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Comparing census methods for the endangered Kirtland's Warbler

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ABSTRACT. We compared transect counts used for the annual official count of male Kirtland's Warblers (*Dendroica kirtlandii*) to an observation-based mapping method of individually sighted males in 155 stands over 10 yrs. The annual census count almost tripled from 1990 to 1999. The transect and observation-based mapping method showed the same increasing trend in population between 1990 and 1999, except from 1992 to 1993. The annual official census transect count was consistently higher than the mapping method for stands censused in common. After standardizing for sample size, the annual number of Kirtland's Warblers per stand increased through time with the transect method, while there was a positive, non-significant trend with the mapping method. After 1992, the two methods began diverging in the number of males per stand. The relationship between the differences in count between methods (mapping count minus transect count) to the official transect count varied among years. At the stand level, the transect-method count was greater than the mapping count in 60% of the stands, while the mapping count was greater than the transect count in 16.3% of the stands. The difference in count between methods at the stand level ranged from −43 to +10. We illustrate the difficulties with interpreting transect counts due to Kirtland's Warblers' large territory sizes, occasional double territories, and active territorial defense during early morning hours. We suggest improvements to help correct these sources of error. We conclude that the official census transect counts are a satisfactory relative index, but results should not be interpreted as an absolute count.

SINOPSIS. **Comparación entre métodos de censar a *Dendroica kirtlandii***
Comparamos los conteos de transectos utilizados para el rastreo anual de *Dendroica kirtlandii* con un método de conteo de mapas que se uso para buscar y observar machos en 155 rodales o parches de rboles en un periodo de 10 años. El conteo anual casi se triplicó de 1990 a 1999. El conteo basado en observaciones en reas mostró el mismo incremento de 1990 al 1999, excepto de 1992 a 1993. El conteo de transecto anual resultó consistentemente ms alto que el segundo método para los rodales censados en común. Una vez se estandarizaron las muestras para tamaño, el número anual de aves incrementó por rodal y a través del tiempo al utilizarse el método de transecto, mientras que hubo una tendencia positiva, pero no significativa, usando el método alterno. Luego, del 1992, ambos métodos comenzaron a diferenciarse en el número machos por rodal. La relación entre las diferencias de conteos entre ambos métodos varió entre años. A nivel de rodal el método del transecto resultó mayor que el conteo de mapa en 60% de los rodales, mientras que el conteo de mapa fue mayor que el de los transectos en 16.3% de los rodales. La diferencia entre métodos a nivel de rodales, varió de −43 a +10. Ilustramos las dificultades de interpretar los conteos de esta ave, en los que se utilizan transectos, dado el gran tamaño del territorio y el uso ocasional de doble territorio y la defenza activa del mismo en las primeras horas de la mañana. Sugerimos alternativas para ayudar a corregir las fuentes de error. Concluímos que el método, oficialmente utilizado de transecto, es un índice relativo satisfactorio. Sin embargo dichos resultados no deben interpretarse como conteos absolutos.

Key words: census, *Dendroica kirtlandii*, Kirtland's Warbler, population trends, spot-mapping, transect counts

The Kirtland's Warbler (*Dendroica kirtlandii*) is an endangered, neotropical migrant bird whose known population during the breeding season is currently restricted to the northern Lower Peninsula of Michigan, an area about 120 by 160 km (Probst 1991) and several locations in Wisconsin and the central Upper Peninsula of Michigan (Probst et al. 2003). A Kirtland's Warbler Recovery Plan was developed under the authority of the Endangered Species Act of 1973 (Kepler et al. 1996) after a comprehensive survey in 1971 in northern Lower Michigan found only 201 male Kirtland's Warblers (Mayfield 1972). This was a significant decline in male Kirtland's Warblers

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from a survey conducted in 1951 that found 432 males and a 1961 survey that found 502 males (Mayfield 1953, 1962). Despite extensive cowbird trapping and a subsequent decline in nest parasitism (Walkinshaw 1983; Bocetti 1994), the Kirtland's Warbler population remained stable at about 200 males until 1990, when the population began increasing (Probst and Weinrich 1993), reaching 1202 in 2003 (J. Weinrich, pers. comm.). This trend has been attributed to reduced habitat quantity and quality during the 1970s and 1980s (Probst 1986), followed by a positive response by the warbler to habitat management (Probst and Weinrich 1993).

Among other steps to reverse the population decline, the Kirtland's Warbler management program began conducting annual censuses, which are performed under the direction of the Kirtland's Warbler Recovery Team (KWRT). This team is a cooperative venture of the Michigan Department of Natural Resources, USDA Forest Service, U.S. Fish and Wildlife Service, Michigan Department of Military Affairs, Michigan Audubon Society, and various other private citizens and organizations (Probst and Weinrich 1993). The objective of the annual Kirtland's Warbler census is to count all singing males within the known breeding range in northern Lower Michigan and the eastern and central Upper Peninsula of Michigan as a relative index of the population to help monitor its response to environmental conditions and management practices.

The breeding habitat of Kirtland's Warblers is restricted to relatively dense (> 2000 stems/ha), patchy jack pine (*Pinus banksiana*) stands growing on sandy ecosystems of Michigan (Mayfield 1960; Walkinshaw 1983; Kashian et al. 2003). The breeding sites are typically larger than 30–35 ha, ranging from six to 23 years old, and having trees 1.7 to 5.0 m tall (Probst 1988; Probst and Weinrich 1993). Because of this narrow range of habitat conditions concentrated in large glacial outwash patches, suitable habitat can be readily identified and searched comprehensively for Kirtland's Warblers during the breeding season (Probst et al. 2003).

The official census plays an integral part in the Kirtland's Warbler recovery evaluation and is an invaluable source of information for research. However, the census index has been interpreted by agencies and the public as an accurate indication of the breeding population's absolute size (e.g., Line 2004), even though the KWRT acknowledges that studies have found that survey results often depend on the bird census technique used (Ralph and Scott 1981; Verner 1985; Verner and Ritter 1988; Bibby et al. 2000). If the population's size is an inaccurate estimate, it could affect management commitment or lead to premature delisting from endangered status, and thus the KWRT has encouraged comparisons of the official census to other survey methods.

Since 1985, most of the Kirtland's Warbler population has been surveyed annually as part of broader research conducted by the USDA Forest Service, North Central Research Station (NCRS). This survey does not attempt to count the entire breeding population. It does, however, result in censuses of male Kirtland's Warblers within most of the stands surveyed by the Kirtland's Warbler official census. The NCRS counts of male Kirtland's Warblers were obtained using observation-based mapping methods (herein referred to as the mapping method). Male traits such as song and plumage variation and simultaneous singing were used to distinguish individual males. These surveys have helped re-locate color-banded birds (banding conducted by the U.S. Geological Survey), and the banded males were used as an aid to the NCRS survey.

We noticed a difference between the mapping method and the official survey (herein referred to as the transect method) in the total number of males counted within each stand, the difference in counts being quite substantial at some sites. Our goal in this paper is to evaluate the annual census for its value as a relative count and suggest ways to improve the official transect census. We compared the official count and mapping counts to ask if the annual difference in count of male Kirtland's Warblers between the methods was constant in space and time, if there were any patterns between the difference in counts and independent variables such as stand size, stand age, and the number of days between counts, and if the difference in count between the two methods increased with bird density. We compared methods at the overall population level between years and at the stand level within years. Additionally, we present examples of censuses done by both methods to illustrate factors that might contribute to differing census results.

STUDY AREA AND METHODS

The Kirtland's Warbler official census is conducted annually from 6–15 June. During this time, the males are conspicuous, active singers even after most have established territories and mates (Hayes et al. 1986). The relatively short census period minimizes counting dispersing birds twice. Jack pine stands of suitable size, site quality, and age within the known breeding range in northern Lower Michigan and the central Upper Peninsula of Michigan are surveyed annually for Kirtland's Warblers; suitable jack pine stands in Wisconsin are also surveyed with some regularity (Probst et al. 2003).

The methods for conducting the Kirtland's Warbler official census are standardized (Ryel 1981). Participants (employees of the management agencies and volunteers) census birds daily between sunrise and 11:00 EDT by walking roughly parallel transects (320–400 m apart) through suitable stands. Under good conditions, the song of Kirtland's Warblers can be heard for 400 m. During poor weather conditions, counts are suspended or redone. In larger stands, transects are run simultaneously by different individuals. Smaller breeding areas and potential new habitats are censused by individuals without use of transects. When a male is heard singing, its distance from the transect line is estimated and its trajectory to the bird's location is marked on a map. However, one of us (Huber) noted that a disproportionate number of males were plotted near the transect lines. To help correct distance estimation, the USDA Forest Service phased in a triangulation methodology in the late 1990s, where participants record trajectories to a singing male from multiple locations. After all participants complete their transects for the stand, notes are compared and reconciled to minimize duplicate observations of male locations.

The NCRS mapping surveys were conducted from approximately 17 May to 26 June by 5–7 field personnel each year. All stands occupied by Kirtland's Warblers in the previous year were surveyed. Because Kirtland's Warblers settle in more suitable stands first (Probst 1988), the stands with the earliest year of initial occupancy were surveyed first, followed by progressively younger (initially less suitable) stands. The survey was repeated three times per year from 1991 to 1995 and twice per year from 1996 to 1999. Only the data from the visit closest to the date of the Kirtland's Warbler official census were used for the comparisons, because the three surveys were cumulative counts rather than independent counts, and included counts done in May before all males have settled.

Accomplishing three visits to almost all of the suitable stands within a 40-d period required working later into the day than the official census; this was possible because Kirtland's Warblers sing actively until late morning or early afternoon (Hayes et al. 1986). Surveying typically began between 5:30–6:30 EDT and finished when bird activity became sporadic, which was usually between 11:00 and 14:00 (Hayes et al. 1986), depending on season and temperature. Because we attempted to obtain visual observations, a general route was planned through a suitable stand, rather than transects. No portion of the route was greater than 400 m from another route, which is within the song detectability range. When a male was heard singing, he was located and mapped using landmarks, topography, and the bird's location relative to other singing males.

An attempt was made to visually observe each Kirtland's Warbler male to record the individual color-band combination of marked birds, distinguish plumage characteristics, determine whether the individual was mated, and note distinctive song traits (e.g., extra or missing notes and deviations from the "typical" seven-note song; sonograms were not required to distinguish males from most neighbors). The remaining males were separated by spatially distinguishing them from simultaneously singing neighbors. We were able to distinguish most males from their nearest neighbors by either location, song, individual plumage, or color bands. In 1998 and 1999, for example we were able to sight 93% of the males mapped. By noting these specific "markers" for male Kirtland's Warblers, we minimized bias and double counts in mapping (e.g., discriminating song-location clusters into territories; Verner and Milne 1990). During the second or third visit, male-distinguishing characteristics from the previous visit were used to help locate previously recorded birds, map new birds, and record abandoned territories.

Table 1. Annual patterns of the official census transect count and the North Central Research Station (NCRS) mapping count of male Kirtland's Warblers, including the difference in number of males between the two methods (NRCS minus official census). The annual count includes only stands censused by both methods.

Year	Number of stands	Official census count	North Central count	Difference	Difference in males per stand[a]	Area sampled/ total occupied area (%)	Male density per 40 ha sampled[a]
1990	39	246	197	−49	1.3	83.0	1.8
1991	50	338	286	−52	1.0	88.0	2.0
1992	52	387	346	−41	0.8	82.3	2.4
1993	56	455	338	−117	2.1	91.5	2.3
1994	72	541	382	−159	2.2	79.5	2.6
1995	78	732	468	−264	3.4	89.4	3.0
1996	76	643	381	−262	2.4	81.4	2.8
1997	92	668	443	−225	2.4	81.9	2.4
1998	86	734	544	−190	2.2	70.8	3.1
1999	82	830	599	−231	2.8	61.5	3.8
Percentage increase		237	204				

[a] Based on the official census count.

We used data from each survey method collected in Lower Michigan from 1990 through 1999 to compare the two survey methods. Only stands checked by both methods, and recorded as occupied by either method were included in data comparisons. During this time, NCRS surveyed up to 91.5% of the occupied areas that the Kirtland's Warbler official census surveyed (Table 1). Most of the stands not checked by NCRS were newly colonized stands occupied by one or two Kirtland's Warblers. Because the number of stands checked was positively correlated with the annual count of Kirtland's Warblers by mapping and transect methods (Table 1; $r_S = 0.89$ and 0.92, respectively, $P < 0.01$), the annual difference in count (mapping count minus the transect count) was standardized to the number of male Kirtland's Warblers per stand (i.e., sample size) to facilitate comparisons among years. Simple linear regressions were used to determine the relationship between the number of males per stand through time for both survey methods. To determine the relationship between the annual difference in count to the reported Kirtland's Warbler annual population, we regressed the count difference to the number of males counted by the official census per stand using covariance analysis (i.e., equal-slopes hypothesis among years; Zar 1999). If the slopes are unequal, the relationship between the difference in count between methods and the official count (i.e., presumed real population) varies among years. To evaluate the associations between independent variables and the difference in counts between methods, we used Spearman rank correlations.

We did not test for the effects of observer variability because we were unable to account for it directly and quantitatively. However, we present maps where the differences between the mapping and official transect counts were greater than average to show what we believe to be the major sources of error.

RESULTS

The male Kirtland's Warbler count increased steadily from 1990 to 1995 and again from 1996 to 1999. Overall, the official census's annual count almost tripled from 1990 to 1999 (Fig. 1). The two census methods showed the same directional trends in population from 1990 to 1999, except from 1992 to 1993 (Fig. 1). The official census transect count was consistently higher than the NCRS mapping count of stands censused in common (Table 1). After standardizing for sample size (i.e., number of stands checked), the transect method showed a significant increase in the annual number of Kirtland's Warblers per stand (linear regression, $r^2 = 0.58$, $P = 0.01$), while there was a positive, non-significant trend using the mapping method ($r^2 = 0.09$, $P = 0.40$; Fig. 1). After

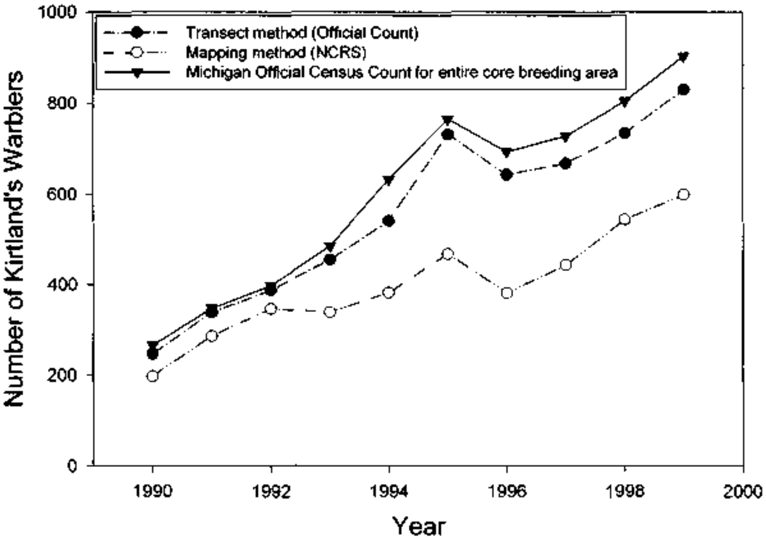

Fig. 1. Kirtland's Warbler population trend in Michigan from 1990–1999 counted by the official census transect method, and by the individual mapping and transect methods for stands censused in common.

1992, the two methods began diverging in the number of males per stand. The annual difference in count between methods was the greatest in 1995 and 1996 followed by 1998 and 1999. These years also coincided with the years having the greatest densities of male Kirtland's Warblers per 40 ha sampled (Table 1).

At the stand level, the transect-method count was greater than the mapping count in 60% of the stands, while the mapping count was greater than the transect count in 16.3% of the stands. There was no difference in count between the methods in 23.7% of the stands. The two methods were within three birds of each other in 72.0% of the stands sampled over 10 years. The difference in count between methods at the stand level ranged from −43 to +10. The difference in count ranged from 0.8 males per stand in 1992 to 3.4 males per stand in 1996 (Table 1, Fig. 2). Also, the relationships between the difference in count between methods and the official census annual count varied among years ($F = 12.3$, $P < 0.001$; Fig. 3).

The number of days between counts was not significantly associated with the difference in counts between methods. Stand size was not associated with the difference in count between methods from 1990 to 1992, but became more associated with the difference in count from 1993 to 1999; stand size was most associated with the difference in count in 1995 ($r_s = -0.59$, $P < 0.01$) and 1996 ($r_s = -0.53$, $P < 0.01$), the years having the larger differences between count methods (Fig. 2). There was a linear relationship between the difference in count between methods and stand age only in 1997 ($F = 4.4$, $P = 0.02$).

Combining census years, the largest discrepancies (>20 males difference) between census methods were recorded in three stands (seven of 683 records; Table 2). This observation led to an examination of NCRS observer consistency in mapping male Kirtland's Warblers. For example, two experienced biologists had almost total agreement on the count and location of male Kirtland Warblers after conducting the count one day apart (Fig. 4a). Similarly, over the three visits for the mapping census, there was general agreement on number and location of males (Fig. 4b). But the transect count recorded 21 males, where as the mapping method recorded 13 males on more than one visit on 17 cumulative territories. Elongated territories that cross transect lines, or territories parallel to transect lines, may lead to multiple counts using the transect method (Fig. 4b). Using the 20 stands with highest discrepancies in count between the methods, the mapping method distinguished neighboring males primarily by plumage and song differences (49%), by general location as plotted from another known

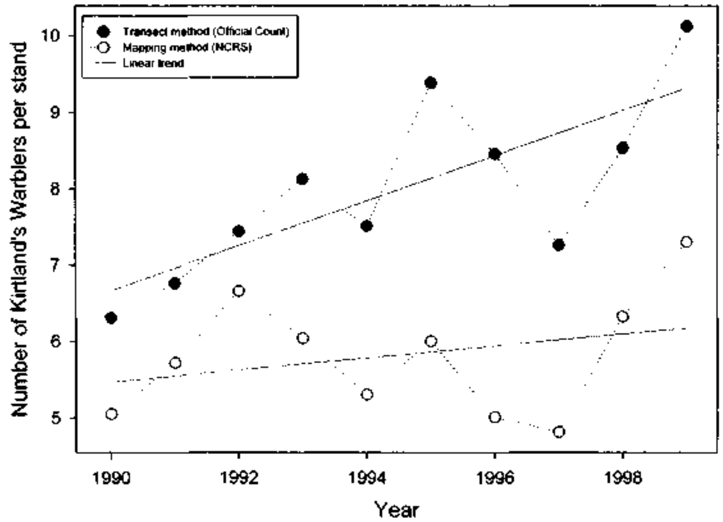

Fig. 2. Numbers of male Kirtland's Warblers per stand as measured by the North Central Research Station mapping method and the official census transect method.

bird (29%), and by color bands (22%; Table 2).

Some additional examples of high discrepancy areas show the transect method recording males where none were found during all three visits of the mapping method (Fig. 5). There were instances of large discrepancies between the census methods when there was one day between the surveys (Fig. 5b,c). These limited cases support our assertion that multiple counts (i.e., over-counting) can occur from birds moving rapidly around large territories and lead to potential interpretation problems, such as distance estimation (Fig. 5a–c) or possible misidentification of song (Fig. 5d).

DISCUSSION

Differences between mapping counts and official census transect counts could be caused by a number of interrelated factors, such as bird density, detectability, and observer error with either method. We demonstrated differential effects of high male density on each method of censusing Kirtland's Warblers, and concluded that transect counts were consistently higher than mapping for annual censuses overall (Table 1). Transect counts may produce errors from 37% to 109% relative to spot-mapping counts (Verner and Ritter 1988). Further, the difference in count between census methods grew with male density at the stand level (Fig. 2). Finally, count differences between censuses with increasing density were not the same among years (Fig. 3), and these differences were greatest in years with the highest overall density (Table 1). These results suggest caution in extrapolating results from one or a few years to other temporal or spatial contexts (e.g., Wiens 1981, 2002). For the Kirtland's Warbler, habitat increased dramatically in two large burned areas from 1988–1992 (Probst and Weinrich 1993). These two areas increased their warbler populations from 1993 to 1996. The population then shifted from overmature burns to new plantations from 1996–2000 (Probst et al. 2003), resulting in high densities in relatively few areas during this habitat turnover, which corresponds with high census discrepancies as well.

Detectability issues include distance estimation by observers, home range sizes of species, diurnal or seasonal song activity patterns, and song identification. Distance estimation is a serious problem for avian census estimates. Point counts or transect counts require an estimate of the distance of a singing bird from an observer. Kirtland's Warblers can be heard for 400–500 m in calm weather, so they may easily be mapped at distances closer to the observer than they really are (P. Huber, pers. obs.). The official census is working to mitigate this problem

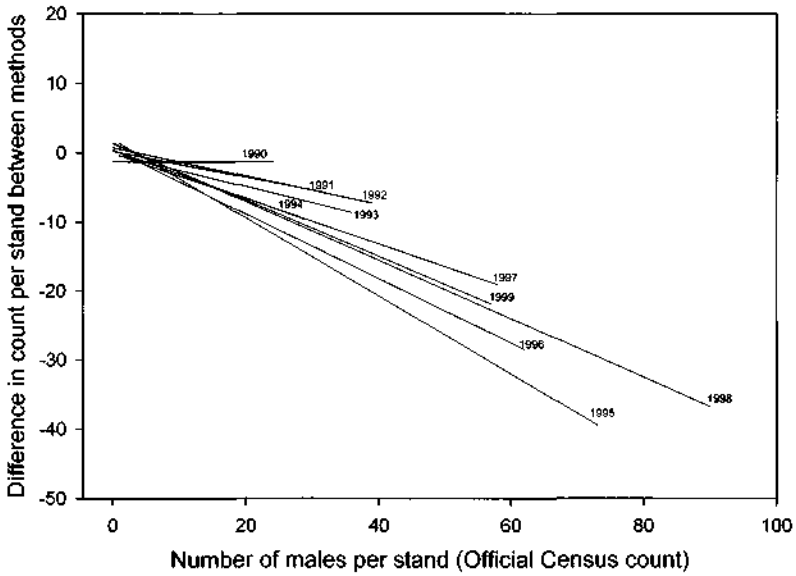

Fig. 3. The relationships between the annual difference in count (mapping count minus official census transect count) to the reported Kirtland's Warbler annual population.

by triangulating positions of males at known distances along transects. Individual male territories range from 1 to 12 ha in size, with an axis of a territory ranging from 0.40 to 0.55 km in length, while some polygynous males may have disjunct territories (Mayfield 1953; Walkinshaw 1983; Bocetti 1994; J. Probst et al., pers. obs.). Consequently, they could be plotted on both sides of a transect by census-takers on different routes or at multiple points along a route (Fig. 4b). These large territorial scales can easily lead to multiple counts of the same male, and compounds the effects of distance estimation. The mapping method minimizes this confusion by direct sighting of males and recording distinguishing characteristics (Table 2).

Many bird species are known to reduce their song frequency later in the day (Robbins 1981; Skirvin 1981). The mapping census was conducted later in the day, which raises the possibility of males going undetected due to reduced singing then. However, for the Kirtland's Warbler, peak singing is around mid-morning with productive censusing lasting into early afternoon (Hayes et al. 1986). We believe diurnal singing was a negligible factor in the differences in count between methods. The advantage of surveying later is that Kirtland's Warblers can be more active in the early morning due to extreme territorial activity and rapid movement of males within large territories (J. Probst, pers. obs.). This rapid movement can lead to multiple counts of males by either method. However, the mapping method is likely to resolve confusion about misidentified simultaneous singing by sighting the same bird repeatedly.

Seasonal variation in avian song detection is likely to vary during the breeding season (e.g., Slagsvold 1976; Skirvin 1981; Bibby et al. 2000). We recorded pronounced differences in males counted in suitable versus less-suitable habitat at different times during the nesting season (Probst 1988). We have four records of color-banded male Kirtland's Warblers recorded in two locations within the same year, suggesting dynamic settlement patterns as noted for other species (Prairie Warblers [*Dendroica discolor*], Nolan 1978; Painted Buntings [*Passerina ciris*], Lanyon and Thompson 1986; Black-headed Grosbeaks [*Pheucticus melanocephalus*], Hill 1988). Thus, males may visit several stands during several weeks, which may result in overcounting males by either method (i.e., males being recorded at two locations). Males may sing infrequently when in close contact with females during nest searching and nest-building (Mayfield 1953; J. Probst, pers. obs.), which is asynchronous among males due to widely different settlement times or re-nesting after nest

Table 2. Number (percent) of male Kirtland's warblers that were distinguished by individual characteristics during the mapping method. Stands listed are the top 20 stands having the largest difference in count (mapping method minus transect method) between methods. Each male was placed in only one category. The number(s) in parentheses after the stand name indicates section number.

Stand name	Year	Mapping count	Transect count	Difference	Male Kirtland's Warbler distinguished by: Color band	Plumage and song	Song	Plumage	Location
Ogemaw (15, 16)	1998	47	90	−43	13 (28)	3 (6)	13 (28)	5 (11)	13 (28)
Ogemaw (21)	1995	13	53	−40	2 (15)	1 (8)	0 (0)	0 (0)	10 (77)
Ogemaw (15, 16)	1995	33	73	−40	3 (9)	6 (18)	8 (24)	7 (21)	9 (27)
Perry Holt Burn	1999	22	57	−35	9 (41)	2 (9)	8 (36)	2 (9)	1 (5)
Ogemaw (15, 16)	1996	36	62	−26	7 (19)	0 (0)	15 (42)	4 (11)	10 (28)
Ogemaw (21)	1996	7	30	−23	1 (14)	0 (0)	2 (29)	4 (57)	0 (0)
Ogemaw (21)	1997	4	26	−22	0 (0)	0 (0)	4 (100)	0 (0)	0 (0)
Mack Lake Burn (8)	1994	3	22	−19	1 (33)	0 (0)	1 (33)	0 (0)	1 (33)
Mack Lake Burn (15)	1995	8	26	−18	2 (25)	3 (38)	0 (0)	0 (0)	3 (38)
Mack Lake Burn (12)	1995	14	31	−17	2 (14)	2 (14)	6 (43)	0 (0)	4 (29)
Mack Lake Burn (2)	1995	6	22	−16	0 (0)	0 (0)	6 (100)	0 (0)	0 (0)
Crapo Lake	1997	11	26	−15	7 (64)	1 (9)	0 (0)	2 (18)	1 (9)
Mack Lake Burn (5)	1996	7	22	−15	1 (14)	2 (29)	2 (29)	0 (0)	2 (29)
Mack Lake Burn (16)	1995	18	33	−15	5 (28)	1 (6)	6 (33)	0 (0)	6 (33)
Mack Lake Burn (3)	1994	4	18	−14	0 (0)	1 (25)	2 (50)	0 (0)	1 (25)
Mack Lake Burn (22)	1994	10	24	−14	2 (20)	0 (0)	3 (30)	4 (40)	1 (10)
Crapo Lake	1999	9	22	−13	1 (11)	1 (11)	5 (56)	0 (0)	2 (22)
Ogemaw (13, 14, 23)	1996	20	33	−13	5 (25)	2 (10)	4 (20)	3 (15)	6 (30)
Perry Holt Burn	1997	13	26	−13	2 (15)	0 (0)	4 (31)	0 (0)	7 (54)
Stephan Burn	1999	22	35	−13	4 (18)	1 (5)	6 (27)	0 (0)	11 (50)
Total		307	731	−424	67 (22)	26 (8)	95 (31)	31 (10)	88 (29)

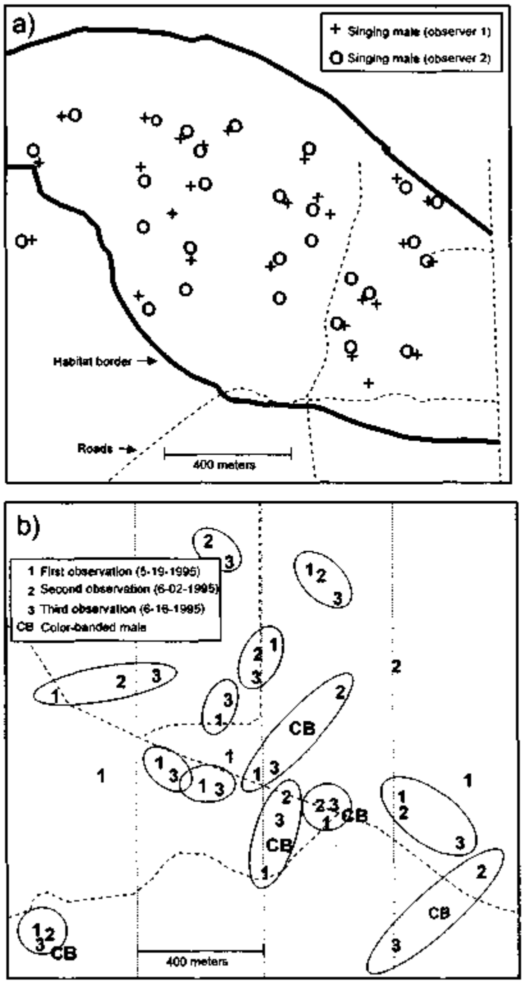

Fig. 4. Illustrations of the consistency among mapping personnel (a) with two degrees of mapping experience (observers 1 and 2 had 60 and 12 mo experience respectively), and (b) variability of independent observations with different observers at three time intervals. Ellipses contain observations of the same male. Vertical dotted lines represent hypothetical quarter-section transect routes to illustrate possible plotting problems on transect counts.

predation. These seasonal movements are more likely to produce differences in the longer census season of the mapping method rather than the two-week period for the official census. However, by using the mapping count from the visit within the official census time frame, we believe seasonal movement is a negligible factor in explaining the difference in count between the methods, but it is a source of potential error in the official census.

Species misidentification of song can lead to over- and under-counts in bird censuses. Other songbirds in the same habitat, such as Eastern Towhees (*Pipilo erythrophthalmus*) or Yellow-rumped Warblers (*Dendroica coronata*), have songs that individual Kirtland's Warblers may partially mimic, potentially leading to under-counts of Kirtland's Warblers. The House Wren's (*Troglodytes aedon*) song can easily be confused with the Kirtland's Warbler's secondary song type or "chatter call" (Mayfield 1953), leading to over-counts of Kirtland's Warblers. The mapping approach could correct for these errors by sighting and confirming males with highly aberrant songs.

In summary, the NCRS mapping effort provides strong support for the official census as a valid relative index of population change, and may provide a lower bound to the official transect count. In this study, the mapping census consistently produced lower annual population estimates for stands than did transect counts, but produced higher estimates in 16% of the stand samples. In summary, the mapping method appears to have less chance for error in high male Kirtland's Warbler density situations because of the ability to discriminate among males with large territories and movements.

We recommend three major improvements to the official transect count. (1) Expand the use of triangulation for improving distance estimation to all larger stands with more than several males; this may have reduced the difference in count after 1996. (2) Emphasize the importance of noting simultaneous singing to help track extensive movements within large territories. (3) Check some transect counts with mapping immediately afterward, especially in high density situations, so transect participants gain appreciation of the scope of male movements. We suggest that field-testing between the two census methods might refine a reasonable range (i.e., bounds) of estimates for the annual census. Finally, any future evaluation of the Kirtland's Warbler census index should consider the substantial, long-term temporal variability in Kirtland's Warbler landscape and habitat change (e.g., Probst and Weinrich 1993).

Research should continue to evaluate the source and size of error in the official transect count, given the importance of accurately as-

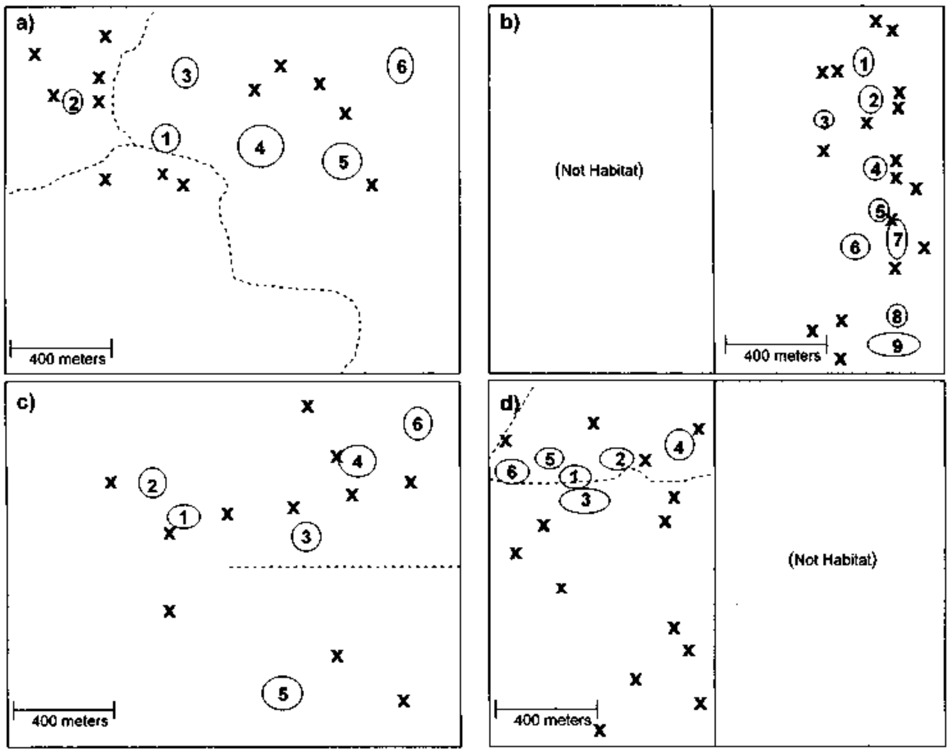

Fig. 5. Illustrations of the differences in counts between transect and mapping methods: (a) Mack Lake Plantation, Oscoda County, mapping census completed two days after the transect census, (b) Ogemaw Management area, Section 22, Ogemaw County, transect census completed one day after the mapping census, (c) Mack Lake Burn, Section 11, Oscoda County, censuses completed on the same day, and (d) Staley lake, Crawford County, mapping census completed six days after the transect census. Ellipses indicate birds counted by the mapping method, and "X" indicates birds counted in the transect censuses. Dashed lines represent roads.

sessing the Kirtland's Warbler Recovery Plan's goal of 1000 males for planning and implementation of conservation measures. Delisting of endangered status could lower commitment by involved agencies instead of sustaining conservation. Consequently, agencies should carefully communicate how counts and estimates based on transect counts alone should be interpreted.

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