

1 APPENDIX

2 Appendix 1. Supplementary material on the variables examined, region-specific results, and
 3 studies included in the meta-analysis.

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 5 **Table A1.** Landscape habitat variables examined for associations with marsh birds in the
 6 Mississippi Flyway and the specific metrics used across studies that were grouped for meta-
 7 analyses.

Habitat variable	Study
Amount of agriculture	
Percent cover cultivated land	Hay and Manseau 2007
Percent cover agriculture	Valente et al. 2011, Martin 2012, Tozer 2016, Harms et al. 2017, Saunders et al. 2019, Tozer et al. 2020
Patch density of agriculture	Harms et al. 2017
Cropland area	Prairie Habitat Joint Venture 2014
Amount of wetlands	
Percent cover marsh	Hay and Manseau 2007, Smith-Cartwright and Chow-Fraser 2012, Tozer et al. 2020
Percent cover wet meadow	Hay and Manseau 2007, Hansen 2019
Percent cover emergent wetland	Scott 2010, Monfils and Corace 2018, Saunders et al. 2019
Percent cover wetland	Budd and Kremenz 2010, Kahler 2013, Glisson et al. 2015, Tozer 2016, Harms et al. 2017
Area of wetland habitat	Harms and Dinsmore 2013, Prairie Habitat Joint Venture 2014, Tozer 2016
Percent cover marsh/fen	Martin 2012
Wetland count	Prairie Habitat Joint Venture 2014
Wetland density	Mushanski 2015
Amount of forest	
Percent cover forest	Budd and Kremenz 2010, Smith-Cartwright and Chow-Fraser 2012, Kahler 2013, Glisson et al. 2015, Tozer et al. 2020
Percent cover mixed wood forest	Martin 2012
Amount of open water	
Percent cover open water	Winstead and King 2006, Scott 2010, Bolenbaugh et al. 2011, Harms and Dinsmore 2013, Glisson et al. 2015, Hill Chpt 2 2015, Tozer 2016, Monfils and Corace 2018
Percent cover water	Hay and Manseau 2007, Clark-Schubert 2009, Valente et al. 2011, Harms et al. 2017, Hansen 2019,
Area open water	Moore 2000
Percent aquatic bed/open water wetland	Kahler 2013
Largest patch index of water	Harms et al. 2017
Water area	Prairie Habitat Joint Venture 2014
Amount of urban	

Percent cover urban	Smith-Cartwright and Chow-Fraser 2012, Tozer 2016, Tozer et al. 2020
Percent cover development	Saunders et al. 2019
Percent cover developed (low-intensity)	Monfils and Corace 2018
Area of urban, road, built- up, or barrenland	Prairie Habitat Joint Venture 2014

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10 **Table A2.** Local scale habitat variables examined for associations with marsh birds in the
 11 Mississippi Flyway and the specific metrics used across studies that were grouped for meta-
 12 analyses.
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Habitat variable	Study
Wetland Size	
Wetland size	Chandler and Weiss 1995, Tozer et al. 2010, Smith-Cartwright and Chow-Fraser 2012, Harms and Dinsmore 2013, Mushanski 2015, Tozer 2016
Interspersion	
Interspersion of water and vegetation	Darrah and Krementz 2009, Bolenbaugh et al. 2011
Edge density of wetland	Harms et al. 2017
Edge density of water	Harms et al. 2017
Percent cover interspersion	Darrah and Krementz 2010
Robust emergent vegetation edge	Moore 2000
Edge index	Moore 2000
Open water edge	Moore 2000
Soil-water interface	Clark-Schubert 2009
Vegetation interface	Clark-Schubert 2009
Water Depth	
Water depth	Johnson and Dinsmore 1986, Reid 1989, Clark-Schubert 2009, Tozer et al. 2010, Darrah and Krementz 2011, Martin 2012, Austin and Buhl 2013, Harms and Dinsmore 2013, Hill Chpt 1 2015, Hill Chpt 2 2015, Fournier 2017, Monfils and Corace 2018, Hansen 2019
Water depth in cover	Moore 2000
Vegetation Height	
Vegetation height	Johnson and Dinsmore 1986, Clark-Schubert 2009, Martin 2012, Hill Chpt 1 2015, Hill Chpt 2 2015,
Maximum vegetation height	Martin 2012, Harms and Dinsmore 2013, Monfils and Corace 2018
Non-woody emergent vegetation	
Robust	
Area robust emergent cover	Moore 2000
Percent cover cattails and bulrush	Mushanski 2015
Percent cover persistent deep-water emergents	Monfils and Corace 2018,
Percent cover persistent shallow-water emergents	Monfils and Corace 2018,
Percent cover persistent vegetation	Hansen 2019
Percent cover persistent emergent vegetation	Blake-Bradshaw 2018

Percent cover robust emergent vegetation	Valente et al. 2011
Percent cover bulrush	
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<i>Typha</i>	
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Percent cover <i>Typha spp</i>	Chandler and Weiss 1995, Moore 2000, Kirk et al. 2001, Hay and Manseau 2007, Brittain and Thieme 2011, Martin 2012, Harms and Dinsmore 2013, Glisson et al. 2015, Hansen 2019
<i>Typha spp</i> stems	Brittain and Thieme 2011
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Non-robust	
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Percent cover non-robust short emergent vegetation < 0.75m	Valente et al. 2011
Percent cover non-robust tall emergent vegetation > 0.75m	Valente et al. 2011
Percent cover non-persistent vegetation (non-woody)	Hansen 2019
Percent cover annual moist soil vegetation	Fournier 2017
Percent cover non-persistent emergent vegetation	Blake-Bradshaw 2018
Percent cover perennial moist soil vegetation	Fournier 2017
Percent cover <i>Polygonum spp.</i>	Clark-Schubert 2009
Percent cover <i>Echinochloa spp.</i>	Clark-Schubert 2009
Percent cover <i>Eleocharis spp.</i>	Clark-Schubert 2009
Percent cover <i>Phalaris spp.</i>	Glisson et al. 2015
Percent cover <i>Carex spp.</i>	Monfils and Corace 2018
Percent cover grass/weeds	Valente et al. 2011
Percent cover sedge-bluejoint grass	Austin and Buhl 2013
Percent cover non-persistent shallow-water emergents	Monfils and Corace 2018
Percent cover sedge	Brittain and Thieme 2011, Harms and Dinsmore 2013
Sedge stems	Brittain and Thieme 2011
Herb stems	Brittain and Thieme 2011
Percent cover grass	Kirk et al. 2001, Brittain and Thieme 2011
Percent cover forbs	Martin 2012
Grass stems	Brittain and Thieme 2011
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Emergent vegetation (non-specific)	
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Percent cover emergent herbaceous wetland	Scott 2010
Percent cover emergent herbaceous vegetation	Glisson et al. 2015, Tozer 2016
Percent cover other emergents	Winstead and King 2006
Percent cover short emergent (<1m)	Darrah and Krementz 2009

Percent cover tall emergent (>1m)	Darrah and Krementz 2009, Darrah and Krementz 2010
Percent cover emergent vegetation	Kirk et al. 2001, Hill Chpt 2 2015,
Proportion rank emergent vegetation (<i>Typha</i> , <i>Carex</i> , <i>Juncus</i> , <i>Schoenoplectus</i>)	Budd and Krementz 2010
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Woody emergent vegetation	
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Shrubs	
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Percent cover trees/shrubs	Kirk et al. 2001, Tozer 2016
Proportion cover scrub/shrub wetland	Monfils and Corace 2018
Percent cover trees <3m	Valente et al. 2011
Percent cover shrubs	Martin 2012
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Non-specific	
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Percent cover woody vegetation	Winstead and King 2006, Darrah and Krementz 2009, Darrah and Krementz 2010, Bolenbaugh et al. 2011, Brittain and Thieme 2011, Harms and Dinsmore 2013, Monfils and Corace 2018, Hansen 2019
Woody stems	Brittain and Thieme 2011
Woody wetland area	Bolenbaugh et al. 2011
Proportion forested wetland	Monfils and Corace 2018
Percent cover woody wetland	Bolenbaugh et al. 2012
Percent cover lowland woody	Austin and Buhl 2013
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15 **Table A3. Great Lakes region:** Summary effect sizes for the relationships of habitat to secretive marsh birds in the Great Lakes
 16 region. Asterisks indicate statistically significant mean effect sizes (95% confidence intervals did not overlap 0). Values are not
 17 reported when there were < 3 studies for a variable or species. Species codes are AMBI = American Bittern, LEBI = Least Bittern,
 18 SORA = Sora, VIRA = Virginia Rail. I^2 indicates the percent of variability in mean effect size estimates of a habitat variable that is
 19 due to heterogeneity rather than sampling error.

Habitat variable	Number of		Mean effect size	I^2	Mean effect size for species			
	Effect sizes	Studies			AMBI	LEBI	SORA	VIRA
Agriculture	36	2	-	-	-	-	-	-
Forest	47	4	-0.041* (-0.077; -0.004)	71.3%	-0.12* (-0.164; -0.076)	-0.053 (-0.152; 0.048)	-0.079* (-0.105; -0.052)	0.08* (0.03; 0.129)
Wetland	64	8	0.147* (0.112; 0.181)	78.0%	0.183* (0.13; 0.235)	0.205* (0.069; 0.334)	0.151* (0.108; 0.193)	0.059* (0.02; 0.098)
Urban	39	4	-0.162* (-0.225; -0.098)	86.7%	-0.409* (-0.546; -0.25)	-0.037* (-0.072; -0.003)	-0.078* (-0.092; -0.064)	-0.123* (-0.147; -0.1)
Open water	21	5	-0.02 (-0.102; 0.064)	88.3%	0.0080 (-0.080; 0.095)	-	-0.006 (-0.254; 0.243)	-0.132 (-0.347; 0.097)
Wetland size	12	4	0.194* (0.077; 0.306)	92.0%	-	0.265* (0.171; 0.355)	0.175 (-0.156; 0.47)	0.161 (-0.237; 0.513)
Interspersion	0	0	-	-	-	-	-	-
Water depth	13	5	0.333* (0.076; 0.549)	91.5%	-	-	0.446 (-0.376; 0.875)	0.104 (-0.302; 0.478)
Vegetation height	5	2	-	-	-	-	-	-
Non-woody emergent veg.	40	7	0.106 (-0.024; 0.233)	91.7%	0.102 (-0.085; 0.281)	0.273 (-0.188; 0.635)	0.139 (-0.064; 0.331)	0.111 (-0.03; 0.248)
Robust emergent veg.	18	5	0.1 (-0.179; 0.365)	93.5%	-	-	0.255 (-0.217; 0.63)	0.167 (-0.067; 0.383)
Typha	9	4	0.217* (0.128; 0.303)	40.8%	-	-	0.136 (-0.057; 0.32)	0.31* (0.132; 0.469)
Non-robust emergent veg.	13	5	0.016 (-0.134; 0.165)	83.6%	-	-	0.0001 (-0.273; 0.273)	-
Emergent veg. (non-specific)	9	3	0.18* (0.087; 0.27)	82.9%	0.281 (-0.294; 0.707)	-	-	0.216* (0.115; 0.312)
Wetland woody veg.	21	5	-0.208 (-0.466; 0.082)	95.4%	-0.12 (-0.29; 0.057)	0.274 (-0.949; 0.983)	-0.473 (-0.921; 0.515)	-0.146 (-0.409; 0.134)
Shrubs	13	3	-0.111* (-0.166; -0.054)	89.5%	-0.132 (-0.336; 0.084)	-	-0.079 (-0.174; 0.017)	-
Wetland woody veg. (non-specific)	11	3	-0.302 (-0.727; 0.29)	96.9%	-	-	-	-

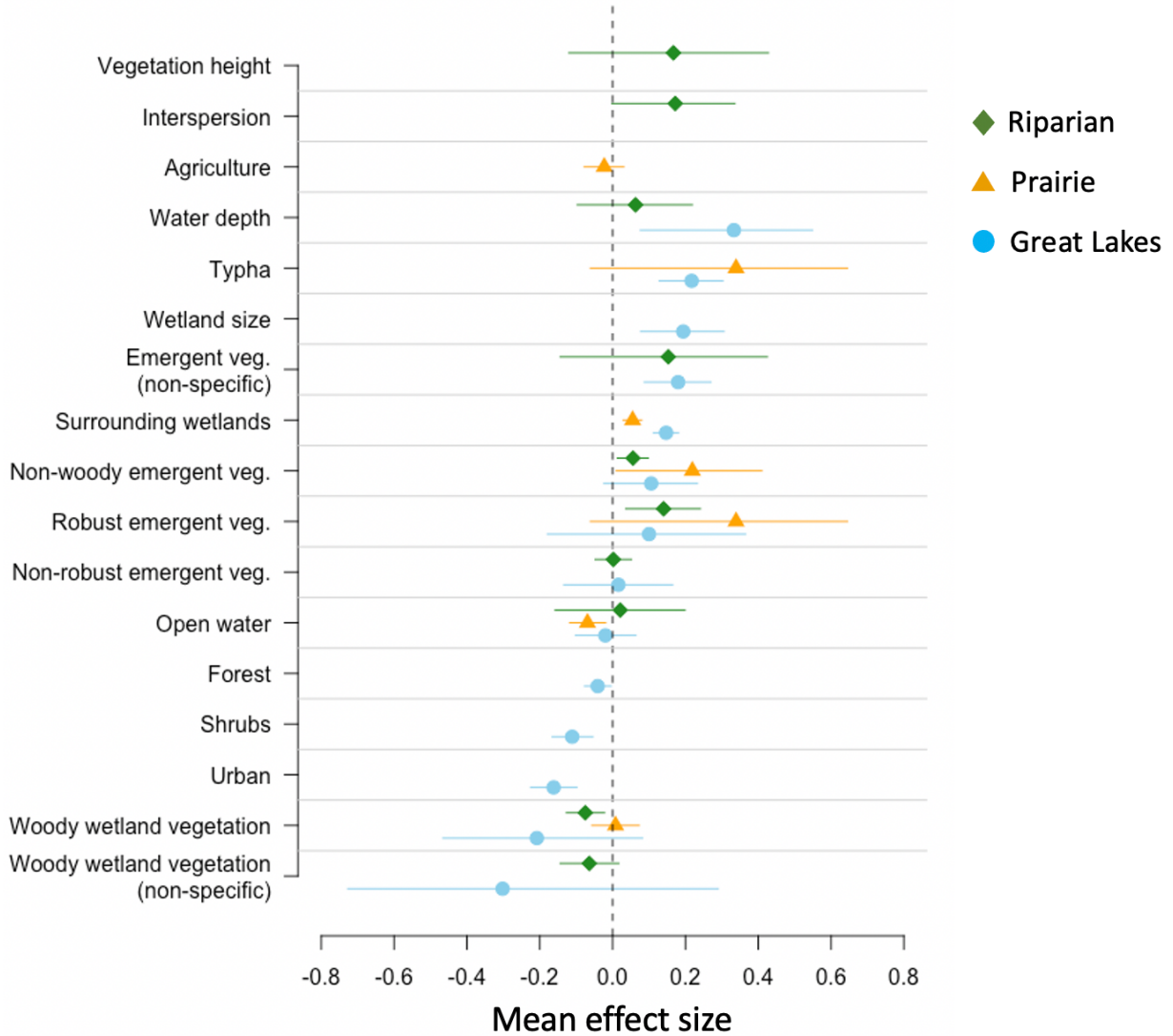
20 **Table A4. Prairie region.** Summary effect sizes for the relationships of habitat to secretive marsh birds in the Prairie region.
 21 Asterisks indicate statistically significant mean effect sizes (95% confidence intervals did not overlap 0). Values are not reported when
 22 there were < 3 studies for a variable and species. Species codes are AMBI = American Bittern, LEBI = Least Bittern, SORA = Sora,
 23 VIRA = Virginia Rail. I^2 indicates the percent of variability in mean effect size estimates of a habitat variable that is due to
 24 heterogeneity rather than sampling error.

Habitat variable	Number of		Mean effect size	I^2	Mean effect size for species			
	Effect sizes	Studies			AMBI	LEBI	SORA	VIRA
Agriculture (percent cover)	31	5	-0.023 (-0.078; 0.031)	89.7%	-0.17* (-0.225; -0.113)	-	0.122* (0.055; 0.188)	0.0004 (-0.093; 0.094)
Forest (percent cover)	1	1	-	-	-	-	-	-
Wetland (percent cover)	50	7	0.055* (0.029; 0.08)	61.9%	0.076* (0.013; 0.139)	-	0.077* (0.044; 0.110)	0.036 (-0.007; 0.079)
Urban (percent cover)	18	2	-	-	-	-	-	-
Open water (percent cover)	26	4	-0.069* (-0.118; -0.019)	93.6%	0.007 (-0.031; 0.044)	-	-	-0.063 (-0.196; 0.072)
Wetland size	3	2	-	-	-	-	-	-
Interspersion	5	1	-	-	-	-	-	-
Water depth	4	2	-	-	-	-	-	-
Vegetation height	4	2	-	-	-	-	-	-
Non-woody emergent veg. (percent cover)	17	4	0.219* (0.01; 0.41)	95.9%	-	-	-	-
Robust emergent veg.	9	4	0.339 (-0.061; 0.645)	97.5%	-	-	-	-
Typha	9	4	0.339 (-0.061; 0.645)	97.5%	-	-	-	-
Non-robust emergent veg.	4	2	-	-	-	-	-	-
Emergent veg. (non-specific)	0	0	-	-	-	-	-	-
Wetland woody veg. (percent cover)	6	3	0.008 (-0.057; 0.073)	0%	-	-	-	-
Shrubs	2	1	-	-	-	-	-	-
Wetland woody veg. (non-specific)	2	1	-	-	-	-	-	-

26 **Table A5. Riparian region.** Summary effect sizes for the relationships of habitat to secretive marsh birds in the Great Lakes region.
 27 Asterisks indicate statistically significant mean effect sizes (95% confidence intervals did not overlap 0). Values are not reported when
 28 there were < 3 studies for a variable or species. Species codes are AMBI = American Bittern, LEBI = Least Bittern, SORA = Sora,
 29 VIRA = Virginia Rail. I^2 indicates the percent of variability in mean effect size estimates of a habitat variable that is due to
 30 heterogeneity rather than sampling error.

Habitat variable	Number of		Mean effect size	I^2	Mean effect size for species			
	Effect sizes	Studies			AMBI	LEBI	SORA	VIRA
Agriculture (percent cover)	3	1	-	-	-	-	-	-
Forest (percent cover)	1	1	-	-	-	-	-	-
Wetland (percent cover)	2	2	-	-	-	-	-	-
Urban (percent cover)	0	0	-	-	-	-	-	-
Open water (percent cover)	8	6	0.021 (-0.158; 0.199)	66.6%	-	-0.031 (-0.259; 0.199)	-	-
Wetland size	0	0	-	-	-	-	-	-
Interspersion	7	4	0.172 (-0.002; 0.336)	75.5%	-	-	-	-
Water depth	9	5	0.063 (-0.097; 0.219)	96.7%	-	-	0.174 (-0.424; 0.666)	-
Vegetation height	7	3	0.167 (-0.12; 0.428)	92.0%	-	-	-	-
Non-woody emergent veg. (percent cover)	66	13	0.056* (0.013; 0.098)			0.036 (-0.086; 0.157)	0.084* (0.003; 0.165)	
Robust emergent veg.	14	4	0.14* (0.036; 0.241)	57.7%	-	0.243 (-0.111; 0.542)		
Typha	11	2	-	-	-	-	-	-
Non-robust emergent veg.	38	5	0.002 (-0.048; 0.052)	85.7%	-	-	0.058 (-0.045; 0.159)	-
Emergent veg. (non-specific)	5	4	0.153 (-0.144; 0.425)	63.9%	-	0.098 (-0.182; 0.363)	-	-
Wetland woody veg. (percent cover)	38	8	-0.075* (-0.127; -0.022)	57.5%	-	-0.05 (-0.104; 0.003)	-0.211* (-0.353; -0.061)	-
Shrubs	1	1	-	-	-	-	-	-
Wetland woody veg.	14	5	-0.064 (-0.144; 0.017)	49.9%	-	-0.085 (-0.218; 0.051)	-	-

32 **Figure A1.** Mean effect sizes (Fisher's z) representing the association of secretive marsh birds
 33 with 17 habitat variables based on meta-analysis of studies conducted within three regions
 34 (Riparian, Prairie, and Great Lakes) in the Mississippi Flyway. Lines around the mean represent
 35 95% confidence intervals.
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39 **Reference A1.** Bibliography of studies used in the meta-analysis on secretive marsh
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