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VARIATION IN EFFORT AND METHODOLOGY FOR THE MIDWINTER WATERFOWL INVENTORY IN THE ATLANTIC FLYWAY

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The midwinter waterfowl inventory (MWI) was designed to determine numbers and distribution of waterfowl on wintering grounds and to provide a long-term data base for assessing population trends. Biologists from state wildlife agencies and the U.S. Fish and Wildlife Service (USFWS) have conducted the survey annually since the mid-1950's. Advantages attributed to the MWI are that it provides the only population estimates for important species such as American black ducks (*Anas rubripes*) and for other species (e.g., seaducks, tribe Mergini), and that it provides supplemental data for other species for which breeding population and harvest information are available (M. J. Conroy, unpubl. rep., USFWS, Laurel, Md., 1981).

MWI counts reported by states to the USFWS were total counts of waterfowl observed on areas of known waterfowl concentrations. This design implies that areas where lower waterfowl numbers or densities occurred may not have been surveyed. Therefore, MWI's were not intended as complete counts or estimates of the total waterfowl population within states, but rather as total counts of specific areas each year. Total counts of the same areas annually would provide an index to temporal changes in populations if the surveyed areas collectively contained a similar proportion of all waterfowl present each year. The objective of our study was to document how well this assumption was met in Atlantic Flyway MWI's.

METHODS

We obtained data on MWI effort expended by states from files of USFWS, Regions 4 and 5, the Atlantic Flyway. These data were compiled from Participation Summary data sheets and annual MWI count data submitted to the USFWS by states. Survey effort data (aircraft flight hours and automobile and boat distance) were available for most states and most years since 1973, but the data set was incomplete. We tabulated available data for each state and distributed tables to technical section representatives (waterfowl biologists) to the Atlantic Flyway Council. We asked representatives to fill in omissions using their file data and to verify the effort data we had already obtained.

We included a questionnaire to qualitatively determine the amount of annual variation in MWI route coverage, personnel, techniques, and equipment. We also were interested in opinions of biologists of how these factors affected MWI results from their state. Respondents were asked to identify and describe the influence of long-term habitat change on waterfowl distributions as reported by the MWI. We viewed information on survey methodology and habitat changes obtained from the questionnaire as subjective appraisals of whether these factors caused the proportion of waterfowl counted to change over time.

We used multiple linear regression analysis to determine the influence of survey effort on MWI counts of diving and dabbling ducks. Aircraft hours and automobile and boat distance travelled were used as the 3 independent variables because they were the only measures of survey effort for which records were available. We also explored these relationships for individual states and the entire flyway. Independent variables in models for individual states consisted of the effort variables appropriate for that state. For states that used only aircraft to conduct their MWI, for example, we used simple linear regression models with aircraft hours as the independent variable. Because data were equally spaced time-series data (collected annually), we tested for the presence of autocorrelated errors using Durbin-Watson statistics (Berenson et al. 1983:407–409). We rejected the hypothesis that no autocorrelations were present ($P < 0.05$) and removed first-order autocorrelations using iterative estimation (Yule-Walker estimates) to calculate regression coefficients and standard errors (Berenson et al. 1983:413–414; PROC AUTOREG, SAS Inst. Inc. 1984:183–219). Residuals were analyzed to evaluate fit of multiple regression models. We tested for the presence of temporal trends in each of the effort variables (aircraft hours, automobile distance, and boat distance for the entire flyway) using simple linear regression.

We could not directly test the question of whether survey effort or methodology biased the MWI as an index to the size of Atlantic Flyway duck populations because no independent estimates of population size were available for comparison.

RESULTS

Sixteen of 17 states in the Atlantic Flyway responded to our request for information. Connecticut, Maine, and New Jersey provided effort data extending back to 1954. For most states, however, complete records were available only since the early 1970's. We were able to compile a nearly complete set of MWI participation data from the 17 states from 1973 through 1987 and a complete data set for all 17 states for the 1976–1987 period. Participation data were missing from 2 states in 1973 and 1 state in 1975. Maps or route descriptions were provided by 12 states.

Florida, North Carolina, New Jersey, Maryland, and South Carolina, combined, counted an average of 72% of the total diving ducks and dabbling ducks on the Atlantic Flyway's MWI (Table 1). These states flew an average of 48% of the total flyway aircraft hours. South Carolina averaged the most automobile kilometers on a flyway percentage basis ($\bar{x} = 30\%$ of flyway total) and the most boat kilometers ($\bar{x} = 58\%$ of flyway total) (Table 2).

Table 1. Average count of diving and dabbling ducks and average percentage of flyway total from midwinter waterfowl inventories in Atlantic Flyway states, 1976–1987.

State	Count	%
Conn.	22,167	1.5
Del.	31,958	2.1
Fla.	282,416	18.9
Ga.	31,958	2.0
Mass.	52,167	3.5
Md.	218,742	12.8
Me.	25,950	1.7
N.C.	243,800	15.6
N.H.	1,350	0.1
N.J.	208,733	14.1
N.Y.	89,250	6.0
Pa.	25,492	1.6
R.I.	19,325	1.2
S.C.	161,492	10.4
Va.	123,217	8.0
Vt.	2,808	0.2
W.Va.[a]	4,400	0.3
Flyway total	1,544,900	

[a] No count was conducted in 1978.

Techniques and Equipment

Methods used by states to conduct annual MWI's were diverse, but, in general, states originally designed their surveys as total counts

Table 2. Average effort and average percentage of total effort expended by states on the Atlantic Flyway midwinter waterfowl inventory, 1976–1987.

	Aircraft				Automobiles				Boats			
	Hours		%		Kilometers		%		Kilometers		%	
State	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Conn.	6.2	0.5	1.7	0.1	2.7	2.7	0	0	0	0	0	0
Del.	7.7	0.3	2.1	0.1	0.8	0.5	0	0	0	0	0	0
Fla.	45.7	2.3	12.3	0.5	17.0	10.9	0.6	0.4	142.1	66.6	30.4	7.0
Ga.	22.2	1.6	6.0	0.4	45.0	16.1	2.8	1.2	25.1	15.3	4.7	2.9
Mass.	18.4	0.7	5.0	0.2	122.0	35.2	8.4	3.2	0	0	0	0
Md.	65.1	4.9	17.7	1.5	0	0	0	0	0	0	0	0
Me.	26.7	2.3	7.2	0.6	0	0	0	0	0	0	0	0
N.C.	39.8	1.8	10.7	0.4	113.9	25.6	8.5	1.8	15.1	3.4	6.1	1.4
N.H.	2.2	0.1	0.6	0	0	0	0	0	0	0	0	0
N.J.	19.0	1.8	5.1	0.5	0	0	0	0	0	0	0	0
N.Y.	49.5	1.4	13.4	0.4	214.2	67.9	11.5	4.5	0	0	0	0
Pa.	9.6	0.5	2.6	0.2	726.9	334.2	27.2	6.4	0.3	0.3	0.1	0.1
R.I.	3.2	0.3	0.9	0.1	37.5	36.0	1.8	1.8	0	0	0	0
S.C.	9.4	1.0	2.5	0.3	459.4	95.2	30.1	5.1	168.9	17.8	58.2	6.6
Va.	37.4	2.3	10.0	0.6	50.4	10.4	3.8	1.2	0	0	0	0
Vt.	2.0	0.2	0.5	0	1.9	1.9	0.1	0.1	0	0	0	0
W.Va.[a]	7.3	0.8	2.0	0.2	136.0	58.2	5.5	2.2	1.9	1.9	0.6	0.6
Flyway total	370.8	5.5			1,916.6	381.6			353.5	87.5		

[a] No count was conducted in 1978.

of traditional locations of waterfowl concentrations. All responding states conducted recent MWI surveys primarily by aircraft. Most states used fixed-wing aircraft, but Rhode Island consistently used a helicopter. Georgia and Florida occasionally substituted with a helicopter. After 1973, 4 states (Md., Me., N.H., and N.J.) conducted surveys solely by aircraft, and the rest (13 states) supplemented aerial coverage, at least in some years, with automobiles (7 states) or a combination of automobiles and boats (6 states). Rhode Island reported that, because of flight-time cutbacks to 2 hours in 1987, a large portion of their survey (434 km) was conducted by automobile.

Route Coverage

We asked respondents to identify years when individual routes were not flown and to indicate how many routes were missed each year. Route coverage has been fairly complete since 1976. Only 5 states (Fla., Ga., N.C., N.Y., and Vt.) indicated that routes had been missed. The number of missed routes in any year and the number of years any routes were missed were small (<6) for all states except Florida. Florida missed an average of 11 of its 80 routes annually since 1976. No survey was conducted in West Virginia in 1978. Total annual aircraft hours spent in the flyway's MWI have tended to increase since 1976 ($r = 0.578$, slope estimate $= 3.31$, $t = 2.55$, $P = 0.029$), but no temporal trends were evident for automobile ($P = 0.20$) or boat ($P = 0.99$) travel.

The intensity of coverage of existing routes changed for several states. Coverage of Atlantic Ocean routes in New Jersey was less thorough after the mid-1970's. As a result, concentrations of scoters (*Melanitta* spp.) probably were missed. Maryland increased coverage of inland agricultural areas after 1970 in response to increasing numbers of geese and swans. Consequently, less survey effort was spent on deep water portions of the Chesapeake Bay. "Only when huge rafts of seaducks, scaups, and geese were encountered in deepwaters were birds recorded in [the deep water portions of upper Chesapeake Bay]," and, as a result, seaduck numbers were "terribly underestimated" by the MWI (L. J. Hindman, Md. Dep. of Nat. Resour., Wye Mills, pers. commun.).

Route Changes

We asked each state whether changes were made in survey routes. Four states (Conn., Fla., Md., and N.C.) indicated that survey routes changed substantially. The purpose of changes in Maryland and North Carolina was to include agricultural areas to better survey geese and swans. Connecticut, which accounted for only 1.5% of the flyway count (Table 1), added 3 routes to their survey in 1982 to include waterfowl, primarily mallards (*Anas platyrhynchos*) and Canada geese (*Branta canadensis*), that were using reservoirs. Florida's routes were revised substantially in 1968 and 1976 (Montalbano et al. 1985), but no information could be found suggesting reasons for these changes.

Personnel

Several respondents believed that the amount of observer and pilot experience and training and the frequency of personnel turnover contributed to variation in MWI counts. Twelve respondents indicated that observers in their state had been generally consistent in recent years, and 9 states reported consistency in pilots. However, Florida and Maryland, which each counted a large proportion of flyway ducks (Table 1), reported lack of consistency in both observers and pilots. New Jersey and Virginia, which counted 14 and 8% of the flyway total, respectively, also reported lack of consistency in pilots. In New Jersey, the use of inexperienced pilots flying the survey resulted in "frustrating experiences and poor results" (F. Ferrigno, N.J. Div. Fish, Game and Wildl., Marmora, pers. commun.). Six states reported that new observers were trained in survey techniques. Ten states provided no observer training, and 3 of these, Florida, Maryland, and New Hampshire, also reported high turnover in observers. Five respondents (Del., Pa., S.C., Va., and Vt.) believed that training was unnecessary because the same observers conducted the survey each year.

Relationships Between Counts and Effort

Regression coefficients for the effect of flyway effort variables on flyway counts of dabbling and diving ducks did not differ from 0 (aircraft hrs: $P = 0.84$; automobile km: $P = 0.73$; and boat km: $P = 0.36$). When separate regression models were fitted for each state, most coefficients for effort variables (34 of 36) did not differ from 0 ($P \geq 0.05$). We examined these relationships for an overall trend (consistency in sign or direction of influence over all states). The relationship between aircraft hours and duck counts was positive for 11 of 17 states. Of 13 states that used automobiles, the influence of automobile kilometers on counts was positive for 8 states and negative for 5 states; and of 6 states using boats, the influence of boat travel on counts was positive for 5 states and negative for 1.

Habitat and Distribution Changes

Six respondents (Fla., Ga., Md., N.C., Pa., and Va.) believed that long-term habitat change or loss influenced waterfowl distribution observability and, consequently, MWI counts. Only Maryland and North Carolina adjusted MWI routes to address shifts in distribution.

Respondents suggested possible habitat changes that may have contributed to the observed changes in distribution. We emphasize that these were subjective appraisals by state biologists. Georgia replied that aging of lakes and increased housing development along lake shores seem to have greatly influenced waterfowl distributions. Also, increases in hydrilla (*Hydrilla verticillata*) and water-milfoil (*Myriophyllum* sp.) in a Georgia reservoir, Lake Seminole, occurred concurrent with apparent shifts in distribution. Georgia's biologist believed that this resulted in increases in the proportion of birds counted on the MWI. Hydrilla expansion in Florida also likely caused distribution shifts, especially of ring-necked ducks (*Aythya collaris*). Some shifts may have been away from MWI survey routes and may have resulted in a decrease in the proportion of ring-necked ducks counted on the survey. Urban development and habitat degradation in Florida's large coastal bays (e.g., Tampa and Biscayne bays) also may have altered distributions.

Maryland's biologist suggested that declines in submerged aquatic vegetation in the Chesapeake Bay may have caused waterfowl to move to inland fields and impoundments. Survey routes were adjusted to address this shift. North Carolina adjusted its routes to account for increases in field feeding by snow geese (*Anser caerulescens*) and tundra swans (*Cygnus columbianus*) and for the building of coastal impoundments. According to Virginia's response, the numbers of beaver (*Castor canadensis*) ponds and farm ponds have increased in Virginia since the 1950's, and, as a result, waterfowl seem to have moved away from survey routes to use these habitats, likely reducing the proportion of waterfowl represented by Virginia's MWI.

Biologists also pointed out the importance of year-to-year changes in habitat and surveying conditions that influence the proportion of waterfowl counted during MWI's in their states. Ice and water conditions during MWI's affected waterfowl distributions, and weather influenced migration timing. Weather (cloud cover, sun glare, and wind) probably affected observability as well.

DISCUSSION

The annual MWI has been a useful tool for biologists to observe patterns and changes in wintering waterfowl distributions and habitats. Several Atlantic Flyway states (Del., Mass., Me., N.H., Va., and Vt.) have conducted their surveys with surprising consistency in methods, personnel, route coverage, and survey effort. Other states (Fla., Ga., Md., and W.Va.) reported dramatic or frequent variation in ≥ 1 of these variables. Each state essentially developed its own MWI design, resulting in little consistency in methods or approach among states. When considering different geographical distributions of waterfowl species among years (because of migration timing, weather, and water and ice conditions), differences in survey design among states probably contributed to variation in the proportion of waterfowl counted in the flyway. Accuracy of population indices obtained by counting animals depends on strict constancy in standardized methods and conditions (Caughley 1977:16, Seber 1982:458).

In the opinion of state biologists, long-term habitat and distribution changes in a large portion of the flyway have influenced the proportion of birds counted on the MWI. Given these likely sources of error, and the fact that MWI counts were not adjusted accordingly, we suggest that past annual MWI counts for the Atlantic Flyway contain substantial amounts of unmeasured error and may have limited utility as sensitive indices to population size. Dramatic changes and substantial, long-term trends of certain species may still be evident in MWI results. For example, the historical decline in MWI numbers of black ducks (Steiner 1984) likely is not solely an artifact of survey effort and methods. In fact, in a flyway-wide comparison of MWI black duck counts and a statistically-designed aerial survey of wintering black ducks, MWI counts were within 95% confidence intervals of estimates from the other survey (Conroy et al. 1988).

Regression analysis, which examined the influence of survey effort variables on the number of ducks counted, indicated no relationship between effort and counts. One explanation for the observed lack of a linear relationship might be that these particular variables were not accurate measures of survey effort. For example, poor or erratic weather conditions may cause an increase in aircraft hours reported because more time is spent flying to and from survey units when no actual increase occurred in survey thoroughness or in the area covered. Another explanation might be that the combined effect of other sources of variation (e.g., differences in techniques among states, temporal changes in personnel, and variation in habitat availability), which we examined only qualitatively, may have masked the comparatively small variation due to changes in the single variable, survey effort.

Evidence presented in this paper underscores the difficulty in interpreting comparisons of MWI counts among states and among years for individual states or for the Atlantic Flyway. We recommend caution when using MWI data from the Atlantic Flyway for these purposes. We do not, however, dismiss all evidence for changes in Atlantic Flyway waterfowl populations as indicated by the MWI. Large-scale population changes and substantial, long-term trends in flyway-wide populations, especially for relatively abundant and well-surveyed species, perhaps are reflected by MWI results.

We recommend that independent estimates of or indices to flyway-wide species population size be obtained and compared with MWI species counts to better evaluate the usefulness of MWI data. Also, MWI participants should take appropriate steps to ensure that, to the degree possible, the proportion of wintering waterfowl represented on the MWI remains similar among years. The MWI can serve as an index to flyway-wide populations when its counts represent a consistent proportion of the population. Additional quantitative evaluations are needed to determine how well the MWI meets this standard.

SUMMARY

We describe how the midwinter waterfowl inventory (MWI) has been conducted in the Atlantic Flyway and discuss the influence of variation in survey effort, coverage, methodology, and habitat change on the proportion of waterfowl counted. We compiled data on effort expended (aircraft hours, automobile and boat travel) and distributed questionnaires to 17 Atlantic Flyway Council Technical Section representatives from the U.S. to qualitatively assess the amount of annual variation in survey coverage, techniques, and personnel.

We found no strong evidence for a relationship between survey effort and waterfowl counts. Several Atlantic Flyway states have conducted their MWI with consistency in effort, coverage, techniques, and personnel, but 5 states have exhibited substantial variation in >1 of these parameters. Little consistency in design or methods exists among states. Survey respondents replied that long-term habitat and distribution changes have occurred in at least 6 states, perhaps influencing the proportion of waterfowl counted on the MWI.

We suggest that past Atlantic Flyway MWI counts contain substantial amounts of unmeasured error. Based on this study, we recommend caution when using MWI data for making comparisons of duck numbers either among states or among years.

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DUCKS NESTING ON ARTIFICIAL ISLANDS IN QUÉBEC

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Construction of islands is a technique that has been used to create nest sites for waterfowl in North America to compensate for loss of natural habitat (Bellrose and Low 1978). Mammalian predation is lower, and nest density and nesting success are generally higher on islands than on mainland sites (Johnson et al. 1978, Hines and Mitchell 1983, Piest and Sowls 1985). Most published studies on duck use of artificial nesting islands have been conducted in the prairie region (Johnson et al. 1978, Giroux 1981, Duebbert 1982, Duncan 1986, Higgins 1986) and not in the northeastern region where densities of breeding ducks are lower. Objectives of our study were to determine the use of artificial nesting islands by waterfowl in Québec and to assess the role of some environmental factors in the selection of these islands by nesting ducks.

STUDY AREA AND METHODS

From 1981 to 1983, we studied 37–42 artificial islands created by Ducks Unlimited Canada in 1979 on the north shore of Lake St. Pierre, a natural widening (365 km^2) of the St. Lawrence River, 100 km east of Montréal, Québec. Islands were located in the 2,000-ha floodplain of the lake. They were constructed with material excavated to create a 3-m wide and 1-m deep channel surrounding each island. Islands were rectangular, were 2–3 m above water, and ranged in size from 0.1 to 0.5 ha. No maintenance had been performed since construction. Details on the study area and artificial islands are presented by Bélanger and Couture (1988). Dominant plant species were reed canary grass (*Phalaris arundinacea*), Canadian reedgrass (*Calamagrostis canadensis*), Canada thistle (*Cirsium*

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