Shoreland Rules Revision Project Using GIS in North-Central Minnesota

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Abstract

Within the Minnesota Department of Natural Resources (DNR), there are concerns about the rate of dock development and the associated impact on lakes and fish habitats. This paper will discuss the elements of a project completed by the DNR that used a digitized GIS dock layer, which was compared to parcel data from a four-county study area (Aitkin, Cass, Crow Wing, and Hubbard counties) to estimate current and projected development on lakes within the study area. The results of this project showed a relatively large impact on shoreline and littoral zone, which could have policy implications for regulatory agencies like the DNR.

Introduction

Littoral Zone

The area along the shore of a lake that contains most of the vegetation, and generally is the spawning area for fish and other animals living in the lake, is called the littoral zone. Since this area is where many organisms live and reproduce, it makes this area one of the more critical areas of a lake.

The littoral zone is defined as the areas of a lake that contain vegetation. This depth can vary based on water clarity and wave/substrate action. For example, if the water in a lake is very clear, the maximum vegetation depth could be twenty feet or more, since sunlight is able to penetrate the water to a deeper depth. However, if water is not clear, sunlight will not be able to support plant life in those deeper areas of the lake and the maximum vegetation depth could be less than ten feet. If the maximum vegetation depth is not known, DNR fisheries uses a standard fifteen-foot maximum vegetation depth to illustrate the littoral zone for the lake.

Since docks and other man-made structures are typically found in these shallow areas, they have an impact on animal habitats. For instance, many dock owners remove vegetation around their structures. While this may create a more "suitable" swimming area, it also adversely impacts fish and other animal habitat. Many species of fish require vegetation to spawn and these areas can serve as refuge for young fish. Removing vegetation can also reduce the amount of invertebrates that are a major food source for many fish species at various life stages. Finally, removing vegetation can disturb sediments that reduce water clarity.

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Habitat Impact Zone (HIZ)

In this study, all dock structures were buffered with a 25-foot buffer to account for loss of vegetation. The 25-foot buffer was chosen because it was the mean distance reported on Aquatic Plant Permits obtained from the Brainerd DNR office. The sum acreage of all buffered structures was defined as the Habitat Impact Zone (HIZ).

The HIZ can be related to the entire acreage of the lake, or to its littoral zone, to estimate the amount of fish habitat impacted by dock structures.

Division of Waters Identification Number

Each lake managed by the DNR is given a unique identification number called a DOW number, assigned by the DNR's Division of Waters.

Each DOW number is made up of 8 digits. For example, 11020300 is the DOW number for Leech Lake. The first two digits designate the county number (in alphabetical order), or in this case, Cass County. The next four digits are the lake number within the county. Finally, the last two digits represent any sub-basins or large bays, if present. For example, if a lake has two sub-basins, the main DOW number would end in "00" (representing the entire lake), one basin would end in "01," and the other basin would end in "02" (Figure 1).

Figure 1. This figure demonstrates how the DOW numbers work. The red dot in the center is DOW number 69129300, which is the main DOW for Miner's Pit Lake. "69" is the county number for St. Louis county and "1293" is the lake number. The dot on the left is DOW 69129301, and represents the west bay of Miner's Pit Lake. The dot on the right is DOW 69129302 and represents the east bay of Miner's Pit Lake.

Lake Class

In Minnesota, each lake greater than 25 acres is given Shoreland Classification Code (General Development, Recreational Development, or Natural Environment). This code has a direct impact on how the shoreland on the lake is managed. The definitions of these classes can be found at http://files.dnr.State.mn.us/waters/watermgmt_section/Shoreland/shoreland_rules_plus_SONAR.doc and are as follows:

A. Natural environment: Lakes that are generally small, often shallow lakes with limited capacities for assimilating the impacts of development and recreational use.
B. Recreational Development: Lakes that are generally medium-sized lakes of varying depths and shapes with a variety of landform, soil, and groundwater situations on lands around them. They often are characterized by moderate levels of recreational use and existing development.
C. General Development: These lakes are generally large, deep lakes or lakes of varying sizes and depths with high levels and mixes of existing development.

The Statewide Shoreland Management Standards are described on the DNR's website http://www.dnr.state.mn.us, and are as follows:

"Minnesota DNR statewide minimum shoreland standards apply to all lakes greater than 25 acres (10 acres in municipalities) and rivers with a drainage area two square miles or greater. These standards apply to the use and development of shoreland property including: a sanitary code, minimum lot size and water frontage, building setbacks and heights, land use, BMPs, shoreland alterations, subdivision and PUD regulations. The Shoreland Management Act regulates all land within 1,000 feet of a lake and 300 feet of a river and its designated floodplain. Upon notification by DNR Waters, local governmental units having shorelands are required to adopt these or stricter standards into their zoning ordinances."

Data

The initial phase of this project was to organize the necessary GIS data layers. ArcView 3.3 was used for all GIS processing. The first step involved creating a dock layer by digitizing all of the dock features visible on a sub-sample of lakes within the study area. The second step was to assemble a master parcel layer from the four separate county parcel layers. The remaining layers used in the project were obtained fom the DNR's Data Resource Site.

Data Resource Site

The Minnesota Department of Natural Resources has a server within the central office in St. Paul, MN that contains all of the statewide GIS data and is available to all DNR employees. Most of this data is also available to the public through the DNR Data Deli, which can be accessed at the DNR's website http://www.dnr.state.mn.us. This server contains a wide variety of both vector and raster data that includes aerial photos, lake outlines, contour data, watershed boundaries and more.

Lakes Layer

In the four-county study area, there are 1,210 managed lakes. A shapefile was created by extracting all of the managed lakes in the study area from the "DNR 100K Lakes and Rivers" layer, located on the DNR Data Resource Site. The new lake outline shapefile contained all 1,210 lakes in the study area. The attribute table for this layer also contained shoreland classification information. Due to the high number of docks in the study area (estimated to be more than 34,000) a weighted 10% sub-sample of lakes was used, based on the total number of General Development, Recreational Development, and Natural Environment lakes in the study area. The sub-sample consisted of: 10 General Development lakes (100 in the study area), 84 Natural Environment lakes (840 in the study area), and 27 Recreational Development lakes (270 in the study area). Since the number of lakes varies from county to county, the number of lakes selected from each of the four counties for the sub-sample was proportional to the total number of lakes in each county. This was a pseudo-random sampling method, since the lakes selected were randomly taken from the attribute table. 121 sub-sample lakes were given a "wave 1" attribute in the shapefile's attribute table (signifying the first wave of analysis). A Boolean field named "Done" was added to the attribute table to easily identify which lakes had been completed.

Dock Layer

Using the 2003-2004 FSA color 1-meter resolution aerial photos, it was possible to create a shapefile containing all of the man-made structures in the study area. Every water structure visible on each study lake was digitized using ArcView

3.3. For each lake, the following steps were implemented to create digital lake features:

1. Select and zoom to a "wave 1" lake.
2. Set view scale to 1:2,000.
3. Using the "draw polygon" button in ArcView, each visible water structure on the lake was digitized.

After all docks were digitized (3,410 structures total), a script was run on the dock layer to calculate the surface area for each structure. For the analysis portion of this project, it was necessary for the attribute table to have a DOW, lake name, shoreland class, and county attribute. These attributes were calculated using the "select by theme" tool in ArcView. Two other layers were used to help create these fields: a layer showing all counties in Minnesota and the lakes layer that was created earlier.

Finally, each dock was classified based on its complexity. A field was created in the dock layer attribute table called "dock_class," and a number was assigned to each dock between zero and six. Figures 2-8 describe each dock class:

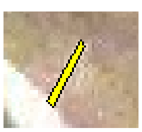


Figure 2. Dock class "0": a simple, straight dock.

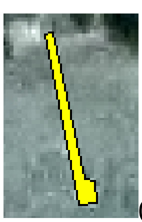
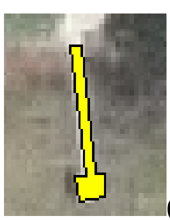

(a)

(b)

Figure 3. Dock class "1": a dock with one slip/lift (a), or a T-shaped dock (b).

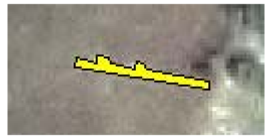


Figure 4. Dock class "2": a dock with two slips/lifts.

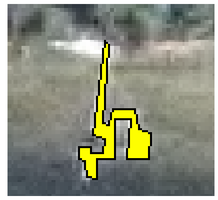


Figure 5. Dock class "3": a dock with multiple slips/lifts.

Figure 6. Dock class "4": a marina or complex resort dock structure.

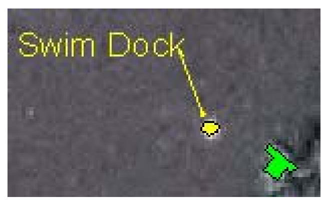


Figure 7. Dock class "5": a swim dock-type structure.

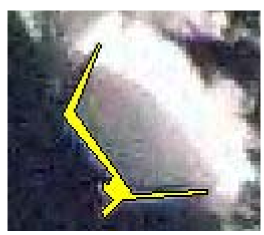


Figure 8. Dock class "6": miscellaneous water structure.

Parcel Layer

Parcel data was needed for this project in order to relate the dock data to ownership information within the parcel layer. This was done to see if there was a correlation between the numbers and/or complexity of docks in public vs. private land.

Parcel data was separately received from each of the four counties. It was necessary to union these shapefiles together into one master parcel layer. Since the data was acquired from four different sources, the attributes for each shapefile were different. This made it necessary to standardize numerous attributes in order to union the shapefiles into one master layer.

Methods

This section of the paper will focus on the methods used to create and organize the data, and the processes used to analyze the data.

Dock Statistics

Once all visible structures were digitized, several categories of statistics were created from the data. The categories of generated statistics consisted of the following:

A. Total/mean number of dock structures by county and shoreland class.

B. Total/mean number of dock structures by dock type and shoreland class.

C. Total/mean number of dock structures per lake and per acre by dock type-county combination.

D. Total estimated buffered dock surface area (HIZ-Habitat Impact Zone) by county and shoreland class.

E. Total estimated buffered dock surface area, per lake and per dock, by dock type.

F. Total estimated ratio of buffered dock surface area (HIZ-Habitat Impact Zone) to Littoral Zone by county and shoreland class.

G. Total/mean shoreline acreage in public vs. private ownership by county and shoreland class.

H. Total/mean shoreline length in public vs. private ownership by county and shoreland class.

I. Percentage of shoreline length impacted by Habitat Impact Zone (HIZ) within county and shoreland class.

Since each dock in the dock layer had county and lake shoreland classes in the attribute table, simply selecting the appropriate records and using the “calculate” option in ArcView to summarize and derive the records generated the aforementioned categories A-C.

To calculate statistical categories D-E, it was necessary to buffer each dock in the dock layer by 25 feet. Once this was completed, the surface area for each feature in the buffer layer was calculated in square feet and acres. Then the areas were multiplied by .75 to account for the portion of the buffer outside of the lake boundary (Figure 9).

Finally, as in categories A-C, appropriate records were selected and summarized to obtain final numbers for categories D and E.

When calculating categories F and I, only 15 of the total 121 lakes were used in the calculation. This was due to the fact that the statistics required using

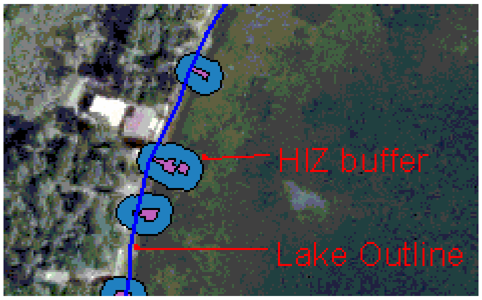


Figure 9. When calculating the acreage of the HIZ, only 75% of the acreage will be used since, on average, about 25% of the buffer fell outside of the lake boundary.

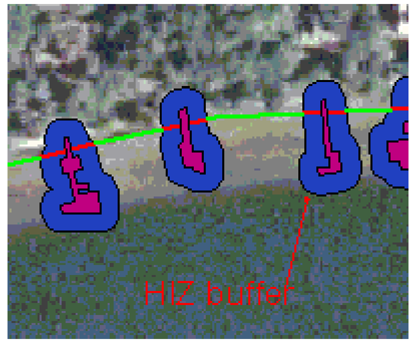


Figure 10. The blue areas in the photo are the HIZ buffer zones and the red and green line is the lake outline. The intersect tool split the shoreline into segments each with attributes showing whether or not the segment was impacted by the buffer polygons.

the "Littoral Zone – Observed" layer, found on the DRS. This layer only had data for 15 of the lakes in the study area. This layer contains estimated littoral zone information based on lake contour maps, and also has very accurate lake outlines. Category F required the littoral zone data, and category I required the accurate lake outlines. After the correct lakes were selected from the littoral zone layer, the total littoral zone acreage was calculated by shoreland class and county and related to the area of the HIZ buffer layer to obtain the numbers necessary for category F. The first step in calculating statistics for category I was to convert the selected 15 lake outlines from polygon features to polyline features. Then, the length of each shoreline was calculated. Next, it was necessary to "intersect" the HIZ buffer layer with the new polyline layer. Intersecting these two layers created a new polyline shapefile that included the attributes from the HIZ buffer layer. This process also split the shoreline features based on where the buffers touched them, in effect showing what parts of the shoreline were impacted by the HIZ layer (Figure 10). It was then possible to calculate the total impacted shoreline length based on county and shoreland class.

For category G, the first step was to select only shoreline parcels from the countywide master parcel layer. In order to accomplish this, all 116 (five lakes were omitted in categories G and H due to missing parcel data) water polygons were selected and a "select by theme" was completed to select all adjacent parcel polygons. Once this was finished, the total areas were calculated based on county and shoreland class.

The first step in calculating category H was to convert all 15 water polygons into polyline features and to use the DNR "intersect" tool to split the lines into public and private sections of shoreline. The total shoreline length of public vs. private land based on county or shoreland class was then calculated.

Results/Discussion

Most docks occur on General Development lakes, but as a function of surface area are highest on Recreational Development lakes. Natural Environment lakes have very few docks but are a growing target for residential development.

Complex docks consisting of more than one boat lift or accessory structure represented the highest number of docks in the sample. This pattern was consistent across all shoreland classes, although docks on General Development lakes were much more abundant. The mean estimated dock surface area per lake ranged from 0.01 acres (Natural Environment) to nearly 4 acres (General Development), as seen in figure 11.

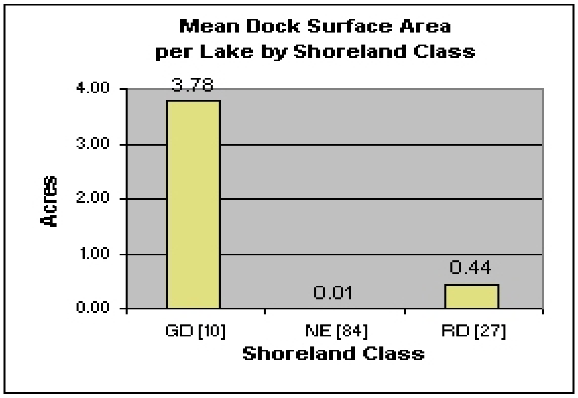


Figure 11. Mean dock surface area per lake ranged from .01 acres on Natural Environment lakes to 3.78 acres on General Development lakes.

Impacts were highest on General Development lakes due to the number of structures relative to other shoreland classes but, as a function of surface area, were highest on Recreational Development lakes.

Habitat impact increased with dock complexity, but overall cumulative impact for these complex structures per lake was relatively low, since there are fewer numbers of these complex structures (Figure 12).

Habitat impact per lake by dock type appeared to differ by shoreland class. When viewed as a function of surface area, the amount of habitat impact for simple dock structure types 0 and 1 was highest for Recreational Development lakes and nearly as high as General Development lakes for more complex dock types 2,3, and 4 (Figure 13).

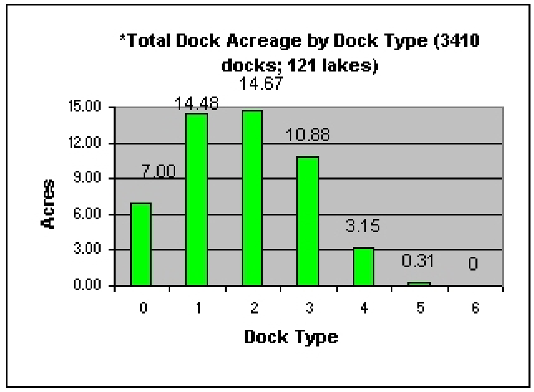


Figure 12. Less complex docks, types 1 and 2, had the highest cumulative impacts because of the large numbers of these structures.

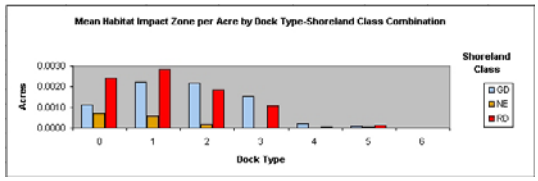


Figure 13. When viewed as a function of surface area, the highest impact came from structure types 0 and 1 on Recreational Development lakes.

Littoral area is a more appropriate measure of dock impacts on aquatic habitats, and this was greatest for Recreational Development lakes. The fact that over 2% of the littoral habitat of Recreational Development lakes on average is impacted by docks and accessory structures was an unexpected finding. While 2% is a relatively small number, even small structures can have a potential cumulative effect on the entire littoral.

The percentage of shoreline length impacted by dock structures was estimated to range from 1.7% for Natural Environment lakes up to nearly 13% for General Development lakes. In both Crow Wing and Aitkin counties, nearly 20% of the combined shoreline of the lakes was impacted by dock structures as referenced in figures 14 and 15. This is a significant number since near-shore littoral habitat is more important to the diversity of aquatic species than offshore littoral habitats.

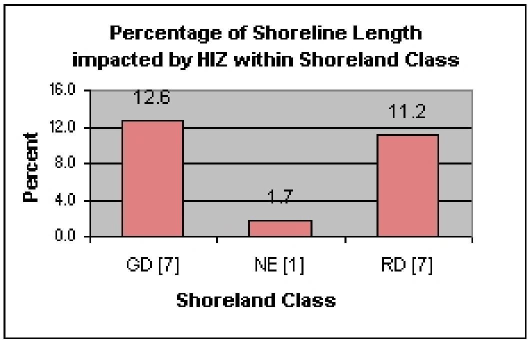


Figure 14. Percentage of shoreline length impacted by structures ranged from 1.7% on Natural Environment lakes to 12.6% on General Development lakes.

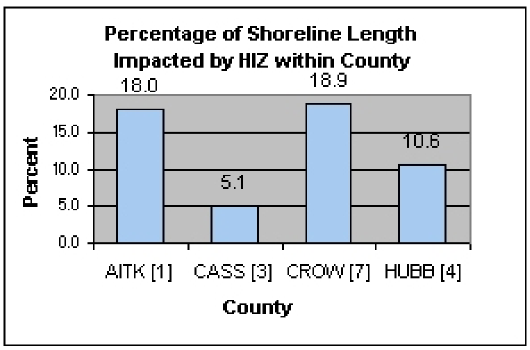


Figure 15. Aitkin and Crow Wing Counties had the highest percentage of shoreline impacted by structures at almost 20%.

Conclusion

This study provides insight into the cumulative impacts of dock structures on lakes in north-central Minnesota. Results suggest that docks and accessory structures can create a sizeable footprint of potential habitat impact on an individual lake scale, under the current development conditions observed in the study lakes for this project. These impacts have consequences for aquatic species dependent on littoral habitats. The proposed next step in the analysis is to estimate impacts under a full development scenario that would be allowable under current shoreland rules. Human-induced reduction of aquatic macrophytes focused around these structures can impact fish species abundance and diversity at the local scale (Pratt and Smokorowski, 2003).

Habitat impacts may be underestimated for several reasons. Additional plant removal activities are allowed under Minnesota Rules without a permit, so this is a conservative estimate of the overall activities occurring statewide. Also, because the structures were digitized using aerial photographs, some structures may have been overlooked because of trees above the structures or because of the fact that the structures may not have been in the water at the time of year the photos were taken (some of the photos used to digitize the structures were taken in early spring).

Although habitat quality is not equal between lake types (e.g., GD vs. RD) or even within the same lake or lake type, the data suggests that at least one lake shoreland class deserves further attention. The relatively large littoral zone impact in RD lakes and the large percentage of shoreline already impacted by dock structures has policy implications for regulatory agencies like the DNR. Some of the possible new policies could include, but are not limited to: multiple shoreland lake classifications on a single lake, sensitive area districts for lakeshore segments where developments standards follow natural environment lake class standards, or new special protection lake classification for lakes where there is considerable wetland fringe, shallow depth, and/or unique fish and wildlife habitat or endangered species.

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