Variation in Band-recovery and Survival Rates of Mottled Ducks in Florida

Fred A. Johnson,[1] *Florida Game and Fresh Water Fish Commission, 3991 S.E. 27th Court, Okeechobee, FL 34974*

David H. Brakhage, *Florida Game and Fresh Water Fish Commission, 8932 Apalachee Parkway, Tallahassee, FL 32311*

Richard E. Turnbull,[2] *Florida Game and Fresh Water Fish Commission, 3991 S.E. 27th Court, Okeechobee, FL 34974*

Frank Montalbano III, *Florida Game and Fresh Water Fish Commission, 620 South Meridian Street, Tallahassee, FL 32399-1600*

Abstract: The failure to recognize heterogeneity in band-recovery and survival rates can lead to biased estimates and spurious inferences regarding population status. We examined band-recovery data for sources of variation in recovery and survival rates of mottled ducks (*Anas fulvigula*) in Florida. Distances between banding and recovery sites were small (median = 38 km), suggesting that mottled ducks live much of their lives within the same drainage basin. Recovery rates varied among regions of banding, perhaps because of spatial heterogeneity in band-reporting rates. Cohort-specific survival rates also may have varied by region, but data were inadequate to test these hypotheses. Fledged and unfledged young had similar recovery distributions and rates. Young of both sexes had higher recovery rates than adults, but age-specific survival differed only among males. Differences in recovery and survival rate estimates between sexes were small (<24%), consistent with reports for other waterfowl species that have long-lasting pair bonds. Temporal variation in recovery and survival rates was not related to restriction of hunting regulations, perhaps because of low statistical power (<0.3) and unmodeled geographic variation in recovery rates.

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Johnson et al. (1984) used estimates of survival and reproductive rates to imply that abundance of mottled ducks in Florida was declining. The authors

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[1] Present address: Office of Migratory Bird Management, U.S. Fish and Wildlife Service, 11500 American Holly Drive, Laurel, MD 20708-4016.

[2] Present address: Division of Land Management, St. Johns River Water Management District, P.O. Box 1429, Palatka, FL 32178-1429.

recognized, however, that poor precision and potential bias in their parameter estimates and lack of a reliable population survey rendered their conclusion equivocal. Annual population surveys (Johnson et al. 1989, 1991) conducted since 1985 have not provided evidence of declining mottled duck numbers (D. H. Brakhage, unpubl. data), although we recognize that the population trajectory could have changed since the original study.

Johnson et al. (1988) demonstrated that unrecognized heterogeneity in demographic variables can lead to spurious conclusions about population growth rates. Johnson et al. (1984) tested for several sources of variation, but concluded band-recovery and survival rates of mottled ducks were homogeneous. Recovery and survival rates of waterfowl often vary by age, sex, location of banding, and year (e.g., Anderson 1975, Krementz et al. 1987, Johnson and Castelli *in press*), and the failure to detect such heterogeneity in mottled ducks may have been a function of small banded samples.

This study represents a second effort to examine sources of variation in band-recovery and survival rates of mottled ducks, and is made possible by recent increases in banded samples. We present tests for geographic, temporal, and demographic (i.e., age and sex) variation in band-recovery and survival rates and discuss the implications of our results for bias and precision. We also discuss if our results are consistent with biological hypotheses advanced for other waterfowl species that are non-migratory and have relatively long pair bonds (cf., Johnson et al. 1992).

We are indebted to the many individuals who participated in banding mottled ducks and to the sportsmen who reported band encounters. In particular, we would like to thank J. Bergan, R. Brust, P. Gray, G. Holder, T. Hines, L. Hord, R. Lloyd, J. McGrady, L. Perrin, T. Regan, and P. Schulz for their assistance with banding. W. Kendall assisted with statistical analyses and P. Keywood prepared the map. R. Barker, M. Conroy, D. Eggeman, R. Frederick, C. Jeske, and G. Smith offered helpful suggestions on earlier drafts.

Methods

We obtained all mottled duck banding and recovery data on file with the U.S. Fish and Wildlife Service Bird Banding Laboratory (BBL) as of 1 October 1992. We confined our investigation to 1977–1991, which is the only set of contiguous years of banding not reported previously (cf., Johnson et al. 1984). We used only normal, wild birds banded preseason (June–September) and recovered during the hunting season (September–February). At time of banding, mottled ducks were classified as locals (pre-fledging, Class II and III) (Bellrose 1976:27), hatch-year (fledged young), or after hatch-year (≥ 1 year old). Recovery rate was defined as the probability that a banded bird alive during the banding period was shot or found dead the next hunting season and its band reported to BBL. Recovery rate indexes harvest rate, assuming that band-reporting rates are constant over time. Survival rate was defined as the probability that a banded bird alive at the midpoint of the banding period survived 1 year.

We estimated recovery and survival rates using stochastic models developed by Brownie et al. (1985). The most appropriate model for a given data set was chosen by examining chi-square goodness-of-fit tests and likelihood ratio tests, which compare a general model (e.g., year-specific recovery rates) against a more specific model (e.g., temporally-constant recovery rates) (Brownie et al. 1985:8). On occasion, there were too few data to estimate recovery rates with the Brownie et al. (1985) models. In these cases we estimated first-year recovery rates using bandings from a particular year and associated recoveries from the first hunting season. This differs from the Brownie et al. (1985) models where recovery rates are estimated using recoveries of newly banded birds (directs) and of previously banded birds (indirects) that survive to the year of interest.

We tested for geographic, temporal, and age- and sex-specific variation in recovery and survival rates using several approaches. Chi-square contingency tables were used to test for differences in direct recovery rates of birds banded at various sites. The Cochran-Mantel-Haenszel test statistic (CMH) was used to summarize results of individual tests (SAS Inst. 1990:873–875). We tested for age- and sex-specificity in recovery and survival rates using chi-square contingency tests, and for temporal variation using likelihood ratio tests (Brownie et al. 1985). We also used program CONTRAST, which employs a generalized chi-square procedure for comparing mean recovery and survival rate estimates (Hines and Sauer 1989, Sauer and Williams 1989). All tests were 2-tailed with $\alpha = 0.10$ unless specified otherwise. Because we hypothesized that there would be little variation in population parameters, we were concerned about our ability to detect it. We used the method described by Anderson and Burnham (1976:61–62) to approximate power (ϕ) of our tests when the departure from the null hypothesis was of the magnitude specified by the data. We also estimated power to detect *a priori* differences of varying magnitudes in recovery rates.

We used information on season lengths and bag limits to distinguish years of relatively liberal (1981–1984) and restrictive (1988–1991) hunting regulations. The liberal period was characterized by a season length of 50–55 days and a daily bag limit of 2 or 1. The restrictive period had a season length of 30 days and a daily bag limit of 1. We used 1-tailed z statistics to test if mean recovery rates were lower, and if survival rates were higher, during years of restrictive regulations than during years of liberal regulations. All estimates used in these tests were based on Brownie et al. (1985) model H1 (goodness-of-fit: $\chi^2 = 44.20$, 32 df, $P = 0.07$ for males; $\chi^2 = 17.74$, 16 df, $P = 0.34$ for females), which assumes year-specific variation in recovery and survival rates.

Geographic distributions of recoveries were compared using Mardia's statistic (U), which tests the null hypothesis that 2 groups of recoveries belong to the same bivariate (i.e., latitude and longitude) distribution (Mardia 1967). Batschelet (1978) provided a good description of Mardia's test and Munro and Kimball (1982) described its use with band-recovery data. The test statistic was computed following Robson (1968).

Results

During 1977–1991, 8,134 mottled ducks of known age and sex were banded preseason and 690 bands were reported to BBL. Birds were banded principally in 4 physiographic regions: (1) the Everglades (34.5%); (2) the St. Johns River marshes and Merritt Island (27.0%); (3) the Kissimmee River Basin (including Lake Okeechobee) (20.3%); and (4) the phosphate-mining region of west-central Florida (14.5%) (Fig. 1). Median dates of banding were 13 July for locals, 28 July for hatch-years, and 28 July and 3 August for after-hatch-year males and females, respectively. Median distance between banding and recovery sites was 38 km and the modal distance was 0 km (designating recovery within the same 10 by 10 minutes block as banding). Only 3 encounters of banded mottled ducks were reported from outside of Florida (Georgia, Virginia, New Jersey).

We first determined if local and hatch-year banding data could be pooled for estimating recovery and survival rates, as is the case for mallards (*Anas platyrhynchos*) (Anderson 1975). Direct recoveries of local ($\bar{x}$ latitude, longitude: 27.5° N, 80.8°W, $N = 76$ for males; 27.4° N, 80.8° W, $N = 76$ for females) and hatch-year ($\bar{x}$ latitude, longitude: 27.7° N, 81.0° W, $N = 57$ for males; 27.5° N, 80.8° W, $N = 46$ for females) mottled ducks had different geographic distributions ($U = 7.20$, $P < 0.03$ for males, and $U = 8.00$, $P = 0.02$ for females), suggesting that the 2 age classes could have been exposed to different mortality risks. Using years when local and hatch-year birds were banded, direct recovery rates of local and hatch-year mottled ducks were similar ($\chi^2 = 0.62$, 1 df, $P = 0.43$ for males, and $\chi^2 = 0.002$, 1 df, $P = 0.97$ for females). Total recovery rates, which included both direct and indirect recoveries, also did not differ ($\chi^2 = 0.19$,

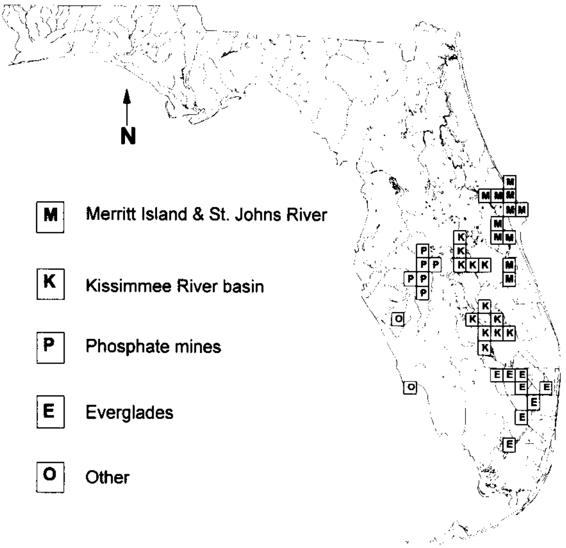

Figure 1. Sites where mottled ducks were banded preseason 1977–1991.

Table 1. Estimates of recovery (f) and survival (S) rates and associated standard errors (SE) of male mottled ducks banded in Florida.[a]

	Adult[b]				Young[c]			
Year	f	SE(f)	S	SE(S)	f	SE(f)	S	SE(S)
1977	0.057	0.028	0.464	0.246	0.033	0.033	0.650	0.409
1978	0.091	0.032	0.298	0.239	0.205	0.065	0.615	0.502
1979	0.039	0.031	0.451	0.396	0.036	0.035	0.411	0.356
1980	0.042	0.028	0.684	0.539	0.067	0.064	0.483	0.536
1981	0.074	0.043	0.143	0.114	0.333	0.272	1.444	1.313
1982	0.060	0.038	1.572	0.769	0.100	0.095	3.369	1.750
1983	0.022	0.008	0.938	0.269	0.300	0.017	1.029	0.423
1984	0.039	0.008	0.237	0.076	0.054	0.017	0.289	0.130
1985	0.070	0.016	0.502	0.191	0.055	0.012	0.827	0.266
1986	0.038	0.011	0.554	0.208	0.076	0.017	0.622	0.251
1987	0.028	0.008	0.356	0.120	0.045	0.013	0.584	0.196
1988	0.038	0.009	0.679	0.229	0.066	0.014	0.506	0.206
1989	0.033	0.009	0.419	0.188	0.067	0.014	0.533	0.247
1990	0.041	0.014	0.380	0.315	0.074	0.022	1.363	1.097
1991	0.022	0.015			0.048	0.017		
$\bar{x}$	0.046	0.006	0.548	0.064	0.086	0.021	0.909	0.193

[a] Estimates are from Brownie et al. (1985) model H1, which assumes age- and year-specific recovery and survival rates (goodness-of-fit $\chi^2 = 44.20$, 32 df, $P = 0.074$).

[b] N = 2,403 bandings, 187 recoveries.

[c] N = 2,217 bandings, 238 recoveries.

1 df, $P = 0.66$ for males, and $\chi^2 = 0.72$, 1 df, $P = 0.40$ for females), suggesting homogeneous survival rates. Consequently, local and hatch-year bandings were pooled as "young" for further analyses.

A model assuming age- and year-specific recovery and survival rates was most appropriate for males banded during 1977–1991 (Table 1). Limited band-recovery data constrained estimation of recovery and survival rates to the period 1983–1990 for females. A model assuming age- and year-specific recovery rates, and age-specific, but temporally constant survival rates was selected (Table 2). Mean recovery rates ranged from 0.030 (SE = 0.004) for adult females to 0.086 (SE = 0.021) for young males. Mean survival ranged from 0.474 (SE = 0.096) for young females to 0.909 (SE = 0.193) for young males. Annual survival estimates for all age and sexes were imprecise and sometimes beyond permissible bounds (i.e., >1); means were more precise (i.e., CV < 0.15).

Geographic Variation

Chi-square contingency tests by sex, age, and period of similar hunting regulations suggested that direct recovery rates of mottled ducks depended on region of banding during 1985–91 (Table 3; CMH = 34.48, 3 df, $P < 0.001$). Differences were most pronounced among young of both sexes. Because most birds were recovered close to banding sites and because recovery rate is a product of harvest rate and band-reporting rate, we concluded that 1 or both of these parameters varied among banding regions. Another possibility is that mortality between the banding period and the hunting season was region-specific.

Table 2. Estimates of recovery (f) and survival (S) rates and associated standard errors (SE) of female mottled ducks banded in Florida.[a]

	Adult[b]				Young[c]			
Year	f	SE(f)	S	SE(S)	f	SE(f)	S	SE(S)
1983	0.038	0.019			0.046	0.018		
1984	0.018	0.007			0.063	0.018		
1985	0.047	0.012			0.088	0.015		
1986	0.021	0.007			0.080	0.019		
1987	0.018	0.006			0.052	0.017		
1988	0.034	0.008			0.058	0.015		
1989	0.029	0.008			0.052	0.013		
1990	0.031	0.009			0.017	0.012		
$\bar{x}$	0.030	0.004	0.503	0.047	0.057	0.006	0.474	0.096

[a] Estimates are from Brownie et al. (1985) model H02, which assumes age- and year-specific recovery rates and age-specific, but temporally constant, survival rates (goodness-of-fit $\chi^2 = 15.63$, 18 df, $P = 0.619$).

[b] $N = 1{,}288$ bandings, 69 recoveries.

[c] $N = 1{,}687$ bandings, 145 recoveries.

Table 3. Tests of the hypothesis of equality of direct recovery rates among birds banded (*N*) in the Everglades, Kissimmee River basin including Lake Okeechobee, Merritt Island and St. Johns River marshes, and the phosphate mining areas of Florida.[a]

		1985–1987			1988–1991		
Age	Sex	*N*	χ^2	*P*	*N*	χ^2	*P*
Adult	Male	636	4.101	0.251	806	4.940	0.176
	Female	470	0.456	0.928	534	7.894	0.048
Young	Male	891	5.911	0.116	904	10.759	0.013
	Female	720	13.114	0.004	797	12.535	0.006

[a] All tests had 3 df.

To determine if band-reporting rate might vary among banding regions, we first classified recoveries using information on who reported the band encounters and why they were reported. A recovery was classified as "unsolicited" if it had been reported on the finder's own initiative (Conroy and Williams 1981). A recovery was classified as "solicited" if the band encounter was reported due to the initiative of someone other than the person who shot or found the banded bird, or if bands were reported on survey questionnaires sent to hunters. Proportion of solicited recoveries varied depending on region where bands were encountered ($\chi^2 = 8.45$, 3 df, $P = 0.04$). The phosphate-mining region and the St. Johns marshes and Merritt Island contained the highest proportion of solicited recoveries (28.6% and 25.4%, respectively), possibly because both regions contain managed sites where hunting activity is monitored closely by state and federal personnel. Thus, band-reporting rates may have varied by banding region, perhaps from the diligence of conservation agents in reporting band encounters. We were unable to make inferences regarding potential variation in harvest rates among regions because estimates of band-reporting rates were not available.

Quantity of band-recovery data was not adequate to estimate region-specific survival rates.

Age-specific Variation

We tested for age-specific variation by comparing Brownie et al. (1985) model H0 (recovery and survival rates are year-specific, but age-independent) with model H1 (recovery and survival rates are year- and age-dependent). Recovery and survival rates were dependent on age for females ($\chi^2 = 50.22$, 29 df, $P = 0.01$), but not for males ($\chi^2 = 37.94$, 29 df, $P = 0.12$). Mean recovery rates of adults were different than those of young among males ($P = 0.07$) and females ($P < 0.001$) (Table 4). Mean survival rate was dependent on age for males ($P = 0.08$), but not for females ($P = 0.78$). Estimated difference in mean survival between adult and young females was small and power of the test was low ($\phi = 0.11$).

Sex-specific Variation

Recovery and survival rates were similar for adult males and females ($\chi^2 = 22.57$, 29 df, $P = 0.80$). We compared estimated mean recovery and survival rates between sexes, including only those years when recovery or survival rate estimates were available for both sexes (Table 5). Recovery rates were dependent on sex among adults ($P = 0.08$), but not among young ($P = 0.88$). There was no differences in mean survival rates between males and females of either age ($P \geq 0.27$), but both tests had low power ($\phi < 0.30$).

Table 4. Tests of the hypotheses of equality of mean recovery (f) and survival (S) rates between adult (a) and young (y) mottled ducks banded in Florida.[a]

	Recovery rates				Survival rates			
Sex	Years	f_a-f_y	χ^2	P	Years	S_a-S_y	χ^2	P
Male	1977–91	−0.040	3.38	0.07	1977–90	−0.360	3.15	0.08
Female	1983–90	−0.028	14.94	<0.01	1983–89	0.030	0.08	0.78

[a] All tests had 1 df.

Table 5. Tests of the hypotheses of equality of mean recovery (f) and survival rates (S) between male (♂) and female (♀) mottled ducks banded in Florida.[a]

	Recovery rates				Survival rates			
Age	Years	$f_♂$-$f_♀$	χ^2	P	Years	$S_♂$-$S_♀$	χ^2	P
Young	1983–90	0.001	0.02	0.88	1983–89	0.153	1.24	0.27
Adult	1983–90	0.009	3.02	0.08	1983–89	0.023	0.11	0.74

[a] All tests had 1 df.

Table 6. One-sided tests of the hypotheses of equality of mean recovery and survival (S) during years of restrictive (r) and liberal (l) mottled duck hunting regulations.

	Recovery rates			Survival rates		
Age/sex[a]	f_r-f_l	z	P	S_r-S_l	z	P
AM	−0.015	−0.97	0.17	−0.230	−1.104	0.87
AF	0.003	0.27	0.61	−0.045	−0.219	0.59
YM	−0.066	−0.90	0.18	−0.732	−1.08	0.86
YF	−0.013	−0.86	0.20	0.074	0.34	0.37

[a] AM = adult male, AF = adult female, YM = young male, YF = young female.

Temporal Variation

We tested for temporal variation in recovery rates by comparing Brownie et al. (1985) model H01 (age-specific, but temporally constant recovery and survival rates) with model H02 (age- and year-specific recovery rates, and age-specific, but constant survival rates). Recovery rates were dependent on year among both males ($\chi^2 = 45.66$, 28 df, $P = 0.02$) and females ($\chi^2 = 22.49$, 15 df, $P = 0.10$). The likelihood ratio test of model H02 versus model H1 (age- and year-specific recovery and survival rates) suggested that survival rates were year-dependent among males ($\chi^2 = 35.83$, 26 df, $P = 0.10$), but year-independent among females ($\chi^2 = 11.15$, 13 df, $P = 0.60$).

Regardless of age/sex class, recovery rates were not higher during years of liberal regulations ($P \geq 0.17$, Table 6). Individual test statistics were pooled (Anderson and Burnham 1976:23) and the composite z also was nonsignificant ($z = -1.23$, $P = 0.11$). All tests had low power ($\phi < 0.30$). Power to detect *a priori* differences of various magnitudes in recovery rates, given the precision of existing estimates, suggested that change in recovery rates between years of liberal and restrictive regulations would need to be very large (i.e., >50% reduction) to achieve acceptable power (i.e., $\phi > 0.70$) (Fig. 2). There were no differences in survival between the 2 regulatory periods for either age/sex class ($P \geq 0.37$, Table 6) or the composite ($z = -1.04$, $P = 0.85$). Because we estimated survival rates with less precision than recovery rates, probability of detecting changes in survival rates was very poor.

Unmodeled heterogeneity in recovery rates among banding regions could have been partially responsible for the failure to detect a regulatory effect (i.e., a Type II error). Despite such variation, our comparisons would be valid if banded samples were proportionally constant among banding regions. However, proportion of birds of each age and sex banded in each region varied among years (CMH = 3,533.10, 32 df, $P < 0.001$). Therefore, we estimated direct recovery rates by age, sex, and year for each banding region whenever banded sample size ≥50. Only the Everglades region had sufficient data to test equality of recovery rates during years of liberal and restrictive hunting regula-

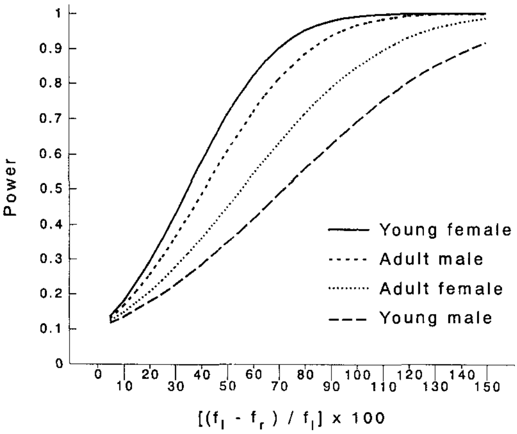

Figure 2. Estimated power to detect changes in mottled duck recovery rates (f) associated with a change from liberal (l) to restrictive (r) hunting regulations [P (Type I error) = 0.1].

tions. We found no differences in recovery rates for either age/sex class ($P \geq 0.20$) or the composite ($z = -0.45$, $P = 0.33$).

Discussion

Ignoring existence of geographic variability in mortality risks could lead to poor model fit and likely would reduce power to detect other sources of heterogeneity. Moreover, pooling across banding regions to attain adequate sample sizes could lead to spurious inferences, particularly if proportion of birds banded at various locales is highly variable over time. The likelihood that band-reporting rates vary among banding regions suggests that region-specific recovery rates are not necessarily indicative of geographic differences in hunting mortality. If only recovery rates are region-specific, then survival rate estimates should be unbiased and recovery rate will represent a weighted average from all regions (Pollock and Raveling 1982). If there are geographic differences in survival, confidence intervals for survival estimates should be largely unbiased if differences in survival are <0.2 (Barker 1992). Many of our inferences regarding age-, sex-, and year-specific recovery and survival rates are based on data pooled across banding regions and, thus, are conditional on underlying spatial patterns in band-reporting rates and mortality risks.

We believe our inferences regarding age were stronger than for other potential sources of variability. Mottled ducks banded as locals and hatch-years had similar direct and total recovery rates, suggesting that mortality risks prior to the hunting season were similar for fledged and unfledged young. While probability of a Type II error may be high, estimated differences in recovery rates were small (<15%) and only 2 weeks separated median dates of banding for local and hatch-year ducks. Ability to pool pre-fledging and fledged young has obvious advantages in attaining sufficient sample sizes for analyses.

Young of both sexes had higher recovery rates than adults, suggesting that risk of hunting mortality declines once a bird survives its first hunting season. Vulnerability of young relative to adults during the hunting season was similar to that reported for mallards (Anderson 1975) and black ducks (*Anas rubripes*) (Krementz et al. 1987), but appeared to be higher than that reported for non-migratory wood ducks (*Aix sponsa*) in the southern United States (Nichols and Johnson 1990). In contrast to many migratory waterfowl species, evidence for age-specific differences in survival was limited. Typically, large age-specific differences in survival are associated with the period August to February, which includes fall migration and the hunting season (Johnson et al. 1992). Greenburg (1980) suggested that mortality risks associated with migration might be higher for young than adults. Because mottled ducks are non-migratory, lack of large age-specific differences in recovery and survival rates is consistent with this hypothesis. Other investigators have reached similar conclusions for southern wood ducks (Nichols and Johnson 1990) and "resident" Canada geese (*Branta canadensis*) (Sheaffer et al. 1987, Johnson and Castelli *in press*).

We found little evidence for sex-specificity in recovery and survival rates. Adult males had higher recovery rates than adult females, but estimates of young male and female recovery rates were nearly identical. The lack of consistent differences between male and female harvest risks may be because no sexual dimorphism in plumage exists that could lead to hunter selectivity. There were no sex-specific differences in survival, but power of the tests was poor. Nonetheless, average estimates of survival in adult males and females were fairly precise (CV < 0.1) and magnitude of the estimated difference in mean survival was very small (<4%). In many duck species, males survive at higher rates than females, even though males are subject to greater hunting mortality (Johnson et al. 1992). The difference in annual survival typically is a function of differential mortality risks during the breeding season (Blohm et al. 1987). However, close association of males and females throughout the breeding season is common in many monochromatic waterfowl species and this may result in similar mortality risks for the sexes (e.g., Johnson and Castelli *in press*). Mottled ducks have long pair bonds (Thomas 1982) and we have observed adult males attending brood-rearing hens. Perhaps this is the reason for a lack of sex-specific survival among adults, although other explanations are possible.

Recovery and survival rates of most mottled duck age and sex classes were year dependent, but there were no differences in average rates between periods of contrasting hunting regulations. Differences in recovery rates between years of restrictive and liberal hunting regulations have been demonstrated for several waterfowl species (Nichols and Johnson 1989), and our results may have been a function of small sample sizes and temporal changes in proportion of bandings in each region. Another possibility is that other factors influencing harvest and band-reporting rates were year-specific, and that our comparisons were confounded by systematic differences in these factors between the 2 periods of different hunting regulations. Even if we had found evidence of changes in harvest rates, the implications of these changes could not have been determined because power to detect changes in survival was poor. We suspect that banded samples necessary to effectively monitor effects of harvest-management actions on mottled ducks will be difficult and costly to attain unless band-reporting rates can be increased substantially (cf., Nichols et al. 1991).

Management Implications

Our findings of some geographic, demographic (i.e., age- and sex-specific), and temporal variation in recovery and survival rates of mottled ducks suggests that the estimates provided by Johnson et al. (1984) likely were biased, perhaps strongly so. Therefore, it would be unwise to place much confidence in the population trajectory presented in that study. In the future, we recommend relying on a population survey for determining trends in abundance because the large banded samples necessary for precise estimates of group-specific survival rates likely would be cost-prohibitive. Even if the necessary banded samples were forthcoming, managers would still face the dilemma of how to combine (or weight) group-specific estimates to make inferences about the Florida mottled duck population.

Other investigators have reported limited movements of mottled ducks within the Florida peninsula (Fogarty and LaHart 1971), and our study suggests that many birds may live much of their lives within the same drainage basin. This finding has important implications for managing mottled ducks if hunting or natural mortality is region-specific. It would be surprising if there were no geographic variation in mortality in light of the variation in physiography, anthropic landscape changes, and potential hunting pressure among banding regions. Accordingly, it may be appropriate to consider this spatial heterogeneity in designing habitat and harvest management practices, particularly if the patterns of heterogeneity can be elucidated. Managers also should be cognizant of the role region-specific selective pressures may play in maintaining genetic diversity (Johnson et al. 1986).

Typically, an important goal of a banding program is to provide a better understanding of important biological and ecological processes. For example, band recovery data can be used in conjunction with ancillary information (e.g., environmental conditions) to make inferences about underlying causes of variation in survival. However, given the high costs of banding and low band-reporting rates, this goal may be somewhat unrealistic for a mottled duck banding program in Florida. It may be that a well-designed population survey used in an adaptive management approach would provide a more powerful tool for understanding and predicting population processes (Johnson et al. 1993).

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