

Evaluation of the relative status of bird density and diversity in the Menominee River Area of Concern using citizen science data.

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Abstract

We utilized data from the citizen science database eBird (www.eBird.org) to investigate a specific management question of interest to management agencies and stakeholders. We compared Menominee River Area of Concern bird populations to two reference sites in order to determine whether the bird populations were impaired relative to the designated beneficial use impairments within the Area of Concern, and if so to what extent, using survey data collected by amateur birders from 2002 to 2012. We used EcoSim7 to calculate the relative average richness, Hurlbert's probability of interspecific encounter, and Shannon's diversity index of each site's avian communities. Grouped coastal change analysis program land cover classes were used to compare the available habitat of each site. All sites were found to have significantly different (95% confidence interval) relative average richness, Hurlbert's probability of interspecific encounter, and Shannon's diversity index values with the Area of Concern ranking lowest in equivalent diversity in all measures. All sites also demonstrated considerably different land cover. The Area of Concern was found to be comprised mostly of urban land cover, while the reference sites were dominated by wetlands. Considering the extent of urbanization in the Area of Concern, our conclusion is that the relative density and diversity are acceptable. Habitat quantity in the Area of Concern cannot be expansively altered or improved, once again considering the extent of urban land cover, however we recommend improving existing habitat within the AOC to the extent possible in an effort to match abundance and diversity metrics in reference sites.

Key Words: citizen science, species diversity, Great Lakes, Area of Concern, eBird

Introduction

Various measures of the diversity of bird species present in a given location are common measures of restoration goals and successes (Butchart et al. 2010). Although the relative importance of the presence or abundance of any particular bird species or group of bird species with regard to ecosystem integrity is often unclear, management plans and local stakeholders view overall diversity measures as important indicators of successful environmental restoration (e.g. WDNR and MDEQ 2011). Similarly, scientific investigations into stressors of bird populations use measures of biodiversity as an indicator of the level of impairment of the landscape (Lailolo et al. 2004).

An accurate measure of the biodiversity of the community of interest are difficult metrics to measure given the relative mobility of birds and the difficulty in accurately observing and identifying bird species in a quantitative fashion (Thompson 2002, Bart 2005). Quantification of the relative density of bird species is an area of importance that requires additional research. Other measures of relative abundance, such as mist net surveys, also have biases (Remsen and Good 1996) and are much more labor intensive to conduct.

There have been numerous efforts to compile environmental data and improve their comparability (e.g. Beard et al. 1998, Beran and Piasecki 2008) although the strength of these databases is often underutilized in a management context (Goodall et al. 2008). Indeed, scientific evidence in general may be underutilized in management decisions in favor of decisions based on experience (Pullin et al. 2004). Therefore, in light of these realities, citizen science databases appear to have utility with regard to management decisions.

Large scale citizen science efforts may aid in providing measures in measures of avian diversity. One large effort is known as eBird (www.ebird.org). eBird is an online database compiling citizen science bird surveys (Cornell Lab of Ornithology 2012). Although checklists are accepted from anywhere in the world, the majority of data comes from the western hemisphere (Hochachka et al. 2012). Each citizen science bird survey checklist records the presence and abundance of bird species seen or heard during an observation period. Metadata on each survey

associated with each checklist is also collected including date, location, duration, protocol, and other details. As a form of quality control, automated filters review all checklists for unusual observations based on date, location, and species before they enter the database (Hochachka et al. 2012). Local experts review any unusual records that are flagged by the filters, and may require additional proof (i.e. photographs) to accept the observation.

eBird encourages participation by providing online tools that maintain personal birding records, acknowledge the contributions of top birders, and enable users to visualize data with interactive maps, graphs, and bar charts. eBird data is available to anyone via the eBird.org website. Raw datasets may be downloaded with permission, although commercial use of the data is restricted. eBird is part of the Avian Knowledge Network, an international institution interested in using observational based bird data to better understand bird distribution and abundance (<http://www.avianknowledge.net>).

The diversity of avian populations are of importance in the Areas of Concern within the United States and Canada. The U.S. and Canada identified 43 AOCs, five of which are located within the State of Wisconsin including the St. Louis River Estuary, Lower Menominee River, Lower Green Bay & Fox River, Sheboygan River, and Milwaukee Estuary (Figure 1). As a border-water, the Wisconsin Department of Natural Resources, along with the Michigan Department of Environmental Quality, are responsible for restoring the Lower Menominee River AOC. Annex 2 of the 1987 Protocol amending the Great Lakes Water Quality Agreement of 1978 defined an “Area of Concern” (AOC) as “a geographic area that fails to meet the General or Specific Objectives of the Agreement where such failure has caused or is likely to cause impairment of beneficial use or of the area’s ability to support aquatic life.”

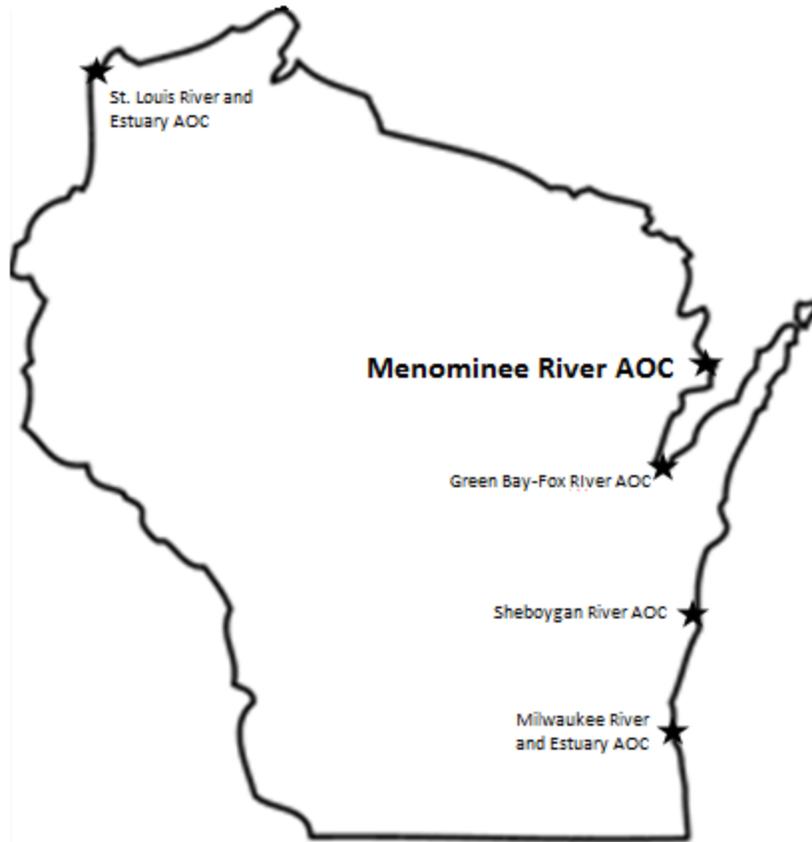


Figure 1. Wisconsin's Great Lakes Areas of Concern.

Six of a possible fourteen beneficial use impairments (BUIs), as designated by the Great Lakes Water Quality Agreement, were identified in the Lower Menominee River AOC (WDNR and MDNR 1990). These impairments are the “restrictions on dredging activities”, “restrictions on fish consumption”, “degradation of benthos”, “degradation of fish and wildlife populations and loss of fish and wildlife habitat” (two BUIs considered as one in the Lower Menominee River AOC), and “restrictions on recreational contact”. Restoration goals or targets have been developed for each of the designated BUIs to provide the decision criteria for determining when a BUI designation may be removed. Restoration targets are recorded in the “2013 Remedial Action Plan Update for the Lower Menominee River Area of Concern”.

The Remedial Action Plan restoration target for the “degradation of fish and wildlife populations and loss of fish and wildlife habitat” BUIs relies on the development of a “Fish and Wildlife Population and Habitat Management

and Restoration Plan” (Fish and Wildlife Plan). The Fish and Wildlife Plan was drafted in 2011 then revised in 2013. The current Fish and Wildlife Plan lists five goals that must be met to remove this BUI.

One goal of the Fish and Wildlife Plan reads “nesting populations of a diverse array of wetland-dependent and riparian-associated birds are consistently present within the AOC” (WDNR and MDEQ 2013). Our aim was to understand the relative abundance and diversity of avian fauna in the Lower Menominee River AOC compared to appropriate reference sites. Specifically our objectives were to compare various measures of diversity between the AOC and reference sites in light of relative land use which is a primary driver of avian habitat (Blair 1996). We perceive that these data would assist management agencies and stakeholders in assessing the status of the aforementioned goal.

Methods

The study area was defined as a one mile (1600 meter) buffer around the Lower Menominee River AOC boundary delineated by the U.S. Environmental Protection Agency (Figure 2). A buffer was required because the Area of Concern boundary does not include adjacent upland areas where the majority of birding occurs. The AOC has a larger footprint than the municipal boundaries of Marinette, Wisconsin and Menominee, Michigan, and therefore municipal boundaries could not be used to delineate the survey area.

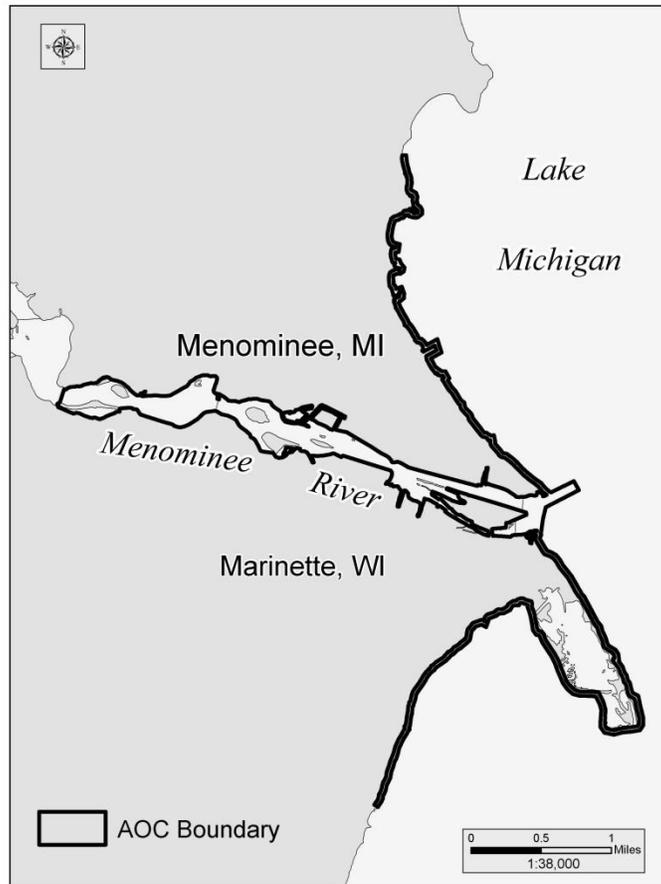


Figure 2. Lower Menominee River Area of Concern as delineated by the U.S. Environmental Protection Agency.

Two reference sites, Oconto and Suamico Wisconsin, were also selected for investigation. Reference sites were selected based on proximity to the Lower Menominee River AOC and similar qualities including; the presence of a small community, river mouth, Bay of Green Bay shoreline, and perceived quality bird habitat in the form of a designated state natural area or state wildlife area.

The 2013 municipal boundary of the City of Oconto was selected as one reference site. The site meets all parameters discussed above. Checklists submitted within the Oconto Marsh unit of the Green Bay West Shores State Wildlife Area are included within the municipal boundary.

The 2013 municipal boundary of the Village of Suamico east of U.S. Highway 41 was selected as the other reference site. Checklists submitted within the Sensiba unit of the Green Bay West Shores State Wildlife Area are included within the municipal boundary. Only the eastern portion of the municipal boundary was used to eliminate the influence from the Brown County Reforestation Camp, which was perceived to contain habitat not in the Area of Concern or Oconto sites. Barkhausen Waterfowl Preserve is also within the Village of Suamico municipal boundary.

We obtained a dataset from eBird.org. Data requested were solely based on location, but were otherwise not exclusive of temporal, species, protocol or other factors. The data included all data from Brown, Marinette, and Oconto counties in Wisconsin and Menominee County in Michigan was requested and received.

We then used Arc GIS to glean data from the study area and each reference site from county-wide datasets. Latitude and longitude coordinates, part of all eBird checklists, were used to enter eBird data into a GIS data layer. Standard Arc GIS tools were then used to import or delineate the study area and reference site boundaries and select eBird data applicable to each.

Extensive data refinement was required to include only those records that met our inclusion criteria. Only checklists recorded between January 1, 2002 and December 31, 2012 were considered. Checklists recorded using protocols other than the eBird “traveling count” and eBird “stationary count”, or when all species identified were not reported to eBird were discarded. Observations from a checklist with an effort of less than five minutes were discarded. Observations failing to identify a bird at least to the species level were discarded. The Menominee River AOC study area yielded the most checklists (599) and participants (19) that met our data selection criteria followed by Suamico (53 checklists and 24 participants) and Oconto (52 checklists and 16 participants).

Relative abundance was estimated by calculating a bird observation rate. Participants using the eBird traveling count and stationary count protocols record survey effort as duration (the traveling count protocol also records

distance), therefore we defined effort as duration. For each site, the total number of birds observed was divided by the total amount of time spent observing (total duration), yielding a site specific bird observation rate.

We used EcoSim 7 to estimate diversity metrics (Gotelli and Entsminger 2001). EcoSim 7 has the advantages of automating the calculation of diversity metrics as well as the incorporation of rarefaction curves. Each sample location received differential survey effort which can affect diversity measures. To determine whether any differences in species richness and diversity represented an actual site specific biological difference among communities rather than an artifact of differential sampling effort we relied on rarefaction techniques. We determined the number of individual birds observed in each area and then computed the expected metrics from each area based on the smallest number of observed individuals. Rarefaction derives expressions for the expectation and variance of species richness and diversity for a sample of a given size (Hurlbert 1971; Heck et al. 1975). EcoSim 7 (Gotelli and Entsminger 2001) derives metric estimates using rarefaction based on number of individuals randomly drawn from a community sample. We chose to repeat the process 1000 times to generate a mean, a variance, and a 95% confidence interval for each measure of species richness and diversity. The 95% confidence intervals of diversity from these simulations were used to determine whether species richness and diversity were equivalent in the three communities. We considered values of species richness and diversity that fell within the 95% confidence interval of each other to be equivalent.

Evenness and diversity are two characteristics of biological communities that are of interest to management agencies and stakeholders. There are numerous metrics that can be used to measure both evenness (i.e. the relative abundance of the various species of interest) and diversity (i.e. the number of species in an area of interest). Since both evenness and diversity are of potential interest to stakeholders and may be reflected in management goals, we examined overall species richness, Hurlbert's probability of interspecific encounter (PIE) (Hurlbert 1971) as our measure of evenness, and Shannon's diversity index (Shannon 1948) which is essentially a combination of diversity and evenness. Species richness is simply the number of different species present in each rarefied sample. The PIE was calculated as:

$$PIE = \left(\frac{N}{N-1} \right) \left(1 - \sum_{i=1}^s p_i^2 \right)$$

Where N is the total number of species in the area of interest and p_i is the proportion of the entire sample that is represented by species i . The Shannon diversity index (H') was calculated as:

$$H' = - \sum_{i=1}^s p_i \ln p_i$$

Where p_i is the proportion of the sample represented by species i .

Available habitat, in the form of relative land cover, was also investigated for the study area and reference sites. Landcover classes as defined by the National Oceanographic and Atmospheric Administration's (NOAA) coastal change analysis program (C-CAP) were used for this purpose (www.csc.noaa.gov/landcover accessed April 2014). Arc GIS was used to retrieve landcover class coverage for the study area and reference sites. To simplify analysis, landcover classes were aggregated into more general categories. Forested, wetland, urban, and pasture/grassland classes were lumped into four categories based on classification scheme descriptions.

Results

Prior to accounting for differences in sampling effort (rarefaction) the Menominee River AOC study area had the highest richness value and the Oconto reference site had the highest diversity and evenness values (Table 1). Once sampling effort was accounted for, the Oconto reference site had the highest diversity, richness, and evenness values, with Menominee ranking the lowest in each metric, and Suamico in the middle (Table 1).

Table 1. Measures of diversity, richness, and evenness (PIE) in the Menominee River AOC and reference sites as well as rarefied values and confidence intervals (CI). Total effort was measured in minutes.

Measure	<u>Observation Area</u>			<u>Rarefaction Values</u>	
	Menominee	Oconto	Suamico	Menominee	Oconto
Individual Observations	35891	13561	6808	6808	6808
Total Effort	37716	7133	3164	-	-
Shannon Diversity	3.681	4.205	3.983	3.67	4.198
Shannon Diversity 95% CI	-	-	-	3.643-3.699	4.176-4.217
Species Richness	184	182	161	147.593	171.902
Species Richness 95% CI	-	-	-	140-155	166-176
PIE	0.956	0.976	0.969	0.956	0.976
PIE 95% CI	-	-	-	0.955-0.958	0.975-0.976

Due to the buffer technique used to delineate the Menominee River AOC study area, open water was found to be the dominant land cover class there (Table 2). Land cover data was not available for a portion of the study site located in Menominee, MI and is represented in Table 2 as unknown. Major land uses in the Oconto reference site included wetlands and urban development. Land cover in the Suamico reference site was more evenly split between wetlands, forest, cultivated crops, and urban development (Table 2).

Table 2. Aggregated land cover classes from NOAA C-CAP 2010 data. Values are in hectares and percent of total.

Land Characteristic	Observation Area		
	Menominee	Oconto	Suamico
Hectares	5957	1850	3280
Bare Land	0.02%	0.24%	0.74%
Cultivated Crops	0.91%	10.79%	19.32%
Forest	2.99%	6.48%	21.35%
Grass/Pasture/Herbaceous	0.95%	3.15%	5.26%
Open Water	40.31%	3.56%	3.68%
Scrub/Shrub	0.16%	0.53%	2.80%
Unconsolidated Shore	0.14%	0.08%	0.40%
Unknown	9.57%	0.00%	0.00%
Urban	32.07%	35.78%	14.30%
Wetland	12.89%	39.44%	32.18%

Land cover differences may be partially responsible for differences in relative abundance and diversity measures among the study area and reference sites. As seen in Table 2, land use in the Menominee River AOC study area and reference sites differs considerably. A substantial amount of open water was included in the Menominee River AOC study area due to the buffer technique used to delineate it. Similar amounts of open water were not included in the reference sites during their delineation, and no suitable checklists were submitted from open water areas. Removing the open water land cover class from the land cover percent calculation in Table 3 has little effect on reference sites (increasing all other land cover classes by approximately four percent). However, because open water was such a large percentage of land cover in the Menominee River AOC study area, other land cover classes in the study area are increased approximately 67 percent. Considering these factors, we feel that the portion of the Menominee River AOC study area accessible to eBird participants is dominated by urban land cover.

Discussion

The Menominee River AOC study area had the highest number of individual observations and greatest survey effort. It also had the highest richness prior to rarefaction (Table 3). Relative abundance, expressed as individual observations per effort (birds observed per minute), was significantly lower in the study area than the reference sites. Likewise, richness, diversity, and evenness were also lower in the study area after accounting for rarefaction. Rarefaction curves were a useful tool in this analysis because they allowed us to account for differences in survey effort. Based on these data, we suggest that actual abundance and diversity of avian species is lower in the Menominee River AOC study area than the reference sites.

Research has documented the decline of bird species richness corresponding to increasing levels of human development (Batten 1972, Blair 1996). We did not attempt to quantify human development from NOAA C-CAP land cover data, but assume that there is a positive correlation between urban land cover and development. The degree of urbanization can affect bird species richness with high levels of development being associated with lower diversity. However, some research has shown bird abundance and richness to increase under light to moderate levels development (Marzluff 2001, McKinney 2002) in response to several factors associated with development. Our results suggest that the level of development in the Menominee River AOC is likely related to its relatively lower levels of species richness.

We do not suggest that bird species abundance or diversity is poor in the Menominee River AOC study area, only that it is less than the selected reference sites. Each site contains perceived quality bird habitat in the form of a designated state natural area or state wildlife area, which are inherently less developed, and therefore are expected to positively contribute towards bird diversity. Proximity to the Bay of Green Bay also contributes positively towards bird species abundance or diversity, because the Bay of Green Bay is a known flyway for migratory birds. Restoration objectives found in the 2013 Fish and Wildlife Population and Habitat Management and

Restoration Plan for the Lower Menominee River AOC call for the protection and improvement of suitable bird habitat and known rookeries. We feel that these restoration targets are justified for the Menominee River AOC based on the results of this study.

Further information regarding the variance of various types of counts in eBird and the implications for population metrics of interest would aid in clarifying the implications of our results as well as other similar future efforts. Similarly, future investigations utilizing eBird data examine possible differences between the stationary count and traveling protocols as far as efficiency (individual observations per unit of duration) would be of utility to resource managers and researchers.

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