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Landbird Population Trends at Isle Royale National Park, Michigan

1996-2012

Natural Resource Technical Report NPS/GLKN/NRTR—2013/692

ON THE COVER
White-throated Sparrow, *Zonotrichia albicollis*. Photo by Paul Brown.

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Alexander T. Egan

Department of Entomology
University of Minnesota
219 Hodson Hall; 1980 Folwell Ave
St. Paul, Minnesota 55108

Theodore J. Gostomski

National Park Service
Great Lakes Inventory and Monitoring Network
2800 Lakeshore Drive East
Ashland, Wisconsin 54806

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Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols. This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

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Abstract

Standardized landbird monitoring has been conducted on Isle Royale since 1996 and was incorporated into a multi-park landbird monitoring protocol coordinated by the National Park Service Great Lakes Inventory and Monitoring Network in 2010. Data are collected annually during the month of June by conducting counts at 130 points distributed along eight transects (hiking trails).

Isle Royale's landbird survey objectives are: 1) to determine the size and composition of the neotropical (long-distance) migrant, continental (short-distance) migrant, and resident landbird communities; 2) to make general comparisons between years so as to identify potential and real trends; and 3) to compare the status of the island bird population with other regional populations. Objective 3 is accomplished through the Great Lakes Inventory and Monitoring Network.

This report presents analyses of point count data collected on Isle Royale from 1996 through 2012. An annual average of 1,457 individuals representing 89 landbird species was recorded during the 17-year period. Using least squares regression, 47 species (52%) had increasing trends, of which twelve were significant, while 24 species (27%) had decreasing trends, of which nine were significant. Of the declining species, only the common raven and chipping sparrow were detected in all thirteen years. We explore the potential causes for the decline of ravens, which is an anomaly compared to the species' trends in the state and region.

The Simpson Index of Diversity values for most transects were 0.94–0.95 with a low standard deviation (0.01 on six of the eight routes). Windigo had a lower mean (0.89) and slightly higher standard deviation (0.02) and Passage Island had a much lower mean (0.85) and much higher standard deviation (0.10).

The remoteness of Isle Royale protects it from many negative influences (e.g., land development, fragmentation), but climate change will likely exert a greater influence on island bird populations both indirectly (via changes to wintering and migratory stopover sites) and directly in the future. We suggest an in-depth study of raven ecology and population dynamics, and incorporating correspondence analysis into future analyses of landbird monitoring data to see how diet, habitat, or other key factors may influence population variations.

Acknowledgments

Thanks in particular to Candy and Rolf Peterson for annual completion since the surveys began of the Mt. Ojibway and Three Mile-to-Lane Cove routes, and to Betsy Bartelt and Kristi Link for regular assistance in the past with the Chippewa Harbor-to-Lake Richie and Passage Island routes. Thanks also to the many seasonal park staff and volunteers who helped as data recorders over the years. We are grateful to Matt Etterson, Katie Koch, and Beth Rigby who reviewed and made substantive comments on an earlier draft of this report.

Introduction

Birds are arguably the most visible wildlife to those visiting the national parks. Their ubiquity, songs, and relative ease of identification make birds especially popular with one-in-every-four American adults who identify themselves as a bird watcher (North American Bird Conservation Initiative 2009).

Public lands play an important role in bird conservation because of the habitats they contain. The North American Bird Conservation Initiative (NABCI) noted that 50% or more of the U.S. distribution for more than 300 bird species occur on public lands and waters (NABCI 2011). Further, among federal agencies, National Park Service lands provide habitat for the highest percentage of the U.S. distribution of at least 39 breeding bird species (NABCI 2011). Accordingly, landbird monitoring is used by many land management agencies and organizations as a means of tracking bird population trends (Ralph et al. 1995, Hutto and Ralph 2005), and some songbirds are used as indicators of change in particular habitats or plant communities (Hutto 2005, Hannon and Drapeau 2005). The Midwest Coordinated Bird Monitoring Partnership lists nearly 80 active landbird monitoring programs across eight Midwestern states (MCBMP 2012), including the programs in the Great Lakes Network (GLKN) national parks. Matteson et al. (2009) identified Isle Royale National Park as one of 22 sites in the upper Great Lakes region that provides an outstanding opportunity for implementing bird conservation measures, including the establishment of Forest Bird Conservation Areas or Forest Bird Management Areas.

Bird Studies and Monitoring on Isle Royale

Isle Royale's bird populations have been the focus of numerous studies for more than a century. Four of the earliest reports are contained in Adams (1909), and checklists have been produced by Janke (1964), Krefting et al. (1966), Johnsson et al. (1981), and Janke et al. (1994). Broader scale documentation was made by Martin (1989), Van Buskirk and Smith (1994), and Gostomski (1996). Studies attempting to detect all species breeding on the island were made during two state-wide atlas surveys (Brewer et al. 1991, Breeding Bird Atlas Explorer 2012). The most recent atlas, utilizing data collected from 2002–2008, recorded 144 species on the island during the breeding season; breeding activity was confirmed for 79 of those species (Breeding Bird Atlas Explorer 2012), and another 44 species were likely to be breeding (Egan, unpublished data).

Isle Royale National Park established a formal breeding bird survey in 1994 (Gostomski and Oelfke 1994), utilizing a 10-minute point count protocol (Ralph et al. 1993) at 83 points distributed along six park trails (transects). In 1996, all the survey points were permanently tagged, ensuring that observers sampled the same locations annually (Beeman and Oelfke 1996). Also, based on the pilot work in 1994 and 1995, the point count duration was reduced to five minutes and the sample size was increased to 130 points distributed along eight transects (trails).

Isle Royale's landbird survey objectives are: 1) to determine the size and composition of the neotropical (long-distance) migrant, continental (short-distance) migrant, and resident landbird communities; 2) to make general comparisons between years so as to identify trends; and 3) to compare the status of the island bird population with other regional populations. Annual analyses include data collected from 1996 to the current year.

Egan (2009) provided the first in-depth analysis of the park's formal monitoring data for the years 1996–2008. At that time, he reported significant ($p \leq 0.05$) declining trends for 8 species and increasing trends for 10 species. Island trends were consistent with those reported by other studies in the region, except for three species that were declining regionally but increasing on the island (song sparrow, Wilson's snipe, and alder flycatcher), and one species that was increasing regionally but declining on the island (common raven). This report updates Egan's previous analyses to include data collected from 2009 through 2012.

Study Area

Isle Royale National Park (Keweenaw County, Michigan, USA) is an archipelago in northwestern Lake Superior consisting of one main island surrounded by several hundred smaller islands. The archipelago is located approximately 100 km (60 mi) north of Houghton, Michigan, and approximately 32 km (20 mi) east of Grand Portage, Minnesota (Figure 1). The park encompasses 544 km^2 (210 mi^2) of land, but the park boundary extends out four miles from shore, making the total park area 2,200 km^2 (850 mi^2) including Lake Superior waters. Ninety-nine percent of the land base is federally designated wilderness.

The Lake Superior shoreline is pocketed by many bays, harbors, peninsulas, and islands, particularly on the northeastern half of the island. Long, narrow inland lakes and wetlands are generally created by the ridge-and-valley topography of the island due to tilted bedrock (Huber 1973). The forest-dominated terrestrial ecosystems are principally composed of northern hardwoods (*Acer saccharum* and *Betula alleghaniensis*) in western portions of the park, and boreal forest (*Picea glauca*, *Abies balsamea*, *Populus tremuloides*, and *Betula papyrifera*) in eastern portions of the park (McInnes et al. 1992).

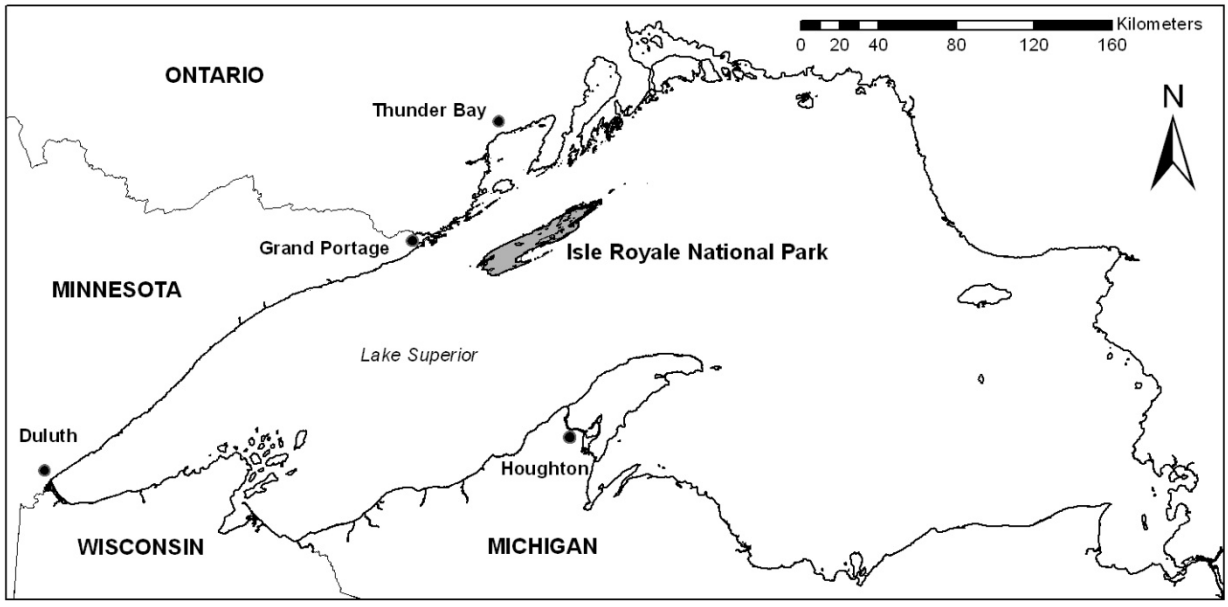


Figure 1. Location of Isle Royale in northwestern Lake Superior.

Methods

Survey Techniques

The point count methods and analyses used here are commonly used in North America (Ralph et al. 1993, Ralph et al. 1995, Nur et al. 1999), and they work well for unlimited distance point counts in heavily forested habitats (Howe et al. 1997). Surveys were conducted at 130 points distributed along eight transects (hiking trails) on Isle Royale and Passage Island (Figure 2, Table 1).

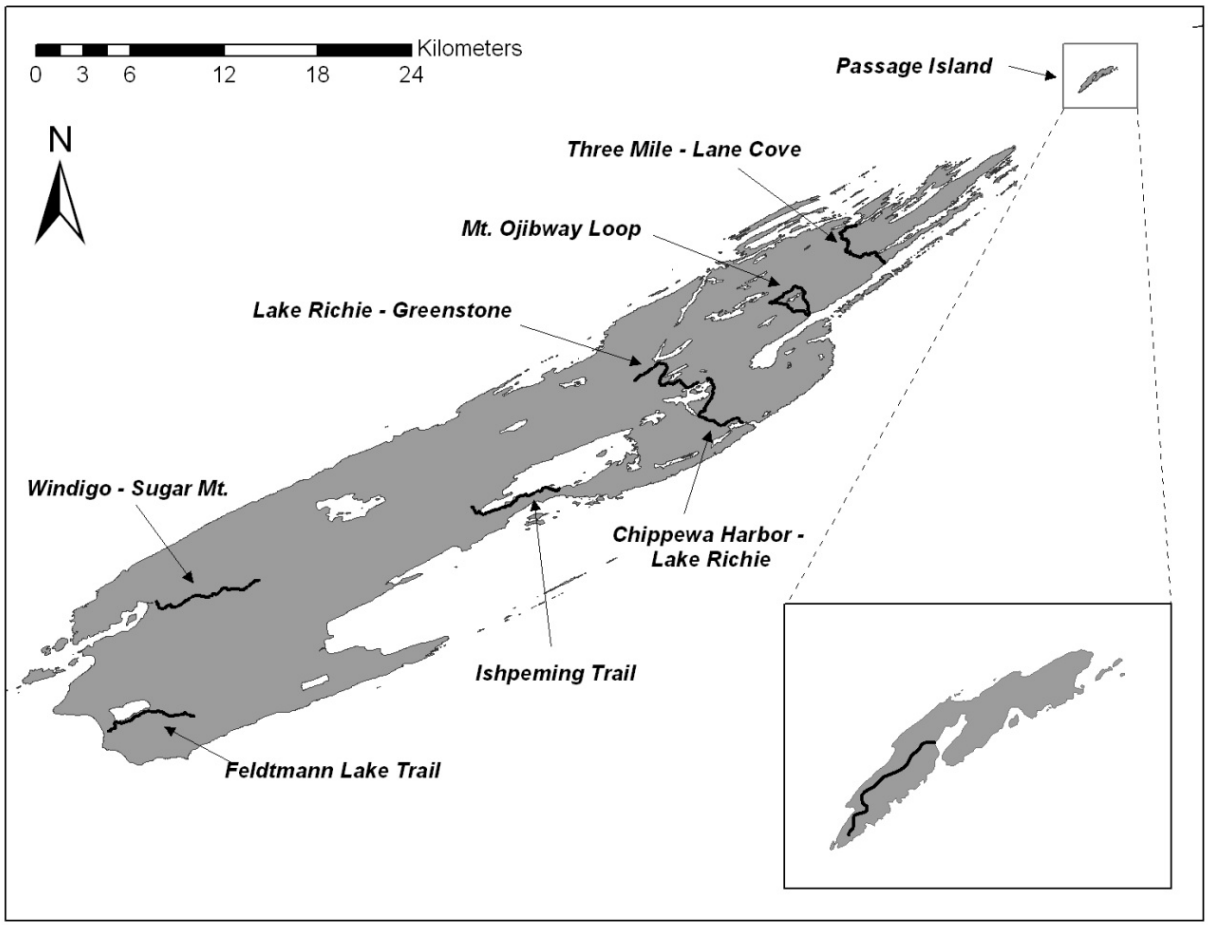


Figure 2. Map of Isle Royale, including the general locations of the eight bird survey routes. Inset shows location of the transect on Passage Island.

Six transects (FELK, ISTR, MTOJ, PASS, TMLC, WIND) were established in 1994 based on GIS analysis of island habitats. Stratification was used to place points in most of the island's general habitats, although upland habitats were favored due to trail construction practices (Gostomski and Oelfke 1994). In 1995, sampling shifted from intensive coverage (by habitat) to extensive coverage in which all parts of the island were represented. To this end, the LRGR route was added in 1995, which placed a second route in the central portion of the island (Gostomski

and Oelfke 1995), and the CHLR route was added in 1996, which established a shoreline-to-ridgetop gradient (Beeman and Oelfke 1996). As a result of route placement, and due to the general topography of upland and lowland habitats being in close proximity, most habitats across Isle Royale were at least partially represented during breeding bird surveys. Because this has not been quantified, current analyses have not taken habitat associations into account.

Table 1. Breeding bird survey transect locations, length of transects, and number of tagged survey points at Isle Royale National Park.

Transect	Transect Length, km (mi)	Number of Points
Passage Island (PASS)	1.3 (0.8)	4
Three Mile-Lane Cove (TMLC)	6.9 (4.3)	16
Chippewa Harbor-Lake Richie (CHLR)	6.4 (3.9)	16
Mt. Ojibway Loop (MTOJ)	8.2 (5.1)	19
Lake Richie-Greenstone (LRGR)	7.8 (4.8)	20
Ishpeming Trail (ISTR)	7.0 (4.3)	18
Feldtmann Lake Trail (FELK)	7.0 (4.3)	16
Windigo-Sugar Mt. (WIND)	8.3 (5.1)	21
Totals	52.9 (32.6)	130

Roadside point counts are known to increase the likelihood of detecting species that prefer edge habitats, but narrow roads in otherwise intact forest habitats do not generally appear to reduce detection of forest species, particularly if the canopy is intact over a single-lane road and there is essentially no change in adjacent vegetation (Keller and Fuller 1995, Hanowski and Niemi 1995, Hutto et al. 1995). Because all Isle Royale transects were in federally designated wilderness or land managed as de facto wilderness, and were located on narrow foot trails, it is unlikely that edge effects influenced species detection or habitat use.

Points were approximately 0.4 km (¼ mi) apart, and each had a tagged tree associated with it to help in relocating the site each year. Points were visited once annually between 0530 (approximately ½ hour before sunrise) and 1000 EDT by one skilled observer and usually one recorder. All routes were completed between 10 June and 30 June (one survey in 2003 was conducted on 1 July due to poor weather conditions in June). Temperature, cloud cover, and wind were recorded at each point. Unlimited radius point counts were five minutes in duration, during which time all species were recorded and categorized as “seen,” “heard,” or “flyover.” Data were recorded in one-minute intervals. Birds not heard or seen during the five-minute count but present at a census point before or after the count period, or while walking between points, were recorded as “miscellaneous.” Miscellaneous species were not included in the data analysis.

Surveys were not conducted, or were discontinued, if weather requirements were not met. Rain and fog were not acceptable conditions, except for very light rain if singing did not appear to be influenced (this occasionally happened on the last few points of a route). Wind was the overwhelming problem for Isle Royale bird surveys. Wind speeds >16 km/hr (10 mph) were

avoided. Occasionally, a route took two or three days to accomplish in order to satisfy wind speed requirements.

Prior to the standardization of point locations in 1996, observers estimated a distance of 250 m between points. Consequently, the number of points completed in 1996 and 1997 varied due to the slower hiking abilities of some observers (resulting in fewer points accomplished on some transects), or to an inability to find tagged trees, which caused observers to revert to the pattern of estimating hiking distances (Beeman and Oelfke 1997). Since 1998 the only fluctuations in number of points surveyed were due to unacceptable weather conditions late in the morning, with no opportunity to return and finish the route at a later date.

Bibby et al. (2000) described many sources of bias that typically occur in bird surveys. The Isle Royale survey methods addressed sources of bias by incorporating standard techniques to estimate bird populations on the island (Ralph et al. 1995). The same three observers have done the surveys since 2000; all had extensive experience identifying by sight and sound the species that were expected to occur on the island, knew island habitats, and were highly motivated to produce quality work. Pre-2000 observers were assumed to have had equal skills and motivation.

Data Analysis

All passerines detected during point counts were included in analyses. For many non-passerine species, such as gulls, raptors, waterbirds, and nocturnal species, point count protocols are not considered appropriate. Landbirds such as woodpeckers (Picidae), kingfishers (Alcedinidae), swifts (Apodidae), and cuckoos (Cuculidae) were included because it is thought that these groups can be sufficiently surveyed by the point count method (Ralph et al. 1993, Ralph et al. 1995, Howe et al. 1997). With vocal displays and winnowing for mate attraction and territoriality fulfilling the same role as in landbirds, three additional species were included in data analysis: American bittern, sora, and Wilson's snipe. The majority of unknown observations (birds detected but not identified to species) were woodpeckers. Without direct visual observation, and due to indistinguishable overlap in many non-vocal noises made by woodpeckers, species confirmation could not be made in some instances. Individuals not identified to species were not included in analyses.

Total and mean numbers of species and individuals within each species were calculated. A Simpson Diversity Index (Southwood and Henderson 2000) was calculated for each transect. Analysis of variance and least squares regression analyses were conducted using the program JMP® 9.0.2 (©SAS Institute Inc. 2010). Total annual count for each species served as the dependent variable and time (year) as the independent variable. As suggested by Nur et al. (1999), the annual total counts for each species were log-transformed prior to trend analysis. The logarithmic transformation enables the slope parameter estimates from the regressions to be interpreted as an instantaneous rate of change, or an average proportional change in the population over time. Moreover, using log-transformation helps the data better fit the assumptions inherent in regression analysis (i.e., normality, homoscedasticity, independence, and a linear relationship between the variables) and reduces variability around the trend line. In order to include years where no individuals were detected for a given species — an ecologically important event, particularly for species in serious decline — annual totals for all species had a

one (1) added before log transformation (thus, log[x+1]; Southwood and Henderson 2000). The program takes outliers into account.

Isle Royale regression data were compared to trends (% change/year) for Minnesota, Michigan, Ontario, and to much wider, habitat-based Bird Conservation Region strata of Boreal Hardwood Transition (including northern portions of Minnesota, Wisconsin, and the entire upper peninsula of Michigan) and Boreal Softwood Shield (a belt across Canada including nearly the entire northern shore of Lake Superior) (Sauer et al. 2010). These regional data were calculated differently due to the unique challenges of interpreting the road-based, continent-wide data used for the North American Breeding Bird Survey (see Geissler and Sauer 1990 for details), and the time frame in which the data were collected is different (1999-2010). Nonetheless, they are very useful as a broader index of species trends.

Trends were calculated for all species that occurred in at least three years between 1996 and 2012. These trends can indicate an implied relationship of annual populations to time, so that a significant trend suggests a strong change during the 17-year period, either increasing or decreasing, but a weak trend generally appears to indicate that numbers are too variable for a trend to have been revealed. P-value and r^2 are included with species trends, allowing the reader to draw their own conclusions regarding a trend's ecological importance.

Based on results of the species trend analyses, a Product Moment Correlation was calculated to compare the raven abundances to wolf and moose kill rates (Fowler et al. 1998, Vucetich and Peterson 2012).

Results

All 130 points were surveyed in most years (Table 2). Fewer points were surveyed in three years due to poor weather at the end of a route and the inability to finish the route later. Three additional points were surveyed in 1996 when points for the new routes (CHLR and LRGR) could not be found and point locations were therefore over-estimated.

An average of 1,457 individuals representing 89 species and 25 families were recorded during the 17-year period. The number of species detected, by family, was dominated by wood-warblers (Parulidae; 23 species). Tyrant flycatchers (Tyrannidae; eight species) were the second-most commonly detected family. Wood-warblers similarly dominated the number of individuals detected during point counts, followed by sparrows (Emberizidae).

Unidentified individuals were generally woodpeckers (Picidae) making drumming or foraging sounds that could not be attributed to a particular species. Woodpeckers were probably the most under-sampled population in this regard. On occasion, individuals from other families fell into the unknown category if only a brief sound or sight was not enough to make identifications with certainty.

Isle Royale species that showed a statistically significant increase from 1996 to 2012 were red-winged blackbird, American goldfinch, golden-crowned kinglet, alder flycatcher, song sparrow, pileated woodpecker, American robin, hermit thrush, common yellowthroat, red-breasted nuthatch, swamp sparrow, and Nashville warbler (Table 3, Figure 3). While P indicates statistical significance, the trend indicates the biological importance in terms of a species' average rate of change during the time period (e.g., golden-crowned kinglets increased an average of 4% annually between 1996 and 2012). In total, 47 species (52%) had increasing trends, of which twelve were significant (Table 4).

A total of 24 species (27%) had decreasing trends, of which nine were significant (Table 4). Isle Royale species that showed a statistically significant decrease from 1996 to 2012 were Cape May warbler, evening grosbeak, chipping sparrow, common raven, Tennessee warbler, least flycatcher, American redstart, American crow, and bay-breasted warbler (Table 3, Figure 4). Of these species, only common raven and chipping sparrow were detected in all thirteen years. We acknowledge that several of these trends are based on limited numbers of individuals detected. Accordingly, we recommend a cautious interpretation of the results for bay-breasted warbler, Cape May warbler, evening grosbeak, and Tennessee warbler. The Product Moment Correlation for both raven and wolf numbers, and raven numbers and wolf-killed moose, had very weak correlations ($r = 0.19$ with 14 d.f. in both cases).

Eighteen species were only detected in one or two years and were not included in trend analysis (Tables 3 and 4). Some species that were common and abundant had considerable annual fluctuations, with only a weak, uncertain trend detected (e.g., ovenbird and white-throated sparrow).

Table 2. Comparisons of species and individuals detected during bird surveys, by year, including number of points surveyed annually at Isle Royale National Park, 1996-2012.

	Year																	
	1996	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*Mean*
Points surveyed	133	122	130	130	129	130	130	130	126	130	130	130	130	130	130	130	130	129
No. of species	57	58	61	60	60	55	54	55	56	54	53	62	59	61	56	57	59	57
No. of individuals	1,430	1,261	1,028	1,610	1,441	1,426	1,513	1,451	1,090	1,420	1,647	1,739	1,458	1,801	1,533	1,464	1,459	1,457

Table 3. Least squares regression trends (average proportional change per year), r^2, P-values and total individuals detected for all species observed during 5-minute point counts at Isle Royale, 1996-2012.

Species[2]	Study Area[1]						r^2	P-value	Total Indiv. Detected
	Isle Royale[2]	*Michigan*	*Minnesota*	*Ontario*	*BHT*	*BSS*			
Red-winged blackbird	**+ 0.04**	—	—	—	—	—	0.35	0.01	46
American goldfinch	**+ 0.04**	—	+	—	—	—	0.33	0.02	35
Golden-crowned kinglet	**+ 0.04**	+	—	+	—	+	0.30	0.02	313
Alder flycatcher	**+ 0.03**	+	+	—	+	—	0.56	0.0006	392
Song sparrow	**+ 0.03**	—	—	+	—	—	0.56	0.0005	197
Pileated woodpecker	**+ 0.03**	+	+	+	+	+	0.33	0.02	194
American robin	**+ 0.02**	+	+	—	—	+	0.50	0.002	765
Hermit thrush	**+ 0.02**	+	+	+	+	+	0.42	0.005	1135
Common yellowthroat	**+ 0.02**	+	—	+	+	—	0.38	0.008	102
Red-breasted nuthatch	**+ 0.02**	+	+	+	+	+	0.35	0.01	676
Swamp sparrow	**+ 0.01**	+	+	+	+	+	0.31	0.02	170
Nashville warbler	**+ 0.01**	—	+	+	+	—	0.27	0.03	2260
Brown creeper	+ 0.03	+	+	+	+	+	0.18	0.09	354
Ruby-crowned kinglet	+ 0.03	—	+	+	—	+	0.17	0.10	35
Blue jay	+ 0.02	—	—	+	+	+	0.22	0.06	685
Hairy woodpecker	+ 0.02	+	+	+	+	+	0.17	0.10	189
Northern waterthrush	+ 0.02	—	+	+	—	+	0.17	0.11	62
Belted kingfisher	+ 0.02	—	—	—	—	—	0.14	0.13	15
Yellow-bellied sapsucker	+ 0.02	+	+	+	+	+	0.13	0.15	69
Cedar waxwing	+ 0.02	+	—	+	—	+	0.11	0.20	389
Red crossbill	+ 0.02	+	+	+	+	+	0.06	0.33	52
Swainson's thrush	+ 0.01	—	+	—	—	—	0.20	0.08	246
Yellow-bellied flycatcher	+ 0.01	+	+	+	+	+	0.15	0.12	257
Mourning warbler	+ 0.01	+	—	—	—	—	0.13	0.16	332
Northern flicker	+ 0.01	+	—	+	+	+	0.12	0.16	188
Black-capped chickadee	+ 0.01	+	—	+	+	+	0.11	0.19	621
Sora	+ 0.01	—	—	+	—	+	0.10	0.23	5
Veery	+ 0.01	—	+	—	—	+	0.10	0.21	185
Scarlet tanager	+ 0.01	+	—	—	—	+	0.08	0.26	22
Northern parula	+ 0.01	+	+	+	+	+	0.06	0.33	33
Gray jay	+ 0.01	—	+	+	+	+	0.02	0.57	69
Pine siskin	+ 0.01	—	—	—	—	—	0.02	0.58	67
Winter wren	+ 0.008	—	—	+	+	+	0.15	0.13	1994
Wilson's snipe	+ 0.008	—	+	+	+	+	0.04	0.43	200
Purple finch	+ 0.008	+	—	—	—	—	0.03	0.53	18

Table 3. Least squares regression trends (average proportional change per year), r^2, P-values and total individuals detected for all species observed during 5-minute point counts at Isle Royale, 1996-2012 (continued).

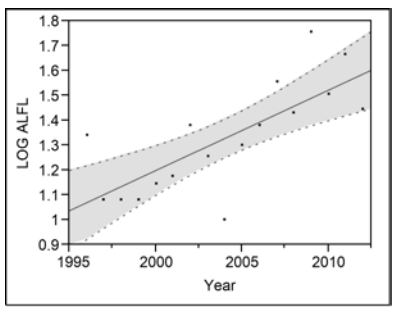
Species[2]	Study Area[1]						r^2	P-value	Total Indiv. Detected
	Isle Royale[2]	*Michigan*	*Minnesota*	*Ontario*	*BHT*	*BSS*			
Magnolia warbler	+ 0.007	+	—	+	+	+	0.11	0.18	945
White-throated sparrow	+ 0.005	+	+	+	—	+	0.12	0.17	2492
Black-throated green warbler	+ 0.005	+	—	+	—	+	0.05	0.41	1153
Eastern wood-pewee	+ 0.005	+	—	—	—	+	0.02	0.59	10
White-breasted nuthatch	+ 0.005	+	+	+	+	+	0.01	0.66	15
Chimney swift	+ 0.005	—	—	—	—	▪	0.007	0.75	24
Black-throated blue warbler	+ 0.004	+	—	+	+	+	0.01	0.70	143
American bittern	+ 0.004	—	—	+	+	+	0.01	0.70	24
Blackburnian warbler	+ 0.003	+	—	+	+	+	0.02	0.64	6
Blue-headed vireo	+ 0.003	+	+	+	+	+	0.003	0.85	26
Yellow-rumped warbler	+ 0.001	+	+	+	+	+	0.004	0.81	463
Ovenbird	+ 0.001	+	+	—	+	—	0.003	0.83	2359
Yellow-billed cuckoo	▪	+	—	+	—	▪	--	--	1
Mourning dove	▪	+	—	+	+	+	--	--	1
Eastern phoebe	▪	—	—	—	—	+	--	--	4
Eastern kingbird	▪	—	—	—	—	—	--	--	2
Philadelphia vireo	▪	+	+	+	+	+	--	--	2
Barn swallow	▪	—	—	—	—	—	--	--	1
Marsh wren	▪	—	+	+	—	+	--	--	1
Sedge wren	▪	—	+	+	+	+	--	--	3
Eastern bluebird	▪	—	+	—	+	+	--	--	1
Gray catbird	▪	+	—	—	—	+	--	--	2
Brown thrasher	▪	—	—	—	—	▪	--	--	1
Yellow warbler	▪	+	+	—	—	—	--	--	3
Yellow-breasted chat	▪	—	▪	—	▪	▪	--	--	1
Wood thrush	▪	+	+	—	—	+	--	--	1
Black-headed grosbeak	▪	▪	▪	▪	▪	▪	--	--	1
Black-backed woodpecker	▪	—	+	+	+	+	--	--	1
Orange-crowned warbler	▪	▪	▪	—	—	+	--	--	1
Northern cardinal	▪	+	+	+	+	▪	--	--	2
Indigo bunting	- 0.005	+	+	+	+	▪	0.009	0.72	28
Red-eyed vireo	- 0.006	+	—	+	+	+	0.16	0.11	1536
Palm warbler	- 0.007	+	+	+	+	+	0.10	0.22	3

Table 3. Least squares regression trends (average proportional change per year), r^2, P-values and total individuals detected for all species observed during 5-minute point counts at Isle Royale, 1996-2012 (continued).

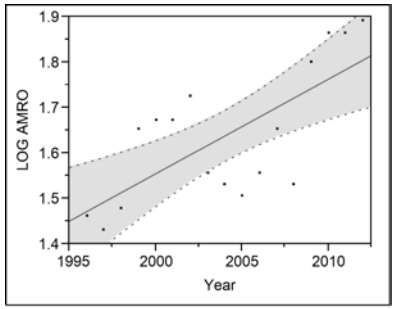
Species[2]	Study Area[1]						r^2	P-value	Total Indiv. Detected
	Isle Royale[2]	*Michigan*	*Minnesota*	*Ontario*	*BHT*	*BSS*			
Canada warbler	- 0.007	—	—	—	—	—	0.03	0.50	73
Olive-sided flycatcher	- 0.001	—	—	+	—	—	0.001	0.89	16
Slate-colored junco	- 0.005	—	—	+	—	+	0.03	0.54	4
White-winged crossbill	- 0.009	+	—	+	—	+	0.007	0.74	70
Great crested flycatcher	- 0.01	—	—	—	—	▪	0.04	0.46	5
Black-billed cuckoo	- 0.01	—	—	—	—	—	0.04	0.42	15
Chestnut-sided warbler	- 0.01	+	—	—	+	—	0.06	0.33	830
Common grackle	- 0.01	—	—	—	—	—	0.06	0.33	98
Downy woodpecker	- 0.01	+	+	+	+	+	0.09	0.25	180
Pine warbler	- 0.01	+	+	+	+	▪	0.09	0.24	5
Black-and-white warbler	- 0.01	+	+	—	—	+	0.20	0.07	199
Rose-breasted grosbeak	- 0.02	—	—	—	—	—	0.10	0.21	25
Bay-breasted warbler	**- 0.02**	—	—	—	—	+	0.33	0.02	6
American crow	**- 0.02**	—	—	+	+	+	0.38	0.008	459
American redstart	**- 0.02**	—	+	—	—	—	0.38	0.008	447
Least flycatcher	**- 0.03**	—	—	—	—	—	0.25	0.04	46
Tennessee warbler	**- 0.03**	+	—	—	—	+	0.30	0.02	14
Common raven	**- 0.03**	+	+	+	+	+	0.66	0.001	219
Chipping sparrow	**- 0.05**	+	+	—	—	—	0.63	0.0001	189
Evening grosbeak	**- 0.06**	—	—	—	—	—	0.59	0.0003	35
Cape May warbler	**- 0.07**	—	+	+	—	—	0.56	0.005	45

[1] Non-Isle Royale data are from Sauer et al. (2010), and are given as trend direction only, without significance. Missing data (▪) are due to low numbers detected on routes. BHT = Boreal Hardwood Transition, BSS = Boreal Softwood Shield (see text for details).

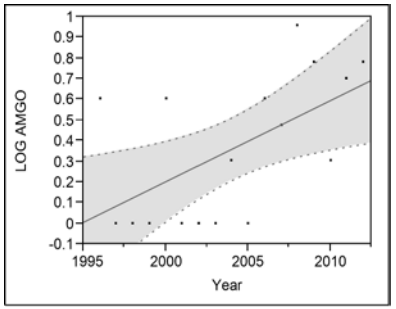
[2] Species and Isle Royale trends in bold indicate P ≤0.05.



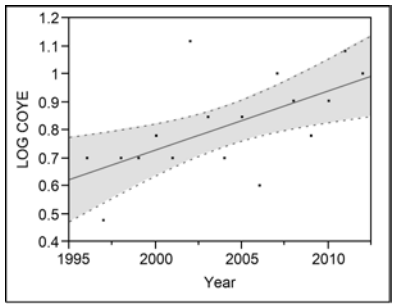
Alder Flycatcher (ALFL)
r^2=0.56, P=0.0006



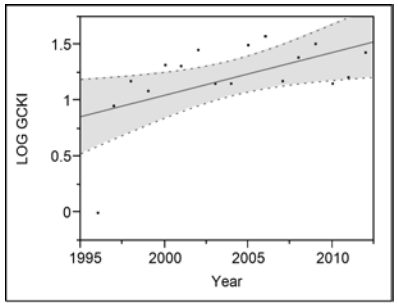
American Robin (AMRO)
r^2=0.50, P=0.002



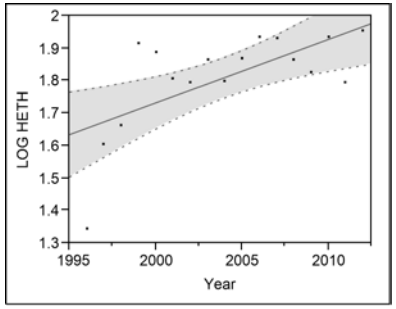
American Goldfinch (AMGO)
r^2=0.33, P=0.02



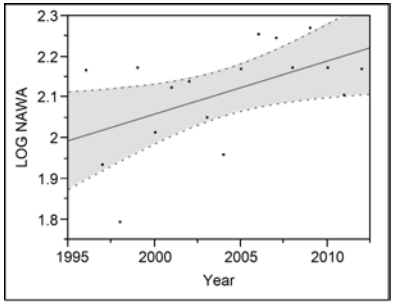
Common Yellowthroat (COYE)
r^2=0.38, P=0.008



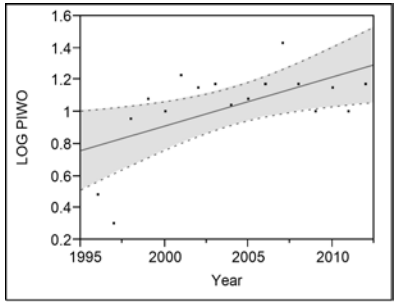
Golden-crowned Kinglet (GCKI)
r^2=0.30, P=0.02



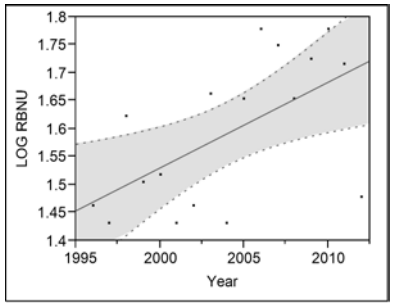
Hermit Thrush (HETH)
r^2=0.42, P=0.005



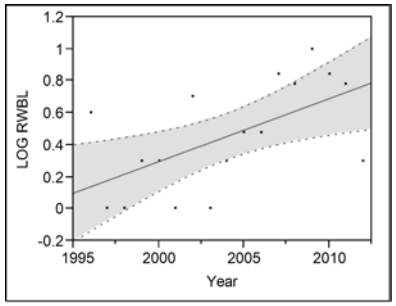
Nashville Warbler (NAWA)
r^2=0.27, P=0.03



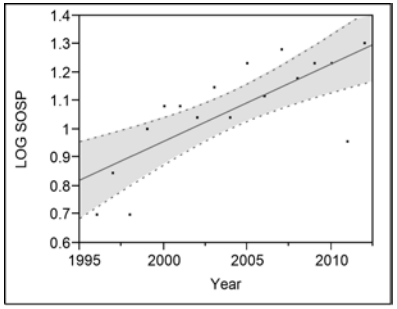
Pileated Woodpecker (PIWO)
r^2=0.33, P=0.02



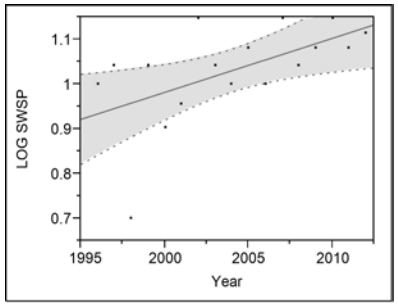
Red-breasted Nuthatch (RBNU)
r^2=0.35, P=0.01



Red-winged Blackbird (RWBL)
r^2=0.35, P=0.01

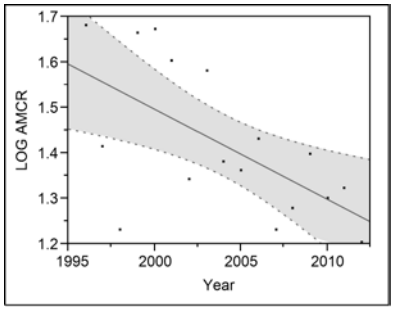


Song Sparrow (SOSP)
r^2=0.56, P=0.0005

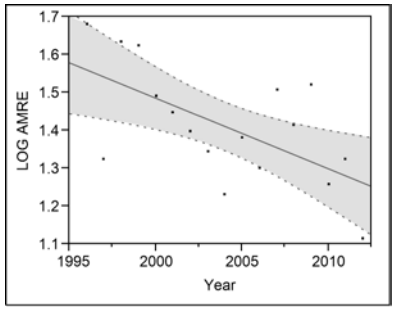


Swamp Sparrow (SWSP)
r^2=0.31, P=0.02

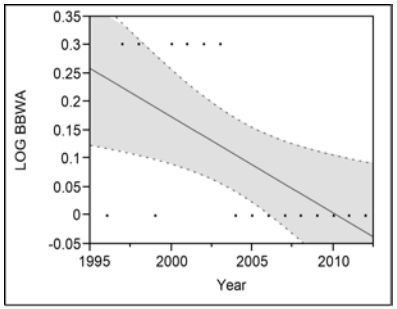
Figure 3. Bivariate fit (log by year) of species with statistically significant increases, Isle Royale National Park, 1996-2012. Trend line and confidence intervals are shown.



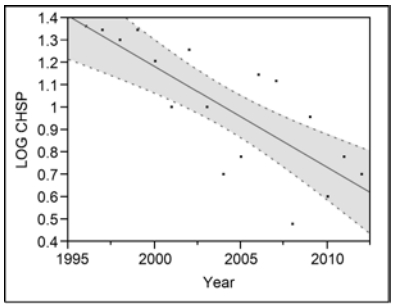
American Crow (AMCR)
r^2=0.38, P=0.008



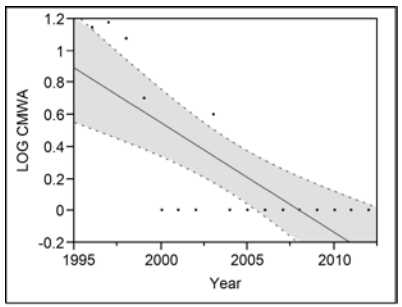
American Redstart (AMRE)
r^2=0.38, P=0.008



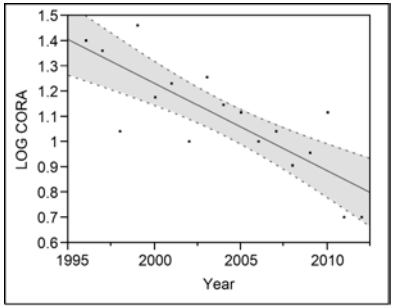
Bay-breasted Warbler (BBWA)
r^2=0.33, P=0.02



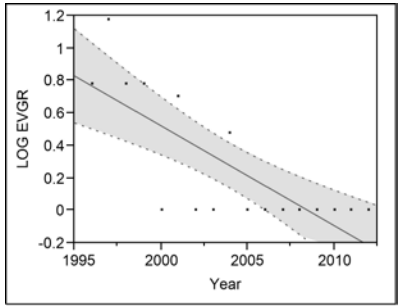
Chipping Sparrow (CHSP)
r^2=0.63, P=0.0001



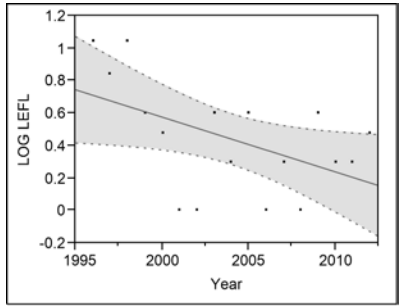
Cape May Warbler (CMWA)
r^2=0.56, P=0.005



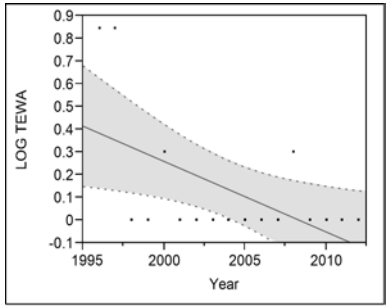
Common Raven (CORA)
r^2=0.66, P=0.001



Evening Grosbeak (EVGR)
r^2=0.59, P=0.0003



Least Flycatcher (LEFL)
r^2=0.25, P=0.04



Tennessee Warbler (TEWA)
r^2=0.30, P=0.02

Figure 4. Bivariate fit (log by year) of species with statistically significant declines, Isle Royale National Park, 1996-2012. Trend line and confidence intervals are shown.

Table 4. Population trends for Isle Royale birds during point-count surveys, 1996-2012.

Trend	1996-2012
Increase	12 species (13%)
Decline	9 species (10%)
No statistical change	50 species (56%): 35 increasing (39%) and 15 decreasing (17%)
Insufficient data	18 species (20%)

A high number of wood-warblers (Parulidae) was observed during point counts, both in terms of the diversity of species represented and in some of the most abundant numbers of individuals occurring annually (e.g., black-throated green warbler, Nashville warbler, and ovenbird). Detections of finches (Fringillidae) and tyrant flycatchers (Tyrannidae), while having a high number of represented species, were comprised of fewer individuals.

The trend for the number of individuals detected shows a steady but non-significant increase ($P = 0.08$, $r^2 = 0.19$) since 1996, while the trend for the number of species is flat ($P = 0.97$, $r^2 < 0.001$; Figure 5). The Simpson Index of Diversity appears to be stable and relatively high on most of the eight routes (Figure 6). Diversity values for most routes were between 0.94 and 0.95 with a low standard deviation (0.01). Windigo had a lower mean (0.89) and slightly higher standard deviation (0.02) and Passage Island had a much lower mean (0.85) and much higher standard deviation (0.10).

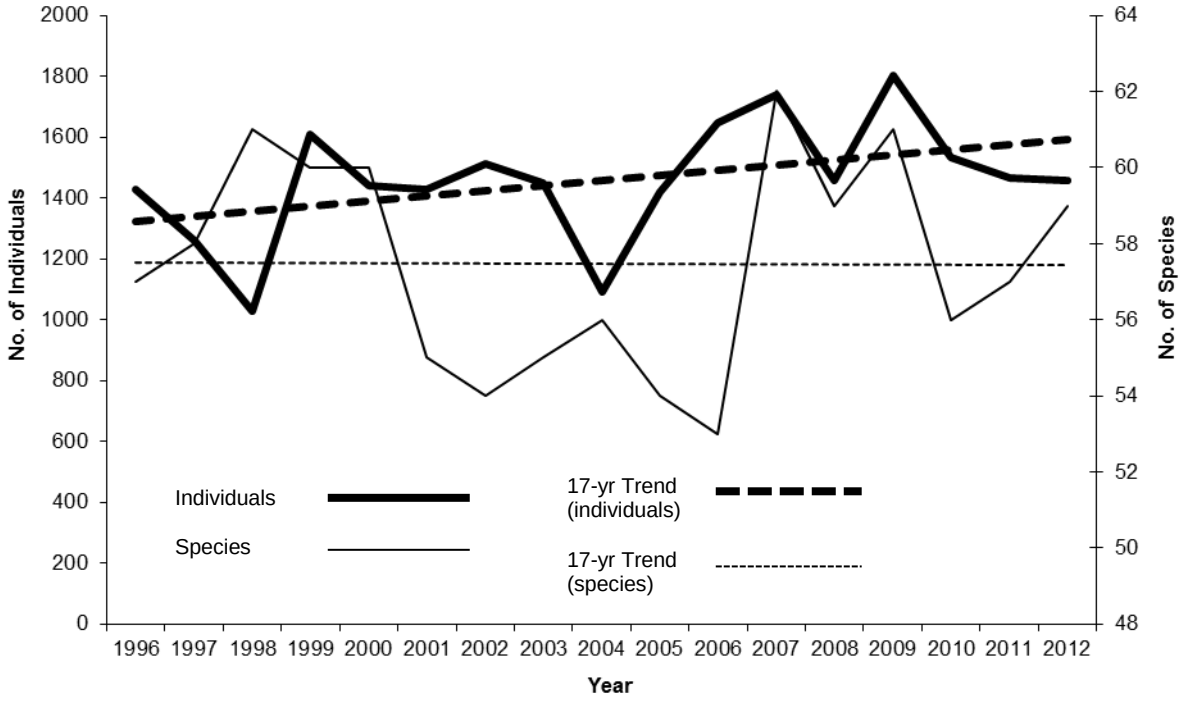


Figure 5. Trends for number of individuals and species detected on bird survey routes, by year, Isle Royale National Park, 1996-2012.

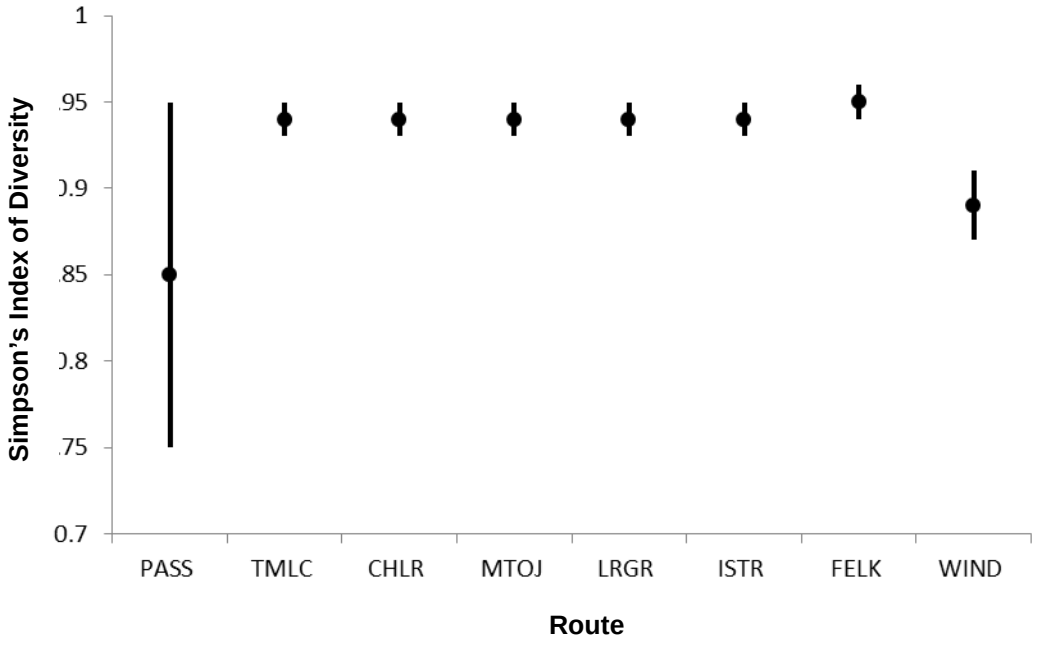


Figure 6. Simpson's Index of Diversity average and standard deviations for landbirds at Isle Royale National Park, by route, 1996-2012.

Discussion

The original goals of the Isle Royale breeding bird survey included assessing avian community composition and how individual species populations change over time, while comparing results with other regional studies. The linear regression trend for the number of detected species is flat and non-significant. The trend for number of detected individuals is also non-significant, but it is increasing and may be doing so at an ecologically important rate (+17 individuals annually, $P = 0.08$, $r^2 = 0.19$).

Other parks in the Lake Superior/Canadian border region have recorded sum totals between 54 and 95 species during their landbird surveys (Table 5; unpublished data). Isle Royale falls within this range, equal to the number of species recorded at Voyageurs National Park, Minnesota.

Table 5. Number of species recorded during landbird surveys at other Great Lakes Network national parks (unpublished data gathered by the NPS Great Lakes Inventory and Monitoring Network).

Park (State)	Number of Species	Number of Years of Data
Apostle Islands (WI)	95	22
Isle Royale (MI)	89	16
Voyageurs (MN)	89	17
Pictured Rocks (MI)	66	1
Grand Portage (MN)	54	3

Regression Analyses and Trends

Even short-term studies can adequately detect trends, particularly if the sample size or magnitude of change is greater than 5% per year (Thogmartin et al. 2007). Lind et al. (2005) found Isle Royale's dataset sufficient enough to detect a 10% annual change in abundance after 10 years, or a 5% change after 15 years for at least some species. However, trend detection abilities vary by species, with white-throated sparrow requiring only eight years of data to detect a 2% change, while 13 years of data would be needed to detect a 10% change in a species like the veery (Lind et al. 2005). As a result, continued monitoring will bring a much more refined understanding of changes occurring among bird populations at Isle Royale, but the current dataset should provide an acceptable understanding of the general avian community.

Significant Increases

Variation between local and regional scales can be seen when comparing Isle Royale data to large states, provinces, and broad ecological categories. There have been differences in species showing a significant trend (positive or negative) since survey data were last analyzed in 2008 (Egan 2009; 1996-2008, hereafter referred to as "2008 analysis period"). Six species showed significant increases at Isle Royale in both the 2008 analysis period and the current analysis period (1996–2012): pileated woodpecker, golden-crowned kinglet, song sparrow, hermit thrush, alder flycatcher, and red-breasted nuthatch. In the current analysis period, five new species (red-winged blackbird, American goldfinch, American robin, common yellowthroat, and Nashville warbler) showed significant increases, while four species (brown creeper, hairy woodpecker, Wilson's snipe, and yellow-bellied flycatcher) dropped to non-significant increases from the

2008 analysis period. Despite changes in significance, all of these species had positive trends in both analyses. Positive trends observed on Isle Royale from 1996–2012 were generally consistent with state-wide and ecological region analyses (Sauer et al. 2010), although several species had declining trends throughout the region, including the red-winged blackbird, American goldfinch, and song sparrow.

Red-winged Blackbird: While red-winged blackbirds are one of the most successful North American species in the past century (Yasukawa and Searcy 1995), few individuals are detected at Isle Royale. Red-winged blackbirds sometimes utilize woodland stream habitat, lakeshores, or abandoned beaver ponds for breeding, and such habitats may be important to this species on the island (Yasukawa and Searcy 1995). Otherwise, marshes and upland fields, the two typical breeding habitats, are not common on Isle Royale and are likely the reason for limited breeding-season use of the island by red-winged blackbirds.

American Goldfinch: Although the species is still abundant continent-wide, a recent decline of the American goldfinch across the Great Lakes region may be influenced by cat predation or changes in agricultural practices (McGraw and Middleton 2009). Preference for early-successional nesting habitats, including some use of forest edge, could be driving the increase at Isle Royale where habitats appear to be influenced in the past 10-15 years by low moose browsing pressure and habitat succession patterns (A. Egan, personal observation). While the increasing trend on Isle Royale is strong, annual abundances are very low. As a result, caution should be used when considering the trends for both American goldfinch and red-winged blackbird, which respectively have an average of two and four individuals detected annually.

Song Sparrow: Negative regional trends for song sparrows are speculatively linked to local habitat changes, or low survival rates coupled with low immigration (Arcese et al. 2002). There is abundant shoreline forest habitat on Isle Royale, and song sparrows are common, so we are not sure why fewer individuals were detected in early years of the survey (mean= 8.5 over the period 1996-2003 and 14.3 over the period 2004-2012).

Significant Declines

Six species had significant declining trends in both the 2008 analysis period and the current one: Cape May warbler, evening grosbeak, least flycatcher, chipping sparrow, Tennessee warbler, and common raven. In the current period, three additional species showed significant declines (American redstart, American crow, and bay-breasted warbler), while two species dropped to non-significant decreases (rose-breasted grosbeak and Canada warbler). All of these species had negative trends in both analysis periods. Negative trends from 1996 through 2012 were generally consistent with state-wide and ecological region analyses (Sauer et al. 2010), although American crow, chipping sparrow, and Cape May warbler yielded mixed results in other study areas.

Caution should be used when interpreting trends for species with few individuals detected annually at Isle Royale, particularly bay-breasted warbler, Cape May warbler, evening grosbeak, and Tennessee warbler (see Figure 4). These species are clearly not frequent members of the Isle Royale avian community, are generally declining across their range, or both. As a result, the park should probably not be concerned about managing for these species.

For crows, mixed trends are common throughout the United States, possibly due to distributional shifts to cities and habitat changes that do not favor crows, such as agriculture (Verbeek and Caffrey 2002). However, Isle Royale habitats are probably not changing quickly enough to cause declines. For Cape May warblers, there is a broader population link to spruce budworm outbreaks (Baltz and Latta 1998), which may also be an important factor for evening grosbeaks and bay-breasted warblers. General declines of least flycatchers across the region may be due to loss of large forest tracts (Tarof and Briskie 2008). At Isle Royale there appears to be a shift in forest habitat characteristics due to low moose population numbers with subsequent changes in browsing pressure, leading to an increase in forest gaps created by natural forest succession. While this may be a contributing factor in the decline of least flycatchers, there still appears to be ample habitat across the island, and a link between the two remains speculative.

The decline in chipping sparrows is curious given that there seems to be an increase in the number of forest gaps on Isle Royale in recent years, as mature trees fall and a shrubby understory grows in the absence of strong moose browsing (A. Egan, personal observation). These forest gaps, and habitat across Isle Royale generally, should favor chipping sparrows as well as American redstarts, which are also declining significantly. American redstart declines in recent decades are likely due to reduced habitat quality, both on breeding and wintering grounds (Thomas and Holmes 1997). The redstart may be a good management indicator for broader (i.e., regional and continental) population changes because it has been relatively common at Isle Royale, which has abundant and presumably high-quality breeding habitat for this species.

Common Raven: The common raven is an interesting case because its populations are exhibiting increasing trends at state, regional, and ecoregional scales, yet they are declining on Isle Royale (r^2=0.66, P=0.001). Ravens are often dependent upon carrion, and wolf-killed moose are likely critical for their winter survival on the island (Vucetich et al. 2004). Post-hoc analyses suggest that raven numbers have at best a weak correlation to either wolf numbers or wolf kill rates. However, the data are not directly comparable, as wolf numbers and kill rates are estimated during the winter (Vucetich and Peterson 2012), while raven numbers are taken from summer point counts.

Without a more in-depth study of ravens on Isle Royale, we cannot say for sure what might be causing the island population to decline in spite of noted increases everywhere else in the region. Food supply and the availability of suitable habitat are the first two parameters to consider in such situations, but the raven's choice of both is so highly variable (Ratcliffe 1962, Boarman and Heinrich 1999) that analysis of them does not provide many clues.

If neither food nor habitat is limiting the number of ravens, we might look at population carrying capacity. Are there too many ravens on Isle Royale? Are we witnessing a return to a population size of ravens that is more suitable to the island following the major moose die-off in the winter of 1996-1997? In the early part of the 20th century, Peet (1909) observed that ravens on Isle Royale were "nowhere common but seemed to occur in limited numbers all over the island." Moose were similarly sparse at that time, but are thought to have been present (Murie 1934).

Studying the breeding density of ravens on El Hierro in the Canary Islands, Nogales (1994) documented more than 90 breeding pairs of ravens in a 278 km^2 area, yielding a density of ca. 35 nesting pairs per 100 km^2. He cites six studies in the United States (all but two in western states)

in which the average study area was 482 km^2 (range = 44–1,020 km^2) and the average breeding density of ravens was 16.1 nesting pairs per 100 km^2.

Isle Royale is 544 km^2. Among the studies cited by Nogales, the one with a study area closest in size to Isle Royale was conducted by Booth (1979) in Orkney, Scotland (58.9833° N, 3.1000° W); his study area was 523 km^2. Booth counted 27 nesting territories in six years (16 of which were occupied every year), yielding an average of 4.8 nesting pairs per 100 km^2. If Isle Royale's breeding density is comparable to this similarly-sized site in Scotland, then we can expect 26.1 breeding pairs of ravens here, or 52.2 ravens (not including non-breeding individuals). In 17 years of songbird surveys on Isle Royale, the highest number of ravens counted was 22, which is far below the population size Isle Royale might be able to support based on its size alone.

If declining carrying capacity is not the cause of declines, could it be that conducting point counts in June is inappropriate for aurally detecting breeding pairs? Even the latest egg-laying among ravens is concluded by mid-June; typically young are already present by that time (Boarman and Heinrich 1999). In Michigan, Evers (1991) noted that ravens begin laying eggs in late February, young are present in mid-to-late March, and families may be seen beginning in late April. With young leaving the nest 4-to-7 weeks post-hatching (Boarman and Heinrich 1999), which is late May or late June in Michigan, it seems possible that any territorial behavior (i.e., calling) has ceased because the raven's nesting season is over. Even if this is not the case, it may be that the standard point count method (Ralph et al. 1993) is not appropriately applied to ravens. Luginbuhl et al. (2001) found that delineating and mapping the survey area was a critical first step to accurately assess the relative abundance of corvids (including ravens). With the survey areas mapped, they employed a modified point count method, using plots as the sampling units instead of survey points. They placed 7–17 evenly-spaced points within each plot, and each point was sampled twice a year.

Despite Luginbuhl et al.'s endorsement of a modified point count method, ravens are not exhibiting a declining trend in any other data set that is derived from use of standard point counts or the North American Breeding Bird Survey's roadside point counts.

There is, as yet, no reason to suggest that ravens are declining on Isle Royale because of ecosystem changes resulting from climate change. To wit, the increasing trends shown in other regional datasets confounds such speculation. Thus, the declines seem isolated to the island, and herein lies a mystery that deserves attention. As an iconic resident of the boreal-hardwood forest, the decline of ravens on Isle Royale is troubling and warrants more in-depth study, from a population assessment to basic ecology.

Species Diversity and Richness

Diversity and richness give a broader evaluation of avian community health, and the Simpson Index of Diversity has generally been accepted as an important indicator of resilience and health in ecological systems (Magurran 2004, Loreau et al. 2001). Isle Royale diversity values, generally 0.94–0.95 on the index scale of 0-1, suggest a high community diversity and even population distribution on six of the eight routes. These values can serve as stand-alone indicators (Buckland et al. 2005, Payne et al. 2005). Lower diversity values were found for the Windigo and Passage Island routes (mean = 0.89 and 0.85, respectively). The Windigo route traverses a relatively uniform habitat of mature sugar maple/yellow birch forest and was

expected to have a lower diversity value due to lower species richness and fewer individuals, which causes the more abundant species to exert a greater influence on the statistic. Passage Island likely had a lower diversity because of the low number of points (4) and because surveys often yield one or two species with very high abundance, but rarely the same species does so from one year the next. Passage Island standard deviation is wide due to large numbers of a single species sometimes detected on that route.

Conservation on a Regional Scale––Maintenance or Resilience?

The Partners in Flight (PIF) Bird Conservation Plan for the Boreal Hardwood Transition Zone (the bird conservation region that includes Isle Royale) identified 39 priority species across 10 habitat types (Matteson et al. 2009). The Isle Royale survey has documented trend data for 21 of those 39 species, in seven of the ten habitat types (Table 6).

Matteson et al. (2009) identified Isle Royale National Park as one of 22 sites in the upper Great Lakes region that provides an outstanding opportunity for implementing bird conservation measures, including the establishment of Forest Bird Conservation Areas or Forest Bird Management Areas. Because of Isle Royale's relative freedom from typical anthropogenic influences (development and logging in particular), there may be opportunities to manage the island landscape in a way that could lead to improved trends for some declining species (e.g., bay-breasted warbler, least flycatcher). Matteson et al. (2009) provide some suggested management guidelines to consider, though many of them may already be part of the park's management by default.

Alternatively, knowing that a changing climate may change the relative proportions of habitat types on the island (i.e., coniferous forests transitioning to deciduous forests), the "secondary" designation of Forest Bird Conservation Area might better fit management aimed at ecosystem resilience—maintaining the function of the island ecosystem, not necessarily the "look" of it (Walker et al. 2004, Zavaleta and Chapin 2010). In other words, management could work to maintain coniferous forests (and coniferous forest species such as bay-breasted warblers) despite the potential lack of conditions conducive to its continued survival, or management could focus on resilience of forests on Isle Royale, creating opportunities to improve conditions that favor species found in the deciduous or regenerating forests (such as the least flycatcher or Nashville warbler), though the coniferous forest birds may continue to decline.

Table 6. Priority bird species in the Boreal Hardwood Transition Bird Conservation Region (Matteson et al. 2009) that are found on Isle Royale. General habitat type as described by the plan, Isle Royale trend for the period 1996-2012 (mean annual proportional change), and P-values are shown. Species names in **bold** exhibited significant trends (P<0.05).

Species	Habitat	Isle Royale Trend	P-value
Bay-breasted Warbler	Coniferous forest	-0.02	0.02
Belted Kingfisher	Shoreline	0.02	0.13
Black-billed Cuckoo	Regenerating forest	-0.01	0.42
Blackburnian Warbler	Coniferous forest	0.003	0.64
Black-throated Blue Warbler	Deciduous forest	0.004	0.70
Black-throated Green Warbler	Coniferous forest	0.005	0.41
Canada Warbler	Coniferous forest	-0.007	0.50
Chestnut-sided Warbler	Regenerating forest	-0.01	0.33
Chimney Swift	Developed/Urban	0.005	0.75
Common Yellowthroat	Shrub-wetland	0.02	0.008
Least Flycatcher	Deciduous forest	-0.03	0.04
Mourning Warbler	Regenerating forest	0.01	0.16
Nashville Warbler	Regenerating forest	0.01	0.03
Northern Flicker	Deciduous forest	0.01	0.16
Olive-sided Flycatcher	Coniferous forest	-0.001	0.89
Purple Finch	Coniferous forest	0.008	0.53
Rose-breasted Grosbeak	Deciduous forest	-0.02	0.21
Swamp Sparrow	Open marsh	0.01	0.02
Veery	Deciduous forest	0.01	0.21
White-throated Sparrow	Regenerating forest	0.005	0.17
Yellow-bellied Sapsucker	Deciduous forest	0.02	0.15

Conclusions

Isolation and wilderness status at Isle Royale likely fulfills most stated or potential management goals for preserving landscapes and ecological diversity within them. The island's isolation also means that most landbird trends at Isle Royale are influenced by external factors, such as land use change or dynamics on wintering and migration grounds. On the island, historic changes have also been important, such as forest regeneration and succession following a major fire in 1936, and logging that occurred on portions of the island in the 1800s. Climate variation has been considered an external influence, but it will likely become more localized in coming years if predicted shifts in plant communities occur and if warming trends contribute to extirpation of moose and wolves from the island. The decline of ravens is potentially one example of this emerging influence.

Ravens are often strongly associated with wolves in order to obtain food resources from wolf kills (Stahler et al. 2002). It is possible that the raven population was at a peak in 1996, when abundant food resources were available, and the decline since that time is linked to much lower moose densities in the past 15 years. However, wolf kill rates, if taken as a metric for raven food availability in winter, appears only weakly correlated to raven abundance in summer. We believe that an investigation of raven population dynamics at Isle Royale is warranted.

Many species showing significant changes are following broader population changes regionally or across North America. Trends in current results suggest that species such as bay-breasted warbler, Cape May warbler, or evening grosbeak experienced a peak in the mid-1990s when bird surveys began. Publications from the 1960s and 1980s note these species as regular migrants but rare or unknown as breeding populations (e.g., Johnsson et al. 1982). Therefore, significant declines among these species in recent years may signal a return to what may be typical numbers. Significant regional declines of species already rare on Isle Royale, along with apparently limited habitat for these species, are expected to further limit potential breeding on the island regardless of pristine conditions. Future analyses of breeding bird survey data should consider correspondence analysis to see if diet, habitat, or other key factors are potentially influential factors for population variations for Isle Royale avian communities.

Literature Cited

Adams, C. C., editor. 1909. An Ecological Survey of Isle Royale, Lake Superior. State Biological Survey, Lansing, Michigan.

Arcese, P., M. K. Sogge, A. B. Marr, and M. A. Patten. 2002. Song sparrow (*Melospiza melodia*). *In* A. Poole, editor, The Birds of North America Online. Cornell Lab of Ornithology, Ithaca, New York. Available at Birds of North America Online, http://bna.birds.cornell.edu/bna/species/704.

Baltz, M. E., and S. C. Latta. 1998. Cape May warbler (*Setophaga tigrina*). *In* A. Poole, editor, The Birds of North America Online. Cornell Lab of Ornithology, Ithaca, New York. Available at Birds of North America Online, http://bna.birds.cornell.edu/bna/species/332.

Beeman, J. L., and J. G. Oelfke. 1996. 1996 breeding bird survey at Isle Royale National Park, Michigan. Isle Royale National Park Resource Management Report 96–3. National Park Service, Houghton, Michigan.

Beeman, J. L., and J. G. Oelfke. 1997. 1996 breeding bird survey at Isle Royale National Park, Michigan. Isle Royale National Park Resource Management Report 96–3. National Park Service, Houghton, Michigan.

Bibby, C. J., N. D. Burgess, D. A. Hill, and S. H. Mustoe. 2000. Bird Census Techniques, 2nd edition. Elsevier Academic Press, San Diego, California.

Boarman, W. I., and B. Heinrich. 1999. Common raven (*Corvus corax*). *In* A. Poole, editor, The Birds of North America Online. Cornell Lab of Ornithology, Ithaca, New York. Available at Birds of North America Online, http://bna.birds.cornell.edu/bna/species/476.

Booth, C. J. 1979. A study of ravens in Orkney. *Scottish Birds* 10:261–267.

Breeding Bird Atlas Explorer. 2012. U.S. Geological Survey Patuxent Wildlife Research Center and National Biological Information Infrastructure. Available online http://www.pwrc.usgs.gov/bba/index.cfm?fa=explore.ProjectHome&BBA_ID=MI2002 (accessed 27 July 2012).

Brewer, R., G. A. McPeek, and R. J. Adams. 1991. The Atlas of Breeding Birds of Michigan. Michigan State University Press, East Lansing, Michigan.

Buckland, S. T., A. E. Magurran, R. E. Green, and R. M. Fewster. 2005. Monitoring change in biodiversity through composite indices. *Philosophical Transactions of the Royal Society (B)* 360:243-254.

Egan, A. T. 2009. Breeding bird monitoring at Isle Royale National Park, Michigan: 1996-2008. Natural Resource Technical Report NPS/GLKN/NRTR—2009/160. National Park Service, Fort Collins, Colorado.

Evers, D. C., 1991. Common raven, *Corvus corax*. Pages 318-319 *in* R. Brewer, G.A. McPeek,

and R.J. Adams, Jr., editors. The Atlas of Breeding Birds of Michigan. Michigan State University Press, East Lansing, Michigan.

Fowler, J., L. Cohen and P. Jarvis. 1998. Practical Statistics for Field Biology, 2nd edition. John Wiley and Sons, West Sussex, England.

Geissler, P. H., and J. R. Sauer. 1990. Topics in route-regression analysis. Pages 54-57 *in* J. R. Sauer and S. Droege, editors. Survey designs and statistical methods for the estimation of avian population trends. U. S. Fish and Wildlife Service Biological Report 90(1).

Gostomski, T. J. 1996. Royale rarities: Notes on unique bird observations in 1995 at Isle Royale National Park, Michigan. *Michigan Birds and Natural History* 3:69-76.

Gostomski, T. J., and J. G. Oelfke. 1994. Results of the 1994 breeding bird survey: Isle Royale National Park, Michigan. Isle Royale National Park Resource Management Report 94–1. National Park Service, Houghton, Michigan.

Hannon, S. J., and P. Drapeau. 2005. Bird responses to burns and clear cuts in the boreal forest of Canada. Pages 1104-1106 *in* C. J. Ralph and T. D. Rich, editors. Bird conservation implementation and integration in the Americas: Proceedings of the third international Partners in Flight conference (volume 2). General Technical Report PSW–GTR–191. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, California.

Hanowski, J. M., and G. J. Niemi. 1995. A comparison of on- and off-road bird counts: Do you need to go off road to count birds accurately? *Journal of Field Ornithology* 66:469-483.

Howe, R. W., G. J. Niemi, S. J. Lewis, and D. A. Welsh. 1997. A standard method for monitoring songbird populations in the Great Lakes region. *Passenger Pigeon* 59:183-194.

Huber, N. K. 1973. Glacial and postglacial geologic history of Isle Royale National Park, Michigan. Geological Survey Professional Paper 754-A. U.S. Government Printing Office, Washington, D.C.

Hutto, R. L. 2005. Northern region landbird monitoring program: A program designed to monitor more than long-term population trends. Pages 956-962 *in* C. J. Ralph and T. D. Rich, editors. Bird conservation implementation and integration in the Americas: Proceedings of the third international Partners in Flight conference (volume 2). General Technical Report PSW–GTR–191. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, California.

Hutto, R. L., S. J. Hejl, J. F. Kelly, and S. M. Pletschet. 1995. A comparison of bird detection rates derived from on-road versus off-road point counts in northern Montana. Pages 103-110 *in* C. J. Ralph, J. R. Sauer, and S. Droege, editors. Monitoring bird populations by point counts. General Technical Report PSW-GTR-149. USDA Forest Service, Albany, CA.

Hutto, R. L., and C. J. Ralph. 2005. Introduction — Regional monitoring programs. Pages 924-925 *in* C. J. Ralph and T. D. Rich, editors. Bird conservation implementation and integration

in the Americas: Proceedings of the third international Partners in Flight conference (volume 2). General Technical Report PSW–GTR–191. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, California.

Janke, R. A. 1964. The Birds of Isle Royale. Isle Royale Natural History Association, Houghton, Michigan.

Janke, R. A., C. Peterson, R. O. Peterson, and T. Lindsay. 1994. Isle Royale National Park checklist of birds. Isle Royale Natural History Association, Houghton, Michigan.

Johnsson, R. G., P. C. Shelton, and P. A. Jordan. 1982. Wildlife of Isle Royale, revised edition. Isle Royale Natural History Association, Houghton, Michigan.

Keller, C. M. E., and M. R. Fuller. 1995. Comparisons of birds detected from roadside and off-road point counts in the Shenandoah National Park. Pages 111-115 *in* C. J. Ralph, J. R. Sauer, and S. Droege, editors. Monitoring bird populations by point counts. General Technical Report PSW-GTR-149. USDA Forest Service, Albany, CA.

Krefting, L. W., F. B. Lee, P. C. Shelton, and K. T. Gilbert. 1966. Birds of Isle Royale in Lake Superior. Special Scientific Report – Wildlife No. 94. Washington, D.C.

Lind, J., N. Danz, and J. Hanowski. 2005. Analysis of landbird monitoring data for national parks in the Great Lakes Network. Great Lakes Network Report GLKN/2005/08, National Park Service, Ashland, Wisconsin.

Loreau, M., S. Naeem, P. Inchausti, J. Bengtsson, J. P. Grime, A. Hector, D. U. Hooper, M. A. Huston, D. Raffaelli, B. Schmid, D. Tilman, and D. A. Wardle. 2001. Biodiversity and ecosystem functioning: Current knowledge and future challenges. *Science* 294:804-808.

Luginbuhl, J. M., J. M. Marzluff, J. E. Bradley, M. G. Raphael, and D. E. Varland. 2001. Corvid survey techniques and the relationship between corvid relative abundance and nest predation. *Journal of Field Ornithology* 72:556–572.

Magurran, A. E. 2004. Measuring Biological Diversity. Blackwell Publishing, Oxford, United Kingdom.

Martin, C. J. 1989. Additions to the bird fauna of Isle Royale National Park, Keweenaw County, Michigan. *The Jack-Pine Warbler* 67: 66-69

Matteson, S., K. Kreitinger, G. Bartelt, G. Butcher, D. Sample, and T. Will. 2009. Partners in Flight bird conservation plan for the boreal hardwood transition (Bird Conservation Region 12 — U.S. portion). Version 1.0. Partners in Flight. Available from www.partnersinflight.org/bcps/plan/BCR%2012-US%20Plan.pdf (accessed 26 July 2012).

McGraw, K. J., and A. L. Middleton. 2009. American goldfinch (*Spinus tristis*). *In* A. Poole, editor, The Birds of North America Online. Cornell Lab of Ornithology, Ithaca, New York. Available at Birds of North America Online, http://bna.birds.cornell.edu/bna/species/080.

McInnes, P. F., R. J. Naiman, J. Pastor, and Y. Cohen. 1992. Effects of moose browsing on vegetation and litter of the boreal forests, Isle Royale, Michigan, USA. Ecology 73:2059-2075.

Midwest Coordinated Bird Monitoring Partnership (MCBMP). 2012. Registry of Midwest bird monitoring programs, Version 2.0. Available from http://midwestbirdmonitoring.ning.com/page/registry-of-midwest-bird (accessed 27 July 2012).

Murie, A. 1934. The Moose of Isle Royale. University of Michigan Museum of Zoology Miscellaneous Publications No. 25. University of Michigan Press, Ann Arbor, Michigan.

NABCI (North American Bird Conservation Initiative, U.S. Committee). 2011. The state of the birds 2011 report on public lands and waters. U.S. Department of the Interior, Washington, D.C.

Nogales, M. 1994. High density and distribution patterns of a raven *Corvus corax* population on an oceanic island (El Hierro, Canary Islands). *Journal of Avian Biology* 25:80–84.

Nur, N., S. L. Jones, and G. R. Geupel. 1999. A statistical guide to data analysis of avian monitoring programs. U.S. Department of the Interior, Fish and Wildlife Service, BTP-R6001-1999, Washington, D.C.

Payne, L. X., D. E. Schindler, J. K. Parrish, and S. A. Temple. 2005. Quantifying spatial pattern with evenness indices. *Ecological Applications* 15: 507-520.

Peet, M. M. 1909. Annotated list of the birds of Isle Royale, Michigan. Pages 4337–386 *in* C. C. Adams, editor. An Ecological Survey of Isle Royale, Lake Superior. State Biological Survey, Lansing, Michigan.

Ralph, C. J., G. R. Geupel, P. Pyle, T. E. Martin, and D. F. DeSante. 1993. Handbook of field methods for monitoring landbirds. General Technical Report PSW–GTR–144. Pacific Southwest Research Station, USDA Forest Service, Albany, California.

Ralph, C. J., J. R. Sauer, and S. Droege (editors). 1995. Monitoring bird populations by point counts. General Technical Report PSW–GTR–149. Pacific Southwest Research Station, USDA Forest Service, Albany, California.

Ratcliffe, D. A. 1962. Breeding density in the peregrine *Falco peregrinus* and raven *Corvus corax*. *Ibis* 104:13–39.

Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, D. J. Ziolkowski, and W. A. Link. 2010. The North American breeding bird survey, results and analysis 1966–2010. Version 12.07.2011. USGS Patuxent Wildlife Research Center, Laurel, Maryland.

Sherry, T. W. and R. T. Holmes. 1997. American Redstart (*Setophaga ruticilla*). *In* A. Poole, editor, The Birds of North America Online. Cornell Lab of Ornithology, Ithaca, New York. Available at Birds of North America Online. http://bna.birds.cornell.edu/bna/species/277.

Southwood, T. R. E., and P. A. Henderson. 2000. Ecological Methods, 3rd edition. Blackwell Publishing, Massachusetts.

Stahler, D., B. Heinrich, and D. Smith. 2002. Common ravens, *Corvus corax*, preferentially associate with grey wolves, *Canis lupus*, as a foraging strategy in winter. *Animal Behaviour* 64:283-290.

Tarof, Scott and James V. Briskie. 2008. Least Flycatcher (*Empidonax minimus*). *In* A. Poole, editor, The Birds of North America Online. Cornell Lab of Ornithology, Ithaca, New York. Available at Birds of North America Online. http://bna.birds.cornell.edu/bna/species/099

Thogmartin, W. E., B. R. Gray, M. Gallagher, N. Young, J. J. Rohweder, and M. G. Knutson. 2007. Power to detect trend in short-term time series of bird abundance. *Condor* 109:943-948.

Van Buskirk, J., and D. C. Smith. 1994. Birds of northeastern Isle Royale National Park, 1981–1994. Unpublished report to Isle Royale National Park Resource Management. National Park Service files, Houghton, Michigan.

Verbeek, N. A., and C. Caffrey. 2002. American crow (*Corvus brachyrhynchos*). *In* A. Poole, editor, The Birds of North America Online. Cornell Lab of Ornithology, Ithaca, New York. Available at Birds of North America Online. http://bna.birds.cornell.edu/bna/species/647.

Vucetich, J. A., and R. O. Peterson. 2012. The population biology of Isle Royale wolves and moose: An overview. Available online at www.isleroyalewolf.org.

Vucetich, J. A., R. O. Peterson, and T. A. Waite. 2004. Raven scavenging favors group foraging in wolves. *Animal Behaviour* 67:1117-1126.

Walker, B., C. S. Holling, S. R. Carpenter, and A. Kinzig. 2004. Resilience, adaptability and transformability in social-ecological systems. Ecology and Society 9:5. Online at www.ecologyandsociety.org/vol9/iss2/art5.

Yasukawa, K., and W. A. Searcy. 1995. Red-winged blackbird (*Agelaius phoeniceus*). *In* A. Poole, editor, The Birds of North America Online. Cornell Lab of Ornithology, Ithaca, New York. Available at Birds of North America Online, http://bna.birds.cornell.edu/bna/species/184.

Zavaleta, E. S., and F. S. Chapin III. 2010. Resilience frameworks: Enhancing the capacity to adapt to change. Pages 142-158 in D. N. Cole and L. Yung, editors, Beyond Naturalness: Rethinking Park and Wilderness Stewardship in an Era of Rapid Change. Island Press, Washington, D.C.

Appendix A: Common and Scientific Names for Bird Species (AOU 1998).

Common Name	Scientific Name
Alder flycatcher	*Empidonax alnorum*
American bittern	*Botaurus lentiginosus*
American crow	*Corvus brachyrhynchos*
American goldfinch	*Spinus tristis*
American redstart	*Setophaga ruticilla*
American robin	*Turdus migratorius*
Barn swallow	*Hirundo rustica*
Bay-breasted warbler	*Setophaga castanea*
Belted kingfisher	*Megaceryle alcyon*
Black-and-white warbler	*Mniotilta varia*
Black-backed woodpecker	*Picoides arcticus*
Black-billed cuckoo	*Coccyzus erythropthalmus*
Blackburnian warbler	*Setophaga fusca*
Black-capped chickadee	*Poecile atricapillus*
Black-headed grosbeak	*Pheucticus melanocephalus*
Black-throated blue warbler	*Setophaga caerulescens*
Black-throated green warbler	*Setophaga virens*
Blue-headed vireo	*Vireo solitarius*
Blue jay	*Cyanocitta cristata*
Brown creeper	*Certhia americana*
Brown-headed cowbird	*Molothrus ater*
Brown thrasher	*Toxostoma rufum*
Canada warbler	*Cardellina canadensis*
Cape May warbler	*Setophaga tigrina*
Cedar waxwing	*Bombycilla cedrorum*
Chestnut-sided warbler	*Setophaga pensylvanica*
Chimney swift	*Chaetura pelagica*
Chipping sparrow	*Spizella passerina*
Common grackle	*Quiscalus quiscula*
Common raven	*Corvus corax*
Common yellowthroat	*Geothlypis trichas*
Connecticut warbler	*Oporornis agilis*
Dark-eyed junco	*Junco hyemalis*
Downy woodpecker	*Picoides pubescens*
Eastern bluebird	*Sialia sialis*
Eastern kingbird	*Tyrannus tyrannus*
Eastern phoebe	*Sayornis phoebe*
Eastern wood-pewee	*Contopus virens*
Evening grosbeak	*Coccothraustes vespertinus*
Gray catbird	*Dumetella carolinensis*
Gray jay	*Perisoreus canadensis*
Great crested flycatcher	*Myiarchus crinitus*
Golden-crowned kinglet	*Regulus satrapa*
Hairy woodpecker	*Picoides villosus*
Hermit thrush	*Catharus guttatus*
Indigo bunting	*Passerina cyanea*
Least flycatcher	*Empidonax minimus*
Magnolia warbler	*Setophaga magnolia*

Appendix A: Common and Scientific Names for Bird Species (AOU 1998) (continued).

Common Name	Scientific Name
Marsh wren	*Cistothorus palustris*
Mourning dove	*Zenaida macroura*
Mourning warbler	*Geothlypis philadelphia*
Nashville warbler	*Oreothlypis ruficapilla*
Northern cardinal	*Cardinalis cardinalis*
Northern flicker	*Colaptes auratus*
Northern parula	*Setophaga americana*
Northern waterthrush	*Parkesia noveboracensis*
Olive-sided flycatcher	*Contupus cooperi*
Orange-crowned warbler	*Oreothlypis celata*
Ovenbird	*Seiurus aurocapilla*
Palm warbler	*Setophaga palmarum*
Philadelphia vireo	*Vireo philadelphicus*
Pine grosbeak	*Pinicola enucleator*
Pine siskin	*Spinus pinus*
Pine warbler	*Setophaga pinus*
Pileated woodpecker	*Dryocopus pileatus*
Purple finch	*Haemorhous purpureus*
Red-breasted nuthatch	*Sitta canadensis*
Red crossbill	*Loxia curvirostra*
Red-eyed vireo	*Vireo olivaceus*
Red-winged blackbird	*Agelaius phoeniceus*
Rose-breasted grosbeak	*Pheucticus ludovicianus*
Ruby-crowned kinglet	*Regulus calendula*
Scarlet tanager	*Piranga olivacea*
Sedge wren	*Cistothorus platenses*
Song sparrow	*Melospiza melodia*
Sora	*Porzana carolina*
Swainson's thrush	*Catharus ustulatus*
Swamp sparrow	*Melospiza georgiana*
Tennessee warbler	*Oreothlypis peregrina*
Tree swallow	*Tachycineta bicolor*
Veery	*Catharus fuscescens*
Warbling vireo	*Vireo gilvus*
White-breasted nuthatch	*Sitta carolinensis*
White-throated sparrow	*Zonotrichia albicollis*
White-winged crossbill	*Loxia leucoptera*
Willow flycatcher	*Empidonax traillii*
Wilson’s snipe	*Gallinago delicata*
Winter wren	*Troglodytes hiemalis*
Wood thrush	*Hylocichla mustelina*
Yellow-bellied flycatcher	*Empidonax flaviventris*
Yellow-bellied sapsucker	*Sphyrapicus varius*
Yellow-billed cuckoo	*Coccyzus americanus*
Yellow-breasted chat	*Icteria virens*
Yellow-headed blackbird	*Xanthocephalus xanthocephalus*
Yellow-rumped warbler	*Setophaga coronata*
Yellow warbler	*Setophaga petechia*

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov