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New Life Member

Doris Day of Tecumseh, Michigan, was born in Plymouth, Michigan, where she attended school graduating as valedictorian of her high school class. Next she attended Eastern Michigan College for two years, then was married and moved to a farm just west of Tecumseh. Farming full time, while raising her family, she came to realize she could not put her daughters through college from the farm profits so she returned to college. In time she graduated from Eastern Michigan University with a B.S. in library science and then went to work for the Tecumseh Public Library where she was on the staff for fourteen years.

Her husband eventually gave up the uneven occupation of farming and went into the gravel hauling business. They were successful enough to build a fine new house on a remote portion of the farm overlooking a meander of Evans Creek, whose flood plain has a superb stand of mature beech-maple climax forest. The curve of the river frames their back yard and the attractive landscaping makes it one of the most beautiful bird feeding areas I have ever seen. Her husband Murray took [illegible] ure in designing the area for just this purpose. With the children [illegible] way from home she began to lead field trips at Hidden Lake Gardens [illegible] and in a short time was part of Jack Wikle's staff. She had the [illegible] five years working in this beautiful botanical garden.

Her hobbies are gardening, music, and square dancing. [illegible] these is quite evident in the beauty of her back yard. It is my hope that Doris [illegible] able to attend some of M.A.S. campouts. She would be fun to share [illegible] field trip with because she would be able to offer so much on her own.

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B. IRVINE

Factors Influencing Kirtland's Warbler Nesting Success

Cowbirds are, indeed, a major threat to warbler nesting but, happily, careful research seems not to be harmful.

WALTER L. ANDERSON AND ROBERT W. STORER

Restricted in its breeding range to a few counties in the northern part of Michigan's lower peninsula, the Kirtland's Warbler (*Dendroica kirtlandii*) is classified as an endangered species and is a subject of national concern. Comprehensive counts of singing males revealed a decline from 502 males in 1961 to a low of 167 males in 1974 (Mayfield 1975). The 1975 count of 179 males (Ryel 1976) and the 1976 count of 200 males (Ryel pers. comm.) are encouraging, but it would be premature to predict that the decline has been arrested.

Nearly all Kirtland's Warbler nests have been found within the drainage of the Au Sable River. The bird appears to favor jack pine (*Pinus banksiana*) stands between 6 and 18 feet in height, usually associated with regeneration after fires. Occasionally red pine (*P. resinosa*) plantations of similar height are occupied. There is a tendency for loose clumping of territories into "colonies" (Wood 1904).

The Brown-headed Cowbird (*Molothrus ater*) is a brood parasite known to have an adverse effect on Kirtland's Warbler nesting success (Mayfield 1960, Walkinshaw 1972, Walkinshaw and Faust 1974, 1975, Shake and Mattson 1975). This warbler is an "acceptor" species, tending to care for cowbird eggs and young which have replaced its own (Rothstein 1974). Mayfield (1965) suggests that the 2 species evolved in separate geographic areas; forest clearing and livestock raising by white settlers may have enabled the cowbird to invade the Kirtland's Warbler's breeding grounds within the past 80 years. Without evolved defense mechanisms and with a small gene pool, the highly localized Kirtland's Warbler appears particularly vulnerable to serious losses through cowbird parasitism (Mayfield 1960, Rothstein 1975).

Even though the adverse effects of cowbird parasitism have long been recognized, other factors that may influence nesting success have been less well documented, and no analysis of even a majority of the available nest records has been undertaken.

In this study we have attempted to collate most existing nesting data, relate these data to environmental factors, and seek statistical relationships which may provide useful management recommendations. The project posed 3 major questions: (1) Is the impact of cowbirds on Kirtland's Warbler nesting success readily detectable by statistical techniques? (2) Do other environmental variables influence nesting success? (3) Finally, does the gathering of scientific data itself pose a threat to the reproductive success of these birds?

Methods and Materials

Initially we selected 47 variables which might affect Kirtland's Warbler nesting success, designed data forms to record these variables, and sent forms with instructions to cooperators. These forms included questions about the stands which the birds used, the size of the colonies, the individual nest sites, and the amount of possible disturbance by investigators. The sources of these data are listed in the Acknowledgments.

The assessment of habitat influences on the warblers necessitated collecting ecological information not ordinarily included in nest record systems. Reconstructing this information proved to be the most time-consuming part of this study. Data for each nest having sufficient basic information on nesting success were entered on computer cards to remain in a permanent data bank at the University of Michigan. New cards will be added as more nests are studied.

For this analysis we used data for 545 nests representing nesting information gathered from 1931 to 1975. We tested differences among means and variances by Student's t-test (if two strata) or by one-way analysis of variance (if three or more strata). For the latter where significant differences were shown to exist, we performed Scheffé multiple comparison procedures to detect which of the various means were significantly different. The decision rule was to reject the null hypothesis of equal means and variances if $p < .05$. If the assumptions of the statistical model failed to hold, we applied Bayesian posterior probability or Kruskal-Wallis nonparametric tests. All inferences were consistent regardless of type of test. Where necessary, we created new categorical variables for a better test of the effects across certain ranges. Finally we checked for correlations among the variables. The data were analyzed using MIDAS, a library of computer programs at the University of Michigan Computing Center.

Results

Walkinshaw (1972) gives evidence to show that the Kirtland's Warbler is parasitized far more heavily by cowbirds than are other passerines within its breeding habitat. Reproductive success varies dramatically according to the number of cowbird eggs present in the completed warbler clutch (Fig. 1). Effective sample sizes are 470 nests at clutch completion, 486 nests at hatching, and 425 nests at fledgling. Differences in sample sizes reflect the fact that some nests were not observed at all stages of the nesting cycle. The number of Kirtland's Warbler eggs in the clutch does not necessarily equal the number laid because cowbirds tend to remove 1 or more of the host's eggs in parasitized nests.

The disparity between number of warbler eggs in the clutch and the number of warblers which hatch or fledge increases as the number of cowbird eggs increases (Fig. 1). Mayfield (1960) found that no nests in which 2 or more cowbirds hatched ahead of the warblers succeeded in fledging warbler young. The implication in Figure 1 that some warblers succeeded with 4 or more cowbird eggs present arises only because of

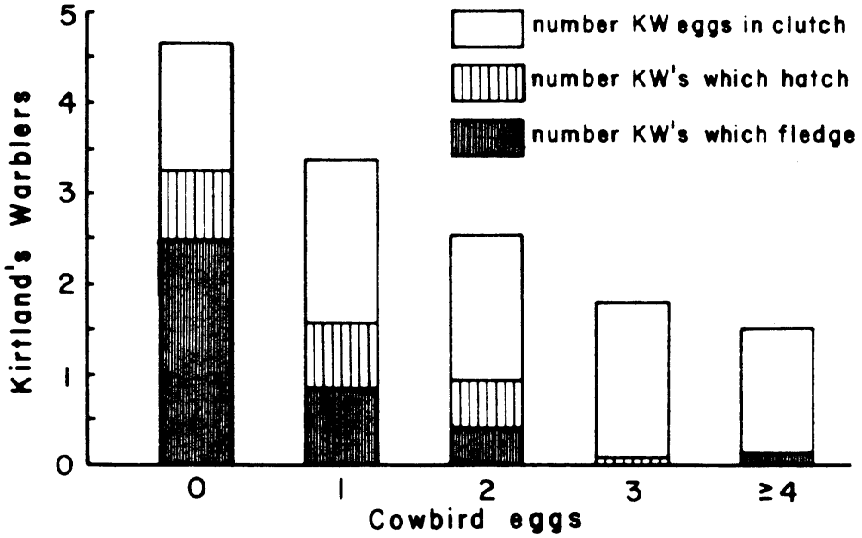

FIG. 1. Kirtland's Warbler nesting success in relation to number of cowbird eggs present in the nest when the warbler begins incubation.

a few cases where cowbird eggs were added to the nest after the warbler young had hatched.

Limited control of Brown-headed Cowbirds within the Kirtland's Warbler breeding range was initiated in 1965 by N. L. Cuthbert. Trapping and shooting reduced the parasitism rate from 65 to 21 percent within the area of control (Cuthbert and Radabaugh, unpublished). Trapping proved to be more effective than shooting and was increased substantially beginning in 1972; more than 4000 cowbirds were removed from Kirtland's Warbler habitat in 1974 alone (Shake and Mattson 1975). For 472 nests at clutch completion, 488 nests at hatching, and 492 nests at fledging, cowbird control effectively increased warbler nesting success (Fig. 2). All differences were highly significant ($p < .001$). Twice as many young fledged with cowbird control as without (2.28 vs. 1.11 young, respectively).

Among the environmental parameters we examined, the presence or absence of large trees and snags (older trees not leveled by the fire or clearing which created the jack-pine habitat) proved to be most closely tied to differential warbler success (Table 1). The A columns for all nests show significantly higher means for Kirtland's Warblers at all nest stages when large trees and snags were absent than when present. The B columns show that no differences are apparent when only non-parasitized nests are considered. These data indicate that the differences in nesting success reflect cowbird pressure. It has been suggested that cowbirds use tall trees or snags as lookouts from which they can more readily watch nesting Kirtland's Warblers.

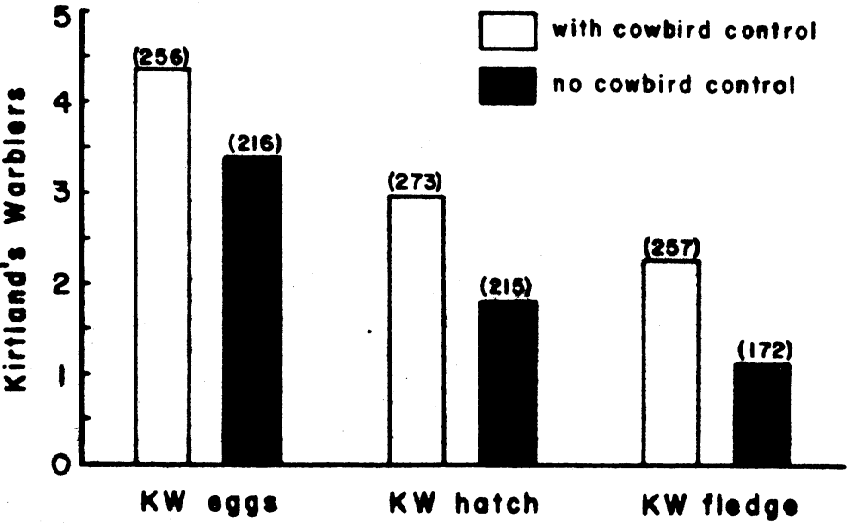

FIG. 2. Kirtland's Warbler nesting success in relation to the presence or absence of cowbird control in the stand which includes the nest.

Further evidence supporting the implied linkage between nearness to large trees or snags and cowbird parasitism is suggested by Table 2. There were significantly smaller warbler clutches near large trees when there was no cowbird control, but equal clutch sizes at all distances when cowbird control was in effect for the stand containing the nest. Nests less than 25 feet from a large tree or snag had substantially smaller warbler clutches when there was no cowbird control and when only parasitized nests were considered. The latter observation suggests that even among parasitized nests, proximity to a large tree or snag decreases warbler success. For the 24 parasitized nests for which distance to the nearest large tree was available, those within 25 feet of a large tree averaged 2.00 cowbird eggs and those further than 25 feet averaged 1.56 cowbird eggs. This apparent difference is not statistically significant, but if the trend holds as more data become available, we might infer that not only is parasitism higher near large trees but also multiple parasitism may be higher.

An important question is whether or not any factor other than cowbird pressure might be involved with decreased warbler success close to large trees or snags. For non-parasitized nests at clutch completion, mean number of warbler eggs was 4.70 and 4.69 for presence versus absence of large trees/snags respectively; at fledging there were 2.50 and 2.79 young respectively. Even though this difference is not statistically significant with present sample size, it is worthwhile considering whether the apparent difference at fledging could have any biological significance. For instance, a somewhat higher predation rate might be associated with large trees or snags.

TABLE 1. The relationship between presence and absence of large trees or snags and nesting data for Kirtland's Warblers (KW) and Brown-headed Cowbirds (CB). Sample sizes in parentheses. A = all nests; B = non-parasitized nests only.

Large trees or snags	Number of KW eggs		Number of KW hatched		Number of KW fledged		Number of CB eggs
	A	B	A	B	A	B	A
Present	3.96	4.70	2.41	3.13	1.87	2.50	0.67
	(238)	(138)	(240)	(149)	(199)	(130)	(269)
Absent	4.44	4.69	3.01	3.30	2.51	2.78	0.20
	(73)	(65)	(84)	(76)	(84)	(76)	(89)
Significance (p)	.003	.97	.018	.54	.016	.36	.0001

As a further test, we examined nest distance from the nearest large tree in relation to nest "failure," which we defined 0-1 warblers fledged, and to nest "success," defined as at least 2 warblers fledged. We looked only at non-parasitized nests. Successful nests averaged about 40 feet further from the nearest large tree than did unsuccessful nests (153 and 115 feet, respectively). The difference was again not significant, but sample size (30 nests) was too small for the test to be considered sensitive.

Taken together, these two tests suggest that there may be some factor apart from parasitism to account for lower warbler success when the nest is close to a large tree or snag, but that any such effect is minor and insignificant relative to cowbird effects. Distance to nearest large tree or snag should be measured in all future studies so that with a larger sample such effects may be detected.

The Blue Jay is well known as a nest predator and is considered a threat to Kirtland's Warbler nesting success (Mayfield 1960). In 1973 and 1974, 513 jays were trapped on the warbler's nesting grounds, banded, and released near Cheboygan, Michigan (Shake and Mattson 1975). Possibly jays or other predators use large trees or snags as lookouts from which to locate prey nests, but we have no behavioral evidence to support

TABLE 2. Mean number of Kirtland's Warbler eggs in relation to distance from nearest large tree, stratified by presence or absence of cowbird control and by presence or absence of cowbird parasitism. Sample sizes in parentheses.

Distance from nearest large tree	No CB control	With CB control	Parasitized nests	Non-parasitized nests
≤ 25 feet	3.00 (9)	4.50 (6)	2.83 (6)	4.63 (8)
26-100 feet	4.14 (14)	4.33 (3)	3.78 (9)	4.63 (8)
> 100 feet	4.38 (16)	4.40 (10)	4.11 (9)	4.53 (17)
Significance (p)	.026	.98	.12	.96

TABLE 3. Kirtland's Warbler nesting success in relation to mean stand height. Sample sizes in parenthesis. A = parasitized nests, B = non-parasitized nests.

Mean stand height	Number of KW eggs		Number of KW hatched		Number of KW fledged	
	A	B	A	B	A	B
< 10 feet	2.74 (63)	4.65 (107)	0.88 (59)	3.38 (119)	0.58 (57)	2.69 (106)
≥ 10 feet	2.81 (104)	4.64 (182)	1.18 (103)	3.12 (188)	0.50 (82)	2.32 (161)
Significance (p)	.75	.85	.16	.24	.65	.15

this hypothesis. Regardless of whether or not the cowbird effects are supplemented by some additional negative factor, the evidence all points to improved warbler success if tall trees and snags are eliminated from those stands managed for Kirtland's Warbler breeding.

Mean tree height within the occupied stand has been suggested as a factor which may affect warbler nesting success. Walkinshaw (1972) found in his sample that 40% of the young fledged from nests in stands averaging up to 15 feet tall compared to 51% for nests in taller stands. Table 3 shows the composite results for data from many researchers. Nesting success appears unaffected by stand height, at least within the range of pine heights accepted by the birds. Varying the heights used to define classes also has no effect. When columns A and B are compared, the depressing effects of cowbird parasitism are again evident.

The number of singing males is a good measure of colony size since few males are polygynous (Mayfield 1960, Radabaugh 1972). As is to be expected, significantly more Kirtland's Warblers occupied larger jack pine stands than small stands (Table 4). There were no significant differences in reproductive success with respect to stand size (though there appears to be an increase in number fledged as stand size, and with it, the number of singing males increase; Table 4). Larger samples from small stands are needed to assess this trend and to differentiate between the possible effects of stand size and the number of singing males present. Cowbird parasitism showed no consistent relationship with stand or colony size. For 281

TABLE 4. Number of singing males and fledging success for Kirtland's Warblers in relation to stand size.

Stand size (acres)	Number of singing males	Sample size	Number of KW fledged	Sample size	Number of KW fledged
< 100	8.27	26	.87	15	1.32
100-199	10.47	34	1.63	22	
≥ 200	28.04	400	1.87	387	1.87
Significance (p)	.001		.15		.12

TABLE 5. Kirtland's Warbler nesting success in relation to colony age. Sample sizes in parentheses.

Colony age in years	Number of KW eggs	Number of KW hatched	Number of KW fledged
≤ 5	4.02 (58)	2.49 (59)	1.86 (49)
6-13	3.74 (92)	2.20 (88)	1.66 (76)
≥ 14	3.93 (194)	2.50 (200)	1.62 (184)
Significance (p)	.40	.50	.75

nests, mean stand size for "failure" nests (0-1 fledglings) was 708 acres, compared to 722 acres for "successful" nests fledging at least two young; the difference is not significant. Mayfield (1960) believes that otherwise suitable habitat may not be used if stands are too small. Few warblers nest in stands of less than 200 acres; of the nests used in calculating fledging statistics (right side of Table 4), only 37 were in stands of less than 200 acres whereas the remaining 387 were in stands of 400 or more acres. If natural selection has favored individuals choosing large stands for breeding, we would expect to find few small stands occupied. Clearly management plans should contain provisions for assuring large stands to maintain viable breeding populations.

Density of breeding birds cannot be determined directly from a knowledge of stand size and population, for colonies do not occupy all of what appears to be suitable habitat. There are at present too few data available to relate territory size to resource availability, though Mayfield (1960) believed that food by itself accounted for differences in territory size.

We speculated that young colonies might be composed of inexperienced birds that might have lower reproductive success than older birds and that there might be a decline in breeding success in the last years a stand is occupied. Mayfield (*in litt.*) points out "the almost certain correlation between the age of the females and the age of the colony (or stand), since there is considerable site fidelity in successive years." We found no differences in breeding success related to colony age (Table 5). Similarly, nesting success for 22 one-year-old females did not differ significantly from that of 116 older females (Table 6). Walkinshaw and Faust (1974) had comparable results for 3 one-year-old females nesting in 1973.

TABLE 6. Kirtland's Warbler and cowbird nesting success in relation to age of breeding female warbler. Sample sizes in parentheses.

Age of female	Number of KW eggs	Number of KW hatched	Number of KW fledged	Number of CB eggs
One year old	4.19 (21)	2.71 (21)	2.06 (18)	0.32 (22)
Older than one	3.99 (104)	2.39 (111)	1.72 (92)	0.69 (116)
Significance (p)	.50	.50	.52	.13

TABLE 7. Kirtland's Warbler nesting success in relation to ground cover density. Sample sizes in parentheses.

Ground cover density	Number of KW eggs	Number of KW hatched	Number of KW fledged	Number of CB eggs
Thick	3.72 (36)	1.82 (40)	1.37 (30)	0.93 (42)
Moderate	4.00 (54)	2.42 (50)	1.56 (39)	0.65 (55)
Sparse	4.23 (13)	2.73 (11)	2.12 (8)	0.69 (13)
Significance (p)	.38	.25	.64	.40

Orr (1975) reported that Walkinshaw and others suspected that red pine plantations with straight rows form travel lanes by which cowbirds and other predators might more easily discover Kirtland's Warbler nests than in the curved lanes used in plantings of jack pine managed for the warbler. Our analysis indicated that breeding success of warblers was essentially the same in jack pine and red pine stands; nevertheless the hypothesis remains reasonable because most of the red pine stands used in the analysis had cowbird control.

Ground-cover types within which Kirtland's Warbler nests are found have been described by Mayfield (1960) and Orr (1975). Our tests showed no relationship between nesting success and the species of ground cover, or nesting success and the direction which the nest faced. Nesting success also appeared to be independent of the distance between the nest and the edge of the stand.

We also tested the possible effect of ground-cover density on rates of predation and parasitism. The differences were not significant, although we were surprised by the apparent trend of more cowbird eggs and lower warbler success in dense cover (Table 7). In addition there was a non-significant relationship between warbler success and the amount of nest concealment (Table 8), unlike the trend for lower parasitism of Song Sparrow (*Melospiza melodia*) nests that were well-concealed (Nice 1937).

Surprisingly, we found significant differences at nearly all levels when we considered topography, with lower warbler success in hilly terrain than in flat (Table 9). Further inspection revealed that the cowbird pressure was higher in hilly terrain, even after a cowbird control program. This implies that cowbird control was either less thorough or less effective in hilly than in flat terrain. For 278 non-parasitized nests only, there were no

TABLE 8. Kirtland's Warbler nesting success in relation to nest concealment. Sample sizes in parentheses.

Nest concealment	Number of KW eggs	Number of KW hatched	Number of KW fledged	Number of CB eggs
Heavy	3.97 (37)	2.21 (42)	1.91 (34)	0.70 (44)
Moderate	3.88 (50)	2.23 (44)	1.39 (36)	0.69 (51)
Light	4.43 (14)	2.00 (13)	1.67 (12)	0.47 (15)
Significance (p)	.29	.93	.55	.67

TABLE 9. Kirtland's Warbler and cowbird nesting success in relation to topography. Sample sizes in parentheses. A = cowbird control, B = no cowbird control.

	Number of KW eggs		Number of KW hatched		Number of KW fledged		Number of CB eggs		
Topography	A	B	A	B	A	B	A	B	A+B
Hilly	4.19	3.25	2.92	1.62	2.03	.91	.37	1.30	.72
	(156)	(101)	(159)	(104)	(144)	(87)	(179)	(107)	(286)
Flat	4.65	3.64	3.04	2.18	2.58	1.38	.09	.90	.49
	(100)	(101)	(114)	(98)	(113)	(73)	(121)	(120)	(241)
Significance (p)	.0007	.046	.601	.036	.033	.081	.0008	.007	.010

significant differences in Kirtland's Warbler success between hilly (2.38 fledged) or flat (2.59 fledged) terrain. There is no reason to believe that terrain or some associated variable other than cowbirds significantly affected warbler success.

While it is obviously impossible to determine possible differences between the success of nests which have been visited and those which have not, the high rate of success in visited nests suggests that the difference, if any, is probably slight. The relationship between the number of visits to a nest and its success was tested in various ways. While there were individual cases of photographers or others causing nest desertion or destruction, overall Kirtland's Warbler success did not differ according to the number of visits. Tampering by removing cowbird eggs or young did not increase warbler success, and there were known instances in which removal of cowbirds resulted in the warbler parents abandoning their own eggs or young. Table 10 illustrates the non-significant effects that researcher visits had on warbler success. No decrease in young fledged accompanying increased numbers of visits was apparent. The number of visits during the nestling period is difficult to assess as a mortality factor, since the longer a nest remains active, the more visits it can receive. This results in a statistical artifact suggesting higher nesting success with more visits. Overall, the available data imply that any mortality which may result from disturbance by researchers is not significantly different from natural mortality from other sources.

TABLE 10. Kirtland's Warbler fledging success in relation to researcher visits during laying and incubation.

Number visits during laying and incubation	Number of KW fledged	Sample size
1	1.15	55
2-3	1.56	61
4-6	1.43	74
7-11	1.15	47
> 12	1.20	5
Significance (p)	.71	Total 242

It should be emphasized that these data apply to serious, conscientious researchers and should not be extrapolated to imply that Kirtland's Warblers are insensitive to any form of human disturbance. The existing policy of controlling human access to warbler breeding habitat is a reasonable management practice. The data merely imply that careful research in itself is not a threat to warbler reproduction.

Summary and Recommendations

Statistical analysis of a large sample of Kirtland's Warbler nest records shows that cowbirds are indeed a major threat to Kirtland's Warbler populations on the nesting grounds and that cowbird control does increase warbler fledging success. The presence of large trees or snags correlates with decreased warbler success, primarily because of increased brood parasitism but perhaps also by increased predation. Parasitism by cowbirds, even in areas where they are controlled, may be significantly greater in hilly than in flat terrain. Larger stands have been preferred by Kirtland's Warblers, but warbler success did not appear related to other habitat variables. The number of researcher visits had no effect on warbler reproduction, at least within the range of visits considered.

Suggestions for management include (1) continue local cowbird trapping, as cowbird reduction prior to Kirtland's Warbler nesting effectively increases warbler success, (2) create or encourage extensive jack pine stands free of tall trees or snags, (3) continue research using marked birds of known age; careful research appears not to lower warbler success and is vital to understanding the dynamics of Kirtland's Warbler populations, (4) perform controlled experiments to judge relative effectiveness of habitat management procedures such as burning versus bulldozing and planting, and (5) attempt to evaluate the factors outside the breeding area which may be responsible for limiting the warbler population despite increased fledging rates in recent years.

Acknowledgments

This study has been a cooperative effort, and it is a pleasure to acknowledge the help of those who have contributed original data or assisted in other ways. Nest records were obtained from the North American Nest Record Card Program at Cornell University, and from Bruce E. Radabaugh, Lawrence H. Walkinshaw, and Harold F. Mayfield. The records of Radabaugh and Walkinshaw made up 77% of the 545 nests upon which this study is based, while those of Mayfield, Josselyn Van Tyne, Warren R. Faust, and Craig D. Orr made up an additional 21%. We are particularly grateful to Mayfield, Radabaugh, and Walkinshaw for their efforts in helping us to reconstruct stand histories.

The basic plan of the study was prepared by Storer, who benefited greatly from consultation with members of the Kirtland's Warbler Advisory Committee and Recovery Team. Storer and Anderson designed the data forms and contacted cooperators. Anderson designed the computer statistical analysis and was responsible for collating the data and running programs. Harold Mayfield and Jeffrey Renner contributed many hours in helping assemble and prepare the data for analysis. Gary Fowler and Mark Burghardt advised on statistical application. Rebecca Anderson typed the manuscript and drafted the figures. The work was supported by a grant from the Kirtland's Warbler Fund of the Michigan Audubon Society and by the University of Michigan Museum of Zoology. Anderson held a National Science Foundation Fellowship while this work was done.

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A Note to the Reader

The Jack-Pine Warbler is now received by nearly 5,000 persons, in addition to the nearly 200 institutional and library subscriptions and exchanges. Each of the 5,000 members can, and we hope will, find something of interest in every issue. Among the regional bird journals, *The Jack-Pine Warbler* has long had a reputation for the high scientific quality of its articles. We believe, further, that every article contains material that can be read with enjoyment and benefit by most, although not all, members. In this issue we begin a small innovation aimed at drawing the attention of the reader to longer articles that he or she might like to read. This is the inclusion of a sentence or two just below the title setting forth some interesting feature or finding of the study. We hope that readers will like the change and find it useful. We should point out that any deficiencies in the short statements preceding the articles are to be blamed on the editorial staff and not the authors. – *Ed.*