Comparison of Wild Rice Data and Waterfowl Surveys

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Methods

The purpose of this study was to determine whether there was a relationship between the acres of wild rice and waterfowl numbers. Many species of waterfowl feed heavily on wild rice so it is reasonable to assume that more rice would equate to higher duck usage. In order to complete this analysis the Leech Lake Band of Ojibwe has had ProWest & Associates take aerial photographs of the major wild rice beds on the reservation. From 1993 to 2013, excluding 1997, all of the major wild rice beds on the reservation had aerial imagery capture for their respective locations. The wild rice bed locations that were flown that coincide with areas that the Minnesota DNR have done waterfowl surveys resulted in a data set with ten wild rice beds that will be part of this analysis. These sites are Pigeon Dam, Natures Lake, Rice Lake, Bowstring River/Cow Bay, Muskrat Bay, Mudd Lake, Raven Creek/Rabbit Lake, Third River Flowage, Boy Bay, and Headquarters Bay. The remaining wild rice beds that have aerial imagery for them were digitized at a 1:2000 scale, and amount of rice determined through digitizing was added to the same table.

The Leech Lake Division of Resource Management received each year's aerial images on compact discs in a JPEG format. The images themselves needed to be geo-referenced, that is their existence had to be defined in physical space. The images were referenced utilizing a combination of Farm Service Agency and United States Geological Survey photos through the MNGEO Web Mapping Server. Since photos were not available from every year that could be used as a point of reference, the closest year photos were used if the same year did not exist. The software used to rectify the aerial images was ArcGIS 10 utilizing the geo-referencing tool set. The aerial images were converted to .tiff file when the geo-rectification took place.

Each of these geo-rectified aerial images that coincided with a lake that the Minnesota DNR had waterfowl data for was put into a mosaic dataset, a new feature with the newest version of ArcGIS. A file geodatabase was created for each individual year that photos were taken for, and within the geodatabase an individual mosaic dataset was created for each wild rice bed. The reasoning for putting the photos into the mosaic dataset is that once all images for a given year are placed into this feature, they will be treated as a single image instead of having to perform analysis on each individual photo. Once the images are all added to the mosaic dataset, statistics were calculated for the dataset and footprints were built for a seamless image appearance. From there, the color balancing mosaic dataset tool was applied to each dataset, using histogram as the balancing method. This ensures that the pixels from all images will be changed to match a target histogram, in this case, the image that covered the most area of the wild rice bed. By doing so, the analysis can be run on the entire image because all features will be represented by the same pixel value.

The next step in preparing the aerial images was to build a mask, in this case, a buffer around all bodies of water on the reservation, and extract just that portion of each mosaic dataset. The reason for this is twofold, one; wild rice grows in the water so it doesn't make sense to analyze areas outside of water, and two; it cuts down on the amount data that the software needs to process. These areas that were queried out are where the analysis takes place.

In order to ensure the best possible result from our existing datasets, two additional bands were created from the original aerial image in order increase the variation in the reflectance values from pixel to pixel, thus allowing for more accurate classification. The first band was created using the Principal Components Tool, found in the ArcGIS tool set. This tool is used to transform data from input bands from a raster dataset from the input multivariate attribute space to a new multivariate attribute space whose axes are rotated with respect to the original space, with the resulting attributes in the new space being uncorrelated. What this new dataset will do is create three new bands from original three band image, with the first band showing the greatest variation in the image, thus that being the fourth band that is added to existing dataset. The second band (in this case the fifth band for the original image) was created using the Band Ratio tool, taking the red band and dividing it by the green band from the original image. This results in a fifth band that is the ratio of the red and green bands, those bands being responsible for most of the reflectance seen from vegetation in aerial imagery.

After creating these additional two bands, the Composite Band tool is used to combine these bands with the original three band image that is represented by the mosaic dataset. The result is a five band image of the rice beds. After combining the five bands together, classification of the images was the next step. This was done using the Maximum Likelihood Classification Tool. The tool runs an algorithm and assigns each pixel to a class which it has the highest probability of being a member. It determines this based upon signature files that that the user defines based upon the aerial image. The classes, in this case, rice or no rice, where defined at this time.

Creating the signature files was done using ten classes per each site for the two classes, rice or no rice. Ten areas in the image that did not have rice were identified as such with the signature file tool as well as ten sites that contain rice. The ability to identify the areas that contained wild rice was the result of several meetings with Lee Westfield at ProWest & Associates. Mr. Westfield has a strong natural resources background, particularly in analyzing aerial imagery, and is a valuable asset for this project. He is an avid ricer from the Leech Lake area, and therefore knows where the rice beds are and what they look like, both from the air and the water. After identifying the different classes, the signature file was built for each site for ever year. From there, the Maximum Likelihood Classification Tool was run using the signature file, creating an output that represented rice and no rice for each site. There were instances where the initial signature files did not accurately define rice or no rice in the resulting output, so reclassification was necessary for certain locations.

As each site was being classified, another tool, the Probability Classes Tool, was also being run. This tool requires the same set up as Maximum Likelihood Classification, with signature files being build, and it gave a similar output file, only in this case, each pixel was given a probability. This output will be used to identify density of wild rice in each location, as the resulting output shows what percent of that pixel is appropriated as wild rice, based upon the signature files. The density was broken into two classes, high density and low density. The cutoff for the groups was 75, anything above was high density and anything below was low density. The cutoff for the bottom of the bracket is 50 percent, since if the pixel is less than 50 percent likely to be composed of rice characteristics based on the signature files, it will be placed in the non-rice category from the Maximum Likelihood Classification Tool. The wild rice identified from this method will be tabulated for each site and compared against waterfowl data from the Minnesota Department of Natural Resources.

Once these methods had been run on the aerial imagery, random points were generated in the areas defined as rice and no rice for ground truthing. The ground truthing for both years was done on the Boy Bay wild rice bed on Leech Lake. There was an equal distribution of points, 25 points in the rice areas, and 25 in the non-rice areas. This was to determine the accuracy of software in determining rice and no rice. These points were placed on a GARMIN 76 GPS unit and samplers canoed into the wild rice beds to sample these points. This sampling was conducted for the years 2012 and 2013, with 2012 ground truthing being completed by Ryan Anderson and 2013 completed being done by Lisa Becker. An additional sampling method was also added in 2013, in which the wild rice seeds themselves were weighed to determine rice density.

The additional wild rice beds that are not part of the study that is being conducted with the Minnesota Department of Natural Resources were calculated using digitizing with ESRI's ArcGIS software. These wild rice beds were digitized at a constant scale of 1:2000 to ensure consistency throughout the digitizing process. Their results are record in the table as total rice acres, with no densities determined for them.

Waterfowl surveys were flown in Minnesota Department of Natural Resources fixed-wing aircraft (Cessna 185) with a DNR pilot and waterfowl biologist observer. Cruise surveys were flown at altitudes of 150-300 feet above ground level and ocular estimates of numbers and species of waterfowl were recorded. The surveys provide a general index to waterfowl abundance, but counts on individual basins can be influences by several factors; for example, wind which may influence altitude of flight and wave action, light conditions may influence how well the observer can detect the birds, or disturbance by hunters, boaters, or eagles may move the birds.

The time frame for when these surveys are conducted were scheduled the week before the duck hunting season opened and week following the opening in all years. Duck season opened the Saturday nearest October 1st (from 28 Sept – 4 Oct) in all years except 2003 and 2004; when it opened the Saturday near September 24th (27 Sept 2003, 25 Sept 2004). From 1993-2002, 2 additional surveys were scheduled at 2 week intervals, typically for mid-October and late-October or early November. Beginning in 2003, Minnesota DNR staff attempted to count waterfowl numbers weekly. The goal was to survey each of the basins on these schedules; however, weather, aircraft maintenance, and other factors contributed to incomplete or canceled surveys. Especially from 1993-2002, when fewer surveys were scheduled, missed counts resulted in sparse data for determining waterfowl use.

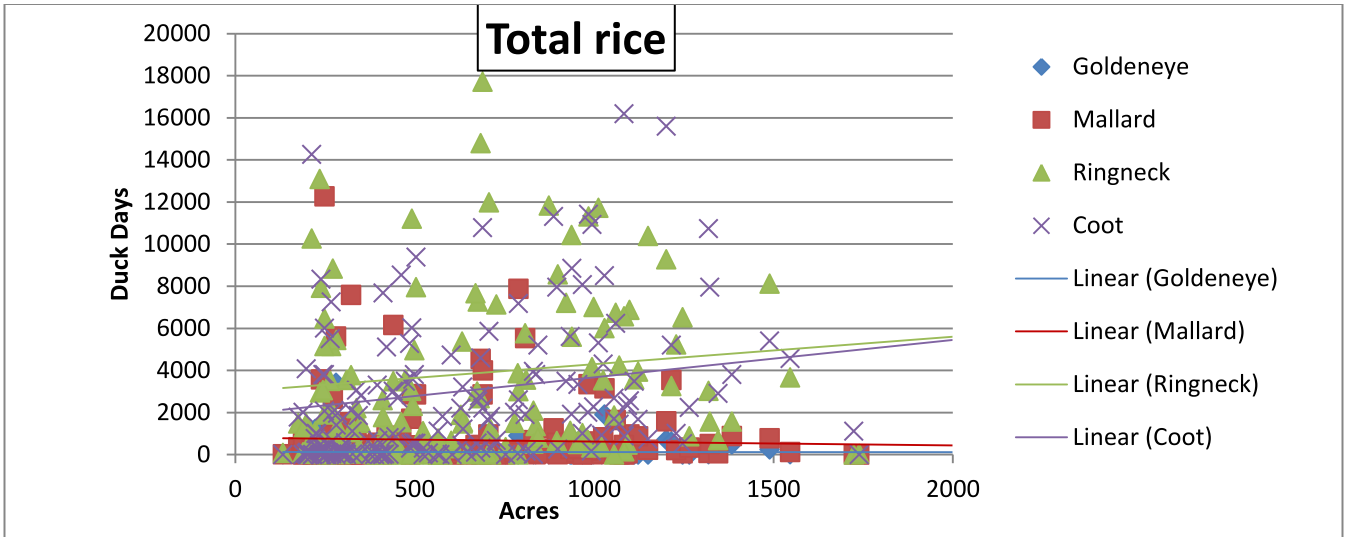
Mallards (*Anas platyrhynchos*), ring-necked ducks (*Aythya collaris*), and coots (*Fulica Americana*) were generally the most abundant species and are species that use wild rice for both food and cover; thus, DNR staff examined counts of these species relative to wild rice abundance. When determining waterfowl abundance, DNR waterfowl staff considered 2 measures:

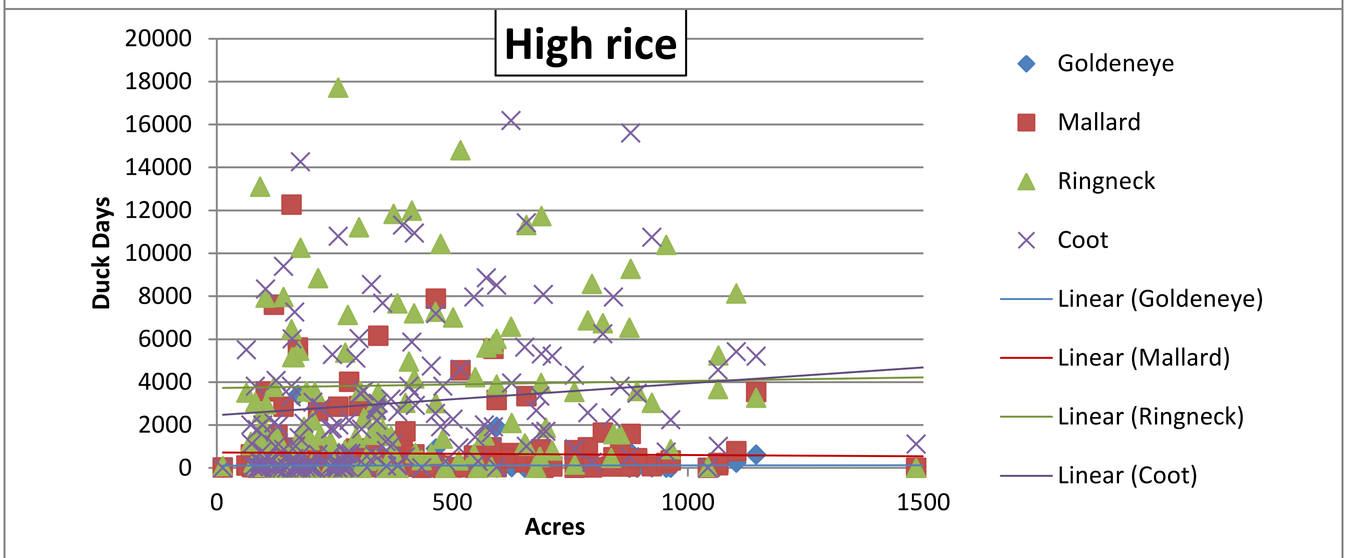
1. The number of each species on the basin the week immediately prior to waterfowl opening.
2. The number of duck use days from the week prior to waterfowl opening through the end of October. Duck use days were calculated as 7 * (the number of ducks counted) for each week of the period. If there was no survey that week, the number was inferred from an average of the counts before and after that week.

From the data set that was provided by the Minnesota DNR, the number of duck days were calculated for mallards, ring-necked ducks, coots, and Canada geese for a four week window in October for each year, using the methods described above to tabulate duck days.

Results

Figure 1. Scatter plots indicating relationship between duck days, an index of waterfowl abundance, and area of total, high, and low density wild rice beds on Leech Lake Reservation, Minnesota.


Total rice
Duck Days
Acres
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
0
500
1000
1500
2000
Goldeneye
Mallard
Ringneck
Coot
Linear (Goldeneye)
Linear (Mallard)
Linear (Ringneck)
Linear (Coot)


High rice
Duck Days
Acres
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
0
500
1000
1500
Goldeneye
Mallard
Ringneck
Coot
Linear (Goldeneye)
Linear (Mallard)
Linear (Ringneck)
Linear (Coot)

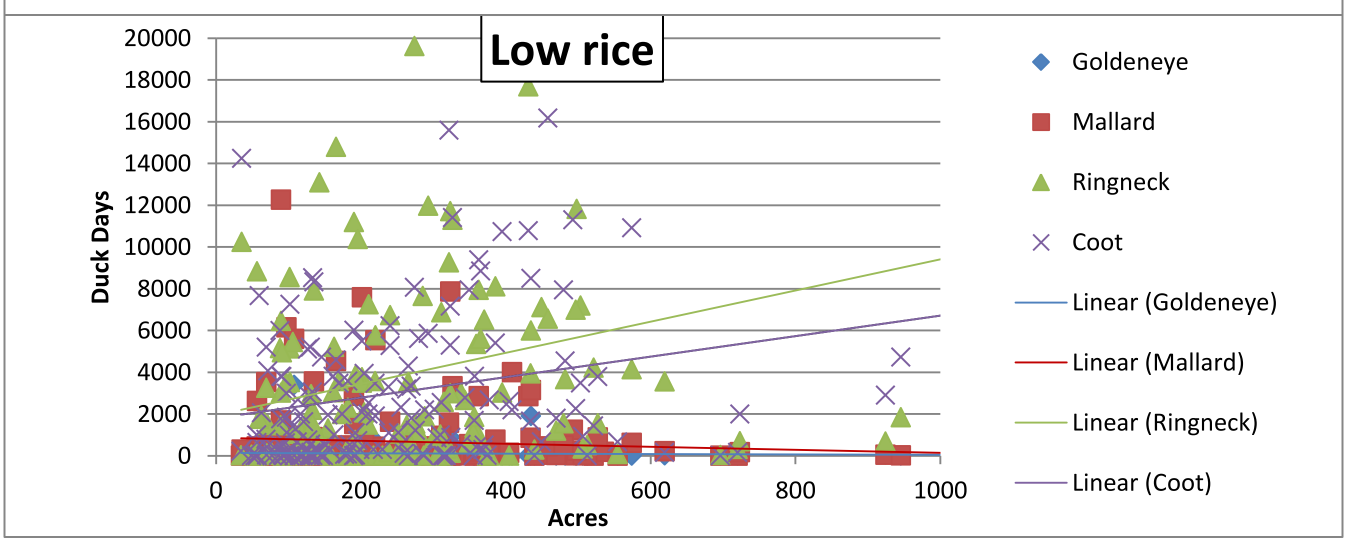

Low rice
Duck Days
Acres
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
0
200
400
600
800
1000
Goldeneye
Mallard
Ringneck
Coot
Linear (Goldeneye)
Linear (Mallard)
Linear (Ringneck)
Linear (Coot)

Figure 2. Duck days for Coots relative to total, high and low density rice acreage on Raven and Rabbit Bays, Leech Lake Reservation.

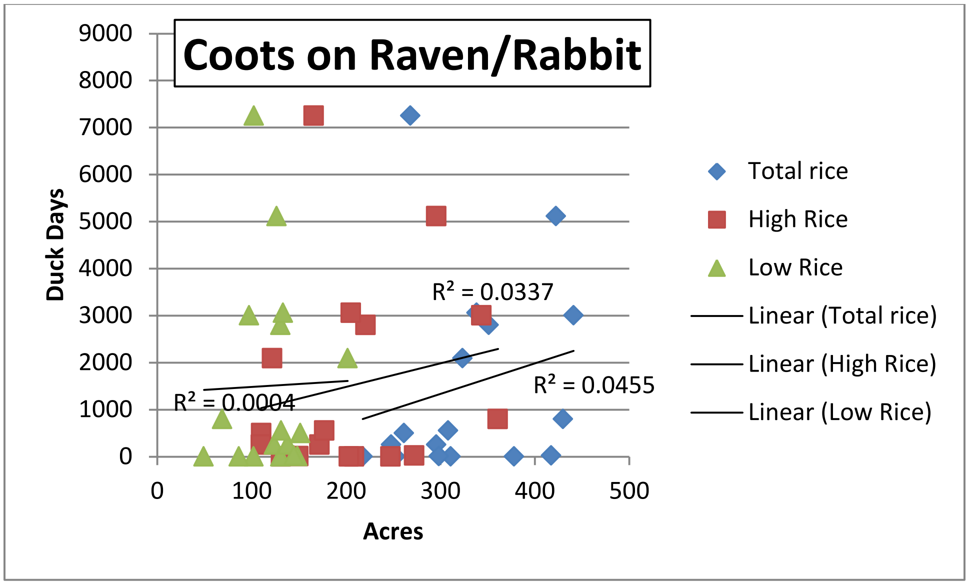


Figure 3. The following image represents the differences between a basic classification, in this case, digitizing wild rice beds (left hand image) based upon visual interpretation of the image. The classification of wild rice based upon utilizing ArcGIS software is

on the right, and the differences are apparent when the images are placed side by side.

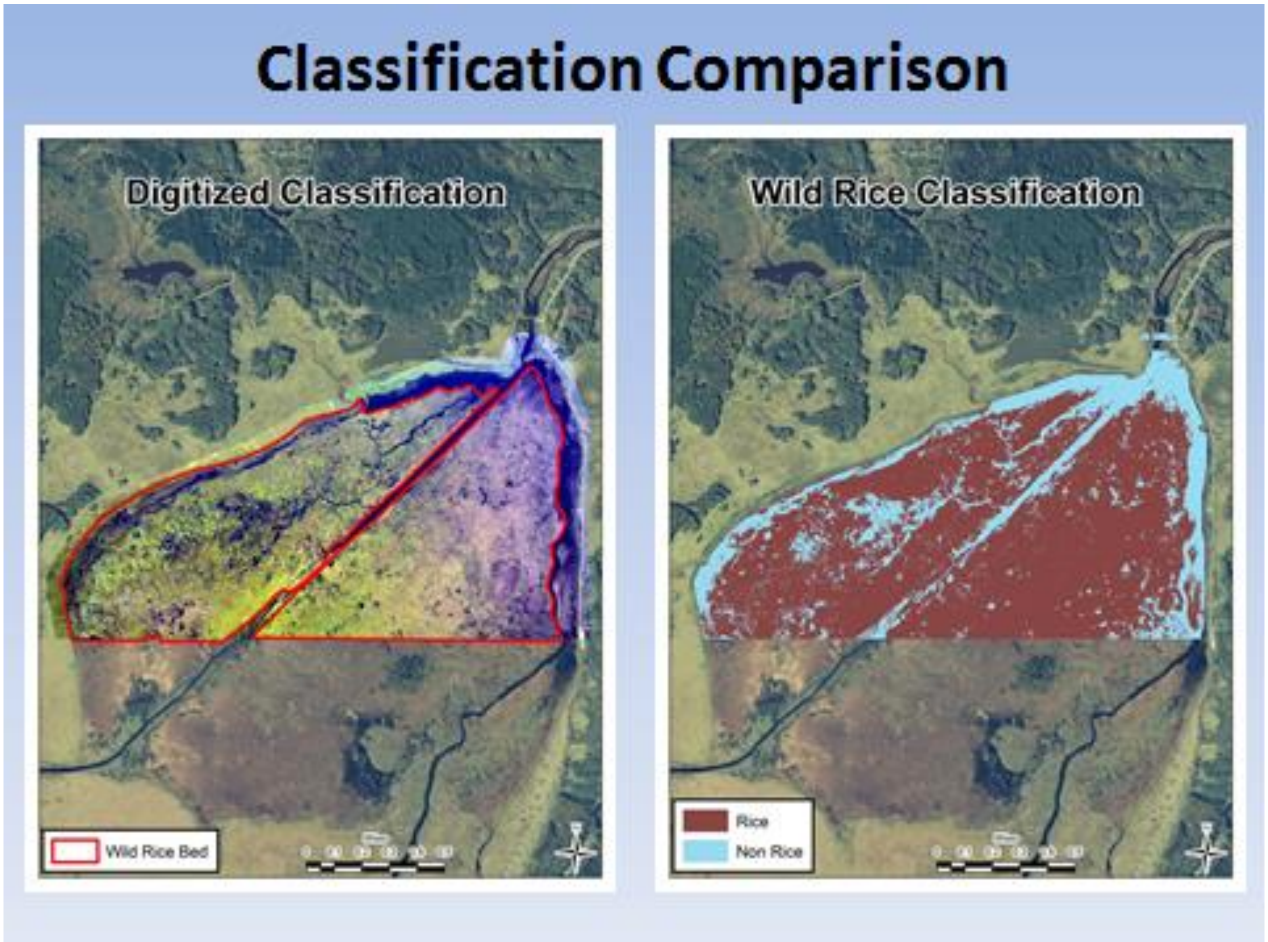


Figure 4. Annual variation in the acreage of total, high and low density rice beds as delineated using aerial imagery and ArcGIS.

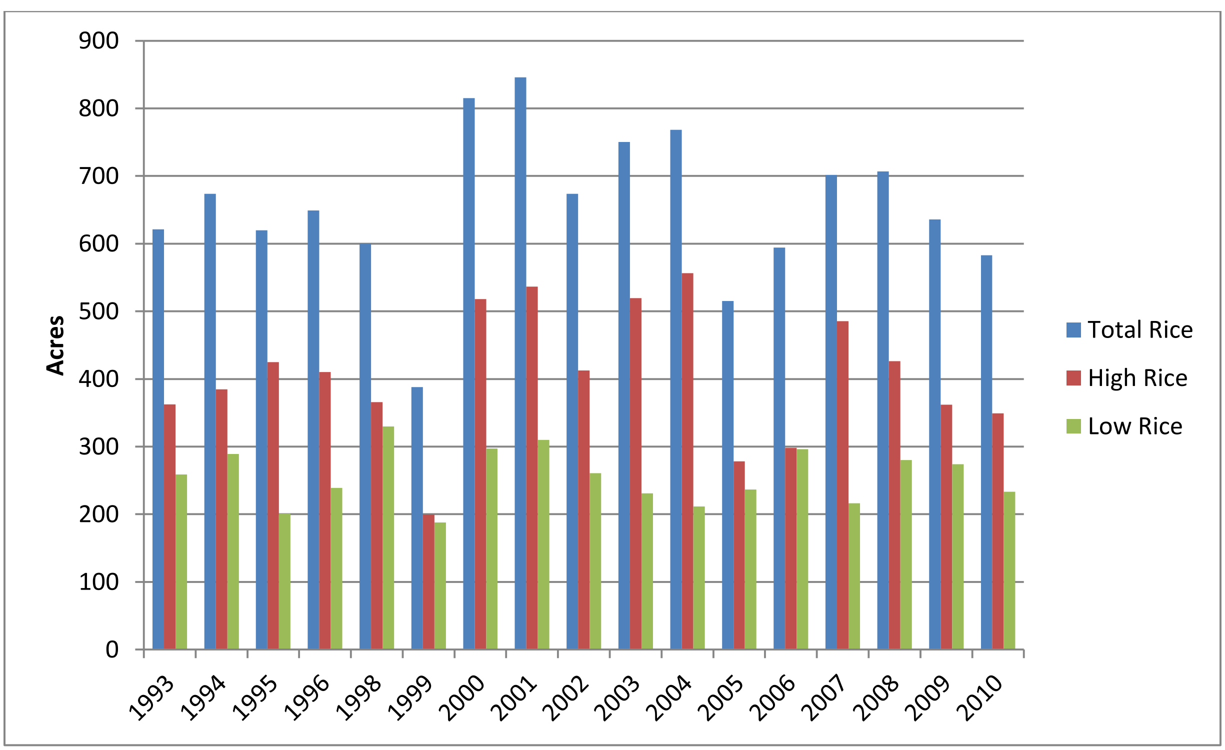
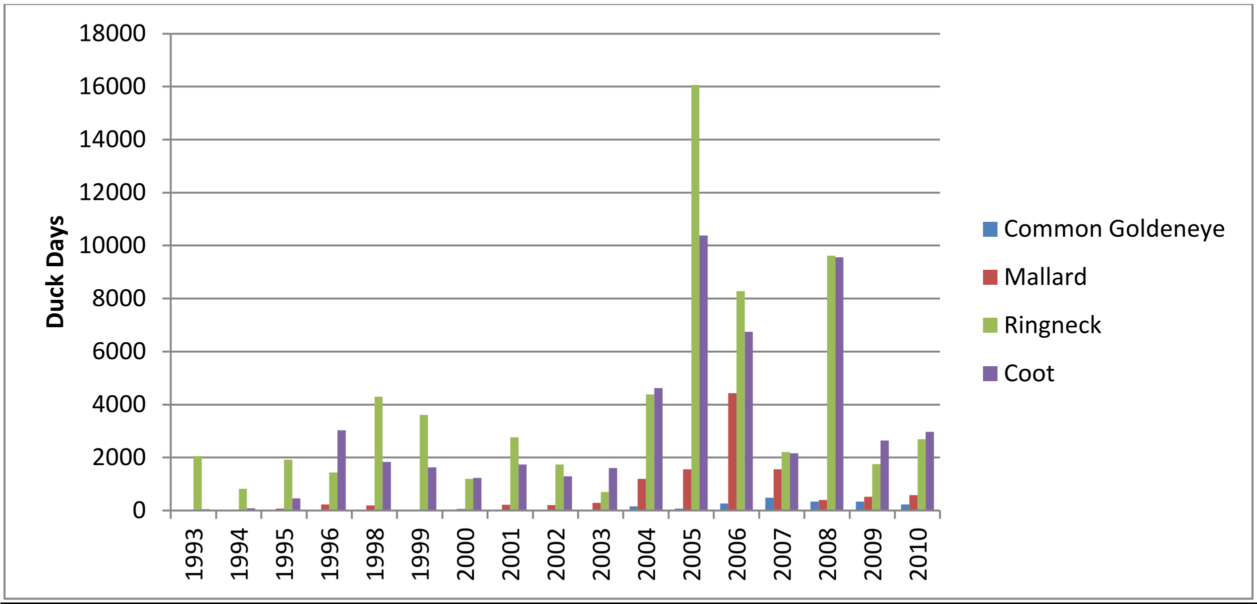


Figure 5.Duck days (log) across all rice beds from 1993 to 2009, excluding 1997 due to missing data.



Discussion

Assessing the accuracy of this GIS process was determining through the use of ground truthing. As stated, using ESRI's ArcGIS software, 50 points were randomly generated, with 25 being no rice, and 25 being rice. In 2012, the software accurately identified 88% of the rice/no rice locations. In order to determine if the Probability tool was correctly identifying densities of rice, a simple density assessment was done at 40 of these 50 points. Using the classification of high/low for density of rice, with < %50 of a 1 meter square covered by rice constituting low and anything above %50 representing high. Of the 20 that were sampled as low density in the field, 18 were correctly identified by the ArcGIS software. Of the 20 that were sampled as high density, 15 were correctly identified by the ArcGIS software, with an overall accuracy by the software for density of 82.5%

Ground truthing in 2013, 50 points were again used in the same as in 2012 to assess accuracy in Boy Bay. Of the 50 points generated, 49 were correctly identified as either rice or no rice using the ESRI's ArcGIS software, for an accuracy of 98%. The 25 points designated as rice only had one instance where rice was not found at a specific location. The densities that were determined in the field (medium and high were lumped into high as the GIS software is only using two classifications, high and low) resulted in only two instances where the field sample gave a density of low and the GIS software labeled those point densities as high. A possible explanation for this is that these two points were on the edge of the rice beds. These densities were determined the same way in the field, percentage covered of a one meter square. Overall, 98% of the points were correctly determined for rice/no rice by the GIS software for Boy Bay.

In 2013, it was speculated that the weight of the wild rice sampled from random points within a one meter square would be assess to see if it was a viable way to determine densities for wild rice. Since the presence of the stalk does not necessarily correlate with a higher density of actual wild rice, this method may lead to a more accurate assessment of wild rice. Random sites were determined on the Natures Lake wild rice bed as well as the Cow Bay rice bed along with collecting from the sites on Boy Bay. It was determined that the weight of the seeds did not correlate with the designated densities the GIS software had predicated, i.e. the lighter weight of seeds was located in high density areas and vice versa. Some explanations for this could be contributed to difficulties that arose. This included trying this method were ricing season had already started, with rice already harvested from sample sites. There was also a large variation in the rice between the three beds, so a sample size of all the rice beds would better sample size.

These initial numbers are promising in regards to utilizing this methodology to determine wild rice through aerial photography. Moving forward there are several techniques that can improve these numbers. An additional step to improve classification will be to add addition metrics to the model, in the hopes that it will “weed out” excess data that does not need to be sampled, and thus reduce the misclassification of wild rice. The datasets can be further trimmed down by the use of bathymetric data, since wild rice will only grow in a certain water depth. By adding this data set to the original mask that was created, the areas that won’t support wild rice can be removed. If further imagery is to be taken of the wild rice beds, a helpful improvement would be if infrared imagery can be taken. The reason for this is that actively growing plants, in this case wild rice, exhibit a high near infrared reflectance (approximately six times stronger than a plant's reflectance of visible green light). As a result, actively growing vegetation will show up prominently on an aerial image as bright red. This would be very beneficial as the water around which wild rice grows in would appear very dark, in contrast to the bright red wild rice. This would be very beneficial in classifying wild rice, not just from a visual standpoint, but by also supplying another band in the image.

Again, these results show promise utilizing this model verses digitizing aerial imagery, in that there is some statistical certainty behind the values in the results table. By no means are they 100 percent accurate, but for now they represent the base of an impressive data set that represents 18 years' worth of valuable data pertaining to wild rice.

Despite use of wild rice by waterfowl, there was limited evidence that wild rice abundance had an impact on waterfowl numbers (Figure 1). Coefficients of determination (R^2) between wild rice abundance and waterfowl numbers ranged from < 0.00001 to 0.035, indicating that at most wild rice abundance explained approximately 3.5% of the variation in waterfowl abundance. The limited impact of rice abundance on waterfowl numbers is surprising, but might be explained by a combination of sampling errors associated with miscounting waterfowl, for which we have no estimate of error, and measuring wild rice abundance. Furthermore, alternative food sources, for which we have no data, may be more important to waterfowl numbers than is wild rice. Hunting pressure probably also plays a role in the number of waterfowl utilizing an area. If hunting pressure is high, ducks are likely to avoid an area even though it may have an abundant food supply.

Acknowledgements

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Appendix 1: Duck days and rice acreage by year on Leech Lake Reservation.

	Duck Days					Rice Acreage			
Year	**Common Goldeneye**	**Mallard**	**Ringneck**	**Coot**	**Total Ducks**	**Total Rice**	**High Rice**	**Low Rice**	**RiceBed**
1993	13	0	3535	0	3548	310.841	208.548	102.293	RavenRabbit
1994	0	5	145	0	150	217.642	131.234	86.408	RavenRabbit
1995	0	13	53	0	66	252.407	203.11	49.297	RavenRabbit
1996	0	506	645	255	1406	295.722	171.89	123.832	RavenRabbit
1998	0	315	265	500	1080	261.629	110.142	151.487	RavenRabbit
1999	0	4	31	5	40	298.323	149.577	148.746	RavenRabbit
2000	35	83	140	0	258	378.147	247.407	130.74	RavenRabbit
2001	0	310	630	250	1190	248.02	109.888	138.132	RavenRabbit
2002	0	500	831	20	1351	417.284	272.418	144.866	RavenRabbit
2003	0	276	131	795	1202	429.935	360.834	69.101	RavenRabbit
2004	0	265	537	554	1356	308.192	176.952	131.24	RavenRabbit
2005	0	943	5144	7253	13340	268.145	165.743	102.402	RavenRabbit
2006	0	7588	3765	2090	13443	323.492	121.772	201.72	RavenRabbit
2007	0	6153	3480	3000	12633	441.113	343.573	97.54	RavenRabbit
2008	105	890	1395	5110	7500	422.399	295.722	126.677	RavenRabbit
2009	105	475	1500	2800	4880	351.341	220.749	130.592	RavenRabbit
2010	190	682	2205	3055	6132	338.498	205.11	133.388	RavenRabbit
1993	10	33	327	90	460	308.63	126.665	181.965	ThirdRiver
1994	11	0	53	25	89	269.578	124.833	144.745	ThirdRiver
1995	0	295	92	110	497	201.854	170.164	95.741	ThirdRiver
1996	6	447	247	1005	1705	224.891	168.357	56.534	ThirdRiver
1998	0	605	150	145	900	297.842	201.854	95.988	ThirdRiver
1999	0	24	238	48	310	198.564	78.568	119.996	ThirdRiver
2000	35	4	290	1850	2179	343.856	246.514	97.342	ThirdRiver
2001	80	311	25	0	416	204.375	86.947	117.428	ThirdRiver
2002	40	127	165	40	372	348.924	254.371	94.553	ThirdRiver
2003	4	555	391	670	1620	398.294	285.647	112.647	ThirdRiver
2004	70	33	36	31	170	349.758	279.634	70.124	ThirdRiver
2005	12	341	1465	1770	3588	175.964	86.594	89.37	ThirdRiver
2006	84	584	1475	4070	6213	198.357	126.384	71.973	ThirdRiver
2007	25	10	115	0	150	202.384	124.674	77.71	ThirdRiver
2008	25	97	1900	2065	4087	248.951	185.674	63.277	ThirdRiver
2009	35	35	550	200	820	236.954	97.569	139.385	ThirdRiver
2010	15	35	275	625	950	371.524	275.161	96.363	ThirdRiver
1993	0	0	1	0	1	256.851	202.651	54.2	PigeonDam
1994	0	80	155	0	235	239.684	123.854	115.83	PigeonDam
1995	0	10	15	220	245	288.954	254.237	34.717	PigeonDam
1996	0	10	25	985	1020	227.548	125.984	101.564	PigeonDam

1998	0	0	22	0	22	241.598	139.548	102.05	PigeonDam
1999	6	0	75	0	81	215.671	86.957	128.714	PigeonDam
2000	0	25	112	415	552	234.821	164.351	70.47	PigeonDam
2001	0	0	110	0	110	189.957	96.284	93.673	PigeonDam
2002	0	110	16	0	126	236.842	179.354	57.488	PigeonDam
2003	61	65	8	40	174	294.856	202.497	92.359	PigeonDam
2004	515	2634	8831	630	1261 0	272.814	215.874	56.94	PigeonDam
2005	138	112	2952	160	3362	236.849	105.375	131.474	PigeonDam
2006	695	12260	6452	3800	2320 7	249.159	158.956	90.203	PigeonDam
2007	3400	5600	1050	0	1005 0	281.184	172.954	108.23	PigeonDam
2008	1215	455	1090	760	3520	223.558	96.524	127.034	PigeonDam
2009	875	620	1200	2000	4695	189.842	72.891	116.951	PigeonDam
2010	1115	513	5445	1400	8473	281.923	175.338	106.585	PigeonDam
1993	0	0	2585	0	2585	411.584	96.854	314.73	NatureLake
1994	0	45	7120	670	7835	728.306	278.596	449.71	NatureLake
1995	0	55	6520	510	7085	1247.72 1	876.942	370.779	NatureLake
1996	10	77	3025	1073 0	1384 2	1320.08	924.614	395.466	NatureLake
1998	40	85	11720	5300	1714 5	1013.22 2	689.589	323.633	NatureLake
1999	0	34	13090	225	1334 9	235.91	92.719	143.191	NatureLake
2000	190	44	7195	3480	1090 9	922.979	419.549	503.43	NatureLake
2001	185	125	7260	2535	1010 5	676.198	465.297	210.901	NatureLake
2002	53	0	4215	1435	5703	1071.16 3	549.281	521.882	NatureLake
2003	8	111	3665	4550	8334	1547.00 6	1064.86 3	482.143	NatureLake
2004	694	1579	9266	1558 8	2712 7	1201.66 1	879.594	322.067	NatureLake
2005	124	1527	54177	3320 5	8903 3	320.628	129.365	191.263	NatureLake
2006	290	1250	21285	1130 0	3412 5	888.15	395.279	492.871	NatureLake
2007	240	775	8120	5400	1453 5	1489.73 1	1103.92 1	385.81	NatureLake
2008	320	185	55400	3540 0	9130 5	887.582	351.943	535.639	NatureLake
2009	135	95	3500	5500	9230	265.382	63.399	201.983	NatureLake
2010	119	222	5150	6000	1149 1	248.934	160.348	88.586	NatureLake
1993	0	0	305	0	305	605.242	165.521	439.721	RiceLake
1994	0	0	1	0	1	571.425	257.516	313.909	RiceLake
1995	0	0	10	115	125	646.176	386.273	259.903	RiceLake
1996	0	240	1885	2200	4325	628.976	340.76	288.216	RiceLake

1998	0	455	7655	100	8210	670.212	384.463	285.749	RiceLake
1999	0	0	25	10	35	404.736	91.509	313.227	RiceLake
2000	0	57	2675	2775	5507	681.594	337.635	343.959	RiceLake
2001	0	75	5360	425	5860	632.82	273.196	359.624	RiceLake
2002	0	25	2995	545	3565	675.013	336.33	338.683	RiceLake
2003	0	0	0	290	290	713.773	555.413	158.36	RiceLake
2004	0	4542	14794	4590	23926	684.269	518.123	166.146	RiceLake
2005	0	4000	63650	2200	69850	690.834	281.802	409.032	RiceLake
2006	0	2850	17700	10775	31325	690.257	258.573	431.684	RiceLake
2007	210	235	1470	3200	5115	634.231	370.513	263.718	RiceLake
2008	150	103	11980	5855	18088	708.106	415.065	293.041	RiceLake
2009	75	85	490	300	950	524.597	155.977	368.62	RiceLake
2010	87	330	4950	3790	9157	500.391	408.884	91.507	RiceLake
1993	0	33	3865	35	3933	787.898	594.852	193.046	BowstringRiver
1994	1	10	332	162	505	993.076	272.599	720.477	BowstringRiver
1995	0	18	7000	2255	9273	999.645	502.583	497.062	BowstringRiver
1996	0	5	1355	3800	5160	838.384	480.905	357.479	BowstringRiver
1998	0	105	10425	1910	12440	938.102	476.115	1414.217	BowstringRiver
1999	0	75	1105	0	1180	523.951	168.464	355.487	BowstringRiver
2000	0	70	513	12	595	831.981	319.32	512.661	BowstringRiver
2001	22	225	3560	160	3967	811.109	191.497	619.612	BowstringRiver
2002	0	204	1855	1695	3754	1056.17	699.268	356.902	BowstringRiver
2003	0	25	340	921	1286	1021.391	514.579	506.812	BowstringRiver
2004	75	62	462	2320	2919	1093.955	838.206	255.749	BowstringRiver
2005	0	250	11825	23055	35130	874.468	376.094	498.374	BowstringRiver
2006	0	625	4150	10925	15700	994.717	420.394	574.323	BowstringRiver
2007	0	0	145	875	1020	1085.249	760.552	324.697	BowstringRiver
2008	20	360	5594	8850	14824	938.437	572.713	365.724	BowstringRiver
2009	25	175	700	2000	2900	983.552	259.939	723.613	BowstringRiver
2010	0	30	1200	1800	3030	711.996	241.888	470.108	BowstringRiver
1993	0	0	1295	25	1355	327.951	197.684	130.267	MuskratBay

1994	0	25	0	10	117	429.607	239.413	190.194	MuskratBay
1995	0	12	0	70	7572	538.854	360.76	178.094	MuskratBay
1996	0	440	3575	3475	12885	475.28	305.443	169.837	MuskratBay
1998	0	105	15	5275	5477	487.016	246.41	240.606	MuskratBay
1999	0	7	75	0	694	133.228	12.924	120.304	MuskratBay
2000	6	31	25	550	3977	499.15	242.457	256.693	MuskratBay
2001	25	85	1305	1950	5566	286.02	131.145	154.875	MuskratBay
2002	0	31	1060	1110	3166	326.784	74.697	252.087	MuskratBay
2003	0	99	331	535	4461	504.314	319.222	185.092	MuskratBay
2004	15	399	397	2685	23304	453.727	340.156	113.571	MuskratBay
2005	6	3562	7915	8325	39893	239.752	104.197	135.555	MuskratBay
2006	0	2865	11200	6020	25310	493.157	302.344	190.813	MuskratBay
2007	0	1700	3025	500	30055	491.37	401.17	90.2	MuskratBay
2008	35	295	10250	14250	29330	213.859	178.282	35.577	MuskratBay
2009	0	500	2000	2000	11501	272.043	97.837	174.206	MuskratBay
2010	25	131	3045	3800	7001	244.451	82.62	161.831	MuskratBay
1993	155	7	8558	250	8970	899.203	797.195	102.008	MuddLake
1994	0	0	350	0	350	754.219	435.684	318.535	MuddLake
1995	150	215	5220	1000	6585	1229.129	1065.828	163.301	MuddLake
1996	0	440	3575	3475	7490	1113.012	893.041	219.971	MuddLake
1998	0	218	10380	725	11323	1150.956	954.8	196.156	MuddLake
1999	0	0	19620	8070	27690	968.572	694.295	274.277	MuddLake
2000	0	337	865	2225	3427	1266.195	964.44	301.755	MuddLake
2001	0	955	6870	2555	10380	1099.749	788.177	311.572	MuddLake
2002	0	860	3940	1665	6465	1123.414	688.981	434.433	MuddLake
2003	35	680	2081	3945	6741	831.543	626.542	205.001	MuddLake
2004	54	1632	6735	6233	14654	1060.874	820.156	240.718	MuddLake
2005	155	3338	11305	11405	26203	984.863	658.039	326.824	MuddLake
2006	675	5535	5765	1900	13875	808.405	588.22	220.185	MuddLake
2007	395	822	3525	4300	9042	1025.975	759.946	266.029	MuddLake
2008	435	447	6565	16180	23627	1084.03	625.694	458.336	MuddLake
2009	1900	3150	6000	8500	1955	1029.64	594.776	434.869	MuddLake

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2010	610	3535	3255	5200	1260 0	1215.78 7	1146.05 2	69.735	MuddLake
1993	0	0	0	20	20	564.298	189.842	374.456	HQBay
1994	0	0	0	0	0	389.596	123.65	265.946	HQBay
1995	0	50	300	0	350	402.65	268.516	134.134	HQBay
1996	0	150	0	2600	2750	789.546	384.564	404.982	HQBay
1998	0	5	0	850	855	448.351	142.711	305.64	HQBay
1999	0	0	0	300	300	489.234	271.658	217.576	HQBay
2000	50	4	0	300	354	685.359	486.24	199.119	HQBay
2001	58	26	656	4730	5470	602.365	456.21	146.155	HQBay
2002	0	175	1540	1220	2935	635.291	359.684	275.607	HQBay
2003	135	953	27	1630	2745	705.642	584.214	121.428	HQBay
2004	0	248	1127	5610	6985	934.624	654.824	279.8	HQBay
2005	132	560	637	7945	9274	896.517	546.834	349.683	HQBay
2006	895	7875	3000	7170	1894 0	789.684	465.951	323.733	HQBay
2007	375	250	1020	1000	2645	968.254	658.251	310.003	HQBay
2008	490	875	1555	3795	6715	1384.48 2	857.125	527.357	HQBay
2009	25	0	0	1100	1125	1724.91 4	1485.89	239.024	HQBay
2010	55	58	685	2900	3698	1346.66 4	422.224	924.44	HQBay
1993	0	0	35	0	35	1740.00 8	1043.23	696.778	BoyBay
1994	0	0	0	0	0	2144.23 2	1857.25 6	286.976	BoyBay
1995	0	0	0	300	300	389.587	159.634	229.953	BoyBay
1996	0	5	0	1800	1805	578.236	307.85	270.386	BoyBay
1998	0	50	2300	3575	5925	495.073	312.765	182.308	BoyBay
1999	0	100	1773	7675	9548	412.456	352.64	59.816	BoyBay
2000	0	2	85	670	757	2307.33 3	1752.49 8	554.835	BoyBay
2001	0	25	1850	4725	6600	3710.19 7	2764.29 4	945.903	BoyBay
2002	25	60	805	5195	6085	844.02	713.156	130.864	BoyBay
2003	0	98	3	2670	2771	1056.38	678.846	377.534	BoyBay
2004	175	495	1560	7950	1018 0	1322.92 2	842.61	480.312	BoyBay
2005	120	890	1525	8525	1106 0	463.107	329.23	133.877	BoyBay
2006	0	2850	7950	9380	2018 0	504.829	141.979	362.85	BoyBay
2007	215	50	180	3300	3745	396.945	158.65	238.295	BoyBay
2008	615	280	500	3330	4725	956.188	686.27	269.918	BoyBay
2009	150	100	1500	2000	3750	779.052	568.7	210.352	BoyBay
2010	85	230	750	1100	2165	566.176 2	373.676 2	192.5	BoyBay