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Monitoring and Prediction of the Fall Flight of Wood Ducks (Aix sponsa) in Michigan: An Investigation of Survey Methods

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Harold H. Prince
Major professor

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MONITORING AND PREDICTION OF THE FALL FLIGHT OF WOOD DUCKS (AIX SPONSA) IN MICHIGAN: AN INVESTIGATION OF SURVEY METHODS

By

Linda A. Briggs

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ABSTRACT

MONITORING AND PREDICTION OF THE FALL FLIGHT OF WOOD DUCKS (AIX SPONSA) IN MICHIGAN: AN INVESTIGATION OF SURVEY METHODS

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Direct estimates of wood duck (*Aix sponsa*) numbers and production are difficult to derive and improved methods are needed to estimate fall flight. The goal of this project is to evaluate survey methods that might provide a finer scale of monitoring wood duck numbers and production and that correlate with estimates derived from the traditional analyses of harvest surveys. In 1994, night surveys for wood duck broods were conducted on 16 to 32 km sections of three rivers in southwest Michigan. Nine road surveys were established in southern Michigan in 1994 and expanded to 17 routes conducted in 1995 and 1996. The road surveys were conducted in early and late time periods. Over 700 nest boxes were checked at 11 sites in 1995 and 1996.

In 1994, only 1 brood was observed over 105 miles of stream surveyed, eliminating this as a potential survey method. The road surveys were not correlated with the Michigan Breeding Waterfowl Surveys (aerial surveys) conducted at corresponding sites. The road surveys and nest box surveys were not correlated at the site level while significant correlations were detected at the unit level ($r_s = 0.94$, $P = 0.0048$). The USFWS harvest estimates were not correlated with the road surveys and the nest box surveys. Of the survey methods conducted in this project, the road surveys may have the best potential and should be evaluated further.

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INTRODUCTION

Wood ducks (*Aix sponsa*) have been a challenge to wildlife managers for the past century. In the early 1900's, wood duck numbers were believed to be so low that many feared they were near extinction. Hunting of wood ducks was stopped in 1918. The recovery of the population is well documented (Bellrose and Holm 1994) and hunting resumed about 60 years ago.

Wood ducks are currently a significant portion of Michigan's annual harvest of waterfowl, second only to the mallard (*Anas platyrhynchos*) (Brakhage 1990). The number of wood ducks harvested in Michigan has increased in the last few decades, from a low of 9,900 in 1961 to a high of 60,800 in 1985, under a stable bag limit of 2 birds per day (Bartlet and Trost 1990). The estimated harvest has plateaued this past decade.

There is some evidence that breeding wood ducks have saturated the prime lowland forest habitats, forcing expansion in lower quality areas (Bellrose and Holm 1994). This is supported by breeding birds being detected in areas with secondary habitat such as northern coniferous forests.

The increases in the numbers of breeding and harvested wood ducks should be evaluated cautiously. Gamble (1990) believes that increases in the length of the hunting season in several areas could be responsible for increases in wood duck harvest. Similarly, Bellrose and Holm (1994) suggested that the increased importance of wood ducks to the annual harvest could be the result of simply harvesting a greater proportion of the wood duck population. They rejected this as a possibility since an expected increase in the rate of band returns did not occur consistently over the areas experiencing an increase of wood duck harvest.

Shifts in bag limit from 1 to 2 birds were easily accommodated in the 1970's and a daily bag of 3 birds in response to population increases could be possible in future seasons (Kelley 1994). However, an increased loss and degradation of primary wood duck habitat (Tiner 1984) makes it imperative that an accurate means of assessing fall flight be developed before any further liberalization of the wood duck harvest occurs.

Direct estimates of wood duck numbers and production are difficult to derive (Geis 1966, Sauer and Droege 1990). A habitat preference of flooded woods and swamps and secretive behavior makes this species difficult to survey (Brakhage 1990). Additionally, the wood ducks' unique breeding range within the continental United States (Bellrose and Holm 1994) is well beyond most of the range of aerial surveys used for counts of breeding waterfowl in the more northern latitudes of the U.S. and Canada (Geis 1966). Currently, only indirect means, such as band returns and harvest data, can be used to monitor status. Although these methods are suitable for the detection of general trends over large areas, finer scaled population estimates are needed for monitoring the libralization of hunting regulations (Mississippi Flyway Council 1994).

Cleveland (1994) estimated the wood duck breeding population based on aerial surveys and input this data in a model designed to calculate the fall flight for Michigan. The estimates of fall flight appeared to overestimate production by 100 to 300 %. The aerial survey's visibility correction factors (VCF) are high for wood ducks compared to other species meaning that wood ducks are more difficult to detect. Wood duck VCFs ranged from 9.0 to 28.0, while the VCFs for mallards range from 2.3 to 5.5 during the 1992 through 1996 surveys (J. Martz, pers. commun.). In addition to poor aerial survey results, available data on clutch sizes and survival rates of wood ducks in Michigan are limited.

A few alternate survey methods for wood ducks have been suggested as independent indices. Road surveys, like those conducted in the Breeding Bird Survey (Sauer and Droege 1990), annual nest box surveys (Zicus and Hennes 1987), and brood surveys on streams (Cottrell and Prince 1990) have been suggested as potential population indices for wood ducks.

The goal of this project is to evaluate survey methods that might provide a finer scale of monitoring of wood duck numbers and production. The degree to which survey methods studied correlate with the estimates derived from the traditional analyses of harvest surveys will also be assessed.

METHODS

Brood Surveys

Night surveys on streams for wood duck broods were conducted from 01 June to 31 July 1994. Surveys were conducted bi-weekly along 16 to 32 km (10-20 mile) sections of three rivers located in south and western Michigan (Figure 1). The surveys began at the upstream end of the study areas at least 30 minutes after sunset. Using a 14 foot flat bottomed boat powered by a 6 hp engine, 2 observers motored downstream, visually scanning the shoreline for wood duck broods. Each observer used a 450,000 candlepower hand held spotlight powered by a 12 volt battery, to monitor the stream channel and banks. The numbers of adults, broods, ducklings per brood, and age classes of the ducklings were recorded.

Road Surveys

Nine road survey routes were established in the southern half of the lower peninsula of Michigan in 1994 and expanded to 17 routes in 1995 (Figure 2). In 1994, four of the routes, Allegan, Maple, Mendon, and Muskegon 1, were placed in areas adjacent to forested rivers used for the stream brood surveys and the five remaining survey routes, Albion, Ann Arbor, Cambria, Fine Lake, and Hastings, were established in sites that corresponded with the flight paths used in the Michigan Breeding Waterfowl Survey

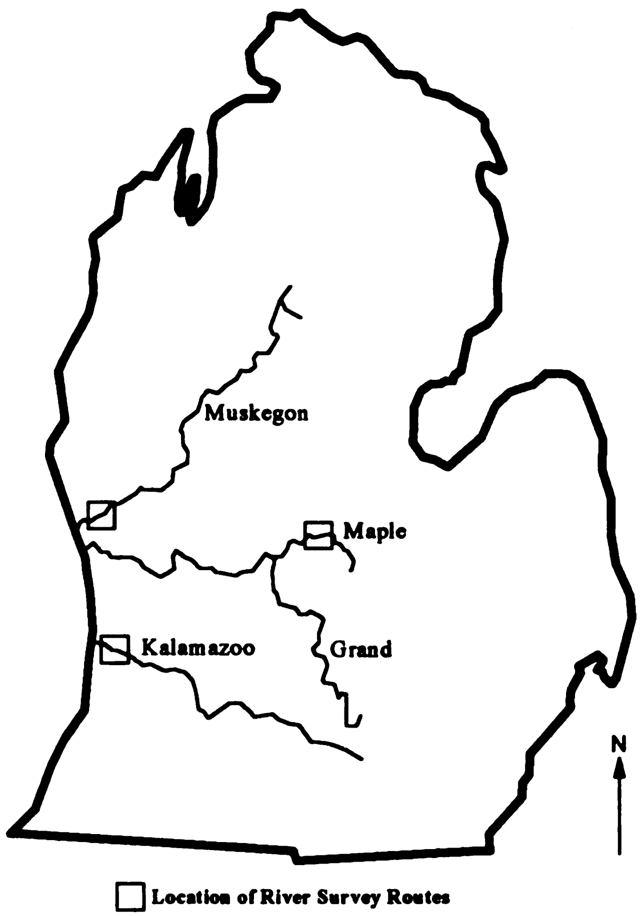
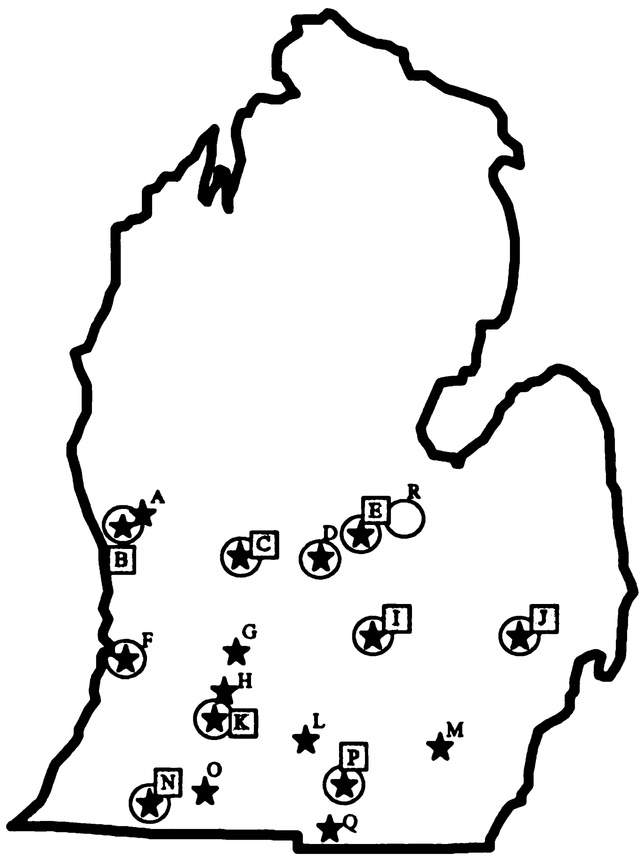


Figure 1. Location of night stream brood surveys conducted in 1994.



★ Road Survey Route
○ Nest Box Survey Site

A = Muskegon 1
[B]= Muskegon 2
[C]= Flat River
D = Maple River
[E]= Gratiot-Saginaw
F = Allegan

G = Hastings
H = Fine Lake
[I]= Rose Lake
[J]= Bald Mtn.
[K]= Gull Lake
L = Albion

M = Ann Arbor
[N]= Crane Pond
O = Mendon
[P]= Somerset
Q = Cambria
R = Shiawassee

Figure 2. Locations of Michigan road survey routes for 1994 to 1996 and nest box surveys conducted in 1995 and 1996.
[ ]= road survey routes conducted only in 1995 and 1996.

(MBWS). In 1995, eight additional routes were established and conducted. The new routes, Bald Mountain, Crane Pond, Flat River, Gull Lake, Gratiot-Saginaw, Muskegon 2, Rose Lake, and Somerset, traversed areas with active nest box programs. The Maple River route is the only survey that met all of the road survey criteria since it is adjacent to the Maple River stream survey route, corresponds with flight path number 60 from the MBWS, and is in Maple River State Game Area which has an active nest box program. All 17 routes were repeated in 1996.

Each 10 mile route was started 30 minutes before sunrise. Surveys were not conducted on days with any precipitation or wind speeds greater than 15 mph. The temperature, time of sunrise, percent cloud cover, time of first observation, and initial odometer readings were recorded at the beginning of each survey. The observer stopped at every half mile, exited the car, and counted the numbers of wood ducks seen and heard over a three minute period. The number and sex (when possible) of the wood ducks observed were recorded. The final time and odometer reading were recorded upon completion of the survey.

In 1994, each route was conducted 8 times on different mornings. The surveys were conducted on 4 days between 15 April and 14 May and repeated on 4 days between 15 May and 5 June. The early period was established because it overlaps the timing of the peak nest initiation for wood ducks in Illinois (17 April to 2 May), Minnesota (15 April to 25 April) (Bellrose 1980), and Michigan (Bellrose and Holm 1994, Prince 1991). The late period was selected by the USFWS Office of Migratory Bird Management as the designated time period for nationwide wood duck road surveys to be conducted (Kelley 1994). To allow for increases in the number of sites surveyed, the number of counts was reduced from 4 to 2 in the early time frame (15 April and 14 May) and the late period (15 May and 5 June) for all 17 survey routes in 1995 and 1996.

Nest Box Surveys

Wood duck nest boxes at 11 sites with active nest box programs (>20 boxes) throughout southern Michigan were checked in 1995 and 1996 (Figure 2). To facilitate comparisons between survey methods, nest box surveys sites were conducted in areas with road surveys. The boxes were checked at least once between 9 May and 30 September. Boxes checked during the breeding season (before 30 June) and boxes with active nests were rechecked after 1 August when all nesting had been completed.

The presence, species, and outcome of nests were recorded for each nest box. The size, shape, and color of the eggs were used to identify species. Nest boxes containing at least 1 wood duck egg were counted as being used. Nests with no down and few or many eggs (as in the case of dump nests) were designated as being in the laying stage. Nests lined with down and at least 8 eggs were recorded as being in the incubating stage. Hatching stage included successfully hatched nests and nests in the process of hatching at the time the nest was surveyed. The success of a nest was determined by the presence of at least 1 shell membrane. Nests with cold whole eggs were recorded as being abandoned. Nests with broken eggs were considered to be unsuccessful. Since nests were only checked once, cases in which nests were abandoned before they were predated could not be detected.

Data Analysis

A General Linear Model (GLM) Analysis of Variance (ANOVA) (SAS Institute Inc. 1990) was used to analyze numbers of wood ducks from the road surveys and rates of nest box use. ANOVAs were completed for the 9 sites surveyed from 1994 to 1996 and the 17 sites run in 1995 and 1996. A three factor ANOVA with interactions using the parameters year, site, and the 2 time periods (early: 15 April to 14 May, late: 15 May to June 5) were tested for road surveys. The assumptions of this analysis are that the effects of the treatment and the environment are additive and that the experimental errors are random, independently and normally distributed about a mean of 0 (Steel et al. 1997). When significant interactions were detected, violating the assumption of independence, the components of the interactions were separated and tested again. Year and site without interactions were the parameters tested for the rate of nest box use. The percent use rates of the nest boxes were adjusted with the inverse sine (arcsin $Y^{-0.5}$) transformation (Steel et al. 1997). Tukey's test (honestly significant difference) (Steel et al. 1997) was used on years and sites for the road surveys and on the sites for the nest box surveys to detect which years or sites may be significantly different ($\alpha = 0.05$).

Spearman's Rank correlations (Steel et al. 1997) were used to compare the results of the different survey techniques using geographical locations and the year as the basis for pairing the survey methods. For each year, Spearman's Rank correlations were on the road survey and nest box survey data pairing the surveys first by sites and then by units which are groupings of the counties based on geographical proximity. Two external surveys were also compared to the nest box and road survey data using Spearman's Rank correlations. USFWS harvest estimates were compared to both road surveys and nest box surveys by regions. The indicated breeding birds calculated from road survey data were compared to indicated breeding birds calculated from Michigan Breeding Waterfowl Surveys conducted at 6 corresponding sites, Albion, Ann Arbor, Cambria, Fine Lake, Hastings, and Maple River from 1994 to 1996. The data were grouped for the 3 years for the comparison (n = 17).

Cluster Analysis on USFWS county harvest estimates were conducted using SYSTAT to visually evaluate the level of harvest across lower Michigan. The cluster analysis used means of 13 years of USFWS harvest estimates for each county from 1983 to 1995. The Euclidian distance and Wards linkage were used for the cluster analysis.

RESULTS

Brood Survey

In 1994, 8 night brood surveys were done between 20 June and 27 July in southern Michigan (Table 1). One brood of wood ducks was observed on the Kalamazoo River in Allegan State Game Area on 25 July. No other broods were contacted. This survey method was not repeated in 1995 or 1996.

Table 1. Broods observed and estimation of effort for night float counts from 20 June, 1994 to 27 July, 1994.[a]

Stream	n[b]	Survey dates	Time started	Miles surveyed	Broods observed	Broods per mile
Kalamazoo	3	6/22	2205	16	0	0.00
		7/11	2200	16	0	0.00
		7/25	2225	16	1	0.06
Maple	2	6/20	2150	13	0	0.00
		7/27	2143	14	0	0.00
Muskegon	3	6/21	2203	10	0	0.00
		7/5	2212	10	0	0.00
		7/26	2202	10	0	0.00
Total	8			105	1	0.01

[a] Four additional surveys were attempted, 1 on the Muskegon River (7/18) and 3 on the Maple River (7/12, 7/14, and 7/20). These were not successful due to weather and equipment failures.
[b] n = # of surveys conducted

Road Survey

The number of wood ducks detected on road surveys varied between sites and years (Table 2). On 9 routes conducted 8 times in 1994, 355 wood duck contacts were made on 1428 three minute listening sessions. An average of 7.6 wood ducks were seen and/or heard per route in the early time period and 3.2 wood ducks were counted per route in the late time period. Although the number of routes was nearly doubled in 1995 and 1996, the reduced sampling intensity per route still amounted to 1407 three minute listening stations in 1995 and 1428 in 1996. The expanded surveys resulted in 154 and 193 wood ducks contacts in 1995 and 1996, with an effort of about 310 person-hours each year. The combined average number of birds per count declined from 5.2 in 1994 to 2.3 and 2.9 birds per route in 1995 and 1996, respectively.

The year ($P = 0.0001$), site ($P = 0.0001$), the time period ($P = 0.0011$) and the interaction between the year and the time period ($P = 0.0369$) of the 9 surveys conducted from 1994 to 1996 were significant (Table 3). Due to the significant interaction, ANOVAs were run with the data separated first by year and then by time period. Site ($P = 0.0001$), time period ($P = 0.0001$), and the site and time period ($P = 0.0011$) interaction were significant sources of variation in 1994. In 1995, the site ($P = 0.0687$) and time period ($P = 0.0900$) seemed to play a role in the variation, while the site and time interaction ($P = 0.7707$) was not significant. Site was the only significant main effect in 1996 ($P = 0.0086$). For the original 9 routes, site ($P = 0.0687$) and time ($P = 0.0900$) appeared to play a role in the variation in 1995, while the site and time interaction was not significant ($P = 0.7707$). Site was the only significant main effect for the 9 routes in 1996 ($P = 0.0086$).

Table 2. Mean number of wood ducks observed and/or heard in Michigan along 17 roadside survey sites conducted between 15 April and 14 May (Early) and between 15 May and 6 June (Late). Nine of the surveys were conducted on the same routes for 3 consecutive years (1994 - 1996). Eight other routes were conducted for 2 years (1995 and 1996). In 1994, routes were conducted 8 times. In 1995 and 1996, routes were conducted 4 times.

Survey Route	1994[A]			1995[B]			1996[B]		
	Early	Late	Combined[C]	Early	Late	Combined	Early	Late	Combined
Albion	7.5	5.3	6.4	1.5	0.5	1.0	1.5	3.5	2.5
Allegan	3.0	1.0	2.0	4.0	1.5	2.8	3.5	4.5	4.0
Ann Arbor	2.3	0.3	1.3	1.0[D]	0.5	0.7	4.0	1.0	2.5
Bald Mtn.				3.0	1.5	2.3	4.0	2.0	3.0
Cambria		1.3	1.3	1.0	0.5	0.8	1.0	0.5	0.8
Crane Pond				3.0	0.5	1.8	0	0.5	0.3
Fine Lake	8.0	3.0	5.5	1.5	1.5	1.5	1.0	3.0	2.0
Flat River				3.0	4.5	3.8	3.5	3.0	3.3
Gratiot-Saginaw				0	1.0	0.5	1.0	1.5	1.3
Gull Lake				2.0	3.5	2.8	0	2.0	1.0
Hastings	5.8	5.8	5.8	4.5	0.5	2.5	6.0	2.5	4.3
Maple River	22.0	6.8	14.4	12.5	4.5	8.5	8.5	11.5	10.0
Mendon	8.0	4.0	6.0	2.0	0	1.0	2.5	2.0	2.3
Muskegon 1	3.8	1.3	2.5	0	0	0	2.5	0.5	1.5
Muskegon 2				4.5	1.5	3.0	3.5	3.0	3.3
Rose Lake				4.0	2.0	3.0	4.0	1.0	2.5
Somerset				2.0	4.0	3.0	7.0	2.5	4.8
Total Birds			355			154			196
Mean / route	7.6	3.2	5.2	2.9	1.6	2.3	3.2	2.4	2.9

A: n = 4 for each survey period
B: n = 2 for each survey period
C: Combined was derived as the mean of the early and late time periods
D: n = 1 for this survey period

Table 3. Analyses of Variance for the 9 road surveys conducted from 1994 - 1996. Due to the significant interaction of site and time in the first ANOVA, the analysis was repeated twice, first separating the data by years and then by time periods.

ANOVA Parameters	Source of Variation	DF	Mean Square	P	Significance
All Years and Times	Year	2	103.9	0.0002	***
	Site	8	123.2	0.0001	***
	Time	1	122.9	0.0011	***
	Year * Site	16	12.5	0.3145	
	Year * Time	2	36.9	0.0369	***
	Site * Time	8	13.1	0.2997	
	Year * Site * Time	15	15.7	0.1378	
Separated by Year					
1994	Site	8	129.0	0.0001	***
	Time	1	240.3	0.0001	***
	Site * Time	7	48.2	0.0011	***
1995	Site	8	25.9	0.0687	
	Time	1	36.0	0.0900	
	Site * Time	8	6.6	0.7707	
1996	Site	8	30.0	0.0086	***
	Time	1	0.3	0.8605	
	Site * Time	8	5.4	0.6943	
Separated by Time Period					
Time 1	Year	2	109.1	0.0033	***
	Site	8	102.4	0.0001	***
	Year * Site	15	22.0	0.2306	
Time 2	Year	2	30.6	0.0066	***
	Site	8	33.3	0.0001	***
	Year * Site	16	6.7	0.2801	

The 2 time periods were separated grouping data for all 3 years. In the early time period, the year (P = 0.0033) and site (P = 0.0001) were both significant with Maple River as the only site significantly higher than all other sites (P < 0.05). The 1994 surveys were significantly higher (P < 0.05) than the surveys from 1995 and 1996. Year (P = 0.0066) and site (P = 0.0001) were also significant sources of variation for the late time period. In this case, the Maple River counts were significantly higher (P < 0.05) than all sites except Hastings and Albion. Hastings and Albion were not significantly different from any of the sites. For the late time period, counts were lowest in 1995 (P < 0.05) and not different between 1994 and 1996.

For the 17 road surveys conducted in 1995 and 1996, sites (P = 0.0001) and time periods (P = 0.0444) were significant sources of variation while the year (P = 0.1731) was not (Table 4). Maple River continued to be the only site with significantly higher counts compared to the other sites (P < 0.05).

Table 4. Analysis of Variance for the 17 road surveys conducted from 1995 - 1996.

Source of variation	DF	Mean Square	P	Significance
Year	1	12.2	0.1731	
Site	16	32.1	0.0001	***
Time	1	27.0	0.0444	***
Year *Site	16	2.5	0.9815	
Year * Time	1	4.5	0.4041	
Site * Time	16	4.1	0.8382	
Year * Site * Time	16	6.6	0.4421	

The total number of indicated pairs of breeding birds was calculated by adding the number of indicated pairs from all road surveys for each year (Table 5). The number of indicated pairs for each road survey was calculated using the formula:

Indicated pairs = ∑Pairs + ∑Lone Males +∑Lone Females +∑Lone Birds with unknown sex.

This formula is similar to Cleveland's (1994) indicated bird formula with modifications allowing the more audible lone females to be counted as an indicated pair. The number of indicated pairs ranged from 80 to 125.

Table 5. Indicated pairs calculated from road survey data for 1994 - 1996. Indicated pairs = ∑Pairs + ∑Lone Males +∑Lone Females +∑Lone Birds with unknown sex.

Year	Number of surveys	Total Birds Counted	Pairs	Lone Males	Lone Females	Lone Sex unknown	Flocks (>2 and unknowns)	Total Indicated Pairs per Season
1994	68	355	34	24	31	36	197	125
1995	67	154	23	21	15	21	51	80
1996	68	196	46	13	16	37	38	112

Comparison of Road Surveys to Aerial Surveys

A total of 146 to 158 wood ducks were observed during helicopter surveys while 4 to 12 % of those totals were counted from a fixed wing aircraft flying the same route (Table 6). The total indicated breeding wood ducks from the road surveys conducted in the vicinity of the aerial routes ranged from 58 to 88.

The indicated birds from helicopter and fixed-wing airplane surveys for the Michigan breeding Waterfowl Survey were compared to the total number of indicated wood ducks detected at each of the 6 road survey routes corresponding to the flight paths using Spearman Rank correlation analysis. Since the road surveys from 1994 had 8 surveys conducted per route, the total indicated birds from this year were not directly comparable to 1995 and 1996 when 4 surveys were conducted per year. To reduce the number of surveys for 1994, 2 surveys were randomly selected from each time period for each site, resulting in 4 surveys used per site in 1994. The 1994 indicated breeding birds were then calculated with the subset of the 1994 surveys. The years were combined for the correlation analysis (n = 17). The road surveys were not significantly correlated with the helicopter surveys (r_s = 0.144, P = 0.583) or the fixed-wing surveys (r_s = 0.075, P = 0.776) on the 6 areas over the 3 year period.

Table 6. Numbers of indicated breeding wood ducks from MBWS helicopter and fixed wing transects (Data from MDNR) and the mean indicated breeding wood ducks from the road surveys.

		1994			1995			1996		
Transect	Site	Helicopter	Fixed wing	Road survey	Helicopter	Fixed wing	Road survey	Helicopter	Fixed wing	Road survey
4	Cambria	14	2	2	36	0	6	14	0	2
19	Ann Arbor	16	4	4	44	0	4	26	0	10
21	Albion	21	0	28	14	0	6	20	2	6
27	Fine Lake	58	0	10	42	2	8	32	6	12
41	Hastings	30	10	20	22	4	8	38	2	16
60	Maple River	10	2	16	-	-	26	16	0	42
Total		149	18	80	158	6	58	146	10	88

While the helicopter surveys appear to be more efficient than the road surveys at detecting wood ducks, differences in the methods and the size of area surveyed should be noted. The helicopters zig-zag along 18 mile by 1/4 mile transect while the road surveys are conducted in sampling plots with a 1/4 mile radius. An area of 4.50 mi^2 are surveyed for each helicopter survey while 1.03 mi^2 are surveyed for each road survey route and a total of 4.12 mi^2 are surveyed for each road survey site. Adjusting the total indicated pairs for the area surveyed results in 5.5, 5.9, and 5.4 wood ducks/mi^2 for the helicopter surveys and 3.2, 2.3, and 3.6 wood ducks/mi^2 which are fairly similar even though the road surveys are a more passive survey.

Nest Box Surveys

Eleven sites with over 700 nest boxes were checked in 1995 and 1996 (Table 7) with an effort of 1160 person-hours. Wood ducks nested in 40 % of the nest boxes while 10 % contained clutches with wood duck and hooded merganser (*Mergus cucullatus*) eggs. Hooded merganser nests were found in an additional 11 % of the nest boxes. Almost 78% of the merganser nests (8% of total number of nests) were located in boxes along the Consumer's Power line in Muskegon on the west side of the state. The remaining 39 % of nest boxes were not used by nesting waterfowl.

All of the Muskegon Power line data were deleted from further analysis since the condominium style nest boxes used at this site with 4 boxes within a 2 meter space at each of the outer support beams for the power line were different from the other sites. The remaining boxes from Muskegon State Game Area were similar in placement to the boxes from the other sites and were included in the analyses.

The percentage of nest boxes used at each site was transformed using an inverse sine transformation before the GLM Anova was applied to the data. Use of nest boxes by wood ducks varied significantly among sites ($P = 0.0001$), ranging from 21 % to 76 % (0.21 to 0.87 upon transformation). Total use rates of 51 and 50 % of the nest boxes was similar between years ($P = 0.8195$).

Table 7. Number of nest boxes and use by wood ducks and hooded mergansers by site, based on surveys conducted May through September in 1995 and 1996.

Site	Usable boxes		# used by wood ducks		# mixed (wood duck & hooded merganser)		# used by hooded merganser		Mean use rates by wood ducks[a]
	1995	1996	1995	1996	1995	1996	1995	1996	
Shiawassee	64	60	37	35	12	11	5	3	77 A
Rose Lake[b]	47	59	26	41	9	2	2	1	74 AB
Flat River	55	45	28	26	5	3	3	0	62 ABC
Gratiot-Saginaw	107	132	61	69	0	9	2	4	58 ABCD
Bald Mountain	36	28	7	8	10	9	0	5	53 ABCDE
Maple River	119	106	59	50	4	3	0	0	52 BCDEF
Allegan	47	45	18	15	4	4	6	3	45 CDEF
Somerset	29	27	9	10	1	0	0	0	36 DEF
Muskegon	32	27	7	7	0	3	0	1	29 EF
Crane Pond	23	24	7	5	1	0	0	0	28 F
Muskegon Power line[c]	153	162	25	19	31	27	52	69	32
Total	712	715	284	285	77	71	70	86	

[a] Means followed by the same letter are not significantly different (P>0.05) using Tukey's test (Steel et al. 1997).

[b] Rose Lake area contains boxes surveyed within Rose Lake Wildlife Research Area and Okemos area parks (Legg Park, Harris Center, and Eastgate Park). The areas were combined to facilitate comparisons between road surveys and nest box surveys. The Rose Lake road survey began at the entrances of Harris Center and Legg Park and ended in Rose Lake Wildlife Research Area.

[c] The Muskegon Power line site was eliminated from the remaining analyses due to differences in box configuration. The boxes in this site were in a condominium setup, with groups of 4 boxes placed together at each location.

The mean of the total number of wood ducks observed and the means for the early and late time periods of the road surveys were examined for correlation with the use rates from nest box surveys. The road survey and nest box data were paired by site and analyzed for each year, giving each site a data point for both road surveys and nest box surveys for each year. No correlation using Spearman's Rank correlation analysis was found between the nest box surveys and the total observed on the road survey ($r_s = 0.059$, $P = 0.816$). The same is true between the percent use rate of nest boxes and totals observed in early ($r_s = 0.148$, $P = 0.558$) and late ($r_s = 0.123$, $P = 0.627$) time periods.

Fall Harvest

The USFWS estimates the number of wood ducks harvested each year by county for every state in the United States by surveying hunters through sampling post offices that sell hunting licenses (Crissey 1984). Harvest estimates for 36 counties of southern Michigan were summarized for 13 years from 1983 to 1996 (Table 8). During this period, between 60 and 122 hunters were surveyed, sending in between 129 and 342 wood duck wings annually. The highest year was 1984 when 41,950 birds were harvested. The estimates for 1986 to 1993 ranged from 9490 to 19,490 wood ducks and were lower than 1994 and 1995 when 27,690 and 26,180 birds were harvested.

The harvest data, used as the baseline index for monitoring wood duck populations trends in Michigan, were compared to both road surveys and nest box surveys. The USFWS calculates harvest estimates at both the county and state levels. If in one year no surveys were sent in from a county, then no estimates were calculated for that county. Due to missing data, the county level is not an appropriate comparison.

Table 8. Estimated wood duck harvest by year for 3 units in lower Michigan including sample sizes of total number of birds sampled and hunters participating. (Data from USFWS)

	Birds/km^2			Sample Size		
Year	Unit A*	Unit B*	Unit C*	Birds	Hunters	Total Harvest
1983	0.7	0.5	0.3	314	122	28780
1984	1.0	0.6	0.6	342	122	41950
1985	0.9	0.3	0.3	262	102	27510
1986	0.4	0.2	0.3	129	60	17770
1987	0.3	0.2	0.3	138	67	15990
1988	0.2	0.1	0.2	134	70	9490
1989	0.3	0.2	0.3	194	96	15810
1990	0.4	0.2	0.1	132	72	13200
1991	0.4	0.4	0.2	154	72	19490
1992	0.4	0.1	0.3	227	87	15450
1993	0.4	0.3	0.2	197	85	16490
1994	0.7	0.3	0.4	228	84	27690
1995	0.8	0.4	0.2	132	61	26180
1996	0.6	0.3	0.2	196	N.A.	21120
Means	0.5	0.3	0.3	199	85	21215

* **Unit A** = Allegan, Barry, Berrien, Branch, Calhoun, Cass, Eaton, Kalamazoo, St. Joseph, and Van Buren counties. **Unit B** = Hillsdale, Ingham, Jackson, Lenawee, Livingston, Macomb, Monroe, Oakland, St. Claire, and Washtenaw counties. **Unit C** = Clinton, Genesee, Gratiot, Huron, Ionia, Kent, Lapeer, Montcalm, Muskegon, Newaygo, Oceana, Ottawa, Saginaw, Sanilac, Shiawassee and Tuscola counties.

To facilitate comparisons using the harvest estimates, the road surveys, and nest box surveys, the counties of southern Michigan were grouped into 3 units (Figure 3). Each unit contained 10, 10, or 16 counties. The harvest data standardized for area from 1983 to 1995 show some differences between units, with Unit A having the highest rate of harvest (Table 8). Units B and C had similar rates of harvest estimates. Data for road and nest box surveys were pooled for each unit.

Spearman Rank correlation analysis was used on combinations of road survey, rates of nest box use, and harvest surveys at the unit level. Harvest data were not positively correlated with either road surveys ($n = 9$, $r_S = -0.270$, $P = 0.482$) or rates of nest box use ($n = 6$, $r_S = -0.754$, $P = 0.084$). However, the mean number of wood ducks observed on the road surveys were correlated with the rate of nest box use ($n = 6$, $r_S = 0.943$, $P = 0.0048$) (Table 9).

Table 9. Comparison of unit means between the numbers of wood ducks per sampling point from the road surveys and the occupancy rates from the nest box surveys. The road surveys and nest box surveys were significantly correlated ($r_S = 0.943$, $P = 0.0048$) at the unit level in 1995 and 1996.

		Road survey		Nest box survey	
Year	Unit	n[a]	Mean # wood ducks (ducks/sampling point)	n[b]	occupancy rate (% of boxes used)
1995	A	576	0.09	79	46.8
	B	383	0.08	84	42.9
	C	448	0.15	404	62.3
1996	A	576	0.11	84	44.0
	B	404	0.15	76	48.7
	C	448	0.16	408	62.2

[a] n = number of 3 minute sampling sites in each unit
[b] n = number of nest boxes surveyed in each unit

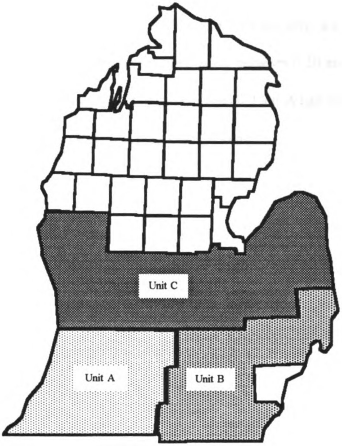


Figure 3. Locations of proposed units A, B, and C in lower Michigan. Unit A = Allegan, Barry, Berrien, Branch, Calhoun, Cass, Eaton, Kalamazoo, St. Joseph, and Van Buren counties. Unit B = Hillsdale, Ingham, Jackson, Lenawee, Livingston, Macomb, Monroe, Oakland, St. Clair, and Washtenaw counties. Unit C = Clinton, Genesee, Gratiot, Huron, Ionia, Kent, Lapeer, Montcalm, Muskegon, Newaygo, Oceana, Ottawa, Saginaw, Sanilac, Shiawassee, and Tuscola counties.

Counties with similar harvest rates were grouped using cluster analysis on the mean harvest rate from 1983 to 1995. This analysis allowed the counties to be grouped by similarities in harvest estimates, showing regions of high and low harvest. The analysis resulted in 3 clusters with similar harvest rates (Figure 4). Muskegon and Allegan with the highest harvest rates, 1.30 and 1.06 birds/km^2 respectively, are both on the west side of the state. The counties with low harvest rates, between 0.30 and 0.03 birds/km^2, are in the thumb area and the middle of the state. Overall, Unit A had more counties in the high and medium categories of harvest than Units B and C.

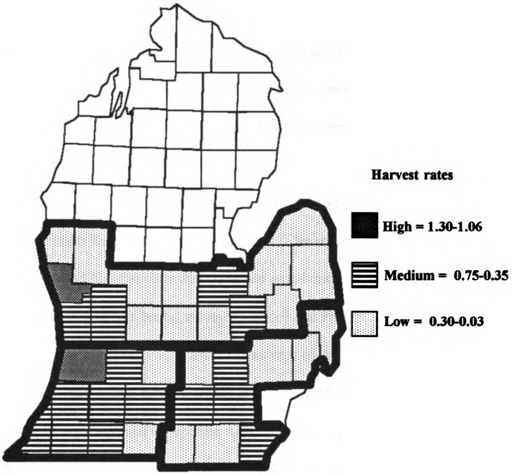


Figure 4. Results of cluster analysis on USFWS harvest estimates (harvest/km^2) means for 36 southern Michigan counties. Means were calculated for 13 years, from 1983 to 1995.

DISCUSSION

Improved methods for monitoring wood ducks to estimate fall flight have been sought by wildlife researchers and managers for the past 30 years. With several states looking to liberalize hunting regulations for wood ducks, the need for better survey methods has never been greater.

Several methods aiming to monitor the number of wood ducks have been attempted. Researchers have examined aerial surveys (Cleveland 1994, Hein 1966) and Kelley (1996) evaluated line-transects that traversed wood duck habitat in Missouri. Other methods including stream brood surveys (Cottrell and Prince 1990), surveys of use of nest boxes (Zicus and Hennes 1987), and road surveys (Sauer and Droege 1990) are designed to provide indices that monitor trends in numbers (Martin et al. 1979). Banding data and harvest surveys are used to estimate survival and annual harvest. Models predicting fall flight of wood ducks in Michigan based on recruitment and survival estimates have also been attempted (Cleveland 1994). These methods have limitations that should be addressed.

Aerial surveys for waterfowl initiated in 1947 and expanded in 1955 to cover most of the breeding habitat of waterfowl are one of the longest running waterfowl survey methods (Martin et al. 1979). These systematic surveys seem to work well for most waterfowl species nesting in prairie potholes and marshes, including mallards and Canada geese (*Branta canadensis*). However, the low visibility in the densely vegetated swamps and lowland forests used as wood duck breeding habitat prohibits this method from working cost effectively for wood ducks (Cleveland 1994).

Line-transects may have more potential than aerial surveys for estimating wood duck densities because the habitat is traversed at the ground level. Kelley (1996) found that in areas with medium wood duck densities similar to the Mingo National Wildlife Refuge in Missouri, 30 km of transects are needed to achieve Coefficients of Variation (CV) of 20 % while 480 km are needed for CV's of 5 %. In areas with low visibility such as dense scrub-shrub habitat, this sampling method would be inefficient. Areas with low densities of wood ducks would also require a higher sampling intensity. Another problem with this method is that it requires areas large enough to run 30 km of transects in sites with uniform habitat. Application of this method across the landscape would be difficult where different habitat and wood duck densities would confound estimates.

Stream brood surveys, which are less arduous than line-transects, can be treated as an index to wood duck populations or, with assumptions made about the area sampled, as density estimates. Stream brood surveys seemed to have potential for monitoring wood duck populations on the Holston River in Tennessee, with 20 % of marked broods observed through biweekly night surveys (Cottrell and Prince 1990). In their study, ducklings were easily observed roosting along the shorelines of the river (Cottrell and Prince 1990). However, in Michigan, only one brood was observed for 105 miles of stream floated in 1994. Obviously, stream brood surveys can not be used to monitor wood duck populations in Michigan.

Major differences between brood survey results between Tennessee and Michigan seem to reflect differences in habitat. Tennessee has several large rivers with the upper Holston River boasting the highest wood duck populations of any streams in the nation (Bellrose and Holm 1994). These river systems are the major brooding habitat available in Tennessee and brooding hens may be more visible on the less densely vegetated and more navigable river systems. In contrast, while Michigan has several smaller rivers, it also has more than 2 million ha of wetlands (Dahl 1990), over 7 times the area in Tennessee. In Tennessee, Cottrell et al. (1990) observed consistent use of the Holston River shoreline habitats by wood duck broods from hatching to fledging. In 1996, a pilot telemetry study at Maple River and Gratiot Saginaw State Game Areas in Michigan (Appendix A) showed many of the brooding hens to be using forested wetlands and lowland hardwoods. Twice a week, visual locations were attempted on radioed hens during daylight hours. None of the hens were found to be using the main river channel of the Maple River.

Nest box surveys, which require 3.5 times the effort of road surveys, have been proposed as a population index. Although the rates of nest box use did correlate with road surveys at the region level, variation in the use of nest boxes may result in less dependable estimates than road surveys. Since most wood ducks nest in natural cavities (Bellrose and Holm 1994), use of nest boxes may not be representative of use in natural cavities (Ryan, et al. Unpublished, Semel et al. 1990). Some areas may have a lower number of natural cavities causing the boxes to increase the numbers of females using the areas (Soulliere 1990). In other areas, low nest box use rates may be caused by poor maintenance of the nest boxes.

The positioning and density of the nest boxes can affect use rates. Nest boxes are usually placed directly over water causing them to be the most obvious nest sites

(Soulliere 1990). In areas with both natural cavities and nest boxes present, the more visible nest boxes probably result in higher use rates (Soulliere 1990). Nest boxes placed in high densities can influence behavior. Females observing other females entering and leaving nest boxes may be attracted to the same nest boxes causing dump nesting even when other nest sites are available (Semel and Sherman 1986).

Since the use rates of the nest boxes may depend on the surrounding habitat, natural cavity availability, maintenance, position, and density of nest boxes, this index may not be reliable for monitoring the population at the site level. However, Zicus and Hennes (1987) found use of nest boxes correlated with the number of hens and juveniles harvested each year over 14 different counties over a 5 year period. As with the road survey data, it is possible that the site by site variation masks any trends that could be detected over time in larger areas.

Harvest surveys, derived from the combination of hunter surveys on the numbers of birds harvested with species and sex composition from Parts Collection Surveys (Martin et al. 1979) are used to monitor wood duck harvest. Since the harvest estimates are derived from a small sample of hunters, especially when broken down to the county level, the data should be used cautiously (P. Padding pers. commun.). Because the USFWS accumulates and analyzes data from the entire United States, they currently do not have the capacity to increase sample sizes for the county level. Even at large scale levels, the USFWS harvest estimates are problematic (Wright 1978, Tautin et al. 1989, and Pendleton 1992).

Harvest estimates were not correlated with nest box use rates or road surveys at the unit level. Numbers of breeding wood ducks based on the road surveys and nest box use seemed to be highest for Unit C while Unit A had the highest harvest estimates.

Road surveys, similar to call counts and Breeding Bird Surveys (BBS), have been used to detect trends of wood duck populations over groups of years (Sauer and Droege 1990). Route regression analysis of wood duck numbers from the BBS can detect population trends (Sauer and Droege 1990). Kelley (1994) suggested that shortening the survey from 40 km to 16 km and focussing efforts in areas with prime wood duck habitat might improve the efficiency of the surveys for wood ducks. The limitations of route regression analysis include the requirement of at least 5 years of data to detect trends and that changes in one year or changes at the local level, such as a management area can not be detected (Kelley 1994).

The surveys focussing only on wood ducks were found to have higher variances associated with them than the BBS (Kelley 1997). To detect a population trend of 2 % change/year ($\alpha = 0.10$, power = 0.80) in the Lake States (MI, OH, and IN) over a 3 year sampling period, 2675 wood duck road survey routes with at least 1 wood duck observed are required while only 299 BBS routes are required. Similarly, to detect a 4% change/year in the same area over a 3 year period, 669 wood duck routes are required while only 75 BBS are needed. Kelley (1997) concluded that establishing wood duck road surveys to replace BBS would be inefficient. However, their analysis was based on a limited number of wood duck routes (only 24 for eastern North America).

Road surveys may have value as an index to wood duck populations in Michigan. Although road surveys were not consistently correlated with nest box use at the site level, unit correlations were significant. The lack of a correlation found between the road surveys and the harvest estimates at the county or regional level could imply differences in the distributions of the density of breeding birds and the fall harvest.

The number of indicated birds from the road surveys are higher for 1994 and 1996 compared to 1995 while similar numbers were harvested each year (Figure 5). The discrepancies could be due to biases in the harvest estimates. The hunters who are more likely to respond to the harvest surveys may be hunting their traditional sites until they are successful instead of going to sites where the birds are at higher densities. Hunters putting in higher levels of effort lead to overestimates of the harvest for that area.

One strength the wood duck road surveys have over the BBS is the sampling of wood ducks throughout the pre-breeding stage. While the BBS is limited to 1 sampling effort in early June (Martin et al. 1979, Kelley 1994), each of the 17 wood duck routes were conducted in early and late time periods between April 15 to June 5 resulting in approximately 68 total routes conducted. The timing of the road surveys did prove to be significant in 1995 and 1996 and more wood ducks were consistently detected in the early time period all 3 years. The variation in annual nesting chronology is an important consideration in the enumeration of wood ducks. In brood surveys conducted in Tennessee, Cottrell and Prince (1990) found variations in the timing of hatching from year to year. They concluded that using specific dates for comparing annual surveys would result in unreliable estimates of production. The same may be true for surveys of the spring breeding population of wood ducks. Surveying wood ducks once annually in June may result in surveys of birds at different points in their breeding chronology from year to year. However, spreading the sampling period over the entire early breeding stage and summing the results for the total indicated birds may result in a more accurate estimate of the number of wood ducks and intensity of the breeding effort along the sample route.

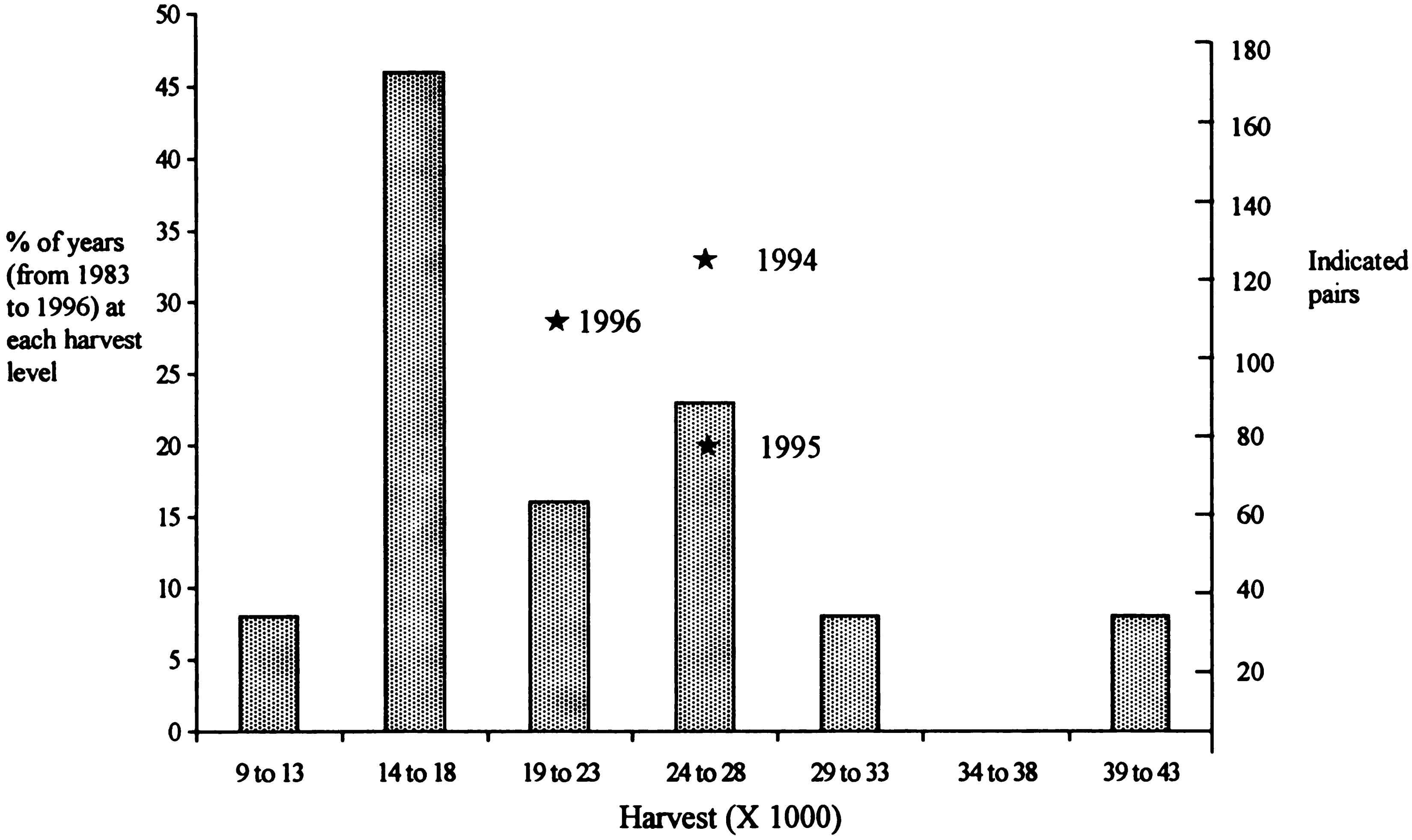


Figure 5. Comparison of the frequency distribution of harvest estimates for 36 counties of Michigan for 1983 - 1996 and the indicated pairs from road surveys for 1994 - 1996. The indicated pairs are marked above the frequency bar containing the harvest estimate for that year.

★ = Numbers of indicated pairs from road surveys for 1994 - 1996.

Fall flight estimates of wood ducks in southern Michigan were calculated using a model based on survival and recruitment with the number of indicated birds from the road surveys input as the adult spring breeding population (Appendix B). A fall flight of 81,504 and 112, 428 wood ducks in 1995 and 1996, respectively was estimated (Table 10). The harvest estimates computed by the USFWS are 30 % and 17 % of the fall flight estimates using the unmodified indicated pairs for 1995 and 1996. The harvest estimates from 1983 to 1996 ranged from roughly ½ to 2 times the current estimates from harvest. To simulate a similar range of road survey results, the numbers of indicated birds were halved and doubled and the model equations were recalculated with these numbers. Estimated fall flight ranged from 40,752 to 224,856 wood ducks.

Table 10. Fall Flight estimates based on varied numbers of indicated pairs from 1995 and 1996 road surveys.

Factor of indicated pairs	# of indicated pairs	Year	Fall flight
Indicated pairs	112	1995	112,428
	80	1996	81,504
½ * Indicated pairs	56	1995	56,214
	40	1996	40,752
2 * Indicated pairs	224	1995	224,856
	160	1996	163,009

CONCLUSIONS AND RECOMMENDATIONS

Of the survey methods conducted in this project, road surveys appear to have the best potential and should be evaluated further. The road survey methodology could easily be expanded into a point sampling survey by refining the estimated sample area which would facilitate the calculation of density. Density could be used to refine estimates of fall flight. Road surveys are relatively low effort compared to nest box surveys or line-transects. Although line-transects can be used to estimate densities of wood ducks (Kelley 1996), the sampling effort required by this method would be extremely difficult to expand to state-wide estimates.

Road surveys also fit well with techniques traditionally used to monitor other game species. Call counts have been evaluated for pheasants (*Phasianus colchicus*), and turkey (*Meleagris gallopavo merriami*) (Scott and Boeker1972). Route regression of road surveys is currently used to monitor woodcock (*Scolopax minor*) (Straw 1992) and mourning dove (*Zenaida aurita*) (Dolton 1993) populations. The methodology is simple and sampling efforts throughout the breeding season may provide useful counts of the breeding wood ducks even with 5 year constraints on the data.

Currently, the predictions from the modified Walters et al. (1974) model with road surveys input as spring breeding populations have high variance estimates (Appendix B). Expanding the results of the road surveys to represent the 31 counties is a large source of this variation. The model may be improved by stratifying the sample points by habitat types. The amount of each habitat type present in the 31 counties could be estimated and the wood duck densities could be expanded separately for each habitat type.

Kelley (1997) found the BBS to be more efficient than routes focussing on wood ducks. However, since the analysis was based on a limited number of wood duck routes (only 24 for eastern North America), further evaluation of the two techniques is warranted. Sampling throughout the breeding season instead of one time may provide a better representation of the breeding wood ducks. Therefore, the wood duck road surveys should continue and undergo further evaluation as a method of monitoring and predicting the fall flight of wood ducks.

APPENDICES

APPENDIX A

A radio telemetry pilot study of female wood ducks in Maple River and Gratiot-Saginaw State Game Areas during the 1996 brooding season.

APPENDIX A

A radio telemetry pilot study of female wood ducks in Maple River and Gratiot-Saginaw State Game Areas during the 1996 brooding season.

To determine where brood survey efforts should be directed, radio telemetry was used in the summer of 1996 to monitor the movements of a small sample of brooding hens. Hens captured through nest box surveys at Maple River State Game Area and Gratiot-Saginaw State Game Area were fitted with necklace style telemeters (Lotek Engineering, Inc., Newmarket, Ontario, Canada) weighing 15 grams equipped with a 15 inch antenna and a 9 hour mortality sensor.

Hens were located with directional antennas using triangulation from 2 locations. Compass directions of each signal were marked on laminated Michigan Inventory Resource Information System (MIRIS) maps of the area. The intersection of the 2 lines from the 2 locations was assumed to be the hen's approximate location. The mapped location was recorded to the nearest 0.01 mi^2 using the X,Y coordinates of a grid overlay. The habitat, as described by the MIRIS map, was recorded for each location. Locations were attempted 7 times for each hen each week. Four of the locations were during daylight hours and 3 of the locations were taken at least 30 minutes after sunset.

Visual locations were attempted for each hen at least once every other week. The radio telemetry equipment, including the receivers, directional antennae, and headphones was used to walk or canoe into the location of the hen. At least 2 observers would use the equipment to walk into the hen from different angles. When hens were visually located, the site, brood size, habitat type, and a qualitative description of the visibility of the area were recorded. Other broods and hens seen in the area of the hen were also recorded.

Twenty female wood ducks were radio-collared in 1996 (Table A1). Twelve of the hens had successful nests, 4 nests were unsuccessful with signs of predation, 3 were abandoned, and 1 did not successfully complete hatching. By the end of the summer, only 4 hens were alive and not censored. Twelve hens had malfunctioning radios or moved far out of the study region. Radios were collected for 4 hens. Upon collection of the radios, 3 of the sites had feathers or showed signs of that the hen died while only the radio was found for the last hen.

Forested wetlands, represented by 611 (Table A1) were the habitat type recorded as the most frequently used by the radio collared wood ducks. Thirteen hens were found to be using forested wetlands as the first of their 3 primary habitats. Lowland hardwoods (414) and herbaceous open fields (31) were also found to be used frequently.

The home range size was calculated for each hen using Telem88 (Coleman and Jones 1988) (Table A2). The harmonic center and harmonic home range calculations were selected in this program.

Table A1. Summary of individual records for wood duck females trapped and marked in the radio telemetry pilot study in 1996. Twenty female wood ducks were trapped, radio collared, and monitored from 10 June to 16 August. The number of locations and the top 3 habitat types birds occupied are listed in the order of use. Number of ducklings observed and the date of the last radio contact with the female are listed.

Site	Radio Freq.	Nesting Attempt	# of Membranes	# of locations	Primary habitats@	Ducklings observed	Fate
Maple	148.496	Successful	13	45	611, 31, 622	2	Alive 8/16
	148.834	Successful	6	48	611, 31, 21	5	Dead 8/6
	148.914	Successful	6	36	611, 31, 622	0	Dead 7/25
	149.115	Successful	6	32	611, 21, 31	0	Lost 7/19
	149.676	Successful	12	31	31, 611, 622/414	6	Radio failed 7/21
	149.706	Successful	5	40	611, 31, 414	8	Alive 8/16
	150.076	Unsuccessful	-	53	611, 31, 414	0	Alive 8/16 Shot & collected
	150.085	Successful	3	8	611, 31	0	Lost 6/22
	150.355	Unsuccessful	-	17	622, 611, 31/21	0	Lost 7/5
	150.476	Unsuccessful	-	51	622, 611, 31	0	Alive 8/16
Gratiot-Saginaw	150.126	Successful	10	20	611, 414, 21	0	Collected radio 7/9
	150.145	Abandoned	-	13	414, 611	0	Dead 7/1
	150.165	Abandoned	-	24	611, 414, 612/21	0	Lost 7/19
	150.175	Unsuccessful	-	7	414, 611	0	Lost 6/24
	150.185	Successful	4	33	611, 32, 414	3	Lost 7/22
	150.204	Abandoned	-	38	414, 611, 32/31	0	Lost 7/26
	150.274	Unsuccessful*	1	22	611/21, 414	0	Lost 7/21
	150.306	Successful	6	36	611, 414, 31	5	Lost 7/26
	150.515	Successful	10	41	31, 414, 611/622	2+	Lost 8/4
	150.546	Successful	3	11	611, 622, 414	0	Lost 6/27

* 1 membrane was found in this nest along with 1 dead chick. It is assumed that no chicks were fledged from this nest.

@ Habitat classifications: 21 = agriculture cropland, 31 = herbaceous open field, 32 = shrub open field, 414 = lowland hardwood, 611 = forested wetland, 612 = shrub wetland, 622 = emergent wetland.

Table A2. Sizes (in ha) of home ranges for hens monitored in radio telemetry study. Home ranges were calculated using harmonic home range formulas in Telem88. 50%, 80% and 95% contours of use were calculated.

Site	Frequency (hen id.)	Nesting attempt	Size of 50 % contour (ha)	Size of 80% contour (ha)	Size of 95 % contour (ha)
Maple River	148.496	Successful	82.90	165.69	327.41
	148.834	Successful	78.43*	135.25*	266.33
	148.914	Successful	16.96	40.88	84.94
	149.115	Successful	38.25	144.93	461.39
	149.676	Successful	20.50	143.56	447.35
	149.706	Successful	91.51	183.69	515.09
	150.076	Unsuccessful	31.58	84.37	183.95
	150.085	Successful	23.18	49.64	95.92*
	150.355	Unsuccessful	31.22	89.97	189.97
	150.476	Unsuccessful	36.47	82.48	185.52
Gratiot-Saginaw	150.126	Successful	98.12	255.50*	347.20*
	150.145	Unsuccessful	33.82	85.10	187.03*
	150.165	Unsuccessful	1218.91	2187.25*	2601.09*
	150.175	Unsuccessful	11.95	47.09*	62.19*
	150.185	Successful	39.84	432.81	666.28*
	150.204	Unsuccessful	51.61*	170.64	285.50
	150.274	Unsuccessful	69.87	986.17	3689.04*
	150.306	Successful	94.46	1660.90	4093.61
	150.515	Successful	682.95*	2381.31*	4169.27*
	150.546	Successful	25.68	65.65	787.37*

* These contours were made up of more than 1 polygon

APPENDIX B

Predictions of the fall flight of wood ducks with mechanistic model equations.

APPENDIX B

Predictions of the fall flight of wood ducks with mechanistic model equations

To predict the fall flight of wood ducks in Michigan, models will need to be developed to expand results from the selected surveys across the area in question. As an exploratory exercise, the results of the indicated pair calculations (Table 5) from the road surveys were input into a model that estimates fall flight of wood ducks (Cleveland 1994). The adult spring population size using road survey data was based on an assumption that the size of the area sampled at each survey point was a 0.403 km (1/4 mile) and 0.201 km (1/8 mile) radius circular plot. Plot sizes of 0.508 km^2 and 0.127 km^2 were multiplied by the number of plots sampled in each survey and expanded across all sites, representing 723 km^2 and 181 km^2 over the 50,383 km^2 survey zone. The adult spring population was calculated using the following formula:

Adult spring pop. = (Total indicated birds) * (Total area of counties/Area surveyed).

Fall Flight was based on the variables identified in Table B1.

The fall flight estimate for the 1/4 mile radius plot sample was much smaller than the 1/8 mile radius estimate (Table B2). For 1995, the 1/4 mile radius estimate was 20,376 wood ducks in the fall flight, while the 1/8 mile radius was 81,504. The 1995 USFWS harvest estimate for the counties is 24,192 wood ducks. Obviously, the 1/4 mile estimate for the fall flight must be low, with a deficit of 3816 wood ducks after harvest. The USFWS harvest estimates are thought to overestimate the harvest (Pendleton 1992) and some wood duck harvested may have been birds migrating through the area. However, the 1/8 mile radius estimate may be more accurate with an estimate of 30 % of the population harvested.

Table B1. Parameters and equations used as the basis for fall flight model (Walters et al. 1974).

Parameter	Variables
Production Rate	(Eggs produced/Adult) * (Surv. rate eggs to hatching) * (Surv. rate chicks to fledging) * (Surv. rate through early flight period)
Production	(New adults in spring * Production rate for 1st year) + (Old adults in spring * Adult production rate)
Fall Adult Population	(New and old spring adults) * (Adult summer surv. rate)
Fall Juvenile Population	(Production) * (Juvenile summer survival rate)
Fall Flight	Fall adult population + Fall juvenile population

The calculations of variance were similar to those from Cleveland's (1994) model, with adjustments for the input of the road survey data. The variance of the fall flight was the total of the variance from the adult fall population and the juvenile fall population. The formula for the variance of the Adult Fall Population was:

Var(Ad. fall pop.) = (Ad. spring pop.)^2 *Var(Survival rate) + (Survival rate)^2 *Var (Ad. spring pop.).

Since the survival rate was assumed to be 0.8 for both males and females, no variance was

Table B2. Estimates of parameters for fall flight model of wood ducks, using indicated birds from 1995 and 1996 road surveys to replace inputs from aerial surveys for adult spring population calculations.

		0.25 mi² radius		0.125 mi² radius	
Model parameters	Year	Estimate	Variance	Estimate	Variance
Adult spring population	1995	11,290	$4.19 * 10^5$	45,150	$6.71 * 10^6$
	1996	15,570	$4.67 * 10^5$	62,280	$7.47 * 10^6$
Production*	1995	12,610	$2.33 * 10^7$	50,430	$3.73 * 10^8$
	1996	17,390	$4.39 * 10^7$	69,570	$7.02 * 10^8$
Adult fall population	1995	9,030	$2.68 * 10^5$	36,120	$4.29 * 10^6$
	1996	12,460	$2.99 * 10^5$	49,820	$4.78 * 10^6$
Juvenile fall population	1995	11,350	$2.44 * 10^7$	45,390	$1.59 * 10^8$
	1996	15,650	$4.60 * 10^7$	62,610	$3.00 * 10^8$
Fall flight	1995	20,380	$3.85 * 10^7$	81,500	$1.63 * 10^8$
	1996	28,110	$7.24 * 10^7$	112,430	$3.04 * 10^8$

*The same production rate estimate from Cleveland (1994) was used. Since the production rate was in units of clutch size/hen, it was multiplied by only the number of hens (half of the adult spring population).

estimated for this term, simplifying the formula to:

Var(Ad. fall pop.) = (Survival rate)^2 *Var (Ad. spring pop.).

The variance of the adult spring population was calculated as:

Var(Ad. Spring pop.) = (Area of counties/area surveyed)^2 * Var(Indicated birds).

To calculate the variance of the indicated birds, the road surveys results were treated as a binomial distribution with birds either observed or not observed at a sample point. The formula for the variance of the adult spring population was:

Var(Ad. Spring pop.) = (Area of counties/area surveyed)^2 * (n)(p)(q).

where n = the number of sampling points, p = (sample points with birds observed/n), and q = (sample points without birds observed/n).

The variance of the juvenile fall population was calculated as:

Var(Juv. fall pop.) = 1/4(Prod.)^2* Var(Surv. juv. female) + (Surv. juv. female)^2 * Var(Production) + 1/4(Prod.)^2* Var(Surv. juv. male) + (Surv. juv. male)^2 * Var(Production).

The variance of the survival rates for juvenile males (0.00526) and females (0.00731) were derived from the study on survival of post-fledgling wood ducks in Minnesota (Kirby

1990) used in Cleveland's (1994) model. The variance of production was calculated as:

$$\text{Var(Prod.)} = 1/4[(\text{Ad. spring pop.}/2)^2 * \text{Var(Prod. rate)} + (\text{Prod. rate})^2 * 1/4\ \text{Var(Ad. spring pop.)}]$$

where the variance of the production rate is 0.714675 from Cleveland's (1994) model.

The variance of the fall flight was high for both density estimates for both years (Table 10). Although the 1/8 mile radius may be a closer estimate to the population size, it had a much larger variance than the 1/4 mile radius, due to the larger expansion factor from the area surveyed to the total area represented in the survey. In both years, the 1/8 mile variance was about 16 times as large as the 1/4 mile estimate.

A number of issues must be clarified before these estimates can be verified. Habitat quality and wood duck population density are confounded which makes the expansion of the surveys to the total area unrealistic. Since there was significant variation within the sites of the 1995 and 1996 road surveys, with Maple River consistently having the highest number of wood ducks seen, the assumption of constant density is violated immediately. Also, most of the road surveys are placed in areas with higher quality wood duck habitat, along rivers (Maple, Mendon, Allegan, Muskegon 1), or in state game areas actively managing for wood ducks, at least the in the form of nest boxes (Maple River, Allegan, Muskegon 2, Bald Mountain, Flat River, Gull Lake, Crane Pond, Somerset, Rose Lake). The density of wood ducks in these areas is likely to be higher than in other areas. In defense of the assumption, the remaining sites (Ann Arbor, Albion, Cambria, Hastings, Fine Lake), which were set up to correspond with the flight surveys and had no actively managed areas nearby, were not significantly different from the other sites. In fact, Hastings ranked in the top 3 sites for the numbers of wood ducks observed. However, it is highly unlikely that the density of wood ducks on the surveys is comparable to more urban areas which are included in the calculations of area. A model that adjusts for the variation in habitat quality and quantity would be more accurate.

Another problem with this model is the assumptions of size of the area surveyed. No adjustment for visibility was made in the calculations of the adult spring population from the indicated bird estimate from the road surveys. It is unlikely that the same sized area would be surveyed at each site. Some areas are more forested with trees lining the road, while agricultural areas have more open areas allowing for wood ducks to be seen at much greater distances.

LITERATURE CITED

Bartlet, G. A. and R. E. Trost. 1990. Populations, harvest, and survival of wood ducks in Wisconsin, Minnesota, and Michigan, 1961-87. Pages 341-348 *in* L. H. Fredrickson, G. V. Burger, S. P. Havera, D. A. Graber, R. E. Kirby, and T. S. Taylor, eds. Proc. 1988 N. Am. Wood Duck Symp., St. Louis, MO.

Brakhage, D. H. 1990. Techniques currently used for monitoring wood duck populations. Pages 201-203 *in* L.H.Fredrickson, G. V. Burger, S. P. Havera, D. A. Graber, R. E. Kirby, and T. S. Taylor, eds. Proc. 1988 N. Am. Wood Duck Symp., St. Louis, MO.

Bellrose, F. C. 1980. Ducks, geese, and swans of North America. Third ed. Stackpole books, Harrisburg, PA. 544pp.

Bellrose, F. C. and D. J. Holm. 1994. Ecology and management of the wood duck. Stackpole Books, Mechanicsburg, PA. 588pp.

Cleveland, K. T. 1994. Predictive Models for the flight of selected waterfowl species in Michigan. M.S. Thesis, Michigan State University, East Lansing, Michigan. 91 pp.

Coleman, J. S. and Jones, A. B. III. 1988. User's guide to TELEM88: Computer analysis system for radio-telemetry data. Dept. of Fisheries and Wildlife, Virginia Polytechnic Institute and State University, Blacksburg, VA. Research Series No.1 . 49pp.

Cottrell, S. D. and H. H. Prince. 1990. Comparison of wood duck survey techniques on the Holston River in East Tennessee. Pages 201-203 *in* L. H. Fredrickson, G. V. Burger, S. P. Havera, D. A. Graber, R. E. Kirby, and T. S. Taylor, eds. Proc. 1988 North Amer. Wood Duck Symp., St. Louis, MO.

Cottrell, S. D., H. H. Prince, and P. I. Padding. 1990. Nest success, duckling survival, and brood habitat selection of ducks in a Tennessee Riverine System. Pages 191-197 *in* L. H. Fredrickson, G. V. Burger, S. P. Havera, D. A. Graber, R. E. Kirby, and T. S. Taylor, eds. Proc. 1988 North Amer. Wood Duck Symp., St. Louis, MO.

Crissey, W. F. 1984. Calculators and Ouija Boards. Pages 259-271 *in* A. S. Hawkins, R. C. Hanson, H. K. Nelson, H. M. Reeves, eds. Flyways: Pioneering Waterfowl Management in North America. U.S. Dept. of Interior, F.W.S., Washington D.C.

Dahl, T. E. 1990. Wetland Losses in the United States, 1780's to 1980's, U.S. Dept. of Interior, F.W.S., Washington, D.C., 21pp.

Dolton, D. D. 1983. Mourning dove breeding population status, 1983. U.S. Dept. Interior, Fish Wildl. Serv. 15 pp.

Gamble, K. E. 1990. Status of wood ducks in the Mississippi Flyway. Pages 115-119 *in* L. H. Fredrickson, G. V. Burger, S. P. Havera, D. A. Graber, R. E. Kirby, and T. S. Taylor, eds. Proc. 1988 North Amer. Wood Duck Symp., St. Louis, MO.

Geis, A. D. 1966. Establishing the status of wood duck populations - successes and problems (Information needs and procedures for establishing status of the wood duck population. Pages 183-192 *in* J.B. Trefethen R.D., ed., Wood Duck management and Research: a symposium. Wildl. Manage. Inst., Washington D.C.

Hein, D. 1966. Float counts vs flight counts as indices to abundance of nesting wood ducks. J. Wildl. Manage. 30(1):13-16.

Kelley, J. R. Jr. 1994. Study proposal: Wood duck population monitoring initiative. U.S. Fish and Wildl. Serv. Office of Migratory Bird Management. Unpublished. 50 pp.

Kelley, J. R. Jr. 1996. Line-transect sampling for estimating breeding wood duck density in forested wetlands. Wildl. Soc. Bull. 24(1):32-36.

Kelley, J. R. Jr. 1997. Wood duck population monitoring initiative: Final report. U.S. Fish and Wildl. Serv. Office of Migratory Bird Management. Unpublished draft. 207 pp.

Kirby, R. E. 1990. Survival of postfledging wood ducks in northcentral Minnesota. Pages 185-189 *in* L.H.Fredrickson, G. V. Burger, S. P. Havera, D. A. Graber, R. E. Kirby, and T. S. Taylor, eds. Proc. 1988 N. Am. Wood Duck Symp., St. Louis, MO.

Martin, F. W., R. S. Pospahala, and J. D. Nichols. 1979. Assessment and population management of North American migratory birds. Pages 187-239 *in* J. Cairns Jr., G. P. Patil, and W. E. Waters, eds. Environmental Biomonitoring, Assessment, Prediction, and Management-Certain Case Studies and Related Quantitative Issues. International Co-operative Publishing House, Fairland, MD.

Mississippi Flyway Council. 1994. A wood duck harvest strategy for the Mississippi Flyway. Mississippi Flyway Technical Section. Unpublished. 16pp.

Pendleton, G. W. 1992. Nonresponse patterns in the Federal Waterfowl Hunter Questionnaire Survey. J. Wildl. Manage. 56(2):344-348.

Prince, H. H. 1991. Species account: Wood duck (Aix sponsa) Pages 122-123 *in* R. C. Brewer, G. A. McPeek, R. J. Adams, Jr., eds. The Altlas of Breeding Birds of Michigan. Michigan State University Press, E. Lansing, MI.

Ryan, D. C., R. J. Kawula, and R. J. Gates. Unpublished report. Breeding biology of wood ducks in natural cavities in southern Illinois. 31 pp.

SAS Institute Inc. 1989. SAS/STAT User's Guide, Version 6, 4th edition, Volume 2. SAS Institute Inc., Cary, NC. 1686 pp.

Sauer, J. R., and S. Droege. 1990. Wood duck population trends from the North American Breeding Bird Survey. Pages 162-168 *in* L. H. Fredrickson, G. V. Burger, S. P. Havera, D. A. Graber, R. E. Kirby, and T. S. Taylor, eds. Proc. 1988 North American Wood Duck Symp., St. Louis, MO.

Scott, V. E. And E. L. Boeker. 1972. An evaluation of wild turkey call counts in Arizona. J. Wildl. Manage. 36(2):628-630.

Semel, B., and P. W. Sherman. 1986. Dynamics of nest parasitism in wood ducks. Auk 103:813-816.

Semel, B., P. W. Sherman, and S. M. Byers. 1990. Nest boxes and brood parasitism in wood duck: A management dilemma. Pages 163-170 *in* L. H. Fredrickson, G. V. Burger, S. P. Havera, D. A. Graber, R. E. Kirby, and T. S. Taylor, eds. Proc. 1988 North American Wood duck Symp., St. Louis, MO.

Soulliere, G. J. 1990. Regional and site-specific trends in wood duck use of nest boxes. Pages 235-244 *in* L. H. Fredrickson, G. V. Burger, S. P. Havera, D. A. Graber, R. E. Kirby, and T. S. Taylor, eds. Proc. 1988 North American Wood duck Symp., St. Louis, MO.

Steel, R. G. D., J. H. Torrie, and D. A. Dickey. 1997. Principles and procedures of statistics, a biometrical approach. The McGraw-Hill Companies, Inc., New York, NY. 666 pp.

Straw, J. A. Jr. 1992. American woodcock harvest and breeding population status, 1993. U.S. Dept. Interior, Fish Wildl. Serv. 15 pp.

Tautin, J., S. M. Carney, and J. B. Bortner. 1989. A national migratory gamebird harvest survey: A continuing need. Trans. N. Amer. Wildl. Natur. Resour. Conf. 54:545-551.

Tiner, R. W., Jr. 1984. Wetlands of the Unites States: Current status and recent trends. National wetlands inventory. U.S. Fish and Wildl. Serv., Washington D.C. 59 pp.

Walters C. J., R. Hilborn, E. Oguss, R. M. Peterman, J. M. Stander, 1974. Development of a simulation model of mallard duck populations. Canadian Wildlife Service Occasional Paper 20. 34pp.

Wright, V. L. 1978. Causes and effects of biases on waterfowl harvest estimates. J. Wildl. Manage. 42(2):251-262.

Zicus, M. C., and S. K. Hennes. 1987. Use of nest boxes to monitor cavity nesting waterfowl populations. Wildl. Soc. Bull. 15:525-532.