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Predictive Models for the Fall Flight of Selected Waterfowl Species in Michigan

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PREDICTIVE MODELS FOR THE FALL FLIGHT OF SELECTED WATERFOWL SPECIES IN MICHIGAN

By

Karen Tay Cleveland

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ABSTRACT

PREDICTIVE MODELS FOR THE FALL FLIGHT OF SELECTED WATERFOWL SPECIES IN MICHIGAN

By

Karen Tay Cleveland

Michigan has traditionally lacked accurate estimates of its populations of breeding waterfowl and fall flight. Models of the production of mallard, black duck, Canada goose, and wood duck were constructed using data from the Michigan Breeding Waterfowl Survey (MBWS). The resultant models take the form of a distribution of values of young produced per adult, and point estimates of young produced to flight stage, adults at migration, newly fledged birds at migration, and total fall flight. Production rates were assessed for their impact on population size. The mallard and black duck models accurately predict the number of young produced annually. The wood duck model overestimates production by 100-300%. The Canada goose model incorporates age specific production and underestimates the fall flight in Michigan. Recommendations to improve the MBWS were made including changes in stratification, modifications of the calculation of visibility correction factors, and reduction of observer bias.

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INTRODUCTION

In recent years, Michigan has gathered more attention as a source of waterfowl production. This is due in great part to the declining populations of breeding waterfowl in the prairie pothole region of North America, which produces about 50% of the ducks in North America, though it contains only 10% of the continental breeding range (Klett et al. 1988). It has been suggested that this decline may be due to more intensive agricultural practices or hunting pressure (Johnson and Shaffer 1987, Nudds and Cole 1991).

Michigan Breeding Waterfowl Survey:

During the late 1940's and early 1950's, the United States Fish and Wildlife Service developed and implemented the aerial Waterfowl Breeding Population and Habitat Survey (WBPHS), which is conducted in the spring to estimate the number of breeding birds and the abundance of suitable breeding habitat, mostly in the form of potholes. This was done in large part to aid in the determination of appropriate management options to comply with the Migratory Bird Treaty Act of 1918. The aerial Waterfowl Production and Habitat Survey (WPHS), established experimentally in 1950 and operational in 1956, has also been used to estimate population sizes and production rates. It is flown in July to estimate the total production of waterfowl and the number of late nesting birds. Since the mid-1950's, both of these surveys have been conducted annually. Beginning in 1959, air-ground comparisons were made in the counts to provide visibility correction factors for all species counted. These adjustments only apply to the WBPHS, however, as problems caused the discontinuance of air-ground sampling on the WPHS. Current efforts in the United States and Canada account for the monitoring of nearly 1.4 million square miles every year (USFWS 1987)

In 1991, efforts to estimate waterfowl production and the size of the breeding population in Michigan were instituted. The initial aim of the project was to estimate the size of the adult spring population using visibility correction factors measured in Ontario and a survey design which was designed for use in the prairie pothole region. It has developed into a program to assess the number of spring breeders and estimate the expected fall flight. The Michigan Department of Natural Resources (MDNR) conducts annual aerial surveys of the entire state during the spring which consist of fixed-wing and helicopter flights to determine the number of breeding waterfowl. The fixed-wing flights establish a rough count which is modified by counts from the helicopter flights.

Due to differences in land use and ground cover in the southern Lower Peninsula, northern Lower Peninsula and Upper Peninsula, the assumption was made that sightability of birds will not be constant for the entire state. A subset of the segments of fixed-wing flights is flown with a helicopter to quantify differences in sightability. As of 1993, visibility correction factors (VCF's) for three species, mallard (*Anas platyrhynchos*), Canada goose (*Branta canadensis*), and wood duck (*Aix sponsa*), were calculated using only data collected on flights in Michigan. Visibility correction factors for all other species have been calculated from flights and ground surveys in Ontario.

Waterfowl Modelling:

Estimating the fall flight of waterfowl from the prairie pothole region of North America has been a goal of the United States Fish and Wildlife Service and the Canadian Wildlife Service since the inception of the WBPHS and the

WPHS. Several models of mallard production have been developed for this region (Walters et al. 1974, Cowardin and Johnson 1979, Martin et al. 1979, Dudderar 1985, Johnson et al. 1986, Johnson et al. 1987, Cowardin et al. 1988, Johnson et al. 1988). No other species on the prairie potholes received this attention, and almost no work has been done to model species outside the prairie pothole region. Waterfowl production models have never been developed for Michigan.

Waterfowl production models have taken two common forms: flowchart based models which determine success of individual animals and mechanistic models which employ survival and reproduction rates at the population level. The flowchart based model (Figure 1) uses a tally of the individual birds which survive the season (② in Figure 1) and the birds which do not (③ in Figure 1). The mechanistic model is composed of a series of equations which apply population derived reproduction and survival rates to individuals, which are then used to estimate end values for the population as a whole (Figure 2).

Estimates from the Michigan Breeding Waterfowl Survey suggest that Michigan accounts for approximately 400,000 breeding mallards, 150,000 breeding Canada geese and 5,500 breeding black ducks (*Anas rubripes*) each year. All of these birds and their young which survive to migrate comprise the

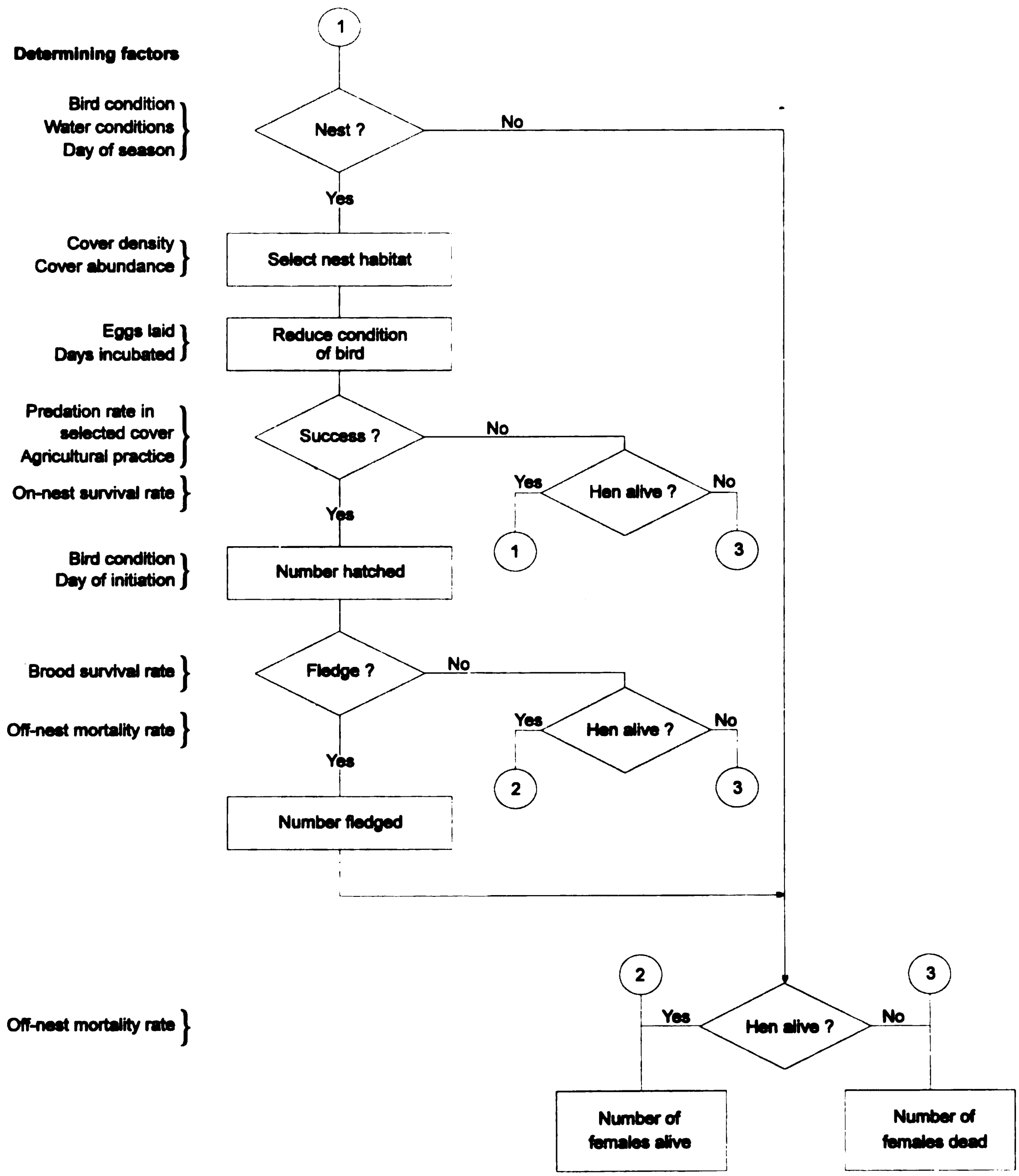

Figure 1: Flowchart based waterfowl model (Johnson et al., 1986)

fall flight, which provide recreation through sport hunting and viewing. An accurate assessment of production within the state is necessary to set appropriate bag limits and season lengths.

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Production rate =(eggs produced per adult)*
                  (survival rate of eggs to hatching)*
                   (survival rate of chicks to fledging)*
                    (survival rate through early flight period)

Production =(new adults in spring *
                         production rate for first breeding) +
          (old adults in spring * adult production rate)

Fall adult population = (new & old spring adults)*
                                (adult summer survival rate)

Fall juvenile population = (production)*
                             (juvenile summer survival rate)

Fall flight = fall adult population + fall juvenile population
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Figure 2: Mechanistic model equations to estimate fall flight by species (Walters et al. 1974)

OBJECTIVES

The objectives of this study were to develop statistically and biologically sound models to predict the fall flight of mallards, black ducks, Canada geese, and wood ducks from Michigan and to provide recommendations for refinement of the Michigan Breeding Waterfowl Survey.

METHODS

Michigan Breeding Waterfowl Survey And Visibility Correction Factors:

Michigan's Breeding Waterfowl Survey (MBWS) was conducted in late April and early May of 1991, 1992, 1993, and 1994. Yearly timing depends on the weather since the survey needs to start after spring migrants have returned and end before complete leafout. Because of these factors, the state is censused earliest in the south and latest in the Upper Peninsula.

Differences in land use and cover types in the state have necessitated the division of the state into two strata for the purposes of the survey (Figure 3). Stratum A, the Forest Stratum, is composed of the Upper Peninsula and the northern Lower Peninsula. The Upper Peninsula consists mainly of forests of conifers and northern hardwoods (Omernik and Gallant 1988). Forest and vegetation cover is very thick with little in the way of cleared areas for either agricultural or residential use. The northern Lower Peninsula is a fairly equal mixture of forests of conifers and northern hardwoods, hardwood stands with moderate agricultural development, and agricultural and urban areas

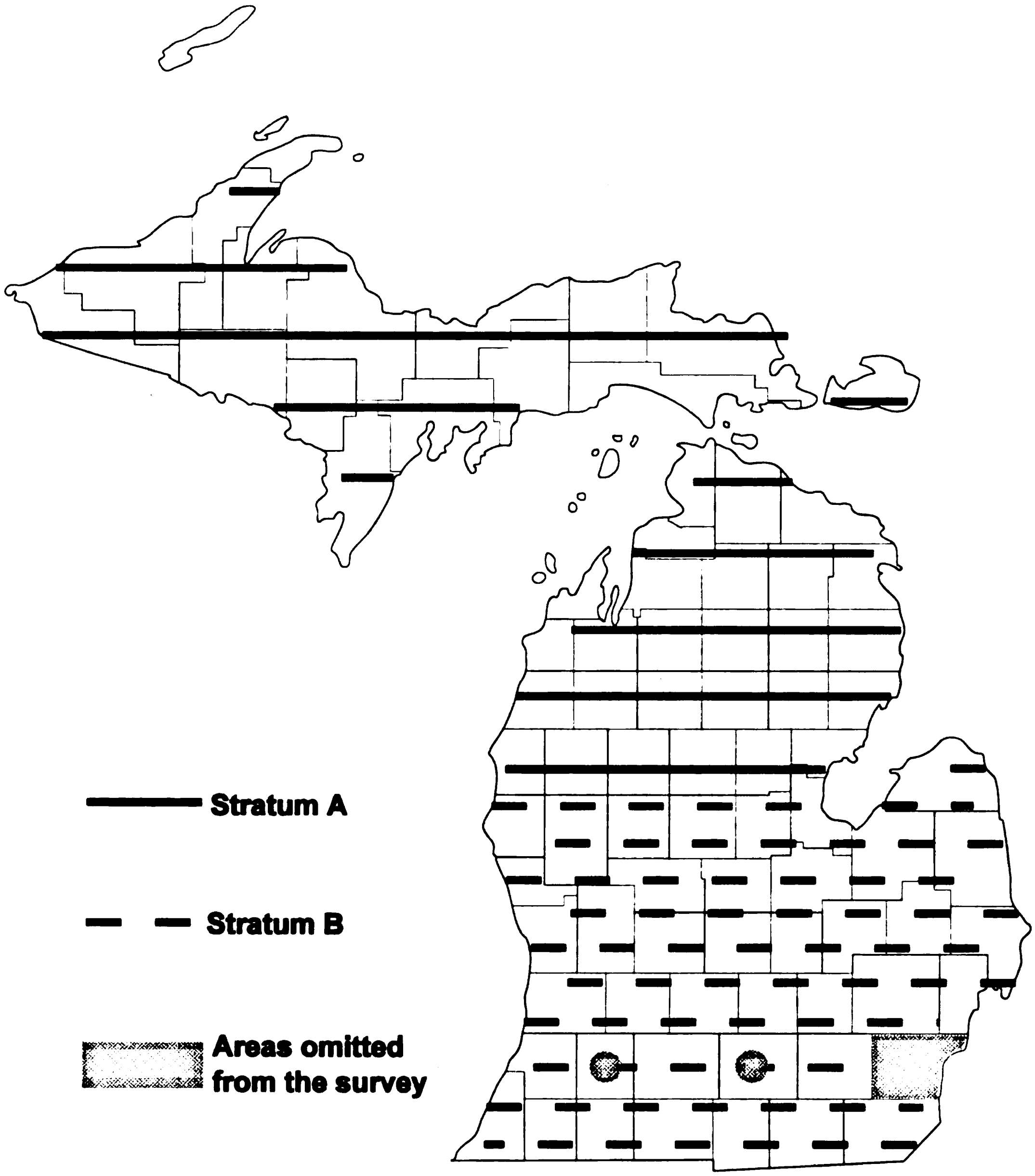

Figure 3: Michigan Breeding Waterfowl Survey transect routes

with woodlots (Omernik and Gallant 1988). Transects flown inthis stratum are 28 miles apart and contain a total of 59 18-mile long segments. Stratum B, the Farm-Urban Stratum, encompasses the remainder of the Lower Peninsula and is characterized by heavy agricultural and urban development with woodlots and swamps dotting the landscape (Omernik and Gallant 1988). At the time of the survey, cover over most of the region is sparse with the exception of flooded swamps and woodlots. The transects in the stratum are 14 miles apart and contain 93 18-mile segments. The difference in survey coverage is due to the greater amount of vegetative cover in the Forest Stratum and the traditional higher density of breeding birds in the Farm-Urban Stratum.

Much of the procedure used in the MBWS follows the techniques set forth in the Standard Operating Procedures for the Aerial Waterfowl Breeding Ground Population and Habitat Surveys (USFWS 1987). The few differences include the use of helicopter flown segments in Michigan for calculation of VCF's, rather than ground walked segments, and the addition of an observer on fixed-wing flights so that the pilot does not act as an observer. The MDNR counts ponds (i.e. "water areas"; e.g. rivers, streams, ditches, marshes, swamps, ponds, lakes) on all segments, as set forth in the Standard Operating Procedures (SOP) from the USFWS.

The fixed-wing flights follow transects across the state, recording the number and species of waterfowl seen. The transects are flown 100-150 feet above the ground with 10-15 minutes being spent on each 18-mile segment. The area observed along each transect is ¼ mile wide, with an observer on each side of the plane being responsible for half of that width. The observer in the front right seat of the plane (next to the pilot) counts birds and acts as the navigator; the rear seat observer (behind the pilot) counts birds and water areas visible on the left side of the plane. Birds are recorded by species and gender; gender is noted by separation into the categories of lone drakes, flocked drakes, and pairs. All unidentified birds are also recorded as such. Individual transects are flown in the same direction (east-to-west or west-to-east) every year.

A subset of the segments of the total survey are flown with a helicopter as well. This allows for some quantification of the visibility bias of the fixed-wing flights. These flights are made with the observers seated as in the fixed-wing flights and performing the same duties. The same amount of area is surveyed on helicopter segments as fixed-wing segments. Unlike the fixed-wing segments, however, on helicopter flights, travel north and south along the segment to search for birds is allowed. The segments are flown at 150 feet or lower; often the helicopter will descend to 5-10 feet to better search for birds. It takes from 34 to 185 minutes to fly each 18-mile segment.

Visibility correction factors in Michigan are calculated using the ratio of birds counted on helicopter flights to birds counted on fixed-wing flights as set forth by Martin et al.(1979).

$$VCF = \frac{\Sigma \text{ indicated birds seen by helicopter on helicopter flown segments}}{\Sigma \text{ indicated birds seen by fixed-wing on helicopter flown segments}}$$

$$\text{where indicated birds} = (2\times\Sigma \text{single drakes})+(2\times\Sigma \text{pairs of birds})+(\Sigma \text{flocked drakes})$$

Variance formulas for VCF's are also set forth by Martin et al. (1979). Estimates of the total adult spring population for each species are calculated using the number of indicated birds from the fixed-wing flights, the relevant VCF's, and an expansion factor to convert from area in the transects to area in the state as follows:

$$\begin{matrix}\text{adult spring}\\ \text{population}\end{matrix} = \left(\begin{matrix}\text{total indicated birds}\\ \text{counted on fixed-wing flights}\end{matrix}\right)\times(VCF)\times\left(\frac{\text{total area of stratum}}{\text{area of stratum surveyed}}\right)$$

Visibility correction factors are calculated separately for each species, each stratum, and for each year.

Species Of Interest:

Species for which the MDNR expressed interest in production models included mallard, Canada goose, wood duck, blue-winged teal (*Anas discors*), black duck, ring-necked duck (*Aythya collaris*), and mergansers (*Mergus* spp.). The scientific literature was searched for estimates of the various inputs to the model. Mergansers, for which very little reproduction research had been conducted, were eliminated as potential model candidates. Blue-winged teal, for which some information was available, were eliminated as potential model candidates, since no information was available on breeding in Michigan, and their VCF's are very high, suggesting that population size estimates are likely to be highly inaccurate. The ring-necked duck, for which there is information on breeding success in Michigan and which has a low VCF, was eliminated since the individuals seen on the MBWS were not on their traditional breeding grounds, suggesting that the estimates of breeding birds include migrants as well as breeders (Reeves 1991). Three of the remaining species, mallard, black duck, and Canada goose, fit the requirements of ample literature values, available Michigan production values, sightings on confirmed breeding grounds, and low VCF's moderately well. A wood duck model was constructed due to current management needs of the MDNR, despite a poor estimate of adult spring population.

Model Framework:

The framework for the four models is the mechanistic model developed by Walters et al. (1974) for mallards in the prairie pothole region as adapted to available information. This model consists of five equations:

$$\textit{Production Rate} = \left(\textit{eggs produced}/\textit{adult}\right)\times\left(\textit{survival rate until hatching}\right)\times\left(\textit{survival rate of chicks through fledging}\right)\times\left(\textit{survival rate through early flight stage}\right)$$

$$\textit{Production} = (\textit{adult spring population})\times(\textit{production rate})$$

$$\textit{Juvenile Fall Population} = (\textit{production})\times(\textit{juvenile summer survival rate})$$

$$\textit{Adult Fall Population} = (\textit{adult spring population})\times(\textit{adult breeding season survival rate})$$

$$\textit{Fall Flight} = (\textit{adult fall population})+(\textit{juvenile fall population})$$

All inputs, except for the adult spring population, are from the scientific literature. Preference was given to values calculated from research conducted in Michigan and to recent values. Where Michigan based research or recent values were not available, values from the northern end of the Mississippi and Atlantic Flyways since 1960 were used preferentially. Values outside these areas, such as clutch sizes in Canada geese, were used when local values were not available or to support local values when few were available. The adult spring population is calculated using the counts of indicated birds and VCF's from the MBWS.

Model Development:

The methodology used to construct the models is outlined in Figure 4. The first model output generated is the production rate, which was calculated using the following process:

1. An equation for production rate was built that incorporated the endpoints available in the literature for each species (e.g. clutch size, nest success, survival from hatching to flight, survival from laying to flight, etc.) The purpose of this equation was to account for all mortality from the point at which eggs are laid until the young reach early flight stage.
2. The available literature values were input into the equations in all possible combinations.
3. The results of this initial calculation were examined for extreme values (Figure 13, Figure 17). Values were judged to be extreme when a single input

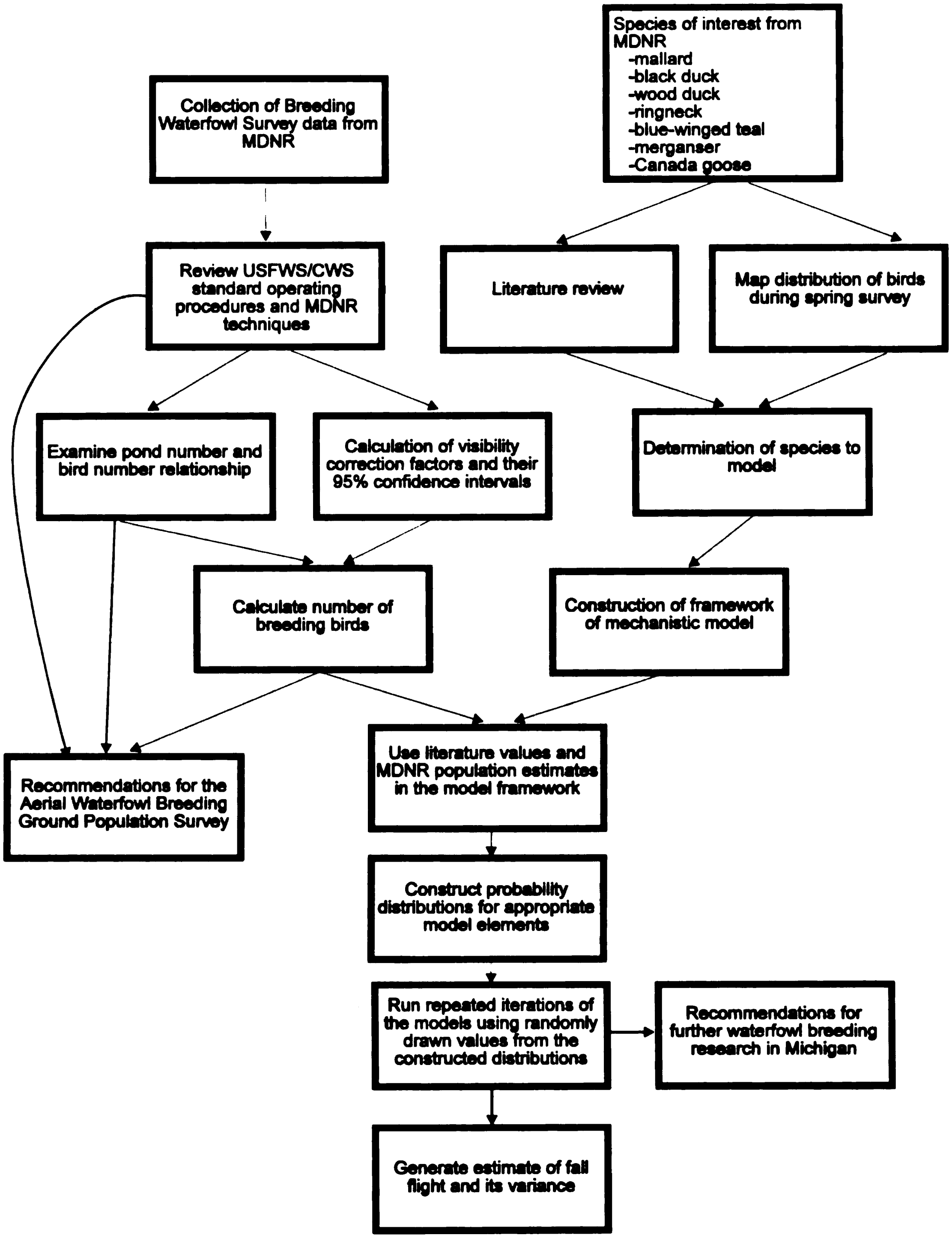

Figure 4: Model development flowchart

was responsible for several very high or very low production rate values. The only example of this found was the value of 9.2% for the survival of black ducks from hatching to fledging (Stotts and Davis 1960). This value alone is responsible for the production rate values in the range 0.15 to 0.40 (Figure 17), therefore, this value was excluded from further model building efforts.

4. After examination of these results, probability distributions were constructed for each production rate component to reflect patterns which were observed in the literature values. An example of this is the high frequency of values in the range 0.5-0.565 for nest success of black ducks. The majority of the area under the curve for the nest success distribution constructed is in the range 0.5-0.565 (Figure 19). When only two or three literature values were available, a uniform distribution between the minimum and maximum was used.
5. An estimate of production rate was then calculated by randomly drawing one value from the distribution of each production rate component. These were input into the model equation of production rate,

generating a value in the units of young produced per breeding adult. This was repeated ten thousand times to generate ten thousand production rate estimates.

6. Production rate frequencies from these calculations serve as the production rate probabilities for the models. The mean and variance of this distribution served as the production rate component of the models.

The remainder of the model consists of point estimates, rather than distributions, and is of a simpler construction. The adult breeding season survival rate is the mean of available literature values. Due to a lack of research on survival of young from fledging to migration, the juvenile summer survival rate for all species except wood ducks, for which literature values are available, is assumed to be equal to 1, with a variance of 0. A point estimate and variance was calculated for each model output value. Renesting values are not included in the model due to a paucity of available literature values for renesting.

To judge the degree to which model values reflect actual conditions, projections of the number of spring breeders in Michigan were produced. Assumptions were made that all birds home to their natal breeding grounds and that the sex ratio in eggs is 1:1. The projections were calculated using a reproduce-then-survive life table approach, and the projections were run for at least 80 years to allow low production rates to drive the population to 0. When low production rates, in units of young produced per breeding adult, were applied to the projections, the population continued to produce young after all the females in the population had died. To avoid this, production rates, in the units of young produced per breeding female, were applied only to the females in each population. These results can be compared to model production rate results, for mallards and black ducks, by dividing projection production rates by 2 since these rates are in the units of young produced per breeding female, and model production rates are in the units of young produced per breeding adult. Wood duck rates, however, are in the units of young produced per breeding female for both the model and the projections as this made it easier to model dump nesting. These projections allow for the determination of which production rates yield declining, stable, or increasing population sizes.

Model production rates were also compared to ratios of immatures per adult in the harvests from Michigan for 1987-1991 (Padding et al. 1992). These numbers do not accurately estimate the number of young produced per adult, but, after modification, they have been used as an approximation of that value for mallards (Fred Johnson, USFWS, pers. com.). As the numbers are calculated using wing survey data, the higher vulnerability of immature birds is reflected in values which are higher than the actual production rate. To adjust for this, immature per adult ratios were divided by two. This will not isolate Michigan's production from overall flyway production as some fraction of the birds harvested in Michigan are a result of production north of Michigan, however, it is the only large scale estimate available which may approximate Michigan's production rate. These numbers were then compared to production rate values for all species except Canada goose. At the time of the harvest, it is difficult to differentiate between adult and juvenile Canada geese based solely on wing plumage, resulting in an highly inaccurate estimate of immatures per adult in the harvest.

RESULTS & DISCUSSION

Mallard:

All of the available appropriate literature values (Table 1) for the mallard were used, though some nest success values were given low probabilities of occurrence, and the adult female survival rate values were supplemented with black duck values. While there are several very low values for nest success (Bilogan 1992), these are the daily survival rates as calculated using the Mayfield method (Mayfield 1960) and cannot be directly compared to the other values, which are simply the ratio of successful nests to total initiated nests. For the purposes of this model, simplistic survival rates were considered to be suitable as they do not assume that days are independent, as Mayfield does, and the survival rates required by the model are in terms of survival to a specific biological endpoint rather than over a set period of time. Due to the sparsity of adult summer survival rates, the female survival rates of the mallard and black duck were combined for a mean value of 0.685. Both the adult male and adult female summer survival rates were assumed to have a variance of 0. Annual survival rates from Anderson (1975) were used in the population

Table 1: Mallard model input values

model input	value	source[a]
clutch size	9.6	Coulter and Miller 1968
	9.0	Bilogan 1992
nest success	0.20	Bilogan 1992
	0.01	Bilogan 1992
	0.04	Bilogan 1992
	0.01	Bilogan 1992
	0.63	Orthmeyer and Ball 1990
	0.78	Krapu and Luna 1991
egg success in successful nests	0.784	Talent 1980
survival from hatching to flight	0.35	Talent et al. 1983
	0.33	Krapu and Luna 1991
survival from laying to flight	0.3951	Orthmeyer and Ball 1990
	0.44	Ball et al. 1975
adult summer survival rate	0.713 (♀)	Kirby and Cowardin 1986
	0.603 (♀)	Blohm et al. 1987
	0.998 (♂)	Blohm et al. 1987
juvenile summer survival rate	1.0 (var.=0)	assumed
adult spring population	1991: 277,729 (var=$8.5*10^8$)	MBWS
	1992: 371,288 (var=$2.3*10^9$)	MBWS
	1993: 412,104 (var=$2.0*10^9$)	MBWS
	1994: 716,918 (var=$2.7*10^{10}$)	MBWS

a:values not found in the literature were set to values designated by "assumed"

projections.

Calculated production rates (Figure 5) compare favorably to those estimated to be necessary to maintain a constant population size (Figure 6) and to immature per adult ratios in Michigan's harvests (Padding et al. 1992). Corrected values of immatures per adult in the harvest range from 0.75 to 0.95 (1987-0.75, 1988-0.95, 1989-0.9, 1990-0.8, 1991-0.8). According to values yielded by the projections, a production rate near 0.79 young produced per breeding adult is necessary to maintain a stable population, and this value lies within the range of production rate values generated by the model.

These runs of the model use the means and variances of the production rate distributions as the model production rates, though this method does not allow for annual variation in breeding conditions. An equally valid method would use the peak of the production rate distribution (0.40) as the model rate of an average year; higher or lower values could then be selected for years during which breeding conditions are better or worse. This choice can be influenced by the timing of spring thaw, number of cloudy days in the spring, amount of available breeding habitat, quality of breeding habitat, amount of available food, and the condition of the birds returning from their wintering

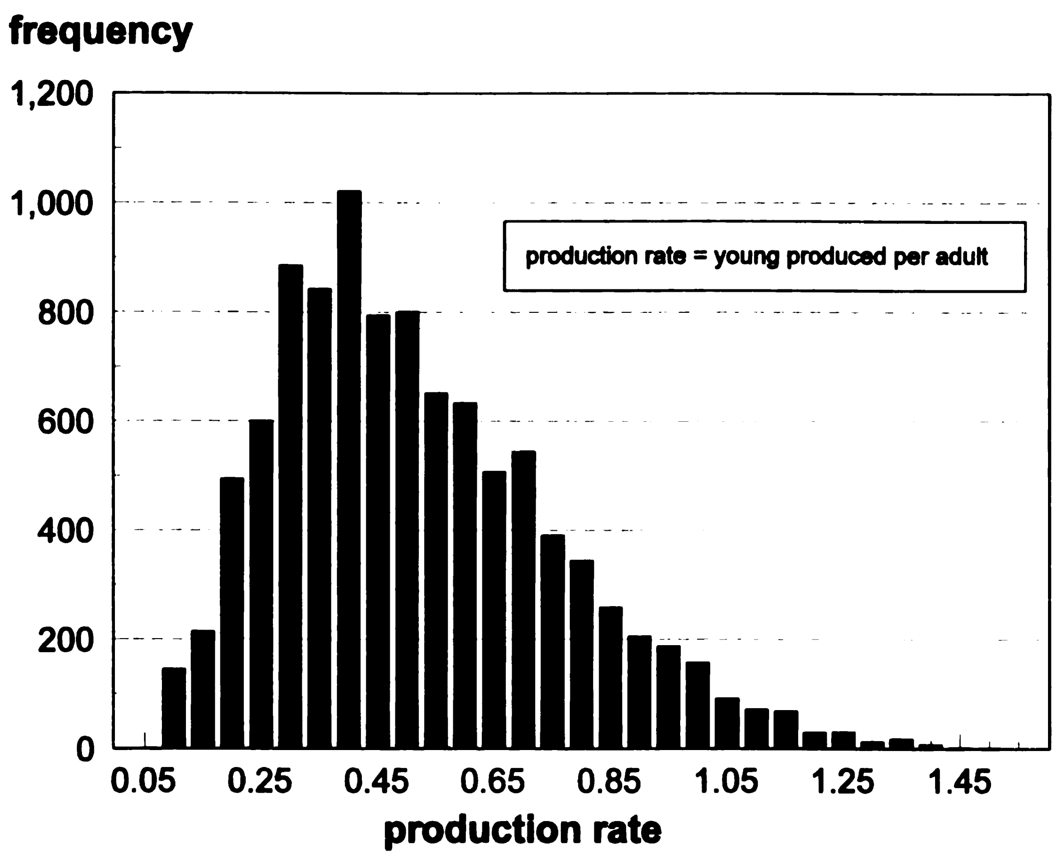

Figure 5. Distribution of mallard production rate values

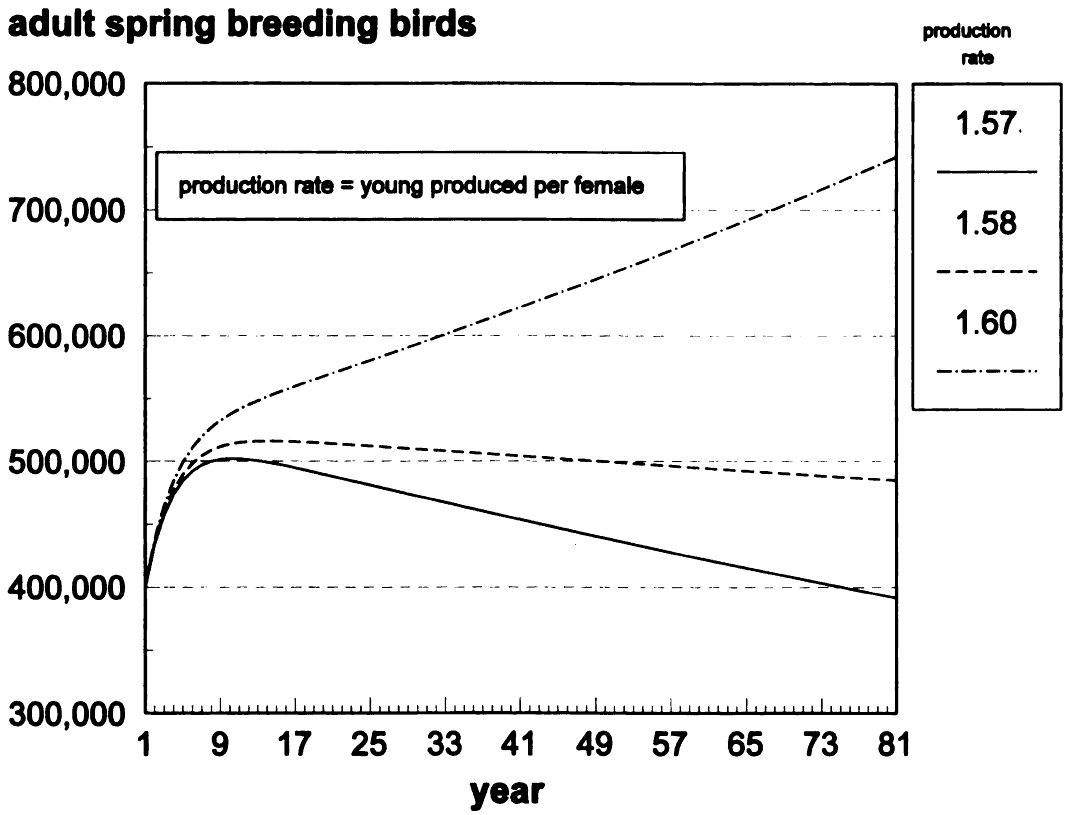

Figure 6. Projected population values for mallards in Michigan

grounds.

The majority of the fall flight variance originates in the estimate of adult spring population (Table 2). The high value for the 1994 fall flight and its variance, almost twice that of 1992 or 1993, is due entirely to the MBWS estimates. All of the estimates of the adult spring population vastly exceed historic estimates of the breeding population in Michigan, making comparison of model estimates of the fall flight to historic values impossible. For example, Bellrose (1976) states that there are 47,000 breeding mallards in Michigan, a figure much lower than the 270,000 to 716,000 arrived at through the MBWS.

Table 2: Mallard model output values

model output	year	estimate	variance
production rate	all years	0.490744	0.057056
production	1991	136,294	$4.6*10^{9}$
	1992	182,207	$8.4*10^{9}$
	1993	202,238	$1.0*10^{10}$
	1994	351,398	$2.1*10^{10}$
adult fall population	1991	238,637	$6.9*10^{8}$
	1992	318,810	$1.8*10^{9}$
	1993	357,786	$1.6*10^{9}$
	1994	617,664	$1.1*10^{10}$
juvenile fall population	1991	136,294	$2.3*10^{9}$
	1992	182,207	$2.1*10^{9}$
	1993	202,238	$2.5*10^{9}$
	1994	351,398	$1.1*10^{10}$
fall flight	1991	374,931	$3.0*10^{9}$
	1992	501,017	$3.9*10^{9}$
	1993	560,024	$4.2*10^{9}$
	1994	969,062	$2.1*10^{10}$

The following equations constitute the mallard model:

Production Rate = $E/A * S_n * S_{l-f}$

where $E/A = C/2$

$S_{l-f} = S_e * S_{h-f}$

or

S_{l-f} = literature values

Var(Production Rate) = variance of production rate distribution

Production = A_s*Production Rate

$$Var(Product.) = \sum_{n\text{-}stratum\ A}^{stratum\ B} [(A_s)_n^2 \times Var(\begin{matrix}product.\\rate\end{matrix})] + [(\begin{matrix}product.\\rate\end{matrix})^2 \times (I_n \times X_n)^2 \times Var(VCF_n)]$$

Adult Fall Population = $A_{fs} * S_{afs} + A_{ms} * S_{ams}$

$$Var(\begin{matrix}adult\\fall\ pop.\end{matrix}) = \sum_{l\text{-}males}^{females} (\sum_{n\text{-}stratum\ A}^{stratum\ B} [(A_s)_{ln}^2 \times Var(S_{as})_l] + [(S_{as})_l^2 \times (I_{ln} \times X_n)^2 \times Var(VCF)_n])$$

Juvenile Fall Pop. = $(0.5 * Product. * (S_{js})_{female}) + (0.5 * Product. * (S_{js})_{male})$

$$Var(\begin{matrix}juvenile\\fall\ pop.\end{matrix}) = \sum_{l\text{-}males}^{females} ([(0.5 \times product.)^2 \times Var(S_{js})_l] + [(S_{js})_l^2 \times 0.25 \times Var(product.)])$$

Fall Flight = Adult Fall Population +Juvenile Fall Population
Var(Fall Flight) = Var(Adult Fall Pop.)+ Var(Juvenile Fall Pop.)

where:

E/A = eggs per adult
S_n = nest success
S_{l-f} = survival from laying to flight
C = clutch size
S_e = egg success in successful nests
S_{h-f} = survival from hatching to flight
A_s = adult spring population (A_{FS} = females; A_{MS} = males)
I = number of indicated birds (from MBWS)
X = area expansion factor (from MBWS)
VCF = visibility correction factor (from MBWS)
S_{as} = adult summer survival rate
S_{js} = juvenile summer survival rate

Black duck:

With the exception of one value for survival from hatching to fledging, all black duck literature values (Table 3) were used in the model. The value from Stotts and Davis (1960) was excluded since its presence caused the production rate distribution to have a peak at the low end of what would otherwise have been a fairly smooth curve (Figure 17). Values for adult summer survival rate were derived using black duck and mallard data. The female survival rate is the mean of the black duck and mallard values; the male survival rate is simply the male mallard survival rate. Due to the similarities of biology between these two species, the assumption of equivalent survival rates is reasonable. Annual survival rates used in the projections are from Blandin (1982).

The mean of the production rate distribution (Figure 7) is considerably lower than what would be necessary, 1.14 young produced per breeding adult, to maintain a stable population (Figure 8). The values do, however, compare favorably to corrected immature per adult ratios in the wing survey (Padding et al. 1992) which range from 0.55 to 0.95

Table 3. Black duck model input values

model input	value	source[a]
clutch size	9.2	Reed 1970
	9.1	Stotts and Davis 1960
	9.5	Coulter and Miller 1968
nest success	0.50+	Reed 1970
	0.55	Coulter and Mendall 1968
	0.67-0.84	Coulter and Mendall 1968
	0.565	Stotts and Davis 1960
	0.55	Laperle 1969
egg success in successful nests	0.911	Reed 1970
	0.848	Stotts and Davis 1960
survival from hatching to fledging	0.4244	Ringelman and Longcore 1982
	0.092	Stotts and Davis 1960
survival from nest exodus to flight	0.29	Reed 1970
adult summer survival rate	0.74 (♀)	Ringelman and Longcore 1983
	0.998 (♂)	assumed
juvenile summer survival rate	1.0 (var.=0)	assumed
adult spring population	1991: 6,105 (var=$1.1*10^6$)	MBWS
	1992:12,988 (var=$3.8*10^6$)	MBWS
	1993: 5,856 (var=$7.1*10^5$)	MBWS
	1994: 8,009 (var=$3.1*10^6$)	MBWS

[a] values not found in the literature were set to values designated by "assumed"

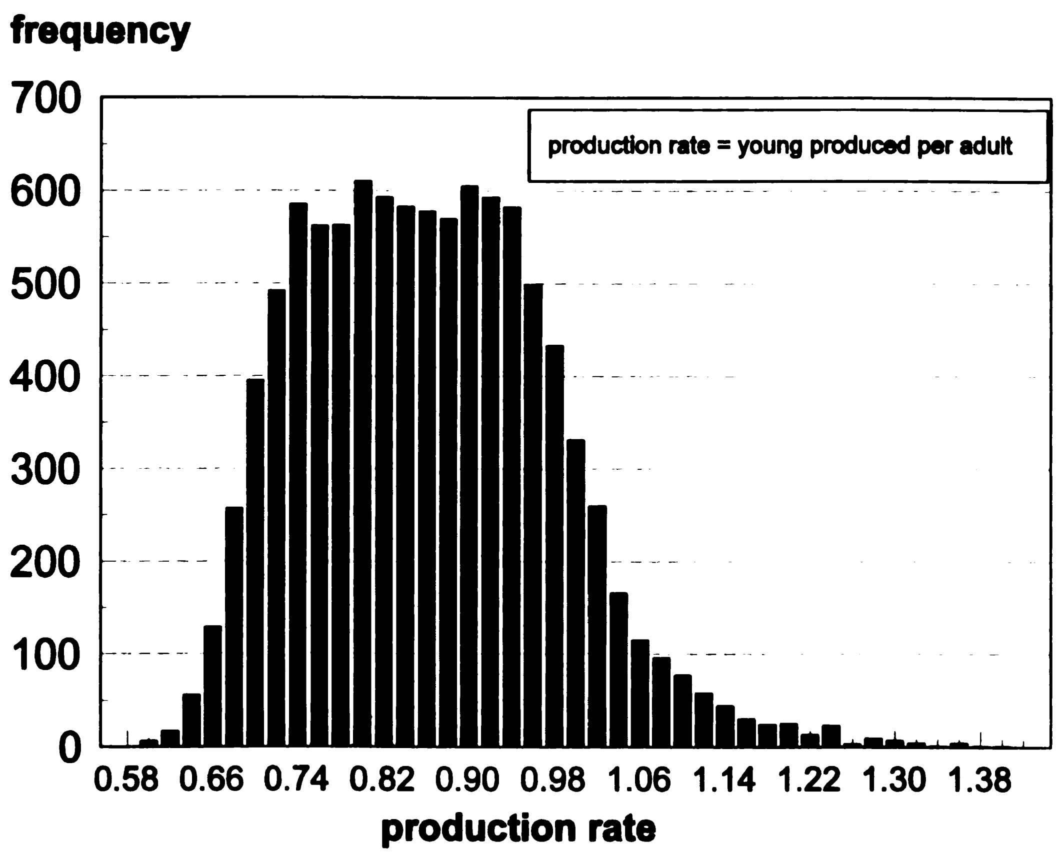

Figure 7. Distribution of black duck production rate values

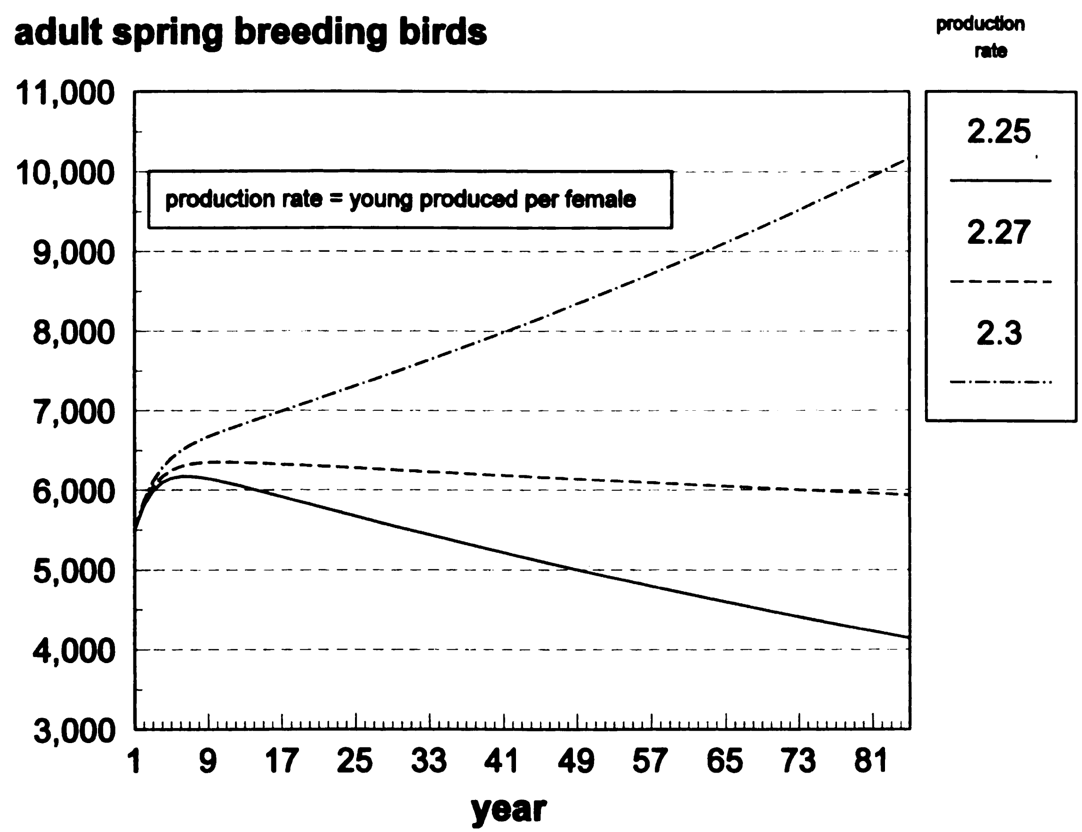

Figure 8. Projected population values for black ducks in Michigan

(1987-0.55, 1988-0.95, 1989-0.85, 1990-0.7, 1991-0.95). While neither the projections nor the immature per adult ratios in Michigan's harvest provide accurate endpoints for production rate, these patterns imply that the model reflects production in Michigan, which is undergoing a decline in black duck numbers. As the model reflects the basic biology of the black duck during breeding, it would appear that there is little potential for growth of the population in Michigan without either improvement of breeding habitat, which would push the production rate toward the high end of the distribution, or reduction in annual or seasonal mortality, which would lower the production rate necessary to maintain a stable population in the projections.

As with the mallard model, the majority of the variability in the model is due to the high variance of the MBWS (Table 4). The black duck VCF's used in Michigan, however, were derived from segments of the WBPHS in Ontario and have lower variances than some of the VCF's calculated in Michigan for other species.

Also, this model may be adapted to perform under varying conditions. Before complete faith is placed in the model, however, verification of the model inputs must be made in Michigan. The values used in the model, at present, were derived from research conducted on the East Coast of North America; none of the values come from Michigan, or anywhere else in the upper Midwest.

Table 4. Black duck model output values

model output	year	estimate	variance
production rate	all years	0.851276	0.013541
production	1991	5,197	$1.3*10^6$
	1992	11,056	$5.1*10^6$
	1993	4,985	$9.8*10^5$
	1994	6,818	$2.9*10^6$
adult fall population	1991	5,137	$8.1*10^5$
	1992	11,489	$3.3*10^6$
	1993	4,927	$5.2*10^5$
	1994	6,740	$1.2*10^6$
juvenile fall population	1991	5,197	$6.5*10^5$
	1992	11,056	$1.3*10^6$
	1993	4,985	$2.4*10^5$
	1994	6,818	$2.9*10^6$
fall flight	1991	10,334	$2.1*10^6$
	1992	22,545	$8.4*10^6$
	1993	9,912	$1.5*10^6$
	1994	13,557	$2.6*10^6$

The following equations constitute the black duck model:

Production Rate = $E/A * S_n * S_{en} * S_{h-f}$
where $E/A = C/2$
Var(Production Rate) = variance of production rate distribution

Production = A_s*Production Rate

$$Var(Product.) = \sum_{n=stratum\ A}^{stratum\ B} [(A_s)_n^2 \times Var(\begin{smallmatrix}product.\\rate\end{smallmatrix})] + [(\begin{smallmatrix}product.\\rate\end{smallmatrix})^2 \times (I_n \times X_n)^2 \times Var(VCF_n)]$$

Adult Fall Population = $A_{fs} * S_{afs} + A_{ms} * S_{ams}$

$$Var(\begin{smallmatrix}adult\\fall\ pop.\end{smallmatrix}) = \sum_{l=males}^{females} (\sum_{n=stratum\ A}^{stratum\ B} [(A_s)_{ln}^2 \times Var(S_{as})_l] + [(S_{as})_l^2 \times (I_{ln} \times X_n)^2 \times Var(VCF)_n])$$

Juvenile Fall Population = $(0.5 * Product. * (S_{js})_{female}) + (0.5 * Product. * (S_{js})_{male})$

$$Var(\begin{smallmatrix}juvenile\\fall\ pop.\end{smallmatrix}) = \sum_{l=males}^{females} ([(0.5 \times product.)^2 \times Var(S_{js})_l] + [(S_{js})_l^2 \times 0.25 \times Var(product.)])$$

Fall Flight = Adult Fall Population+Juvenile Fall Population
Var(Fall Flight) = Var(Adult Fall Pop.)+ Var(Juvenile Fall Pop.)

where:
- E/A = eggs per adult
- S_n = nest success
- S_{h-f} = survival from hatching/nest exodus to flight
- C = clutch size
- S_{en} = egg success in successful nests
- A_s = adult spring population (A_{fs} = females; A_{ms} = males)
- I = number of indicated birds (from MBWS)
- X = area expansion factor (from MBWS)
- VCF = visibility correction factor (from MBWS)
- S_{as} = adult summer survival rate (S_{afs} = females; S_{ams} = males)
- S_{js} = juvenile summer survival rate

Canada goose:

Most of the literature values for Canada goose (Table 5) were used in the construction of the model. The clutch size values of Dow (1943) and Williams and Nelson (1943) were included as they confirmed the range found by Sherwood (1966) and Kaminski (1975). The 16% survival rate of goslings to flight was removed from the model as it was due entirely to an outbreak of *leucocytozoon* at the Seney National Wildlife Refuge. This was considered to be an isolated event which could be adjusted for in the event of a reoccurrence and need not be included in the general model. The variance of adult summer survival rate is assumed to be 0.

The Canada goose model differs from the other models in that it allows for age specific production rates. This also requires an age structure of breeding females. The initial production rate, calculated in the same manner as the other models, is called the optimal production rate (Figure 9) and represents what the production rate would be in a situation where all birds on the breeding grounds attempted to breed and all had similar, high success rates. Each of the ten thousand calculated estimates is then converted to an

Table 5. Canada goose model input values

model input	value	source[a]
clutch size	5.6	Kaminski 1975
	5.3	Sherwood 1966
	5.2	Sherwood 1966
	4.9	Sherwood 1966
	5.09	Dow 1943
	5.10	Dow 1943
	4.88	Williams and Nelson 1943
survival rate of eggs to hatching	0.902	Sherwood 1966
	0.67	Kaminski 1975
survival rate of goslings to flight	0.78	Sherwood 1966
	0.16	Sherwood 1966
	0.72	Sherwood 1966
	0.76	Kaminski 1975
relative breeding rate	2 year olds ---7%	Moser and Rusch 1989
	3 year olds ---15%	Moser and Rusch 1989
	4 year olds ---40%	Moser and Rusch 1989
	5 year olds ---100%	Moser and Rusch 1989
	6 year olds ---95%	Moser and Rusch 1989
	>7 year olds - 94%	Moser and Rusch 1989
age structure of females	1 year olds ---35%	Kelley 1993
	2 year olds ---27%	Kelley 1993
	3 year olds ---19%	Kelley 1993
	4 year olds --- 9%	Kelley 1993
	5+ year olds --10%	Kelley 1993
adult summer survival rate	0.85 (♀)	assumed
	0.85 (♂)	assumed
juvenile summer survival rate	1.0 (var.=0)	assumed
adult spring population	1991: 58,787 (var=$1.8*10^7$)	MBWS
	1992: 101,587 (var=$4.7*10^7$)	MBWS
	1993: 177,999 (var=$1.7*10^9$)	MBWS
	1994: 308,083 (var=$1.0*10^{10}$)	MBWS

a:values not found in the literature were set to values designated by "assumed"

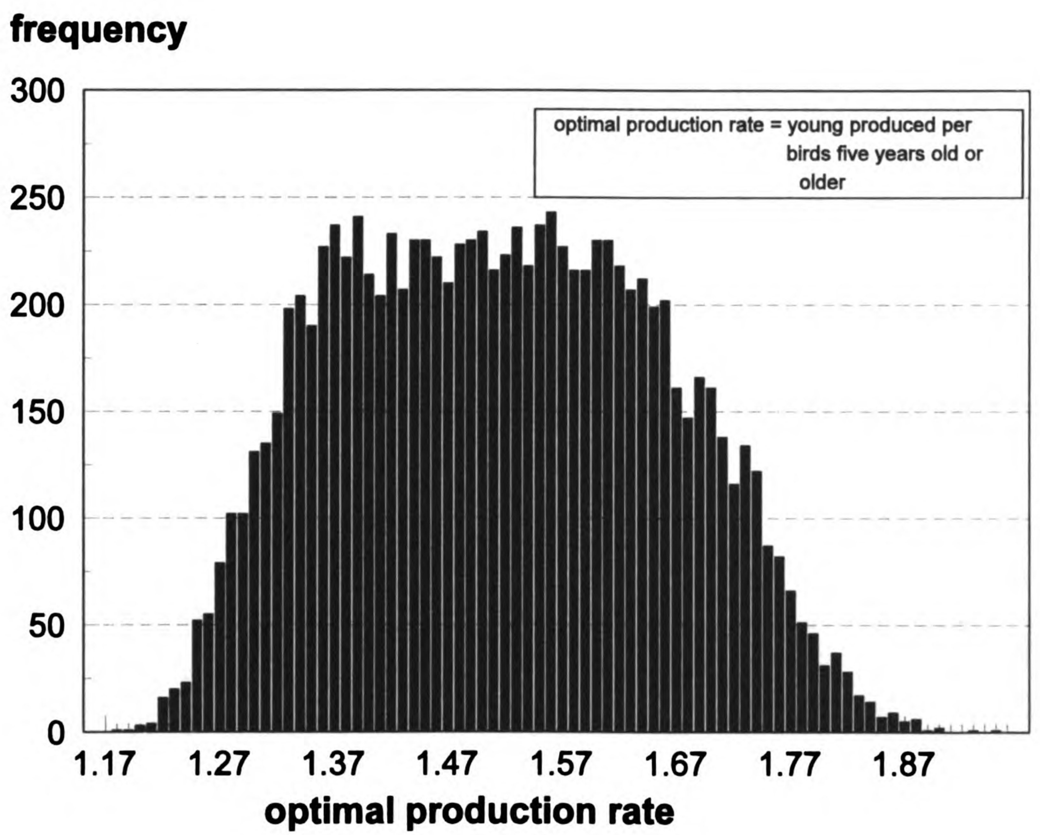

Figure 9. Distribution of Canada goose optimal production rate values

estimate of the realized production rate. This is accomplished by multiplying each optimal production rate estimate by the percent of the population which is one year old females, then multiplying by the relative breeding rate of one year old females; this is done for all ages through five year olds and older. The sum of these values is the estimate of the realized production rate. Repeating this procedure results in ten thousand estimates of the realized production rate and a distribution which represents the production rate of the population corrected for age specific reproductive output (Figure 10).

No projections were calculated as the results are highly dependent on the age structure of the population. At present, little information is available for accurate assessment of the age structure of Canada geese in Michigan. The age structure used here is the result of band returns of only a few hundred birds and is not likely to be representative of the actual values. As stated earlier, immatures per adult, as recorded using the wing survey, are not representative of immatures per adult in the harvest or immatures produced per adult in Michigan and cannot be used as an indicator of accuracy of the model. Anecdotal information on general population trends in Michigan from

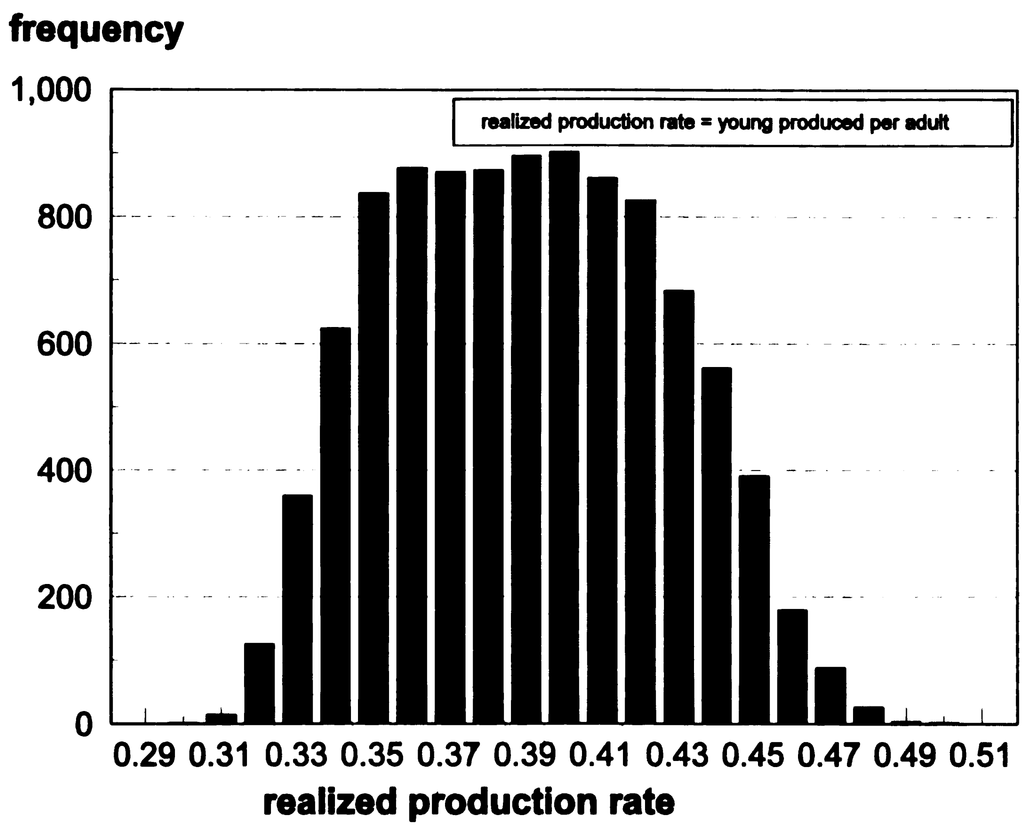

Figure 10. Distribution of Canada goose realized production rate values

Gerald Martz of the MDNR (pers. com.) has proved to be the best index to actual production. Increasing nuisance goose complaints and annual harvests indicate a large and increasing population. This suggests that the realized production rate yielded by the model underestimates actual production.

As with the other models, most of the fall flight variance is due to values from the MBWS (Table 6). Likewise, any improvements in the survey would improve the model. However, its greatest needs lie in the areas of accurate measurement of age specific reproductive output and the population's age structure. Until such time as these values are improved and a fall census is made, there will be no way to judge the accuracy of the estimates from the model.

Table 6. Canada goose model output values

model output	year	estimate	variance
optimal production rate	all years	1.510178	0.019617
realized production rate	all years	0.385397	0.001278
production	1991	22,656	$7.1*10^{6}$
	1992	39,152	$2.0*10^{7}$
	1993	68,600	$3.0*10^{8}$
	1994	118,734	$1.7*10^{9}$
adult fall population	1991	49,969	$1.3*10^{7}$
	1992	86,349	$3.4*10^{7}$
	1993	151,299	$1.3*10^{9}$
	1994	261,871	$4.2*10^{9}$
juvenile fall population	1991	22,656	$3.5*10^{6}$
	1992	39,152	$5.0*10^{6}$
	1993	68,600	$7.5*10^{7}$
	1994	118,734	$8.4*10^{8}$
fall flight	1991	72,625	$2.0*10^{7}$
	1992	125,501	$5.4*10^{7}$
	1993	219,900	$1.6*10^{9}$
	1994	380,605	$5.0*10^{9}$

The equations of the Canada goose model are as follows:

Optimal Production Rate = $E/A*S_e*S_g$
where $E/A = C/2$
Var(Opt. Prod. Rate)=variance of Optimal Production Rate distribution

Realized Production Rate (RPR) = $\sum$(Optimal Prod. Rate$*B_r*F_r$)
for r = 1 year olds, 2 year olds, 3 year olds, 4 year olds, 5+ year olds
Var(Realized Prod. Rate)=variance of the Realized Prod. Rate distribution

Production = A_s*Realized Production Rate

$$Var(Product.) = \sum_{n=\text{stratum } A}^{\text{stratum } B} [(A_s)_n^2 \times Var(RPR)] + [(RPR)^2 \times (I_n \times X_n)^2 \times Var(VCF_n)]$$

Adult Fall Population = $A_{fs}*S_{afs} + A_{ms}*S_{ams}$

$$Var(\text{adult fall pop.}) = \sum_{l=\text{males}}^{\text{females}} \Big(\sum_{n=\text{stratum } A}^{\text{stratum } B} [(A_s)_{ln}^2 \times Var(S_{as})_l] + [(S_{as})_l^2 \times (I_{ln} \times X_n)^2 \times Var(VCF)_n] \Big)$$

Juvenile Fall Population = $(0.5*Prod.*(S_{js})_{females}) + (0.5*Prod.*(S_{js})_{males})$

$$Var(\text{juvenile fall pop.}) = \sum_{l=\text{males}}^{\text{females}} ([(0.5 \times product.)^2 \times Var(S_{js})_l] + [(S_{js})_l^2 \times 0.25 \times Var(product.)])$$

Fall Flight = Adult Fall Population+Juvenile Fall Population
Var(Fall Flight) = Var(Adult Fall Pop.)+ Var(Juvenile Fall Pop.)

where:
- E/A = eggs per adult
- S_e = survival rate of eggs to hatching
- S_g = survival of goslings to flight
- C = clutch size
- B_r = relative breeding rate
- F_r = % of population
- A_s = adult spring population (A_{fs} = females; A_{ms} = males)
- I = number of indicated birds (from MBWS)
- X = area expansion factor (from MBWS)
- VCF = visibility correction factor (from MBWS)
- S_{as} = adult summer survival rate (S_{afs} = females; S_{ams} = males)
- S_{js} = juvenile summer survival rate

Wood duck:

The input values for wood ducks (Table 7) differed from the other species in that two of the inputs already existed as distributions of raw data rather than point estimates. Distributions were given for clutch size and survival from laying to hatch. Clutch size values were broken down into natural nest values and nest box nest values. The ratio of natural nests to nest box nests in Michigan is not known and was assumed to be 1:1 for the purposes of the model (Figure 25). To simplify conversion of this data into a model input, it was retained in the form of clutch size rather than set to eggs per adult. This results in a model production rate value in the units of young produced to flight stage per breeding female, rather than per breeding adult. Similarly, survival from laying to hatch values were segregated between normal and dump nests; again, a 1:1 ratio was assumed (Figure 26). Otherwise, the model was constructed similarly to the mallard and black duck models. Annual survival rates for the projection were found in Bellrose and Holm (1994).

Due to the poor quality of input values, most notably MBWS data, and the poor understanding of wood duck breeding biology in Michigan, the model value of production rate (Figure 11) and projection values (Figure 12) are

Table 7. Wood duck model input values

model input	value	source[a]
clutch size	natural nest values (p.225)	Bellrose and Holm 1994
	nest box values (p.226)	Bellrose and Holm 1994
survival from laying to hatch	normal nest values (p.250)	Bellrose and Holm 1994
	dump nest values (p.250)	Bellrose and Holm 1994
survival from hatch to flight	0.41	Klein 1955
	0.53	Grice and Rogers 1965
	0.42	Grice and Rogers 1965
	0.48	Grice and Rogers 1965
	0.59	Prince 1965
	0.38	Holloman 1967
	0.53	McGilvrey 1969
	0.50	McGilvrey 1969
	0.59	McGilvrey 1969
	0.53	McGilvrey 1969
	0.56	Baker 1971
	0.52	Baker 1971
	0.52	Brown 1972
	0.59	Haramis 1975
	0.61	Haramis 1975
	0.68	Hepp 1977
	0.44	Cottrell 1979
	0.58	Rothbart 1979
	0.40	David 1986
	0.56	Bellrose and Holm 1994
	0.56	Bellrose and Holm 1994
	0.48	Bellrose and Holm 1994
	0.55	Bellrose and Holm 1994
	0.53	Bellrose and Holm 1994
adult summer survival rate	0.8 (♀) (var.=0)	assumed
	0.8 (♂) (var.=0)	assumed
juvenile summer survival rate	0.91 (♀)	Kirby 1990
	0.89 (♂)	Kirby 1990
adult spring population	1991: 57,588 (var=$1.1*10^9$)	MBWS
	1992: 485,008 (var=$1.0*10^{11}$)	MBWS
	1993: 206,182 (var=$1.4*10^{10}$)	MBWS
	1994: 99,759 (var=$1.8*10^9$)	MBWS

a:values not found in the literature were set to values designated by "assumed"

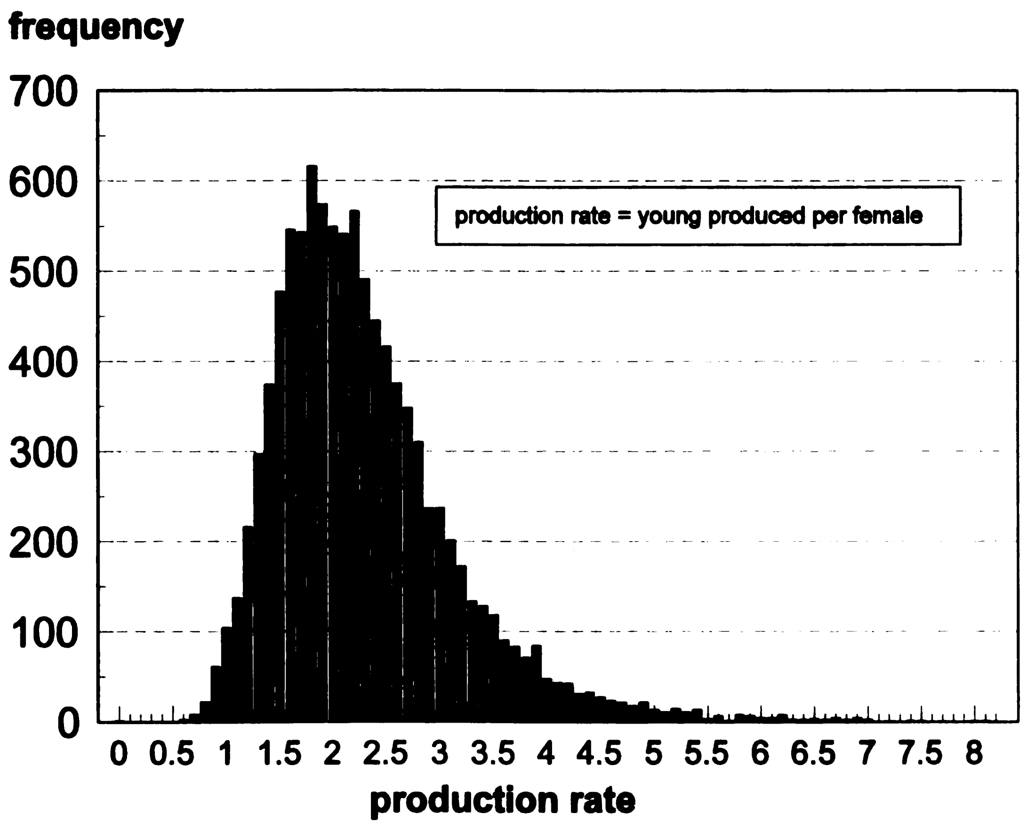

Figure 11. Distribution of wood duck production rate values

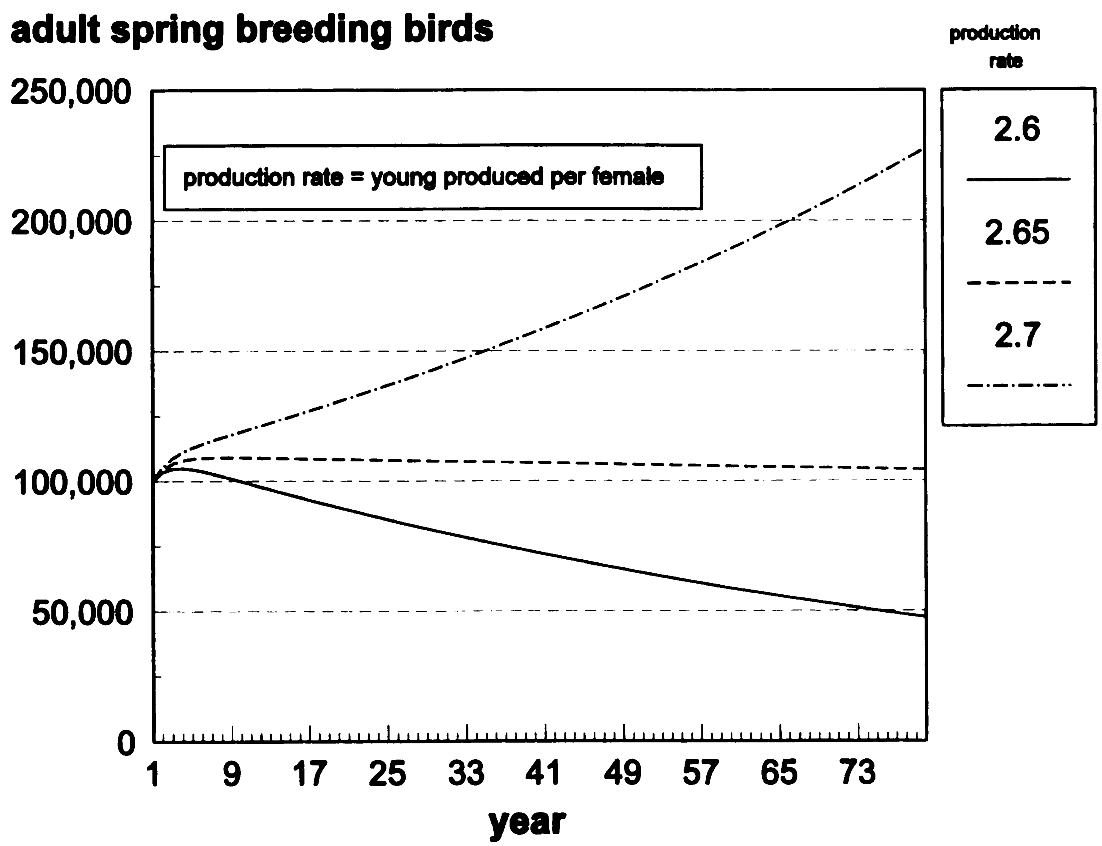

Figure 12. Projected population values for wood ducks in Michigan

considerably higher than the corrected ratios of immatures per adult in the wing survey. The corrected wing survey fall in the range of 0.6 to 1.25 (corrected wing survey ratios: 1987-0.85, 1988-0.9, 1989-1.25, 1990-0.6, 1991-0.7) (Padding et al. 1992), while the model value and projection value required for a stable population range from 2.23 to 2.65. This suggests that the production rate specified by the model overestimates the actual production rate by 100% to 300%.

Any of a number of steps could be taken to improve the model (Table 8). The VCF's for wood ducks have been, for the most part, at least a factor of ten higher than the VCF's for other species; the variances of these VCF's are also very high. This is a result of surveying wood ducks with fixed-wing aircraft, which cannot be used to effectively observe all wood ducks in an area. Helicopter surveying of wood ducks is more effective than fixed-wing surveying, as can be seen on the segments used for the visibility correction factors. Michigan-based estimates of clutch size and ratios of natural nests to nest box nests, survival from laying to hatch and ratios of normal to dump nests, and survival from hatching to flight should go a long way toward reducing the difference between model outputs and external measures of production.

Table 8. Wood duck model output values

model output	year	estimate	variance
production rate	all years	2.23414	0.714675
production	1991	128,660	$7.6*10^{9}$
	1992	1,083,576	$6.8*10^{11}$
	1993	460,638	$9.8*10^{10}$
	1994	222,876	$1.3*10^{10}$
adult fall population	1991	46,070	$6.7*10^{8}$
	1992	388,007	$6.6*10^{10}$
	1993	164,945	$8.7*10^{9}$
	1994	79,807	$5.9*10^{8}$
juvenile fall population	1991	115,794	$3.5*10^{9}$
	1992	975,219	$1.7*10^{11}$
	1993	414,575	$2.5*10^{10}$
	1994	200,589	$5.2*10^{9}$
fall flight	1991	167,623	$4.0*10^{9}$
	1992	1,411,725	$3.6*10^{11}$
	1993	600,137	$5.1*10^{10}$
	1994	280,396	$5.8*10^{9}$

The wood duck model equations are as follows:

Production Rate = $C*S_{l-h}*S_{h-f}$
  Var(Production Rate) = variance of production rate distribution

Production = A_s*Production Rate

$$Var(Product.) = \sum_{n=stratum\ A}^{stratum\ B} [(A_s)^2_n \times Var(\genfrac{}{}{0pt}{}{product.}{rate})] + [(\genfrac{}{}{0pt}{}{product.}{rate})^2 \times (I_n \times X_n)^2 \times Var(VCF_n)]$$

Adult Fall Population = $A_{fs}*S_{afs}$ + $A_{ms}*S_{ams}$

$$Var(\genfrac{}{}{0pt}{}{adult}{fall\ pop.}) = \sum_{l=males}^{females} (\sum_{n=stratum\ A}^{stratum\ B} [(A_s)^2_{ln} \times Var(S_{as})_l] + [(S_{as})^2_l \times (I_{ln} \times X_n)^2 \times Var(VCF)_n])$$

Juvenile Fall Population = $(0.5*Prod.*(S_{js})_{females})+(0.5*Prod.*(S_{js})_{males})$

$$Var(\genfrac{}{}{0pt}{}{juvenile}{fall\ pop.}) = \sum_{l=males}^{females} ([(0.5 \times product.)^2 \times Var(S_{js})_l] + [(S_{js})^2_l \times 0.25 \times Var(product.)])$$

Fall Flight = Adult Fall Population +Juvenile Fall Population
  Var(Fall Flight) = Var(Adult Fall Pop.)+ Var(Juvenile Fall Pop.)

where:

- C = clutch size
- S_{l-h} = survival from laying to hatching
- S_{h-f} = survival from hatching to flight
- A_s = adult spring population (A_{fs} = females; A_{ms} = males)
- I = number of indicated birds (from MBWS)
- X = area expansion factor (from MBWS)
- VCF = visibility correction factor (from MBWS)
- S_{as} = adult summer survival rate (S_{afs} = females; S_{ams} = males)
- S_{js} = juvenile summer survival rate

General Summary:

As has been already mentioned, these models require additional testing to verify that the results yielded are valid for the populations of waterfowl in Michigan. However, at this point, it is reasonable to use both the mallard and black duck models as rough estimates of the fall flight. Both models yield comparatively small ranges of values for production rates and realistic estimates of production based on anecdotal information and data from the wing survey.

The single greatest need of the Canada goose model is an accurate estimate of the age structure of birds in the state. This would necessitate the banding of large numbers of birds each year; the current level of banding, 1000 to 2000 birds each year, is much too low to yield useful information from band return data from the annual harvest. The optimal production rates yielded by the model appear to reflect production observed in the state, implying that either the age structure used is skewed toward younger birds or that production of mature birds has been underestimated.

The wood duck model should not be used in its current state for several reasons: the estimates of the spring adult population are extremely imprecise and highly variable from year to year, the role of nest boxes on overall reproductive output is unknown, the frequency of dump nesting is unknown, and little research into the breeding ecology of the wood duck in Michigan has been performed to allow for reasonable estimates of clutch size and survival rates. Of greatest concern, among these factors, is the estimate of the adult spring population. The use of fixed-wing aircraft is inappropriate for the calculation of an accurate population estimate for wood ducks, which are usually found in association with wooded areas and swamps where they are extremely difficult to observe. If wood ducks are a species of interest for future surveys, the increased use of helicopter flown segments is imperative.

RECOMMENDATIONS FOR THE MICHIGAN BREEDING WATERFOWL SURVEY

Three general areas can be described in which the MBWS should be improved: strata designation, VCF calculation, and observer bias. The first is in reference to a lack of uniformity within the currently defined strata. The second refers to the selection of segments for VCF calculation and the techniques used on those segments. The third covers various inconsistencies in survey techniques among the individuals who conduct it.

Strata Designation:

While the division of the state into smaller strata is a sound policy, the specific strata designated are not necessarily appropriate. As stated earlier, the Farm-Urban stratum is fairly homogeneous, as is the Upper Peninsula. However, the northern Lower Peninsula contains a mixture of cover types, which makes it unlike either the Upper Peninsula or southern Lower Peninsula, and yet it is grouped into the same stratum as the Upper Peninsula.

A more appropriate subdivision would take into account the cover type of the areas being censused. At the least, this would mean the designation of three strata: a Farm-

Urban stratum, a Mixed Farm-Forest stratum, and a Northern Forest stratum. The Farm-Urban stratum would remain as it is, the section of the present Forest stratum which is in the Lower Peninsula would become the Mixed Farm-Forest stratum, and the Upper Peninsula would become the Northern Forest stratum. VCF's would then tend to be more accurate for the northern Lower Peninsula and Upper Peninsula, as VCF's are highly dependent on air to ground visibility.

While minor subdivision of the current strata would be helpful, while incurring modest costs, restructuring the survey to sample exclusively along cover type lines would be more likely to yield more accurate estimates of the number of breeding birds. Since the primary source of error in aerial surveys is generally considered to be the failure to observe all animals present on transects (Caughley 1977), efforts to either increase the number of animals counted during the fixed-wing portion of the survey or increase the accuracy of the measurement of that error are the most effective means of improving survey results. Several studies have shown that the visibility of animals differs between different cover types, due both to cryptic coloration and density of cover (Diem and Lu 1960, Grier et al. 1981, Gasaway et al. 1985, Short and Bayliss 1985). As the vast majority of waterfowl counted during the census are observed on open water or in wetlands, stratification need only apply to the various types of water areas present in the state. These areas would fall under the general categories now used in the MBWS of artificial and natural, but in addition would be subdivided into channels (rivers, streams, and irrigation ditches), marshes (those wetlands dominated by emergent vegetation), swamps (wetlands dominated by woody vegetation), and open water. While water type is not equivalent to cover type, this would increase the homogeneity within the categories sampled and the areas could be easily classified by survey observers. This finer subdivision requires individual VCF's for each of these areas. As this classification scheme reduces variability within sampled groups, it also should improve the survey by providing a better estimate of error. This change to the survey alone would make the greatest improvement in the results.

Visibility Correction Factor Calculation:

While the practice of attempting to quantify the number of birds present but not counted on the fixed-wing flights of the MBWS is sound, some of the techniques used to arrive at these numbers could and should be improved. Currently, there is a tendency toward increasing amounts of time spent on each segment during the helicopter survey. Segments selected for helicopter flights are chosen because they have traditionally had high numbers of birds observed during the fixed-wing portion of the survey. Total numbers of indicated birds are compared to arrive at the correction factor, rather than correcting based on individual segment results or observed group size.

Unfortunately, helicopter based correction counts are not widely used by the USFWS at this time, and there is not as extensive a standard operating procedure as exists for the fixed-wing flights. While the goal of the helicopter flights is to count all birds on a segment, yielding the most accurate count possible, when the helicopter spends increasingly more time on a segment, there is a greater chance that flushed birds will land further along the segment, only to be counted again since the observers do not realize that they are the same birds. A minimum maintained speed would correct this since it could both ensure that segments were covered slowly enough to observe waterfowl and that the helicopter moved quickly enough that birds can be recorded with a higher certainty that they are observed only once. A speed of 5 mph (ground speed) approximates walking speed, allowing water areas to be covered at a speed similar to that used for the ground survey, which is the predominant method used for calculating visibility correction factors.

While VCF's can only be calculated when birds are observed on the fixed-wing portion of the segments which are also flown by helicopter, the strict selection of segments based on their tendency to have large numbers of waterfowl does not represent either a random or a representative subsample of the state. As previously stated, VCF's are closely tied to cover; segments with fewer birds counted on the fixed-wing survey may have this condition as a result of thicker cover while segments with higher counts may be a result of thinner cover. Combining these segments in a strata while calculating the VCF from segments with high counts would grossly underestimate actual numbers if all segments are actually equally populated. Segments to be flown by helicopter need to be a truly representative sample of the cover available to waterfowl if the VCF's calculated are to be meaningful.

The low number of segments which have been flown by helicopter do not allow for visibility correction either on group size or sexually dimorphic coloration. As the size of a group of animals increases, the sightability of that group increases (Gasaway et al. 1985, Samuel et al. 1987, Drummer et al. 1990), therefore, any VCF for single birds or pairs should be higher than that for groups of birds. Similarly, most species of waterfowl possess sexually dimorphic coloration where the female has a mottled brown patterned plumage. Any VCF for single females should be higher than that for single males. The current VCF calculation scheme lumps all animals on a segment, regardless of gender or group size. A much larger database of flown segments would be necessary, however, before VCF's could be calculated which reflect these influences since many segments have values of zero for lone drakes, pairs, or grouped birds counts.

Assumptions inherent in the current calculation of VCF's need to be examined, as alternatives to the current methods may be feasible if additional effort is expended in the refinement of accurate VCF's. The variance of the current estimate of VCF is biased (Martin et al. 1979). This technique also assumed no difference in sightability due to group size, variable cover within a stratum, and density of birds within segments. As long as fewer than 10 segments in each stratum are flown each year, there are not markedly superior methods of VCF calculation. If either greater numbers of segments are flown annually or segments are combined across years, there are two other methods which may be used and should be investigated. The first of these is to calculate VCF's for each segment, then take the mean of these VCF's as the stratum VCF. The variance of this estimate would simply be the variance of the distribution of individual VCF's. The other method is to calculate a regression of helicopter counted birds on fixed-wing counted birds. Ideally, VCF's could be calculated for each counted component of indicated birds: lone drakes, pairs, and groups.

Observer Bias:

Despite the strict constraints placed on survey techniques by the USFWS standard operating procedures, there have been a variety of techniques used both between years and within a single year's survey. Examples of this include differences in the speed and height at which the survey is flown, differences in the notation of unidentified birds, differences in the width of the transect observed, and irregular reporting of segment length. All of these factors increase error in the survey, though reduction of most is simple.

The survey is flown by a combination of MDNR pilots and outside contractors. For fixed-wing flights, the 1991 survey used two pilots, the 1992 used one, the 1993 survey used four, and the 1994 survey used four. No pilot was used in more than two surveys, resulting in a total of eight different pilots. Not all of these pilots are equally skilled in survey techniques or are equally familiar with the area being surveyed. Pilots unfamiliar with survey techniques flew segments either considerably faster or slower than the speed specified in the USFWS standard operating procedures and were more likely to not remain a constant distance above the ground, as required for the survey. This variability reduces the ability to confidently compare results either between strata of the survey in one year or between separate survey years (Pennycuick and Western 1972, Caughley 1974, Caughley et al. 1976, Bayliss and Giles 1985, Briggs et al. 1985). While helicopter flights were piloted by only one individual each year, no individual piloted for more than one year.

Observers on the flights do not consistently mark unidentified birds on survey sheets. As most observers have remained constant on the transects over the years of the survey, this only affects comparisons among strata, not among years. This problem could be resolved through annual training sessions. At the present, observers often use one segment as a practice segment before they begin recording data. While a practice segment is a sound practice, it is not reinforced by instruction in techniques and a refresher in waterfowl identification, which are the areas in which the majority of errors are made. Several studies have indicated that the number of animals sighted generally increases with increasing experience (Erickson and Siniff 1963, Caughley et al. 1976, Grier et al. 1981); this effect can be observed in the MBWS by comparing estimated numbers of breeding birds from the first survey year with all other years.

Since transect area increases and sightability decreases with transect width (Edwards 1954, Pennycuick and Western 1972, Caughley 1974, Caughley et al. 1976, Briggs et al. 1985), insuring that the proper transect width is observed is critical. The technique generally used to set transect width for an observer is to sight along a piece of tape applied to the wing strut of the aircraft. Often, two pieces of tape are applied for observers of different heights or for flights at different heights. This technique is useful and can provide useful guidelines to the observers, however, it is not used on all transects, as some planes do not have tape on the wing struts. On transects for which the tape guidelines are used, they only accurately demarcate the transect area when the transect is flown at the appropriate height. As stated earlier, this may or may not actually occur.

The current survey design, which uses a navigator/observer tends to result in segments either being overestimated or underestimated. The navigator/observer is responsible for keeping the aircraft over the transect line, noting the beginning and end of segments, and observing waterfowl to the right side of the plane. When there are readily available landmarks for the pilot to use as an aid for staying on the transect, the navigator/observer has a tendency to spend more time observing waterfowl. This often results in the end of segments not being noted, creating one long and one short segment. This can have the most impact when the long or short segment is also chosen for a helicopter flight. Norton-Griffiths (1978) has stated that it should be the pilot's responsibility to navigate and notify observers of the end of segments. This would be more likely to result in accurate notation of segment length. Another solution would simply involve following the procedures set forth by the USFWS by using a tape recorder to store data on waterfowl seen rather than on survey sheets. This would allow more time to be spent on checking the maps and less time on recording data. Also, the use of GPS equipment could facilitate the observation of transect length and position by the pilot.

Sample size:

To estimate the optimal number of survey segments to be flown, the variance of the survey due to changing the number of segments flown was calculated. The variance equation for the survey consists of three input values: the area expansion factor, the number of indicated birds from the survey, and the variance of the visibility correction factor.

$$\mathit{STRATUM\ VARIANCE} = \left(\frac{\mathit{area\ of\ the\ stratum}}{\mathit{area\ of\ the\ survey}} \times \begin{matrix}\mathit{number\ of}\\ \mathit{indicated\ birds}\end{matrix}\right)^2 \times \mathit{VAR}(\mathit{VCF})$$

While decreasing the area of the survey results in a decrease in the number of indicated birds, a change in the number of indicated birds was not included in the analysis so that the effects due solely to survey area could be isolated. The survey was broken down into three strata for the purposes of this analysis: the Farm-Urban stratum of the MBWS, the northern Lower Peninsula, and the Upper Peninsula. The number of indicated birds was held constant at the mean value for the four years of the survey, and the number of segments flown was varied from 1 to 175. The VCF values used were those from the 1993 survey. Variances of the estimates of both mallard and Canada goose were calculated.

Similar trends can be seen in the curves for both mallards and Canada geese (Figure 13, Figure 14, Figure 15), suggesting that a survey size selected to minimize variance and cost for one species would be favorable for the other.

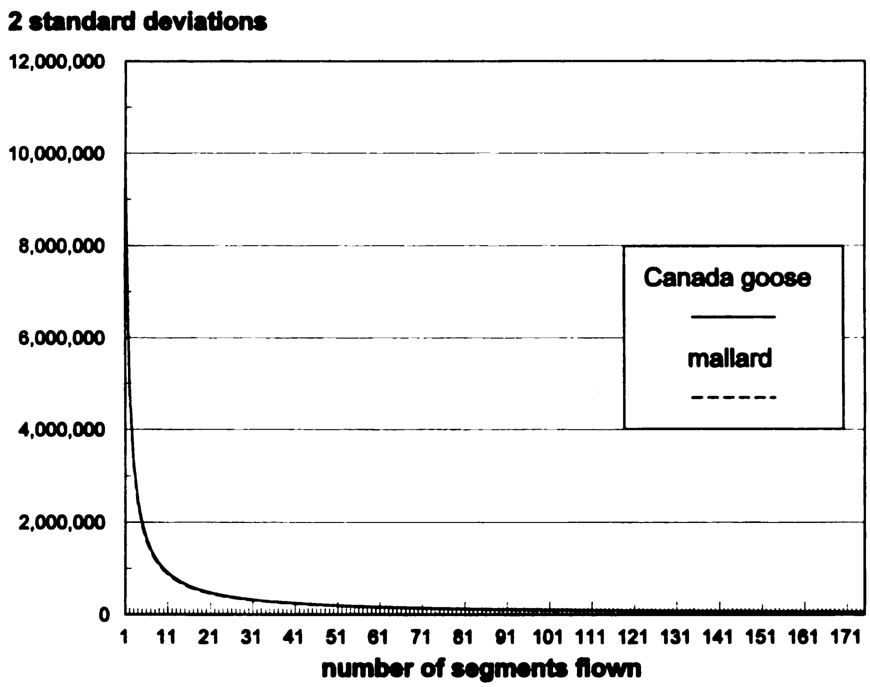

Figure 13. Stratum variance across changing survey sample sizes for the Southern Lower Peninsula

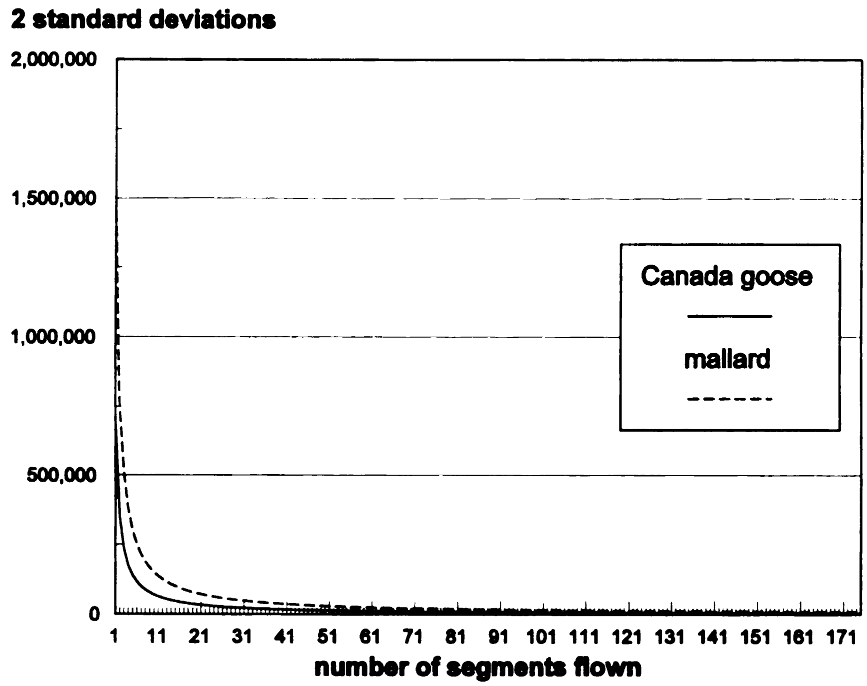

Figure 14. Stratum variance across changing survey sample sizes for the Northern Lower Peninsula

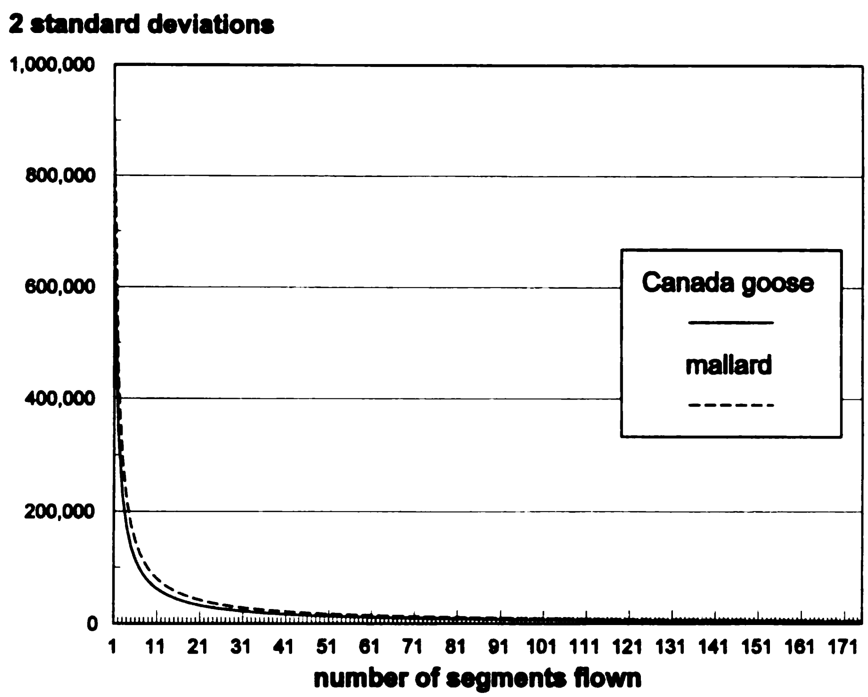

Figure 15. Stratum variance across changing survey sample sizes for the Upper Peninsula

Currently, there are 93 segments flown in the Farm-Urban stratum, 29 flown in the northern Lower Peninsula, and 30 flown in the Upper Peninsula. As the difference in the curves for the two species is due to the number of indicated birds and the variance of the VCF, the effects of a combination of low numbers of indicated birds and a high VCF or high numbers of indicated birds and a low VCF can be observed. The number of Canada geese observed on the flights is much lower in all three strata than the number of mallards observed, and the VCF's for Canada geese are higher than those for mallards.

Minimization of the variance of the estimates of population size for each stratum requires that the number of indicated birds, the area expansion factor, or the variance of the VCF must be reduced. If the reduction of one of these factors results in the increase in another, net gains in precision may be small or nonexistent. This suggests that the course which is most likely to result in a reduction of survey variance is to attempt to reduce the VCF variance.

GLOSSARY

adult fall population: the number of after hatch year birds which survive to migrate

area expansion factor: the result of division of the total area in a stratum by the area within that stratum which is contained in the transects flown in that stratum

dump nests: generally nests in which more than one egg per day is laid, nonterm eggs are present when the rest of the clutch hatched; in wood ducks, where clutch size exceeds 18 eggs(Clawson et al. 1979); implies that more than one female is laying eggs in the nest.

fall flight: the total number of birds which leave a region on migration which either bred there or were hatched there

fixed-wing aircraft: airplane

indicated birds: estimate of total birds present in a survey area which assumes that lone drakes sighted are paired, but that groups of five or more drakes represents unmated birds

juvenile fall population: the number of young of the year birds which survive to migrate

juvenile summer survival rate: the survival rate of young of the year birds from early flight stage to the beginning of migration

leucocytozoon: (*Leucocytozoon simondi*), an avian parasite which causes malaria-like symptoms and death, transmitted by blackflies. (Herman et al. 1975)

MBWS: Michigan Breeding Waterfowl Survey, conducted annually and following the procedures of the Waterfowl Breeding Population and Habitat Survey

marsh: a frequently or continually inundated wetland characterized by emergent herbaceous vegetation adapted to saturated soil conditions. (Mitsch and Gosselink 1986)

Mayfield Method: a technique used to calculate survival; it provides a daily survival rate and a survival distribution over a period of time (Mayfield 1960)

nest box: box constructed for use, generally, by wood ducks and mounted on snags in wetlands; baffles are often installed below the boxes to reduce predation

nest success: the fraction of nests which are initiated which produce at least one egg that hatches optimal production rate: calculated production rate which represents the highest output obtainable by experienced birds

production: total number of young which reach early flight stage during one breeding season

production rate: young produced per breeding adult in the model, young produced per breeding female in the projections

realized production rate: calculated production rate of a population which has been corrected to account for different reproductive efforts and success rates among age classes

segment: an 18 mile sampling unit, having a total width of ¼ mile. (USFWS 1987)

stratum (strata): a specific geographic unit encompassing areas of similar waterfowl densities and generally of a specific habitat type. Transects extend from one side of a stratum to the other. (USFWS 1987)

swamp: wetland dominated by trees or shrubs (Mitsch and Gosselink 1986)

transect: a continuous series of segments. Transects are oriented in an east-west direction and are parallel to the other transects at regular intervals within any given stratum. (USFWS 1987)

VCF: visibility correction factor; correction factor used to modify fixed-wing survey flights for birds which are not seen

WBPHS: Waterfowl Breeding Population and Habitat Survey; continental survey of breeding waterfowl and available habitat

WPHS: Waterfowl Production and Habitat Survey; continental survey of young of the year waterfowl and late nesting adult birds

wing survey: results of analysis of parts collected during annual harvests

APPENDIX

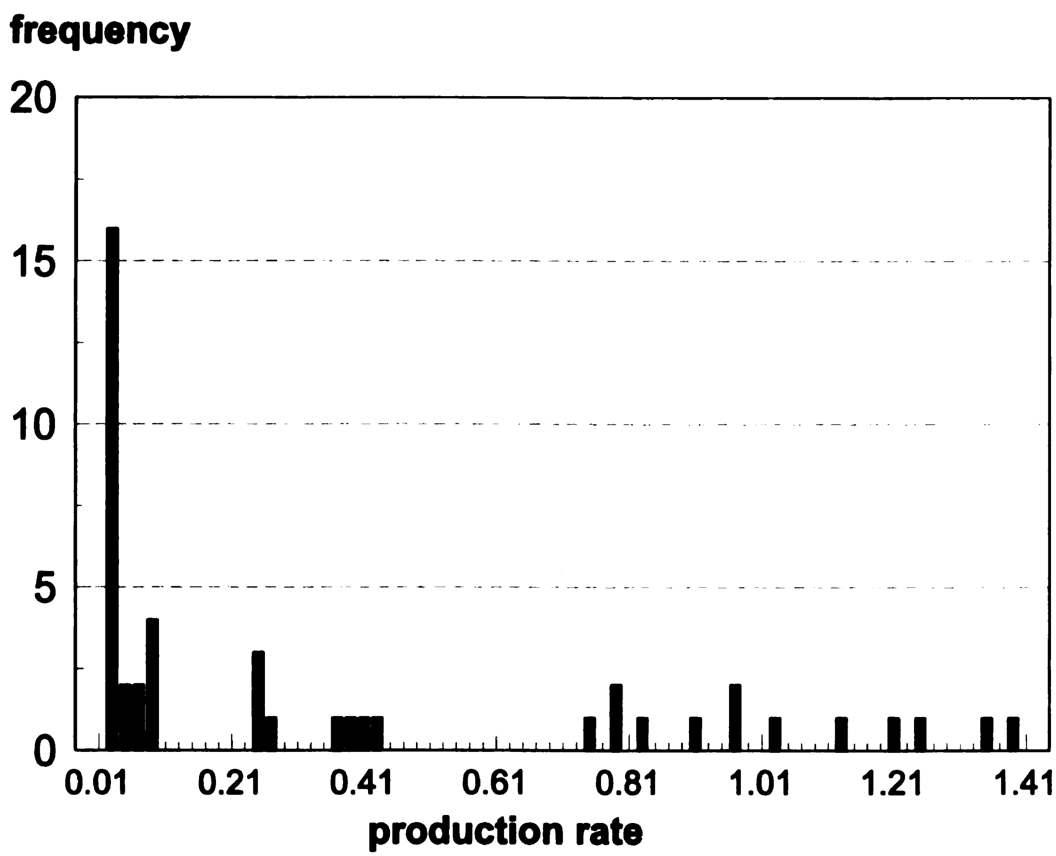

Figure 16. Production rate distribution calculated from mallard literature values

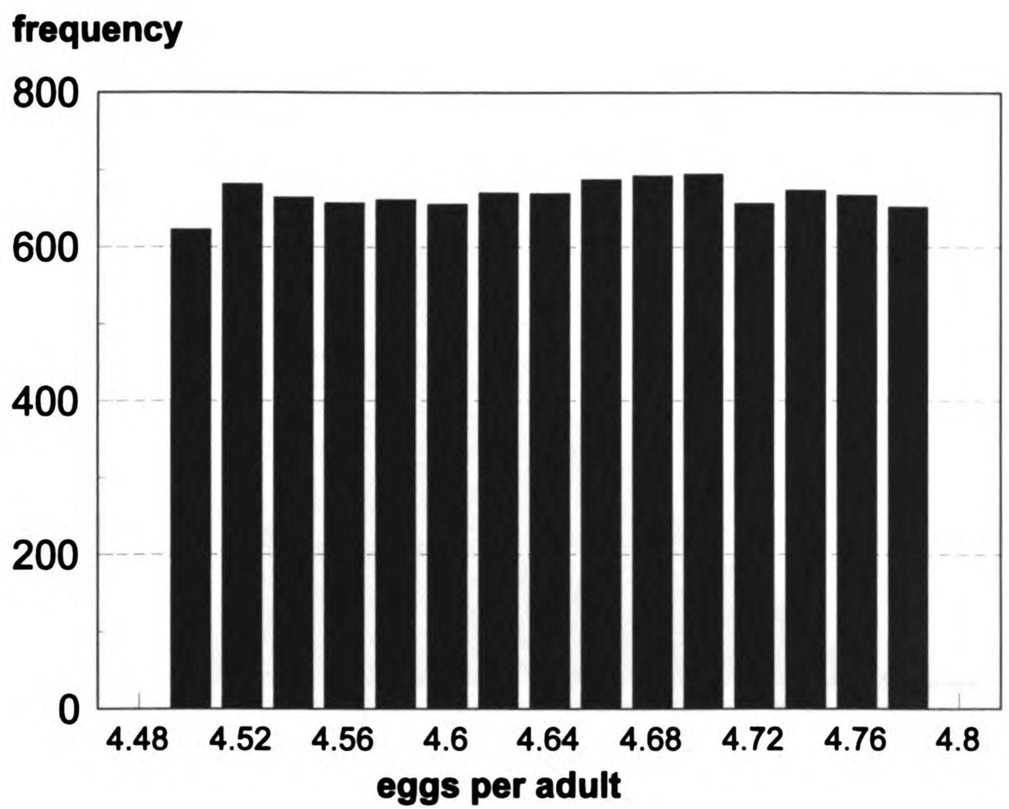

Figure 17. Result of 10,000 random draws from the constructed distribution of mallard eggs per adult values

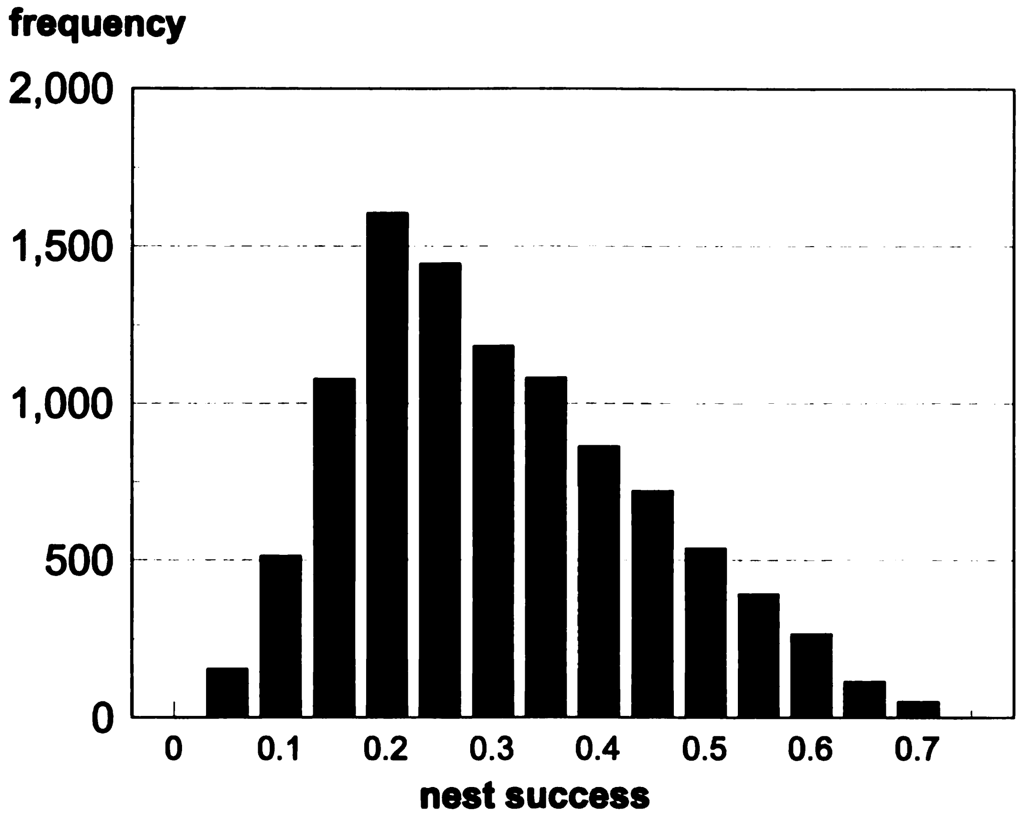

Figure 18. Result of 10,000 random draws from the constructed distribution of mallard nest success values

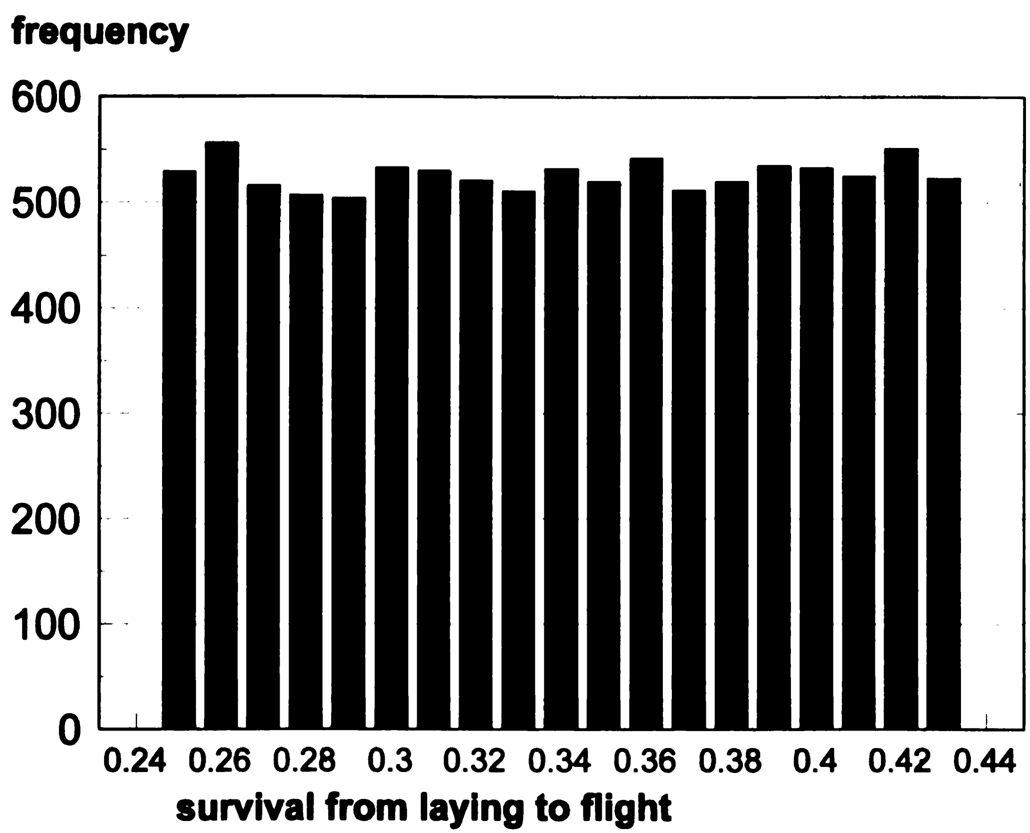

Figure 19. Result of 10,000 random draws from the constructed distribution of mallard survival from laying to flight values

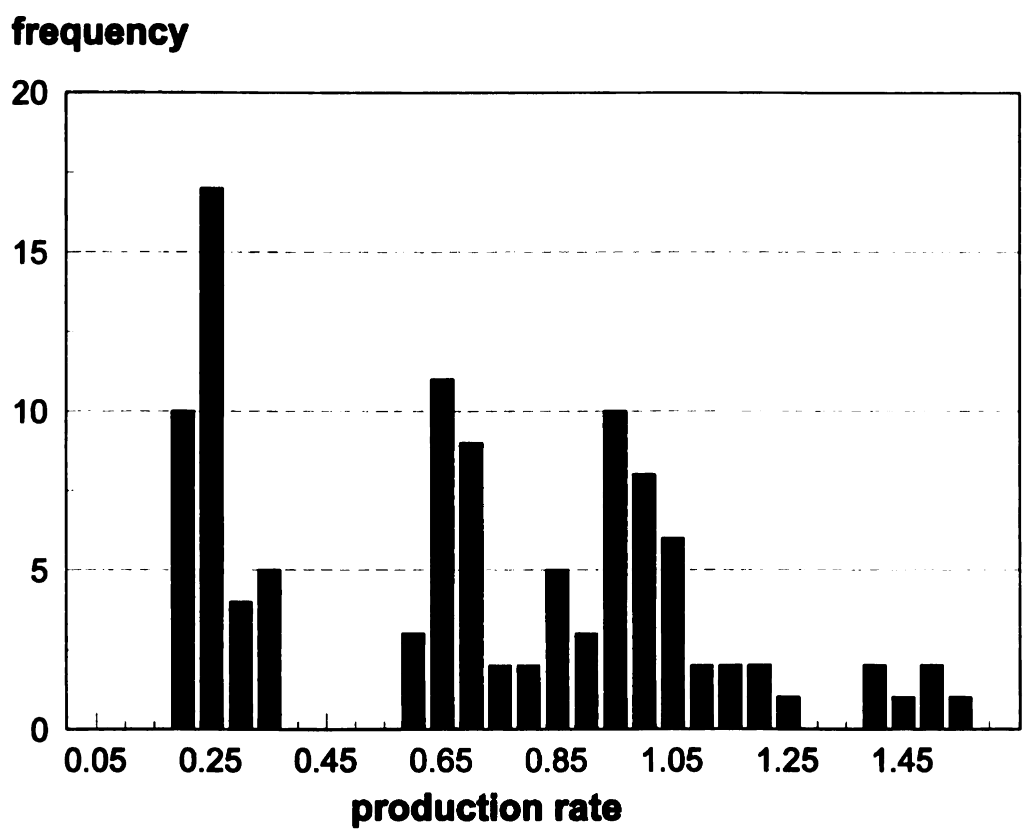

Figure 20. Production rate distribution calculated from black duck literature values

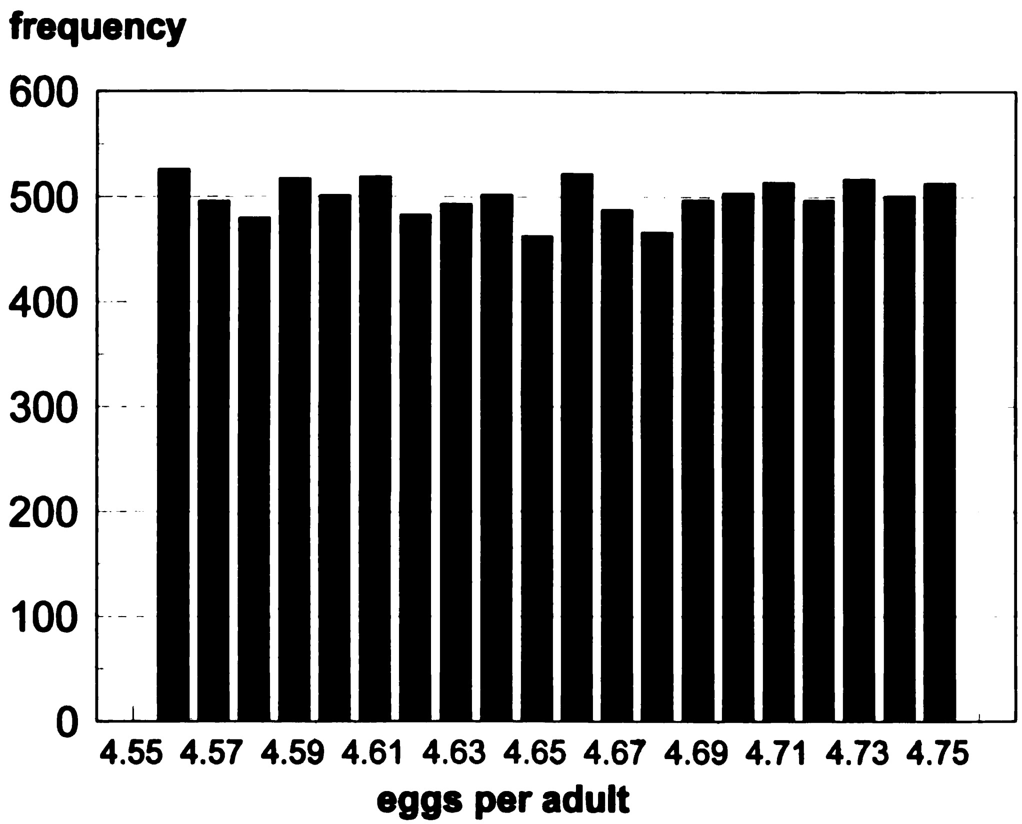

Figure 21. Result of 10,000 random draws from the constructed distribution of black duck eggs per adult values

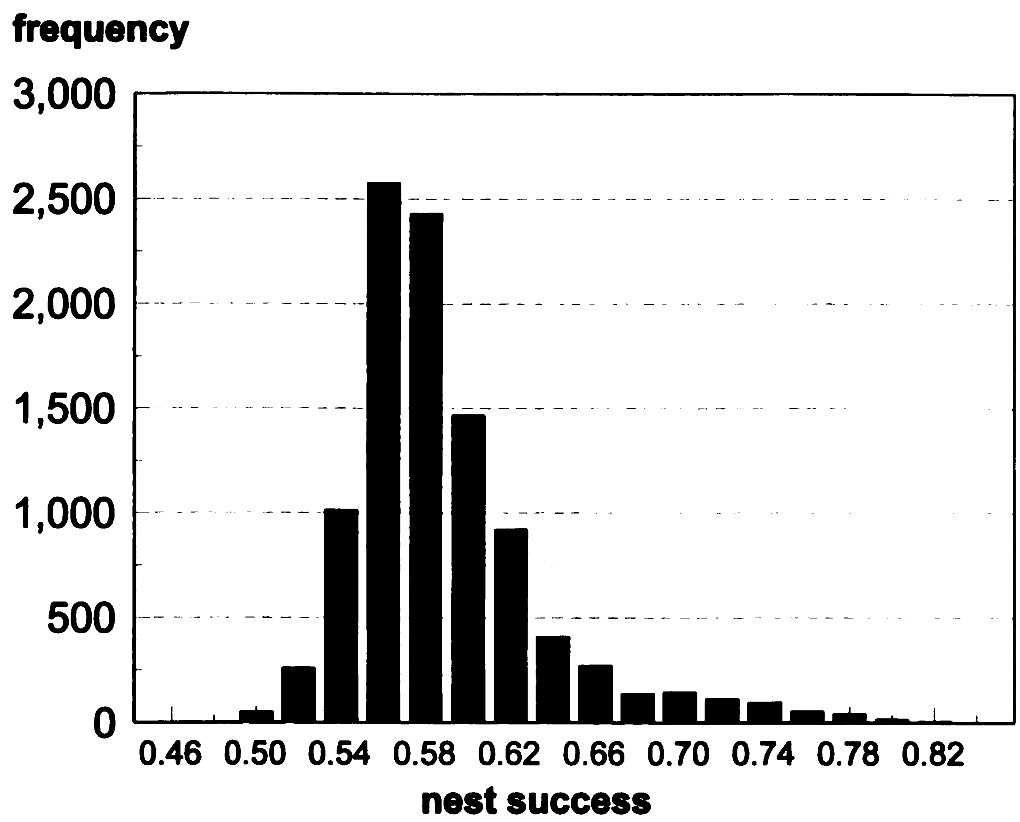

Figure 22. Result of 10,000 random draws from the constructed distribution of black duck nest success values

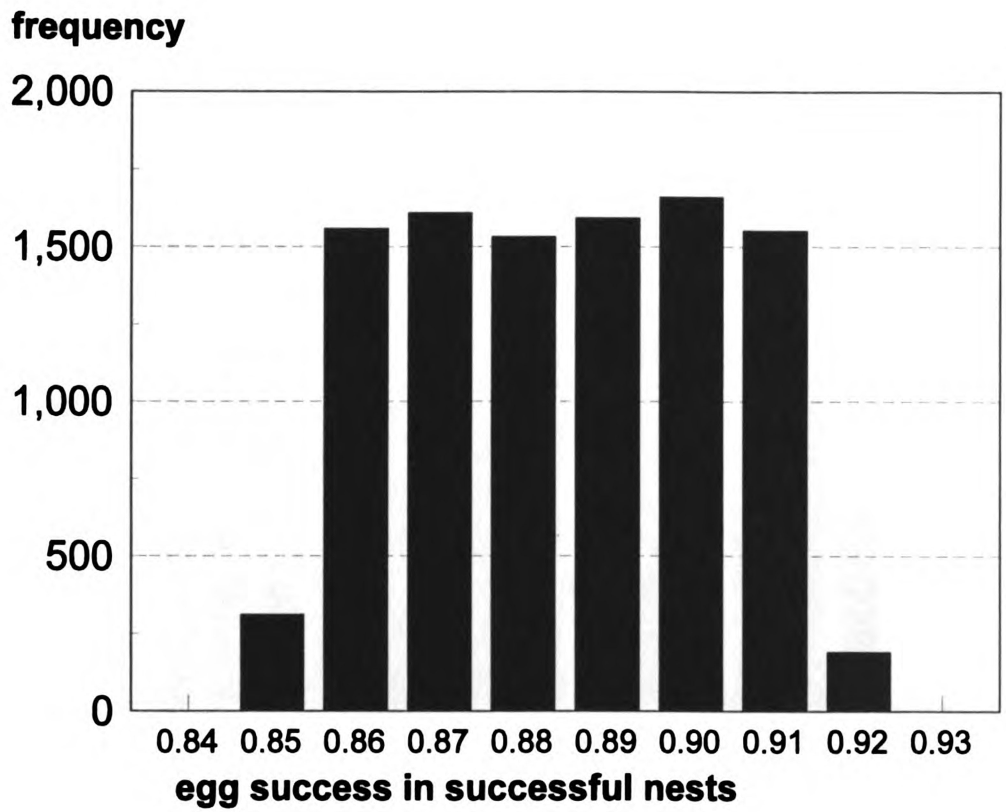

Figure 23. Result of 10,000 random draws from the constructed distribution of black duck egg success in successful nests values

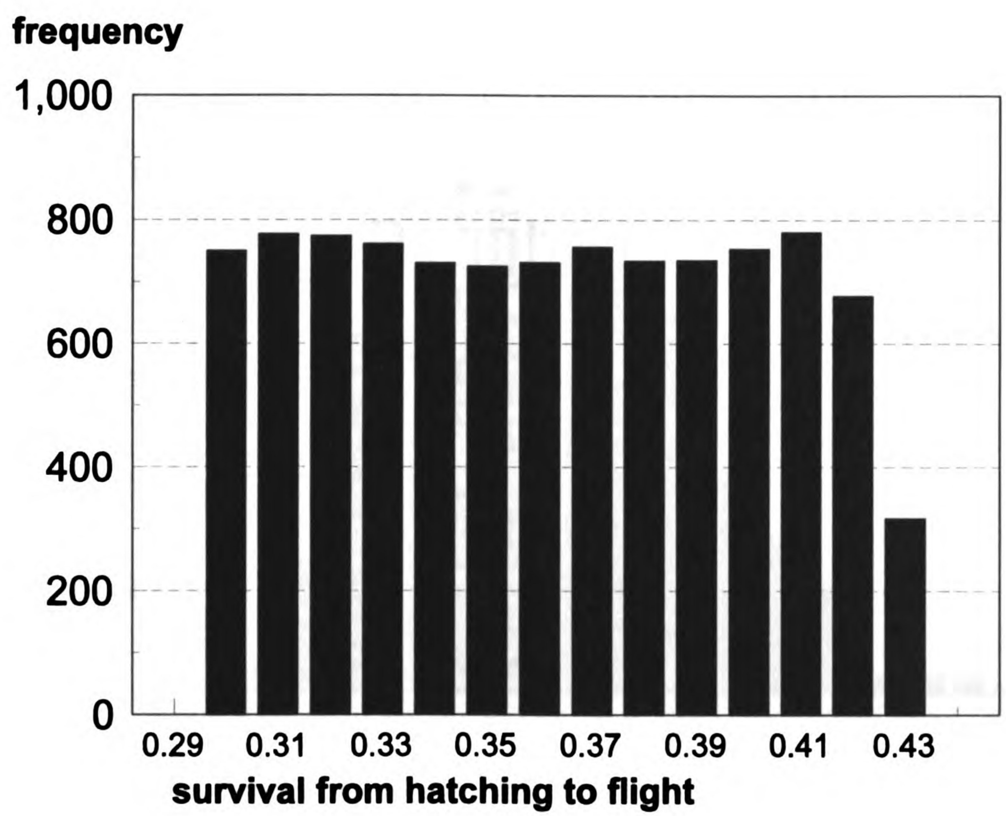

Figure 24. Result of 10,000 random draws from the constructed distribution of black duck survival from hatching to flight values

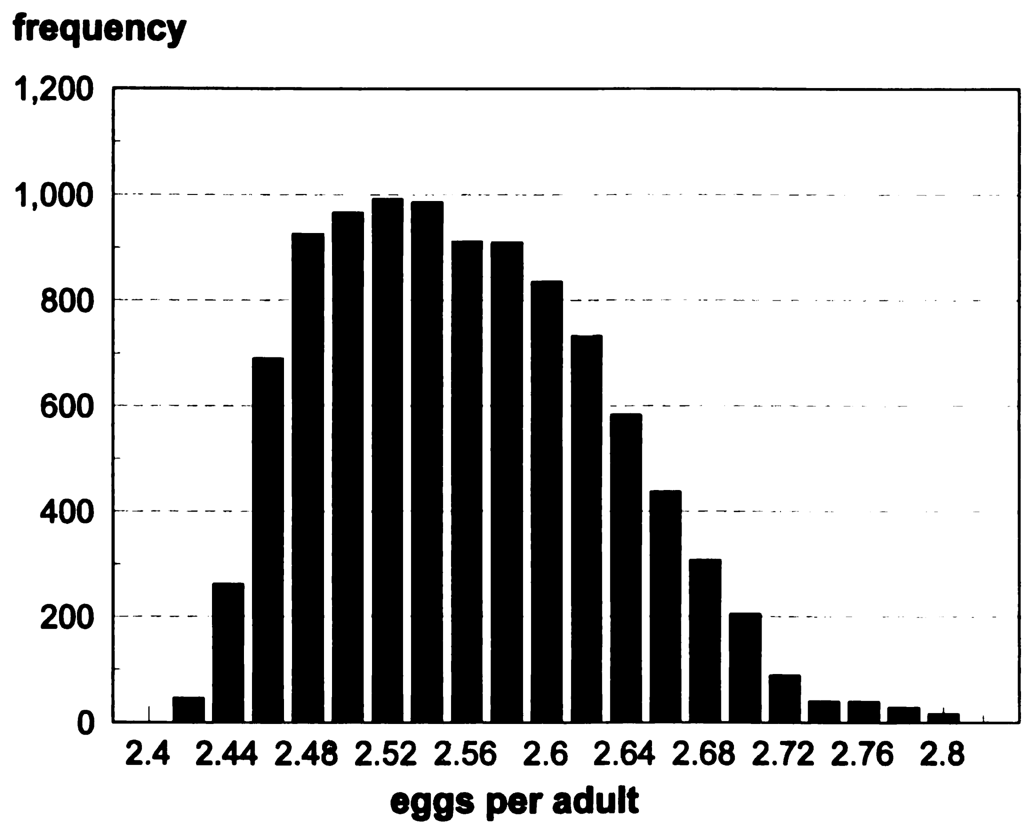

Figure 25. Result of 10,000 random draws from the constructed distribution of Canada goose eggs per adult values

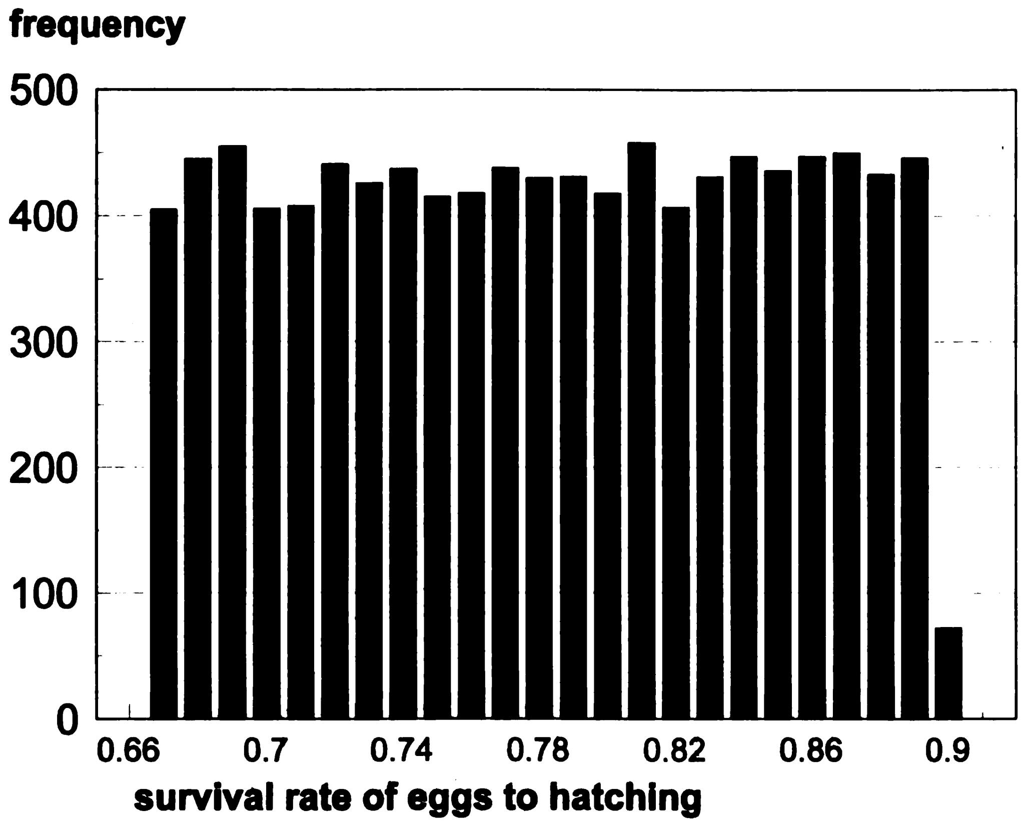

Figure 26. Result of 10,000 random draws from the constructed distribution of Canada goose survival rate of eggs to hatching values

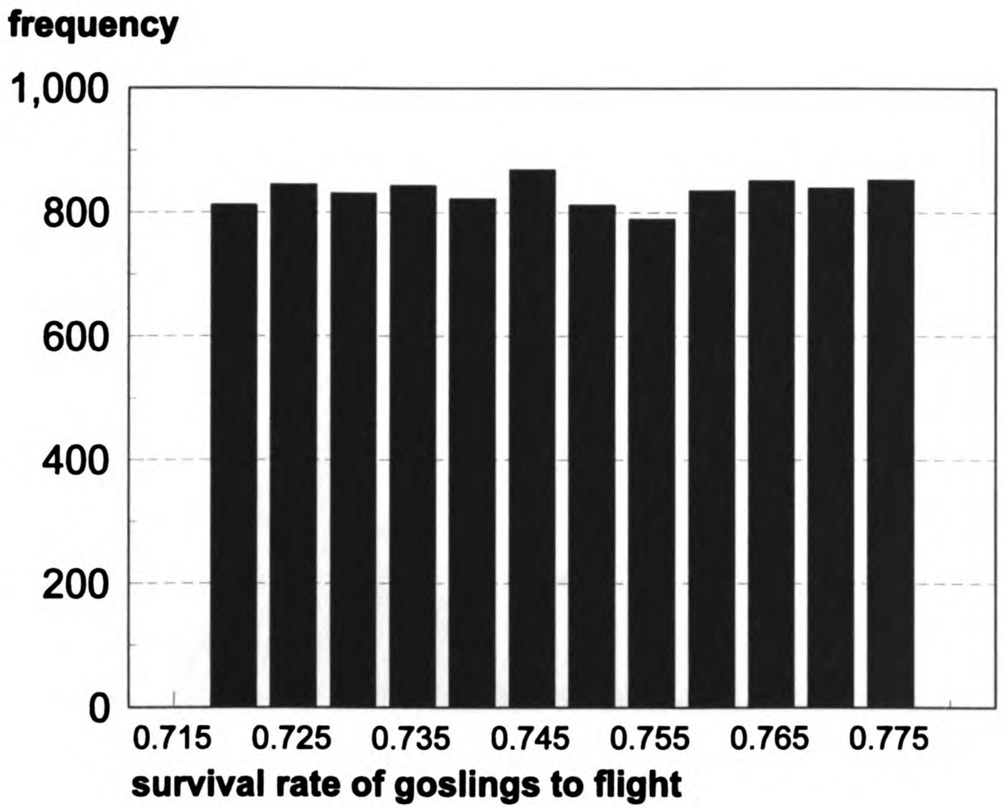

Figure 27. Result of 10,000 random draws from the constructed distribution of Canada goose survival rate of goslings to flight values

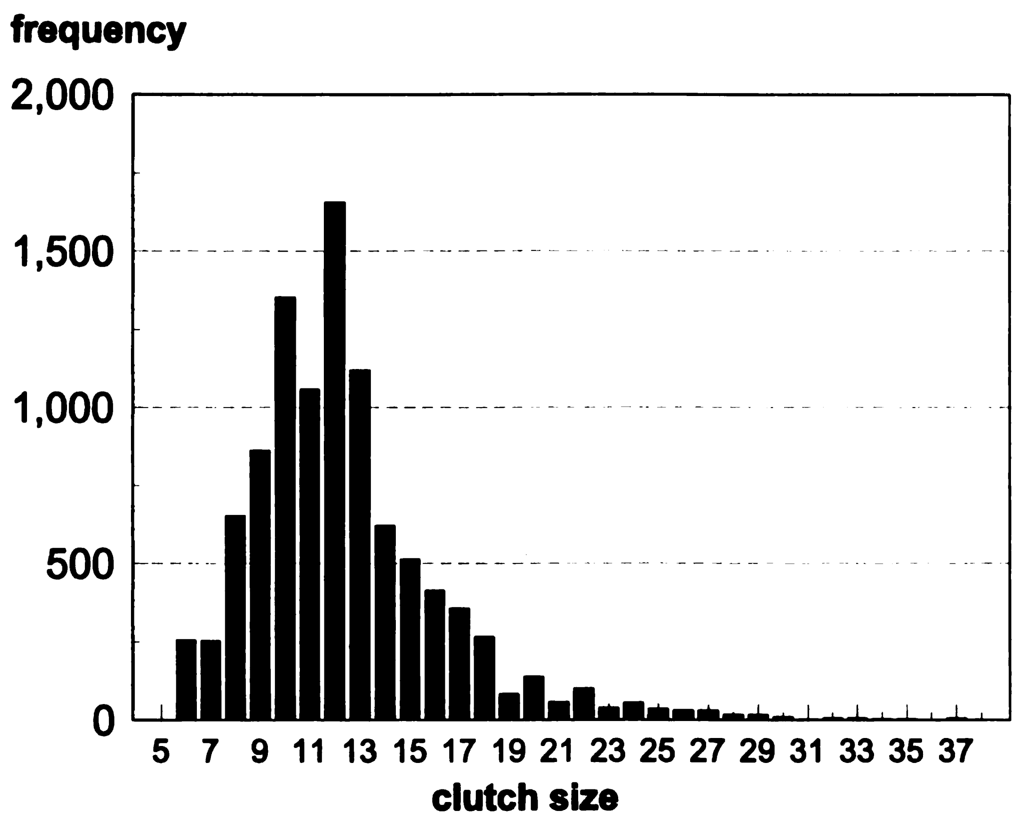

Figure 28. Result of 10,000 random draws from the constructed distribution of wood duck clutch size values

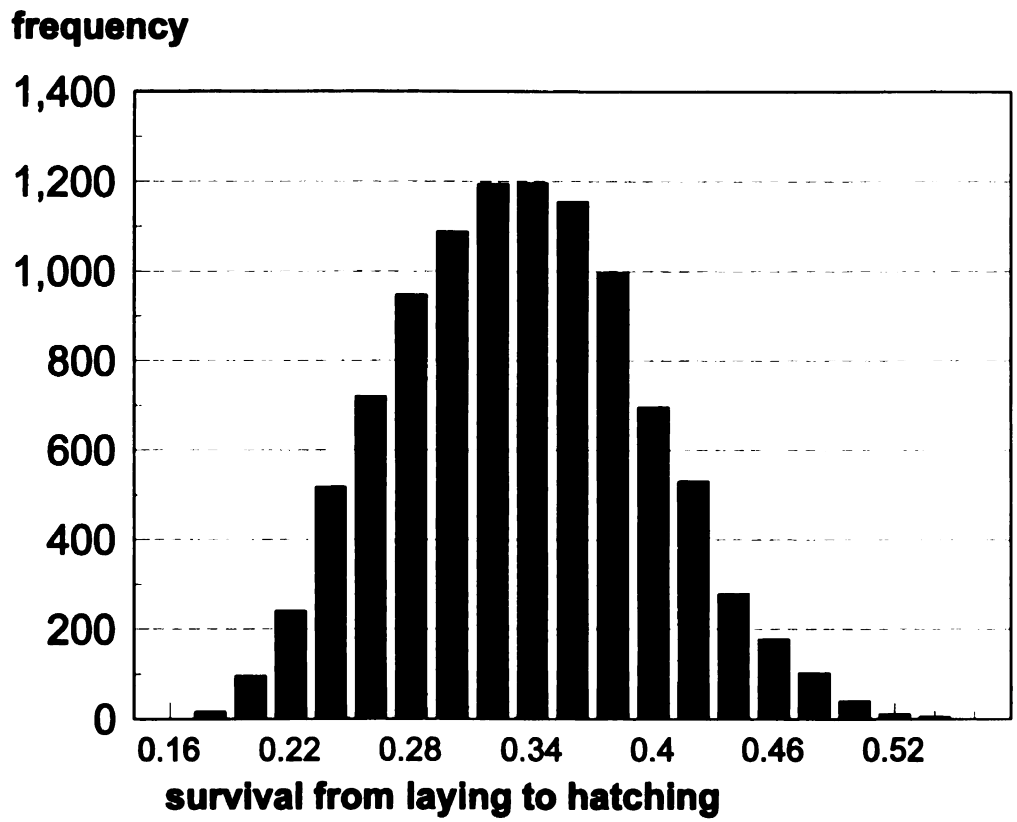

Figure 29. Result of 10,000 random draws from the constructed distribution of wood duck survival from laying to hatching values

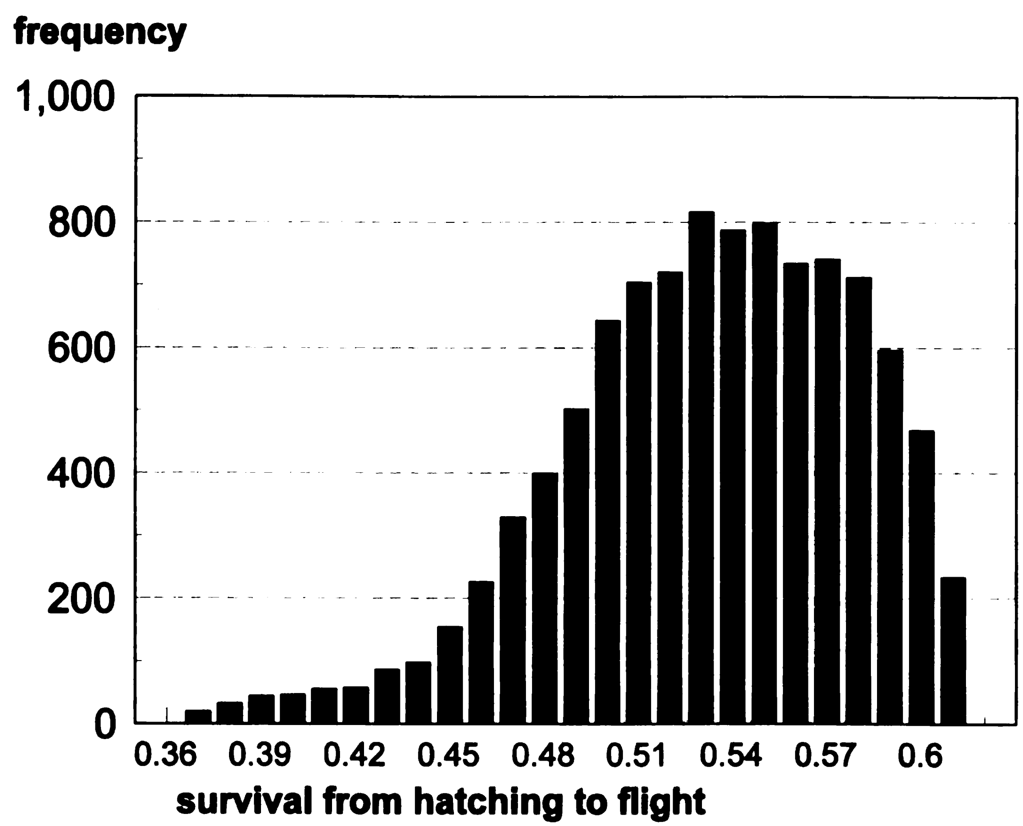

Figure 30. Result of 10,000 random draws from the constructed distribution of wood duck survival from hatching to flight values

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