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COMMUNAL STARLING ROOSTS: IMPLICATIONS FOR CONTROL

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ABSTRACT: Roosting behavior is common to most avian pests of agriculture. Movements from highly aggregated distributions in roosts to highly dispersed distributions on foraging grounds determine pattern and severity of avian pest problems. This research seeks an understanding of how roosting behavior influences the dispersion of avian agricultural pests and the damage they cause. My focus is on why birds form communal roosts and how communal roosting influences the selection of foraging sites. I document patterns of roosting behavior in European starlings (Sturnus vulgaris) through population level studies, followed by analysis of individual behavior using radio telemetry. Starlings maintain long-term fidelity (up to 130 days) to the same diurnal activity center (DAC), while using a variety of roosting sites at night. DACs tend to be at the center of the distribution of roosting sites used by individual birds. These and other results contradict expectations based on the most widely held explanations for roosting behavior and have led us to a new interpretation based on an association between large roosts and high-quality feeding sites (e.g., agricultural fields). Examination of previous attempts to manage avian pest problems in light of these new findings helps explain some earlier successes and failures, and may also promote development of new more efficient approaches to avian pest problems.

INTRODUCTION

Attempts to manage avian pest problems in agriculture likely began soon after the first seed was purposefully poked into the ground by some primitive but ambitious agronomist. Nonetheless, growers are still forced to share their profits with birds, and consumers are still required to subsidize the diets of wild birds with higher grocery bills. Despite the considerable length of the unwelcome relationship agriculture has had with avian pests, attempts at management have largely failed to provide broadly applicable solutions. Problems are still approached on a case-by-case basis, with individual solutions crafted from an arsenal of management strategies limited in both diversity and efficacy.

The integrated approaches that have become in recent years the hallmark of the best pest management strategies (mainly insects) all share the common need for a thorough understanding of the natural system that spawns the pest situation. It is all too easy to forget or ignore the fact that a species is responding to factors beyond the borders of the corn field or feedlot that is being managed for a pest problem. Success in developing management programs is dependent on our understanding how the pest situation is related to other aspects of a species' way of life. Given the mobility of birds, broadly based approaches are particularly important in solving avian pest problems.

Many avian pest problems are not problems of magnitude. Rather they are problems stemming mainly from the dispersion of damage. During 1981 in the central U.S., bird damage to corn averaged only 0.32 bu/ha (Besser and Brady 1986). Figuring only a modest average production of 250 bu/ha, this results in regional losses of less than 1%. For field corn this is surely well below any reasonable economic threshold. However, the true expression of these problems comes at a more local level because the dispersion of damage within the region may be such that certain areas or even individual growers incur devastating losses. Similar patterns exist for other crops such as rice, sunflowers, and fruits, including blueberries, cherries, and grapes. In such situations the pest problem originates primarily from the manner in which birds select feeding areas and only secondarily from the fact that they consume a portion of the crop. If it can be accepted that the dispersion of damage is the real basis for

some of the most serious avian pest problems, then it is an easy step to recognize that the dispersion of damage is a direct result of foraging-site selection.

Communal roosting plays an important part in the daily process of foraging-site selection. The often very large roosting assemblages represent a highly aggregated state from which birds disperse each day to their feeding grounds. It is the transition from highly aggregated in roosts to highly dispersed on foraging areas that determines the pattern and hence the severity of crop damage.

Most avian pests of agriculture form communal roosts. DeGrazio (1976) examined avian pest problems on a worldwide basis and identified a total of 97 categories of problems. Of these 74 were either directly related to roosting activities or involved species that formed roosts at times when the problems were most severe. Because roosting behavior plays such a prominent role in the daily dispersion of birds in their foraging habitats, and because it is such a common characteristic of avian pests, understanding the biological basis of roosting systems will surely play an important role in the eventual development of integrated approaches to avian pest problems.

Despite over 500 papers published on avian communal roosting in the past 50 years (Allen and Young 1982), this behavior remains poorly understood. There is still no broadly accepted explanation for why birds form roosts or how various patterns of roosting behavior are influenced by environmental factors. Without such understanding it seems unlikely that predictive tools will be developed similar to those that have formed the basis for successful insect pest management strategies.

The immediate goal of my research is to understand the factors influencing the dispersion of avian agricultural pests and how these are related to foraging-site selection. My initial questions have focused on why birds form communal roosts and how communal roosting affects the selection of foraging sites. My approach has been to document patterns of roosting behavior through population level studies followed by analysis of roosting behavior for individual birds using radio telemetry. In the near term such information may help to explain some of our failures in the management of avian pest problems and also help with the efficient application of

current solutions. Ultimately, this work should provide a better understanding of the basic biology of the pest system and thereby contribute to the eventual development of effective and efficient integrated approaches to avian pest management.

BACKGROUND

Some Explanations Why Birds Form Communal Roosts

Several competing hypotheses have been offered to explain why birds form nighttime roosts. Foraging-based explanations propose that roosting enhances foraging opportunities such that individuals that roost are better able to meet dietary requirements. Nonforaging-based explanations propose that by joining roosts individuals gain protection, either from climatic conditions or from predators. For roosting systems typical of avian pests, protection from climatic conditions has been largely discounted on the basis of empirical evidence (e.g., Yom-Tov 1976, Kelty and Lustick 1977, Walsberg and King 1980). Similarly, the importance of predator protection in the formation of very large roosts has been questioned on theoretical grounds (Pulliam and Millikan 1982) and empirical evidence (Caccamise et al. 1983, Morrison and Caccamise 1990), although the possible importance of mutual protection has been recognized as a factor in the formation of small local roosts common during certain times of the season (Caccamise et al. 1983, Caccamise and Fischl 1985).

The information center hypothesis (ICH, Ward and Zahavi 1965) is by far the most widely cited and intensely studied explanation for communal roosting behavior (e.g., Mock et al. 1988). Under the tenets of the ICH, birds must often switch to new feeding sites because food patches are ephemeral. Birds learn the location of new sites by flying to a roost where they are able to identify successful foragers by their behavior. By following successful foragers to their feeding areas, individuals in need of a new feeding site can locate food without facing the risks and costs inherent in an independent search.

Despite the apparent broad appeal of the ICH, unambiguous tests to support or refute it have proven very difficult to construct (e.g., Kiis and Moller 1986, Loman and Tamm 1980). Nonetheless there are at least two predictions that present reasonable opportunity for investigation. The first is that birds joining roosts in order to gain information should change feeding areas more often than roosts. The second is that the roost should be roughly at the center of the distribution of the foraging areas for any individual bird. Both follow from the suppositions that (1) successful and unsuccessful foragers return to the roost, and (2) the roost is the location where unsuccessful foragers learn the location of new foraging sites.

Our studies of roosting behavior have shown that neither of these expectations (as well as others) holds true for European starlings (Sturnus vulgaris), and are unlikely to apply to several other roosting species for which we have similar but less complete information (Red-winged blackbirds, Agelaius phoeniceus; Common grackle, Quiscalus quiscula; American robin, Turdus migratorius; Common crow, Corvus brachyrhvnchos). As a result we proposed a new working hypothesis that takes into account our observations on roosting and foraging behavior of radio-tagged starlings.

Observations Leading To A New Explanation For Communal Roosting In Starlings

Our initial studies of roosting behavior in central New Jersey were designed to examine how avian pests used roosts to locate feeding sites (i.e., agricultural fields) during periods of peak agricultural damage. Our goal was to develop predictive tools that would allow management efforts to be concentrated where birds were going to cause the most trouble.

My study area in central New Jersey is comprised of typical urban and suburban habitats intermixed with agricultural fields and woodlots (Fischl and Caccamise 1985). We located and monitored size of all roosts within this 1000 k^2 area over several years. Starlings begin to roost in early summer near the end of the breeding season (Caccamise et al. 1983). At first roosts are small and numerous, but as the season progresses the number and size increase until both peak near the middle of summer (Fig. 1). Later the number declines as small scattered roosts coalesce into the large roosts typical of the period near the end of the local roosting season (early November).
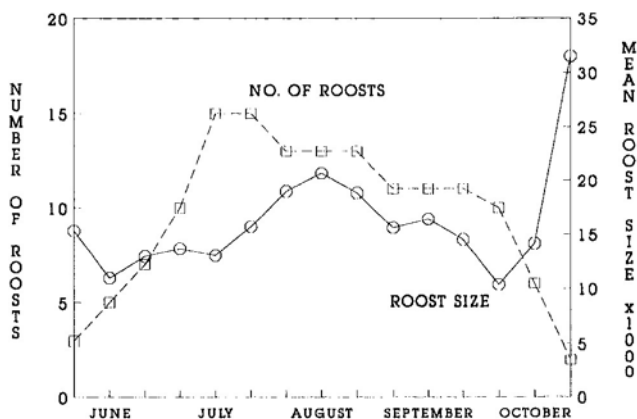

Figure 1. Relationship between number of roosts (>2000 birds) and average roost size for all large (>2000 birds) roosts in the study area throughout one roosting season.

Our radio-telemetry studies of roosting starlings (Morrison and Caccamise 1985) revealed that individual starlings returned day after day to the same 1-2 km^2 feeding area. We coined the term "diurnal activity center" (DAC) to refer to the spatial clustering apparent in the diurnal sightings made on individual starlings during the roosting season (June - November, Fig. 2a). Subsequent studies have shown that DACs are not unique to starlings. We have found similar patterns in several other roosting species, although our data are far less complete than those for starlings (Fig. 2b-d). Common grackles and American robins which roost communally with starlings, establish starling-like DACs after leaving their breeding territories (Bovitz and Caccamise, in review; Morrison and Caccamise 1990). Similarly, Red-winged blackbirds and American crows show fidelity to specific feeding areas while commuting to distant roosts (Caccamise

and Stouffer, unpubl. data). Other researchers have provided corroborating evidence for DAC-based roosting behavior through qualitative descriptions of communally roosting birds: Red-winged blackbirds (Johnson 1979), Wing-tagged starlings (Feare 1984), Cattle egrets (Siegfried 1971), and great blue herons (Krebs 1974). The number of communally roosting species showing pronounced DAC fidelity will likely increase as more studies are done using marked individuals.

Home range analyses (Samuel et al. 1983) of telemetry locations are very similar for all roosting species examined so far. Utilization distributions for DACs are all highly concentrated within a relatively small area (Fig. 3). Nonetheless, some variations in the ways in which DACs are used are apparent among species. For example, American robins have small-focused DACs; grackles tend to have larger less well-defined DACs; starlings are the most faithful of all species to their DACs; and red-wings are least faithful to their DACs. But in all cases the DAC is clearly defined, with no indication of the type of "patch switching" assumed under the tenets of the ICH.

Starlings are far less faithful to roost sites than to their DACs. During our observation periods (radio life = 70-140 days) individual starlings commuted 3 to 12 kilometers to as many as 12 different roosts (mode = 7). They appeared at a new roosting site an average of 7.8% of the nights they were observed (Morrison and Caccamise 1990). High turnover rates at roosts have been shown in other studies as well (Heisterberg et al. 1984). The result of such roost switching is that over time an individual's DAC tends to be central to the distribution of roosts used by that bird (Fig. 4). This is quite different from the "roost-centered" relationship predicted by the ICH.

Roosting starlings spend all or most of each day feeding or loafing on their DACs. However, beginning as early as mid-August, DAC-based birds begin to utilize feeding sites away from the DAC. We coined the term "supplemental feeding area" (SFA) to refer to food sources clearly outside the DAC; i.e., more than 1 k from the DACs nearest boundary (Caccamise and Morrison 1988). The SFAs are most often used on the morning and evening commute to distant roost sites. SFAs were typically seed-rich substrates such as agricultural fields and feedlots, or stands of fruiting trees. For starlings, SFA's generally represent the foraging areas involved in pest situations. These areas appear to be used at times when DACs fail to provide adequate food.

For example, Fig. 5 shows a map of the spatial relationships between roosts, DAC, and SFA of the first radio-tagged starling we found using an supplemental feeding area. This individual had a DAC (site 1) in the southern portion of our study area which it used very faithfully on every day that it was checked. It roosted at night in a nearby local roost (site 2) just 1.25 k away. At a normal roost check in mid-August it was discovered roosting at a site 9 k to the north (site 3), although the roost at site 2 was still active. At sunrise on the morning after its initial discovery at site 3, we followed it out of the roost. It went directly to a ripening corn field just 1 k to the southeast (site 4). It remained there for about 45 minutes (presumably feeding) before proceeding to its normal DAC. This pattern was observed several more times over the remaining life of its radio transmitter. Since this initial example, numerous similar observations of many other radio-tagged birds led us to conclude that travel to distant roosts and use of associated feeding sites were often clearly related.
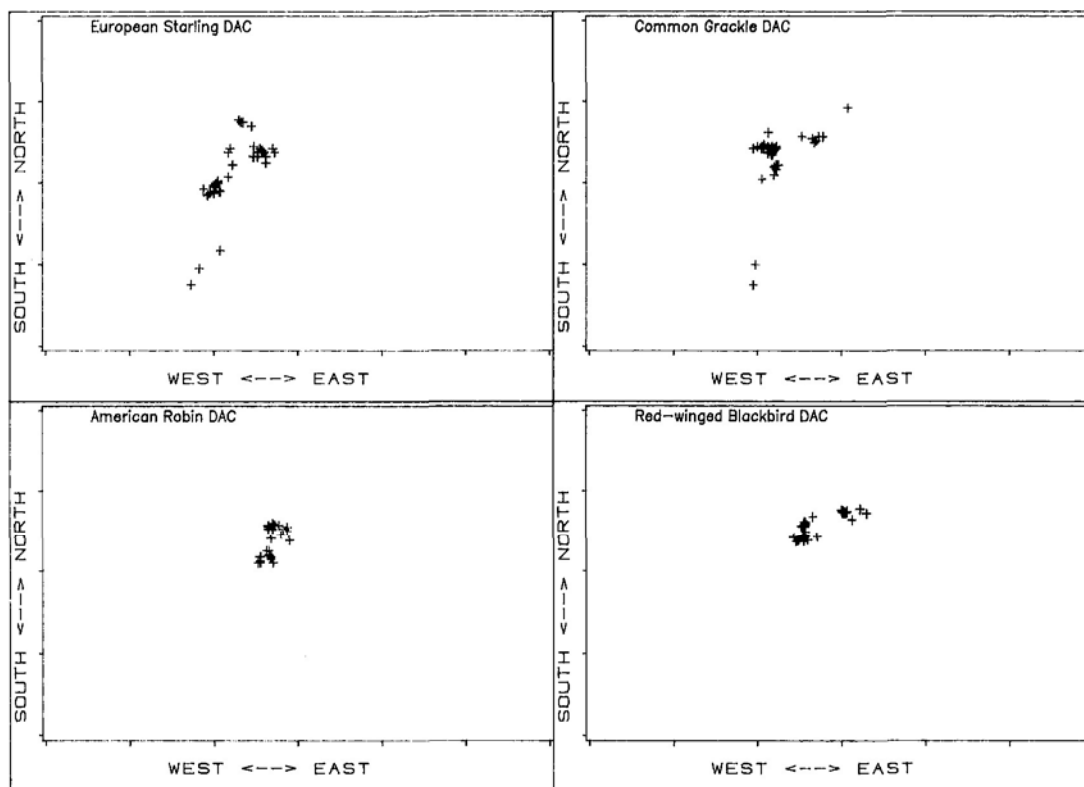

Figure 2. Spatial clustering of locations for 4 species of radio-tagged birds showing fidelity to small diurnal activity centers. Periods of observations were starling - 103 days, grackle - 100 days, robin 103 days, red-wing - 75 days; vertical and horizontal tick marks are 4 k apart.
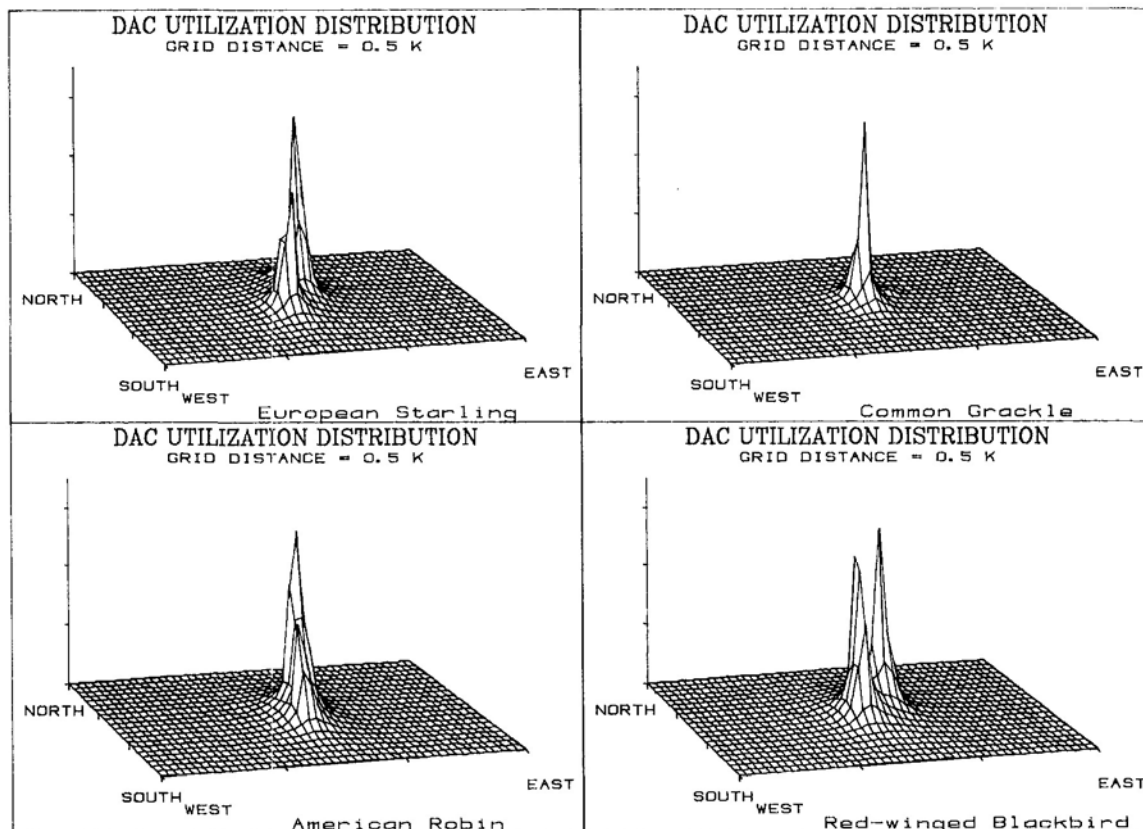
Figure 3.   Home range analysis showing concentrated DAC utilization distributions for 4 species of radio-tagged birds (see Fig. 2 for observation periods).
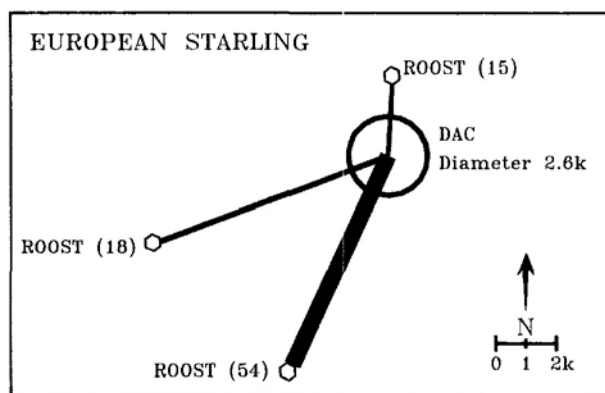

Figure 4. Spatial relationships between the DAC (large circle) and roost sites (small hexagons) used by one radio-tagged European starling.   Width of lines connecting DAC with roosts are proportional to number of times each roost was used (parenthetic number). This shows that the DAC tends to be at the center of the distribution of roost sites.

A New Explanation For Roosting.

It appeared to us that the most widely held explanation for why birds roost (ICH) could not apply tot the starlings (and perhaps other species) we were observing; a new interpretation was necessary. We proposed an explanation taking into account the DAC-based behavior and the use of SFAs we had observed (Caccamise and Morrison 1986). I have summarized below the observations and assumptions that form the basis of our interpretation of roosting behavior in starlings.

Observations:
1. The pattern of starling foraging dispersion is DAC-based throughout the post-breeding roosting season (June-November).
2. Early in the season (June - mid-August) starlings forage mainly on their DACs and use nearby roosts at night.
3. Late in the season (mid-August – November) starlings often use a variety of large more distant roosts.
4. The basis of the starling diet changes from primarily invertebrates early in the season to mainly fruits and grains later. This is indicated by changes both in diet composition and foraging habitat preference. The change occurs at about the same time starlings begin to (1) forage at sites off the DAC, and (2) use larger more distant roosts.
5. Late-season roosts are usually associated with high-quality food patches that are heavily exploited by starlings, particularly during morning and evening commutes between roost and DAC.
6. Juvenile starlings show adult-like patterns of DAC and roost use soon after they gain independence.

Assumptions:
1. DAC fidelity is beneficial.
2. Starlings forage in a manner that ends to maximize their net rate of energy gain; i.e., they tend to minimize the amount of travel necessary to reach foraging areas while maintaining DAC fidelity.
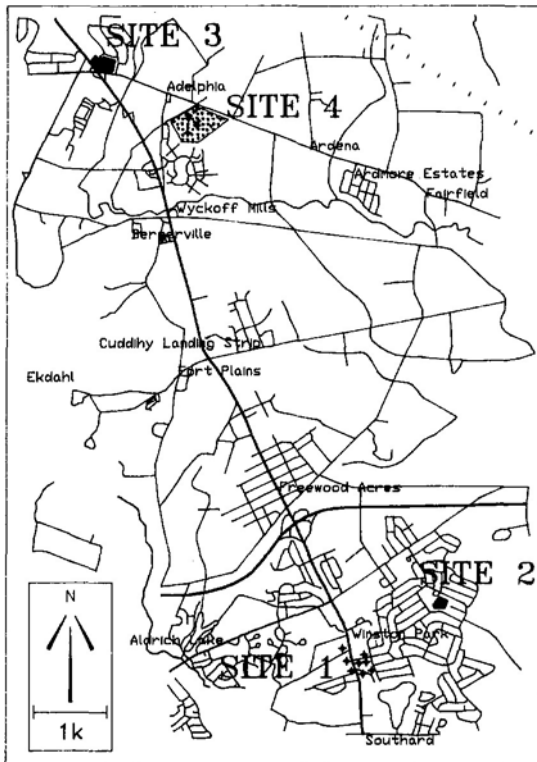
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Figure 5. Map of the Spatial relationships of a DAC, SFA, and two roosts used by a radio-tagged bird. Site 1 (small circles with cross) is the DAC; Site 2 (dark area) is the small local roost used early in the season; Site 3 (dark area) is a large distant roost; Site 4 (spotted area) is an SFA (ripe corn field) used by the radio-tagged bird and presumed associated with roost at Site 3.

Interpretation:

DACs likely serve a number of purposes, but clearly foraging is one of the more important benefits, particularly early in the season when invertebrates make up a large part of the diet. When most foraging occurs on the DAC, starlings form small roosts that are located near the DAC. These serve mainly for mutual protection (e.g., predation protection). Beginning in August starlings no longer are able to meet their requirements by foraging only on the DAC. They seek supplemental food sources by traveling to distant roosts and feed at high-quality sites near or along the way to (or from) distant nighttime roosts. By feeding during morning and evening commutes, starlings are able to forage twice at high-quality sites for the travel costs of a single round trip. By changing roost sites on different days starlings are able to evaluate the quality of potential feeding sites and select those that provide the best compromise between travel distance and foraging substrate quality.

IMPLICATIONS FOR MANAGEMENT

The immediate goal of my research is to understand the biological basis of pest situations. At such an early stage in the development of our ideas, it is difficult to leap directly to techniques for the management of avian pest problems; much remains to be learned. Nonetheless, there may be some opportunity for benefit by examining some avian pest problems in light of what we have learned about starling roosting behavior.

It has always been perplexing why it is so difficult to move or induce abandonment of large roosting assemblages. The monumental efforts to manage problems associated with large roosts at places like Graceham, Maryland, and Fort Cambell, Kentucky, are well known (e.g., Robertson et al. 1978). Short of eradication, little success has been achieved at inducing site abandonment once roosts become established. Yet, if the birds congregate at these sites because of the associated food sources (e.g., SFAs) rather than the characteristics of the sites, then the intransigence of the roosting populations is easier to understand, particularly in consideration of the very high day-to-day turnover rates at roosts (Heisterberg et al. 1984, Morrison and Caccamise 1990). For example, one of our very large fall roosts in central New Jersey formed for several years less than 1 k from a large corn field. Each year the birds did considerable damage to the corn until finally the field was left permanently fallow. That year the roost failed to form, and it has not formed in any succeeding year. In that same year, one of our radio-tagged birds with a DAC at some distance from the abandoned corn field spent 2 successive nights alone at the old roost site. Why would a lone starling fly a considerable distance to sit alone in an abandoned roost? This suggests that the corn field was the main attraction at this roost and our radio-tagged bird went there in search of it. Not finding corn, it went on to the next closest roost (where we subsequently found it) which was adjacent to an active grain field. I would propose that this bird traveled to the first roost because previous experience had taught it that corn was available there-not because of the site itself or the roostmates it found there. Therefore, trying to dissuade roosting birds by implementing a control program at the roost is bound to be difficult when the birds select roost sites mainly for the food they find nearby.

Staging areas or preroost assemblies (Stewart 1973) have long puzzled biologists. Viewed in terms of DAC-based roosting it becomes clear that in many cases staging areas are actually SFAs. For example, West (1968) managed to kill 150,000 starlings by baiting at a staging area, clearly indicating that the birds readily fed there. On the other hand Boyd and Hall (1987) were unable to lure American crows to baiting stations placed only a short distance from normal staging areas. However, when treated baits were placed right at staging areas, the crows readily took them making lethal control quite practical. We had a similar experience while capturing crows for our radio-telemetry studies. Even highly attractive baits (chicken eggs) failed to lure crows from traditional staging areas only a very short distance away (0.5 k). Yet the eggs were readily taken when moved to the staging area. If crows stage at a site where food is abundant (SFA), then it is easy to understand why alternate foods only a short distance away fail to attract them; they do not need the alternate food.

The traditional view has been that damage is worst near roosts (e.g., Besser et al. 1972, Johnson 1979). Perhaps a more useful interpretation is that roosts often form near food sources and these are exploited. Of course birds need both a place to feed and a place to roost, so the most severe damage will occur where both resources are available. Knowing why birds choose particular roost sites will not directly lower damage, but this information might be useful in designing management strategies. For example, lethal control at roosts might be more efficiently implemented or, alternately, less destructive approaches to management may be

easier to recognize when the reasons are known why birds choose particular roost sites. Such information can also help growers decide to select alternate crops for fields adjacent to likely roosting sites.

Starling depredation at feedlots is one of the more important avian pest problems in some parts of the U.S., and provides another example of how consideration of DAC-based roosting behavior might have a direct impact on the development of management strategies. In selecting techniques for managing avian pest problems at feedlots, it is important to consider whether the birds causing the problem are (1) DAC-based at the feedlot, (2) using the feedlot as a supplemental feeding area, or (3) some combination of the two. From the standpoint of management, the simplest situation would have the pest population DAC-based at the feedlot. Lethal control programs designed to reduce the resident population could be very efficient (cost per bird removed) because they would only have to deal with a relatively small population, and they would need to be implemented only over a relatively short interval. A possible complicating factor is that at this point we have no information on how quickly birds removed from DACs are replaced, or what actually limits the number of birds using any particular feedlot.

If the feedlot is being used as an SFA, the problem becomes vastly more difficult because of the greater effective size of the pest population. Our radio-telemetry studies show that individual birds usually use a variety of SFAs, each over a relatively short interval. The result is that from day to day birds at a feedlot would likely originate from DACs over an extensive area and there would be a high turnover in the pest population.

Studies of marked starlings at a Kentucky feedlot (Glahn et al. 1987) show very conclusively that the feedlot was being used by two sub-populations: (1) resident DAC-based birds, and, (2) transients using the area in much the same way as we have seen for birds using SFAs at some distance from their DACs. When feedlots are used as SFAs the efficiency of lethal control is much lower than when the pest population is composed of DAC-based residents. Not only is the effective size of the population much larger, but the transient nature of the birds on an SFA requires far greater materials and effort applied over a far longer interval. The net effect is lower efficiencies and higher costs for management.

Strategies might be better focused on factors influencing how birds select SFAs. If starlings choose SFAs on the basis of a compromise between travel distance and feeding rates (as we have suggested), then decreasing the feeding efficiency at the feedlot even a small amount would likely significantly reduce the number birds electing to use that site as an SFA. For example, Twedt and Glahn (1982) showed that changing the physical characteristics of the feed at a feedlot substantially reduced the amount of feed starlings took. Food pellets of inappropriate size likely decrease feeding efficiency for starlings, making alternate foods, or alternate feeding places, better (more efficient) choices.

Another possible approach is based on the observation that DAC-based birds use SFAs primarily during morning and evening commutes between DAC and roost. These are the times when losses of cattle feed are likely most severe. Minor adjustments in feeding schedules near dawn and dusk might lower the suitability of a feedlot as a potential SFA, thereby lowering the size of the transient pest population. And finally in some cases it might be possible to make travel distances

between roost and SFA unacceptable by modifying or eliminating traditional roost sites (e.g., Lyon and Caccamise 1981).

I have tried to show by example how a better understanding of the biological factors behind pest situations may improve our ability to manage some problems. Our results on starling roosting and foraging are far from complete and may yet undergo substantial modification as work continues. Notwithstanding changes in interpretation of biological properties of pest situations, surely our ability to deal with avian pest problems will be substantially enhanced when techniques are founded on an understanding of the biological system that spawns the pest situation.

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