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Original Article

Accuracy of Aging Ducks in the U.S. Fish and Wildlife Service Waterfowl Parts Collection Survey

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ABSTRACT The U.S. Fish and Wildlife Service conducts an annual Waterfowl Parts Collection Survey to estimate composition of harvested waterfowl by species, sex, and age (i.e., juv or ad). The survey relies on interpretation of duck wings by a group of experienced biologists at annual meetings (hereafter, flyway wingbees). Our objectives were to estimate accuracy of age assignment at flyway wingbees and to explore how accuracy rates may influence bias of age composition estimates. We used banded mallards (*Anas platyrhynchos*; $n = 791$), wood ducks (*Aix sponsa*; $n = 242$), and blue-winged teal (*Anas discors*; $n = 39$) harvested and donated by hunters as our source of birds used in accuracy assessments. We sent wings of donated birds to wingbees after the 2002–2003 and 2003–2004 hunting seasons and compared species, sex, and age determinations made at wingbees with our assessments based on internal and external examination of birds and corresponding banding records. Determinations of species and sex of mallards, wood ducks, and blue-winged teal were accurate (>99%). Accuracy of aging adult mallards increased with harvest date, whereas accuracy of aging juvenile male wood ducks and juvenile blue-winged teal decreased with harvest date. Accuracy rates were highest (96% and 95%) for adult and juvenile mallards, moderate for adult and juvenile wood ducks (92% and 92%), and lowest for adult and juvenile blue-winged teal (84% and 82%). We used these estimates to calculate bias for all possible age compositions (0–100% proportion juv) and determined the range of age compositions estimated with acceptable levels of bias. Comparing these ranges with age compositions estimated from Parts Collection Surveys conducted from 1961 to 2008 revealed that mallard and wood duck age compositions were estimated with insignificant levels of bias in all national surveys. However, 69% of age compositions for blue-winged teal were estimated with an unacceptable level of bias. The low preliminary accuracy rates of aging blue-winged teal based on our limited sample suggest a more extensive accuracy assessment study may be considered for interpreting age compositions of this species. Published 2013.

KEY WORDS age composition, *Aix sponsa*, *Anas discors*, *Anas platyrhynchos*, Anatidae, blue-winged teal, mallard, wing plumage, wood duck.

The U.S. Fish and Wildlife Service has conducted an annual Waterfowl Parts Collection Survey since 1961 to collect information about harvested waterfowl, including composition by species, sex, and age (Martin and Carney 1977, Raftovich et al. 2009). Primary products from the survey include estimates of species composition of harvested ducks during the hunting season and species-specific sex and age ratios (Raftovich et al. 2009, U.S. Fish and Wildlife Service 2011). Data from the survey have been used in numerous management and research efforts pertaining to North American waterfowl. Age ratios provide indices of annual recruitment that have been related to waterfowl density, time, environmental conditions, and landscape change (Kaminski and Gluesing 1987, Reynolds and Sauer 1991, Afton and Anderson 2001, Zimpfer and Conroy 2006). Age ratios also have been used to assess

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status of waterfowl populations for establishing annual harvest regulations. Since the implementation of adaptive harvest management in 1995, age-ratio data have been explicitly used to develop models of recruitment, ultimately influencing selection of harvest models and regulatory packages (U.S. Fish and Wildlife Service 2012*a*). Currently, information from harvested mallards (*Anas platyrhynchos*) is used in determining which regulatory packages will be used for regular duck-hunting seasons (i.e., those beginning near 1 Oct and terminating near the end of Jan). Other species-specific harvest strategies exist, some of which use species-specific age-ratio data (i.e., American black duck [*Anas rubripes*], northern pintail [*Anas acuta*], lesser scaup [*Aythya affinis*], and canvasback [*Aythya valisineria*]; U.S. Fish and Wildlife Service 2010, 2012*a*, *b*; Silverman 2012). Furthermore, other harvest strategies are in development, which may require species-specific age-ratio data (e.g., wood duck [*Aix sponsa*], blue-winged teal [*Anas discors*]; Garrettson 2007, Fleming 2013).

Although techniques for interpreting wing plumage to assign species, sex, and age were developed decades ago (Carney and Geis 1960, Carney 1962), the accuracy of these methods has not been assessed within the context of the Waterfowl Parts Collection Survey. Previous users of data from the Waterfowl Parts Collection Survey have suggested potential for biases related primarily to biased samples of wings from hunters (Martin and Carney 1977, Afton and Anderson 2001, Oetgen 2002). Based on historical use of these data to determine species-specific harvest estimates (Raftovich et al. 2009) and their more recent use in harvest management (e.g., U.S. Fish and Wildlife Service 2012*a*), an extensive evaluation of accuracy of assessment of species, sex, and age using wing plumage was warranted. Our objectives were primarily to assess accuracy of age assignment based on wing plumage and, secondarily, to determine accuracy of determining species and sex. Earlier evaluations focused on accuracy of the wing plumage method as performed by individual participants (Carney and Geis 1960, Hopper and Funk 1970). Our evaluations estimated accuracy of protocols within the operational survey procedure by incorporating wings from birds of known species, sex, and age. We determined whether error rates differed by species, sex, date harvested, or administrative flyway (i.e., Atlantic, Mississippi, Central, and Pacific). Finally, we assessed potential for bias in age composition estimates derived from aging protocols used in the Waterfowl Parts Collection Survey with accuracy rates estimated from our evaluations.

WATERFOWL PARTS COLLECTION SURVEY

Each migratory bird-hunting season, the U.S. Fish and Wildlife Service, Division of Migratory Bird Management conducts national surveys of migratory bird-hunting activity and harvest (Raftovich et al. 2009). One component of the annual survey is the Waterfowl Parts Collection Survey, wherein participating hunters are requested to submit an entire wing from each duck harvested to a central location in the appropriate administrative flyway (i.e., Atlantic, Mississippi, Central, and Pacific). After the close of each waterfowl-hunting season, biologists convene at "wingbees" and use primarily qualitative plumage characteristics to assign species, sex, and age to each wing submitted. Methods for assignment of sex and age from wing plumage are detailed in Carney (1992). In general, age is assessed from wing plumage by inspecting wings for juvenile characteristics and, if none are observed, classifying the specimen as an adult (Carney and Geis 1960). During flyway wingbees, duck wings are sorted by species, and individual participants (<6) within each of several small groups (≤ 8) make initial assessments of sex and age (Carney 1992). Each group has a leader, an experienced observer who had successfully identified a set of reference wings as proof of proficiency, who reviews each participant's initial assessment and verifies or revises it. If questions arise regarding assessment of a wing, group leaders examine and discuss attributes of the wing until they reach consensus. Data are entered electronically on site, subsequently error-checked with original data sheets, and archived.

METHODS

For evaluations, we acquired a sample of banded ducks that had been harvested during the latter half of the 2002–2003 regular duck-hunting season (17 Dec 2002–24 Jan 2003) and during both the September teal season and regular duck season in 2003–2004 (19 Sep 2003–25 Jan 2004). This sample included ducks that were primarily banded during June–October (98% of mallards, 96% of wood ducks, and 100% of blue-winged teal). Phone operators at the U.S. Geological Survey Bird Banding Laboratory requested that hunters reporting banded ducks contact research staff by toll-free phone number. Upon receiving calls from referred hunters, we solicited carcasses of banded birds and recorded date and location where the bird was killed. We arranged for shipment of carcasses to a field station of Northern Prairie Wildlife Research Center and, after inspecting the carcass and band, we returned the band to the participating hunter and stored the carcass in a freezer for later examination.

After hunting seasons, we removed both wings in their entirety and inserted a passive integrated transponder tag in muscle tissue of each wing for identification and retrieval to facilitate their use in multiple wingbees. Overall, study wings were in relatively good condition, and we did not exclude wings based on condition or other factors with the explicit intent to collect a sample that would emulate wings provided to the Waterfowl Parts Collection Survey by hunters. Wings from the 2002 to 2003 hunting season were sent surreptitiously to Mississippi and Central flyway wingbees in official survey wing envelopes. We sent wings from the 2003 to 2004 hunting season sequentially to the Atlantic, Mississippi, Central, and Pacific flyway wingbees. At flyway wingbees, study wings were inspected along with wings submitted by hunters, and wingbee participants had no knowledge of which specimens were study wings. After each wingbee, we scanned all wings, retrieved those with passive integrated transponder tags, repackaged them in official envelopes, and sent them to the next flyway wingbee. We collated 1) data reported during banding and reporting of birds, including banding and harvest date, species, sex, and assigned age of each bird contained in the U.S. Geological Survey Bird Banding Laboratory; 2) information we collected during inspection of carcasses, including external verification of species and internal verification of sex; and 3) data from wingbees, including assigned species, sex, and age.

Our primary interest was accuracy of aging mallards, but we also collected wood duck and blue-winged teal specimens. We compared species and sex determinations from in-hand examinations and wingbee reports for misidentification errors. To assess accuracy of aging, we grouped birds into 2 categories. We identified birds that had been harvested >365 days after banding as adult birds (i.e., known-aged ad), regardless of their reported age at banding. Birds banded as juveniles during banding and harvested during the first hunting season after being banded were considered juveniles for our analyses.

Data Analysis

We compared accuracy rates among wingbees for all birds by species with contingency tables and chi-squared statistics. Because misclassification rates for adults and juveniles could be unequal and potentially related to different factors, we analyzed each age group separately. We partitioned variation in aging accuracy of adults and juveniles with generalized linear models (GENMOD procedure; SAS Institute, Inc., Cary, NC). We modeled discrepancies between known age and age assigned at wingbees with a binomial distribution ($1 = $ agreement and $0 = $ discrepancy) and logit link function. Multiple assessments of age (i.e., trials) were conducted on each bird (≤ 8); thus, we included an overdispersion parameter (i.e., $\hat{c} = $ deviance/df) in the models (McCullagh and Nelder 1989). Reliability of aging characteristics may differ between sexes because of differences in plumage characteristics used to make a determination (Carney and Geis 1960). Plumage characteristics on wings could vary by harvest date because of molting or feather wear, creating misleading characteristics. In addition, male and female dabbling ducks have different molt schedules (Pyle 2005); thus, any effect of harvest date on aging accuracy may be expressed differently between sexes. Therefore, we constructed models with error rates potentially related to fixed effects, including sex, date of harvest (i.e., no. of days past 31 Aug), and the interaction of sex and harvest date. For all fixed effects, we estimated effect size as regression coefficients on the logit scale (β). Blue-winged teal were harvested both during the September teal season in 2003 and during the regular duck-hunting seasons in 2003–2004, and we collected fewer blue-winged teal than other species. Based on these differences, we computed mean accuracy rates for both adult and juvenile blue-winged teal separately by harvest season (i.e., Sep teal season or regular duck season) and by sex in lieu of generalized linear models as described above.

We calculated potential bias of age composition (i.e., proportion of juv) by first estimating accuracy rates for adults and juveniles using a linear model and estimated parameters (Table 1) from sex ratios and average harvest date of wings received as part of the Waterfowl Parts Collection Survey during 1998–2008. We used these estimates to calculate biases for all possible age compositions (0–100%). Finally, we compared the ratio of estimated bias and standard deviation of the age composition in relation to levels of bias deemed inconsequential in survey sampling procedures (bias $\leq$10% of standard deviation; Cochran 1963:14). These analyses identified ranges of species-specific estimated age compositions that would have an acceptable amount of bias, assuming that aging accuracy was constant at the magnitude estimated from our assessment.

RESULTS

We examined 1,072 banded ducks received from hunters. Discrepancies in species identification between the in-hand assessment and wingbee results occurred once each for 2 different birds. One mallard wing trial was coded as a wood duck and another mallard wing trial was coded as a Mexican duck (*Anas platyrhynchos diazi*). Accuracy rate for species identification was >99.9% ($n = 8{,}096$).

We acquired 555 adult and 236 juvenile mallards and recorded 4,089 trials of adults and 1,812 trials of juveniles in which flyway wingbees assigned sex and age. Assignment of sex from internal examination and at wingbees agreed in 99.4% of trials. Accuracy of age assessment for both age classes combined varied little among flyway wingbees

Table 1. Results of generalized linear models explaining variation in accuracy rates of aging adult and juvenile mallards and wood ducks from wing plumage at flyway wingbees from ducks harvested in the United States, 2002 and 2003.

		Ad				Juv			
Species	Effect	Estimate[a]	SE	χ^2	*P*	Estimate	SE	χ^2	*P*
Mallard	Intercept	2.662	0.347			2.743	0.480		
	Sex (F)	−0.945	0.504	3.5	0.061	1.034	0.835	1.6	0.206
	Date[b]	0.011	0.004	13.1	≤0.001	0.001	0.006	0.9	0.349
	Sex × date	−0.003	0.005	0.3	0.587	−0.011	0.009	1.6	0.206
Wood duck	Intercept	2.858	0.607			5.049	0.979		
	Sex (F)	−1.031	0.805	1.7	0.197	−2.786	1.123	7.5	0.006
	Date[b]	−0.002	0.006	0.1	0.931	−0.030	0.009	12.7	≤0.001
	Sex × date	0.004	0.009	0.2	0.643	0.025	0.011	5.9	0.015

[a] Parameter estimates on logit scale.
[b] Days past 31 Aug.

(Atlantic = 96.2%; Mississippi = 95.8%; Central = 96.1%; Pacific = 95.9%; $\chi^2_3 = 0.4$, $P = 0.95$). We found evidence of overdispersion of errors for adult ($\hat{c} = 1.33$) and especially juvenile ($\hat{c} = 2.26$) mallards. The probability of correctly identifying a mallard as an adult increased with harvest date, whereas the classification rate of juvenile mallards varied little by variables in our models (Table 1). We estimated an accuracy rate of 96.3% (95% CI = 95.5–97.0%) for adult mallards, based on a sex ratio of 2.4 males/female and an average harvest date of 24 November from 1998 to 2008 wing receipts. Juvenile mallards had an estimated 94.8% (95% CI = 92.9–96.1%) accuracy rate based on the same sex ratio and average harvest date.

For 122 adult and 120 juvenile wood ducks, we recorded 948 and 939 trials in which flyway wingbees assigned sex and age for adults and juveniles, respectively. Assignment of sex from internal examination and wing plumage corresponded in 99.7% of trials. Accuracy of wood duck aging was similar among flyway wingbees (Atlantic = 92.3%; Mississippi = 88.8%; Central = 91.6%; Pacific = 90.0%; $\chi^2_3 = 4.1$, $P = 0.25$). We found evidence of overdispersion of errors for adult ($\hat{c} = 2.29$) and juvenile ($\hat{c} = 3.34$) wood ducks. Accuracy of aging juveniles varied by sex and harvest date; whereas, accuracy of aging adults did not vary by these covariates (Table 1). Accuracy of aging juvenile wood ducks decreased with harvest date for males ($\beta_{Male\_date} = -0.030$, 95% CI = −0.047 to −0.013), but less so for females ($\beta_{Female\_date} = -0.005$, 95% CI = −0.017–0.006). We estimated an accuracy rate of 92.1% (95% CI = 88.9–94.5%) for adult wood ducks, based on a sex ratio of 1.7 males/female and an average harvest date of 12 November from 1998 to 2008 wing receipts. Juvenile wood ducks had an estimated 92.3% (95% CI = 87.3–95.4%) accuracy rate based on the same sex ratio and average harvest date.

We obtained 20 adult and 19 juvenile blue-winged teal and recorded 159 trials of adults and 149 trials of juveniles in which flyway wingbees assigned sex and age. Sixty-two percent of our sample of blue-winged teal was harvested during the September teal season (Table 2). Sex determination from internal examination and at wingbees agreed in 99.7% of trials. Accuracy of aging was similar among flyway wingbees (Atlantic = 84.2%; Mississippi = 84.4%; Central = 83.3%; Pacific = 80.5%; $\chi^2_3 = 0.5$, $P = 0.91$). Accuracy of aging adult blue-winged teal was lower for females than for males during both September teal and regular duck seasons (Table 2). Accuracy of aging juveniles of both sexes was greater during the September teal season than the regular season (Table 2). We estimated an average accuracy rate of 84.3% (95% CI = 69.8–98.8%) for adult blue-winged teal from a sex ratio of 1.2 males/female from wing receipts for 1998–2008 and a rate of 60% of teal harvested during the September teal season from our data. Juvenile blue-winged teal had an estimated 82.3% (95% CI = 71.6–93.1%) accuracy rate.

Because of the dichotomous nature of age assignment (i.e., juv or ad), bias in age composition varied with the age composition of birds submitted for age assessment (Fig. 1). Bias would be greatest when the true age composition of individuals in a sample is 100% adults or 100% juveniles, and complete off-setting of errors could be expected at a certain age ratio depending on the difference in error rates of adults and juveniles. Age composition of mallards was estimated with acceptable levels of bias (bias ≤10% of standard deviation; Cochran 1963) in samples ranging from 10% to 85% juveniles. This range was more restrictive for wood ducks (24–77%) and most limited for blue-winged teal (33–61%; Fig. 1).

DISCUSSION

Age determination of ducks from wing plumage relies on identifying and interpreting various qualitative characteristics (Carney 1992). Wingbee procedures include redundant assessment of wings by participants and group leaders, which decrease opportunities for errors by individuals; therefore, we were able to assess error by comparing accuracy rates among wingbees rather than among individuals. Similarities in accuracy rates among wingbees provides evidence that participants identified and assessed wing plumage characteristics and implemented error-checking procedures consistently among flyways.

Misleading or absent identifiable markings on wings also have potential to cause errors in age determination, and our analyses revealed some characteristics of birds related to misclassifying age. Adult mallards were aged with less accuracy when harvested early in the hunting season compared with later in the season (94% on 1 Oct vs. 98% on 25 Jan). In contrast, estimated accuracy of aging juvenile male wood ducks was greater for birds harvested early in the season (98% on 1 Oct) than later (66% on 25 Jan). Accuracy of aging of juvenile blue-winged teal also was greater for birds harvested during the September teal season than in the regular duck season (97% Sep teal season; 60% regular duck

Table 2. Sample size, number of trials, and accuracy rates (%) of aging male and female blue-winged teal at flyway wingbees harvested during the September teal season and during the regular duck season from ducks harvested in the United States, 2002 and 2003.

		Ad				Juv			
Season	**Sex**	***n***[a]	**Trials**[b]	**%**	**SE**	***n***	**Trials**	**%**	**SE**
Sep teal	F	6	48	77.1	8.2	5	37	100	
Sep teal	M	6	48	91.7	5.3	7	56	94.6	2.5
Regular	F	3	24	62.5	19.1	5	40	50.0	18.1
Regular	M	5	39	100		2	16	68.8	6.3

[a] Banded birds contributed by hunters.
[b] Age determinations made at all flyway wingbees.

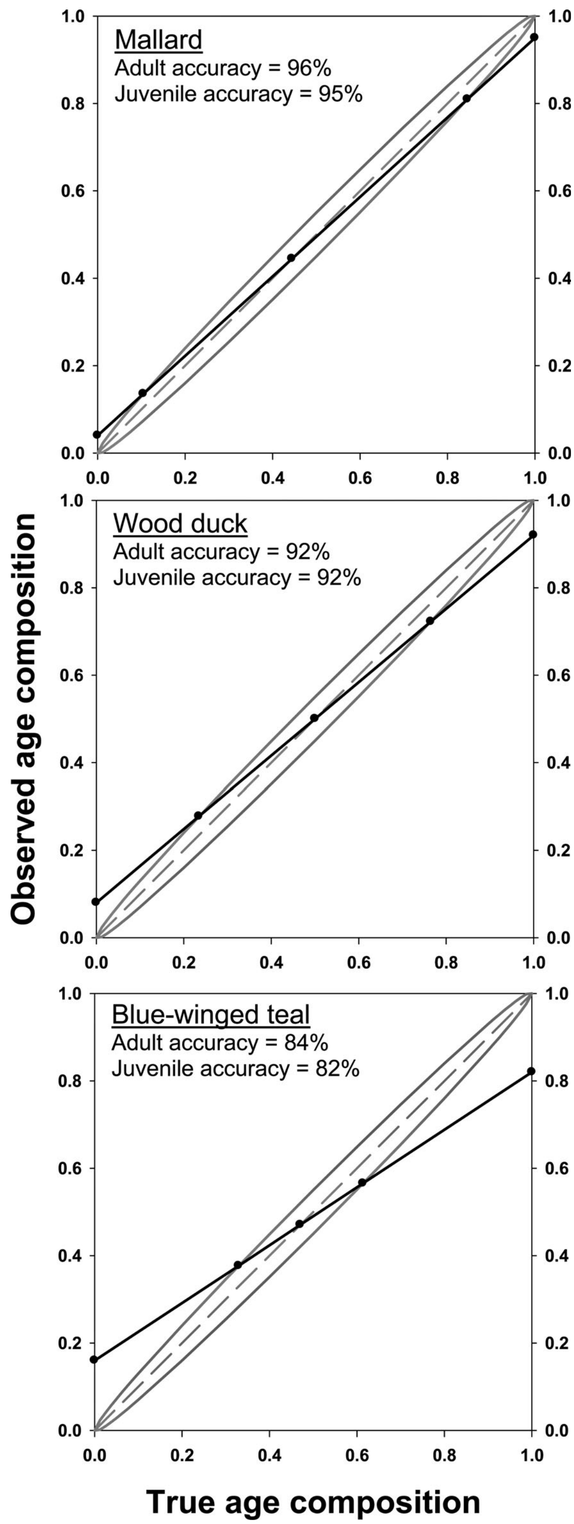

Figure 1. Relationship between true age composition and age composition that would be observed by bias introduced due to errors in aging mallards, wood ducks, and blue-winged teal from wing plumage at flyway wingbees in conjunction with the U.S. Fish and Wildlife Service Waterfowl Parts Collection Survey (solid black lines). Area bounded by solid gray lines represents age compositions where bias is ≤10% of standard deviation. Dashed gray line references no bias in observed age composition.

season). The lower accuracy of aging juvenile wood ducks were likely due to the replacement of juvenile with adult feathers as the year progressed.

We found little indication of sex-specific differences in accuracy of aging birds beyond interactions with harvest date for juvenile wood ducks, which was likely related to sex-specific variation in plumage change throughout autumn and winter. An exception was for blue-winged teal, for which adult males were consistently aged with greater accuracy than adult females, similar to findings of Hohman et al. (1995). Improvements of current aging criteria for adult female blue-winged teal would increase overall aging accuracy of adult blue-winged teal.

The use of wing plumage to determine age of ducks has not been evaluated extensively at wingbees. Carney and Geis (1960) assessed the technique on mallards from birds aged by cloacal examination and found that mallards could be aged with a 95% accuracy rate. This first evaluation of wing-aging techniques, however, lacked blind assessment (i.e., participants were aware of the evaluation) and certainty that birds were of known age, because cloacal examination may not provide definitive determination of age (Esler and Grand 1994; F. C. Rowher, unpublished data). In a later study to determine persistence of juvenile characteristics on captive live mallards, Hopper and Funk (1970) found that wingbee participants had accuracy rates between 84% and 91%. Their study provided detailed information regarding the progressive loss of juvenile characteristics, yet results from entire live birds may differ from those based on wings alone. Furthermore, characteristics may differ between captive and free-living birds because of differences in feather wear and diet, resulting in unknown direction and magnitude of bias (Blohm 1977, Wishart 1981). Carney (1993) summarized accuracy rates of aging numerous species of ducks, including mallards, wood ducks, and blue-winged teal, which were in the same rank order as we found. Estimated accuracy rates also were similar, although Carney (1993) combined adult and juveniles. In addition, investigators have developed quantitative models to determine age of several species of ducks, which generally involve making multiple wing and feather measurements (e.g., Dane and Johnson 1975, Krapu et al. 1979, Gatti 1983, Hohman et al. 1995). Although many of these models were fairly accurate, none have replaced the original wing-plumage method at flyway wingbees.

Expected bias of age compositions, the major result of interest for the Waterfowl Parts Collection Survey, can be determined by comparing accuracy rates of adults and juveniles as well as the age composition of a specific sample. Errors in aging have a compensatory nature because only 2 age categories are used (i.e., ad and juv); thus, incorrectly assigning a juvenile as an adult in a sample would be compensated for by incorrectly assigning an adult as a juvenile in the same sample. The age composition of complete compensation (i.e., unbiased age composition) depends on relative differences in accuracy of aging adults and juveniles. For example, we estimated accuracy of aging adult wood ducks to be similar to juveniles, resulting in complete compensation of errors at 51% juveniles in a hypothetical sample. Alternatively, accuracy of aging mallards and blue-winged teal differed more between adults and juveniles, causing points of complete compensation at compositions of fewer juveniles than for wood ducks. The greatest bias in age compositions of a particular species is expected to occur for samples made up of entirely adult or juvenile birds because no compensation of errors is possible.

Bias is common in survey estimates and, although methods exist to adjust for bias, an assessment of the magnitude of bias often is useful. Because accuracy rates of aging adult and juvenile mallards are high, bias associated with a large range of age compositions could be considered inconsequential. Assuming that accuracy rates of aging have been relatively consistent over time, these age composition ranges can be compared with those estimated from the Waterfowl Parts Collection Survey since its inception. Specifically, age compositions of mallards estimated from the Waterfowl Parts Collection Survey at the flyway and national level have not been outside of this range during any annual survey conducted between 1961 and 2008 (proportion juv: 0.31–0.70; K. D. Richkus, unpublished data). A wide range of age compositions for which bias may be acceptable also exists for wood ducks; age compositions of this species have been estimated within bounds in 99% of flyway-specific and 100% of national estimates. We found that blue-winged teal had the smallest range of age compositions that yielded acceptable bias. Flyway-specific age compositions have been estimated within these bounds during only 38% of surveys for flyway estimates and 31% of surveys for national estimates during 1961–2008. The range of acceptable bias we used was based on a general survey-sampling criterion; thus, different standards could be enacted based on specific objectives and applications for survey results.

Our analyses assumed that ages of test birds were known. We relied on banding records to verify age of birds in our sample of adults; thus, errors in these records were a potential source of bias. We believe the likelihood of such recording errors to be small. Our sample of juveniles would be subject to error if adults were mistakenly classified as juveniles during banding, which was unlikely because our juveniles were banded in mid- to late-summer, when characteristics such as notched rectrices are relatively reliable and obvious characteristics of juveniles (Siwarski 2006).

MANAGEMENT IMPLICATIONS

Our findings suggest that no corrective action is required for methods of determining species and sex of mallards, wood ducks, and blue-winged teal and age of mallards and wood ducks for typical Waterfowl Parts Collection Surveys. Unacceptable levels of bias may exist for highly skewed age compositions, and correction for bias may be necessary if such samples are encountered. Because of preliminary low accuracy rates from our limited sample of blue-winged teal ($n = 39$), further assessments for this species may be warranted before extensive interpretation of age compositions. Results from additional studies could indicate whether bias correction or re-evaluation of plumage methods is necessary to provide reliable age compositions. Accuracy rates for aging varied somewhat among species (also see Hohman et al. 1995); therefore, inferences regarding accuracy of aging using wing plumage characteristics beyond the species assessed in this study may be tenuous.

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