Lake Wausau in-lake Habitat (draft report April 17, 2014)

INTRODUCTION

Over eleven selected shoreline miles (11.6 miles) of Lake Wausau's in-lake, near-shore habitat was mapped with side-scan sonar technology which provided continuous coverage of the lake bottom visible underwater (Figure 1). The shoreline areas were selected by the Wisconsin Department of Natural Resources (WI DNR) local fisheries biologist with input from additional researchers involved with this project. Habitat features that were mapped include substrate (bottom type information) distribution and coarse woody habitat (CWH) abundance. In-lake habitat is particularly important to the fish community for spawning success, juvenile nursery habitat, protection, and foraging sites. The in-lake habitat information collected in this study was used to assist the WI DNR with critical habitat designation areas on Lake Wausau in October, 2013. Recommendations for designation areas from this study were given to the WI DNR prior to their evaluation of critical habitat on Lake Wausau (Figure 2).

Protection of critical habitat is important for the sustained health of aquatic fauna including fish, insects, and amphibians. Healthy lake habitat attracts a wide variety of waterfowl and shorebirds including Osprey, Great Blue Heron, Loons, and Willets to name a few. A well-established Great Blue Heron rookery is noticeably visible on island areas east of Rookery View Park in the Town of Rib Mountain where over 100 nests have been reported.

From 2002 to 2006 (WI DNR) Lake Sturgeon (*Acipenser fulvescens*) were re-introduced to the Wisconsin River near Merrill in Marathon County. These stocked populations have access to Lake Wausau and beyond, and stocking attempts were performed to improve populations of this rare fish. Because of their slow sexual maturity, long spawning cycles, and specific habitat requirements, successful natural reproduction of Sturgeon in Lake Wausau or elsewhere Marathon County is uncertain for the future. Female Lake Sturgeon reach sexual maturity between 24-26 years of age and spawn every 4-6 years thereafter (Becker, 1983). Sturgeon spawning is dependent on water temperature (53-59 degrees Fahrenheit) and flow. Sturgeon prefer to spawn in shallow, fast-moving water over hard substrate such as cobble and boulder, similar to habitat found downstream of Whitewater Park in the City of Wausau.

Mapping substrate in lakes also has many practical applications for resource managers. Spawning and cover habitat for fishes is often controlled by distributions of substrate (Cunningham, 2008). For example, Walleye (*Sander vitreus*) prefer to spawn on gravel versus sand areas; however, if gravel areas are not available Walleye will utilize muck and sand areas, but egg survival rates are best on gravel-rubble bottoms (Johnson 1961). Smallmouth Bass construct nests from gravel and flat rocks, and it has been shown that nests built with more uniform substrate particle diameter and are more likely to be successfully spawned (Winemiller and Taylor 1982). Recent research shows that gravel substrate abundance (>40% in $1m^2$) is a key feature in successful Smallmouth Bass nesting habitat for Wisconsin lakes (Bozek et al. 2002).

Submersed aquatic vegetation growing patterns are also related to substrate distribution. For example, Eurasian watermilfoil (*Myriophyllum spicatum* L.) (EWM), a nuisance aquatic invasive that is present in Lake Wausau, prefers moderately dense, fine-textured substrate and conversely does not grow well on coarse substrates such as sand and gravel (Smith and Barko, 1990). Curly-leaf pondweed (*Potamogeton crispus* L.), another nuisance aquatic invasive plant found in Lake Wausau, prefers soft substrates (Nichols, 1999). Substrate preferences associated with aquatic plant growth patterns coupled with depth distribution information can be used to monitor for early detection of invasive plants in lakes.

Coarse woody habitat (CWH) is another important habitat component of the aquatic ecosystem that influences the distribution of aquatic life (Everitt and Ruiz 1993, Sass et al. 2006b). It is attractive to predatory fish for foraging (Newbrey et al. 2005). Woody habitat with complex branching and increased surface area can lead to greater insect density and diversity, a necessary diet for many fish species (Schmude et al. 1998). Common perch (*Perca fluviatilis*) and were found to prefer woody structured habitats over reed at both day and night, showing increased abundances with CWH structural complexity (Lewin et al. 2004).

The aquatic animal community structure and diet can be altered by the removal of CWH (Sass et al. 2006a, Sass et al. 2006b). When the majority of CWH was removed from a basin on Little Rock Lake in Wisconsin, Yellow Perch (*Perca flavescens*) populations rapidly declined and Largemouth Bass (*Micropterus salmoides*) diet changed from predominantly perch (>60%) to a diet with an average of 14% perch and 51% to 55% terrestrial prey (Sass et al. 2006a). Additional research shows prey fish including Yellow Perch, Pumpkinseed (*Lepomis gibbosus*), Bluegill (*Lepomis macrochirus*), and the Fathead Minnow (*Pimephales promelas*) had decreased predation risks when protected within CWH (Sass et al. 2006b).

As human development around a lake increases the amount of CWH significantly decreases, which can negatively impact lake ecosystems (Christensen et al. 1996). Input and decay rates of CWH are altered when development increases (Christensen et al. 1996). Intolerant fish species (darters *Etheostoma* spp., Mottled Sculpin *Cottus bairdii*, Smallmouth Bass (*M. dolomieu*), and Rock Bass (*Ambloplites rupestris*)) in Wisconsin lakes were found in significantly greater abundances in less disturbed lakes, and were rare or not present in developed lake systems (Jennings et al. 1999). Understanding the distribution of CWH in Lake Wausau will be important for lake planning and habitat improvement.

There are many traditional methods for collecting in-lake habitat information of the near-shore littoral area; however most traditional methods including transect point-intercept methods fail to provide complete coverage and a holistic picture of the littoral habitat. In addition, these traditional methods for habitat mapping are time-consuming and therefore expensive to operationalize. Side-scan sonar has the ability to record continuous bottom habitat images very quickly anywhere in a lake, which cannot be done with traditional survey methods. Side-scan sonar has the ability to look through turbid, stained waters (such as Lake Wausau) and detects density changes (from recorded sound wave returns) at the bottom resulting from

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differences in bottom substrate type and presence of structures such as logs, docks, fish cribs, and more.

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Figure 1: Selected near-shore areas of Lake Wausau (outlined in green) scanned with side-scan sonar for in-lake habitat features in 2013. Total scanned shoreline distance = 11.6 miles.

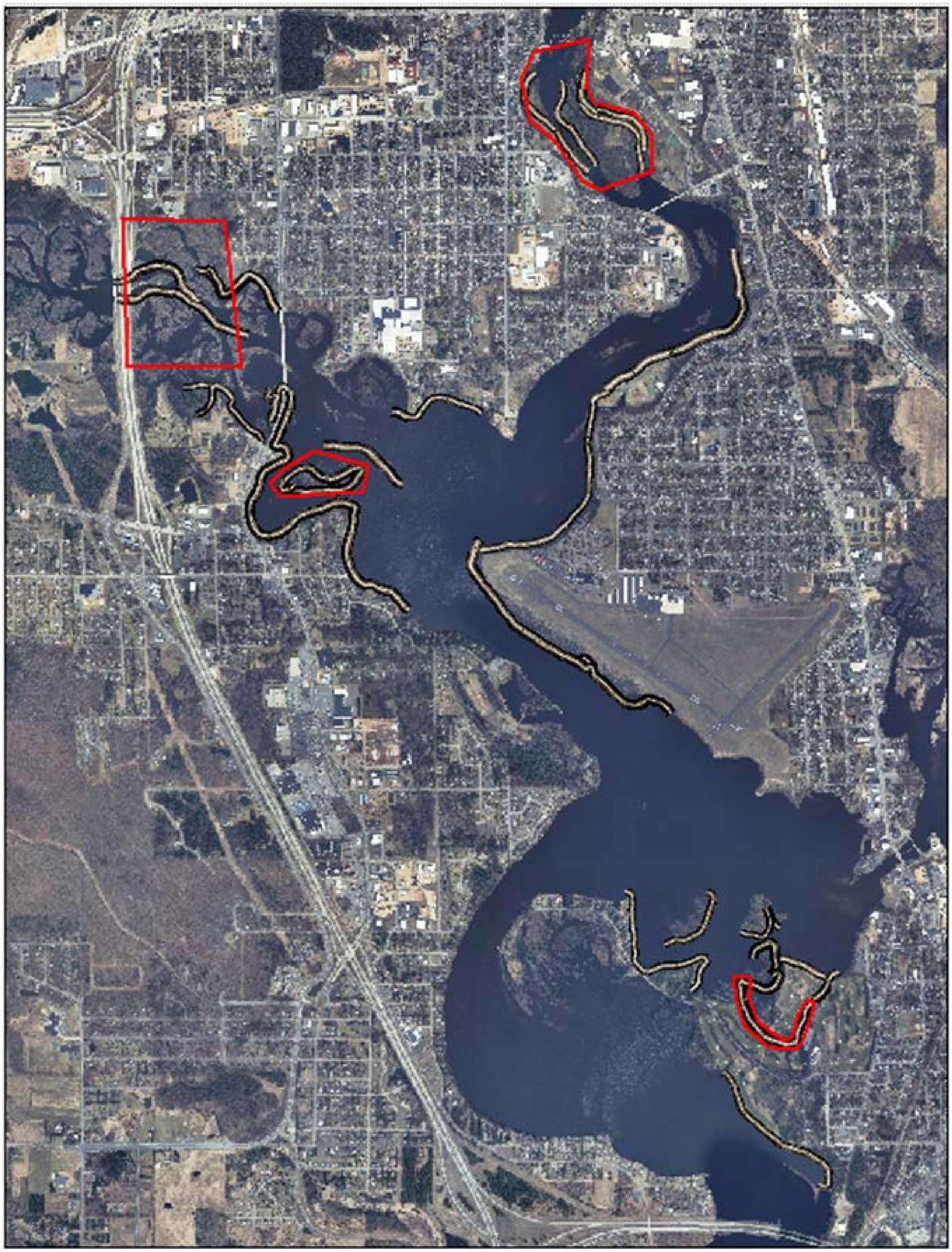

Figure 2: Areas of Lake Wausau recommended for evaluation of critical habitat designation (outlined in red) as performed by the WI DNR in October, 2013. Areas were selected based on features detected during the 2013 side-scan sonar survey.

METHODS

Lake Wausau was mapped for in-lake habitat features in spring 2013. Littoral bottom habitat (substrate) was sampled with side-scan sonar to create maps of bottom substrate classes and CWH abundance (log diameter >10 cm and length >1.5 m) extending from the shoreline to a range of 100 feet. The substrate classes used are modifications to those found in the WI DNR critical habitat designation manual (Cunningham, 2008): muck, sand, gravel, cobble, mixed (sand/gravel, sand/gravel/cobble, gravel cobble, sand/cobble), and boulder (Table 1). Classifications were determined from previous research showing the interpreter ability to distinguish between different substrate types.

Table 1: Substrate classifications and descriptions for Lake Wausau habitat map (2013).

Class	Acronym	Description
Muck	M	>50% particle size is <0.06mm.
Sand	S	>50% particle size range is 0.06mm - 2mm.
Gravel	G	>50% particle size range is 2mm - 64mm.
Cobble	C	>50% particle size range is >64mm - 256mm.
Mixed	X	S/G, G/C, S/C, or S/G/C combinations.
Boulder	B	>50% particle size range is >256mm.

Side-scan data was collected in May 2013 using a Lowrance HDS5 side-scan sonar (LSSS). The LSSS was front-mounted to a 6hp Jon boat at approximately 6 inches below the water surface. The LSSS left/right viewing range covered a minimum of 100 feet from the shoreline. A boat speed of five miles per hour or less was maintained and data was collected perpendicular to the shoreline at a distance of approximately 50 feet where accessible. Multiple passes around each shoreline were collected to give the interpreter additional images to verify habitat features, to pick up areas missed in the first pass, and/or increase the extent of viewing outward to 100 feet from the shoreline.

Sonar imagery was rectified using SonarTRX v10.13 (2012) software and then spatially displayed using Esri's ArcGIS 10.0 mapping software. Habitat substrate was then manually interpreted inside the 100 foot range from shoreline, and substrate distribution boundaries were digitized with polygon shapefiles in ArcMap 10.0. A minimum mapping unit (mmu) of 845 square feet (a circle with 16.4 foot radius) was used to delineate substrate habitat (Kaeser and Litts 2010). Coarse woody habitat was also manually interpreted and marked with point locations in ArcMap 10.0 in order to calculate logs/mile.

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Ground-truth Verification

Ground truth surveys were conducted in scanned areas of Lake Wausau in late September and early October of 2013. Ground truth sampling locations for each substrate type were randomly assigned using ArcMap 10.0. All similar habitat class polygons were grouped, buffered by 4 meters (13.1 feet) to account for GPS positional error, and assigned approximately 50 random sampling points. Random points were equally distributed among different substrate classes despite large variations in percent cover between classes.

Ground-truthing was completed at the randomly assigned point locations described above using a combination of an underwater camera, visual observations, wading, and dredging. Where applicable, substrate samples were grabbed by hand or with the use of an Ekman dredge and manually hand-textured to determine particle size/s. At each point location, the substrate type was documented and verified against a second field technician to ensure good agreement of substrate type. A standard error matrix was used to show user and interpreted accuracy of ground-truth data vs. interpreted data.

Coarse woody habitat abundance was also verified with ground-truth sampling. All interpreted shorelines in Lake Wausau were grouped and split into 160-foot sections. Each section was coded as 0, 1, or 2 depending on interpreted abundance of CWH (0=no CWH or absent, 1=1-3 logs or moderate abundance, 2=4+ logs or dense abundance). Twenty-one sections of shoreline that were coded absent (0) and 22 sections of shoreline that were coded as dense abundance (2) were randomly selected for ground-truthing in the field Figure 3). Using a hand-held Garmin 76CS GPS receiver for navigation, waders and a Jon boat were used to locate logs within the first 100 feet of shoreline out to a wading depth of 4 feet. Every log observed was measured for length and diameter using calipers and measuring tape. Logs deeper than wading depth were omitted from measurements. A standard error matrix was used to show user and interpreted accuracy of ground-truth data vs. interpreted data.

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RESULTS

Interpretation accuracy of substrate distribution was evaluated using a standard error matrix (Figure 3). Gravel substrates were interpreted with the lowest accuracy (21%), although gravel was generally present at the sites in some quantity. Muck or soft bottoms were interpreted with the highest accuracy (87%). Most incorrect interpretations of muck bottom were verified to be sandy bottoms. Most locations interpreted as boulder substrate were verified as a mixed substrate which had boulders present. Substrate distributions in the selected study areas can be seen in Figures 7 and 8.

Interpreted data	**Point Sampling data (field sampling)**						**Row Total**	**User's Accuracy**
	M	**S**	**G**	**MIX**	**CO**	**BO**		
M	41	17	1	0	0	0	59	**69%**
S	5	21	4	5	1	0	36	**58%**
G	0	1	9	0	1	0	11	**82%**
MIX	1	8	26	41	18	19	113	**36%**
CO	0	0	2	2	27	0	31	**87%**
BO	0	0	0	1	0	18	19	**95%**
Column Total	47	47	42	49	47	37	269	*
Interpreted Accuracy	**87%**	**45%**	**21%**	**84%**	**57%**	**49%**	*	**Overall accuracy 64%**

Figure 3: Standard error matrix for interpreted vs. actual substrate distribution at random sampling locations in Lake Wausau (2013).

Interpretation accuracy of CWH abundance was also evaluated using a standard error matrix (Figure 4). A total of 233 logs were measured at random sampling locations (Figure 9, Figure 10). Interpretation accuracy was best in areas that were coded with dense abundance (95%) and overall LSSS image interpretation accuracy was 85 percent. Actual CWH abundance (absent, moderate, or dense abundance) that was determined from ground-truth sampling can be seen in Figures 11 and 12.

	Point Sampling data (field sampling)				
Interpreted Data	**0 (no CWH)**	**1 (1-3 logs)**	**2 (4+ logs)**	**Row Total**	**User's Accuracy**
0 (no CWH)	13	5	4	22	59%
1 (1-3 logs)					
2 (4+ logs)	0	1	18	19	95%
Column Total	13		22	41	
Interpreted Accuracy	100%		82%		Overall Accuracy 84%

Figure 4: Standard error matrix for interpreted vs. actual CWH abundance at random site locations in Lake Wausau (2013).

The number of logs measured at the random sampling locations varied. Average log length at sites coded with dense abundance was 11 feet, although most measured logs were less than 11 feet in total length (Figure 5). Average log length at sites coded as absent of CWH was 9.2 feet,

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and it is visually clear that abundances were generally less than at sites coded with dense abundance (Figure 6). Nearly 2800 (2799) individual pieces of CWH were identified from LSSS images in the areas covering the 11.6 miles of interpreted in-lake habitat (Figures 13 and 14). The total estimated abundance of CWH in Lake Wausau (interpreted data) was 241 logs per mile.

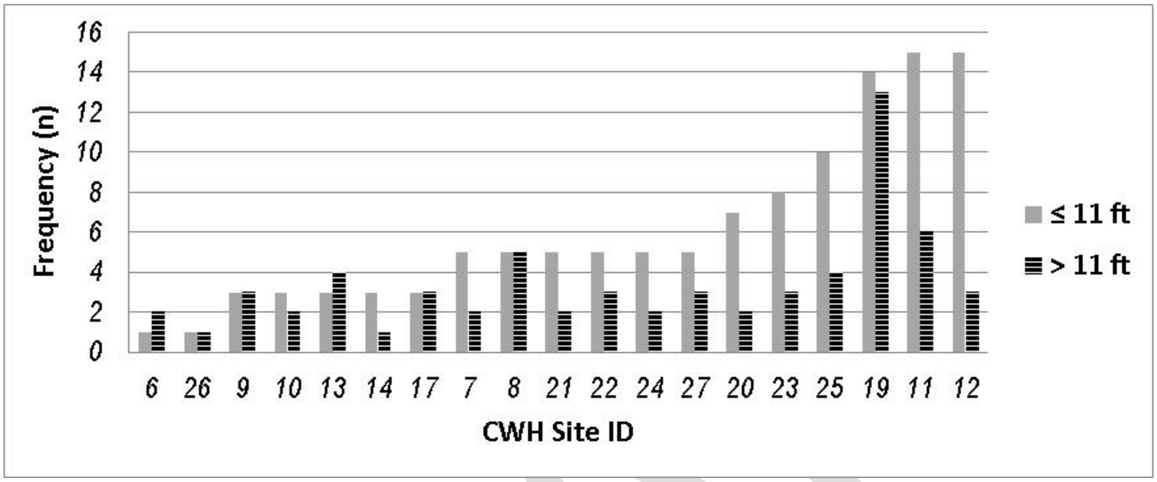

Figure 5: Abundance of CWH at ground-truth locations (coded with dense CWH abundance) sorted by log size (≤ average log length or > average log length of 11 feet) (2013).

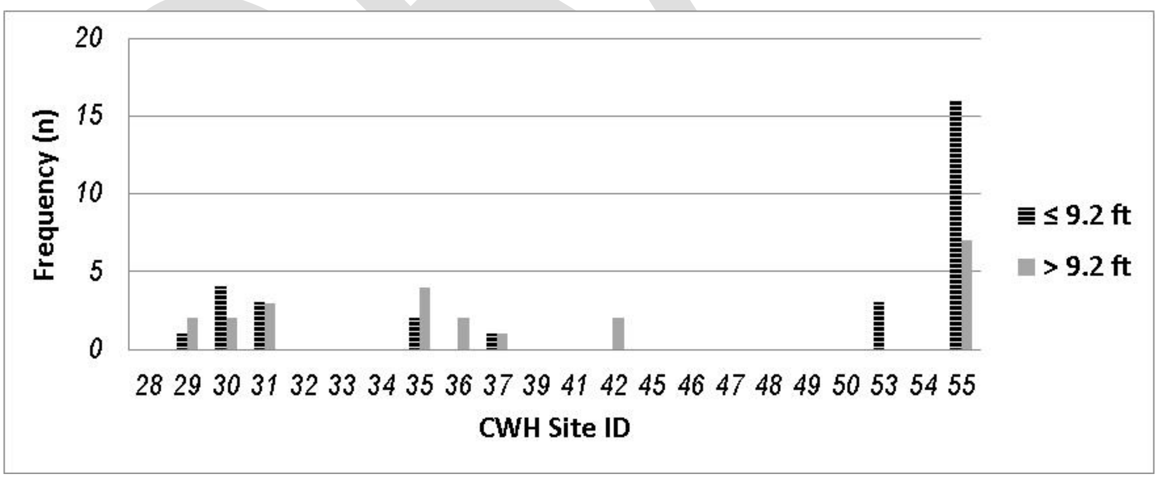

Figure 6: Abundance of CWH at ground-truth locations (coded as absent of CWH) sorted by log size (≤ average log length or > average log length of 9.2 feet) (2013).

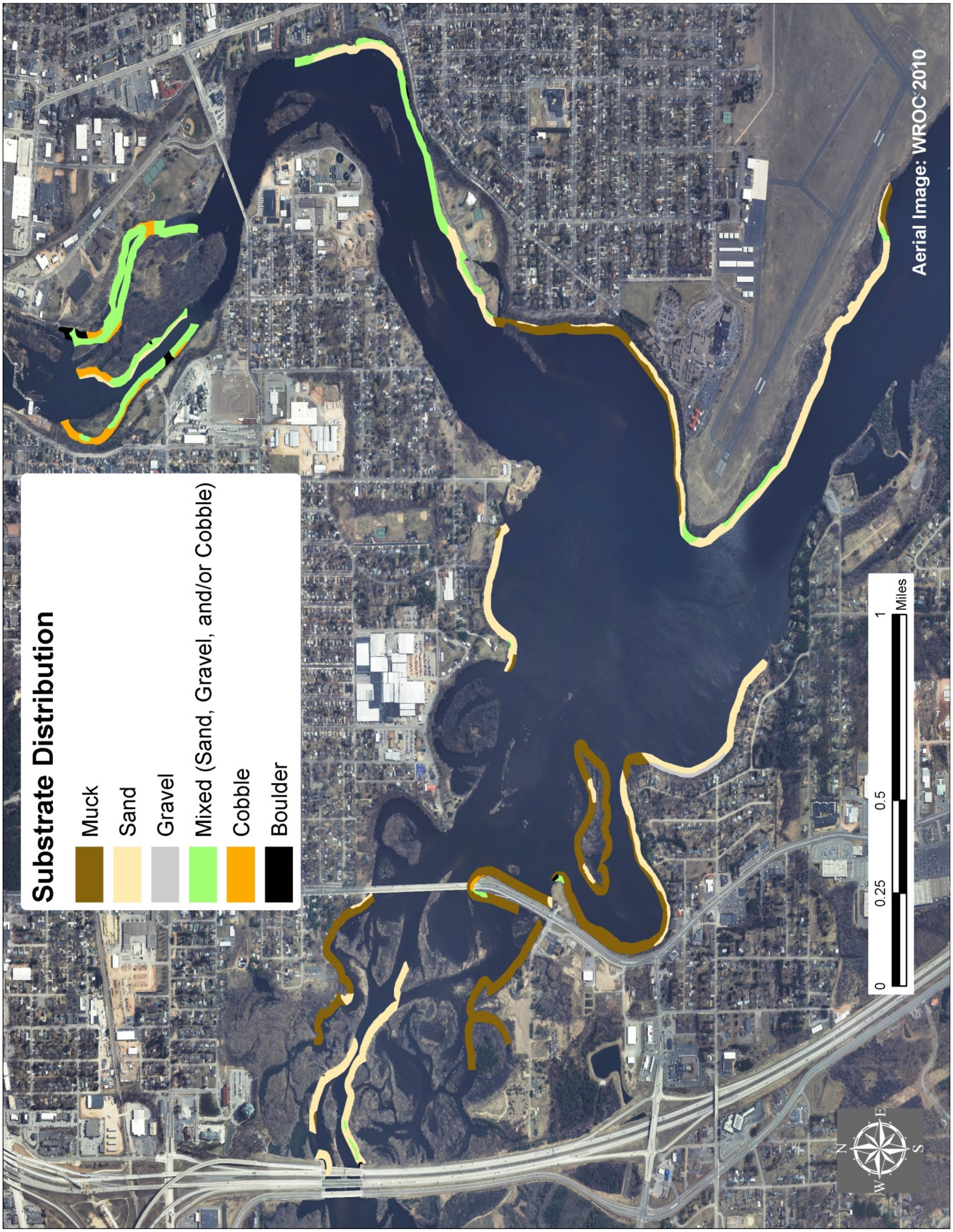

Figure 7: Substrate distribution of north Lake Wausau, 2013.

Figure 8: Substrate distribution of south Lake Wausau, 2013.

Figure 9: CWH ground-truth site locations on north Lake Wausau, 2013.

Figure 10: CWH ground-truth site locations on south Lake Wausau, 2013.

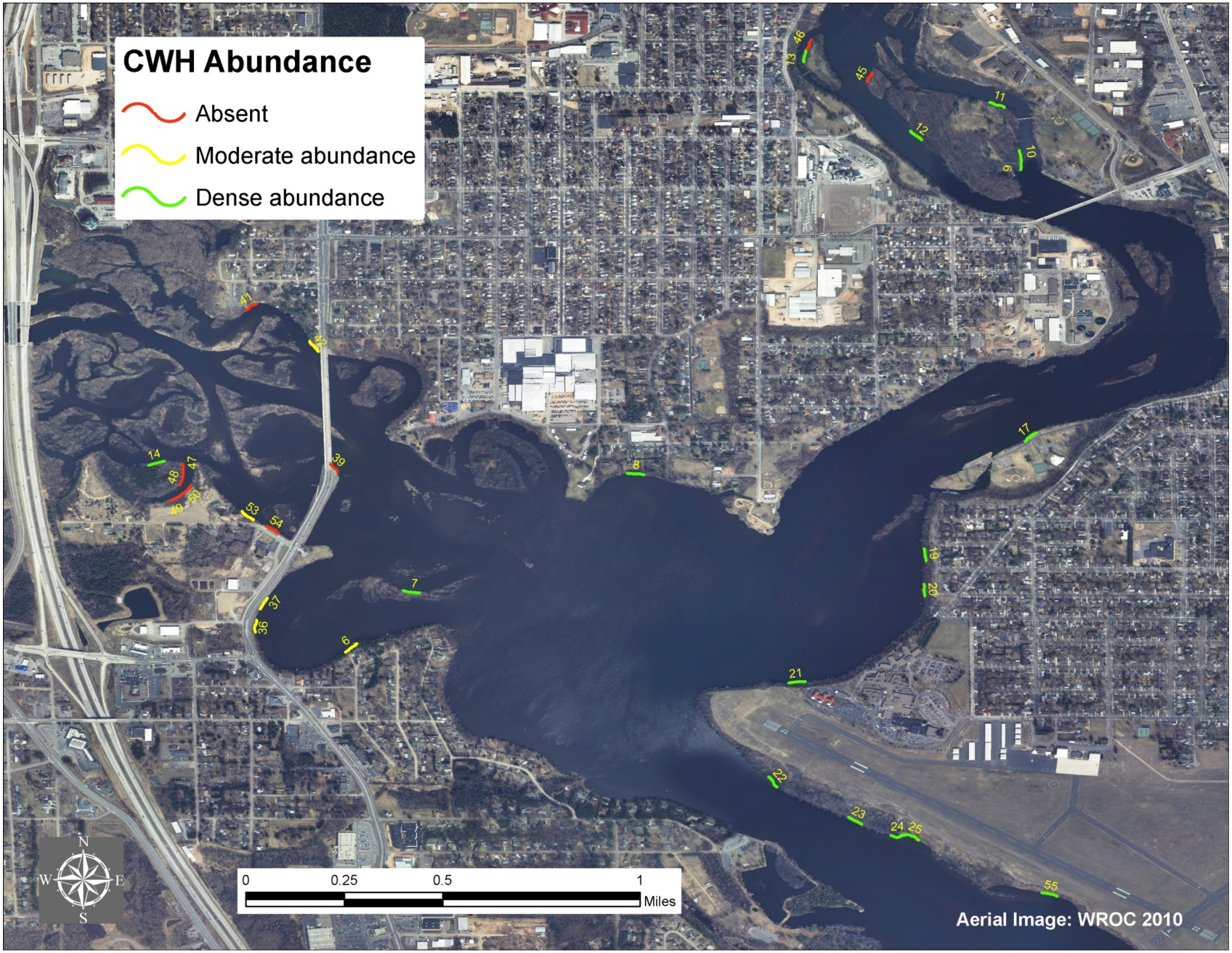

Figure 11: CWH abundance (absent, moderate, dense) determined from ground-truth sampling on north Lake Wausau, 2013.

Figure 12: CWH abundance (absent, moderate, dense) determined from ground-truth sampling on north Lake Wausau, 2013.

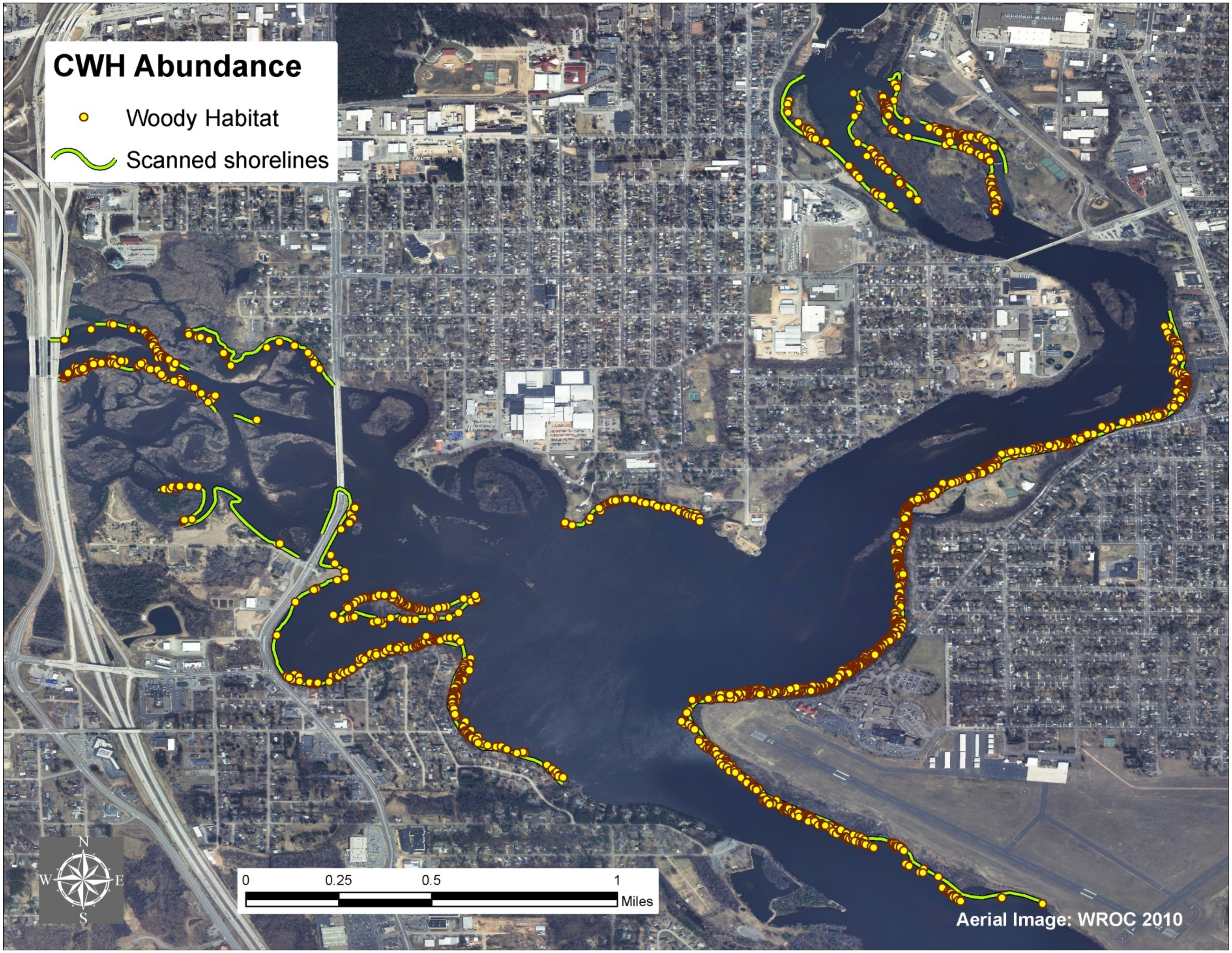

Figure 13: CWH interpreted log locations from side-scan sonar survey on north Lake Wausau, May 2013.

Figure 14: CWH interpreted log locations from side-scan sonar survey on south Lake Wausau, May 2013.

DISCUSSION

Lake Wausau in-lake habitat was mapped using LSSS to determine CWH abundance and substrate distribution in areas selected by the Marathon County Fisheries Biologist. Over 11.5 miles of shoreline area were scanned; these areas were selected to provide useful habitat information related to Lake Wausau's fishery. Previous studies show LSSS can successfully detect CWH that is greater than 1 meter in length and 10 centimeters in diameter (Kaeser and Litts 2008). However, determining actual logs/mile from LSSS images is limited by factors such as log orientation, log size, and blockage from other objects and bottom variation (Kaeser and Litts 2008). Vegetative cover can also problematic when interpreting LSSS image since it distorts sonar imagery and blocks habitat occurring beyond its reach. It is best to scan lakes with dense plant growth early in the sampling season, shortly after ice-out. Care should also be taken to record high-resolution images at a constant speed with limited boat turns. In this study, we also experienced limitations of determining CWH abundance during ground-truth surveys beyond a safe, wadeable depth of approximately four feet. Comparisons between interpreted CWH abundance (number of logs) and actual CWH abundance (number of logs) could not be made due to sampling limitations.

Despite limitations of LSSS data collection and image interpretation, useful information was collected regarding Lake Wausau's in-lake habitat study. Our approach to quantify CWH abundance as absent, moderate, or dense abundance was successful (84% overall accuracy). This method will be useful for determining presence/absence of CWH in lake systems quickly and economically. Classification of lake bottom substrate distribution was not as successful (overall accuracy = 64%) as other studies reaching interpretation accuracy of 77% (Kaesar and Litts 2010); however a few substrate categories were interpreted with good success including muck (87%) and mixed bottoms (84%). Distinction of gravel substrate was most problematic; although most sites interpreted as gravel did indeed have gravel present as noted in the ground-truth survey. Most ground-truthing of near-shore areas was done by hand, without the use of a sieve or lab analysis to verify that the hand-texturing was correct, which can also introduce error into these results.

Lake-bottom hardness is an important component to Lake Wausau's fishery. Some fish (game and non-game species) prefer soft substrates for spawning/habitat including bullhead, catfish, Muskellunge (*Esox masquinongy*), and Warmouth (*Lepomis gulosus*). Other fish species prefer harder substrates (such as sand, gravel, or cobble) for spawning and habitat but have also been observed spawning over soft muck bottoms. These species include non-game fish (Tadpole Madtom (*Noturus gyrinus*), Golden Shiner (*Notemigonus crysoleucas*), Spotfin Shiner (*Cyprinella spiloptera*), Fathead Minnow (*Pimephales promelas*) and game-fish (Black Crappie (*Pomoxis nigromaculatus*), Bluegill, Largemouth Bass, Northern Pike (*Esox lucius*), Pumpkinseed, and Walleye). Other fish species prefer only hard bottoms for spawning and habitat (such as sand or gravel) including Bluntnose Minnow (*Pimephales notatus*), Central Mudminnow (*Umbra limi*), Rock Bass, Smallmouth Bass, Mottled Sculpin (*Cottus bairdii*), Yellow Perch, Sturgeon, and darter species. Although game-fish are more desirable for angling, successful reproduction of non-game species is equally important in a lake ecosystem. To anglers, non-game fish are an

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essential food source to large, desirable sport fish. The continued successful reproduction of different game and non-game species of fish that are already present in the system is needed to maintain fish diversity and ecosystem health. Understanding substrate distribution in Lake Wausau is key to understanding the ecological requirements for a sustainable fish community in the future. Introduction of harder substrates such as gravel and/or cobble may improve fish spawning habitat in certain areas, although consideration for spawning depth, oxygenation, and flow requirements are also important.

There was an abundance of CWH observed in Lake Wausau (241 logs/mile). Coarse woody habitat provides forage areas for predators (Newbrey et al. 2005), increases insect diversity (Schmude et al. 1998), alters fish diet (Sass et al. 2006a), and reduces predation risks for prey fish (Sass et al. 2006b). Since the CWH input rate into aquatic ecosystems is a slow process (Guyette and Cole 1999), abrupt removal can negatively alter habitat for long-term periods. Tree-lined shores should be protected and trees that fall into the water should be left in place to provide cover. Natural shorelines also add aesthetic scenic beauty to Lake Wausau. Although CWH was abundant during the survey, it should be noted that most measured logs were below the average log size of 11 feet. Although it's difficult to determine the cause of this, it is possible the logs that are currently present are older and fragmented, and new inputs of large logs/trees with complex branching are less abundant.

Many Wisconsin lakes continue to face developmental pressures. Humans remove trees both on the landscape and in near-shore aquatic habitats, reducing CWH inputs (Christensen et al. 1996) and significantly lowering sequestration of carbon by CWH (Guyette et al. 2002). Downed trees in littoral areas represent the most permanent and often only year-round cover for fish. Fish populations in Lake Wausau benefit from the availability of CWH below the lowest reported water levels where it remains continuously submerged.

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