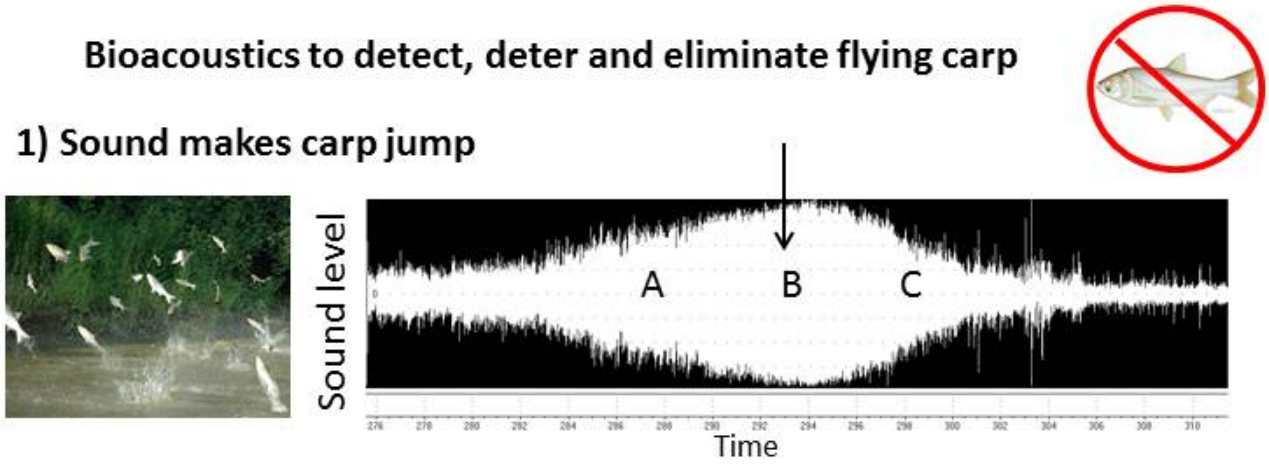

Figure 1. Field recording of underwater outboard motor noise motor boat noise that stimulated carp to jump in the Illinois River as boat passed by designated recording area. Arrow indicates when boat was in center of area. A) initiation of jumping; B) peak jumping; C) cessation of jumping.

2) Different sounds and boat speeds will effect carp jumping

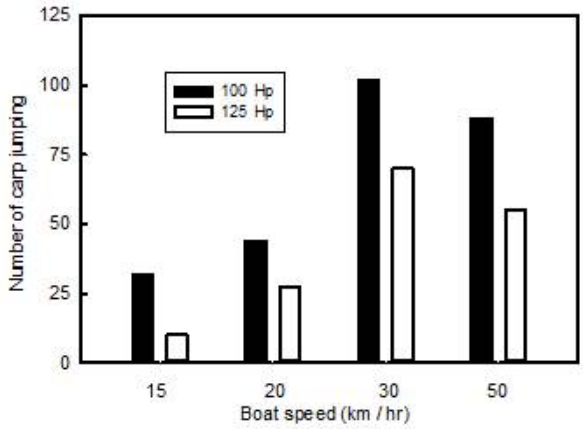

Figure 2. Number of carp jumping vs boat speed (km / hr) and engine size (hp).

3) Sound will repel carp

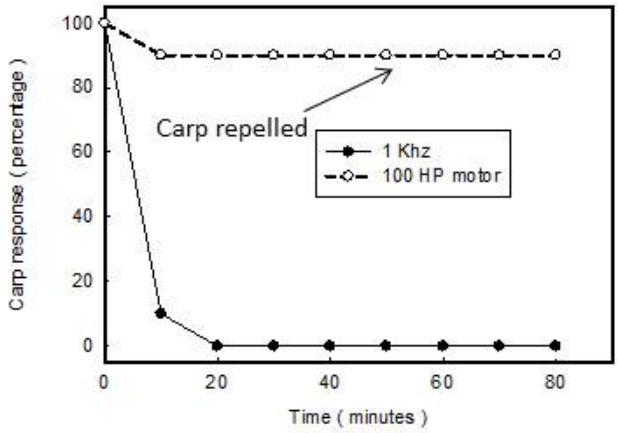

Figure 3. Percentage of carp (N=10) repelled by a 1 KHz pure tone sound and 100 hp outboard motor sounds versus time (min).

X. ACQUISITION/RESTORATION REQUIREMENTS WORKSHEET: N/A

XI. RESEARCH ADDENDUM: N/A

XII. REPORTING REQUIREMENTS:
Periodic work plan status update reports will be submitted no later than January 15, 2015; July 15, 2015; January 15 , 2016; July 15, 2016; and January, 15 2017. A final report and associated products will be submitted between June 30 and August 15, 2017.

Environment and Natural Resources Trust Fund

M.L. 2014 Project Budget

Project Title: Bioacoustics to detect, deter and eliminate flying carp

Legal Citation: M.L. 2014, Chp. 226, Sec. 2, Subd. 04b

Project Manager: Allen F. Mensinger

Organization: University of Minnesota Duluth

M.L. 2014 ENRTF Appropriation: $ *262,000*

Project Length and Completion Date: 3 Years, June 30, 2017

Date of Report:

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Activity 1 Balance	Activity 2 Budget	Amount Spent	Activity 2 Balance	Activity 3 Budget	Amount Spent	Activity 3 Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	***Early warning and detection system***			***Bioacoustical movement of carp***			***Carp deterrence***				
Personnel: **PI Allen F. Mensinger PhD.** The PI has a 9 month position at the University of Minnesota Duluth. A total of 3 months of summer salary (1 month /yr) is budgeted. The PI will be on sabatical during the 2014-15 academic year which is a 50% salary appointment. Two months of salary is budgeted for this period to work on the project. Total salary reflects 5 months total over 3 yrs and reflects 74.8% salary and 25.2% fringe (.55 FTE). Estimated total ($67,218) **Graduate student** - support is budgeted for 30 months of support for one graduate student. Total reflects 57.3% salary and 42.7% fringe (2.5 FTE). Estimated salary ($103,471). **Graduate student summer salary**. 50% summer salary is budgeted for an additional graduate student for 3 summers (total 4.5 months) 80.6% salary and 19.4% fringe (.75 FTE). Estimated salary ($12,711). **Undergraduate student summer salary:** 2 months summer salary is budgeted for two undergraduate students each summer (total 12 months) 93.1% salary and 6.9% fringe (.49 FTE). Estimated salary ($12,000).	$65,134	$0	$65,134	$65,133	$0	$65,133	$65,133	$0	$65,133	$195,400	$195,400
Professional/Technical/Service Contracts Boat Rental Illinois River. Illinois River Biological Field Station- $25 per hour for motorboat rental. 8 hrs per for 5 days each week. $1000 per week for nine weeks total	$3,000	$0	$3,000	$3,000	$0	$3,000	$3,000	$0	$3,000	$9,000	$9,000
Equipment/Tools/Supplies: Bouy or floating platform for early warning system plus floats, mooring lines, cables and materials	$7,500	$0	$7,500							$7,500	$7,500
Equipment/Tools/Supplies: Two amplifiers for underwater speakers arrays @$1000	$2,000	$0	$2,000							$2,000	$2,000
Equipment/Tools/Supplies: Wireless video cameras, digital video recorders and DC power supplies for filming carp jumping from bouy or boats	$2,500	$0	$2,500	$2,500	$0	$2,500				$5,000	$5,000
Equipment/Tools/Supplies: Electronics supplies including cables, wireless routers, camera and underwater speaker and control units for remote operation of early warning system, sound exhaustion and deterent **systems**	$5,000	$0	$5,000	$5,000	$0	$5,000				$10,000	$10,000
Equipment/Tools/Supplies: Fish food and water testing kits for carp in captivity	$500	$0	$500	$250	$0	$250	$250	$0	$250	$1,000	$1,000

Other: Out of state travel: Travel to the Illinois Biological Research Station in Havanna, IL. This out of state travel is essential to the project as it allows us to test the equipment and strategies in carp infested water. We will travel in spring, summer and fall for one week each. Car ($620 per trip based on 1100 miles RT @ $0.565 per mile), lodging ($77 per night) and meals ($46 per day) based on Univeristy of Minnesota travel plan rates = $861 per person per week. 9 weeks total for grant with two people each week.	$7,000	$0	$7,000	$7,000	$0	$7,000	$7,000	$0	$7,000	$21,000	$21,000
Other: Out of State Travel: Travel is requested to the USGS facility in Lacrosse, WI to monitor carp behavior in outdoor ponds and test equipment. This out of state travel is essential for the project as these are the only large and outdoor secure ponds that house silver carp that are available for this research. The graduate student will spend approximately one month in residence at the facility each year to compelete the experiments. Car ($283 per trip based on 500 miles RT). Lodging and meals are $861 per week and 4 weeks are anticipated each year. All rates are based on University of Minnesota travel plan rates.	$3,700	$0	$3,700	$3,700	$0	$3,700	$3,700	$0	$3,700	$11,100	$11,100
COLUMN TOTAL	**$96,334**	**$0**	**$96,334**	**$86,583**	**$0**	**$86,583**	**$79,083**	**$0**	**$79,083**	**$262,000**	**$262,000**