Environment and Natural Resources Trust Fund

Research Addendum for Peer Review

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Project Title: Assessing the Cumulative Impacts of Shoreline Development

Project number: 024-A3

1. Abstract - Human structures related to shoreline development, such as docks, boatlifts, and other structures, and disturbance from recreational activity may have a cumulative impact on aquatic ecosystems. Near-shore areas (less than 4 meters deep) often contain most of the vegetation and are generally the spawning area for fish. Few studies have addressed the effects of incremental changes on lake ecosystems despite ongoing concerns about the rate and extent of near-shore, in-water habitat alterations, and expansion of in-lake structures. The lack of scientific knowledge on the cumulative effects of human activities on aquatic habitat, water quality, and fish populations has hindered regulatory authorities and lake managers who need better information to guide landowners toward lower impact practices. To address this lack of information, we will assess the extent of near-shore vegetation, fish, and macroinvertebrates along a gradient of shoreline development and develop a framework to assess cumulative impacts on whole lake systems. We will use aerial photos and existing DNR data to measure whole lake disturbances of ~100 lakes in the Northern Lakes and Forests Ecoregion. We will also conduct assessments of a subset of lakes (~30) at the individual lot scale, to quantify impacts to vegetation, fish, and macroinvertebrates along a gradient of shoreline development and shoreline types. We will use our research develop a model to predict the cumulative impact of development on aquatic ecosystems, providing a tool to guide lake managers toward sustainable near-shore, in-water development.

2. Background - Aquatic plant communities are important for the health of fisheries and aquatic ecosystems (Becker 1983, Engel 1985, Janecek 1988). Aquatic vegetation provides critical habitat for fish and other aquatic organisms, providing spawning and juvenile rearing areas, and refuge from predators. Other benefits include stabilizing soft sediments, trapping suspended particulates, and absorbing wave energy that contributes to shoreline erosion (Garrison et al. 2005). Development of lakeshore properties (Kelly and Stinchfield 1998) and subsequent alterations may negatively effect fish populations. Shore alterations may include removing submergent and emergent aquatic vegetation, hard-armoring shoreline with rip-rap or retaining walls. In addition, in-water structures, such as docks, piers, boat lifts, and other structures added for recreation may have a site specific and cumulative effect on aquatic vegetation and the functions they provide (Engel and Pederson 1998, Bryan and Scarnecchia 1992, Jennings et al 2003). In-water structures have been related to declines in aquatic vegetation (Radomski and Goeman 2001), as well as reduced fish growth rates (Schindler et al. 2000, Scheuerell and Schindler, 2004). Despite concerns about the rate of shoreline development, the extent of near-shore, in- water habitat alterations, and expansion of in-lake structures, few studies have addressed the effects of these incremental changes on lake ecosystems. The lack of scientific knowledge on the cumulative effects of human activities on aquatic habitat, water quality, and fish populations has hindered regulatory authorities and lake managers who need better information to guide landowners toward lower impact practices. Our goal is to understand the ecological consequences of development and associated activity on near-shore lake ecosystems. We have three objectives (Results): (1) Assess near-shore, in-water habitat across lake ecosystems, (2) Assess impacts of shoreline development on near-shore habitat, and (3) Develop a framework to evaluate cumulative impacts.

3. Hypothesis – We hypothesize that local near-shore, in-water habitat alterations will contribute to changes in species richness and other metrics for aquatic macrophytes, fish, and macroinvertebrates. These alterations will result in gradient of habitat complexity (*sensu* Jennings et al. 1999) that will provide evidence for a cumulative effect for near-shore development.

4. Methodology – We will address near-shore, in-water habitat complexity at two scales. At a broad scale (Result 1), we will select approximately 100 lakes for this study based on a number of criteria. We will control for differences in watersheds between lakes by selecting lakes that have primarily forested watersheds with no more than two upstream catchments from the Northern Lakes and Forests (NLF) ecoregion, excluding the low alkalinity lakes of northeast Minnesota. Over 700 lakes in the NLF ecoregion have two or fewer upstream catchments. Watershed land use will be at least 85% forest and wetlands, with no more than 10% consisting of agriculture (cultivated and pasture combined), and minimal urbanization typical for lakes in the NLF ecoregion (Heiskary and Wilson 2005). We plan to use a GIS tool that the DNR is developing to calculate land use by catchment for potential study lakes. Additional criteria may be used as the number of remaining lakes allows. Lakes will be limited to mesotrophic waters with total phosphorus levels from 12-30 ppb typical of most lakes in this ecoregion (Heiskary and Wilson 2005). After compiling a list of candidate lakes, we will select 100 lakes that represent a range of shoreline development conditions. Using the most recent available aerial photographs (currently 2008), we will use a similar approach to Radomski and Goeman (2001) to categorize lakes by the amount of developed and undeveloped shoreline, choosing study lakes along a range from 100% undeveloped to 100% developed. Candidate lakes will be grouped by percentage of shoreline development in increments of 20%. Lakes will be drawn randomly from these groups in proportion to the numbers in each group. We will use a technique developed by Radomski and Goeman (2001) to evaluate relative biomass of several fish species in relation to frequency of occurrence of bulrush, water lilies, arrowhead, and cattails in lakes. We will rely on DNR Fisheries data for our analysis and will select lakes that have been surveyed recently.

At a local scale (Result 2), we will select a sub-sample of approximately 30 lakes for intensive sampling, drawing these lakes from the 100 study lakes to ensure a gradient of habitat alteration. We will ground truth the GIS data and aerial photo analysis by collecting detailed aquatic habitat data for this subset of lakes. At each lake, a minimum of 15 lots (or locations where no development has taken place) will be selected for habitat assessment. We will assess a length of shoreline not to exceed 30m at each lot**.** For undeveloped areas, a transect 15 m on either side of a selected point will be surveyed. We will evaluate at least five dock sites per lake, plus an additional 10 randomly chosen sites, or regularly chosen sites to calculate a fish-based index of biotic integrity (Fish-IBI) (Drake and Pereira 2002). At each site, all in-water features will be measured, mapped, and marked with GPS waypoints. These features may include docks, boat lifts, watercraft, rafts, or any other recreational structures in the water. The water depth at the corner of each dock or other structure will be recorded, along with the water depth. We will note and estimate the linear distance of retaining walls or rip-rap along the shore, as well as the note vegetative cover type(s) adjacent to the wall or rip-rap. Coarse woody structure (CWS) will also be inventoried on each lot, using methods adapted from those used in other studies (Newbrey 2002, Newbrey et al. 2005, Marburg et al. 2006).

During our initial field season (July-August 2010), we will evaluate several potential sampling techniques for aquatic macrophytes, fish, and macroinvertebrates. Our goal for evaluating several techniques is to collect sufficient information in a time efficient manner for a limited number of lakes (5-10). For example, Jennings et al. (1999) used combined DC electrofishing and seining to sample fish in the near-shore zone after evaluating boomshocking, fyke nets, wading electrofishing, and seining. Based on these initial surveys, we will use the most efficient techniques in the summer of 2011 and 2012.

Initially, aquatic plant density and biovolume will be measured along a transect parallel to the shoreline. Half meter diameter circular quadrats will be placed every 3 m along the length of this transect, and we will measure stem density and plant height in each quadrat. We will also compile a list of all aquatic plant species observed at each site along the sampling transect. Emergent vegetation will be marked with a GPS waypoint and its area measured. When *Chara* sp. is present we will record areal coverage and height. We will also measure areas substantially cleared of vegetation around each dock and the shoreline, and measure the distance from the dock or shoreline, to the weed line.

An estimate of the cover that submerged aquatic vegetation provides larval and juvenile fish will be made using Weimer's modification (E. Weimer, ODNR, personal communication) of the Robel pole method (Robel et al 1970, citied in Litvaitis et al 1996). The Robel technique estimates both the height and density of vegetation with a significant correlation between height and density and the biomass of vegetation. Weimer took underwater photographs of a 3" diameter PVC pipe seen through submerged aquatic vegetation at a distance of 1 m, measured water depth, and plant height. The Robel technique will be used at regularly-spaced sites on a transect parallel to the shoreline. We will estimate plant density (stems/m^2) after photographing the amount of visual barrier to establish the relationship between the two variables.

We will assess species composition of macroinvertebrates using activity and light traps. Activity traps will be distributed along each transect at 5 m intervals. Light traps will be set near a dock or other structure and at the farthest point from a dock (including neighboring lots) for developed sites. For sites with no shoreline disturbance, the traps will be placed at the mid-point of the site and the end of the station having the most aquatic vegetation. Light traps have been used to assess macroinvertebrates in aquatic vegetation where shoreline restoration has been implemented (Cynthia Tomcko, Minnesota Department of Natural Resources, Personal Communication). At each sampling station, we will also collect invertebrates associated with macrophytes from 0.1 m^2 quadrats spaced at 3 m intervals or at selected sites based on the distribution of aquatic macrophytes. All plant material in a quadrat will be clipped at the sediment interface and immediately placed in a sealable bag underwater, returned to a boat, and immediately placed on ice. The samples will be rinsed of invertebrates and will be picked with forceps from macrophytes at 2x magnification and from the wash water at 8x magnification following Newman and Biesboer (2000).

Nearshore fish communities will be sampled following the methods of the Fish-IBI of Drake and Pereria (2002). We will sample a shoreline, beginning at the edge of docks, lifts, or at the water access point for the lot, or at one end of the station for undeveloped lots. Some lots may not allow for a 30 m sample, and in those cases we will sample as much of the shoreline as possible. We will make two passes with a backpack electroshocker parallel to the shore, one near the shoreline and one at 75-100 cm depth. We will also complete one 30 m seine haul at each station parallel to the shoreline and out to the length of the seine or maximum wadable depth (Drake and Pereria 2002). Cynthia Tomcko (Minnesota Department of Natural Resources, personal communication) has found light traps used to sample macroinvertebrates also attract larval fish. When larval fish are present in a light trap, we will identify and record larval fish.

We will use a boat electrofisher along a transect parallel to shore at a depth of 2.0 m or 20 m from the shoreline, whichever is closer. Finally, we will assess fish species composition visually. We will compare and contrast the boat electrofishing samples and visual observations with those collected with the backpack electrofisher and seine. We will retain either or both the boat electrofishing and visual surveys if additional information is collected that complements the data required for the Fish-IBI.

We will develop a cumulative impacts model (Result 3) by creating a framework for assessing the cumulative impact of human development on lakes by linking our fine-scale data on near-shore habitat changes to the whole lake impacts. We will examine the site-level habitat data for sensitivity to the variables measured in the GIS and photo analysis. In conjunction with a complementary DNR Project, we will summarize the habitat data and analyze both the means and variances of the habitat variables in relation to various measures of development, such as area of docks or amount of disturbed shoreline. Increased variability is a common response to disturbance, thus variance will be treated as a response variable in our analysis (Fraterrigo and Rusak 2008).

After determining the best measure of development pressure for predicting habitat disturbance, we will compute a development rating for each lake. We will then evaluate this development rating for its ability to explain differences in fish populations of the lakes. We will examine several fish variables that may be impacted by littoral habitat disturbance, including a fish IBI (Drake and Pereira 2002) and individual metrics within the fish IBI, such as species composition. Fish data at the broad scale will largely be gathered from existing DNR Fisheries Lake Survey Data and DNR Ecological Resources fish IBI surveys. However, the 30 lakes sampled for habitat will have Fish-IBIs and additional measures of fish species composition that will be used to further refine a development rating model for lakes in the NLF Ecoregion.

5. Results and Deliverables - Result 1: Assess near-shore, in-water habitat on lake ecosystems.

Using aerial photographs, we will estimate the loss of emergent and floating-leaf coverage from development for lakes in the NLF region. We will also correlate the occurrence of emergent and floating-leaf plant species and relative biomass and mean size of fish, such as northern pike *Esox lucius,* bluegill *Lepomis macrochirus,* and pumpkinseed *Lepomis gibbosus* following Radomski and Goeman (2001).

Result 2: Assess impacts of shoreline development on near-shore habitat

We will provide detailed aquatic habitat data for 30 lakes that can also confirm or “ground truth” the information from the aerial photographs. For these 30 lakes, we will quantify in-water features, such as docks, lifts, watercraft, rafts, or any other recreational structures, retaining walls or rip-rap along the shore, vegetative cover type(s) adjacent to the wall or rip-rap, and aquatic macrophytes, fish, and macroinvertebrates along a development gradient that will help refine the information from Result 1. These data on the biological characteristics will be correlate with the extent of rip-rap, CWS, and in-water structures.

Result 3: Develop a cumulative impacts model

Our development rating model will provide a quantitative assessment of the local and cumulative effect of changes to near-shore, in-water habitat complexity and the cumulative effect of these changes for macrophyte, macroinertebrate, and fish populations of the lakes in the NLF region.

The cumulative impact of our research will provide shoreline owners and lake managers with information about the impacts of development on aquatic ecosystems. Lakeshore managers may use this information to guide shore land management practices and to focus protection or restoration strategies on sensitive areas.

6. Timetable

Year	Task	Summer	Fall	Winter	Spring
First	Acquire aerial photos Result 1	XXX			
First	Assess aerial photos Result 1		XXX		
First	Data analysis of aerial photos Result 1		XXX	XXX	XXX
First	Field work to assess techniques Result 2	XXX			
First	Data analysis of field work Result 2		XXX	XXX	XXX
Second	Data analysis of aerial photos Result 1		XXX	XXX	
Second	Field work Result 2	XXX			
Second	Data analysis Result 2		XXX	XXX	XXX
Third	Field work Result 2	XXX			
Third	Data analysis Result 2		XXX	XXX	XXX
Third	Develop cumulative impact model Result 3		XXX	XXX	XXX
Third	Write final reports & ms.		XXX	XXX	XXX

7. Budget –

Project Budget

PROPOSAL BY: *Vondracek*

Assessing the cumulative impacts to near-shore, in-water habitat

IV. TOTAL PROJECT REQUEST BUDGET (*[3]* years)

BUDGET ITEM	AMOUNT
Personnel: One graduate student (masters) 2 years plus tuition and benefits	$70,337

One graduate student (Ph.D.) 3 years plus tuition and benefits	$105,787
one undergraduate student (fulltime in summer and 10 hours week during academic year)	$23,720
Contracts: one Specialist (6L) with the Minnesota Department of Natural Resources for 1.83 years	$81,439
Equipment/Tools/Supplies: Preservative for specimens	$500
Sample jars to preserve and store specimens	$2,717
Nets	$400
Acquisition (Fee Title or Permanent Easements):	$-
Travel: 10 trips to study areas per year 800 mi @0.60 mi for Federal vehicle	$11,600
Per Diem $50.00/day per person for graduate and undergraduate students for 30 days per year	$3,500
Additional Budget Items:	
TOTAL PROJECT BUDGET REQUEST TO LCCMR	$300,000

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ Being Applied to Project During Project Period: /	$-	
Other State $ Being Applied to Project During Project Period:	$-	
In-kind Services During Project Period: Assistance from DNR as needed and use of electrofishing boat	$-	
Remaining $ from Current Trust Fund Appropriation (if applicable):		
Funding History:	$-	

8. Credentials - Provide brief background of the principal investigators and cooperators who will carry out the proposed research and selected publications (targeted/abbreviated resumes are acceptable).

Bruce Vondracek is the principal investigator on the project. He has maintained an active research program focusing on aquatic ecology for 34 years, and is a specialist in the ecology of freshwater systems, specifically interactions of fish, macroinvertebrates, hydrology, water quality, and geomorphology. He is the Assistant Unit Leader-Fisheries for the US Geological Survey, Minnesota Cooperative Fish and Wildlife Research Unit (1991-2009) and an Adjunct Professor in the Department of Fisheries, Wildlife, and Conservation Biology at the University of Minnesota (2002-2009). He has published 62 peer-reviewed articles related to research he and graduate students have conducted across a spectrum of systems from small streams in California to the Great Lakes. He has been PI or Co-PI on 3.5 million dollars of grant-funded research projects since 2006, with current or past funding from the National Science Foundation, US Geological Survey, US Environmental Protection Agency, US Forest Service, and National Council for Air and Stream Improvement.

Donna Dustin will be an important collaborator on the project and will supervise the DNR employee on the project. She is a Senior Fisheries Biologist with the Fisheries Research Group of the Minnesota Department of Natural Resources. Over the past 11 years, her research has focused on aquatic habitat impacts on fish, including methods for improving walleye spawning habitat and stream restoration impacts on trout. She has recently been investigating large-scale stressors, such as climate change and watershed development in relation to aquatic vegetation and fish populations. Donna has a B.S. from Cornell University and M.S. from the University of Saskatchewan. Prior to coming to Minnesota, she worked for Cornell University and University of Wisconsin-LaCrosse in research programs studying lake ecology and zebra mussels.

9. Dissemination and Use – We will collaborate with people, such as Paul Radomski with the Minnesota Department of Natural Resources who works on a project "Score Your Shore", to disseminate the information to agency managers and lakeshore owners.

10. References

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