

Research Proposal

For

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Candidate for Master of Science in

Wildlife, Fisheries, and Aquaculture

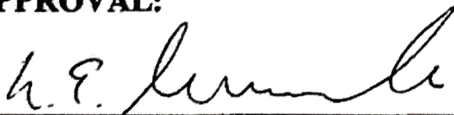
December 2018

PROPOSED TITLE: Evaluating agricultural crops on reservoir mudflats to enhance fish habitat.

OBJECTIVES:

- I. Evaluate performance of agricultural crops on the mudflats of Enid reservoir.
- II. Evaluate the use of agricultural crops by aquatic organisms following inundation.
- III. Create a decision model to quantify the likelihood of successful planting under alternate hydrological regimes associated with variation in local climate.

APPROVAL:



Leandro E. Miranda, PhD: Major Advisor

3/8/19

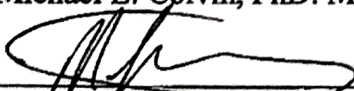
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Michael E. Colvin, PhD: Major Advisor

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Marcus A. Lashley, PhD: Committee Member

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Introduction

Reservoirs often experience water level fluctuations that are uncharacteristic of natural systems. These fluctuations are generally determined by a guide curve, which is designed to meet the specific operational goals of that reservoir (Mower and Miranda, 2013; Kennedy, 1999). Flood control reservoirs follow these guide curves to produce seasonal drawdowns and create storage capacity for anticipated runoff. This type of reservoir operation creates stable flows and flood protection downstream, but results in water level fluctuations within the reservoir. The area within the reservoir between high and low pool elevations, called the regulated zone, is highly affected by this altered hydrology. Sediment exposure and acidification during annual drawdowns reduce macrophyte diversity, and higher frequency and amplitude of drawdowns often result in a loss of vegetation. In reservoirs with gently sloping contours, this creates expanses of mudflats that lack the vegetation characteristics of typical littoral zones or floodplains. In addition to poor aesthetics at low water levels, mudflats also increase turbidity and shoreline erosion (Carmignani and Roy, 2017; Miranda, 2017).

The extent of mudflats formation and their ecological impact depends on the slope of the reservoir basin, and the timing and severity of drawdown. Steeper gradient contours result in smaller per capita area exposed, with low gradient contours result in exposure of larger per capita areas. Vegetation colonizes mudflats exposed during the growing season (Casanova and Brock, 2000; Wilson, 1973); however, exposure during growing season typically only happens in drought years. Regular inundation of the regulated zone during the growing season causes vegetation communities to die out, resulting in a barren mudflat, which is common to reservoirs across the Southern United States (Krogman and Miranda, 2016; Miranda, 2017).

Traditional littoral zones provide spawning areas, refuge, and abundant algal and invertebrate forage for many fish species. As a result, fish diversity is typically higher in vegetated areas (Carmignani and Roy, 2017; Cross and McNerny, 2001; Dibble et al., 1996). Savino and Stein (1982; 1989a,b) and Savino et al. (1992) reported that vegetated areas play important roles in foraging behaviors of both Largemouth Bass (*Micropterus salmoides*) and Bluegill (*Lepomis macrochirus*), and Bluegill on invertebrate prey. Loss of vegetation causes fish to experience reduced foraging opportunities and increased predation risk (Carmignani and Roy, 2017). Additionally, vegetation provides spawning and nursery areas for many important sport fishes (Poe et al., 1986; Bryan and Scarnecchia, 1992; Hutt et al., 2013; USFWS, 2011). In Big Clear Lake Ontario, open mud bottoms were considerably lower in fish diversity, richness, and abundance, with macrophyte presence being the dominant factor in fish habitat selection (Pratt and Smokorowski, 2003). Hatcher (2018) found lower fish richness in barren mudflat areas relative to adjacent areas with structure. Reduced littoral vegetation correlates with declines in fish diet, growth rate, biomass, and abundance (Carmignani and Roy, 2017).

Desiccation and loss of macrophytes change benthic invertebrate assemblage and density, and are especially limiting on immobile taxa (Carmignani and Roy, 2017). Brauns et al. (2008) reported that macrophyte roots were an important habitat component of littoral invertebrates, and Savino et al. (1992) observed that invertebrate densities increased with macrophyte densities. Benthic invertebrates such as chironomidae, amphipoda, talitridae, dytiscidae, corixidae, oligochaetes, and ceratopogonids are characteristic of sites that experience annual drawdowns, and may survive by burrowing into sediment or moving with water level (Carmignani and Roy, 2017). However, benthic invertebrates occur at lower densities and richness on reservoir mudflats than those permanently inundated (Schultz, 1966; Aroviita and

Hämäläinen, 2008). Water level fluctuations can create large seasonal variability in invertebrate communities (Baumgartner et al., 2008) and it may take several months after inundation for invertebrates to recolonize mudflats (Aroviita and Hämäläinen, 2008; Carmignani and Roy, 2017). The lack of invertebrates on mudflats may cause reduced growth and higher mortality of age-0 fish, which in combination with reduced availability of spawning areas, can limit fishery recruitment (Carmignani and Roy, 2017).

Seeding mudflats with agricultural plants may allow reservoir managers to address some of the ecological complications of reservoir mudflats, as terrestrial plants may mimic floodplain vegetation once inundated. The use of cool season agricultural plants allows establishment and dormancy through fall and winter during which mudflat exposure typically occurs, and rapid growth the following spring prior to inundation. Two prior attempts with cereal rye (*Secale*) and barley (*Hordeum vulgare*) have shown that planting terrestrial grasses can result in lush vegetation stands on mudflats, and were correlated with increases in invertebrate biomass and age – 0 fish abundance (Strange et al., 1982; Ratcliff et al., 2009). However, a successful planting likely depends on regional climate and timing and duration of mudflats exposure, all of which vary with reservoir location and operational goal. Coppola (*in review*) reported accelerated post inundation decomposition in agricultural plants that were given shorter growing times prior to flooding. In addition to available growing time, successful growth of cool season plants also likely depends on species adaptations to poor soil conditions, such as low pH, sparse nutrients, and poor drainage. Herbivory may also play a role in planting success on mudflats. Ryegrass (*Lolium*), Triticale (*x Triticosecale sp.*), and Clover (*Trifolium*) have adaptations that may allow them to be successful on mudflats. Ryegrass and Triticale germinate relatively quickly, are resistant to herbivory, and tolerate a wide variety of soil conditions. Clover (*Trifolium*) may

establish well due to its ability to fix nitrogen in otherwise poor soils, and additionally can be used in conjunction with ryegrass and Triticale to aid in crop growth (Harper, 2008).

Long term changes in climate patterns may affect the hydrology of reservoir watersheds. Changes to the amount and temporal distribution of precipitation in a watershed influence the timing and severity of water level fluctuations within the associated reservoir (Abrahams, 2008). Variability in these fluctuations, along with changes in temperature and direct precipitation, make the decision to plant less certain for reservoir managers. A decision model could be developed that estimates the likelihood of planting to be successful. Historic climate data such as watershed precipitation, pool level, day of the year, evaporation, temperature, and discharge can be used to estimate probabilities for various outcomes. This would allow reservoir managers to determine planting sites, purchase seed, and designate necessary equipment with more certainty, as oppose to making these decisions arbitrarily.

Methods

Study site

This study will be conducted in flood control reservoirs in the Upper Yazoo River Basin of northwest Mississippi. There are four major reservoirs (i.e., Arkabutla, Enid, Grenada, and Sardis) which were impounded between 1940 and 1954 and range from 4,500 to 26,000 ha in size. These reservoirs were constructed as part of the Yazoo Headwater Project to reduce flooding in the Lower Yazoo River Basin. Objectives 1 and 2 will be developed in Enid Lake, and Objective 3 in Sardis Lake.

Enid Lake is a 6,528 ha reservoir on the Yocona River. The USACE manipulates the pool elevation of Enid Lake according to a predetermined guide curve, which fluctuates between 70.1 and 76.2 m above MSL. Drawdown typically begins in August (Day of Year 213), with subsequent refilling beginning in January (Day of Year 16). This annual fluctuation exposes roughly 4,000 ha of lake bottom over fall and winter. The rate of drawdown and refilling, coupled with coincident seasonal temperature changes, create a gradient of contours, where upper contours are exposed longer and during warmer temperatures, and lower contours are exposed for fewer days during colder temperatures.

Sardis Lake is a 12,991 ha reservoir on the Little Tallahatchie River. Manipulation of Sardis Lake's pool elevation is also governed by a predetermined guide curve, which reduces the lake to 3,966 ha during fall and winter. Precipitation from a 4,000 km² drainage area refills the reservoir in spring. Annual rainfall in the drainage averages 144 cm, with a low of 7.8 cm in August and a high of 16.5 cm in December. Average snowfall in the watershed is approximately 7 cm annually. Sardis Lake was chosen for objective 3 due to the prevalence of historical data at precipitation stations throughout its watershed. The abundance of data from the Sardis Lake watershed is expected to make estimating outcome probabilities more robust.

Objective 1 – Establish and evaluate growth of agricultural crops

Planting - Experimental plots of agriculture crops will be seeded in late October in Long Branch Creek embayment of Enid Lake. A total of 70 plots, 30x40m each, will be designated on mudflats exposed prior to October 16th 2018. This date was chosen to allow exposed sediments time to dry prior to seeding. Soil will be sampled from each plot for analysis of pH and nutrients to aid in interpretation of planting success. One herbivore enclosure will be installed in each plot after seeding. Enclosures will be constructed with rebar and chicken wire to encompass 1 m².

Comparison of growth assessment characteristics between enclosure and non enclosure samples will allow for evaluation of herbivory.

Combinations of three species, Balansa Clover (*Trifolium michelianum*), Marshal Ryegrass (*Lolium*), and Triticale (*x Triticosecale sp.*), will be used to comprise six different treatments. Treatments will consist of three monocultures (one per species), and three mixed crops, (Balansa/Ryegrass, Balansa/Triticale, and Triticale/Ryegrass). This will allow for 10 replicates of each treatment, as well as 10 control (unseeded) plots. Plots will be randomly assigned a treatment using R program's 'sample()' call on a matrix of treatment types. Four additional 5x15m test plots will be monocultured with Persian Clover (*Trifolium resupinatum*), Crimson Clover (*Trifolium incarnatum*), Berseem Clover (*Trifolium alexandrinum*), and Oats (*Avena sativa*) to evaluate their efficacy as candidate species on reservoir mudflats.

In accordance with Natural Resource Conservation Service guidelines, germination rate and percent purity provided by manufacturers will be used to adjust seeding rate for pure live seed to ensure the proper amount of viable seed is applied to each plot. An additional 20% will be added to seeding rates in anticipation of poor soil quality which may limit germination rate. Mixed treatments will consist of 30% Ryegrass/ 70% Balansa, 30% Triticale/ 70% Balansa, and 40% Ryegrass/ 60% Triticale seeding rates. Plots will be top sown using a Solo 421S Portable Spreader.

Growth assessment - One growth assessment will be conducted for each plot in early Spring, prior to anticipated inundation of the planted area. Timing of growth assessment will be adjusted based reservoir refill rate to maximize the time between planting and flooding. Growth variables will consist of dry biomass, stem density, height, and ground cover.

Dry biomass and stem density will be evaluated by clipping all vegetation within the herbivore exclosures, as well as one randomly selected 1-m² unit from each plot. Clippings will be dried, weighed, and stems counted. Height and ground cover will be evaluated using a Robel pole and point intercepts along 15-m transects. Three transects will be evaluated per plot, with each transect radiating from the plot center in a random direction. Measurements will be taken every 1 m along these transects.

Following completion of growth assessment, one anchored buoy will be placed in the center of each plot. Buoys will be numbered with the associated plot number, and will facilitate expedient location of the plots post inundation.

Data analysis – Multivariate analysis of variance methods will be used to test for differences in the four plant growth metrics among treatments. If necessary, appropriate data transformations will be applied to meet the assumptions of parametric tests. Alternatively, non-parametric methods may be applied. All data will be processed and analyzed using R Program.

Objective 2 – Evaluate use of agricultural crops by aquatic organisms

Aquatic organism assessment will be conducted following inundation of the planted area, which is expected to begin in early April. This will consist of juvenile (age-0) fish surveys, and macroinvertebrate surveys.

Fish surveys - Three sequential juvenile surveys will be conducted in each plot. The first survey will be conducted in mid to late May, approximately one month after inundation. Subsequent surveys will be conducted at 2-3 week intervals. A 30x2 m block net will be used to isolate a circular section of each plot roughly 9.6 m in diameter, and 70 m² in area. Rotenone will be applied at 1 ppm within the isolated area, and all fish will be collected, put on ice, and returned

to the lab. Fish will be identified to species, and individual lengths and batch weights will be recorded.

Macroinvertebrate surveys – Benthic invertebrate surveys will be conducted in concurrence with the three juvenile fish surveys. Given expected differences in vegetation growth characteristics, i.e. stem density or height, invertebrate sampling methods such as sweep nets are unlikely to be standardized. Sweeps at different depths likely select for different organisms, and sweeps at a uniform depth may bias toward stem associated organisms in taller vegetation while simultaneously biasing against stem associated organisms in shorter vegetation. Introduced substrate techniques can provide greater uniformity for replication, therefore, invertebrates will be sampled using Hester-Dendy plate samplers. Three plots from each treatment type will be selected randomly for a total of 21 plots, and three Hester-Dendy plate samplers will be deployed randomly within each of the selected plots prior to inundation. This will allow invertebrates time to colonize plates prior to start of survey (approximately one month after inundation). During each of the juvenile fish surveys, one plate sampler will be retrieved from each plot, which will create three different soak times and allow assessment of changes in invertebrate assemblage. Upon retrieval, each plate sampler will be placed in a plastic bag, sealed, put on ice, and returned to the lab. Plate samplers will be individually rinsed with 95% ethanol over a collection basin to remove colonized invertebrates, and samples will then be run through a 500 um sieve.

Invertebrates will be identified to family and counted, and batch weights will be recorded.

Relative abundance and biomass for each taxa will be calculated on a 1 m² basis.

Data analysis – Two-way multivariate analysis of variance will be used to test for differences in fish and macroinvertebrates among treatments, with abundance and biomass for each taxa as dependent variables, and treatment and time as class variables. If necessary, appropriate data

transformations will be applied to meet the assumptions of parametric tests. Alternatively, non-parametric methods may be applied. All data will be processed and analyzed using R Program.

Objective 3 – Planting decision model

NORSYS's Netica is an application used to build belief networks and influence diagrams. Netica will be used in conjunction with R program to build a decision model for planting on Sardis mudflats. The National Water Quality Monitoring Council's Water Quality Data Portal will be used to delineate Sardis Lake's associated watershed. Historic precipitation data from rain gauges within the watershed will be retrieved from NOAA's National Centers for Environmental Information database, and discharge volume for Sardis Dam will be obtained from USGS's National Water Information System. Historic pool elevations, guide curve, bathymetry, temperature, and evaporation rates will be obtained from USGS and USACE. This historic data will be used to determine how these factors interact, and estimate probabilities for various conditions. This will allow managers to input current climate parameters and determine the likelihood of having a successful planting. Similarly, anticipated climate parameters could be input to determine likelihood of planting success for future dates. Once the model is operating, given their similar regional climate and operational protocols, the model can be easily adapted for use on Enid Lake.

Timeline

Designation and seeding of all plots will be completed prior to November 1, 2018. Herbivore exclosure will be completed prior to December 20, 2018. Growth assessment and Hester-Dendy sampler placement will be completed by the end of March 2019, pending reservoir

refill rate. Aquatic organism assessment will begin in May 2019, approximately one month after inundation. Data collection is expected to be completed by August 2019, with analysis and model building expected to be completed by December 2019.

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