Midwest Glacial Lakes Partnership

CORRELATING HABITAT QUALITY TO DOCK FREQUENCY: A MEASURE OF HUMAN IMPACT ON GLACIAL LAKES

Lonnie E. Treese, Dr. Aaron W. Johnson & Maureen Gallagher

Introduction:

Humans have an impact on their surroundings simply by virtue of being in their environment. Their influence upon the flora and fauna immediately surrounding lake habitats has been noted in studies in Alabama (Purcell 2011), Michigan (Hecht-Leavitt 2011), Minnesota (Bergquist et al. 2005 and Willquett 2006), and Wisconsin (Asplund 2000 and Garrison et al. 2005). Representative human impact is shown in the two pictures below taken during the 2013 ground truthing trip in northern Iowa on two of the glacial lakes in the study area. The figure on the left was taken on Upper Gar Lake (dock UG010) and the figure on the right was taken on Spirit Lake (docks SP598 in the foreground and SP599 the closest one in the background).

Type 7 multiple dock (2013)

Spirit Lake individual docks. (2013)

The Midwest Glacial Lakes Partnership (MGLP) supplied a grant to study the glacial lakes in Iowa to ascertain human impact caused by piers and docks, not all of which are attached to the shore. This study grant was influenced in part by an article in Fisheries magazine entitled "Potential Impacts of Docks on Littoral Habitats in Minnesota Lakes" (Radomski et al. 2010). As outlined in that paper, five counties in northern Minnesota containing more than 2000 lakes regulated by Minnesota shoreland rules were studied. Using those rules, the authors identified a sub-set of 174 lakes, which were separated into three classes and subjected to a stratified random sampling scheme (51 of these lakes had no dock structures) to ensure equal representation across the study area. The authors identified 9,284 docks that were categorized into seven classification based on size and complexity. The hypothesis behind their study was that docks caused a littoral and adjacent area impact whether through shading or direct and indirect human actions on the flora and fauna within a 25-foot buffer area surrounding the docks. Similar studies conducted on Minnesota lakes by Payton and Fulton (2004), Beachler and Hill (2003) and Asplund (2000), and on Wisconsin lakes by Jennings et al. (1999) and Garrison et al. (2005) have looked at direct shading effects killing plants and allowing suspension of sediments with boat traffic and swimming, direct human actions of placing sand for beaches around the docks, human killing plants with herbicides and a limited impact study on how these actions affect the fish community and spawning activities.

Introduction (Cont'd):

MGLP has designated 100 lakes in their Iowa portion of responsibility that are glacial in origin. Of these, 60 do not have structures and the remaining 40 have at least one (using Google Earth Pro and figures from the Iowa DNR). Complete analysis of the percentage of shoreline and overall lake coverage impacted in addition to comparisons with habitat quality indices supplied by Midwest Glacial Lakes Partnership (MGLP) is the scope of this presentation.

MGLP has provided data on the Cumulative Natural Quality Index (CNQI) and the Cumulative Anthropogenic Stress Index (CASI) figures for four (4) focus groups: (1) lake trout, lake whitefish and lake herring/cisco (coldwater species), (2) walleye (coolwater species), (3) bluegill (warmwater species), and (4) northern pike (species of special interest, keystone species). The addition of MGLP CNQI and CASI figures to this endeavor gives more weight to the findings in this study.

U.S. Fish and Wildlife Service and the Midwest Glacial Lakes Partnership have developed a Boosted Regression Tree (BRT) model with two designated categories to explain habitat quality indices: response variables and predictor variables. The response variables were typically in-stream measures of condition, including biological measures such as species abundance, presence, richness, or in-stream physicochemical measures, such as pH, conductivity, or physical habitat measures or scores. The predictor variables were typically measures of land use or land cover derived from a GIS analysis, such as percent impervious surface area or road crossing density. The process utilizes a statistical modeling approach, called Boosted Regression Trees (BRT), to relate the in-stream response variable to the landscape-based predictor variables. The statistical outcomes are used to generate post-modeling indices of anthropogenic stress and natural habitat quality. These indices are derived directly from the measures of variable influence and their functional relationships with the response. Specifically, each predictor variable in the statistical model is classified, along with its importance value and functional plot, to generate an individual metric for use in calculating a cumulative index of stress or natural quality. The individual predictors that are anthropogenic in nature (e.g., impervious surface cover) are used to generate anthropogenic stress metrics and the cumulative anthropogenic stress index (CASI), whereas predictors that are natural in origin (e.g., bedrock geology or soil type) are used to generate natural quality metrics and the cumulative natural quality index (CNQI). Also, the two indices, CNQI and CASI, can be used to generate and visualize restoration and/or protection priorities. For example, areas of high natural quality (i.e., high CNQI score) and low stress (i.e., low CASI score) could represent protection priorities, whereas areas of high natural quality and high stress may represent restoration priorities (Bergquist *et al.* 2012).

Research Objectives:

The objective of this thesis is to expand on the studies completed in Alabama, Minnesota, Michigan, and Wisconsin and to apply them to glacial lakes in Iowa in an attempt to enhance the understanding of the effects of human (manmade) structures on the lake habitat. To accomplish these objectives, values will be gleaned from all of the various studies and compared with the findings for the glacial lakes in Iowa. These comparisons will, in turn, be used to confirm and modify the mathematical formula (if needed) used to predict dock and pier impacts. Through this process, it is hoped that a potential link between dock frequency and habitat quality can be found.

Justification:

Beyond Midwest Glacial Lakes Partnership's (MGLP's) request for information in this research project is the importance of this study to provide for the building of better remediation and conservation of fisheries habitats by the MGLP and others who apply the results of this study to fisheries. This study will also help the state of Iowa manage the width, length and number of docks, piers and other structures built upon their lakes. Lakes and their structures then become a portion of Iowa's Department of Natural Resources management focus. The control, licensing and taxation of those lakes and their structures by the state of Iowa can assist with the proper management of Iowa's natural resources for future generations.

Research Background:

Categorization of dock outlines was identified by Garrison *et al.* (2005). As there had not been any previously documented representative pier structure diagrams, this proved to be the only source. Garrison's example only showed one dock with one deck and one lateral as a representative category of dock structures, but it aided in the establishment of a chart to identify and categorize docks into ten (10) categories for this study.

Identification and categorization of docks into six (6) categories using air and satellite photos was refined and updated to ten (10) after a method suggested by Bergquist *et al*. (2005). For my presentation, Google Earth Pro provided composite overhead views with sufficient quality to provide identification and allow categorization following the lead provided by Bergquist *et al*. (2005). Bergquist *et al.* also showed how to digitize the docks and piers to determine surface area impact. Additionally, this method seemed to be the most logical and easiest to use for methodology purposes.

Radomski *et al*. (2010) also categorized docks and piers based on shapes and sizes, from which identification, categorization and enumeration of docks and piers was accomplished using Google Earth Pro satellite views. Additionally, Radomski *et al.* made the first introduction of figures showing how to identify, build and map impacted shorelines areas and Habitat Impact Areas around pier structures. This also seems to be the best process for methodology.

MGLP supplied natural quality (Cumulative Natural Quality Index, CNQI score) values and anthropogenic stress (Cumulative Anthropogenic Stress Index, CASI score) values for: (1) lake trout, lake whitefish and lake herring/cisco (coldwater species), (2) walleye (coolwater species), (3) bluegill (warmwater species), and (4) northern pike (species of special interest, keystone species) habitat quality index figures. These were used to establish a comparison against dock frequency. Additionally, MGLP also provided a Shoreline Development Index (SDI) that will be used to verify the human impact on the glacial lakes with structures in Iowa.

The United States Environmental Protection Agency (2012), State of Washington Department of Ecology (2014) and Boyd (2004) provided information on Secchi disks. The articles describe how to use Secchi disks and the formula used to convert direct readings to Secchi depths. Secchi depth is a measure of the clarity of the water (low turbidity) and of how deep sunlight can penetrate to encourage plant growth and oxygen generation. The information and formula make it possible to convert Secchi depths to percent of light penetration.

The Secchi ground truthing field trip was completed in July 2014.

The 100 Midwest Glacial Lakes Partnership (MGLP) Lake IDs, Lake Names and Designators assigned.

LAKE_ID	LAKE_NAME	ACRES	PERIM_FT	DESIGNATOR
IA75	Barringer Slough	91.9408	33233.6061	Barringer Slough
IA7	Big Wall Lake	578.2165	71521.7049	BW
IABHA81	Black Hawk Lake	904.9456	64881.1001	BL
IA89	Blue Wing Marsh	50.99386	13632.8747	Blue Wing Marsh
IA44	Brenton Slough	52.44629	14729.4229	Brenton Slough
IA73	Bur Oak Lake	88.49246	8156.42506	Bur Oak Lake
IACEN30	Center Lake	258.7006	19661.6819	CL
IA82	Cheever	107.5589	13023.8907	Cheever Lake
IA54	Christopherson Slough	68.79595	11649.0006	Christopherson Slough
IA32	Clay_05	22.05201	6135.7798	Clay_05
IA12	Clay_10	28.40389	8732.5693	Clay_10
IACLE17	Clear Lake	3628.54	73396.3669	CE
IACRY41	Crystal Lake	263.565	15923.269	CY
IA70	Cunningham Slough	242.1655	29865.7547	Cunningham Slough
IA68	Cunningham Slough2	45.38368	9824.52055	Cunningham Slough 2
IA88	Dan Greene Slough	250.963	34020.2197	Dan Green Slough
IADIA30	Diamond Lake	131.4212	12335.4953	Diamond Lake
IA55	Dickinson_03	89.47044	9285.3538	Dickinson_03
IA20	Dickinson_04	53.27616	13590.4162	Dickinson_04
IA19	Dickinson_05 (Yager Slough)	26.70934	6445.86399	Dickinson_05
IA23	Dickinson_06	25.50477	6090.06703	Dickinson_06
IA13	Dickinson_07	24.39755	4583.85319	Dickinson_07
IA27	Dickinson_12	25.29353	9477.76386	Dickinson_12
IA18	Dickinson_13 (Trappers Bay)	34.0935	6051.01849	Dickinson_13
IA21	Dickinson_17	27.87514	5370.26902	D17
IA24	Dickinson_18	24.77911	4049.8982	Dickinson_18
IA16	Dickinson_20	29.61075	10101.7827	Dickinson_20
IA17	Dickinson_21	29.28808	4861.81643	Dickinson_21
IA52	Dunbar Slough	134.1246	19844.3656	Dunbar Slough
IA58	Eagle Lake	22.20383	9941.30721	Eagle Lake
IA38	East Hottes	279.2131	32441.2229	East Hottes Lake
IAEOK30	East Okoboji Lake	1838.609	90024.5841	EO
IAELK21	Elk Lake	260.5033	15587.7733	EK
IA9	Elm Lake	449.231	30076.4697	EM
IA83	Emmet	22.28625	5446.64875	Emmet
IA59	Emmet_1	36.79248	6226.97488	Emmet_1
IA57	Emmet_2	108.621	10856.9509	Emmet_2
IA69	Emmet_3	67.71338	8910.07514	Emmet_3
IA80	Emmet_4	30.84479	9613.8744	Emmet_4
IA79	Emmet_7	95.75722	26250.1292	Emmet_7
IAFIS74	Five Island Lake	966.7085	84425.3041	FI
IA81	Fourmile Lake	89.83461	13983.971	Fourmile
IA34	Garlock Slough	51.70026	8969.38739	Garlock Slough
IA49	Goose Lake (Greene)	62.61522	17685.9968	Goose Lake (Greene)
IA50	Goose Lake (Hamilton)	49.34339	10891.7315	Goose Lake (Hamilton)
IA63	Goose Lake (Kossuth)	74.13188	7031.93929	Goose Lake (Kossuth)
IA46	Greene_3	69.72371	13618.297	Greene_3
IA53	Greene_8	24.27866	6982.58525	Green_8
IA51	Guthrie_2	43.78515	7918.58189	Guthrie_2
IA31	Hale Slough	26.45867	6605.87932	Hale Slough
IA94	Hancock_1	40.95484	7318.9928	Hancock_1
IAHIG32	High Lake	552.2992	36946.1831	HL
IA66	High Lake 2	63.52478	7100.07692	High Lake 2
IA72	High Lake 3	47.04318	5717.40575	High Lake 3
IAING32	Ingham Lake	368.212	23913.3622	IL
IA14	Jemmerson Slough	52.02917	10143.2298	Jemmerson Slough
IA60	Kossuth_1	61.53145	11384.9687	Kossuth_1
IACOR99	Lake Cornelia	244.4756	12747.3308	LC
IA4	Little Clear Lake	157.4025	15197.382	Little Clear Lake
IALWA40	Little Wall Lake	247.6284	15716.9011	LW
IALIZ76	Lizard Lake	280.0463	16427.3165	LL
IALIS74	Lost Island Lake	1222.012	56104.1829	LI
IALGA30	Lower Gar Lake	250.7233	21274.1459	LG
IA39	Marble Lake	161.2011	15316.0922	Marble Lake
IA28	McClelland Slough	23.16612	4828.72642	MS
IAMIN30	Minnewashta Lake	120.7515	11225.6981	MN
IAMOR99	Morse Lake	107.6151	10832.9112	MR
IA77	Mud Lake	297.4441	20633.532	ML
IA61	North Slough	45.60447	9531.26629	North Slough
IANTW13	North Twin Lake	456.7557	30110.0568	NT
IA74	Palo Alto_2	50.40379	8357.34003	Palo_Alto_2
IAPIC11	Pickerel Lake	169.1947	11344.9731	Pickerel Lake
IA30	Pleasant Lake	81.32471	9267.93285	PL
IA3	Pocahontas	26.75285	7104.5167	Pocahontas
IA29	Prairie Lake	88.92314	13542.0569	Prairie Lake
IARIC95	Rice Lake	890.141	76137.095	RL
IA15	Rush	104.9216	10957.1093	Rush Lake
IA40	Sandbar Slough	58.07107	8755.82531	Sandbar Slough
IASIL30	Silver Lake (Dickinson)	1032.57	37667.2017	SL
IASIL74	Silver Lake (Palo Alto)	641.2106	31125.2767	PA
IASIL98	Silver Lake (Worth)	331.8319	22734.1515	WSL
IA45	South Twin Lake	481.5659	23112.2475	ST
IASPL30	Spirit Lake	5330.093	82984.4292	SP
IA33	Stony	54.51132	10217.2899	Stony Lake
IASTL11	Storm Lake	3040.699	61556.6289	SR
IA42	Storm Lake_2	74.38307	7712.03591	Storm_2
IA1	Sunken Island Lake	94.85261	22271.9756	SI
IASWA30	Swan Lake (Dickinson)	175.392	13120.4609	SWA
IAWSW32	Swan Lake (Emmet)	794.9614	50770.2779	SWE
IATRU21	Trumbull Lake	1080.023	43122.6375	TL
IA65	Twelve-Mile Lake	200.1589	16083.3899	TW
IAUGR30	Upper Gar Lake	35.86672	7327.40782	UG
IA95	Ventura Marsh	245.2746	42833.0839	VM
IAVIR74	Virgin Lake	220.0364	25697.2632	Virgin Lake
IA26	Welsh Lake	57.51307	6137.0588	WL
IAWOK30	West Okoboji Lake	3871.587	101010.948	WO
IA62	West Slough	52.58784	8734.50371	West Slough
IAWTW41	West Twin Lake	113.4323	8449.2226	West Twin
IA91	Worth_1	167.0097	39674.435	Worth_1
IA97	Zerbel Slough	52.0194	7066.33466	Zerbel Slough

Dr. Johnson (left) verifying dock size (UG010).

Dock and boat hoist viewed from lake (SP264).

Dock not restored to lake after winter (PL002).

No weed control around this dock and boat hoist (UG010).

Study Area:

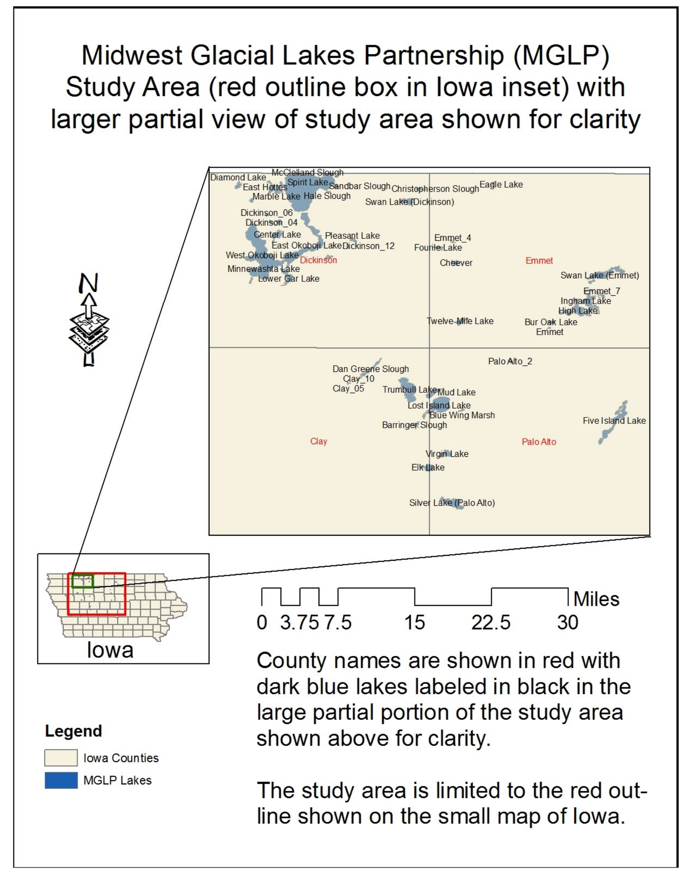
The study area covers the 100 glacial lakes in Iowa as designated by the Midwest Glacial Lakes Partnership (MGLP). MGLP's Region of Fisheries and Habitat Management is shown at right. The area shaded in gold, comprises the entire Midwest Glacial Lakes Partnership region.

This presentation is limited to the portion extending into Iowa.

Midwest Glacial Lakes Partnership (MGLP)

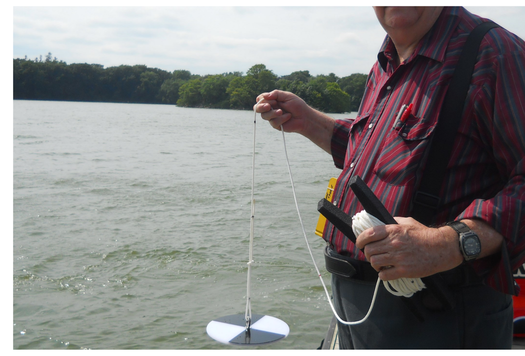
Representative swim dock (UG010).

Midwest Glacial Lakes Partnership (MGLP) Study Area (red outline box in Iowa inset) with larger partial view of study area shown for clarity



County names are shown in red with dark blue lakes labelled in black in the large partial portion of the study area shown above for clarity.

The study area is limited to the red outline shown on the small map of Iowa.



Secchi disk with calibrated line (FI094).

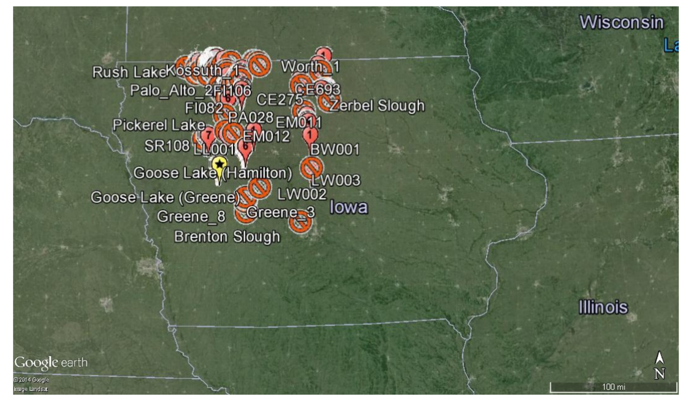
Gathering Secchi disk reading (FI094).

Google Earth Pro (GEP) identified structures and Iowa DNR listed docks/piers. (Table limited to just the lakes with structures.)

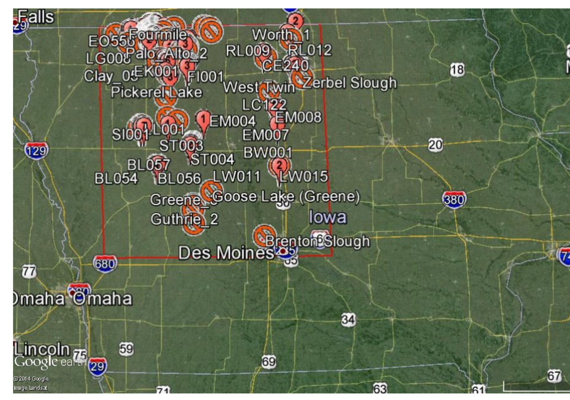
LAKE_NAME	ACRES	PERIM_FT	GEP Structures	Iowa DNR	Checked	Designator
Big Wall Lake	578.2165049	71521.70487	1	0	No	BW
Black Hawk Lake	904.9456498	64881.10006	60	216	No	BL
Center Lake	258.7005592	19661.68192	45	52	No	CL
Clear Lake	3628.540174	73396.36686	769	827	No	CE
Crystal Lake	263.5650117	15923.26901	12	10	No	CY
Dickinson_17	27.87513729	5370.269024	2	0	No	D17
East Okoboji Lake	1838.609023	90024.58414	845	880	No	EO
Elk Lake	260.5033494	15587.77325	1	1	No	EK
Elm Lake	449.2309624	30076.46967	14	5	No	EM
Five Island Lake	966.7085046	84425.30411	115	129	12	FI
High Lake	552.2991754	36946.1831	7	9	No	HL
Ingham Lake	368.2119662	23913.3622	19	27	No	IL
Lake Cornelia	244.4756466	12747.33079	143	141	No	LC
Little Wall Lake	247.628427	15716.90106	22	24	No	LW
Lizard Lake	280.0462756	16427.31655	3	0	No	LL
Lost Island Lake	1222.011713	56104.18288	265	286	No	LI
Lower Gar Lake	250.7232877	21274.14593	118	118	No	LG
McClelland Slough	23.16612374	4828.726421	2	1	No	MS
Minnewashta Lake	120.7514797	11225.69808	114	117	No	MN
Morse Lake	107.6151359	10832.91122	4	0	No	MR
Mud Lake	297.4441354	20633.53204	4	0	No	ML
North Twin Lake	456.7557	30110.05675	247	351	No	NT
Pleasant Lake	81.32471141	9267.932851	2	0	2	PL
Rice Lake	890.1409647	76137.09502	12	0	No	RL
Silver Lake (Dickinson)	1032.570486	37667.20172	101	168	No	SL
Silver Lake (Palo Alto)	641.2105887	31125.2767	32	0	No	PA
Silver Lake (Worth)	331.8318945	22734.15147	15	0	No	WSL
South Twin Lake	481.56591	23112.24752	8	5	No	ST
Spirit Lake	5330.092741	82984.4292	702	796	71	SP
Storm Lake	3040.698657	61556.6289	131	228	13	SR
Sunken Island Lake	94.85261161	22271.97558	1	0	No	SI
Swan Lake (Dickinson)	175.3919504	13120.46091	1	0	No	SWA
Swan Lake (Emmet)	794.9614056	50770.27792	8	2	No	SWE
Trumbull Lake	1080.022625	43122.63752	4	4	No	TL
Twelve-Mile Lake	200.1588976	16083.38992	1	0	No	TW
Upper Gar Lake	35.86671598	7327.407816	28	31	3	UG
Ventura Marsh	245.2745998	42833.08386	4	0	No	VM
Welsh Lake	57.5130725	6137.058804	2	0	No	WL
West Okoboji Lake	3871.587234	101010.9485	1613	1538	No	WO
West Twin Lake	113.4322667	8449.222603	0	2	No	West Twin
Average	796.1630319		5478	5968		
Std Deviation	1155.699002		structures	docks		

Part of Iowa DNR records showing dock sizes. "Dock" indicates extension into water and "lt" indicates lateral from the dock. (NOTE: sizes are in inches!)

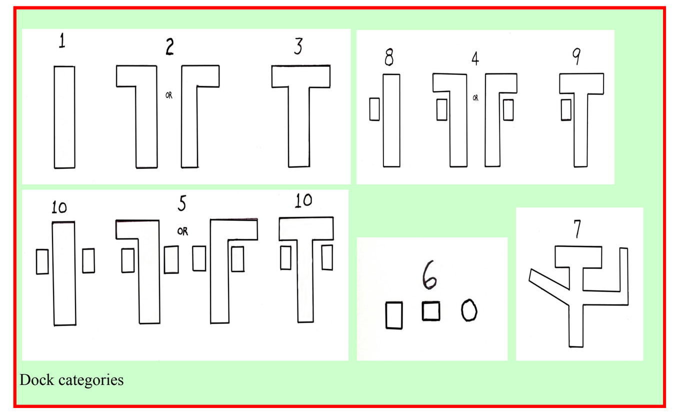
body_of_water	dock_length	dock_width	lt_length	lt_width	width_shore_property
Blackhawk Lake	288	50	96	69	1032



Google Earth Pro map of Study Area showing several lakes. Lakes are shown by name and a barred circle or a sequentially numbered designator with a balloon indicating dock/pier category.



Google Earth Pro map showing Study Area outlined in red.



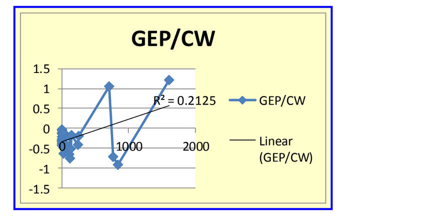
Dock categories

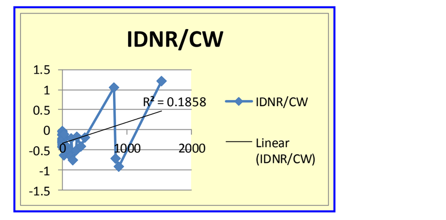
Google Earth Pro view of part of North Twin Lake in Calhoun County with sequentially numbered designators and balloons showing dock category based on shape.

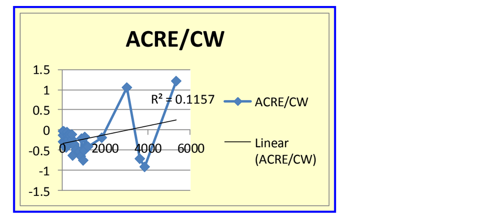
CNQI/CASI compared to dock frequency

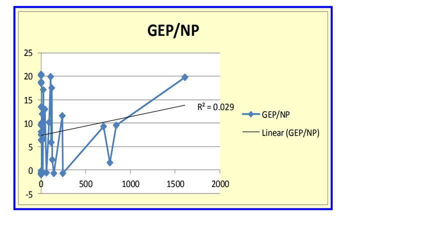
(Google Earth Pro values compared with Iowa DNR values)

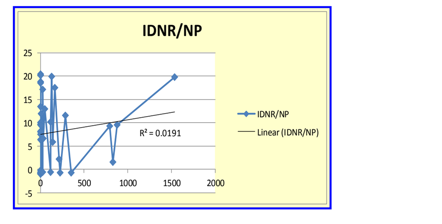
LAKE_NAME	ACRES	GEP_count	Iowa DNR	CW_CNQI/CA	NP_CNQI/CA	W_CNQI/CA	BG_CNQI/CA
Big Wall Lake	578.2165	1	0	0.139454051	0.249060484	1.312415648	9.82322071
Black Hawk Lake	904.9456	60	216	0.494543678	0.599666898	0.99674192	2.128575609
Center Lake	258.7006	45	52	0.387260996	12.91100077	0.728841854	8.276035903
Clear Lake	3628.54	769	827	0.72514612	1.60042863	1.450971554	2.819521739
Crystal Lake	263.565	12	10	0.137125275	8.079162205	0.969947214	1.61422575
Dickinson_17	27.87514	2	0	0.339586909	20.16600337	0.541184123	1.457290528
East Okoboji Lake	1838.609	845	880	0.913023329	9.588520133	1.309059878	3.035993764
Elk Lake	260.5033	1	1	0.306853187	9.67005294	0.856686414	2.496755422
Elm Lake	449.231	14	5	0.145840271	0.451395799	1.327305533	7.656412809
Five Island Lake	966.7085	115	129	0.215945592	5.903319151	1.274227196	1.412651168
High Lake	552.2992	7	9	0.24952992	10.04701075	1.453112084	2.315868953
Ingham Lake	368.212	19	27	0.231956113	9.392805704	1.359301197	3.831753345
Lake Cornelia	244.4756	143	141	0.181300502	0.665555688	0.990248356	1.45232632
Little Wall Lake	247.6284	22	24	0.121656315	0.544794227	0.937173947	5.316111904
Lizard Lake	280.0463	3	0	0.120073437	0.514498721	1.215126327	2.486668968
Lost Island Lake	1222.012	236	286	0.42117678	11.52471868	1.149487485	5.194649098
Lower Gar Lake	250.7233	118	118	0.753822933	17.54835637	0.737514875	2.435720151
McClelland Slough	23.16612	0	1	0.303203464	7.450303584	0.775548152	1.721614873
Minnewashta Lake	120.7515	107	117	0.663089478	19.9593366	0.705572563	2.629824568
Morse Lake	107.6151	4	0	0.057714716	0.91761139	0.765713304	2.296664089
Mud Lake	297.4441	5	0	0.293926244	13.49324426	1.009374651	1.776318057
North Twin Lake	456.7557	247	351	0.193627141	0.669675712	1.343566573	1.126981551
Pleasant Lake	81.32471	2	0	0.325052501	18.75719168	0.882034258	11.91815535
Rice Lake	890.141	12	0	0.233766393	11.9783878	1.030216383	3.829588622
Silver Lake (Dickinson)	1032.57	88	168	0.541421128	10.10389596	1.621592413	1.775512556
Silver Lake (Palo Alto)	641.2106	28	0	0.350382485	6.615603267	1.150846053	1.876331763
Silver Lake (Worth)	331.8319	13	0	0.120927255	10.01031853	1.05441603	3.668312178
South Twin Lake	481.5659	4	5	0.223720772	0.87517671	1.414832008	1.493587411
Spirit Lake	5330.093	702	796	1.05331769	9.264301182	1.455843199	2.512792684
Storm Lake	3040.699	128	228	0.519855423	2.144108659	1.605402474	1.262008426
Sunken Island Lake	94.85261	1	0	0.034159593	0.927498089	0.873395065	2.050077871
Swan Lake (Dickinson)	175.392	1	0	0.422603639	20.4492568	0.622389496	1.697268372
Swan Lake (Emmet)	794.9614	4	2	0.335662892	6.326128116	1.513159484	1.942877658
Trumbull Lake	1080.023	2	4	0.445580356	9.557610965	1.422493972	1.779353348
Twelve-Mile Lake	200.1589	1	0	0.27457504	8.099268886	1.196546714	5.244742273
Upper Gar Lake	35.86672	25	31	0.634678662	17.0645112	0.674456346	2.427724417
Ventura Marsh	245.2746	4	0	0.136806727	0.736924681	0.921484753	2.015494985
Welsh Lake	57.51307	2	0	0.383072144	18.50435563	0.539833204	1.514854561
West Okoboji Lake	3871.587	1613	1538	1.213236504	19.76502707	1.213549125	1.312393705
West Twin Lake	113.4323	0	2	0.03926336	0.943978094	1.168028403	2.1112661

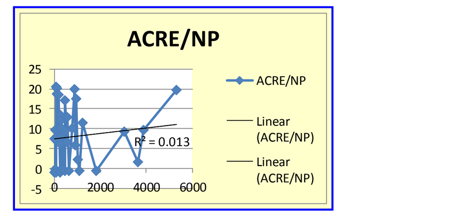


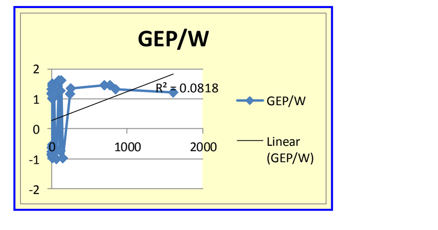


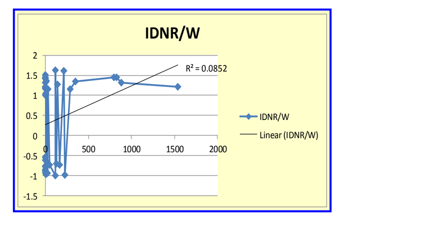


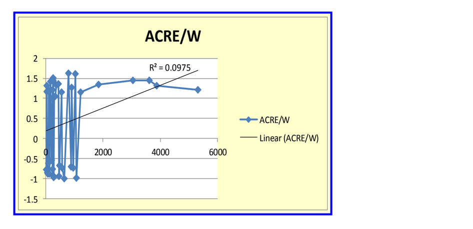


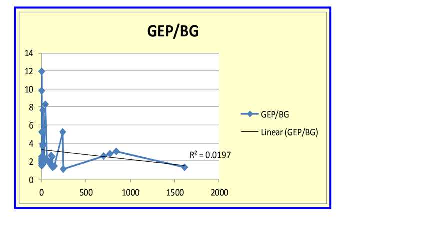


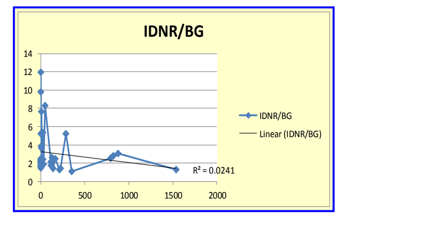


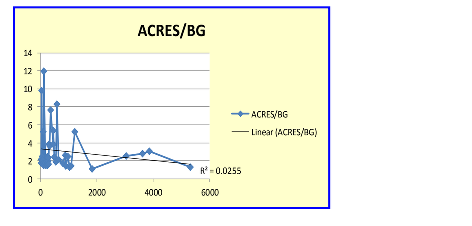












Surface covered "**without**" buffer

(Using Google Earth Pro values where Iowa DNR values were not available)

LAKE_NAME	ACRES	Dock Cover acre/ACRES	Dock Cover %
Big Wall Lake	578.2165049	0.000051	0.005095
Black Hawk Lake	904.9456498	0.001407	0.140716
Center Lake	258.7005592	0.001181	0.118128
Clear Lake	3628.540174	0.002556	0.255574
Crystal Lake	263.5650117	0.000222	0.022237
Dickinson_17	27.87513729	0.000431	0.043104
East Okoboji Lake	1838.609023	0.003993	0.399333
Elk Lake	260.5033494	0.000011	0.001102
Elm Lake	449.2309624	0.000063	0.006265
Five Island Lake	966.7085046	0.000729	0.072920
High Lake	552.2991754	0.000063	0.006276
Ingham Lake	368.2119662	0.000274	0.027445
Lake Cornelia	244.4756466	0.002921	0.292076
Little Wall Lake	247.628427	0.000540	0.053969
Lizard Lake	280.0462756	0.000192	0.019241
Lost Island Lake	1222.011713	0.001210	0.120951
Lower Gar Lake	250.7232877	0.003072	0.307154
McClelland Slough	23.16612374	0.000095	0.009513
Minnewashta Lake	120.7514797	0.006120	0.611961
Morse Lake	107.6151359	0.000189	0.018942
Mud Lake	297.4441354	0.000051	0.005131
North Twin Lake	456.7557	0.004586	0.458607
Pleasant Lake	81.32471141	0.000110	0.010968
Rice Lake	890.1409647	0.000063	0.006279
Silver Lake (Dickinson)	1032.570486	0.000934	0.093355
Silver Lake (Palo Alto)	641.2105887	0.000273	0.027334
Silver Lake (Worth)	331.8318945	0.000381	0.038123
South Twin Lake	481.56591	0.000049	0.004882
Spirit Lake	5330.092741	0.001309	0.130942
Storm Lake	3040.698657	0.000711	0.071105
Sunken Island Lake	94.85261161	0.022794	2.279427
Swan Lake (Dickinson)	175.3919504	0.000028	0.002792
Swan Lake (Emmet)	794.9614056	0.000010	0.001011
Trumbull Lake	1080.022625	0.000033	0.003317
Twelve-Mile Lake	200.1588976	0.000004	0.000367
Upper Gar Lake	35.86671598	0.013681	1.368110
Ventura Marsh	245.2745998	0.000216	0.021620
Welsh Lake	57.5130725	0.000100	0.010024
West Okoboji Lake	3871.587234	0.003806	0.380560
West Twin Lake	113.4322667	0.000064	0.006436

Surface covered "**with**" buffer

(Using Google Earth Pro values when Iowa DNR values were not available)

LAKE_NAME	ACRES	BUFFER acre/ACRES	BUFFERED %
Big Wall Lake	578.2165049	0.000243	0.024252
Black Hawk Lake	904.9456498	0.019693	1.969291
Center Lake	258.7005592	0.014205	1.420546
Clear Lake	3628.540174	0.033117	3.311698
Crystal Lake	263.5650117	0.002485	0.248456
Dickinson_17	27.87513729	0.004372	0.437173
East Okoboji Lake	1838.609023	0.049979	4.997859
Elk Lake	260.5033494	0.000121	0.012117
Elm Lake	449.2309624	0.000813	0.081253
Five Island Lake	966.7085046	0.008789	0.878932
High Lake	552.2991754	0.000819	0.081885
Ingham Lake	368.2119662	0.004478	0.447806
Lake Cornelia	244.4756466	0.034991	3.499115
Little Wall Lake	247.628427	0.006051	0.605144
Lizard Lake	280.0462756	0.001002	0.100249
Lost Island Lake	1222.011713	0.015117	1.511745
Lower Gar Lake	250.7232877	0.035281	3.528131
McClelland Slough	23.16612374	0.001536	0.153600
Minnewashta Lake	120.7514797	0.090695	9.069505
Morse Lake	107.6151359	0.001072	0.107240
Mud Lake	297.4441354	0.000604	0.060394
North Twin Lake	456.7557	0.054512	5.451165
Pleasant Lake	81.32471141	0.001301	0.130146
Rice Lake	890.1409647	0.000673	0.067339
Silver Lake (Dickinson)	1032.570486	0.011377	1.137750
Silver Lake (Palo Alto)	641.2105887	0.002807	0.280705
Silver Lake (Worth)	331.8318945	0.003203	0.320270
South Twin Lake	481.56591	0.000611	0.061138
Spirit Lake	5330.092741	0.016057	1.605708
Storm Lake	3040.698657	0.008449	0.844916
Sunken Island Lake	94.85261161	0.000454	0.045380
Swan Lake (Dickinson)	175.3919504	0.000279	0.027923
Swan Lake (Emmet)	794.9614056	0.000108	0.010829
Trumbull Lake	1080.022625	0.000393	0.039323
Twelve-Mile Lake	200.1588976	0.000070	0.006977
Upper Gar Lake	35.86671598	0.135550	13.554999
Ventura Marsh	245.2745998	0.000790	0.079011
Welsh Lake	57.5130725	0.000805	0.080497
West Okoboji Lake	3871.587234	0.040873	4.087287
West Twin Lake	113.4322667	0.000754	0.075388

Shoreline impacted

(Using Google Earth Pro values where Iowa DNR values were not available)

LAKE_NAME	PERIM_FT	Shoreline	Shoreline/Perim	Perim cover %
Big Wall Lake	71521.7	61.00	0.0009	0.0853
Black Hawk Lake	64881.1	14,040.33	0.2164	21.6401
Center Lake	19661.68	2,877.17	0.1463	14.6334
Clear Lake	73396.37	50,168.20	0.6835	68.3524
Crystal Lake	15923.27	540.00	0.0339	3.3913
Dickinson_17	5370.269	108.67	0.0202	2.0235
East Okoboji Lake	90024.58	54,733.77	0.6080	60.7987
Elk Lake	15587.77	55.00	0.0035	0.3528
Elm Lake	30076.47	268.00	0.0089	0.8911
Five Island Lake	84425.3	7,142.92	0.0846	8.4606
High Lake	36946.18	484.00	0.0131	1.3100
Ingham Lake	23913.36	1,836.00	0.0768	7.6777
Lake Cornelia	12747.33	7,591.33	0.5955	59.5523
Little Wall Lake	15716.9	1,295.75	0.0824	8.2443
Lizard Lake	16427.32	171.67	0.0105	1.0450
Lost Island Lake	56104.18	15,745.42	0.2806	28.0646
Lower Gar Lake	21274.15	6,360.25	0.2990	29.8966
McClelland Slough	4828.726	53.00	0.0110	1.0976
Minnewashta Lake	11225.7	8,992.50	0.8011	80.1064
Morse Lake	10832.91	217.00	0.0200	2.0032
Mud Lake	20633.53	228.33	0.0111	1.1066
North Twin Lake	30110.06	19,314.24	0.6415	64.1455
Pleasant Lake	9267.933	107.67	0.0116	1.1617
Rice Lake	76137.1	655.92	0.0086	0.8615
Silver Lake (Dickinson)	37667.2	9,304.42	0.2470	24.7016
Silver Lake (Palo Alto)	31125.28	1,755.08	0.0564	5.6388
Silver Lake (Worth)	22734.15	708.00	0.0311	3.1143
South Twin Lake	23112.25	268.50	0.0116	1.1617
Spirit Lake	82984.43	43,676.25	0.5263	52.6319
Storm Lake	61556.63	12,591.58	0.2046	20.4553
Sunken Island Lake	22271.98	12,591.58	0.5654	56.5355
Swan Lake (Dickinson)	13120.46	55.33	0.0042	0.4217
Swan Lake (Emmet)	50770.28	110.00	0.0022	0.2167
Trumbull Lake	43122.64	216.17	0.0050	0.5013
Twelve-Mile Lake	16083.39	53.00	0.0033	0.3295
Upper Gar Lake	7327.408	2,897.00	0.3954	39.5365
Ventura Marsh	42833.08	261.67	0.0061	0.6109
Welsh Lake	6137.059	115.17	0.0188	1.8766
West Okoboji Lake	101010.9	96,061.98	0.9510	95.1006
West Twin Lake	8449.223	109.00	0.0129	1.2901

Author comparing local GPS with GPS of next dock to ground truth while steering to those coordinates. (Photo courtesy of Deloris Trower)

Representative secchi disc light penetration figures

Lake	Dock	Secchi depth in meters	Standard light depth in meters	K	Depth in feet
Five Island Lake	FI109	0.500	1.000	3.540	3.28084
Five Island Lake	FI094	0.500	1.000	3.540	3.28084
Five Island Lake	FI001	0.500	1.000	3.540	3.28084
High Lake	HL003	0.250	0.500	7.080	1.64042
Ingham Lake	IL001	0.250	0.500	7.080	1.64042
Silver Lake	SL060	0.250	0.500	7.080	1.64042
Silver Lake	SL077	0.400	0.800	4.425	2.624672
	Average	0.378571429	0.757142857	5.183571429	2.484065

Calculations of the Shoreline Development Index (SDI)

WERE **NOT** COMPLETED

The SDIs used in the MGLP database were not related to the human impact or development of the shoreline, but rather were a ratio of the lake's irregular surface area compared to a lake with identical surface area that was circular in shape. This would equate to a lake with the smallest perimeter, but having the same surface area. And while the values were used in the calculations of the CNQI and CASI values, they would not change based on human impact.

CONCLUSIONS:

As evidenced by the table of Google Earth Pro (GEP) identified structures and the Iowa DNR dock/pier listings, there is some disparity between the two sources used to enumerate the docks. The GEP identified structures were taken from visible overhead (satellite and/or aerial) views and included individual structures (docks, piers, swim docks, boat hoists, etc.) that were either on the lake surface or on shore and would have been put on the lake at some time during the year. The Iowa DNR listing contains only the docks/piers that are licensed with their sizes whether or not they are actually on the lake surface. Except for 5 instances where the GEP count exceeds the Iowa DNR count, the Iowa DNR count is equal to or greater than the GEP count. There were 14 lakes where GEP identified structures that the Iowa DNR has no listings for licensed docks; and there is only one lake where the Iowa DNR has licensed docks, but GEP detected no structures on that lake. It must be noted that most of the GEP views date from 2011 and 2012 while the Iowa DNR records date from 2013 and some 2014.

Lake surface area covered by docks (no buffer included) ranged from a low of 0.001% on two lakes to a high of 2.279% on one lake. When the buffer area was included, the lowest surface area covered was 0.012% and the highest was 13.555%. The lake shoreline impact zone was based on a 25 foot area on each side of the dock plus the width of the dock, which was then converted to a percentage of the perimeter of the lake. These percentages ranged from a low of 0.085% to a high of 95.101%. And as stated in a panel located above this one, the shoreline development index was not recomputed as it had nothing to do with human impact.

Representative Secchi disk measurements gave a rather high "K" value (an average of 5.184). According to numerous sources, the depth of light penetration can be figured to be twice the measured Secchi disc depths, which, as shown in the accompanying table, amounts to about 2.48 feet of Standard light penetration depth. Although not all lakes in the study area were subjected to Secchi disc measurements, the ones which were measured serve as a representative standard for all of those in the study area.

The above charts show comparisons of CNQI/CASI to dock frequency; both Google Earth Pro count and Iowa DNR count were used, as well as a comparison to the lake sizes in acreage. The largest R^2 value obtained was 0.2125 when comparing GEP count values to the CW (Cold Water species CNQI/CASI) values. All other R^2 values were lower than this value and clearly indicate that there is very little correlation between either set of dock counts and the CNQI/CASI values. Additionally, there is very little correlation between lake sizes and the CNQI/CASI values. Therefore, the conclusions reached with this study indicate that the habitat quality values (CNQI/CASI) are not influenced by the number of docks and piers on the lakes.