EFFECTS OF CAPTURE AND HANDLING ON SURVIVAL OF FEMALE NORTHERN PINTAILS

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Abstract.—Identification of capture and handling procedures that influence survival of waterfowl has important research and management implications. We captured 347 female Northern Pintails (*Anas acuta*) using rocket nets, fitted them with harness (backpack-type) radio transmitters, and monitored their survival during the first 10 d following release. Females were 16 times more likely to die during the first 4 d of exposure than during days 5–10. Survival of females captured with small numbers of waterfowl ($n \leq 172$) was not related to holding time (time from capture until release), but survival of females captured with large numbers of waterfowl ($n = 594$) declined as holding time increased. Survival did not vary with age (immature or adult) or body condition (body mass adjusted for body size) of females. Survival was positively related to flight quality (scored as poor, moderate, or good) of females upon release; poor and moderate fliers were twice as likely to die as those scored in the next higher level of flight quality. Flight quality of females captured with small numbers of waterfowl was unrelated to holding time, but that of females captured with large numbers of waterfowl declined as holding time increased. In all cases where cause of mortalities could be determined ($n = 12$), we attributed proximate cause of death to predation. We recommend that holding time of ducks be minimized, particularly for those captured with large numbers of waterfowl in rocket nets.

EFECTOS DE LA CAPTURA Y LA MANIPULACIÓN EN LA SUPERVIVENCIAS DE *ANAS ACUTA*

Sinopsis.—Identificar procedimientos para la captura y manipulación que influencien la supervivencia de aves acuáticas tiene importantes implicaciones para la investigación y el manejo. Capturamos 347 hembras de *Anas acuta* utilizando redes de cañón, les ajustamos radiotransmisores en ameses (tipo mochila), y seguimos la supervivencia durante los primeros diez días tras su liberación. Las hembras tendian a morir 16 veces más comunmente durante los primeros 4 días de exposición que durante los días 5 a 10. La supervivencia de hembras capturadas con números pequeños de aves acuáticas ($n \leq 172$) no está relacionada al tiempo de retención (entre captura y liberación), pero la supervivencia de hembras capturadas con grupos grandes de aves acuáticas ($n = 594$) se redujo al aumentar el tiempo de retención. La supervivencia de las hembras no varió con la edad (inmaduras o adultas) o condición corpórea (masa corporal ajustada al tamaño corporal). La supervivencia se halló positivamente relacionada con la calidad de vuelo (señalado como pobre, moderado, o bueno) de hembras al liberarlas; aves volando pobre o moderadamente murieron dos veces más cue las identificadas en el próximo nivel de calidad de vuelo. La calidad del vuelo de hembras capturadas junto a pocas aves acuáticas no se relacionó con el tiempo de retención, pero la de hembras capturadas junto a muchas aves acuáticas declinó segun aumentó el tiempo de

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retención. En todos los casos donde se pudo determinar la causa de muerte ($n = 12$), atribuimos la causa próxima de muerte a la depredación. Recomendamos que el periodo de retención de Anseriformes sea minimizado, particularmente para aquellos capturados junto a grandes grupos de aves acuáticas utilizando redes de cañón.

In most telemetry studies of wintering dabbling ducks, a small number of ducks die shortly after they are captured, handled, and released (e.g., Conroy et al. 1989, Migoya and Baldassarre 1995). Investigators often attribute this early mortality to stress associated with capture and handling or to radio effects (i.e., inability of radio-tagged ducks to adjust to trans-mitters). Accordingly, investigators conducting survival analyses usually ex-clude deaths occurring from 1–5 d following release (e.g., Bergan and Smith 1993, Miller et al. 1995). However, we found no objective criteria in the literature for deciding whether to include or exclude early mor-talities in survival analyses. The length of the "adjustment period" in which ducks are adversely affected by capture, handling, or radio effects, thus far has been determined arbitrarily by researchers.

We noted considerable early mortality of radio-tagged female Northern Pintails (*Anas acuta*) captured by rocket-netting in southwestern Louisi-ana during the winters of 1990–1991 through 1992–1993. Consequently, we identified factors associated with incidence of early mortality of female pintails. Our objectives were to: (1) objectively determine the length of time in which females were adversely affected by capture and handling following release, and (2) identify factors associated with survival and flight quality of females shortly following capture, handling, and radio tagging.

STUDY AREA AND METHODS

We studied pintails within 80 km of the perimeter of Lacassine Pool (29°58′N, 92°54′W; Tamisier 1976) in southwestern Louisiana (Cox and Afton 1996, 1997). We used rocket nets set on baited and unbaited (loaf-ing) sites to capture female pintails during 22 Oct.–10 Nov. 1990 (plus 1 additional female on 27 Jan. 1991), 30 Sep.–27 Oct. 1991, and 4–25 Oct. 1992 (Cox and Afton 1994). Numbers of waterfowl (all species) captured during 12 trapping events using multiple rocket nets ranged from 6 to 594 ($\bar{x} \pm SD = 100.9 \pm 162.9$; median $= 48$).

We aged females as adult or immature using cloaca and feather char-acteristics (Carney 1964, Duncan 1985, Hochbaum 1942). We weighed (± 5 g) each female and measured (± 0.01 mm): (1) culmen, (2) bill width (at nares), (3) total tarsus (Dzubin and Cooch 1992), and (4) mid-dle toe length. Before processing birds captured on unbaited sites, we allowed their plumage to dry (ca. 2 h). Most birds captured on baited sites had large amounts of rice (*Oryza sativa*) in their esophagi; we held these birds 6–12 h (overnight for females captured at dusk) before we began processing them (e.g., Conroy et al. 1989). We held ducks awaiting processing in holding pens (up to 20 birds per pen) placed either out-doors in the shade during the day or in a warehouse at night. We provided food and water *ad libitum* to birds while being held to meet animal care

requirements, but found no direct or indirect evidence that birds ate while being held. We applied standard USFWS leg bands and fitted females with 21-g harness radio transmitters (Dwyer 1972). We tightened neck and body loops so that an index finger (1-cm diameter) fit between the harness and the base of the furcula and keel, respectively, and preened harness loops under feathers (Houston and Greenwood 1993). Harnesses were constructed of plastic coated stainless steel braided wire, and RRC inspected and made final adjustments to all harnesses. Mortality sensors were activated if transmitters remained motionless for 4 h. Transmitters had minimum ground-to-ground ranges of 7 km to truck-mounted 4-element null-peak antennas and minimum ground-to-air ranges of 60 km to aircraft at 1300–1700 m altitudes (Cox 1996). We released radio-tagged females individually in batches of 1–39 birds ($\bar{x} \pm$ SD = 14.5 ± 9.7) during daylight hours at capture sites from 5.7–62.9 h ($\bar{x} \pm$ SD = 33.3 ± 12.2) following capture. Holding times (time from capture until release) were long in our study because we radio tagged large numbers of females from a small number of trapping events each winter. We weighed, measured, banded, and radio tagged each female during a single handling; thus, our measures of body mass and condition (see below) were made closer to the time of release than to the time of capture.

Upon release, we tossed each female into the wind and scored her flight as poor (flight weak or visibly interrupted by skipped wingbeats, attained only low altitude, generally flew <100 m before landing, and showed little or no selectivity in choosing a landing site), moderate (flight good and attained moderate altitude, flew 100–200 m before landing, and showed reduced selectivity in choosing a landing site), or good (flight strong and attained high altitude, flew at least 200 m before landing, and showed selectivity in choosing a landing site by circling or flew out of sight from the point of release). We attempted to assess status (alive or dead) of radio-tagged females once each day using permanent towers, truck-mounted null-peak antennas, and aircraft (Cox and Afton 1996, 1997). We immediately retrieved carcasses and transmitters when activated mortality sensors were detected, except for those consumed by American alligators (*Alligator mississippiensis*). Because carcasses were consumed almost entirely, we used predator sign (e.g., tracks and scat) at mortality sites to determine proximate cause of death. We attributed cause of death to unknown causes if we found no sign of predators.

Statistical analysis.—We indexed body size using principal components analysis (PROC PRINCOMP; SAS Inst. Inc. 1990) of the correlation matrix of the 4 morphometric variables. We used first principal component (PC1) scores as a measure of body size for each female (Alisauskas and Ankney 1987). We then regressed (PROC GLM; SAS Inst. Inc. 1990) body mass of females on PC1, and adjusted each female's body mass for her size by adding the overall mean body mass of all females to the residuals from the regression (Ankney and Afton 1988). We used size-adjusted body mass of each female as a measure of condition (Dufour et al. 1993).

We initially used Cox (1972) proportional hazards regression (PROC

PHREG; SAS Inst. Inc. 1996) to test for differences in survival among 2-d time intervals (treated as a categorical explanatory variable with five levels, e.g., days 1 and 2, 3 and 4, etc.). We reset the continuous time origin to zero for each bird at the beginning of each time interval (Allison 1995:157). No deaths occurred on days 9 or 10; thus, we combined this time interval with days 7 and 8 to allow the partial likelihood to converge (Allison 1995). We used results from this analysis to combine 2-d time intervals into time periods in which survival did not differ ($P > 0.05$). We subsequently used Cox proportional hazards regression to test for differences in survival in relation to female age (adult or immature), condition, holding time, number of waterfowl captured, and time period. We used the exact method to handle ties among event times in all proportional hazards models (SAS Inst. Inc. 1996). We initially included all two-way interactions in the model, and used backward, stepwise procedures to eliminate non-significant ($P > 0.05$) terms, beginning with the interactions. We compared predicted survival rates from our final fitted model using generalized Chi-square procedures (Sauer and Williams 1989) and PROC IML (SAS Inst. Inc. 1990). We made multiple comparisons following significant ($P < 0.05$) overall tests using contrasts (Sauer and Williams 1989). We computed product-limit (Kaplan and Meier 1958) survival estimates and associated 95% confidence limits using PROC PHREG (SAS Inst. Inc. 1996).

We neglected to score flight quality for 13 females (11 females captured in the first rocket-net shot in 1990 and one additional female in each later winter). For this reason, and also because we considered flight quality to be a response to other covariates in our previous survival analysis (e.g., holding time, number of waterfowl captured, etc.), we tested for variation in survival of females in relation to flight quality in a separate analysis. We again used Cox (1972) proportional hazards regression to test for differences in survival in relation to flight quality (treated as a continuous covariate because of its ordinal nature), time period, and their interaction. We used a proportional-odds model (PROC LOGISTIC; SAS Inst. Inc. 1990) and a generalized logits model (PROC CATMOD; SAS Inst. Inc. 1990) to examine variation in flight quality in relation to holding time, number of waterfowl captured, and female age. We initially fit fully specified models (all interactions included), and used backward-stepwise procedures to eliminate non-significant ($P > 0.05$) terms, beginning with the highest-order interactions (Stokes et al. 1995).

We recovered the transmitters of two females intact, and believe that they escaped unharmed from their harnesses. Three females departed the study area during the first 10 days of exposure. We censored individuals of these types on the last date they were known to have retained radios or been in the study area, respectively.

RESULTS

Body condition.—We radio tagged 347 females: 29 adults and 12 immatures in 1990–1991, 96 adults and 58 immatures in 1991–1992, and

108 adults and 44 immatures in 1992–1993. PC1 explained 49.9% of the overall variation among the four morphometric variables. All factor loadings were positive, and ranged from 0.26 (bill width) to 0.61 (middle toe length). Body mass of females was positively related to PC1 ($F_{1,345} = 23.55$; $P < 0.0001$; $r^2 = 0.06$). The equation was: body mass (g) = 748.8 + 15.9 (PC1).

Temporal variation in survival.—Survival of females differed among time intervals (Wald $\chi^2 = 14.37$; df = 3; $P = 0.002$). Survival of females during days 1–2 did not differ from that during days 3–4 (Wald $\chi^2 = 0.26$; df = 1; $P = 0.61$), but survival in these intervals was lower than in days 5–6 (Wald $\chi^2 = 5.79$; df = 1; $P = 0.02$ and Wald $\chi^2 = 4.73$; df = 1; $P = 0.03$, respectively) and days 7–10 (Wald $\chi^2 = 9.40$; df = 1; $P = 0.002$ and Wald $\chi^2 = 8.00$; df = 1; $P = 0.005$, respectively). Survival did not differ between days 5–6 and days 7–10 (Wald $\chi^2 = 0.23$; df = 1; $P = 0.63$). Accordingly, we pooled 2-day time intervals into two time periods (days 1–4 and 5–10) for subsequent analyses. The Kaplan-Meier survival rate of females was 0.933 ± 0.013 (SE) during the first 4 days of exposure, 0.994 ± 0.004 in days 5–10 of exposure, and 0.928 ± 0.014 for the 10-day interval.

Causes of death.—Of 23 female deaths in the first 4 days, we attributed 7 to mammalian predation, 3 to avian predation, 2 to alligator predation, and 11 to unknown causes. We were unable to determine causes of death for two additional females that died six and eight days post-release. We recovered 19 of 23 females that died in the first 4 days within 0.5 km of their capture/release site.

Predictors of survival.—Survival differed between time periods (Wald $\chi^2 = 14.07$; df = 1; $P = 0.0002$), and the effect of holding time on survival varied with the number of waterfowl captured (holding time-by-number of waterfowl captured interaction; Wald $\chi^2 = 4.56$; df = 1; $P = 0.03$). Effects of age, condition, and remaining interactions were not significant ($P > 0.21$ for all tests). The risk ratio for time period (16.1; 95% CI = 3.8–68.1) indicated that females were 16 times more likely to die in days 1–4 than in days 5–10. Survival was unaffected by holding time when females were captured with relatively small numbers of waterfowl ($n \leq 172$), but survival declined as holding time increased for females captured with large numbers of waterfowl ($n = 594$; Table 1).

Flight quality.—Female survival increased as flight quality increased (Wald $\chi^2 = 7.18$; df = 1; $P = 0.007$), and survival was lower (Wald $\chi^2 = 13.76$; df = 1; $P = 0.0002$) during the first 4 days of exposure than during days 5–10. The interaction between flight quality and time period was not significant (Wald $\chi^2 = 0.60$; df = 1; $P = 0.44$). The risk ratio for flight quality (2.0; 95% CI = 1.2–3.3) indicated that poor and moderate fliers were twice as likely to die during the 10-day interval than those scored in the next higher level of flight quality. Similar to our previous analysis, the risk ratio for time period (15.5; 95% CI = 3.6–65.8) indicated that females were 16 times more likely to die in days 1–4 than in days 5–10.

Treating flight quality as ordinal we found weak evidence that the pro-

TABLE 1. Predicted survival rates (± 1 SE) during the first 10 days following capture and handling for female Northern Pintails in southwestern Louisiana (1990–1991 through 1992–1993) for values of holding time (days) and numbers of total waterfowl captured in rocket nets.

Number captured[a]	Holding time[b]	Survival rate	P[d]
53	0.91	0.949 ± 0.019	0.83
	1.33	0.959 ± 0.013	
	1.54	0.963 ± 0.013	
172	0.78	0.959 ± 0.016	0.86
	1.72	0.950 ± 0.015	
	2.62	0.939 ± 0.037	
594	0.65	0.989 ± 0.015 A[c]	0.001
	1.41	0.911 ± 0.035 B	
	1.83	0.737 ± 0.078 C	

[a] Number of total waterfowl captured in rocket nets. Values are actual numbers from our sample with a relatively wide range of holding times.

[b] Time from capture until release in days. Values represent the minimum, mean, and maximum holding times for each level of number captured.

[c] Predicted survival rates within levels of number of waterfowl captured followed by the same letter do not differ ($P < 0.05$) as determined by generalized Chi-square procedures and contrasts.

[d] P-value from generalized Chi-square test that one or more predicted survival rates within levels of number of waterfowl captured differ (Sauer and Williams 1989).

portional-odds assumption was not met (score test from full model; $\chi^2 = 12.88$; df $= 7$; $P = 0.08$). Accordingly, we treated flight quality as nominal and used a generalized logits model. Our final model fit the observed data (likelihood ratio $\chi^2 = 509.46$; df $= 488$; $P = 0.24$), and indicated that flight quality of females captured with small numbers of waterfowl ($n \leq 172$) was unaffected by holding time, but that of females captured with large numbers of waterfowl ($n = 594$) declined as holding time increased (holding time-by-number of waterfowl captured interaction; $\chi^2 = 8.06$; df $= 2$; $P = 0.02$; Fig. 1). Effects of age and other interactions were not significant ($P > 0.11$ for all tests).

DISCUSSION

Female pintails were 16 times more likely to die in the first 4 days of exposure than in days 5–10 in our study. We conclude that a 4-day "adjustment period" is most appropriate for our sample of radio-tagged pintails prior to considering them at risk for subsequent survival analysis. We encourage investigators observing notable early mortality to consider statistical analyses as a tool for objectively determining the length of time in which waterfowl are at high risk from capture, handling, or radio-transmitter effects.

We were unable to necropsy dead females because little remained of carcasses, and some carcasses appeared to have been scavenged. Although we attributed proximate cause of death to predation for over half of our
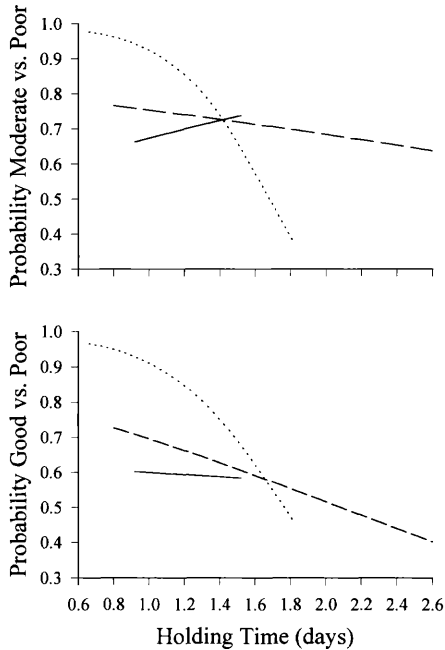
FIGURE 1.   Predicted flight quality of female Northern Pintails upon release in southwestern
    Louisiana in relation to holding time for various levels of number of waterfowl captured
    (solid lines = 53, dashed lines = 172, dotted lines = 594). Y-axis of top graph is prob-
    ability of flight quality being scored as moderate vs. poor, and Y-axis of bottom graph is
    probability of flight quality being scored as good vs. poor.

mortalities, we were unable to identify factors which may have contributed
indirectly to these deaths. Capture myopathy is a condition in which in-
tense muscular exertion and trauma associated with restraint leads to an
acute degeneration of muscle tissue (Dabbert and Powell 1993). In ex-
treme cases of capture myopathy, waterfowl are unable to fly (Wobeser
1981). Blood enzymes indicative of capture myopathy increase as Mallards
(*Anas platyrhynchos*) spend greater lengths of time struggling under rock-
et nets (Bollinger et al. 1989, Dabbert and Powell 1993). Although we
did not record the time that birds spent under nets prior to removal in
our study, we are confident that time spent by female pintails under nets
increased, on average, as numbers of waterfowl captured increased. Thus,
several of our results are consistent with the hypothesis that capture my-
opathy contributed to the early mortality in our study: (1) holding time
affected flight quality and survival only for females captured with large
numbers of waterfowl, (2) survival of females was positively related to
flight quality, and (3) most mortalities occurred within 0.5 km of release
sites.
    Aside from increased time spent under nets, we believe that an addi-

tional complicating factor associated with capturing very large numbers of waterfowl may affect survival. We captured 594 waterfowl in three nets in our final and largest rocket-net shot. We observed ducks moving freely under two nets that contained the most waterfowl, and they moved as a group under the nets while attempting to escape. Of 102 females instrumented from this rocket-net shot, 13 (12.9%) died in the first four days of exposure. Thus, the greater freedom of movement permitted by very large numbers of waterfowl under rocket nets may increase incidence of injury or encourage greater exertion compared to smaller captures. However, because mortalities from this single event greatly influenced our results that flight quality and survival were related to number of waterfowl captured, our findings should be interpreted with caution.

Incidence of early mortality in our study was high compared to other telemetry studies of wintering dabbling ducks (Table 2). Numbers of waterfowl captured per rocket-netting event were higher in our study than in most others using rocket-nets (B. D. Dugger, J. P. Fleskes, J. R. Longcore, R. Migoya and M. R. Miller, pers. comm.). Clearly, holding times were greater in our study than in others (Table 2). Therefore, our finding that the interaction of number of waterfowl captured and holding time was an important predictor of early mortality is consistent with the relatively greater incidence of early mortality in our study.

Our finding that holding time interacted with number of waterfowl captured to affect survival soon after release also is consistent with greater incidence of early mortality in our study compared to other studies of wintering pintails (Table 2). J. P. Fleskes (pers. comm.) reported that 14 of 433 female pintails (all captured by rocket-netting in the San Joaquin Valley of California, including several captures of >100 waterfowl) failed to adjust to harness transmitters as indicated by their failure to make feeding flights, and that all of these were killed by predators in the first six days of exposure. M. R. Miller (pers. comm.) reported that nine of 194 female pintails (all captured by rocket-netting, including several captures of >200 pintails) were killed by predators within four days after release in Suisun Marsh, California. Thus, all of our results are similar in that most mortality occurred within four–six days after release, early mortality of female pintails was associated with impaired flight capability, relatively large numbers (>100) of waterfowl were captured frequently, and in cases where cause of death could be determined, all early mortalities were attributed to predation. In contrast, Migoya and Baldassarre (1995) and Miller et al. (1995) rarely captured >50 total waterfowl in rocket nets, and holding times in these studies were <14 h (R. Migoya and M. R. Miller, pers. comm.). We conclude that incidence of early mortality of wintering female pintails generally increases as larger numbers of waterfowl are captured in rocket nets.

Predicted incidences of early mortality for females captured in small groups or with short holding times in our study (Table 1) still are higher than those observed in most studies of wintering waterfowl (Table 2). We observed mink (*Mustela vison*), raccoons (*Procyon lotor*), coyotes (*Canis*

TABLE 2. Capture method, holding time (h), number of birds radio tagged, number of mortalities excluded from survival analysis, and length of adjustment period (d) for wintering dabbling ducks equipped with harness transmitters.

Species	Capture method	Holding time	Number tagged	Excluded mortalities	Adjustment period	Reference
Anas rubripes	rocket nets	3–12[a]	106	0	0	Longcore et al. 1991
Anas rubripes	bait traps	8–12[a]	243	16[b]	2	Conroy et al. 1989
Anas platyrhynchos	rocket nets, bait traps	4–6[a]	100	0	3	Dugger et al. 1994
Anas platyrhynchos	bait traps	6–14	183	30[b]	1	Bergan and Smith 1993
Anas platyrhynchos	—	—	223	—	—	Reinecke et al. 1987
Anas acuta	rocket nets	6–63	347	23	4	This Study
Anas acuta	rocket nets	<14	170	1	2	Migoya and Baldassarre 1995
Anas acuta	rocket nets, bait traps	<12	191	1	5	Miller et al. 1995
Anas acuta	rocket nets	<1–19	433	14	6	J. P. Fleskes, pers. comm.
Anas acuta	rocket nets	<12	194	9	5	M. R. Miller, pers. comm.

[a] Holding time reported as number of hours until processing; otherwise, holding time is time held from capture until release.
[b] Includes birds excluded from survival analysis for reasons other than mortality, e.g., emigration, radio failure, etc.

latrans), Northern Harriers (*Circus cyaneus*), Red-tailed Hawks (*Buteo jamaicensis*), and Peregrine Falcons (*Falco peregrinus*) at our release sites, the latter three of which also were observed frequently near pintails in other locales in southwestern Louisiana (Rave and Cordes 1993). Raccoons, in particular, were so numerous at our bait sites that they were a nuisance. Our more frequent sightings of potential predators suggest that predator densities, at least mammalian, were greater at our pintail release sites than at those in California (J. P. Fleskes and M. R. Miller, pers. comm.) or Mexico (R. Migoya, pers. comm.). Thus, relatively greater predator densities may have contributed to the greater incidence of early mortality in our study as compared to studies in other areas.

We recommend that investigators monitor radio-tagged waterfowl closely (at least once but preferably twice or more each day) for several days following release. We further recommend that future studies test for differences in incidence of early mortality and capture myopathy in pintails and other waterfowl in relation to capture method (particularly between bait traps and rocket nets), time spent in rocket nets prior to removal, holding time, and types of radio packages (e.g., implants, glue and suture, and harness transmitters). We caution managers and researchers that capturing large numbers of waterfowl in rocket nets may increase the incidence of early mortality. Further, we recommend that holding times of waterfowl be minimized, particularly when large numbers are captured, by processing birds after allowing time only for their plumage to dry. Body mass of individuals retaining food in their esophagi after their plumage had dried could be adjusted by estimating the volume of food retained and comparing it to similar volumes of known mass (Albright 1981).

lished capture and handling data for female pintails. C. F. Bryan, R. H. Chabreck, C. R. Chandler, R. G. Clark, R. D. DeLaune, B. Dugger, E. H. Dzus, J. P. Fleskes, L. D. Igl, M. R. Miller, R. M. Pace, III, R. C. Reigh, M. R. Riggs, S. L. Sheriff, and V. L. Wright provided helpful comments on the manuscript.

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