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ESTIMATING FEED LOSS FROM STARLING USE OF LIVESTOCK FEED TROUGHS

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Feed losses due to large congregations of wintering starlings (*Sturnus vulgaris*) at livestock feeding operations are well documented in the United States and Great Britain (Levingston 1967, Lynch et al. 1973, Palmer 1976, Dolbeer et al. 1978, Feare 1980). However, attempts to assess the extent of these losses have been limited by the lack of a practical assessment technique. Besser et al. (1968) first attempted to measure these losses by combining the feed consumption capability of starlings determined in the laboratory with extensive field observations of bird use at a Colorado feedlot. However, he cautioned that the estimates projected may not be reliable for other geographic areas. In Great Britain, Feare (1975) and Feare and Swannack (1978) estimated the percentage of time that starlings fed at troughs and factored this with feeding rates (items/bird/min) for each feed ration examined. Glahn and Otis (1981), using time-lapse photography to monitor starling use of feed troughs, developed regression models of feed consumption to starling use but offered no practical application of these models. In this study, we substantiate the models developed by Glahn and Otis (1981) and develop new models with practical application to assessing feed loss from starlings.

METHODS

The study was conducted at the Western Kentucky University Farm, Bowling Green, Kentucky, January–March 1980. Two complete feed types, a 0.5-cm diameter pig pellet with either 13 or 18% protein and a 16% protein granular (2.0-mm diameter) hog meal, were studied because they were typical of the cattle and swine rations preferred by starlings (Glahn and Otis 1981).

This study incorporated the general procedures and data collected in 1979 (Glahn and Otis 1981). Briefly, these procedures were as follows. At the beginning of each trial day (0750–0900 hours), samples of preweighed livestock ration were placed 50 m apart in 2 (3 × 0.6-m) experimental troughs located near livestock feeding areas but with livestock excluded. Meal and pellet rations were alternated among trial days so that both troughs would contain the same ration on a given day. Daily feed consumption by birds (almost exclusively starlings) was measured by weighing back 1 or more feed samples from each trough when depleted or at the end of the trial day (1530–1700 hours). Daily starling use of troughs was sampled at 10-sec intervals with Kodak®[1] Analyst Super-8 Surveillance Cameras. Film was analyzed for each trial day by totaling the number of starlings on all frames and on every sixth frame or 1-min interval. Starling use (birds over time) at troughs was defined as all birds both in or on the edge of the trough; no distinction was made between feeding and loafing birds. These data were then paired with feed consumption data for each trial day and analyzed by weighted (variance proportional to x) least-squares regression analysis.

Before and during feed consumption trials, 271 starlings were captured in the vicinity of the experimental troughs using Kniffin collapsible baited traps (Reeves et al. 1968), marked using a modification of a back-tag described by Furrer (1979), and released. Individual starling use of troughs, identified on film, was analyzed to determine the number of consecutive frames that individual birds spent at a trough during a visit; the median of these observations was taken to be the best estimate of the length of a trough visit per feed type. A trough visit was defined as the total number of consecutive frames or 10-sec intervals that a bird was observed at the trough. Data were converted to minutes per visit and the number of starling visits to the trough per day was then estimated by dividing the daily bird-minutes of starling use recorded from film by median minutes per visit. These estimates (film visits) were compared by weighted least-squares regression analysis to grams of feed consumed by feed type.

Estimates of bird visits were collected by an observer positioned at a selected vantage point in a parked vehicle used as a blind. Five trained observers collected these data on separate occasions. A randomly selected trough was observed during 4, 0.5-hour observations per day at systematic 2-hour intervals beginning at a randomly selected 0.5-hour interval between 0800 to 1000 hours and ending between 1430 and 1645 hours. At the beginning of each sampling period, starlings at the trough were flushed and their number estimated. The observation period was timed with a stopwatch and began as soon as the first bird landed at the trough or at the end of a 15-min waiting period, whichever came first. Using a portable cassette tape recorder, observers recorded the number of birds landing at the trough (observed starling visits) for the 0.5-hour period. Immediately after each observation period, the birds at the trough were flushed again and the number of starlings estimated. Starling visits were estimated for the day by dividing the total observed visits from 4 observation periods by the percentage of the trial day the observation periods made up. These estimates of observed starling visits per day were paired with daily film-calculated visits and with grams of feed consumed per day in regression models to assess the precision of the systematic sampling procedure. Flush count data from before and after observations also were summarized to estimate daily starling trough use (bird-min), and paired with corresponding data of filmed starling use and grams of feed consumed by feed type in weighted least-squares regression analyses. All regression models were forced through the origin, so that no intercept terms were included.

RESULTS AND DISCUSSION

Trough Use-Feed Consumption Models

Sixty-nine trough use-feed consumption data pairs were obtained for starlings during 1980. These included 34 pairs on the meal ration, 11 on the 13% protein pig pellet, and 24 on the 18% protein pellet ration. Although trough use was calculated both by totaling birds on every frame (birds-10 sec = FB10) and every sixth frame (bird-min = FB60), the close agreement of these 2 estimates, when adjusted for frames examined, suggested that the FB60 value was an adequate sample and subsequent analysis dealt with the FB60 value. The resulting regression model for the meal ration relating FB60 (x) to grams (y) produced a slope of 0.722 ± 0.069 (±SE) and an r^2 value of 0.77. The same analysis of the 13 and 18% protein pellet rations by protein content had

[1] Reference to trade names does not imply U.S. Government endorsement of commercial products.

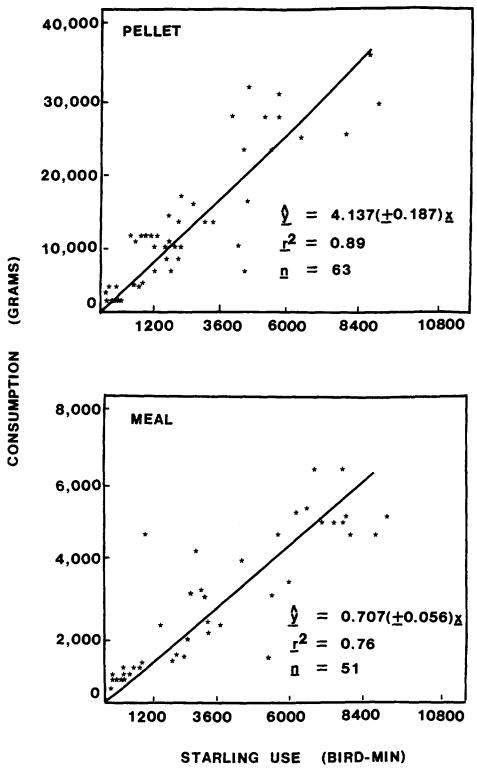

Fig. 1. Regression models (slopes [±SE]) of feed consumption for 2 feed rations relating starling use measured with time-lapse photography (x) to grams of feed consumed (y).

slopes of 3.81 ± 0.290 and 3.98 ± 0.226 with r^2 values of 0.94 and 0.93, for 13 and 18% protein, respectively. Because these latter slopes did not differ significantly ($P > 0.5$) from each other, they were subsequently pooled.

In comparison with the 1979 data previously reported (Glahn and Otis 1981), there were no significant differences ($P > 0.1$) in the corresponding meal and pellet slopes between years; the slopes from 1979 were 0.59 ± 0.082 and 4.49 ± 0.373, respectively. (The latter slope is different than previously reported by Glahn and Otis [1981] because 1 significantly outlying data point ($P < 0.05$) was removed. Dogs were observed subsequently on the film to have removed feed on that trial day.) The 1979 and 1980 data were therefore pooled by ration type with the subsequent models presented in Fig. 1. Pooled models for meal and pellet rations differed significantly ($P < 0.001$) and consumption rates for pellets (4.137 g/bird-min) were about 6 times that of meal (0.707 g/bird-min). These data indicate that feed consumption rates of starlings are influenced primarily by feed form or size and not by percentage protein, bird populations, or weather conditions between years. By observing individual starlings at feed troughs, Feare and Swannack (1978) estimated starling feed consumption rates on a 0.19 g (0.5 cm) calf pellet and barley grains (0.041 g) at 3.0 g/bird-feeding-min and 0.54 g/bird-feeding-min, respectively. Because these rates considered only those birds actively feeding at the trough, they may not be directly comparable with ours. However, the similarity of these rates compared with ours on a similar size pellet ration and a smaller particle-size meal would suggest that these 2 methods might be estimating the same parameter.

These findings indicate considerable differences in starling consumption rates among feed rations. These differences appear related to particle size of rations. Similar relationships in consumption rates between meal and pelleted rations have been observed with domestic fowl (Jensen et al. 1962) and Japanese quail (*Coturnix coturnix japonica*) (Savory 1980). Differences in consumption rates among rations tend to limit the versatility of this procedure for damage assessment at operations using other than the rations for which a consumption rate is known. A further limitation to this procedure is the lack of a direct method to sample bird use by observation. Flush counts at troughs, as used by Feare (1975) and Feare and Swannack (1978), were evaluated for this purpose, but our analysis indicated no significant ($P > 0.05$) relationship between flush counts and daily starling trough use or feed consumption. However, our results may be in-

fluenced by the large within-day variation of starling trough use in southern Kentucky (Glahn and Otis 1981).

Trough Visits-Feed Consumption Models

Because of the limitations of trough use-feed consumption models, we examined a similar approach by estimating trough visits and relating the estimated daily visits to the amount of feed consumed per day. From consecutive trough-use data of marked starlings, we tabulated 926 starling trough visits on the meal ration and 1,475 visits for the pelleted rations. Because of the degree of positive skewness of both data sets (coefficient of skewness = 19.74 and 6.45, $P < 0.01$ for pellets and meal, respectively), the median was used as a measure of central tendency of length of trough visit. The median length of a trough visit with estimated 95% confidence limits (Snedecor and Cochran 1971:125) was 0.46 ± 0.04 min for pellets and 1.36 ± 0.12 min for meal.

These median times were divided into their respective FB60 estimates for each trial day to obtain a film estimate of the number of starling trough visits per day (film visits) and paired with daily feed consumption by feed type in regression models (Fig. 2). In comparison with bird-use models, these models estimate that about twice as much feed is consumed per visit with the pellet ration (1.91 ± 0.09 g/visit) than with the meal ration (0.96 ± 0.08 g/visit), and consumption per visit was significantly different ($P < 0.01$) between ration types. These results suggest that differences in consumption rates on different rations are in part compensated for by corresponding differences in the length of trough visits on these rations. Savory (1980) found similar differences in consumption rates by Japanese quail on pelleted and meal rations, but indicated that the average meal size (amount consumed during a discrete feeding bout) was about the same with all foods, as meal length reflected the time taken to consume about the

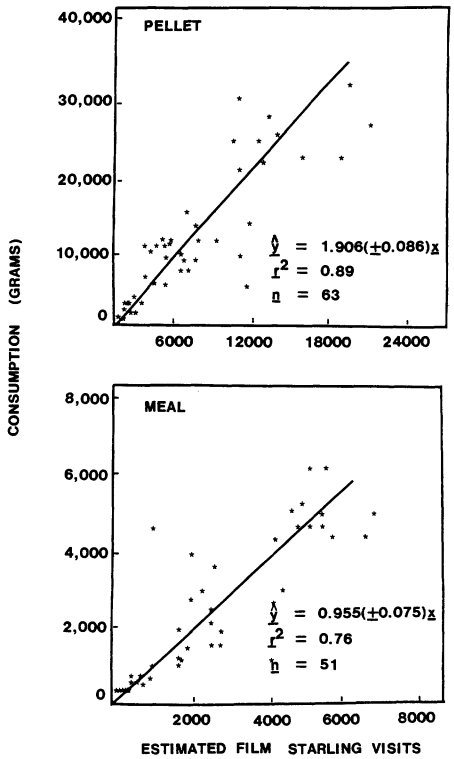

Fig. 2. Regression models (slopes [±SE]) of feed consumption for 2 feed rations relating starling trough visits (x) (projected from starling trough use and median visit length) to grams of feed consumed (y).

same amount of feed regardless of form or nutrient content. A similar pattern is also suggested when comparing our data with starling foraging behavior on insects in meadows (Tinbergen 1976). In contrast to the brief foraging visits (0.46–1.36 min) we obtained when consumption rates were high (0.7–4.1 g/min), this insect feeding study reported foraging visit lengths several times longer (2–4 min) when consumption rates were relatively small (20–100 mg/min).

Film Visit-Observed Visit Estimates

Film estimates of trough visits theoretically should predict the number of observed starlings to visit a feed trough per day. To ex-

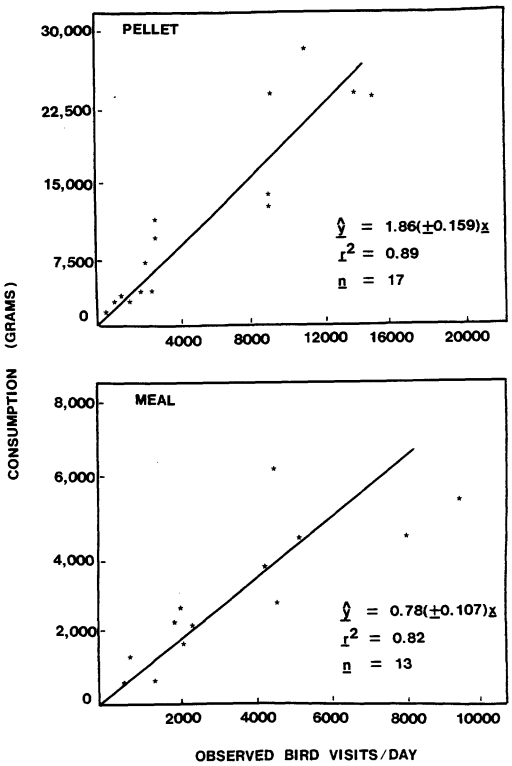

Fig. 3. Regression models (slopes [±SE]) of feed consumption for 2 feed rations relating observed starling visits for a trial day (x) (projected from 4, 0.5-hour systematic observations) to grams of feed consumed (y).

amine the relationship between film visits and observed visits we paired projected daily trough visits from 28 days sampled by observers on both the meal and the pellet ration with corresponding film calculated daily visits in a weighted least-squares regression analysis. The results of this analysis indicated a significant ($P < 0.001$) relationship between these estimates and a slope estimate of 0.99 when the model was forced through the origin. These results suggest that film visit estimates are reliable indicators of the trough-visit parameter and, can in turn, be predicted by field observation.

Sampling Trough Visits

We evaluated whether 4 observed trough-visit samples per day, when used to project total daily trough visits, would provide a similar relationship with feed consumption as predicted by film visit-feed consumption models. Although sample sizes were small, models of projected observed visits per day and feed consumption fit well (Fig. 3) and had slope estimates for the pellet and meal ration similar ($P > 0.2$) to film visit-feed consumption models. The similarity in these models suggests that the 4, 0.5-hour systematic trough-visit samples provide a valid prediction of daily feed consumption. The precision of these observed visit estimates will be influenced largely by observer error in visit estimation, within-day variation of starling visits, as well as natural variation in starling feed consumption per visit. These combined errors are reflected in the standard errors of the respective slope estimates (Fig. 3) as 5 different observers were used under conditions of relatively high within-day variation in starling visits.

APPLICATION OF MODELS

This study indicates that 2 methods can be used to estimate losses of livestock feed to starlings. In the first method, rates of consumption based on starling use (bird-min) over time can be used to estimate feed consumption. The use of this method could involve converting observed trough-visit data to starling use (bird-min) based on the median length of feeding visits reported. A practical limitation to starling-use indices of feed consumption is the large variation in feeding rates between feed types, requiring that relationships be established for numerous types of feed before having widespread application as a damage assessment method.

The second approach to assessing feed losses to starlings is based on relating the amount of feed consumed per trough visit. This approach

provides greater consistency among feed types in the amount of feed consumed by starlings per visit, as differences in rates of consumption among feed types appear partly compensated by duration of trough visits. Thus, trough visit-feed consumption models for the pellets and meal ration differed by a factor of only 1 (1.9 vs. 0.96), whereas similar models based on bird-minutes of starling use predict consumption rates differing by a factor of 3.5 (4.1 vs. 0.7).

Additional trough-visit models on other feed rations are needed to determine if slopes fall within limits of the 2 rations tested. We hypothesize that they would, considering the modification in foraging behavior observed between these rations and similar patterns of feeding regulation reported in the literature. Using this rationale, starling consumption of most livestock feeds could be grossly estimated at a rate of between 1 and 2 g/visit. Considering that trough visits observed in this study numbered in the thousands per day, the magnitude of the error accepted with the use of this estimated consumption rate per visit may be acceptable.

Although we did not examine variation in trough use throughout the winter, our observations and the results of past studies (Besser et al. 1968, Feare and Swannack 1978) indicate that repeated sampling throughout the damage period is necessary to estimate total loss to starlings. At a large feedlot where multiple feed troughs are being used by starlings, 1 or more troughs could be selected randomly for observation. Flush counts of all troughs could provide a relative index to starling use among troughs for extrapolating total starling use of the feedlot.

The trough-visit approach should be applicable to most damage situations regardless of location or climatic conditions. Although this method was developed for the rations tested, we suggest that these models could be extended to other feed types. The trough-visit approach provides feedlot operators with a reliable and practical method of assessing feed loss to starlings and should help evaluate cost-benefits of proposed control measures.

SUMMARY

Regression models of feed consumption rates by starlings on 2 livestock feed types were developed by comparing feed consumption and starling use of experimental troughs measured with time-lapse photography and with film-calculated estimates plus observed estimates of starling visits to these troughs. Individual use of troughs by marked starlings was monitored to estimate the median length of trough visits, and combined with trough-use data to develop film-calculated estimates of trough visits per day. Results suggest that both rates of consumption per bird-minute of trough use and amounts of feed consumed per starling visit are reliable estimators of feed consumption. However, consumption rates based on starling visits may be preferable due to less variation in rates of consumption among feed types and more precision in the use of observers to estimate starling visits. The practical application of this approach for estimating starling losses in feedlots is suggested.

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MOUNTAIN SHEEP RESPONSES TO AERIAL SURVEYS

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Aircraft are used widely for radio-tracking animals, and their uses in wildlife management and research are increasing (Gilmer et al. 1981). Additional use of aircraft in wildlife programs may cause harassment of ungulates especially (Geist 1971, MacArthur et al. 1979, Miller and Gunn 1979). In this study, we asked 2 questions: (1) do overflights by light aircraft disturb mountain sheep (*Ovis canadensis mexicana*) enough to cause them to move to new areas, and (2) will such movements and area changes caused by the aircraft be detected by aerial observers? We report the responses of 32 groups of mountain sheep (211 animals in group sizes of 1–18) to low-flying aircraft between March 1980 and July 1982.

METHODS

In an ongoing study on distribution and movement patterns of mountain sheep in western Arizona, 15 sheep were fitted with radio-collars. The sheep were located during weekly flights in a Cessna 172 or 182. The response of sheep to the airplane was evaluated by a ground observer who located a collared sheep and recorded its behavior plus the behavior of others with it prior to, during, and after 32 overflights (Table 1). Without knowing which sheep was being observed from the ground, the aerial crew located animals from 30 to 300 m aboveground (ag) depending on terrain, weather conditions, and location of animals. Up to 10 passes were made directly over the instrumented sheep during the locating process. We conducted aerial searches between 0600 and 1245 hours.

Aircraft elevations were grouped into 3 categories: <50, 50–100, and >100 m ag. Sheep reactions to the aircraft were classified as not disturbed, slightly disturbed, or greatly disturbed. Sheep that continued their