GIS-Based Evaluation of Waterfowl and Wading Bird Habitats in Maine

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Table of Contents

Abstract: The Maine Department of Inland Fisheries and Wildlife (MDIFW) has the authority under the state's Natural Resources Protection Act to identify and conserve high and moderate value waterfowl and wading birds habitats (WWH). While MDIFW has developed a manual system for identifying high and moderate value non-tidal wetlands for waterfowl and wading bird habitat, it is so labor and time intensive that approximately 10% of the state's WWHs have been evaluated. Our objectives are to: (1) automate the existing non-tidal WWH delineation process and evaluation system, (2) compare results for individual WWHs in Kennebec County to determine if the automated system is operating similarly to the manual system, (3)apply the automated system to all mapped wetlands in Maine , and (4) determine if the ratings related to and the predicted presence of wetland birds and other vertebrate groups and the observed presence of wading birds. Boundaries and partially completed manual ratings for 3,448 WWHs in organized towns in Maine provided by MDIFW and digital National Wetlands Inventory (NWI) maps for Maine were used in a Geographical Information System (GIS) to automate the WWH delineation and evaluation process. A series of programs in ARC Macro Language for ARC/INFO GIS were written to analyze WWH wetland composition from the NWI map to evaluate the following 5 WWH criteria: dominant wetland type, habitat size, diversity of wetland types, wetland type interspersion, and percent open water. Over 68% of WWHs rated moderate or high by MDIFW's manual system were also rated moderate or high by the automated system. The automated system delineated over 18,000 WWHs across Maine, 44 % of which were rated high or moderate, and this percentage varied little regionally. Predicted occurrences of vertebrate species regularly breeding in Maine, obtained from the Maine Gap Analysis Project, were used to determine if WWH ratings related to the predicted presence of wetland vertebrates. Species were placed into three groupings differing in level of wetland habitat specialization: wading birds and waterfowl, wetland-associated non-fish vertebrate species (divided into wetland-associated amphibians and reptiles, mammals, and birds), and wetland-using non-fish vertebrate species. Non-parametric methods (Kruskall-Wallis analysis of variance and Spearman correlation) were used to test for a linear relationship between WWH category (i.e. high, moderate, and low) and number of predicted species occurrences. High and moderate wetlands had significantly higher predicted use across all vertebrate classes than those rated low. In addition, high rated WWHs had a significantly higher number of observed wading bird species present than WWHs rated moderate or low. Due to the reliance of the automated system on NWI maps, which are based on interpretation of aerial photographs taken mostly in the mid-1980s, and the dynamic nature of Maine's inland wetlands, especially hydrological modifications by beaver (*Castor canadensis*), we recommend field checking any wetlands rated low or of concern to local biologists.

Introduction

Wetlands are increasingly a focus of research, regulation, management, and restoration due to their high productivity, biological diversity and water quality enhancement functions, and the high rate at which they have been modified and developed. In the conterminous United States (U.S.A.) less than half the estimated wetland acreage at the time of European settlement still remains. Wetlands were lost at a rate of 23,700 ha (58,500 acres) annually between 1986 and 1997, with 98% of those losses to freshwater wetlands (Dahl 2000). This is an 80% reduction in the average annual rate of wetland loss compared to the period between 1975 to 1986, attributed to increases in various wetland protection measures (Dahl 2000).

Due to climate and glacial history, water and wetlands make up an unusually high percentage (15%) of land cover in Maine (Krohn et al. 1998). While wooded swamps predominate Maine wetlands, a wide variety of other inland wetland types commonly occur in the state, including fresh emergent marshes, wet meadows and peatlands, the diversity of which is unsurpassed in the United States (Krohn et al. 1998, Davis and Anderson 2001). While rates of wetland loss in Maine have remained below national averages, percent wetland land cover in the state is thought to have decreased from an estimated 30% in the 1780's to the present 15% (Dahl 1990, Krohn et al. 1998).

Currently, two thirds of the U.S.A. lack comprehensive state wetland regulatory programs. Maine is one of the minority of states with wetland laws, including the state mandatory Shoreland Zoning Ordinance (1974) and Natural Resources Protection Act (NRPA), passed in 1988 (Venno 1991). NRPA regulates the human alteration of significant wildlife habitat, defined as: "…habitat for endangered and threatened species, critical spawning and nursery areas for Atlantic sea run salmon, seabird nesting islands, shorebird nesting feeding and staging areas, high and moderate value waterfowl and wading bird nesting and feeding areas, high and moderate value deer wintering areas and travel corridors, and significant vernal pools" (Venno 1991). Under NRPA, the Maine Department of Inland Fisheries and Wildlife (MDIFW) has the authority to identify and map significant wildlife habitat, including high and moderate value waterfowl and wading bird habitats (Venno 1991).

MDIFW has developed delineation procedures and an evaluation system for the identification and assessment of non-tidal waterfowl and wading bird habitats (WWHs). Since 1993, WWH identification and evaluation have been only partially completed due to the time consuming process of manually deriving the necessary information from aerial photographs, and Maine Wetlands Inventory (MWI) and National Wetlands Inventory (NWI) paper maps. However, newly available statewide digital NWI data allow for the process to be automated using a geographic information system (GIS), potentially increasing efficiency, cost effectiveness, and objective application of the criteria.

Purposes and Objectives

The purpose of this study is to develop an automated, spatially explicit system that identifies high and moderate value waterfowl and wading bird habitats similarly to the manual system developed by MDIFW. This GIS-based system is needed to delineate and evaluate individual wetland complexes across the state. Specific objectives are as follows:

(1) Automate the existing non-tidal WWH delineation process and evaluation system to identify moderate and high value waterfowl and wading bird habitats in Maine.

(2) Compare the results for individual WWHs in Kennebec County to determine if the automated system is delineating and evaluating wetland complexes similarly to the manual system.

(3) Assuming the automated system performs similarly to the manual one, then apply the automated system to wetlands across Maine.

(4) Assess the value of WWH rating system for wading birds, waterfowl, and other species by comparing WWH ratings (i.e. low, moderate, and high) to the numbers of regularly breeding vertebrates predicted to use these wetland complexes and numbers of wading birds observed using these wetland complexes during surveys.

Methods

<u>Manual System</u>

To protect habitats for waterfowl and wading birds, MDIFW must identify high and moderate value WWHs. MDIFW created a set of delineation guidelines and developed a system to rate wading bird and waterfowl habitat value based on wetland characteristics (Figure 1). Delineation guidelines call for combining all adjacent wetlands, with the exception of peripherally located wooded swamps and areas of deep open fresh water of over 100 acres, which are generally not lumped into wetland complexes. However, wetland complexes smaller than 10 acres adjacent to areas of deep open fresh water greater than 100 acres are combined. Furthermore, coves of ponds and lakes may be separated from open water if they are physiographically distinct from the water body or offer visually different habitat.

MDIFW drew on information from Golet (1978), Weller (1978), and Gibbs and Melvin (1990) to create 5 criteria for use in WWH assessment: dominant wetland type, wetland type diversity, habitat size, wetland type interspersion, and amount of open water. In the first phase of WWH assessment, WWHs are assigned scores ranging from 0 to 3 for wetland type diversity and habitat size, and a score ranging from 0 to 6 for dominant wetland type. These 3 scores are then summed and WWHs assigned ratings as follows: total scores of 10 or greater are high value, scores between 8 and 9 are moderate value, scores ranging from 5 to 7 are indeterminate value, and scores less than or equal to 4 are low value. In the second assessment phase, indeterminate WWHs are assigned to one of three wetland type interspersion categories (Figure 2) by manually comparing maps and photos of the wetland complex to simplified examples of the interspersion types from Golet and Larson (1974). Indeterminate value WWHs are then moved to high, moderate, or low based on interspersion category and percent open water.

Automated System

To automate the WWH delineation and evaluation process, ARC/INFO GIS (Version 8.0.2, ESRI 2000; use of trade names does not imply endorsement) was used. Digital National Wetlands Inventory (NWI) maps for Maine, based on interpretation of aerial photographs taken between 1973 and 1987 (95% of the photos were taken between

Habitat Size (m^2)	Score
< 40,470	1
40,470 - 404,700	2
> 404,700	3

+

Wetland Diversity (# Types)	Score
0 – 1	0
2	1
3	2
> 3	3

+

Dominant Wetland Type	Score
Inland Shallow Fresh Marsh	6
Inland Deep Fresh Marsh	6
Shallow Open Fresh Water	4
Bog	2
Inland Fresh Meadow	2
Shrub Swamp	2
Wooded Swamp	0
Inland Deep Open Fresh Water	0
Upland	0

Total Score	WWH Category
10 – 12	High
8 – 9	Moderate
5 – 7	Indeterminate
0 – 4	Low

Indeterminate WWHs only

Interspersion Category	Percent Open Water 0	< 35	35 – 65	> 65
1	Low	Low	Moderate	Low
2	Low	Moderate	Moderate	Moderate
3	Low	Moderate	High	Moderate

Figure 1. Evaluation system used by the Maine Department of Inland Fisheries and Wildlife to identify high and moderate value inland waterfowl and wading bird habitats.

1983 and 1986) by the U.S. Fish and Wildlife Service, were reclassified to correspond with MDIFW wetland types (Table 1). The reclassed NWI coverage was used to delineate WWHs first in Kennebec County (GIS commands listed in Appendix A). The WWH boundaries delineated by MDIFW, within organized towns in Maine and including a 75 m (250 ft) buffer around each WWH, were used for comparison. Adjacent wetland polygons in the NWI layer were dissolved to delineate WWH boundaries, excluding areas of deep open fresh water greater than 404,700m^2 (100 acres) and wooded swamps. Coves of ponds or lakes were not separated from open water due to difficulty in automating the determination of physiographical distinctness or evaluation of visually different habitat. This resulted in the delineation of over 5,000 WWHs in Kennebec County, 13 times more than in the existing MDIFW coverage which did not include WWHs rated low. In the automated coverage, 84% of the WWHs delineated were less than 20,235 m^2 (5 acres). In the MDIFW coverage, only 3% of all WWHs were less than 20,235 m^2 (5 acres) and of these just 16% were rated moderate or high. Therefore, delineated WWHs smaller than 20,235 m^2 (5 acres) were eliminated and the remaining WWHs were buffered out by 75 m (250 ft). This procedure was subsequently applied statewide.

To automate the WWH evaluation process, the WWH boundaries delineated by MDIFW were overlaid onto the reclassified NWI data layer. A program written in ARC Macro Language (AML) for ARC/INFO was developed to determine dominant wetland type, habitat size, and diversity of wetland types for each WWH in the MDIFW coverage

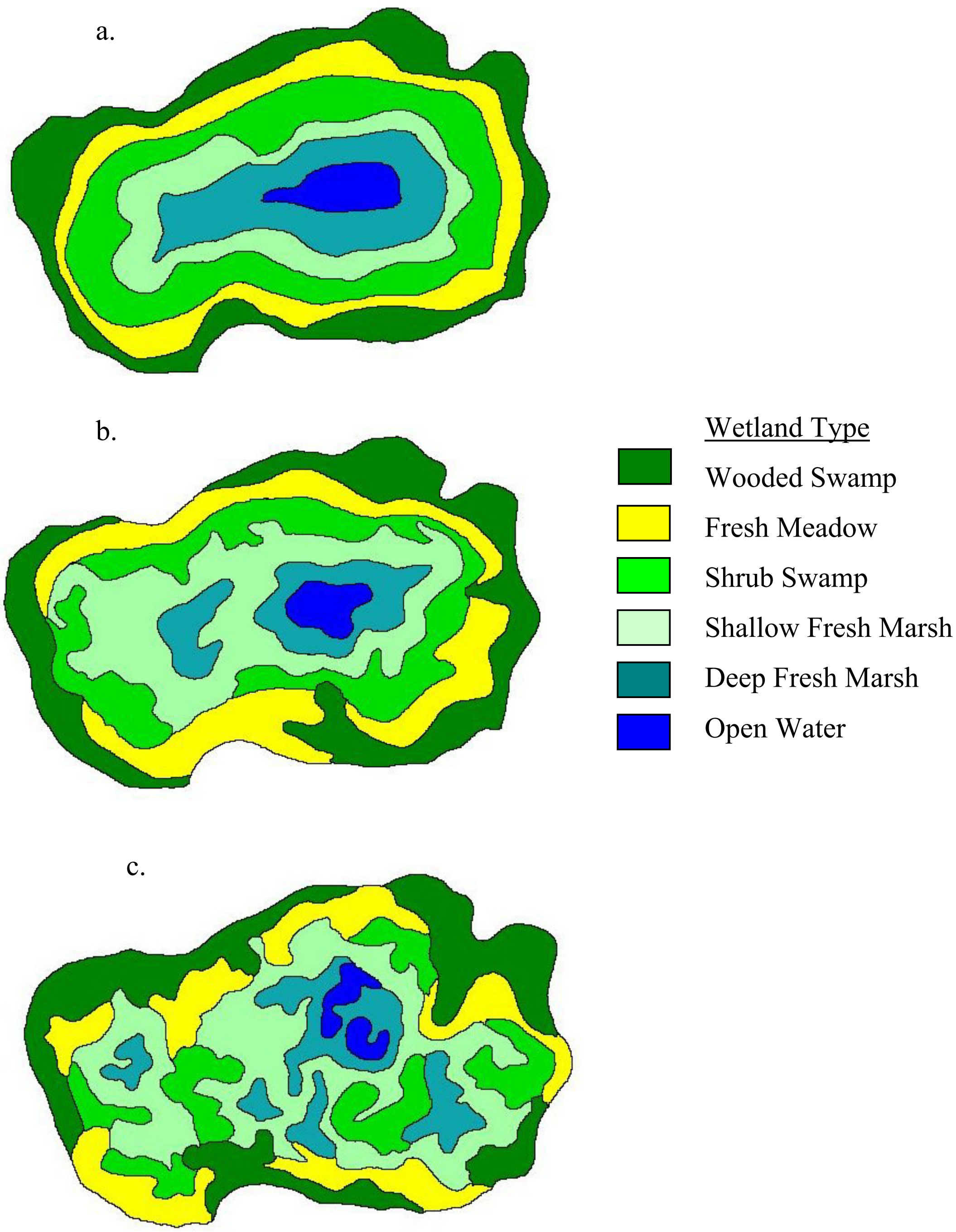

Figure 2. Wetland type interspersion categories for evaluating waterfowl and wading bird habitats in Maine: (a) interspersion category 1, (b) interspersion category 2, and (c) interspersion category 3 (adapted by Maine Department of Inland Fisheries and Wildlife from Golet and Larson [1974]).

Table 1. Crosswalk of wetland types used in Maine Gap Analysis map and Maine Department of Inland Fisheries and Wildlife's waterfowl and wading bird and habitat evaluation system. See Hepinstall et al. (1999: Appendix D) for crosswalk of ME-GAP and NWI wetland types.

ME-GAP Wetland Type[a]	**MDIFW Wetland Type**[b]
Deciduous Forested Coniferous Forested Dead-Forest	Wooded Swamp
Deciduous Scrub-Shrub Coniferous Scrub-Shrub Dead Scrub-Shrub	Shrub Swamp
Fresh Aquatic Bed	Inland Deep Fresh Marsh
Fresh Emergent	Inland Shallow Fresh Marsh
Peatland	Bog
Meadow Wet	Inland Fresh Meadow
Shallow Water	Inland Shallow Open Fresh Water
Open Water	Inland Deep Open Fresh Water

[a]Hepinstall et al. (1999).

[b]Maine Department of Inland Fisheries and Wildlife (1993).

by evaluating WWH wetland composition from the NWI map (Appendices B, C, and D). Habitat size was evaluated as the total wetland area, omitting any upland areas that were within the WWH boundary due to the buffer. An area score of 1 was assigned to WWHs with areas less than 40,470 m^2 (10 acres), 2 for WWH area between 40,470 m^2 (10 acres) and 404,700 m^2 (100 acres), and 3 for WWH area greater than 404,700 m^2 (100 acres). Following the manual WWH rating procedures of MDIFW, the diversity of wetland types was evaluated as the number of wetland types comprising at least 8,094 m^2 (2 acres) or 10% of total WWH area. Diversity scores were assigned as follows: 0 for 0-1 type, 1 for 2 types, 2 for 3 types, and 3 for greater than 3 types. Dominant wetland type was evaluated as the wetland type comprising the greatest area within a given WWH and was given twice as much weight as the diversity and size criteria. Dominant wetland types of inland shallow fresh marsh and inland deep fresh marsh were assigned a dominant type score of 6, shallow open water a 4, bog, inland fresh meadow, and shrub swamp a 2, and 0 for inland deep open fresh water, wooded swamp, and upland. Scores for each of these three criteria were summed and ratings assigned as follows: scores of 10 to 12 were high, 8 to 9 were moderate, and 0 to 4 low. WWHs with scores between 5 and 7 were rated indeterminate and further evaluated.

Indeterminate WWHs were assessed for wetland type interspersion and percent open water. In order to automate this process, a method of quantifying wetland type interspersion was needed. We conducted a preliminary analysis of indeterminate WWHs in York County, using FRAGSTATS*Arc (Version 302, Pacific Meridian Resource 2001), a spatial pattern analysis program for quantifying landscape structure.

FRAGSTATS was run on each indeterminate WWH individually, with any upland included in the boundaries of a WWH assigned a weight of 0 and all wetland-wetland boundaries were assigned weights of 1 for the computation of weighted metrics, such as total edge weighted. Various landscape structure metrics and combinations of metrics were compared with results of a manual classification of the WWHs into the interspersion categories. The following combination performed best at separating out the 3 categories: Interspersion and Juxtaposition Index * Total Edge Weighted (IJI*TE_WGT, Figure 3). York County indeterminate WWHs were divided into the 3 interspersion categories using the natural breaks (Jenk's Optimization) classification method on IJI*TE_WGT, resulting in an 87% agreement with the manual classification. This method was subsequently used for the entire WWH layer (see Appendices E and F for programs). Indeterminate WWHs were then reassigned ratings of high, moderate, or low based on their wetland type interspersion category and percent open water (Figure 1). Manual and automated WWH categories were compared to determine overall operational agreement rates (both automated and manual ratings of high or moderate) for the MDIFW WWH layer. However, nearly half of the WWHs in the MDIFW coverage were incompletely rated by MDIFW as indeterminate and could not be used for comparison. Operational agreement rates ranged from 56.6% to 69.5% (Table 2). MDIFW records for WWHs in Kennebec County assigned a manual rating of high or moderate and an automated rating of low (n = 24) were examined to determine possible sources of disagreement between the two processes. The majority of the discrepancies were due to conflicting dominant wetland types. This could be due to the sole reliance of the automated system on NWI maps as input, while the manual process had additional and

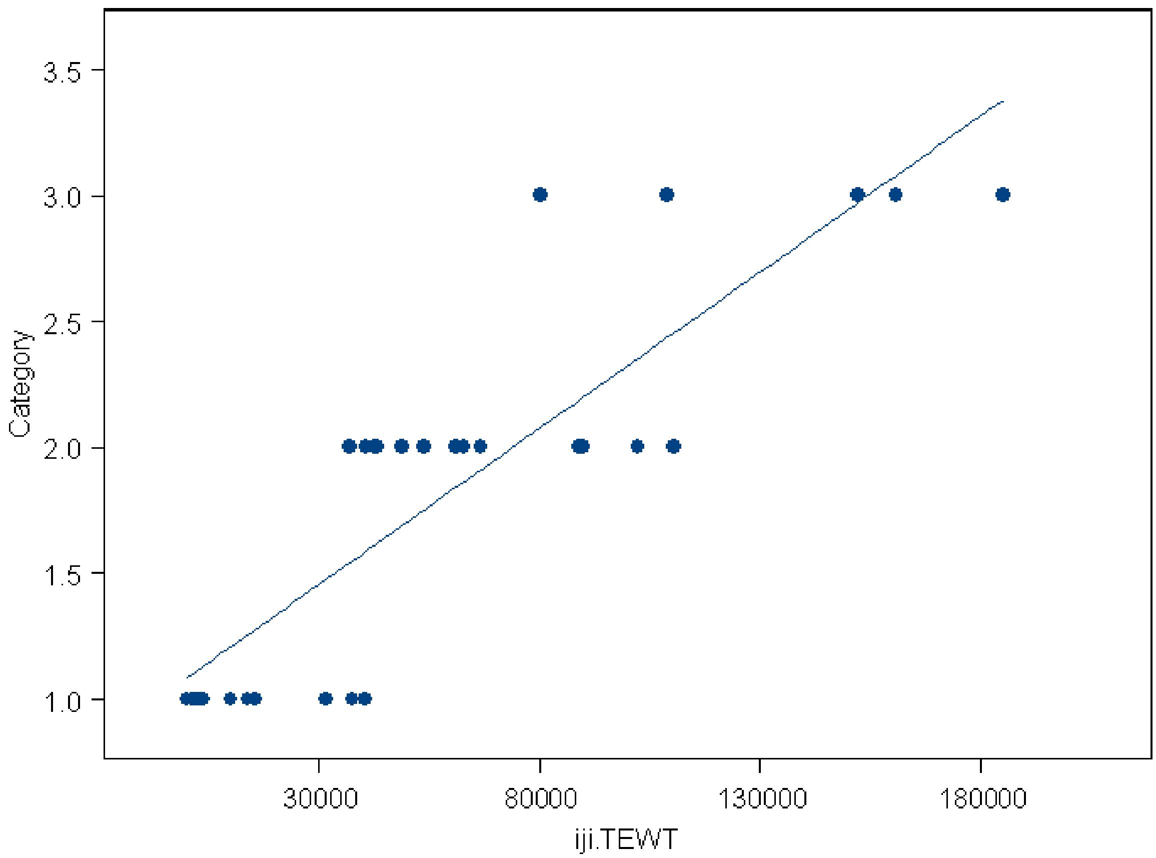

Figure 3. Relationship between interspersion and juxtaposition index * total edge weighted (iji.TEWT) and manually determined wetland interspersion category for York County 'Indeterminate' WWHs (n = 38 with 1 outlier removed, $r^2 = 0.73$).

Table 2. Comparison of manual and automated WWH ratings. Operational agreement refers to the percentage of WWHs rated as high or moderate by Maine Department of Inland Fisheries and Wildlife (MDIFW) and as high or moderate by the automated system.

MDIFW Rating	N[a]	Automated Rating	Auto-mated N	Operational Agreement	Auto-mated N[b]	Operational Agreement[b]
High	392	High	88	66.8	88	76.3
		Moderate	174		211	
		Low	130		93	
Moderate	1485	High	161	53.6	161	66.5
		Moderate	635		827	
		Low	689		497	
Indeterminate	1571	High	225	NA[c]	225	NA
		Moderate	536		770	
		Low	810		576	

[a]Number of WWHs

[b]Incorporates 2nd dominant wetland type.

[c]Not applicable. No operational agreement was determined for indeterminate WWHs due to the transitory nature of the rating. In the automated system, all indeterminate WWHs were re-evaluated as high, moderate, or low. This process was not completed under MDIFW's manual system.

often more recent sources of information, such as aerial photos, field checks, and the personal knowledge of regional biologists. Discrepancies in dominant type also may be attributed to beaver (*Castor canadensis*) modification of the landscape, thus altering wetland regimes and shifting dominant wetland type since NWI maps were developed in the 1980s. Therefore, all WWHs assigned a rating of low were re-evaluated for second dominant wetland type (Figure 4). Low WWHs with a second dominant type of shallow fresh marsh, deep fresh marsh, or shallow open fresh water comprising greater than or equal to 20% of total WWH area were moved to moderate. This increased operational agreement rates by 6.8 to 9.9% (Table 2). This automated evaluation process was subsequently applied statewide on the automated delineated coverage. Regional variation in WWH density was examined by comparing MDIFW and automated delineated WWHs by MDIFW administrative region (Figure 5) and biophyisical region (Krohn et al. 1999; Hepinstall et al. 1999, Figure 6).

Species Richness and WWH Ratings

WWH ratings in the MDIFW coverage were compared with predicted occurrences of non-fish vertebrates regularly breeding in Maine from the Maine Gap analysis (ME-GAP, Boone and Krohn 1998a and 1998b) to determine if the WWH evaluation system discerns wetlands which provide habitat for high numbers wetland-associated vertebrate species. Automated WWH ratings were used for comparisons because the manual ratings were incomplete and a reasonable agreement rate was found between the automated and manual ratings. Species predictions for ME-GAP were modeled at a resolution of 90 m and overall accuracy rates, at the resolution of state/federal wildlife areas, ranged from

Habitat Size (m^2)	Score
< 40,470	1
40,470 - 404,700	2
> 404,700	3

+

Wetland Diversity (# Types)	Score
0 – 1	0
2	1
3	2
> 3	3

+

Dominant Wetland Type	Score
Inland Shallow Fresh Marsh	6
Inland Deep Fresh Marsh	6
Shallow Open Fresh Water	4
Bog	2
Inland Fresh Meadow	2
Shrub Swamp	2
Wooded Swamp	0
Inland Deep Open Fresh Water	0
Upland	0

Total Score	WWH Category
10 – 12	High
8 – 9	Moderate
5 – 7	Indeterminate
0 – 4	Low

Indeterminate WWHs only

Interspersion	Percent Open Water			
Category	0	< 35	35 – 65	> 65
1	Low	Low	Moderate	Low
2	Low	Moderate	Moderate	Moderate
3	Low	Moderate	High	Moderate

Low WWHs only

2nd Dominant Type	WWH Category
Inland Shallow Fresh Marsh	Moderate
Inland Deep Fresh Marsh	Moderate
Inland Shallow Open Fresh Water	Moderate
Bog	Low
Inland Fresh Meadow	Low
Shrub Swamp	Low
Wooded Swamp	Low
Inland Deep Open Fresh Water	Low
Upland	Low

Figure 4. Automated version of the evaluation system used by the Maine Department of Inland Fisheries and Wildlife to identify high and moderate value inland waterfowl and wading bird habitats.

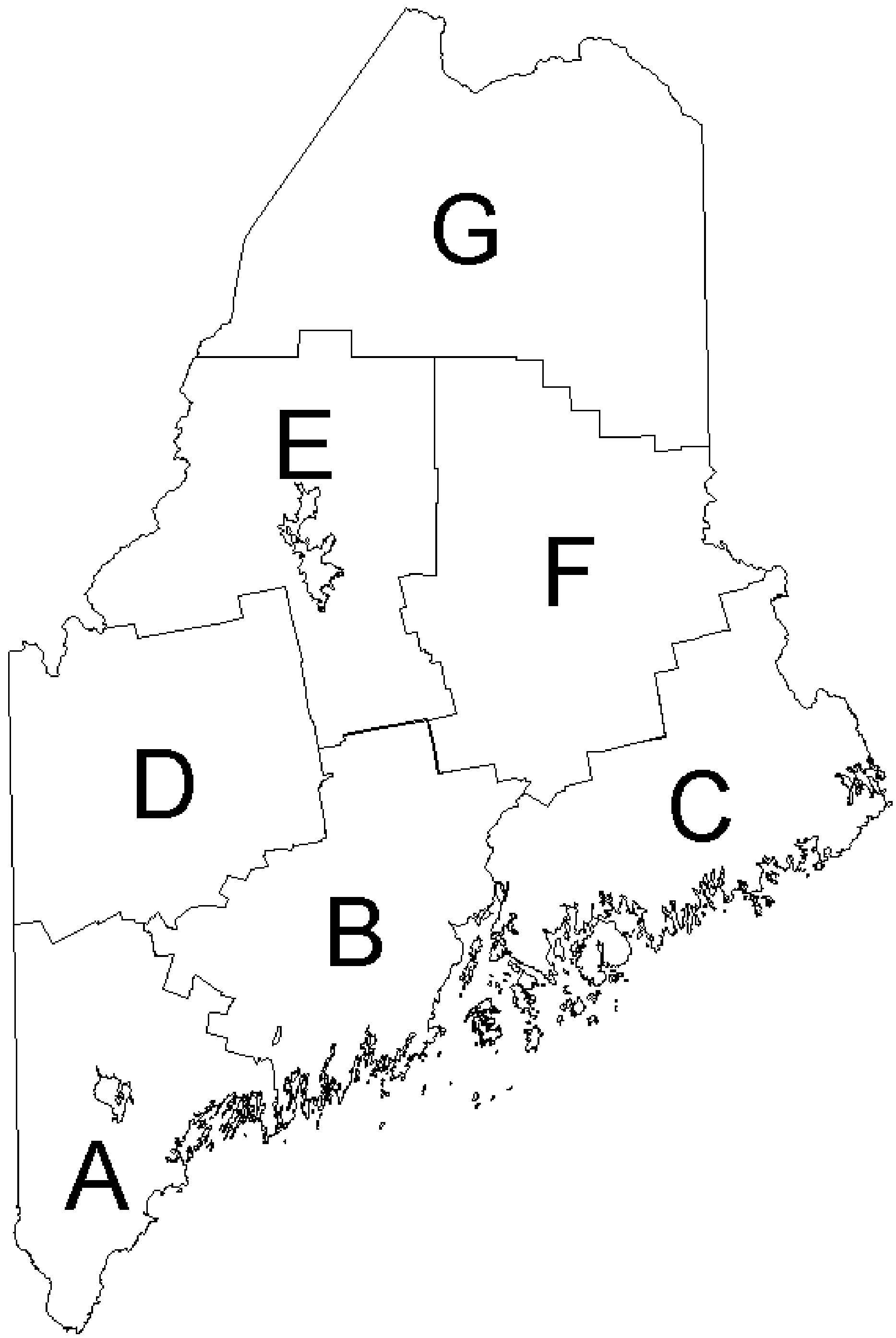

Figure 5. Administrative regions used by the Maine Department of Inland Fisheries and Wildlife.

1999).

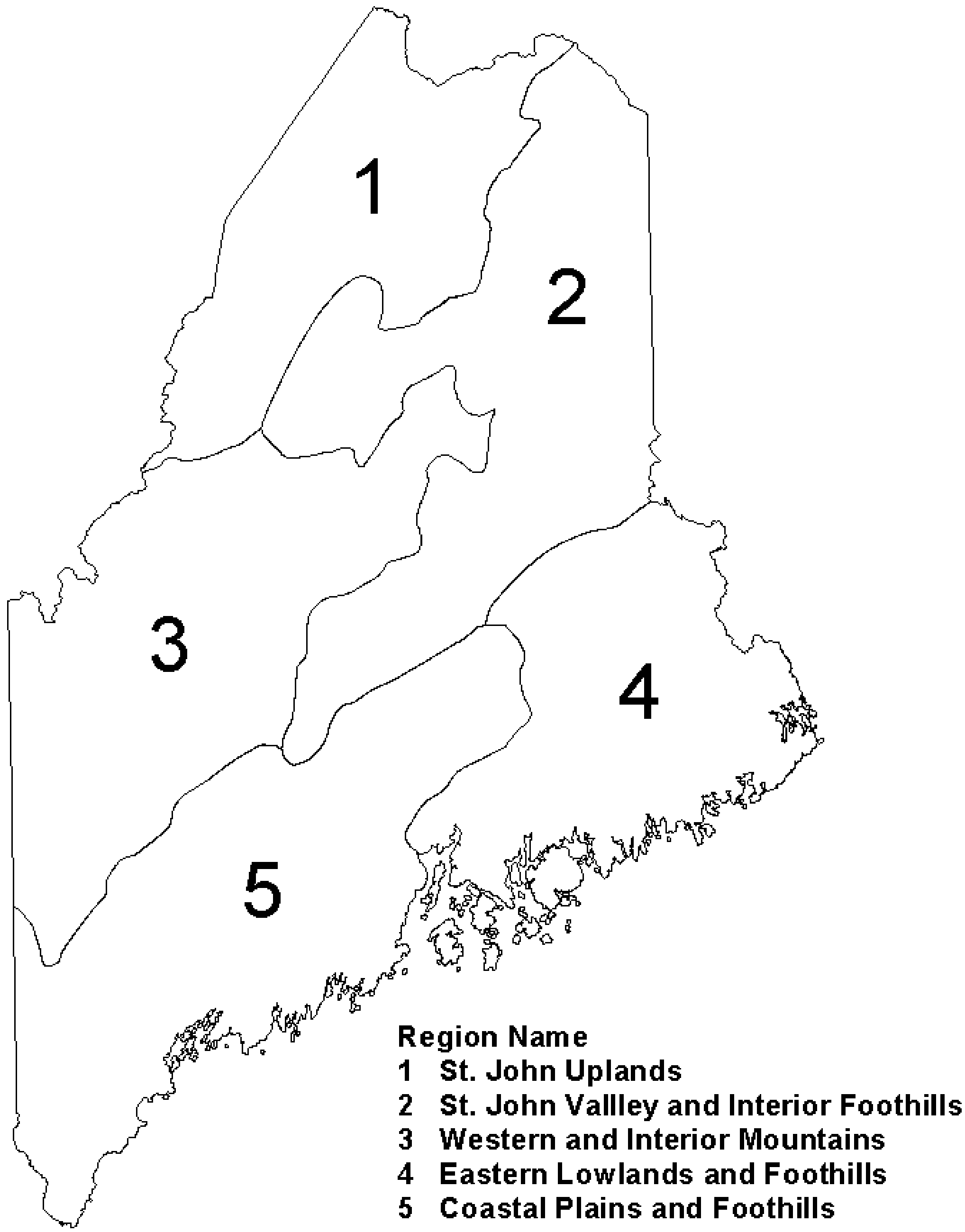

Figure 6. Major biophysical regions of Maine (from Krohn et al. 1999, Hepinstall et al. 1999).

74% for birds to 100% for amphibians (Table 3).

Three species groupings differing in level of wetland habitat specialization were used in the comparisons to ascertain if the applicability of the WWH evaluation system extends beyond wading bird and waterfowl habitat for which it was intended, also incorporating important habitat of other wetland taxa. Habitat descriptions in Boone and Krohn (1998a and 1998b) were used to assign species to the different groups (Appendix G). Wetland-using non-fish vertebrates, the most inclusive group, with 183 species, and incorporated all species whose general habitat descriptions included non-tidal wetlands, but species were not necessarily limited to these habitats. The 73 species in the wetland-associated non-fish vertebrate group incorporated species whose specific habitat descriptions were limited to wetlands. This group was divided into wetland-associated amphibians and reptiles, with 23 species, wetland associated mammals, with 12 species, and wetland-associated birds, with 38 species. The last group, wading birds and waterfowl, incorporated the 25 species defined by NRPA and included in ME-GAP.

The ratio of the number of species predicted by ME-GAP to occur to the number of species that could possibly occur, given range and habitat considerations, was determined for each WWH in the MDIFW coverage. Due to the high degree skewness in the data, a rank transformation was applied and non-parametric tests were used for analyses. Kruskal-Wallis analysis of variance was used to test for differences in rank sum for the 3 categories (high, moderate, and low). A non-parametric test for differences in mean rank was used for individual comparisons (Zar 1999). Spearman correlation was used to test for a linear relationship between WWH category and mean rank.

Table 3. Reliability of species occurrence predictions from the Maine Gap analysis (ME-GAP, from Krohn et al. 1998). Tests made by comparing species predicted to be present/absent in ME-GAP data to occurrences from long-term field data at 5 test sites.

Taxonomic Class	Omission Error[a] % (Median)	Commission Error[b] % (Median)	Overall Accuracy %
Amphibians	0.0	0.0	100
Reptiles	10.0	5.0	85.7
Birds	5.4	18.9	74.0
Mammals	0.7	34.2	79.6
Total	0.0	17.9	

[a]Species present on test sites but missed by ME-GAP.

[b]Species absent on test sites but predicted by ME-GAP to occur there (some of this error could be due to incomplete field surveys; Boone and Krohn 1999).

WWH ratings were also compared to MDIFW inland marsh bird survey data from 1998 to 2000 (Tom Hodgman, MDIFW, personal communication). Seven wading bird species considered under NRPA (great blue heron, *Ardea herodias*; green heron, *Butorides striatus*; least bittern, *Ixobrychus exilis*; American bittern, *Botaurus lentiginosus*; Virginia rail, *Rallus limicola*; sora, *Porzana carolina*; and the common moorhen *Gallinula chloropus*) were targeted in the surveys. Sedge meadows, deep marshes, and adjacent open water areas in over 100 wetland complexes in regions 4 and 5 were surveyed (Figure 6). Survey site boundaries corresponded with 54 WWHs in the statewide delineated coverage, 7 of which are rated low, 36 moderate, and 11 high (Figure 7). T-tests were used to test for differences in mean species richness for the 3 ratings (high, moderate, and low).

Results and Discussion

<u>Automated Evaluation</u>

The MDIFW GIS layer was completed for organized Maine towns only and consisted of 3,448 WWHs, nearly half of which were rated by MDIFW as indeterminate (Table 2). Of the 1,571 WWHs rated by MDIFW as indeterminate, the automated evaluation process rated 14.3% of these as high, 49.0% as moderate, and 36.7% as low. The automated evaluation process resulted in 13.8% of all state delineated WWHs rated high, over half (52.4%) rated moderate, and 33.8% rated low. The automated evaluation process yielded an overall operational agreement of 68.6% (number of WWHs with both automated and MDIFW ratings of moderate and high). The automated WWH evaluation process was found to be comparable to the manual process, but limited by available data.

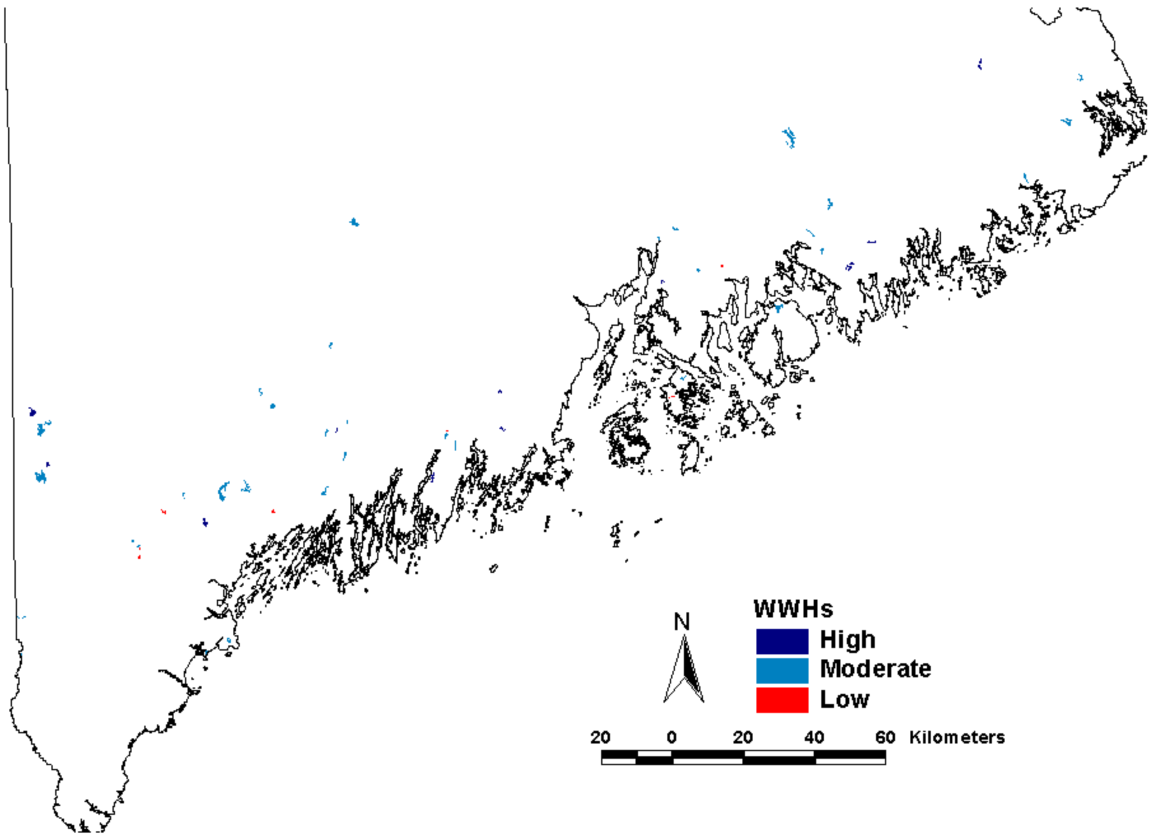

Figure 7. Locations and ratings of WWHs corresponding with MDIFW inland marsh bird survey sites for 1998 through 2000.

It is recommended that MDIFW field check any WWHs deemed of questionable rating by local biologists (e.g., affected by beaver activity).

Species Richness and WWH Ratings

Results of the Kruskal-Wallis tests provided convincing evidence that rank sum ratio of predicted to possibly occurring species differed by rating (high, moderate, and low) for all vertebrate groupings: wading birds and waterfowl; wetland-associated amphibians and reptiles; wetland-associated mammals; wetland-associated birds; all wetland-associated non-fish vertebrates; and all wetland-using non-fish vertebrates ($p = 0$, Table 4). Mean ranks for low WWHs were significantly different from mean ranks of those rated as moderate and high for all vertebrate groupings ($p < 0.001$, Table 5). Differences in mean ranks of high and moderate WWHs were found for wading birds and waterfowl, wetland-associated birds, all wetland-associated non-fish vertebrates, and all wetland-using non-fish vertebrates ($p < 0.05$, Table 5), but not for wetland-associated amphibians and reptiles or wetland-associated mammals ($p > 0.5$, Table 5). Spearman rank correlation tests showed weak ($0.13 \leq r \leq 0.32$) but statistically significant ($p < 0.001$) linear relationships between ranked ratio of predicted to possibly occurring species and rating for all groupings (Table 6).

The WWH evaluation system distinguishes wetlands predicted by ME-GAP to have high wading bird and waterfowl diversity. Furthermore, our results suggest that protection of high and moderate value WWHs in Maine may function as an “umbrella,” conferring habitat protection for other wetland-associated non-fish vertebrate species as well. However, while the relationship between WWH category and ME-GAP predictions

Table 4. Kruskal-Wallis Test for differences in rank sum ratio of predicted to possibly occurring species among high, moderate, and low value wading bird and waterfowl habitats.

Taxonomic Group[a]	N	H[b]	p-value
Wading Birds and Waterfowl	25	376.2	0
All Wetland - Associated Non - Fish Vertebrates	73	341.9	0
Wetland - Associated Amphibians and Reptiles	23	91.9	0
Wetland - Associated Mammals	12	69.3	0
Wetland - Associated Birds	38	371.4	0
All Wetland - Using Non - Fish Vertebrates	183	296.2	0

[a]Arranged, top to bottom, from most to least closely associated with wetlands; refer to Appendix G for list of species included in each group.

[b]Kruskal-Wallis test statistic (Zar 1999).

Table 5. Multiple comparisons between high, moderate, and low value wading bird and waterfowl habitats of mean rank ratio of predicted to possibly occurring species.

	High vs. Low		Moderate vs. Low		High vs. Moderate	
Taxonomic Group[a]	Q[b]	p	Q	p	Q	p
Wading Birds and Waterfowl	15.2	0.001	16.8	0.001	3.6	0.001
All Wetland - Associated Non - Fish Vertebrates	13.9	0.001	16.5	0.001	2.5	< 0.05
Wetland - Associated Amphibians and Reptiles	6.4	0.001	9.0	0.001	0.1	> 0.5
Wetland - Associated Mammals	5.4	0.001	7.9	0.001	-0.1	> 0.5
Wetland - Associated Birds	15.1	0.001	16.7	0.001	3.6	0.001
All Wetland - Using Non - Fish Vertebrates	14.6	0.001	13.8	0.001	5.1	0.001

[a]Arranged, top to bottom, from most to least closely associated with wetlands; refer to Appendix G for list of species included in each group.

[b]Non-parametric multiple comparison test statistic (Zar 1999).

Table 6. Spearman rank correlation coefficients, t-statistics, and associated p-values, testing for linear relationship between ranked ratio of predicted to possibly occurring species and WWH rating.

Taxonomic Group[a]	r	t	p-value
Wading Birds and Waterfowl	0.32	20.2	< 0.001
All Wetland - Associated Non - Fish Vertebrates	0.31	18.8	< 0.001
Wetland - Associated Amphibians and Reptiles	0.15	9.1	< 0.001
Wetland - Associated Mammals	0.13	7.8	< 0.001
Wetland - Associated Birds	0.32	20.0	< 0.001
All Wetland - Using Non - Fish Vertebrates	0.29	18.0	< 0.001

[a]Arranged, top to bottom, from most to least closely associated with wetlands; refer to Appendix G for list of species included in each group.

is statistically significant, it explains only a small proportion of the variation in species richness. For instance, of the 1,408 WWHs predicted by ME-GAP to have 100% species occurrence, 22% were rated low. Of the 68 WWHs predicted to have less than 20% species occurrence, 9% were rated high and 28% moderate. Possible explanations for the weakness of the relationship between WWH rating and rank proportion of the number of species possible predicted to occur include differences in the scales of ME-GAP and WWH project or unstudied factors influencing the number of vertebrate species using wetlands. Further studies are necessary to validate the premise that efforts to protect wading bird and waterfowl habitat will adequately confer protection to other species of concern (e.g., see Gibbs 2000).

The WWH evaluation system was found to distinguish wetlands observed to have high wading bird diversity (Figure 8). High rated WWHs were found to have a significantly higher number of wading bird species present than WWHs rated moderate or low ($p < 0.02$, Table 7). American bittern, great blue heron, green heron, sora, and Virginia rail were the most common species observed across all three ratings (Table 8).

Automated Delineation and Regional Variation

The automated WWH delineation process resulted in the identification of 18,085 WWHs statewide, of these 55.5% were rated low, 37.5% moderate, and 7% high. MDIFW and automated delineated WWHs were compared in Kennebec County and found to be similar: MDIFW rated 66 WWHs high and 184 moderate, while the automated system rated 68 WWHs high and 223 moderate.

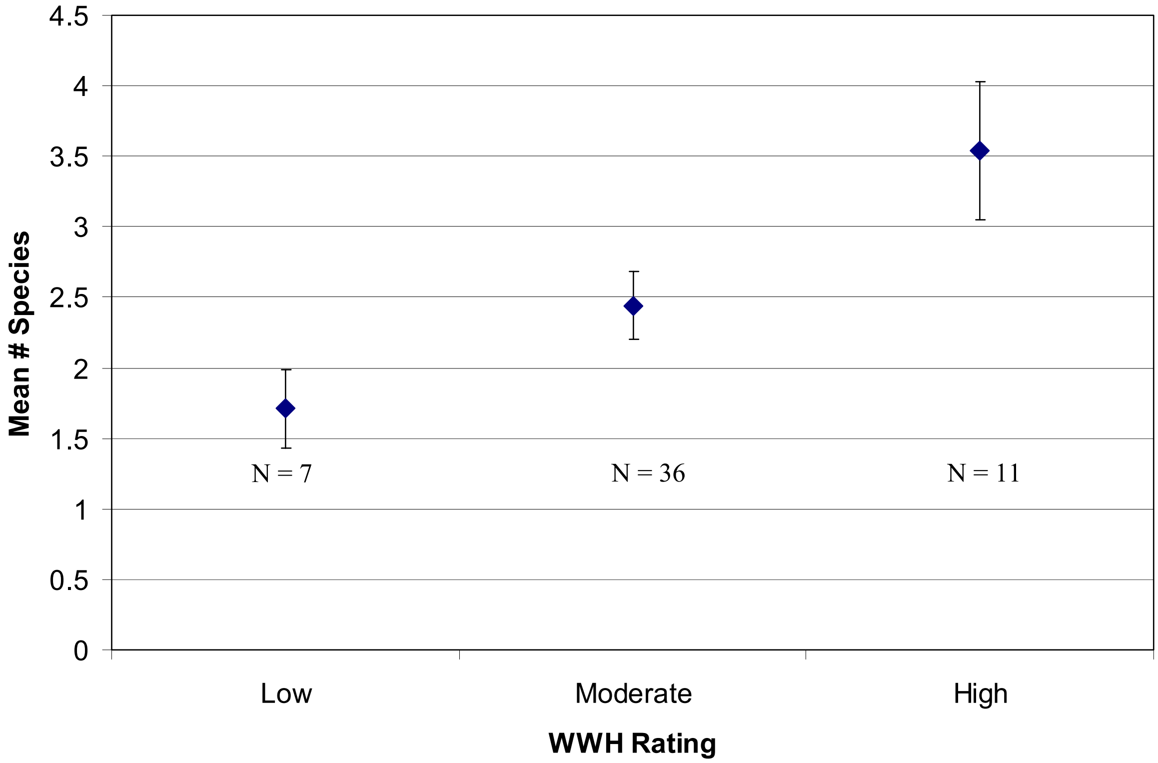

Figure 8. Mean number of wading bird species (± 1 SE) observed per wetland by WWH rating.

Table 7. T-tests for differences in mean number of wading bird species observed by WWH ratings.

Comparison	t-statistic	p-value
High-Moderate	2.25	< 0.02
Moderate-Low	1.24	< 0.15
High-Low	2.66	< 0.01

Table 8. Species of wading birds observed using wetland by WWH ratings (data from Hodgman et al. 2001).

	Species						
WWH Rating	AMBI[1]	COMO[2]	GBHE[3]	GRHE[4]	LEBI[5]	SORA[6]	VIRA[7]
High	0.82	0	0.73	0.45	0.09	0.73	0.73
Moderate	0.56	0.03	0.50	0.25	0.06	0.42	0.64
Low	0.43	0	0.29	0.14	0	0.29	0.43

[1]American Bittern
[2]Common Moorhen
[3]Great Blue Heron
[4]Green Heron
[5]Least Bittern
[6]Sora
[7]Virginia Rail

Variation in WWH numbers, ratings, and density was examined by comparing MDIFW and automated delineated and evaluated WWHs by MDIFW administrative regions, though only Region B appears to have been completely delineated by MDIFW (Table 9). The automated system delineated from 2 (Regions A and C) to 13 (Region E) times more high and moderate WWHs than MDIFW, even after accounting for MDIFW's indeterminate WWHs, except in Region B where the difference dropped from 5 times to 0.8 times after the inclusion of indeterminate WWHs. The density of high and moderate rated WWHs varied little by MDIFW administrative region. High and moderate rated WWHs were most dense in Regions B and C ($0.12/km^2$) and least dense in Region G ($0.07/ km^2$). Regional variation in WWH density was examined by comparing WWHs delineated and evaluated by the automated system by biophyisical region (Figure 9). The proportion of WWHs by rating (high, moderate, and low) varied little by region, with highs making up 5 to 9%, moderates 35 to 40%, and lows 52 to 57% of all WWHs (Table 10). The density of high and moderate rated WWHs varied little by biophysical region (Table 11). High and moderate rated WWHs were most dense in the eastern lowlands and foothills and coastal plains and foothills ($0.11/km^2$) and least dense in the St. John Uplands ($0.07/km^2$). The total area of high and moderate rated WWHs per biophysical region area also varied little, ranging from 0.04 to 0.08.

Summary and Conclusions

Under NRPA, MDIFW is authorized to identify and map high and moderate value wading bird and waterfowl habitat. While MDIFW has developed delineation procedures and an evaluation system for the identification and assessment of non-tidal

Table 9. Numbers of WWHs delineated and rated by MDIFW and automated system by MDIFW administrative region (see Figure 4 for locations of regions).

MDIFW Region	Area (km^2)	Number of WWHs: High Auto	High MDIFW	Moderate Auto	Moderate MDIFW	Indeterminate MDIFW	Low Auto
A	8,479	131	41	661	325	32	1,225
B	10,294	270	110	987	139	1,277	1,463
C	10,379	228	102	1,045	363	16	1,414
D	11,254	129	34	721	253	38	1,060
E	11,921	168	11	1,086	63	19	1,432
F	13,363	240	56	1,310	249	162	1,749
G	18,476	117	41	1,107	110	44	1,826

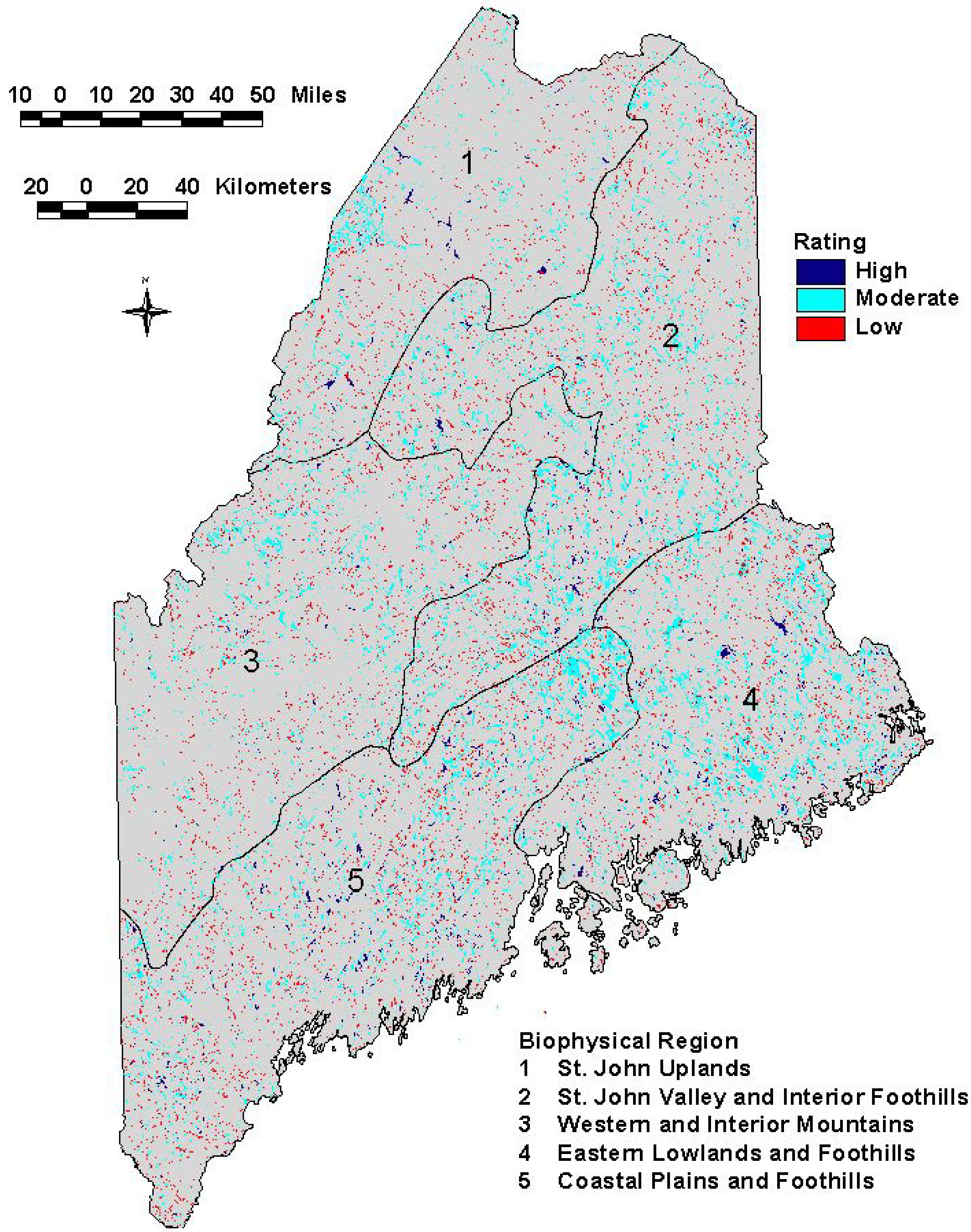

Figure 9. Locations of waterfowl and wading bird habitats delineated and evaluated by automated assessment system.

Table 10. Percentage (number) of WWHs delineated and rated by automated system by major biophysical region (see Figure 5 for locations of regions).

Region	Area (km^2)	High	Moderate	Low	Total
St. John Uplands	12,527	5% (95)	38% (747)	57% (1,126)	1,968
St. John Valley and Interior Foothills	19,916	6% (267)	37% (1,697)	57% (2,559)	4,523
Western and Interior Mountains	19,079	7% (238)	40% (1,448)	53% (1,924)	3,610
Eastern Lowlands and Foothills	14,323	8% (276)	40% (1,364)	52% (1,778)	3,418
Coastal Plains and Foothills	19,513	9% (415)	35% (1,717)	56% (2,750)	4,882

Table 11. Density and area of high and moderate WWHs delineated and rated by automated system by major biophysical region (see Figure 5 for map of regions).

Region	Density (#/km^2)	Area Covered by WWH (km^2)	WWH Area / Regional Area
St. John Uplands	0.07	451.7	0.04
St. John Valley and Interior Foothills	0.10	1,303.1	0.06
Western and Interior Mountains	0.09	722.9	0.04
Eastern Lowlands and Foothills	0.11	1,205.5	0.08
Coastal Plains and Foothills	0.11	1,240.1	0.06

waterfowl and wading bird habitats (WWHs), WWH identification and evaluation had been only partially completed. The purpose of this project was to automate the WWH identification and evaluation process to obtain results similar to the manual system. Furthermore, we wanted to compare WWH ratings with species occurrences to determine if the WWH evaluation system discerns wetlands predicted to have high numbers of wetland-associated non-fish vertebrate species and wetlands observed to have high numbers of wading bird species.

The automated evaluation process yielded an overall operational agreement of 68.6% (number of WWHs with both automated and MDIFW ratings of moderate and high) and was found to be comparable to the manual process, but limited by available data. It is recommended that MDIFW field check any WWHs with an automated rating of low.

The automated WWH evaluation system was found to distinguish wetlands predicted by ME-GAP to have high wading bird and waterfowl diversity and other wetland-associated non-fish vertebrate species diversity as more species were predicted to use high and moderate WWHs than low rated WWHs. While the relationship between WWH category and ME-GAP species predictions was statistically significant, it explained only a small portion of variation in species richness. Therefore, further studies are necessary to validate the premise that efforts to protect wading bird and waterfowl habitat will adequately confer protection to other species of concern. The WWH evaluation system was also found to distinguish wetlands observed to have high wading bird diversity as high rated WWHs were found to have a significantly higher number of wading bird species present than WWHs rated moderate or low, increasing confidence that the automated ratings are performing as intended.

The automated WWH delineation process resulted in the identification of over 18,000 WWHs statewide, of which over 44% were rated high or moderate. The automated WWH delineation and evaluation system applied the WWH assessment criteria uniformly, objectively, efficiently, and comprehensively. Therefore, the process is easy to explain and justify to the public. However, the results of the automated delineation and evaluation process are only as good as NWI data used as the system input and MDIFW will be required to maintain both the automated and manual system until field biologists have reviewed the results.

Acknowledgments

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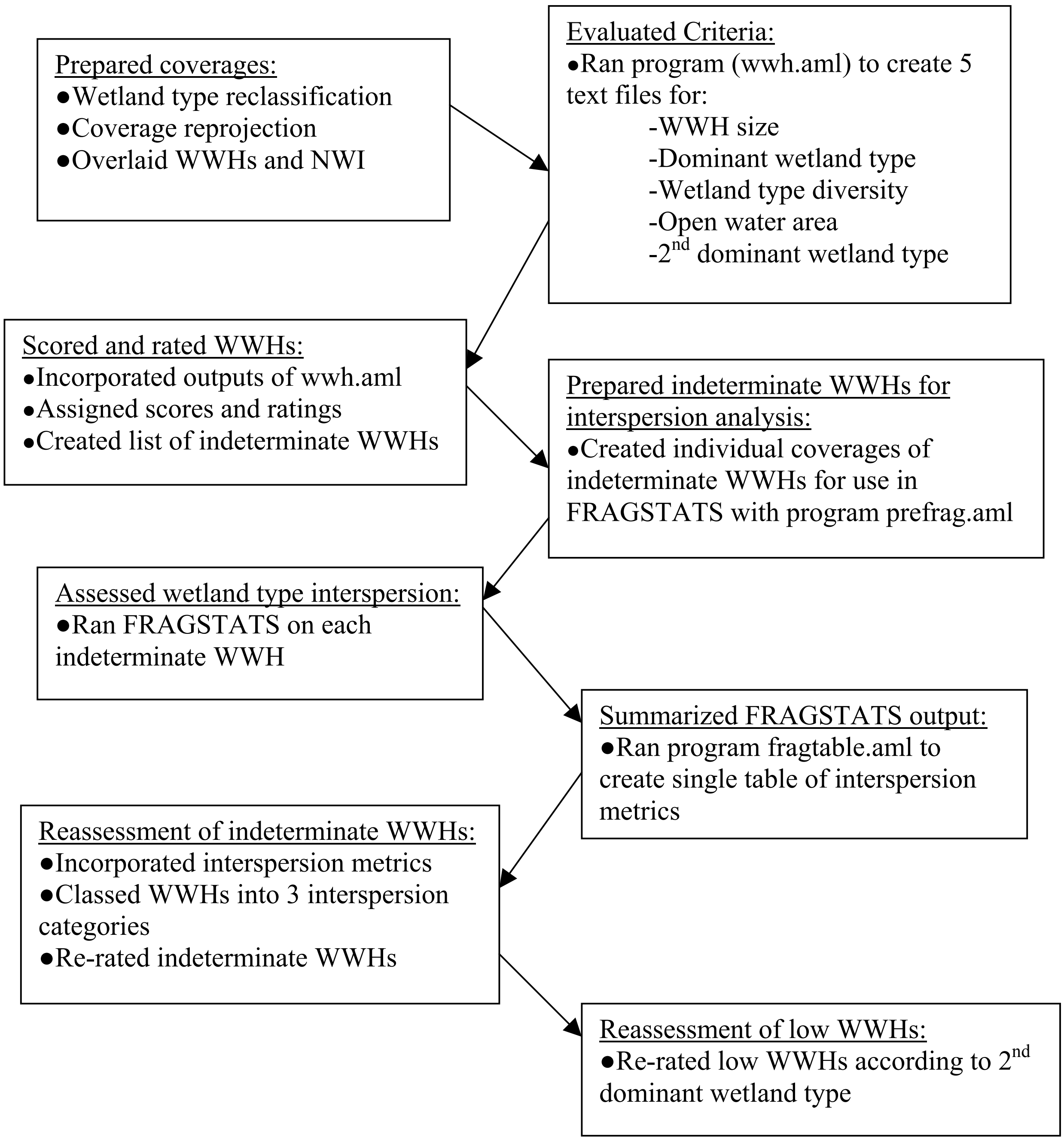
Appendix A. ARC/INFO commands used to delineate wading bird and waterfowl habitats by removing open water bodies > 100 acres, wooded swamps, and uplands; lumping remaining adjacent wetlands; adding 250 ft buffer; and removing polygons smaller than 5 acres.

```
TABLES
ADDITEM NWI.PAT WTLD 1 1 C
SEL NWI.PAT
RSEL TYPE CN 'NONE'
MOVE 'N' TO WTLD
NSEL
RESEL TYPE CN 'WOODED SWAMP'
MOVE 'N' TO WTLD
RESELECT TYPE CN 'INLAND DEEP OPEN FRESH WATER'
RESEL AREA > 404700
MOVE 'N' TO WTLD
SEL NWI.PAT
RESEL WTLD CN 'N'
NSEL
MOVE 'Y' TO WTLD
DISSOLVE NWI NWIDIS WTLD POLY
Q
BUFFER NWIDIS NWIDISB # # 75

RESELECT NWIDISB NWIDELIN POLY
RESELECT WTLD CN 'Y'
~
N
Y
RESELECT AREA > 20,235
~
N
N
```

Appendix B. Overview of automated wading bird and waterfowl habitat (WWH) evaluation procedure.



Appendix C. Commands used to evaluate WWHs with ARC/INFO GIS.

```
/*Reclassed ME-NWI with GAP codes to MDIFW wetland types
/* Reprojected ME-NWI coverage to same datum as WWH2000
/*Dissolved ME-NWI coverage on wetland types
/*Intersected ME-NWI coverage with WWH polygons
TABLES
ADDITEM ME-NWI.PAT TYPE 35 35 C
SEL ME-NWI.PAT
RESEL GAP_INT = 14
ASEL GAP_INT = 15
ASEL GAP_INT = 16
MOVE ‘WOODED SWAMP’ TO TYPE
SEL ME-NWI.PAT
RESEL GAP_INT = 17
ASEL GAP_INT = 18
ASEL GAP_INT = 19
MOVE ‘SHRUB SWAMP’ TO TYPE
SEL ME-NWI.PAT
RESEL GAP_INT = 20
MOVE ‘INLAND DEEP FRESH MARSH’ TO TYPE
SEL ME-NWI.PAT
RESEL GAP_INT = 21
MOVE ‘INLAND SHALLOW FRESH MARSH’ TO TYPE
SEL ME-NWI.PAT
RESEL GAP_INT = 22
MOVE ‘BOG’ TO TYPE
SEL ME-NWI.PAT
RESEL GAP_INT = 23
MOVE ‘INLAND FRESH MEADOW’ TO TYPE
SEL ME-NWI.PAT
RESEL GAP_INT = 30
MOVE ‘INLAND SHALLOW OPEN FRESH WATER’ TO TYPE
SEL ME-NWI.PAT
RESEL GAP_INT = 31
MOVE ‘INLAND DEEP OPEN FRESH WATER’ TO TYPE
SEL ME-NWI.PAT
RESEL TYPE CN ‘WOODED SWAMP’
ASEL TYPE CN ‘SHRUB SWAMP’
ASEL TYPE CN ‘INLAND DEEP FRESH MARSH’
ASEL TYPE CN ‘INLAND SHALLOW FRESH MARSH’
ASEL TYPE CN ‘BOG’
ASEL TYPE CN ‘INLAND FRESH MEADOW’
ASEL TYPE CN ‘INLAND SHALLOW OPEN FRESH WATER’
ASEL TYPE CN ‘INLAND DEEP OPEN FRESH WATER’
NSEL
```

```
MOVE ‘NONE’ TO TYPE
Q

PROJECT COVER ME-NWI ME-NWI83
OUTPUT
PROJECTION UTM
ZONE 19
UNITS METERS
SPHEROID GRS1980
DATUM NAD83
PARAMETERS
END
BUILD ME-NWI83 POLY
TOLERANCE ME-NWI83 FUZZY 0.01

TOLERANCE WWH2000 FUZZY 0.01

DISSOLVE ME-NWI83 NWIRECLS TYPE POLY
TOLERANCE NWIRECLS FUZZY 0.01
IDENTITY WWH2000 NWIRECLS WWHTYPE POLY

/*Created WWH identifier.list:
TABLES
SEL WWH2000.PAT
RESEL IDENTIFIER = 999
ASEL IDENTIFIER = 0
NSEL
 UNLOAD IDENTIFIER.LIST IDENTIFIER
Q

/*Opened Identifier.list in editing program and make sure just one record for each
/*identifier.
/*Ran wwh.aml to evaluate WWH wetland type diversity, dominant type, size, 2nd
/*dominant type, and open /*water individually for each WWH (eliminates upland areas).
/*When completed, created info table from /*aml output, and joined to WWH2000.pat:
&RUN WWH.AML
/*For wwh.aml, see Appendix C.
TABLES
DEFINE DIVINFO
TYPE#
2
2
I
IDENTIFIER
6
6
```

```
I
~
SEL DIVINFO
ADD FROM DIV-TABLE
ADD
0
999
0
0
~
Q
JOINITEM WWH2000.PAT DIVINFO WWH2000.PAT IDENTIFIER

TABLES
ADDITEM WWH2000.PAT DIV_SCORE 1 1 I
SEL WWH2000.PAT
RESEL TYPE# LE 1
CALCULATE DIV_SCORE = 0
NSEL
RESEL TYPE# = 2
CALCULATE DIV_SCORE = 1
NSEL
RESEL TYPE# = 3
CALCULATE DIV_SCORE = 2
NSEL
RESEL TYPE# > 3
CALCULATE DIV_SCORE = 3

DEFINE DOMINFO
IDENTIFIER
6
6
I
DOM_TYPE
35
35
C
SUM-AREA
8
18
F
6
~
SEL DOMINFO
ADD FROM DOM-TABLE
ADD
```

```
0
NONE
0
999
NONE
0
~
Q
JOINITEM WWH2000.PAT DOMINFO WWH2000.PAT IDENTIFIER
TABLES
ADDITEM WWH2000.PAT DOM_SCORE 1 1 I
SEL WWH2000.PAT
RESEL DOM_TYPE CN ‘INLAND SHALLOW FRESH MARSH’
ASEL DOM_TYPE CN ‘INLAND DEEP FRESH MARSH’
CALCULATE DOM_SCORE = 6
NSEL
RESEL DOM_TYPE CN ‘INLAND SHALLOW OPEN FRESH WATER’
CALCULATE DOM_SCORE = 4
NSEL
RESEL DOM_TYPE CN ‘BOG’
ASEL DOM_TYPE CN ‘INLAND FRESH MEADOW’
ASEL DOM_TYPE CN ‘SHRUB SWAMP’
CALCULATE DOM_SCORE = 2
NSEL
RESEL DOM_TYPE CN ‘WOODED SWAMP’
ASEL DOM_TYPE CN ‘INLAND DEEP OPEN FRESH WATER’
ASEL DOM_TYPE CN ‘NONE’
CALCULATE DOM_SCORE = 0

DEFINE AREAINFO
IDENTIFIER
6
6
I
WWH_AREA
8
18
F
5
~
ADD FROM AREA-TABLE
ADD
0
0
999
0
```

```
~
Q
JOINITEM WWH2000.PAT AREAINFO WWH2000.PAT IDENTIFIER
TABLES
ADDITEM WWH2000.PAT AREA_SCORE 1 1 I
SEL WWH2000.PAT
RESEL WWH_AREA > 404700
CALCULATE AREA_SCORE = 3
NSEL
RESEL WWH_AREA > 40469
RESEL WWH_AREA < 404701
CALCULATE AREA_SCORE = 2
NSEL
RESEL WWH_AREA < 40470
CALCULATE AREA_SCORE = 1

/* Assigned ratings. Added diversity, dominance, and area score to determine rating:
ADDITEM WWH2000.PAT DDA_SCORE 2 2 I
SEL WWH2000.PAT
CALCULATE DDA_SCORE = DOM_SCORE + DIV_SCORE + AREA_SCORE
ADDITEM WWH2000.PAT HRATING 16 16 C
SEL WWH2000.PAT
RESEL DDA_SCORE > 9
MOVE ‘HIGH’ TO HRATING
NSEL
RESEL DDA_SCORE > 7
MOVE ‘MODERATE’ TO HRATING
NSEL
RESEL DDA_SCORE > 4
RESEL DDA_SCORE < 8
MOVE ‘INDETERMINATE’ TO HRATING
NSEL
RESEL DDA_SCORE < 5
MOVE ‘LOW’ TO HRATING

/* % Open Water Analysis
DEFINE OPWAT-INFO
IDENTIFIER
6
6
I
OPENWATER-AREA
8
18
F
5
```

```
~
SEL OPWAT-INFO
ADD FROM OPENWATER-TABLE
SEL OPWAT-INFO
SORT IDENTIFIER
Q

JOINITEM WWH2000.PAT OPWAT-INFO WWH2000.PAT IDENTIFIER

TABLES
ADDITEM WWH2000.PAT PEROPWAT 8 8 F 4
SEL WWH2000.PAT
CALCULATE PEROPWAT = OPENWATER-AREA / WWH_AREA

ADDITEM WWH2000.PAT HRATING2 16 16 C
SEL WWH2000.PAT
RESEL HRATING CN ‘INDETERMINATE’
NSEL
MOVE HRATING TO HRATING2
SEL WWH2000D.PAT
RESEL HRATING CN ‘INDETERMINATE’
RESEL PEROPWAT = 0
MOVE ‘LOW’ TO HRATING2

/*Pulled out WWHs with Indeterminate rankings and >0% open water for interspersion
/*analysis
/*Created text file listing Indeterminate WWH2000-ids with >0% openwater:
SEL WWH2000.PAT
RESEL HRATING CN ‘INDETERMINATE’
RESEL PEROPWAT > 0
UNLOAD INDETERMINATE.LIST IDENTIFIER DELIMITED

/*Created individual coverages of each Indeterminate WWH for analysis in
/*FRAGSTATS:
&RUN PREFRAG.AML
/* Prefrag.aml provided in Appendix D.
/*When completed, ran FRAGSTATS on all coverages:
&run /usr/people/heather/fragstats/pro/code/fs_batch run_job wwh_* TYPE METERS 'r'
# # # # # CLASS LANDSCAPE N Y
/*Combined all output tables into one:
DIR *LAND
/*Highlighted, copied, and saved with text editor as table.list.
/*Removed quotes from identifiers in fragresults
Q
&RUN FRAGTABLE.AML
/* Fragtable.aml provided in Appendix E.
```

```
TABLES
SEL WWH2000.PAT
RESEL HRATING2 CN 'INDETERMINATE'
NSEL
UNLOAD FRAGTABLE IDENTIFIER DELIMITED
DEFINE FRAGTABLE2
IDENTIFIER
6
6
I
~
SEL FRAGTABLE2
ADD FROM FRAGTABLE
ADDITEM FRAGTABLE2 IJI 8 8 N 2
ADDITEM FRAGTABLE2 TE_WGT 16 16 N 3
SEL FRAGTABLE2
UNLOAD FRAGRESULTS DELIMITED
DEFINE FRAGRESULTS2
IDENTIFIER
6
6
I
IJI
8
8
N
2
TE_WGT
16
16
N
3
~

SEL FRAGRESULTS2
ADD FROM FRAGRESULTS
Q
JOINITEM WWH2000.PAT FRAGRESULTS2 WWH2000.PAT IDENTIFIER

/* Reassigned ratings to Indeterminate WWHs:
ADDITEM WWH2000.PAT IJI*TE_WGT 16 16 N5
SEL WWH2000.PAT
CALCULATE IJI*TE_WGT = IJI * TE_WGT

/*Removed outliers (n = 15, IJI*TE_WGT > 1000000) and used ArcView to classify data
/*with Jenk's optimization method (natural breaks):
```

```
/*Category 1: 0-88859 (N = 637)
/*Category 2: 88860-358553 (N = 496)
/*Category 3: 358554 –1000000 (N = 87)

TABLES
ADDITEM WWH2000.PAT INT_CAT 1 1 I
SEL WWH2000.PAT
RESEL HRATING2 CN ‘INDETERMINATE’
RESEL IJI*TE_WGT < 88000
CALCULATE INT_CAT = 1
SEL WWH2000.PAT
RESEL HRATING2 CN ‘INDETERMINATE’
RESEL IJI*TE_WGT < 350000
RESEL IJI*TE_WGT > 88000
CALCULATE INT_CAT = 2
SEL WWH2000.PAT
RESEL HRATING2 CN ‘INDETERMINATE’
RESEL IJI*TE_WGT > 350000
CALCULATE INT_CAT = 3
ADDITEM WWH2000.PAT HRATING3 16 16 C
SEL WWH2000.PAT
RESEL HRATING2 CN ‘INDETERMINATE’
NSEL
MOVE HRATING2 TO HRATING3
SEL WWH2000.PAT
RESEL HRATING2 CN ‘INDETERMINATE’
RESEL INT_CAT = 1
RESEL PEROPWAT < 0.35
MOVE ‘LOW’ TO HRATING3
SEL WWH2000.PAT
RESEL HRATING2 CN ‘INDETERMINATE’
RESEL INT_CAT = 1
RESEL PEROPWAT GE 0.35
RESEL PEROPWAT LE 0.65
MOVE ‘MODERATE’ TO HRATING3
SEL WWH2000.PAT
RESEL HRATING2 CN ‘INDETERMINATE’
RESEL INT_CAT = 1
RESEL PEROPWAT > 0.65
MOVE ‘LOW’ TO HRATING3
SEL WWH2000.PAT
RESEL HRATING2 CN ‘INDETERMINATE’
RESEL INT_CAT = 2
MOVE ‘MODERATE’ TO HRATING3
SEL WWH2000.PAT
RESEL HRATING2 CN ‘INDETERMINATE’
```

```
RESEL INT_CAT = 3
RESEL PEROPWAT < 0.35
MOVE ‘MODERATE’ TO HRATING3
SEL WWH2000.PAT
RESEL HRATING2 CN ‘INDETERMINATE’
RESEL INT_CAT = 3
RESEL PEROPWAT GE 0.35
RESEL PEROPWAT LE 0.65
MOVE ‘HIGH’ TO HRATING3
SEL WWH2000.PAT
RESEL HRATING2 CN ‘INDETERMINATE’
RESEL INT_CAT = 3
RESEL PEROPWAT > 0.65
MOVE ‘MODERATE’ TO HRATING3

/* Incorporated 2nd dominant type:
DEFINE DOMINFO2
IDENTIFIER
6
6
I
DOMTYPE2
36
36
C
DOMTYPE2AREA
16
16
N
6
SEL DOMINFO2
ADD FROM DOM2-TABLE
SEL DOMINFO2
ADD
999
NONE
0
0
NONE
0
Q
JOINITEM WWH2000.PAT DOMINFO2 WWH2000.PAT IDENTIFIER
TABLES
ADDITEM WWH2000.PAT DOMTYPE2PER
SEL WWH2000.PAT
CALCULATE DOMTYPE2PER = DOMTYPE2AREA / WWH_AREA
```

```
ADDITEM WWH2000.PAT HRATING4 16 16 C
SEL WWH2000.PAT
RESEL DOMTYPE2 CN ‘INLAND DEEP FRESH MARSH’
ASEL DOMTYPE2 CN ‘INLAND SHALLOW FRESH MARSH’
ASEL DOMTYPE2 CN ‘INLAND SHALLOW OPEN FRESH WATER’
RESEL DOMTYPE2PER GE 0.2
RESEL HRATING3 CN ‘LOW’
MOVE ‘MODERATE’ TO HRATING4
```

Appendix D. Program used to automate WWH evaluation process. The program, called WWH.aml, is written in ARC Macro Language (AML) and evaluates dominant wetland type, habitat size, wetland type diversity, percent open water, and second dominant wetland type for each WWH listed in the text file identifier.list. The item 'sum-frequency' refers to wetland type diversity. The program creates 5 text files: div-table, dom-table, area-table, dom2-table, and openwater-table.

```
&echo &on
&sv listfile = identifier.list
&sv fileunit = [open %listfile% openstat -read]
Tables
&do &until %readstat% = 102
  &sv element = [read %fileunit% readstat]
  &if %readstat% eq 0 &then &do
    &end

sel wwhtype.pat
resel identifier = %element%
statistics type table_%element%
sum area
~
N
N
additem table_%element% identifier 6 6 I
sel table_%element%
calculate identifier = %element%
resel type cn 'none'
nsel
&s num = [show number select]
&if %num% = 0 &then &do
additem table_%element% sum-frequency 8 18 F 6
calculate sum-frequency = 0
calculate sum-area = 0
sel table_%element%
resel $RECNO = 1
unload area-table identifier sum-area delimited
unload div-table sum-frequency identifier delimited
unload dom-table identifier type sum-area delimited
unload dom2-table identifier type sum-area delimited
unload openwater-table identifier sum-area delimited
```

```
&end
&else &do

sel table_%element%
resel type cn 'none'
purge
y

statistics identifier table_%element%-4
sum sum-area
~
N
N
sel table_%element%-4
unload area-table identifier sum-sum-area delimited
&system arc joinitem table_%element% table_%element%-4 table_%element%-5
identifier
sel table_%element%-5
resel sum-area > 8094 or  sum-area / sum-sum-area  > 0.1
&s num2 = [show number select]
&if %num2% > 0 &then &do
sel table_%element%-5
resel sum-area > 8094 or  sum-area / sum-sum-area  > 0.1
nsel
purge
y

sel table_%element%
sort sum-area (D)
resel $RECNO = 1
unload dom-table identifier type sum-area delimited
sel table_%element%
sort sum-area (D)
resel $RECNO = 2
&s num = [show number select]
&if %num% > 0 &then &do
unload dom2-table identifier type sum-area delimited
&end
&else &do
define table_%element%-6
identifier 6 6 I
type 35 35 C
sum-area 8 18 F 6
~
sel table_%element%-6
add
```

```
%element%
none
0
~
sel table_%element%-6
unload dom2-table identifier type sum-area delimited
&end

sel table_%element%
resel type cn 'inland deep fresh marsh'
asel type cn 'inland shallow open fresh water'
asel type cn 'inland deep open fresh water'
&s num = [show number select]
&if %num% = 0 &then &do
additem table_%element% openwater-area 8 18 f 5
sel table_%element%
add
no-open
0
0
%element%
0
~
sel table_%element%
resel type cn 'no-open'
unload openwater-table identifier openwater-area delimited
&end
&else &do
statistics identifier opwat-table_%element%
sum sum-area
~
N
N

sel opwat-table_%element%
unload openwater-table identifier sum-sum-area delimited
&end

sel table_%element%-5
statistics type table_%element%-2
min frequency
~
N
N
sel table_%element%-2
statistics frequency table_%element%-3
```

```
sum frequency
~
N
N
additem table_%element%-3 identifier 6 6 I
dropitem table_%element%-3 frequency
sel table_%element%-3
calculate identifier = %element%
unload div-table sum-frequency identifier delimited
kill table_%element%* noprompt
kill opwat-table_%element%* noprompt

&end
&end
&end

&return
```

Appendix E. Program used to prepare indeterminate indeterminate WWHs for interspersion analysis. The program, written in ARC Macro Language (AML), and called Prefrag.aml, creates individual coverages of ‘indeterminate’ WWHs for use in FRAGSTATS interspersion analysis and requires a list of identifiers associated with the indeterminate WWHs (identifier.list).

```
&echo &on
&sv listfile = indeterminate.list
&sv fileunit = [open %listfile% openstat -read]
&do &until %readstat% = 102
  &sv element = [read %fileunit% readstat]
  &if %readstat% eq 0 &then &do
    &end

reselect wwhtype wwh_%element% poly
resel identifier = %element%
~
n
n

&end

&return
```

Appendix F. Program used to summarize interspersion analysis results. The program, written in ARC Macro Language (AML), and called Fragtable.aml, creates a single table of wetland interspersion metrics from individual tables created for each 'indeterminate' WWH by FRAGSTATS. Requires list of output tables from FRAGSTATS analysis (table.list).

```
&echo &on
&sv listfile = table.list
&sv fileunit = [open %listfile% openstat -read]
tables
&do &until %readstat% = 102
  &sv element = [read %fileunit% readstat]
  &if %readstat% eq 0 &then &do
    &end

sel %element%
unload fragresults LID IJI TE_WGT delimited
&end
&return
```

Appendix G. List of species used in comparison of wading bird and waterfowl habitat ratings with Maine Gap Analysis Program species occurrence predictions. Footnotes refer to species groupings used in the comparisons.

<u>Birds</u>
Common loon (*Gavia immer*)[c]
Pied-billed grebe (*Podilymbus podiceps*)[b,c]
American bittern (*Botaurus lentiginosus*)[a,b,c]
Least bittern (*Ixobrychus exilis*)[a,b,c]
Great blue heron (*Ardea herodias*)[a,b,c]
Snowy egret (*Egretta thula*)[a,b,c]
Little blue heron (*Egretta caerulea*)[a,b,c]
Cattle egret (*Bubulcus ibis*)[a,b,c]
Green heron (*Butorides virescens*)[c]
Black-crowned night-heron (*Nycticorax nycticorax*)[a,b,c]
Glossy ibis (*Plegadis falcinellus*)[a,b,c]
Canada goose (*Branta canadensis*)[a,b,c]
Wood duck (*Aix sponsa*)[a,b,c]
Green-winged teal (*Anas crecca*)[a,b,c]
Mallard (*Anas platyrhynchos*)[a,b,c]
American black duck (*Anas rubripes*)[a,b,c]
Blue-winged teal (*Anas discors*)[a,b,c]
American wigeon (*Anas americana*)[a,b,c]
Ring-necked duck (*Aythya collaris*)[a,b,c]
Common goldeneye (*Bucephala clangula*)[a,b,c]
Hooded merganser (*Lophodytes cucullatus*)[a,b,c]
Common merganser (*Mergus merganser*)[a,b,c]
Red-breasted merganser (*Mergus serrator*)[a,b,c]
Turkey vulture (*Cathrates aura*)[c]
Osprey (*Pandion haliaetus*)[b,c]
Bald eagle (*Haliaeetus leucocephalus*)[c]
Northern harrier (*Circus cyaneus*)[b,c]
Sharp-shinned hawk (*Accipiter striatus*)[c]
Cooper's hawk (*Accipiter cooperii*)[c]
Red-shouldered hawk (*Buteo lineatus*)[c]
Red-tailed hawk (*Buteo jamaicensis*)[c]
Golden eagle (*Aquila chrysaetos*)[c]
American kestrel (*Falco sparverius*)[c]
Merlin (*Falco columbarius*)[c]
Peregrine falcon (*Falco peregrinus*)[c]
Spruce grouse (*Falcipennis canadensis*)[c]
Ruffed grouse (*Bonasa umbellus*)[c]
Wild turkey (*Meleagris gallopavo*)[c]
Virginia rail (*Rallus limicola*)[a,b.c]

Sora (*Porzana carolina*)[a,b,c]
Yellow rail (*Coturnicops noveboracensis*)[a,b,c]
Common moorhen (*Gallinula chloropus*)[a,b,c]
American coot (*Fulica americana*)[a,b,c]
Killdeer (*Charadrius vociferus*)[c]
Spotted sandpiper (*Actitis macularia*)[c]
Upland sandpiper (*Bartramia longicauda*)[c]
Common snipe (*Gallinago gallinago*)[b,c]
American woodcock (*Scolopax minor*)[c]
Herring gull (*Larus argentatus*)[c]
Great black-backed gull (*Larus marinus*)[c]
Common tern (*Sterna hirundo*)[c]
Black tern (*Chilidonias niger*)[b,c]
Mourning dove (*Zenaida macroura*)[c]
Black-billed cuckoo (*Coccyzus erythropthalmus*)[c]
Yellow-billed cuckoo (*Coccyzus americanus*)[c]
Great horned owl (*Bubo virginianus*)[c]
Barred owl (*Strix varia*)[c]
Long-eared owl (*Asio otus*)[c]
Short-eared owl (*Asio flammeus*)[c]
Northern saw-whet owl (*Aegolius acadicus*)[c]
Common nighthawk (*Chordeiles minor*)[c]
Whip-poor-will (*Caprimulgus vociferus*)[c]
Chimney swift (*Chaetura pelagica*)[c]
Ruby-throated hummingbird (*Archilochus colubris*)[c]
Belted kingfisher (*Ceryle alcyon*)[c]
Yellow-bellied sapsucker (*Sphyrapicus varius*)[c]
Downy woodpecker (*Picoides pubescens*)[c]
Hairy woodpecker (*Picoides villosus*)[c]
Three-toed woodpecker (*Picoides tridactylus*)[c]
Black-backed woodpecker (*Picoides arcticus*)[c]
Northern flicker (*Colaptes auratus*)[c]
Pileated woodpecker (*Dryocopus pileatus*)[c]
Olive-sided flycatcher (*Contopus cooperi*)[c]
Eastern wood-pewee (*Contopus virens*)[c]
Yellow-bellied flycatcher (*Empidonax flaviventris*)[b,c]
Alder flycatcher (*Empidonax alnorum*)[b,c]
Willow flycatcher (*Empidonax traillii*)[c]
Least flycatcher (*Empidonax minimus*)[c]
Eastern phoebe (*Sayornis phoebe*)[c]
Great crested flycatcher (*Myiarchus crinitus*)[c]
Eastern kingbird (*Tyrannus tyrannus*)[c]
Purple martin (*Progne subis*)[c]
Tree swallow (*Tachycineta bicolor*)[c]
Northern rough-winged swallow (*Stelgidopteryx serripennis*)[c]
Bank swallow (*Riparia riparia*)[c]

Cliff swallow (*Petrochelidon pyrrhonota*)[c]
Barn swallow (*Hirundo rustica*)c
Gray jay (*Perisoreus canadensis*)[c]
Blue jay (*Cyanocitta cristata*)[c]
American crow (*Corvus brachyrhynchos*)[c]
Common raven (*Corvus corax*)[c]
Black-capped chickadee (*Parus atricapillus*)[c]
Boreal chickadee (*Parus hudsonicus*)[c]
Tufted titmouse (*Parus bicolor*)[c]
Red-breasted nuthatch (*Sitta candensis*)[c]
White-breasted nuthatch (*Sitta carolinensis*) [c]
Brown creeper (*Certhia americana*) [c]
House wren (*Troglodytes aedon*) [c]
Winter wren (*Troglodytes troglodytes*) [c]
Marsh wren (*Cistothorus palustris*)[b,c]
Sedge wren (*Cistothorus platensis*) [c]
Carolina wren (*Thryothorus ludovicianus*) [c]
Golden-crowned kinglet (*Regulus satrapa*) [c]
Ruby-crowned kinglet (*Regulus calendula*) [c]
Blue-gray gnatcatcher (*Polioptila caerulea*) [c]
Eastern bluebird (*Sialia sialis*) [c]
Veery (*Catharus fuscescens*) [c]
Swainson's thrush (*Catharus ustulatus*) [c]
Hermit thrush (*Catharus guttatus*) [c]
Wood thrush (*Hylocichla mustelina*) [c]
American robin (*Turdus migratorius*) [c]
Gray catbird (*Dumetella carolinensis*) [c]
Northern mockingbird (*Mimus polyglottus*) [c]
Brown thrasher (*Toxostoma rufum*) [c]
Cedar waxwing (*Bombycilla cedrorum*) [c]
Blue-headed vireo (*Vireo solitarius*) [c]
Yellow-throated vireo (*Vireo flavifrons*) [c]
Warbling vireo (*Vireo gilvus*) [c]
Philadelphia vireo (*Vireo philadelphicus*) [c]
Red-eyed vireo (*Vireo olivaceus*) [c]
Blue-winged warbler (*Vermivora pinus*) [c]
Tennessee warbler (*Vermivora peregrina*) [c]
Nashville warbler (*Vermivora ruficapilla*) [c]
Northern parula (*Parula americana*) [c]
Yellow warbler (*Dendroica petechia*) [c]
Chestnut-sided warbler (*Dendroica pensylvanica*) [c]
Magnolia warbler (*Dendroica magnolia*) [c]
Cape May warbler (*Dendroica tigrina*) [c]
Black-throated blue warbler (*Dendroica caerulescens*) [c]
Yellow-rumped warbler (*Dendroica coronata*) [c]
Black-throated green warbler (*Dendroica virens*) [c]

Blackburnian warbler (*Dendroica fusca*) [c]
Pine warbler (*Dendroica pinus*) [c]
Prairie warbler (*Dendroica discolor*) [c]
Palm warbler (*Dendroica palmarum*)[b,c]
Bay-breasted warbler (*Dendroica castanea*) [c]
Blackpoll warbler (*Dendroica striata*) [c]
Black-and-white warbler (*Mniotilta varia*) [c]
American redstart (*Setophaga ruticilla*) [c]
Ovenbird (*Seiurus aurocapillus*) [c]
Northern waterthrush (*Seiurus noveboracensis*)[b,c]
Louisiana waterthrush (*Seiurus motacilla*) [c]
Mourning warbler (*Oporornis philadelphia*) [c]
Common yellowthroat (*Geothlypis trichas*) [c]
Wilson's warbler (*Wilsonia pusilla*) [c]
Canada warbler (*Wilsonia canadensis*) [c]
Scarlet tanager (*Piranga olivacea*) [c]
Northern cardinal (*Cardinalis cardinalis*) [c]
Rose-breasted grosbeak (*Pheucticus ludovicianus*) [c]
Indigo bunting (*Passerina cyanea*) [c]
Chipping sparrow (*Spizella passerina*) [c]
Vesper sparrow (*Pooecetes gramineus*) [c]
Savannah sparrow (*Passerculus sandwichensis*) [c]
Saltmarsh sharp-tailed sparrow (*Ammodramys caudacutus*) [c]
Nelson's sharp-tailed sparrow (*Ammodramus nelsoni*) [c]
Fox sparrow (*Passerella iliaca*) [c]
Song sparrow (*Melospiza melodia*) [c]
Lincoln's sparrow (*Melospiza lincolnii*) [c]
Swamp sparrow (*Melospiza georgiana*)[b,c]
White-throated sparrow (*Zonotrichia albicollis*) [c]
Dark-eyed junco (*Junco hyemalis*) [c]
Bobolink (*Dolichonyx oryzivorus*) [c]
Red-winged blackbird (*Agelaius phoeniceus*)[b,c]
Eastern meadowlark (*Sturnella magna*) [c]
Rusty blackbird (*Euphagus carolinus*)[b,c]
Common grackle (*Quiscalus quiscala*) [c]
Brown-headed cowbird (*Molothrus ater*) [c]
Baltimore oriole (*Icterus galbula*) [c]
Pine grosbeak (*Pinicola enucleator*) [c]
Purple finch (*Carpodacus purpureus*) [c]
Red crossbill (*Loxia curvirostra*) [c]
White-winged crossbill (*Loxia leucoptera*) [c]
Pine siskin (*Carduelis pinus*) [c]
American goldfinch (*Carduelis tristis*) [c]
Evening grosbeak (*Coccothraustes vespertinus*) [c]

Amphibians and Reptiles
Blue spotted salamander (*Ambystoma laterale*)[b,c]
Spotted salamander (*Ambystoma maculatum*)[b,c]
Eastern newt (*Notophthalmus viridescens*)[b,c]
Northern dusky salamander (*Desmognathus fuscus*) [c]
Northern two-lined salamander (*Eurycea bislineata*) [c]
Spring salamander (*Gyrinophilus porphyriticus*)[b,c]
Four-toed salamander (*Hemidactylium scutatum*)[b,c]
American toad (*Bufo americanus*)[b,c]
Gray treefrog (*Hyla versicolor*)[b,c]
Spring peeper (*Pseudacris crucifer*)[b,c]
Bullfrog (*Rana catesbeiana*)[b,c]
Green frog (*Rana clamitans*)[b,c]
Pickerel frog (*Rana palustris*)[b,c]
Northern leopard frog (*Rana pipiens*)[b,c]
Mink frog (*Rana septentrionalis*)[b,c]
Wood frog (*Rana sylvatica*)[b,c]
Common snapping turtle (*Chelydra serpentina*)[b,c]
Common musk turtle (*Sternotherus odoratus*)[b,c]
Painted turtle (*Chrysemys picta*)[b,c]
Spotted turtle (*Clemmys guttata*)[b,c]
Wood turtle (*Clemmys insculpta*)[b,c]
Blanding's turtle (*Emydoidea blandingii*)[b,c]
Eastern box turtle (*Terrapene carolina*)[b,c]
Racer (*Coluber constrictor*) [c]
Milk snake (*Lampropeltis triangulum*) [c]
Northern water snake (*Nerodia sipedon*)[b,c]
Smooth green snake (*Liochlorophis vernalis*) [c]
Brown snake (*Storeria dekayi*) [c]
Redbelly snake (*Storeria occipitomaculata*) [c]
Eastern ribbon snake (*Thamnophis sauritus*)[b,c]
Common garter snake (*Thamnophis sirtalis*) [c]

Mammals
Virginia opossum (*Didelphis virginiana*) [c]
Masked shrew (*Sorex cinereus*) [c]
Water shrew (*Sorex palustris*)[b,c]
Smoky shrew (*Sorex fumeus*) [c]
Long-tailed shrew (*Sorex dispar*) [c]
Pygmy shrew (*Sorex hoyi*)[b,c]
Northern short-tailed shrew (*Blarina brevicauda*) [c]
Star-nosed mole (*Condylura cristata*)[b,c]
Little brown myotis (*Myotis lucifugus*) [c]
Northern myotis (*Myotis septentrionalis*) [c]
Eastern small-footed myotis (*Myotis leibii*) [c]
Silver-haired bat (*Lasionycteris noctivagans*)[b,c]

Eastern pipistrelle (*Pipistrellus subflavus*)[b,c]
Big brown bat (*Eptesicus fuscus*) [c]
Eastern red bat (*Lasiurus borealis*)[c]
Hoary bat (*Lasiurus cinereus*) [c]
New England cottontail (*Sylvilagus transitionalis*) [c]
Snowshoe hare (*Lepus americanus*) [c]
Eastern gray squirrel (*Sciurus carolinensis*) [c]
Red squirrel (*Tamiasciurus hudsonicus*) [c]
Southern flying squirrel (*Glaucomys volans*) [c]
Northern flying squirrel (*Glaucomys sabrinus*) [c]
American beaver (*Castor candensis*)[b,c]
Deer mouse (*Peromyscus maniculatus*) [c]
White-footed mouse (*Peromyscus leucopus*) [c]
Southern red-backed vole (*Clethrionomys gapperi*) [c]
Meadow vole (*Microtus pennsylvanicus*) [c]
Rock vole (*Microtus chrotorrhinus*) [c]
Woodland vole (*Microtus pinetorum*) [c]
Muskrat (*Ondatra zibethicus*) [b,c]
Southern bog lemming (*Synaptomys cooperi*) [b,c]
Northern bog lemming (*Synaptomys borealis*) [b,c]
Meadow jumping mouse (*Zapus hudsonius*) [c]
Woodland jumping mouse (*Napaeozapus insignis*) [c]
Common porcupine (*Erethizon dorsatum*) [c]
Coyote (*Canis latrans*) [c]
Red fox (*Vulpes vulpes*) [c]
Common gray fox (*Urocyon cinereoargenteus*) [c]
Black bear (*Ursus americanus*) [c]
Common raccoon (*Procyon lotor*) [b,c]
American marten (*Martes americana*) [c]
Fisher (*Martes pennanti*) [c]
Ermine (*Mustela erminea*) [c]
Long-tailed weasel (*Mustela frenata*) [c]
Mink (*Mustela vison*) [b,c]
Striped skunk (*Mephitis mephitis*) [c]
Northern river otter (*Lutra canadensis*)b,c
Lynx (*Lynx canadensis*) [c]
Bobcat (*Lynx rufus*) [c]
White-tailed deer (*Odocoileus virginianus*) [c]
Moose (*Alces alces*) [b,c]

[a]Species included in wading birds and waterfowl analysis.
[b]Species included in wetland-associated non-fish vertebrates analysis.
[c]Species included in wetland-using non-fish vertebrates analysis.