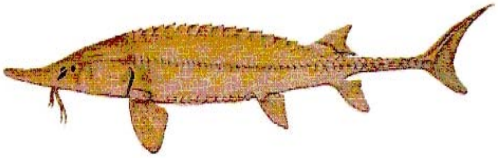
Mapping Potential Lake Sturgeon Habitat in the Lower Bad River Complex



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Introduction

Lake sturgeon (*Acipenser fulvescens*) is a species of concern in the Great Lakes region. Once abundant throughout the Great Lakes basin, lake sturgeon populations began to decline dramatically in the 1860's first from over harvest and later from man-induced environmental changes such as dams and pollution. The Bad River supports one of only two self-sustaining spawning populations remaining in the U.S. waters of Lake Superior. Running through the Bad River reservation of the Lake Superior Chippewa Tribe, the Bad River and its tributaries drain approximately one million five hundred and fifty-four thousand hectares of land and provide more than six hundred twenty-nine kilometers of cold and cool water habitats. The most valued fisheries are for walleye (*Stizostedion vitreum)* and lake sturgeon, with the river supporting spawning runs of both species (Elias 2001).

In the summer of 2000, the Great Lakes Trust Fund (GLFT) held a workshop to determine the assessment and research needs to restore lake sturgeon in the Great Lakes. Workshop participants identified a lack of sufficient understanding of habitat constraints on the lifecycle of sturgeon, and the role of habitat in the regulation of sturgeon population structure as research priorities. To address information needs, the GLFT recommended studying the habitat requirements of all life stages of lake sturgeon in an individual system. The Bad River Band of the Lake Superior Tribe of Chippewa Indians, the U.S. Fish and Wildlife Service-Ashland FRO (USFWS) and the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) recommended that the Bad River serve as a model river to begin answering research priorities. A proposal for such a project under the USFWS administered 2002 Great Lakes Fish and Wildlife Restoration Act was submitted and awarded. This report summarizes our efforts to map the Bad River substrates using acoustic techniques.

A number of acoustic mapping studies have been conducted on the Great Lakes. Hydroacoustic methods were used to examine lake trout spawning reefs (Edsall et al. 1989). The United States Geological Survey's Lake Superior Biological Station has been instrumental in developing and applying acoustic techniques to map habitat for a number of species and locations, including lake trout spawning habitat in Minnesota's near shore waters of Lake Superior (Richards and Bonde 1999), larval sea lamprey habitat in Lake Superior's Batchawana Bay (Fodale et al. 2003), lake whitefish spawning habitat in Tahquamenon Bay of Lake Superior (Bronte, unpublished data) and Lake Huron's De Tour near shore waters (Cholwek et al. 2001). Since these previous studies were finalized, acoustic hardware and software, Global Positioning Systems (GPS) and Geographical Information Systems (GIS) technologies have all progressed at rapid rates. The goal of the current study was to integrate these advancements to develop a map of habitat types in the Lower Bad River and adjacent lake Superior waters (hereafter, the lower Bad River complex).

Objectives

Prior to this survey, detailed substrate maps of the lower Bad River complex, sufficient for identifying potential lake sturgeon habitats were nonexistent and only bathymetric point data existed. This survey was designed to provide a more complete understanding of the bottom characteristics of the lower Bad River complex with the goal that this information could assist in identifying and quantifying potential lake sturgeon habitat. It is expected the information collected can be used for a variety of other purposes.

Report Format

This report describes our effort to collect data during the fall of 2004 to develop a GIS database to generate accurate maps of substrate classes and bathymetry of the lower Bad River complex. The **Methods** describe how the data were collected and processed. Survey results and a brief discussion of habitats available to sturgeon are presented in the **Results** and **Discussion**. The GIS files subdirectory on a CD-ROM contains the processed data suitable for importing into a GIS. The people who helped with this project are listed in the **Acknowledgments** section. Citations are in the **Literature Cited** section.

Methods

Survey Design - The portion of the lower Bad River surveyed was 9.6 kilometers in length (Figure 1) and extended roughly 0.8 kilometers upriver from the confluence of the White and Bad rivers to the Bad River mouth at Lake Superior. Boat speed during the river survey averaged ≈ 4.2 kilometers per hour (≈ 1.2 meters per second). Depths surveyed ranged from one to 10.8 meters. From government landing to the furthest point surveyed upriver, three transects were surveyed: one mid-river and one as close as feasible to each bank. From government landing to the Bad River mouth, five transects were surveyed: one mid-river, one as close as feasible to each bank and one half way between each bank and the mid-river transect.

In Lake Superior, we established thirty-two parallel transects, oriented perpendicular to the shoreline. Initial transects were spaced at two hundred meter intervals and covered 1.6 kilometers of shoreline on both sides of the Bad River mouth. Sampling occurred from roughly one hundred to one hundred fifty meters from shore out to two kilometers in the open lake. In the field it became apparent from returning acoustic signals that sand was the predominant substrate. The decision was then made to conduct fewer transects. With the influence of wind, transects were separated by roughly two hundred twenty-five to three hundred meters. Boat speed averaged ≈ eight kilometers per hour (≈2.2 meters per second). Depths along the lake transects ranged from 1.7- to 18.3-meters.

Instrumentation - In order to map bottom substrates, we employed a Biosonics DT-X digital hydroacoustic system. During the Lower Bad River survey we collected data by fast multiplexing with two transducers (120 kHz 6^0 transducer and a 208 kHz 10^0 transducer) both mounted on a tow fish 1.2 meters in length. Data were collected on both channels at one ping per second with a 0.4 milli-second pulse duration. Signals exceeding –80 decibel (dB) on-axis mark threshold were digitized and continually stored to a laptop computer. During the survey of Lake Superior we used only the120 kHz transducer. We previously collected information to classify lake substrates with this transducer during our spring 2004 lake-wide forage fish cruise of Lake Superior. Acoustic signals exceeding –75 dB threshold were continually recorded during the lake survey. An Ashtec BR2G differential GPS receiver/antenna system provided accurate positioning data on the order of one meter.

Substrate Classification- To produce accurate maps of these areas we applied the RoxAnn substrate classification method (Chivers et al. 1990) as described previously by Cholwek et al. (2000). Briefly, the echo sounder measures E1 and E2 values, and these correspond to the bottom hardness and roughness, respectively. The general approach is to collect E1 and E2 values at sites (i.e., ground truth sites) with known substrates to develop a classification model for prediction of substrates at unknown sites based upon measured E1 and E2 values. Measurements of E1 and E2 values were gathered from computer files with BioSonics Visual Bottom Typing (VBT) software version 1.9. Parameters used to track bottom depth and measure E1 and E2 values during data playback are presented in Appendix A.

The following approach was used to develop the Bad River substrate classification model. After completing the Bad River survey, we used Echoview software version 3.10 (SonarData Pty Ltd) to examine echograms. Sixteen ground truth sites were chosen with echo signals we wanted to explore in greater detail. We returned to these sites and collected E1 and E2 samples (an average of ten contiguous pings constituted a sample) while anchored to maintain a fixed boat position for two to five minutes. Simultaneous with the acoustic data collection, substrates were sampled as close to the transducer as feasible with a petite ponar dredge. The dredge samples were examined for grain diameter and classified to the geometric graduated scale for clastic sediments formulated by Wentworth (1922) and modified by Edsall et al (1992) and Cummins (1962). The E1 and E2 measurements were plotted in JMP 5.1 statistical software (SAS Institute Incorporated) to show clusters of like E1 and E2 data pairs from which substrate types can be inferred. A statistical technique called recursive partitioning (i.e. decision tree) was used to develop the substrate classification model. Briefly, E1 and E2 means are calculated by substrate type, and splits are created that most significantly separate the means by examining the sums of squares, due to the means differences. The plot is split into regions (i.e., trees) and the probability of each substrate type in each region is calculated. The classification model was then applied to predict substrate types based on measured E1 and E2 values along our survey path. A similar approach was used to classify the lake portion of our survey. The Lake Superior model was developed from fifty ground truth samples of each substrate type. Samples were based on averaging twenty contiguous pings.

Research has shown that E1 and E2 measurements can vary over contiguous pings even at a fixed site with a homogenous substrate. To account for this ping-to-ping variability, contiguous E1 and E2 samples are usually averaged over a small number of pings (five to twenty).   We were interested in learning how this averaging affected the development of the GIS habitat layer. The CD-ROM includes data sets where substrates were predicted from every ping, and also where substrates were predicted after averaging five contiguous pings in the Bad River and twenty contiguous pings in Lake Superior.

Development of GIS layers- The resultant point data for bathymetry and substrates was used to produce GIS layers. From these layers, maps were produced and juvenile lake sturgeon capture data from the Bad River was overlaid.

Results

Three of the sixteen ground truth sites were eliminated due to either an inability to anchor the boat to maintain position or inconclusive results of the ponar grabs. After reviewing the remaining thirteen E1 and E2 ground truth data files and petite ponar samples, we identified three categories of substrates in the Lower Bad River. These categories were: red clay (very densely packed with fine particles between 1/2048 mm diameter to 1/256 mm diameter, Figure 2A) which was most abundant at seventy percent, sand (1/16 to 1/4 mm, Figure 2B) which was least abundant at only seven percent, and a mixture of sand and red clay (Figure 2C) at twenty-three percent. Total number of acoustic samples for all substrates was thirteen thousand seven hundred and fifteen.

The 208 kHz transducer signals from the river survey provided the greatest contrast in E1 and E2 values over these substrate classes, so we did not process the 120 kHz signals further. The E1 and E2 ground truth data for the three substrate categories are shown in Figure 3A. A total of one hundred and seven acoustic samples from each substrate type were used in the recursive partitioning statistical procedure, the results are shown in Figure 3B.   The data was split into four regions and the proportion of each substrate type in each region is displayed. This model was used to predict substrates (based on the highest probability) at Bad River locations with measured E1 and E2 values.

A similar classification model (Figure 4) was developed for the120 kHz 6^0 transducer from ground truth samples collected around Lake Superior. Five substrate categories in the open water areas of Lake Superior were identified: clay (particles between 1/2048 and 1/256 mm diameter), sand/silt (1/256 to 1/8 mm), sand (1/16 to 1.5 mm), coarse sand/medium pebbles (0.5 to 10 mm) and cobble/boulder (64 to > 256 mm).

Example bathymetric and substrate data gathered near the lower Bad River mouth are in Figures 5 and 6, respectively. Lake Superior substrate data offshore of the Bad River are in Figure 7.

Discussion

This survey produced a geo-referenced and classified substrate and bathymetric point data set from which GIS layers were produced. The maps produced were then overlaid with lake sturgeon survey data. Future data collected on lake sturgeon can be added to these maps to better understand the habitat features important to different life stages.

The distribution of substrates in the lower Bad River complex reflects both the area’s geology, and the erosion and deposition processes it is exposed to. The upland portion of the lower Bad River has lacustrine red clay banks extending from the bottom to just above the waterline and a considerable sandy soil overburden, and both contribute to the river’s sediment load during higher water events. The inner bends of the river have lower velocities that allow sand to settle out, forming bars that extend out from the bank towards the mid-channel. The outer bends have increased water velocities, resulting in greater scouring that leaves only the underlying dense red clay and creates the greater depths of the river’s thalweg. Backwater areas and depressions form catchments that collect fine substrates and in these areas sand/clay mixtures tend to predominate. Outside the river mouth in the open water of Lake Superior, long shore currents transport fine sediments that consist primarily of sand with some silt. A large, shallow (< 1 m in depth) sand bar is formed a short distance from the mouth and runs parallel to the shoreline for some distance. The few harder and rougher substrates were nearly all found in the deeper areas farthest from shore. Since the lower Bad River complex is an active and dynamic system subject to seasonal changes from storm events and ice scour, it is important to understand our survey results represent but a snapshot in time and may be subject to considerable future change. However, over the near term, basic processes of erosion and deposition, parent materials and landscape features remain relatively constant and will likely maintain the substrate categories and bottom features found in our survey, albeit in possibly different locations and quantities over time.

Hydroacoustic survey methods we employed were quite rapid. The field survey and ground truth work took three people four working days. An additional workweek was required to post process data to the point that it was ready for importation into GIS. Report writing took seven days.

The field data collection technique was not effective in waters less than one meter in depth due to the transducer near field effect. For navigable rivers with depths greater than one meter, this method can be applied to classify and map bottom substrates.

Although the driving force behind this project was to map sturgeon habitat, substrate maps can also indicate areas suitable for larval sea lamprey and this information might lend itself to more effective sea lamprey control. Schleen et al. (1996) reported the Bad River accounts for twenty to thirty percent of Lake Superior's entire sea lamprey production. Sea lamprey larvae burrow in bottom substrate with the ability to hold the shape of the burrow. The clay/sand mixture category found in the lower Bad River complex is soft enough to burrow in and has a gelatinous consistency that can hold the shape of a burrow and is likely to be inhabited by these species. Locating this material can help effectively target larval sea lamprey habitats for treatment, thus reduce the amounts (and subsequently the cost) of larvicide's, and would help limit mortality of non-target species.

During our ground truth sampling with a petite ponar, we collected several Eastern elliptio (*Elliptio complanata*) specimens (Figure 8) in a backwater near the Bad River mouth (Figure 1). This mussel species has yellow perch as a known host and is thought to also use lake sturgeon as a host.

Acknowledgements

This project was funded in 2002 by the USFWS administered Great Lakes Fish and Wildlife Restoration Act. Johnathon Pyatskowit (of the USFWS Ashland Fishery Resource Office) skillfully piloted the R/V Coaster during preliminary fieldwork in the fall of 2003. Lori Evrard of USGS did the same for one November day in 2003 and all the surveying during the fall of 2004. Lori also took the digital photographs used in figures 2 and 8. E.J. Isaac (USGS) plotted the offshore transects in the Captain Voyager navigation software. Seth Moore (USGS) assisted one field day in 2003. Glen Miller (USFWS Ashland Fishery Resource Office) provided expert identification of the eastern elliptio mussels found during the survey. Last and most importantly, we thank the Bad River Band of the Lake Superior Chippewa Indians for their co-operation and the privilege of working on their unique and beautiful river.

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Figure Captions

Figure 1 – A digitized USGS aerial photograph of the lower Bad River portion where acoustic sampling occurred. Labeled with landmark locations referred to in the text.

Figure 2 – Photographs of the three substrate types encountered at ground truth sites i.e. 2A) red clay, 2B) sand and 2C) a mixture of sand and red clay. Photograph credits- Lori Evrard (USGS).

Figure 3. 3A - Bivariate plot of E1 (Hardness) and E2 (Roughness) values measured at thirteen lower Bad River ground truth sites. E1 and E2 acoustic samples collected simultaneously with a bottom substrate sample from a petite ponar grab. 3B - Lower Bad River substrate classification model with recursive partitioning splits (red lines) and the probability of each substrate type in each region.

Figure 4 - Lake Superior substrate classification model with recursive partitioning splits (red lines) and the probability of each substrate type in each region.

Figures 5 and 6 - Example point data showing bathymetry (Figure 5) and substrate types (Figure 6) in the lowest 2 km of the lower Bad River. Data overlaid on digitized USGS aerial photographs of the area.

Figure 7 - Example point data showing substrate types surveyed in Lake Superior offshore of the Bad River mouth. Data overlaid on a digitized USGS aerial photograph of the area.

Figure 8 - Eastern elliptio (*Elliptio complanata*) collected by petite ponar grab in a backwater area near the Bad River mouth (see Figure 1 for location). Photograph credit- Lori Evrard (USGS).