An Indirect Estimate of Mass Loss in Birds Between Capture and Banding

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ABSTRACT

Mass loss between capture and weighing was estimated from multiple regression analysis of nearly 183,000 weights of 48 species of small birds banded during migration. In effect, the analysis compared mass of birds weighed immediately after capture to mass of birds captured at the same time but not weighed until later. No individual had to be recaptured or weighed more than once. Significant mass loss occurred in 36 of the 48 species, at a median rate of 1.18% of lean body mass/h (1.41% in the first hour); rates considerably lower than from direct measures involving repeated weighing of the same individuals.

Excretion and water loss comprise most of the decline in mass, but banders should take extra steps to minimize holding time in arid regions, in hot weather, or when feeding conditions are poor.

INTRODUCTION

At the peak of migration, banders may sometimes be unable to weigh birds for an hour or more after they are captured. A few authors have measured mass loss during captivity by weighing birds immediately after capture and again after intervals of captivity (Castro et al. 1991, Refsnider 1993). Such studies are limited in sample size, however, and involve weighing the bird at the start of holding time, which might cause stress-related mass loss additional to what would otherwise occur.

The Long Point Bird Observatory records both the time of capture and time of weighing for every bird handled, and with three banding stations the sample size of birds held for various intervals is large.

Although each bird is weighed only once, it is possible to model change in mass over the course of time, including mass loss during holding periods, using multiple regression. In effect, the analysis compares the mass of birds that were weighed immediately after capture with mass of individuals that were caught at the same time but not weighed until later, while simultaneously adjusting for other factors that influence mass.

The aim of this paper is to compare indirect estimates of mass loss in small songbirds during captivity with direct measurements, and to evaluate the importance of short-term captivity on energy balance of migrants.

METHODS

The Long Point Bird Observatory operates three banding stations on Long Point, north shore of Lake Erie, Ontario, on a daily basis from dawn to at least 6.5 h thereafter (weather permitting) through both migration seasons. Data analyzed here were collected in 1980-1996.

Birds were captured primarily in mist nets, but also in Heligoland traps (Hussell and Woodford 1961), then were transported to banding rooms in cloth bags (rarely in carrying boxes) where they were held for processing. Time of capture and time of weighing were recorded to the nearest 10 min (converted here to hours after sunrise, to adjust for progressive change in timing of sunrise through each season). All birds were weighed with a triple beam balance or electronic scale to the nearest 0.1 g, and wing chord (unflattened) was measured to the nearest mm. Fat (in furcular deposits) was scored as “0” for no fat, “T” for trace of fat (converted arbitrarily here to 0.3 for numerical analysis), "1" for little fat (filling no more than 1/3 of furculum), "2" for moderate fat (furculum 1/3 to 2/3 filled) and "3" for heavy fat (furculum nearly filled to over-flowing).

Analyses were limited to data for birds held less than 2 h, with weights and wing chord measurements falling between the 1st and 99th percentile of all measurements for the species, in order to exclude probable errors in measurement or data recording. In addition, data were limited to birds handled during the first 12 h after sunrise and to the species-specific migration periods in which 98% of migrants pass through the Long Point area.

Mass change was modeled for each site and season according to the following multiple regression:

$$\hat{M}=b_0+b_1T+b_2W+b_3H+b_4D+b_5D^2+b_6D^3$$

in which $\hat{M}$ *is* the regression estimate of mass, T = holding time (period between removal from nets and weighing, in hours), W=wing length, *H*=time at removal from nets (hours since sunrise, to the nearest 1/6 h), *D* =day, D^2=day^2, D^3=day^3, and $b_0,...,b_6$ are the coefficients estimated by the regression. All terms other than *T* were included because they significantly influence mass (Dunn *in press, unpubl),* and accounting for their effects should increase the probability of detecting mass loss during holding periods. Date and wing length terms account for some of the variation in mass related to differential migration of age and sex groups by date, and the higher-order date terms model nonlinear changes across the season. Hour of capture was included because there is often significant increase in mass over the course of a day (Winker et al. 1992, Morris et al. 1996, Dunn *in press).* In this model, b_1, the regression coefficient for *T,* represents the amount of mass lost per hour between capture and weighing, providing an estimate of mass loss during holding time without ever having to weigh a bird twice.

Data were analyzed for 48 species for each season and for each banding area at which there were sample sizes of at least 120 (20 cases per independent variable, as recommended by Tabachnick and Fidele 1989; see Table 1 for list of species). Preliminary analyses showed there were no significant differences in estimated mass loss among sites or seasons ($P > 0.05$; paired *T*-tests for all site-season combinations, treating each species as one case). Therefore, analyses were repeated, combining data from all sites and seasons for each species. Because most mass loss occurs in the first hour after capture (Refsnider 1993), analyses were also run for birds held one hour or less.

All estimates of hourly mass loss during holding were converted to percent of lean body mass to allow direct comparison among species. Lean body mass was derived from a multiple regression of mass (all birds combined from both seasons and all banding areas) on wing, wing^2, wing^3, fat, fat^2, fat^3 and a dummy variable for season. Lean mass was defined as mass of an average-sized bird when fat level was zero, in the season when mass was lowest.

RESULTS

Total sample size for the results presented here was 182,987 individuals, evenly divided between spring and fall (median sample size per species = 2,127, range = 685 - 17,550; Table 1). Holding time was typically short (mean for 1980-1996 = 23 min, SE = 0.007).

The median significant value for mass loss between capture and weighing was 1.18% of lean body mass/h (Table 2). Values were significant ($P < 0.05$) in 36 of the 48 species (mostly those with samples >2000). When analysis was restricted to birds held for one hour or less (n=180,267), mass loss was significant for 31 species, with a median value of 1.41% of lean body mass/h (Table 2).

There was a tendency for smaller species to lose more mass during holding than species with higher lean body mass ($r = 0.27$, $P = 0.07$, $n = 48$ species); however, this depended on estimates for the eight species with lean body mass ≥30 g, all of which had non-significant losses close to zero. When non-significant values were omitted, the relationship between mass loss and body mass was reversed and remained insignificant ($r = -0.28$, $P = 0.10$, $n = 36$).

Table 1. Species included in study, with mean mass at weighing, estimated lean mass (see methods), estimated mass loss (percent of lean body mass/h) and sample size. Symbols for significance of mass loss: +, 0.05 < *P* <0.10; *, *P* <0.05; **, *P* <0.01; *, *P* <0.001.**

Species	Mean Mass (g)	Lean Mass (g)	Mass Loss	Sample Size
Northern Flicker *(Colaptes auratus)*	130.4	127.9	0.00	2,011
Eastern Wood-Pewee *(Contopus virens)*	14.0	13.5	-1.54**	1,647
Yellow-bellied Flycatcher *(Empidonax flaviventris)*	11.3	10.9	-1.51**	1,897
Least Flycatcher *(E. minimus)*	10.2	10.0	-1.72***	6,590
Red-eyed Vireo *(Vireo olivaceus)*	17.6	16.3	-0.02*	2,655
Brown Creeper *(Certhia americana)*	8.0	7.6	-0.01*	11,183
House Wren *(Troglodytes aedon)*	10.9	10.5	-0.00	1,664
Winter Wren *(T. troglodytes)*	8.9	8.3	-0.02***	1,582
Golden-crowned Kinglet *(Regulus satrapa)*	6.1	5.4	-0.02***	6,112
Ruby-crowned Kinglet *(R. calendula)*	6.5	6.1	-0.05***	15,966
Veery *(Catharus fuscescens)*	31.9	30.2	-0.41	1,643
Swainson's Thrush *(C. ustulatus)*	30.4	29.0	-1.61***	6,146
Hermit Thrush *(C. guttatus)*	29.7	29.7	-1.10***	6,103
Gray-cheeked Thrush *(C. minimus)*	31.3	30.0	-2.31***	2,044
Wood Thrush *(Hylocichla mustelina)*	49.6	48.3	0.75	685
American Robin *(Turdus migratorius)*	78.4	76.2	0.28	857
Gray Catbird *(Dumatella carolinensis)*	36.9	34.8	0.01	2,978
Brown Thrasher *(Toxostoma rufum)*	69.4	68.1	-0.01	850
Tennessee Warbler *(Vermivora peregrina)*	9.9	9.2	-0.07***	2,085
Nashville Warbler *(V. ruficapilla)*	8.6	8.1	-2.12***	2,559
Yellow Warbler *(Dendroica petechia)*	10.6	9.6	-2.22***	6,682
Chestnut-sided Warbler *(D. pensylvanica)*	9.8	9.3	-0.04***	1,741
Magnolia Warbler *(D. magnolia)*	8.6	8.1	-2.36***	9,909
Cape May Warbler *(D. tigrina)*	11.0	10.3	-2.81***	2,451
Black-throated Blue Warbler *(D. caerulescens)*	9.8	9.4	-0.05***	1,720
Yellow-rumped Warbler *(D. coronata)*	12.3	11.7	-2.12***	12,637
Black-throated Green Warbler *(D. virens)*	9.1	8.6	-0.02*	1,163
Blackburnian Warbler *(D. fusca)*	10.1	9.5	-0.04***	1,032
Palm Warbler *(D. palmarum)*	10.4	9.8	-0.04***	1,381
Bay-breasted Warbler *(D. castanea)*	12.2	11.9	-0.85*	2,169
Blackpoll Warbler *(D. striata)*	12.4	13.3	-2.49***	3,458
Black-and-white Warbler *(Mniotilta varia)*	10.6	10.0	-0.03**	1,676
American Redstart *(Setophaga ruticilla)*	8.2	7.8	-2.31***	3,482
Ovenbird *(Seiurus aurocapillus)*	19.6	18.8	-0.03***	1,882

Table 1. (Cont'd).

Species	Mean Mass (g)	Lean Mass (g)	Mass Loss	Sample Size
Northern Waterthrush *(S. noveborecensis)*	17.5	16.6	-0.06***	1,958
Common Yellowthroat *(Geothlypis trichas)*	10.5	10.2	-1.20**	3,928
Wilson's Warbler *(Wilsonia pusilla)*	7.9	7.5	-0.05*	2,226
Canada Warbler *(W. canadensis)*	10.4	9.9	-0.07***	1,951
Chipping Sparrow *(Spizella passerina)*	12.6	12.1	-1.28*	1,821
Field Sparrow *(S. pusilla)*	12.7	12.3	-1.40*	1,237
Song Sparrow *(Melospiza melodia)*	20.9	20.0	-0.56*	4,261
Lincoln's Sparrow *(M. lincolnii)*	18.0	16.2	-1.49**	2,188
Swamp Sparrow *(M. georgiana)*	16.6	16.1	-1.15*	2,371
White-throated Sparrow *(Zonotrichia albicollis)*	26.5	25.0	-1.77***	17,550
White-crowned Sparrow *(Z. leucophrys)*	30.0	26.9	-1.53***	3,586
Dark-eyed Junco *(Junco hyemalis)*	19.3	18.1	-1.41***	8,352
Rose-breasted Grosbeak *(Pheucticus ludovicianus)*	46.0	43.1	0.01	1,515
Northern Oriole *(Icterus galbula)*	34.2	32.5	0.01	1,403

DISCUSSION

Refsnider (1993) weighed small species (mostly passerines, as in this study) both at capture and every half hour thereafter up to 2 h. On average, birds lost 2% of capture mass in the first 30 min after weighing, and an additional 1% in the next 30 min, for a total loss in the first hour of 3% (n = 130). In a study of shorebirds, Castro et al. (1991) also measured mass loss of about 3% in the first hour after capture. These values are twice as high as the median significant estimate presented here of 1.4% of lean body mass lost by birds in the first hour after capture (Table 2). The indirect estimate would be slightly lower still if mass loss had been calculated as percent of capture mass instead of as percent of lean body mass (the latter being about 5% lower than capture mass, Table 1). In Refsnider's (1993) study, birds lost only about 0.33% of capture mass in the second hour of holding, for an average over 2 h of 1.67%/h — about 30% higher than the indirect estimates presented here (median significant estimate = 1.18%/h; Table 2). None of the studies found significant variation in mass loss according to body size.

A 20 g bird (close to the mean size for birds analysed here) is estimated to metabolize about 0.21 kJ/h at rest during the daytime (King 1974, based on 1.8 x basal metabolic rate). If this were fueled entirely by fat (which has a caloric value of 39.8 kJ/g), then this bird would lose 0.053 g/h, or 0.27% of its body mass. This is close to the 0.33% of body mass lost in the second hour of holding according to Refsnider (1993). Additional mass loss in the first hour is likely to consist of excretory and water losses, as has been demonstrated for shorebirds, and mass loss rises considerably (up to 8% of capture mass/h) when temperature is greater than 30° C (Castro et al. 1991).

Table 2. Estimated mass loss during the period between capture and banding (% of lean body mass/h).

	N species	Mean	Median
Birds held up to 2 hr (n=182,967):			
All estimates	48	-0.81	-0.24
Significant estimates	36	-1.02	-1.18
Birds held ≤ 1 hr (n=180,267):			
All estimates	48	-0.81	-0.25
Significant estimates	31	-1.18	-1.41

The fact that indirect estimates of mass loss were lower than direct measures might depend on several factors, including differences in mean temperature during the studies. Moreover, Refsnider worked primarily with granivores whereas this study was mainly of small insectivores, and these groups might have different excretion rates.

Another factor may be a handling effect. In this study, birds were handled during removal from nets, but not weighed until later. In direct measurements of mass loss, birds were weighed immediately after capture, and then a second time later on. Possibly the extra handling at capture causes stress that leads to increased defecation or respiratory water loss. This possibility could be tested with an experiment that compares pairs of birds of the same species captured at the same time (a design that eliminates species, time, date and weather effects). Both birds of each pair would be weighed immediately after capture: one of each pair without removing the bird from its pre-weighed holding bag (no direct handling after removal from nets), and the other weighed conventionally as a part of normal banding procedures. Both birds could then be held for an additional half hour before being removed from bags and weighed a second time, to test whether birds handled during the first weighing lose significantly more mass in the interval. If they do, a similar experiment could be conducted to test whether minimal handling (recording less information) causes less mass loss than a great deal of handling.

If mass loss is increased by the banding and weighing process, then it is probable that birds weighed once and released immediately following banding continue to have high mass loss for a short while. There is some evidence of this, in that individuals recaptured within a day of first capture often show a decline in body mass (e.g., Loria and Moore 1990). Several explanations have been offered (Yong and Moore 1997): effects of capture and handling, poor physiological condition (since birds later recaptured were usually lighter at first capture than those never recaptured), competition with conspecifics, and inefficient foraging because the stopover site is unfamiliar. Yong and Moore favored the latter hypothesis and did not support the first because there was no relationship between mass change and the number of times an individual was captured. Comparison of results from this study and those from Refsnider (1993) are consistent with at least a short-term mass loss associated with handling stress, although other explanations for the differences are possible, as noted above.

Mass loss that consists of water alone should be easily replaceable after a bird is released, except in very dry regions. While stress-related defecation might clear the gut of incompletely digested food, thereby costing the bird some energy that would otherwise have been absorbed, the greatest energetic cost to being held in captivity may be in lost foraging time. In the fall, small passerines at Long Point gain mass at a rate well above that estimated necessary for daily energy balance, but in spring they are much closer to the break-even point (Dunn *in press, unpubl)* and inability to forage for an hour in that season could have an important effect on energy balance. (At certain other sites, birds fare more poorly in fall than in spring; Winker et al. 1992, Morris et al. 1996.) Banders always strive to process birds as quickly as possible, but should be especially conscientious when feeding conditions are poor, temperature is high, or water is scarce in the area. It should be kept in mind as well that birds are captured prior to the time they are actually removed from nets, so reduction of "holding time" includes reducing intervals between net rounds.

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