ESTIMATING DRC-1339 MORTALITY USING BIOENERGETICS: A CASE STUDY OF EUROPEAN STARLINGS

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Abstract: We developed a bioenergetics model for European starlings (*Sturnus vulgaris*) that estimated mortality from baitings with CU Bird Carrier pellets treated with 1% DRC-1339 Concentrate and diluted 5:1 (untreated:treated pellets). A bioenergetic analysis of heat and radiative energy exchanges between the starling body surface and surrounding environment was converted to daily caloric demand based on a steady-state energy balance. The amount of Bird Carrier eaten per starling was governed by subroutines in the model that used probability distributions to simulate variability in dietary intake at the bait site. Mortality was estimated through dose-response regression analysis. Compared to onsite pre- and post-baiting counts conducted during winter 2004-2005 at 33 Midwestern dairies, model estimates were greater for 23 of the 33 counts. Onsite counts estimated 148 mortalities/kg pellets removed from the site compared to 204/kg for the model. The model was programmed in Visual Basic© with Microsoft® Excel 2002 as the platform. The model requires input of 11 variables, including ambient temperature, latitude, wind speed, and amounts of bait applied and remaining. The model can be modified for use with other bird species, baits, dilutions, and concentrations.

Key words: bioenergetics, CU Bird Carrier, dairies, DRC-1339, European starlings, feedlots, mortality, simple energy budget, *Sturnus vulgaris*

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INTRODUCTION

Wildlife Services uses Compound DRC-1339 Concentrate at feedlots and dairies to reduce populations of European starlings (*Sturnus vulgaris*). The standard procedure is to pre-bait with untreated feed (usually, CU Bird Carrier pellets). After the pre-bait is being taken by the target population, a 1% concentration of DRC-1339 is applied to the pellets then mixed with untreated pellets in a 5:1 dilution (untreated:treated). Poisoned birds often succumb in thick vegetation far from the bait site (DeCino et al. 1966, Besser et al. 1967). Carcass searches are therefore problematic. Pre- and post-baiting counts are frequently used. Counting is highly subject to human-induced errors due to difficulties associated with tracking dense, roving flocks of European starlings (henceforth, starlings). Moreover, during post-baiting counts remnant flocks may attract new members from the local population, which can lead to underestimates of true DRC-1339 mortality. In some cases, post-baiting counts have given the anomalous result of higher numbers of birds after the baiting. Changes in foraging behavior (e.g., use of alternate feeding sites or food sources) or emigration – immigration further exacerbate inaccuracy of counts.

An accurate and fairly precise method to assess mortality may be to extrapolate from the amount of DRC-1339 baits taken during the baiting period. This method, based on the work of Besser et al. (1968), is used infrequently by Wildlife Services (S. Beckerman, USDA/WS, personal communication 2003). Besser et al. (1968) estimated feeding rates on cattle feed rations, not CU Bird Carrier pellets, which differ substantially in nutritional value. Furthermore, the starlings fed selectively on mixed-feed rations, and the data were summed over a 6-month period in Colorado (October – March). The potential influence of nutritionally different foods on feeding rates and the influences of changes in environmental conditions and locale can not be assessed. Under current baiting practices used by Wildlife Services, the data of Besser et al. (1968) may not yield good estimates of mortality.

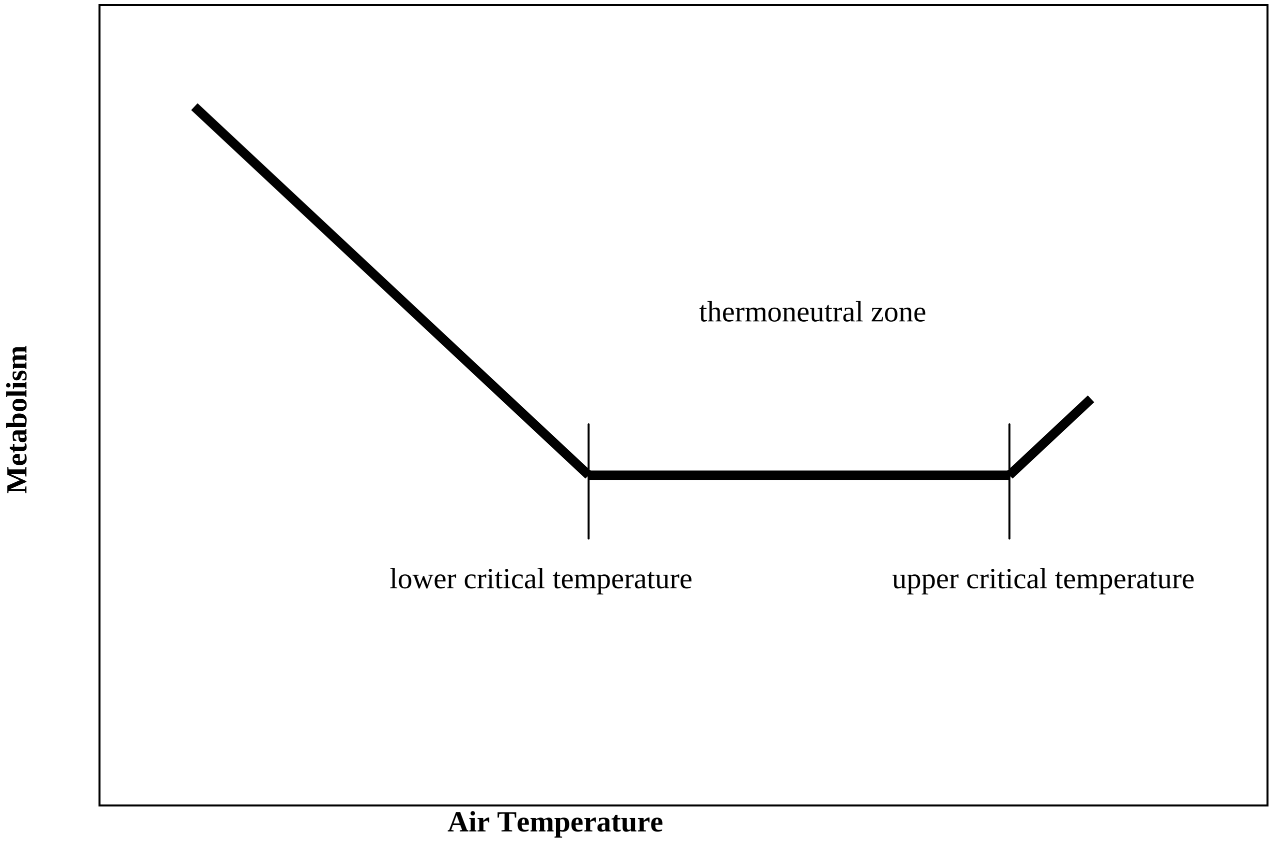
The lack of a standardized methodology to estimate DRC-1339 mortality at feedlots and dairies is one of the major concerns of Wildlife Services. Indeed, an *ad hoc* committee listed DRC-1339 in 11 of its top 14 priority issues involving lethal techniques used by Wildlife Services. Here, we provide a general discussion of the methods employed to create a bioenergetic - biophysical model capable of predicting DRC-1339 mortality. We then compare mortality estimates generated from our bioenergetic model with empirical data collected at Midwestern dairies duringwinter 2004-2005. The model may be used by itself or in conjunction with pre- and post-baiting counts to provide 2 independent estimates of mortality. In addition to helping assess efficacy of current management actions with DRC-1339, bioenergetic models can be employed to judge potential impacts of future management strategies.

METHODS

Metabolism

Metabolism generates heat through energy releases resulting from breaking chemical bonds in carbohydrates, fats, and proteins. About one-third of energy generated from metabolism produces the work necessary to support life; whereas, two-thirds is lost as heat. For homeothermic endotherms, some of the heat generated from metabolism is used to maintain a stable core body temperature greater than ambient temperature. At ambient temperatures below the lower critical temperature (LCT; the temperature where physical, physiological, and behavioral adjustments have reduced body and surface heat conductances to their minima), starlings respond to further losses of heat by increasing their metabolic rate (a physiological process called thermoregulation). Once below the LCT, the metabolic response increases linearly to decreases in ambient temperature (Figure 1). Increases in metabolic rate cause concomitant increases in food demand. Our bioenergetics model was constructed to predict mortality from baitings conducted between fall and late winter, when ambient temperatures will usually be lower than the LCT (~15°C for starlings, Dmi’el and Tel-Tzur 1985)

Figure 1. Once the temperature goes below the lower critical temperature, about 15°C for European starlings, metabolic rate must increase to compensate for the net heat loss from the body. The increase in rate of metabolism once below the lower critical temperature is a linear function of decrease in ambient temperature (*from* Campbell and Norman 1998).



Energy Exchange

We based our bioenergetics model on the concept of a Simple Energy Budget (SEB). The SEB sets a steady-state condition of energy balance between an organism and its environment. In a steady-state, fluxes of heat and radiative energy away from the body surface (caused by gradient differences at the interface between organism surface and environment) are balanced by heat energy inputs from absorbed radiation and metabolic heat production. Heat storage and energy storage equal zero. A good assessment of gradient strength at the organism – environment interface is necessary to produce accurate estimates of energetic costs of thermoregulation under varying temperatures, weather, and sky conditions. Ambient air temperature alone does not capture the magnitude of the true energy gradients. We used the operative temperature (T_e) (equivalent blackbody temperature) to assess gradient differentials between starlings and their microclimatic environment (Bakken 1980). The T_e incorporates effects of ambient air temperature (T_a); radiation exchanges, including surface emissivity; and convective heat flow at the boundary layer. It also includes body resistance factors to convective and radiative energy transfers.

Of course, resistance to energy transfers depend upon absorbed radiation (e.g., orientation in respect to the sun, angle of incidence of solar beams), wind speed, characteristic dimension and morphological body shape, and ambient temperature.

Model Logic

The bioenergetics model is started by macro in Excel 2002. A menu-driven series of questions prompts the user to provide data, including month, weather and sky conditions, latitude, and the amounts of bait applied and remaining (Table 1). The following description of the model's logic does not strictly follow programming sequence; however, it is probably the best way to visualize the process of estimating mortality with bioenergetics. Briefly, we calculate total number of CU Bird Carrier pellets consumed by dividing the difference between amounts applied and amount remaining by average pellet weight (~0.05 g). After this integer is obtained, a starling is randomly drawn from a normal distribution of body masses. Basal metabolism and area of body surface are estimated from body mass (Aschoff and Pohl 1970, Kendeigh 1970). Hourly estimates of absorbed radiation are made for a 24-h period using a combination of climate and weather variables provided by the user onsite, and physical, physiological, and morphological parameters obtained from literature sources on biophysics and avian bioenergetics (Kendeigh 1970, Calder and King 1974, Johnson and Cowan 1975, Bakken 1976, Campbell 1977, Kendeigh et al. 1977, Mahoney and King 1977, Torre-Bueno and LaRochelle 1978, Walshberg et al. 1978, Walshberg and King 1978, Nagy et al. 1999). Energy gained from absorbed radiation is subtracted from the combined sum of energy expended on basal metabolism, thermal metabolism, and activity metabolism. Total energy expended is then converted to demand for chemical food energy. Feeding behavior at the bait site is simulated with probability distributions based in part on video observations of Glahn et al. (1983). The probability distributions governing feeding behavior allow from 0-40% of daily food requirements to be met by consumption of CU Bird Carrier. Daily energy taken as pellets (using a digestive efficiency of 70%) is divided by energy content of a single pellet to arrive at number of pellets ingested. From this integer, number of baits laced with 1% DRC-1339 is estimated, along with milligrams of DRC-1339 consumed. A dose response regression analysis is then used to calculate chances of mortality from receiving varying Lethal Doses ranging from $LD_{25-99.9}$. The model continues to iterate in this fashion (using another starling drawn from the body-mass distribution) until the total number of pellets removed during the baiting period is exhausted. Finally, all mortalities are totaled and outputted.

Table 1. Ten onsite variables[a] used to bioenergetically model DRC-1339 mortality from baitings of European starlings at feedlots and dairies. Entry of the variables is prompted when the user starts the program in Microsoft® Excel 2002.

1	Air temp	6	Cloud cover
2	Sunrise	7	Cloud type
3	Sunset	8	Wind speed
4	Latitude	9	Pounds bait applied
5	Month	10	Pounds bait remaining

[a] An eleventh variable, distance from roost, may be entered if it is known.

Table 2. Comparisons of estimates of DRC-1339 mortality between a bioenergetics model and onsite pre- and post-baiting counts of European starlings at diaries in Michigan during winter 2004-2005.

Baiting	Pellets removed (kg)	Model take	Onsite take	Diff.[a]
1	13.6	2,318	3,900	-1,582
2	6.8	1,714	3,250	-1,536
3	10.2	1,897	2,980	-1,083
4	13.6	3,050	4,000	-950
5	6.8	1,337	1,600	-263
6	3.4	656	900	-244
7	3.4	575	700	-125
8	18.1	3,097	3,200	-103
9	3.4	760	800	-40
10	10.2	1,837	1,850	-13
11	20.4	3,836	3,800	36
12	6.8	1,302	1,200	102
13	2.2	344	190	154
14	6.8	1,323	1,000	323
15	9.0	1,826	1,500	326
16	6.8	1,133	800	333
17	6.8	1,280	900	380
18	3.4	762	350	412
19	6.8	1,413	1,000	413
20	3.4	844	300	544
21	13.6	2,598	1,900	698
22	6.8	1,253	500	753
23	10.2	2,079	1,100	979
24	10.2	2,543	1,400	1,143
25	13.6	2,695	1,500	1,195
26	6.8	1,394	80	1,314
27	10.2	2,067	700	1,367
28	6.8	1,618	0	1,618
29	17.0	3,737	2,000	1,737
30	13.6	2,977	1,100	1,877
31	10.2	2,629	716	1,913
32	10.2	2,536	500	2,036
33	27.2	5,380	1,200	4,180

[a] Model take minus onsite take.

RESULTS

We compared model estimates to differences between pre- and post-baiting counts for 33 DRC-1339 operations conducted at Michigan dairy farms between 22 December 2004 and 11 March 2005. The model estimates were based on weather and baiting data provided Michigan Wildlife Services personnel. The average ambient temperature was 5°C for the 33 baitings. The model predictions were greater than take estimates from onsite counts in 23 of the 33 baitings (Table 2). The average take per baiting from onsite counts was 1,422 starlings compared to the model's average of 1,964. The greatest difference between the 2 methods estimates was 4,200. In this case, the model predicted 5,440 starlings killed (27 kg of CU Bird Carrier pellets removed) compared to 1,200 from onsite counts. The average standardized take produced from onsite counts was 148 birds/kg pellets removed; whereas, the model produced an estimate of 204 birds/kg pellets removed. The model predicted on average that each starling poisoned and killed by DRC-1339 consumed 4.5 g of pellets. If an average Bird Carrier pellet weighs 0.05 g, then about 90 pellets were eaten per bird.

DISCUSSION

Advances in the fields of avian bioenergetics and environmental biophysics have steadily accrued over the last 30 years and have made bioenergetic modeling a reliable tool for assessing DRC-1339 mortality. Bioenergetic models do not require a numerical estimate of size of the targeted population, thereby avoiding the bias, high variance, and chance events that decrease precision and accuracy of counts (Faanes and Bystrak 1981). The main assumption behind undertaking a bioenergetics model is that it should produce better estimates than those from counts or carcass searches. The comparisons between model estimates and count estimates from the Michigan baiting operations in 2004-2005 showed that at the very least both methods on average gave numbers of the same magnitude. Although we can not be certain whether model estimates or count estimates were the most accurate for the Michigan data, we were not surprised that the model produced higher estimates than the counts. All post-baiting counts are susceptible to the possibility that starlings killed during a baiting will be replaced by other members from the local population. For example, there was one case (baiting number 28 in Table 2) where the count estimate of take indicated no birds killed with nearly 7 kg of pellets removed from the bait site.

We will continue to work on the bioenergetics approach for estimating DRC-1339 mortality and make adjustments to our model as more data are collected from the field. We encourage participation from all interested programs involved with managing starlings at feedlots and dairies. Finally, the model is flexible in its design and scope and is capable of being used (with some modifications) under other baiting scenarios with different bird species.

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