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BIRD STRIKE HAZARDS AND WASTE MANAGEMENT FACILITIES IN URBAN LANDSCAPES

Donald F. Caccamise, Lisa M. Reed
Department of Entomology, Rutgers University
New Brunswick, NJ 08903

Jerzy Romanowski
Department of Vertebrate Ecology, Institute of Ecology
Polish Academy of Science, Dziekanòw, Lomianki, 05-150, Poland

Summary

Airports and waste management facilities have similar siting requirements resulting in a tendency to place waste facilities near airports. Putrescible materials associated with many types of waste facilities can attract large numbers of birds, particularly gulls. Here we assessed avian use of 4 types of waste management facilities. Our goal was to characterize the avian communities attracted to these facilities providing information that can be used to assess the actual risks to air operations posed by the waste facilities. Our most revealing observations were the considerable variation we found in attractiveness to birds among the types of waste management facilities and among the individual facilities within types. These differences were based on factors including: (1) volume of waste material processed, (2) physical characteristics of the facilities, (3) cleanliness of the operation, and (4) nature of the avian community near the facilities. With many factors affecting the size of bird populations attracted to waste facilities, generalizations concerning potential interference of these facilities with safe air operations are difficult. It is clear that most facilities do attract birds, some considerable numbers. Nonetheless, other factors, including how the facility is operated can influence the impact on local bird populations and must be considered in any evaluation of bird strike hazards. proceedings

(Key words: airport, bird strike, landfills, waste management, trash transfer stations, compost)

1. INTRODUCTION

Airports are best located near surface transportation networks, yet away from concentrations of human activity. At the same time they must be reasonably close to the urban centers that require air service. Unfortunately these same characteristics apply equally well to the siting requirements for waste management facilities. In many areas waste disposal problems are growing worse because many of the older waste storage facilities are nearing capacity, thus requiring new sites and new technologies to manage waste material. As a result there is an increasing tendency to propose sites for various types of waste management facilities near major airports. The amounts of putrescible materials associated with many types of waste management facilities can attract large numbers of birds, particularly gulls. When these sites are located near airports the presence of birds presents a significant risk of bird strikes with aircraft resulting in unacceptable danger to air traffic.

The hazard posed by waste management facilities varies depending on a variety of factors including (1) the location of the facility in relation to the airport, (2) the characteristics of the surrounding landscape features, (2) the nature of the native avian communities present naturally in the region, (3) the quality of the waste material present at the facility, and (4) the manner in which the waste material is processed. Solid waste practices vary considerably depending on a variety of factors including local traditions, regulations, density of the human population, and local geographical features. Nonetheless, in recent years changing needs in many areas has led to the replacement of traditional waste management practices with newer technologically based methods. The newer methods are often specially designed to address particular waste management problems like the disposal of vegetative waste, or non-putrescible matter such as incinerator ash. In some highly populated areas, waste is re-packaged at trash transfer stations for shipment to other sites for eventual recycling, incineration, or entombment. Each waste handling technique including composting operations, construction landfills, sanitary landfills, and trash transfer stations offers its own unique set of characteristics that interact with the local avian communities in particular ways. It is the result of these interactions that determines the actual risk posed by the waste management facility.

In this study we assessed avian use of various kinds of waste management facilities. Our goal was to provide information that could be used to assess the potential danger to air operations posed by the attractiveness of the waste management facilities to birds. Our approach determined the numbers and species of birds associated with 4 types of waste management facilities located at 7 different sites located in the mid-Atlantic coastal region of the United States. We conducted regular bird survey at our study sites over a complete annual cycle.

2. METHODS

We selected 2 general areas in coastal New Jersey for our studies (Fig. 1). In the southern area, we sampled 5 sites representing 4 types of waste management including 1 solid waste landfill (Galloway with 2 locations), 1 township composting facility (Galloway compost), 2 trash transfer stations (ACUA and CTS), and 1 construction/demolition facility (Winzinger). In

the north, we sampled 2 sites that included 1 large solid waste landfill (Edgeboro with 3 locations) and an associated vegetative waste composting facility (Edgeboro compost). All sites were surveyed 5 days per week from the week of 3 June - 4 August 1991, 3 times per week from the week of 11 August - 18 August 1991, and twice per week from the week of 25 August 1991 through May 1992.

Surveys at landfills consisted of direct enumeration to estimate total number of birds present by species. Due to the size of the landfills several non-overlapping locations were used to ensure counting all the birds. Locations were summed to provide an estimate of the total number of birds directly associated with each landfill.

Galloway Township Landfill was permanently closed at the end of December 1991. On 20 January 1992 Edgeboro-II (next to Edgeboro-I) opened and gradually replaced operations at Edgeboro-I. Our estimates of bird populations sizes represent pooled values for both Edgeboro-I and II.

At the 2 composting sites, vegetative material was piled in long rows spaced approximately 30 m apart. Birds were counted by traveling along the access road which ran perpendicular to the rows of compost. This provided an unobscured view down the length of each row. Surveys were generally conducted from within a vehicle driven slowly along the road. At times a barrier prevented automobile access to the composting areas in which case the survey was performed on foot.

At the remaining 3 sites (CTS, ACUA and Winzinger Landfill) surveys were based on a modified variable circular plot method (Reynolds, et al. 1980). At predetermined sites the observer counted all birds seen or heard over a 3 minute interval. For each bird or group of birds identified we made an estimate of the horizontal distance from the sample point to the bird (or group of birds). Birds flushed while approaching a point (before the count period started) were also recorded using the distance from the point to where they were first observed as the detection distance. By assuming that the flushed birds would have been counted in the normal survey interval we attempt to minimize the bias of under counting the more easily frightened birds or those that happen to frequent areas near the sample sites.

3. RESULTS AND DISCUSSION

3.1 Solid Waste Landfills

The most abundant birds at both solid waste landfills were the Herring Gull, *Larus argentatus*, Laughing Gull, *L. atricilla*, Great Black-backed Gull, *L. marinus*, Ring-billed Gull, *L. delawarensis*, European Starling, *Sturnus vulgaris*, and American Crow, *Corvus brachyrhynchos*. These 6 species accounted for nearly 87% of all individuals observed at either site (Table 1). Thus, species richness was low in comparison to the nearby communities in more natural settings. At Edgeboro we found only 23 bird species and at Galloway we found 28 species.

All 4 species of the common gulls in New Jersey occurred at the landfills. The Great Black-backed Gull and the Herring Gull were most abundant in the winter months while the Laughing Gull and the Ring-billed Gull were most abundant in summer months. The number

of Laughing Gulls differed at the solid waste landfills with the smaller landfill (Galloway) attracting fewer birds. At Edgeboro we recorded on average 118 (SE=11.5) Laughing Gulls per survey, while at Galloway we found 38 (SE=6.4). Laughing Gulls showed a seasonal difference in use of landfills as they were present only from late spring to early fall, and absent the rest of the year. Their absence reflected migratory patterns, as Laughing Gulls leave the northeastern US in fall to winter in the southern US, and Central and South America (Belant and Dolbeer 1993).

At Edgeboro Laughing Gulls showed 2 peaks in abundance. Before the nesting season in early spring (March - May) numbers of Laughing Gulls peaked at a mean of 498 gulls/survey (SE = 154). This early peak was followed by a period of low numbers coinciding with the breeding season (June, July). Near the end of July a second peak developed (mean = 378 gulls/survey, SE = 122) which persisted through migration in October. At Galloway we found a similar pattern. However, we observed only the post breeding peak of the first season (June, July) because the landfill closed in late December 1991. The pre-breeding peak (March - May) failed to develop the following spring after the landfill closed.

As with Laughing Gulls, the number of Ring-billed Gulls differed between the landfills. Over the entire season we recorded more Ring-billed Gulls at Edgeboro (mean = 29 gulls/survey, SE=4.1) than at Galloway (0.5 gulls/survey, SE=0.2). Ring-billed Gulls were uncommon at Galloway Landfill throughout our study. They did not appear in our samples until the biweek of 16 July and remained uncommon through the summer. It was unusual that they reached their maximum abundance of 6.2 birds/survey in the biweek of 17 December, a time when most ring-bills had left the study area. Another important difference between the 2 landfills occurred in the fall. Ring-bills at Edgeboro showed a distinct fall peak in numbers (maximum mean per biweek = 253 gulls/survey) while numbers remained relatively constant at Galloway. The fall peak at Edgeboro likely represented a pre-migratory assemblage, yet no similar pattern developed at Galloway.

Herring Gulls were very abundant at Edgeboro in winter. They averaged about 2,500 birds/survey (SE = 524), and dwarfed all other bird species including Laughing Gulls in spring (peak numbers about 500 birds/survey, SE = 154). The concentration of Herring Gulls in winter suggested a pronounced dependence by this species on the anthropogenic foods available at the landfill. The mean number of Herring Gulls/survey at Edgeboro was 765 (SE=63.0), while at the smaller Galloway landfill it was 132 birds (SE=19.5). At Edgeboro and Galloway numbers of Herring Gulls were highest in the winter months and lowest in summer.

The number of Great Black-backed Gulls at Edgeboro (57 gulls/survey, SE=13.0.) was higher than at Galloway (5 gulls/survey, SE=1.1). Great Black-backed Gulls were similar to Herring Gulls in their seasonal use of landfills; highest abundances occurred during the winter and lowest in summer. At Edgeboro Great Black-backed Gulls were about as abundant in fall and winter as Laughing Gulls were in summer. Numbers of Great Black-backed Gulls remained low throughout our study at Galloway, showing only a small influx in late fall. As with Herring Gulls, Great Black-backed Gulls disappeared from Galloway in early March.

The American Crow was the most seasonally persistent bird species at the landfills. Their numbers were never large in comparison to the gulls, but they were present consistently

throughout the entire study period. We know from collateral studies on crows that the number of crows recorded represented only a small fraction of the birds that actually used the landfill daily (Stouffer and Caccamise 1991). This was because individual birds came and went on a regular basis through the day, so at any given moment only a small percentage of the population using the landfill was actually present.

Overall crows were about 4 times more abundant at Edgeboro than at Galloway (20.5, SE=1.59; 4.8 mean birds/survey, SE=0.60 respectively). The seasonal pattern in abundance was different between the landfills. There was a very large winter population that used Edgeboro through the winter. Numbers peaked in December at 59 crows/survey, SE = 20. At Galloway there was a rapid decrease in crow numbers in early winter followed by constant low numbers after December.

European Starlings were present at both landfills, but their numbers were substantial only from fall through spring and only at Edgeboro. Starlings were more than 125 times more abundant at Edgeboro than at Galloway (mean number of birds per survey were 166, SE=25.3 and 1.3, SE=0.42 respectively). Starlings are known to congregate at concentrated food supplies at times of the year when more typical foods may be in short supply (Morrison and Caccamise 1985). In New Jersey this occurs most often in winter when invertebrates and fruits are uncommon in preferred habitats. Starlings were most abundant at the landfills during December and January as compared with the rest of the year. However, seasonal patterns in numbers of starlings differed at Edgeboro and at Galloway. Numbers of starlings were far more variable at Galloway with starlings absent in some biweeks during winter periods when peak numbers occurred at Edgeboro. Like crows, numbers of starlings actually using the landfill were likely considerably higher than the numbers we recorded. This is because starlings used such sites to feed for brief periods, then returned to their more traditional diurnal habitats. Our counts provided only instantaneous estimates of numbers, and as such did not account for the turnover of birds during the course of the day.

Turkey Vultures *Cathartes aure* were almost always present at both sites, but their numbers were generally lower at Edgeboro (mean = 0.29 birds/survey with SE=0.07) than at Galloway (1.19 birds/survey with SE=0.17). Nonetheless, the large mass of this species and their propensity for soaring high on thermals and updrafts makes vultures deserving of special attention in terms of bird strike hazards. They were generally present during the summer and absent during winter, but we did record them at Galloway in February and March.

We regularly recorded several other species at the landfills, but they were relatively minor components of the overall avian communities (mean < 1 bird/survey). Fish Crows *C. ossifragus* were present at Galloway in early summer, but their numbers were very low. They breed commonly on the salt marshes near Galloway and likely showed up at the landfill following their breeding season. Rock Doves, *Columba livia* were also present in low numbers at Edgeboro (mean = 0.6 with SE=0.13), but they were absent from Galloway. Edgeboro is in a much more urbanized region of the state than Galloway. The Rock Doves at Edgeboro were probably either local to the landfill or they may have been from nearby urban populations that only come to the landfill periodically to feed. The number of doves seen each biweek did not differ appreciatively over the season. Common Grackles, *Quiscalus quiscula* were sufficiently abundant to meet our criteria for analysis (i.e., at least 1 survey week with mean number of birds>1), but they were occurred at Galloway only briefly during 1

week in early October. These were probably migratory birds that were simply passing through the area.

Although Galloway Township Landfill closed near the end of December 1991, we recorded more bird species there than at the much larger Edgeboro Landfill. This apparent anomaly occurred because a small wetland and adjacent woodland located on one edge of the Galloway Township Landfill attracted some bird species that actually did not use the landfill (e.g., American Robin *Turdus migratorius*, Glossy Ibis *Plegadis falcinellus*, Great Blue Heron *Ardea herodias*). The wetland had to be included in our survey because many of the gulls used the area for loafing when they were not actively foraging on the landfill. Our counts at Edgeboro were confined to the top of the landfill which was quite large enough to provide plenty of loafing areas for the non foraging gulls.

We found a total of only 11 bird species that averaged more than 1 bird/survey but several that were very abundant (e.g., gulls). In general numbers of birds at Edgeboro were much higher than at Galloway. This might be expected considering that the average amount of waste material processed per day at Edgeboro is approximately 55 times greater than the amount received by Galloway (2,600 versus 47 tons/day). Most of the bird species detected in our surveys averaged less than 1 individual/survey. These we considered uncommon and incidental to the landfill operations, and they were not included in any further analyses. They appeared in our surveys because they were using habitats surrounding the landfills.

3.2 Trash Transfer Stations

We recorded a total of 26 and 22 species respectively at the Atlantic City Utilities Authority Trash Transfer Station (ACUA) and the Cardiff Transfer Station (CTS) (Table 1). As with the landfills, Laughing Gulls, American Crows, and European Starlings were abundant. Wood Thrushes *Hylocichla mustelina* were abundant at CTS but not at ACUA. Three Passeriformes and 1 Charadriiformes accounted for nearly 70% of all the birds seen at the trash transfer stations. Species of Ciconiiformes, Falconiformes, and Galliformes occurred at ACUA, but were absent from CTS.

Many of the species recorded at these trash transfer stations were unaffiliated species. These we define as species that were present at the sites because they were components of the natural surrounding communities and not specifically attracted to, or associated with the trash processing facilities. For the most part, differences between sites were in the unaffiliated component of the avian communities, and were based mainly on variations in habitat availability in the immediate vicinity of the facilities. For example, at the ACUA Little Blue Herons *Egretta caerulea* and Glossy Ibis were attracted to the site because of an adjacent wetland, rather than any affinity displayed by the species for the waste management facility itself. Other differences can be attributed to chance observations of species generally uncommon at these sites (e.g., Ovenbird *Seiurus aurocapillus,* Red-tailed Hawk *Buteo lagopus*), and provide little insight into specific affinities for waste management facilities exhibited by individual bird species.

At the 2 trash transfer stations we found 13 species that we considered abundant (mean number of birds/survey >1 for at least 1 biweek interval). Except for the gulls and starlings,

we considered these unaffiliated species whose presence was generally unrelated to the operation of the trash transfer stations.

Gull abundance at trash transfer stations was low in comparison to the landfills. The highest single biweek abundance for Herring Gulls at transfer stations occurred at CTS (8 birds/survey with SE=2.04). Herring Gulls were more numerous at CTS (mean = 0.78 birds/survey and SE=0.19) than at ACUA (mean = 0.02 birds/survey and SE=0.01). Laughing Gulls averaged from 4-7 birds/survey over most of July and August making them the most common gull overall. Like Herring Gulls, Laughing Gull numbers were higher at CTS than at ACUA (mean at CTS = 2.02, SE=0.37; mean at ACUA was 0.44, SE=0.13 birds/survey). Ring-billed Gulls were uncommon at CTS and absent from ACUA, while Great Black-backed Gulls were never detected at either site. As at the landfills, Laughing Gulls were most common in the warm months and Herring Gulls were most common in the colder months. Due to the low and variable numbers of Ring-billed Gulls at CTS, no seasonal differences were found between the two sites.

Common Grackles, and Rock Doves were generally more abundant at CTS than at ACUA. Grackles were present at ACUA for only 1 biweek in spring, thus the mean number of birds/survey was only 0.03 (SE=0.02) at ACUA as compared to a mean of 0.18 (SE=0.06) at CTS. Grackles also differed seasonally with higher numbers of birds in spring and fall than at other times. Rock Doves were present at CTS (mean = 0.15 birds/survey), but were absent at ACUA.

The Killdeer *Charadrius vociferus* was the only species with appreciably greater numbers at ACUA (mean = 0.09, SE=0.04) than CTS (where they were absent). The presence of Killdeer at ACUA occurred because a patch of their preferred habitat (an open field) was available adjacent to the transfer station building.

Representatives of the avian communities from the surrounding habitats were present at both transfer stations. Abundance of the following species were similar at both transfer stations: American Crows, American Robins, Mourning Doves *Zenaidura macroura*, Northern Mockingbirds *Mimus polyglottis*, and Tree Swallows *Tachycineta bicolor*. Abundance of American Crows tended to be equal at both sites or higher at ACUA, but in early July the relationship was reversed as there were more crows at CTS. However, there were no crows seen at CTS from fall until the last biweek in the study in May. At ACUA crows were seen throughout the study period. The low numbers of crows at both sites suggests that territories of family groups occupied the areas near the trash transfer stations, and were not specifically associated with transfer stations. American Robins increased in numbers at both sites during the last biweek of the study. This period coincided with the breeding season of robins, and may reflect an increase in either territorial displays or in foraging to feed their young.

The differences we found in bird numbers and species composition between 2 essentially similar transfer stations reflect: 1) differences in operating characteristics including cleanliness of the operation, and 2) differences in habitat at or near the station. For the non-affiliated species, habitat was likely more important, while for affiliated species such as the gulls, operating characteristics were likely more important.

3.3 Vegetative Waste Composting Facilities

The proximity of landfill operations to both composting facilities influenced how they were used by birds. The Galloway site was just across the street from the Galloway Township Landfill, and Middlesex County Composting Facility was located approximately 300 meters from Edgeboro Landfill. This situation was the result of siting practices that reasonably and expectedly placed such operations near existing waste management facilities. While this was an appropriate approach in terms of efficiency of operations for the waste processors, it complicates the design of unambiguous field experiments meant to determine the attractiveness of these sites to birds. Our results are, therefore, likely biased by the presence of those species of birds initially attracted to the landfills and which only secondarily used the composting sites. We added control sites at both facilities in January in an effort to separate the effect of the compost piles themselves from the effect of the landfills. Both control sites were located near to the compost sites (Galloway - 1km away from the compost site, Middlesex - 0.5km), and were therefore subject to the same "landfill effect." They were similar in physical features with the exception of the absence of the compost piles themselves.

The most abundant species at the compost piles were Herring Gulls, Laughing Gulls, American Crows, and European Starlings (Table 1). These species accounted for 95% of the birds at the composting sites, with crows making up the majority (47%). Ring-billed Gulls were uncommon at both the Edgeboro and Galloway composting facilities. We recorded 18 species of birds at the Edgeboro composting site and 19 species at the Galloway site. Bird species diversity was similarly low at both composting facilities, with 70% of the species occurring at both sites. The control sites for both facilities had fewer total species than either composting site. The Galloway control site may have been impacted by the shorter sampling period (we did not begin surveying until 10 January 1992), while the Edgeboro control site was likely affected by the large number of birds using the near by landfill.

American Crows were the only species of large birds that occurred regularly at either composting site (Fig. 5). At Middlesex County Composting Facility crow abundance approached a maximum of 240 birds/survey in late winter (SE=90.8). Mean number of crows at the compost pile was considerably higher (mean = 71 birds/survey, SE=16.3) than at the control site (mean = 24 birds/survey, SE=11). They remained abundant through most of the winter and early spring then declined during the late spring.

At the Galloway site, American Crows were present throughout the study, but their numbers were low ranging only between 0-3 birds/survey (mean = 0.31 birds/survey, SE=0.15). Numbers of crows were similar between Galloway and the control site. The low numbers suggest that a single family group occupied the general area around the composting facility, and their presence was probably unrelated to the waste management operations that occurred there. We never saw these birds engaged in feeding behavior on the compost piles as we had at Edgeboro.

The only species of gull that used the Galloway composting facilities to any great extent was the Herring Gull. Herring Gulls appeared at Galloway late in the year, and stayed until just after the adjacent landfill closed at the end of December. The number of Herring Gulls at the Galloway composting facility and the control site were similar. Herring Gulls were less

common at the Middlesex County Composting site even in winter when they were very abundant at the adjacent Edgeboro Landfill. The number of Herring Gulls at the Edgeboro compost and control sites were similar.

At the Galloway composting site and the control site the number of Great Black-backed Gulls and Ring-billed Gulls were very low and subsequently neither species showed any seasonal change in abundance.

The only other gull to appear in numbers at the compost sites were Laughing Gulls. However, appreciable numbers came only in late September at the Edgeboro site. Given that this occurred during migration, their appearance was likely tied to general population movements rather than any particular attraction to the composting operation.

The compost piles attracted little in the way of birds, yet American Crows found them a source for food and social interaction. Our observations of crow behavior on the compost piles led us to conclude that their main activity was feeding. Our first hypothesis was that there must be some kind of invertebrate present (i.e., worms, beetles). We took samples of the compost and sorted them in search of the suspected invertebrates. We found none. However, what we did find were large numbers of acorns and other tree fruits many of which were partially eaten or bore surface marks suggestive of crow feeding. Since acorns are a regular food item of crows, we concluded that crows were most likely searching for and feeding on acorns and other tree fruits at the Middlesex County composting facility.

3.4 Construction/Demolition Landfill

The avian community at the Winzinger Landfill was very typical of the mixed oak-pine woodland surrounding this site. The numbers of birds were quite low and unremarkable throughout the study interval (Table 1), yet Winzinger had the greatest number of species of all the sites (31). Most of the species at this site were Passeriformes.

Several species showed distinct peaks in abundances. Most of the short-term increases in abundance represented population movements unrelated to activities at the landfill. One such peak occurred in early summer and likely reflected the movements of birds late in the nesting season when food demands of young were greatest. At this site most observations of Laughing Gulls were of flying birds in transit to somewhere else. These gulls had no apparent attachment to the landfill itself. Similar short-term increases in population size occurred for Barn Swallows *Hirundo rustica*, Tree Swallows, Song Sparrows *Melospiza melodia*, and Dark-eyed Juncos *Junco hyemalis*.

American Crows were the only large birds that occurred regularly at this site. However, numbers of crows were generally low (maximum biweek mean = 3 birds/survey, SE=1.5), although they were present consistently throughout the study. The number of crows were similar at both the construction landfill and the control site. The crows were probably a single family group that was often detected in the course of our surveys, and like at the trash transfer stations, they were probably not specifically attracted to the operations at the landfill.

The Construction/demolition landfill that we surveyed provided little to attract birds. The species we recorded at Winzinger landfill were most likely part of the natural avian

communities in the surrounding habitats rather than associated with specific landfill operations.

4. CONCLUSIONS

In this study our goal was to provide information that can be used to assess the potential dangers to air operations posed by birds attracted to waste management facilities. We examined how birds use various types of waste management facilities so that the potential conflicts between these facilities and air operations can be better understood and better managed. In our approach we determined the numbers and species of birds associated with 4 types of waste processing facility located at 7 different sites (2 solid waste landfills, 2 vegetation composting sites, 2 trash transfer stations, and 1 construction/demolition landfill).

We found that solid waste landfills attracted the most birds from among the 4 types of waste processing facility we investigated. The most numerous birds were the 4 species of gulls common in New Jersey. In summer Laughing Gulls were the most abundant bird (maximum ~500 birds/survey), followed by Ring-billed Gulls (maximum ~250 birds/survey). In winter the situation changed dramatically. Laughing Gulls and Ring-billed Gulls left our study sites for their wintering grounds to the south. They were replaced by Herring Gulls and Great Black-backed Gulls. In winter, numbers of Herring Gulls achieved levels nearly 5 times higher than those of Laughing Gulls in summer (maximum ~2,500 birds/survey), whereas numbers of Great Black-backed Gulls became about as abundant as Laughing Gulls (maximum ~400 birds/survey). Together, these species of gulls render solid waste landfills potentially far more hazardous in winter than in summer.

Age composition of gulls and their diurnal pattern in abundance varied seasonally. Adult gulls were much more common than subadults at both municipal landfills, although we found considerable variation in patterns among individual species. We found diurnal patterns in landfill use only for Herring Gulls at 1 landfill. Otherwise gulls used the landfills in similar ways in both morning and afternoon hours.

Apart from gulls, we found only 7 additional bird species common (mean birds /survey > 1) on the solid waste landfills. Of these American Crows were most important (maximum ~ 60 birds/survey), but their numbers were never very large in comparison to gulls. They were, however, a very regular component of the avifauna.

The other waste processing facilities had much lower numbers of birds and comparatively few gulls. The birds at these sites were, in general, species typical of the habitats in which the sites were located, and not necessarily attracted to the waste processing facilities themselves. There were 2 exceptions to this. First, both composting facilities were relatively close to the solid waste landfills and at times they attracted some birds from landfills. Second, the numbers of Laughing Gulls at both transfer stations, although not large relative to the solid waste landfills, were higher than what might be expected based on the habitat type they both occupied (mixed oak-pine woodland). Our conclusion is that some gulls were attracted to the transfer stations, and while the numbers were not high, they did vary considerably between the 2 sites. This variation was probably a result of differences in the operating cleanliness of the 2 facilities.

Our studies included samples from an entire year. The winter data provided a very dramatic change in our interpretations from what the summer information alone provided at the end of 1991. In winter when natural food supplies were less abundant for gulls, solid waste landfills attract large numbers of resident gulls. Because winter abundance of gulls at these sites was so much higher than in summer, the danger to air traffic was potentially far greater in winter than summer. However, it is important to point out that the potential for conflict with air operations is influenced considerably by gull behavior as well as other factors that might change seasonally (e.g., breeding status, alternate food sources) or that might be different among gull species (e.g., body mass, flight characteristics). Therefore, the potential for conflict may not be a simple linear relation with numbers. Accurate assessment of potential conflict requires additional information on movements, behavior and population structure of gulls at different times of the year.

Our studies indicate that there is considerable variation in attractiveness to birds among types of waste processing facilities, and between individual facilities within types. This leads us to conclude that generalizations concerning potential conflict of these types of facilities with safe air operations will often require site specific qualifications concerning how the waste processing facilities are operated.

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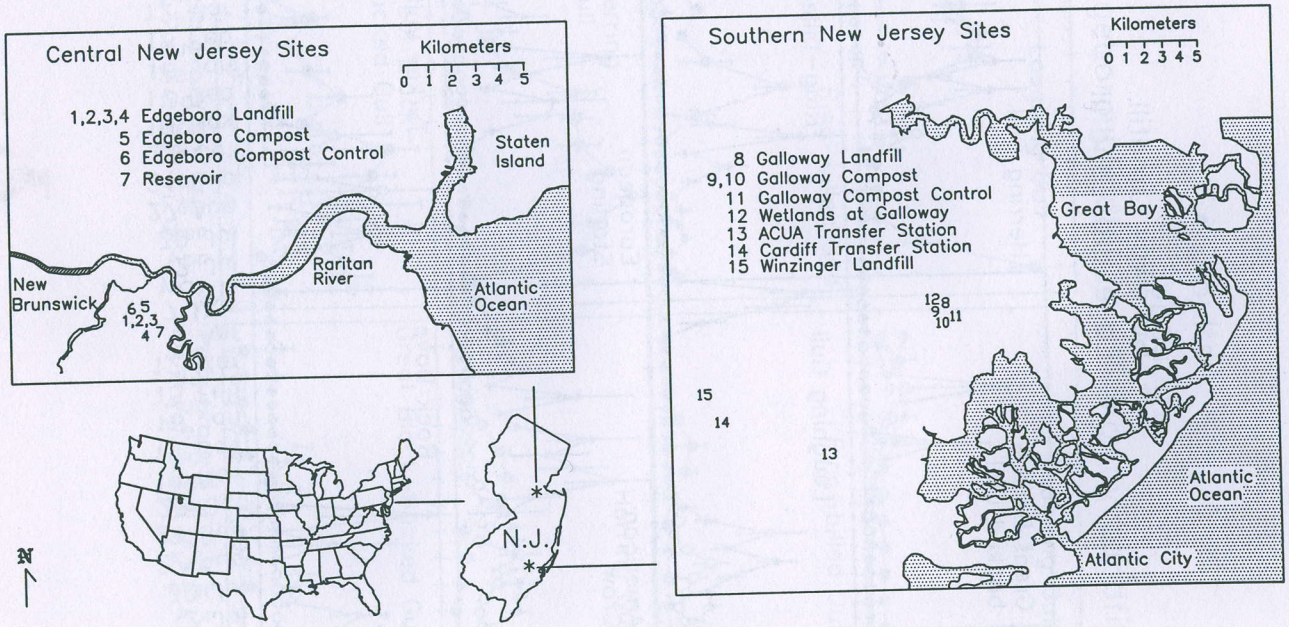
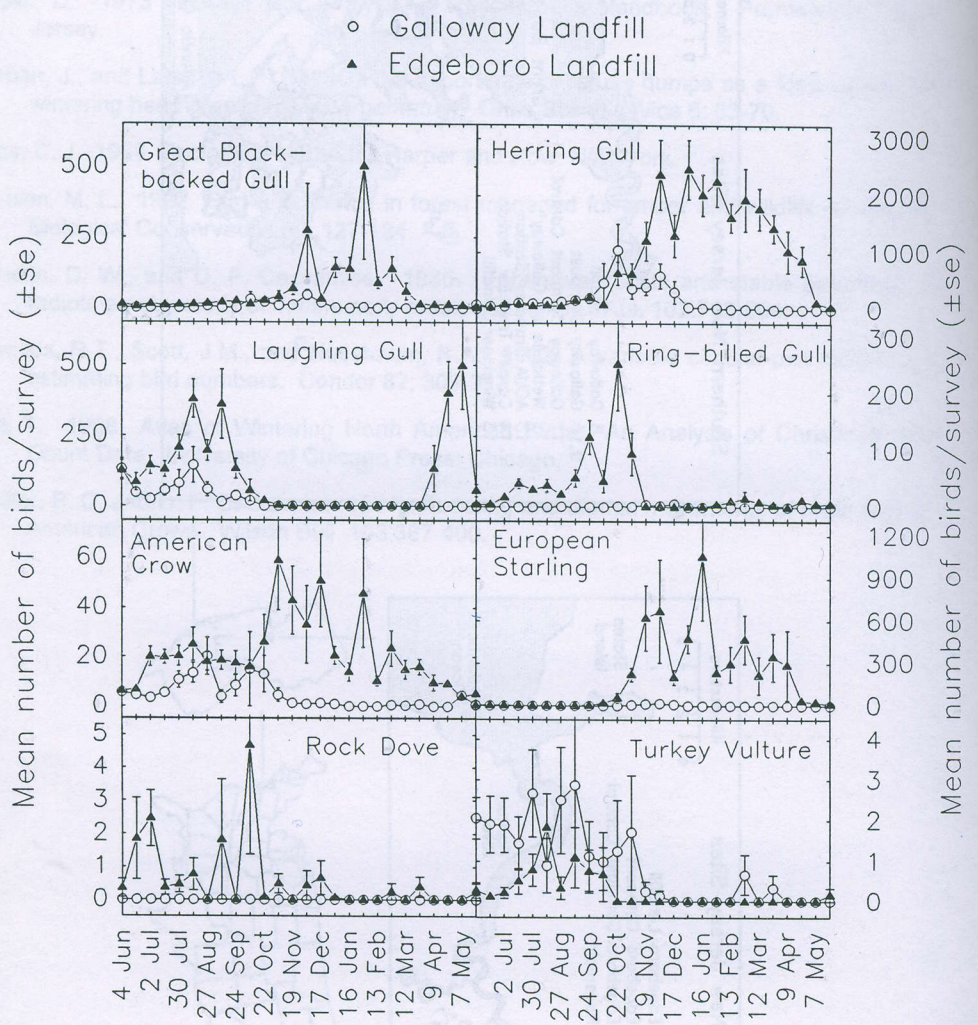
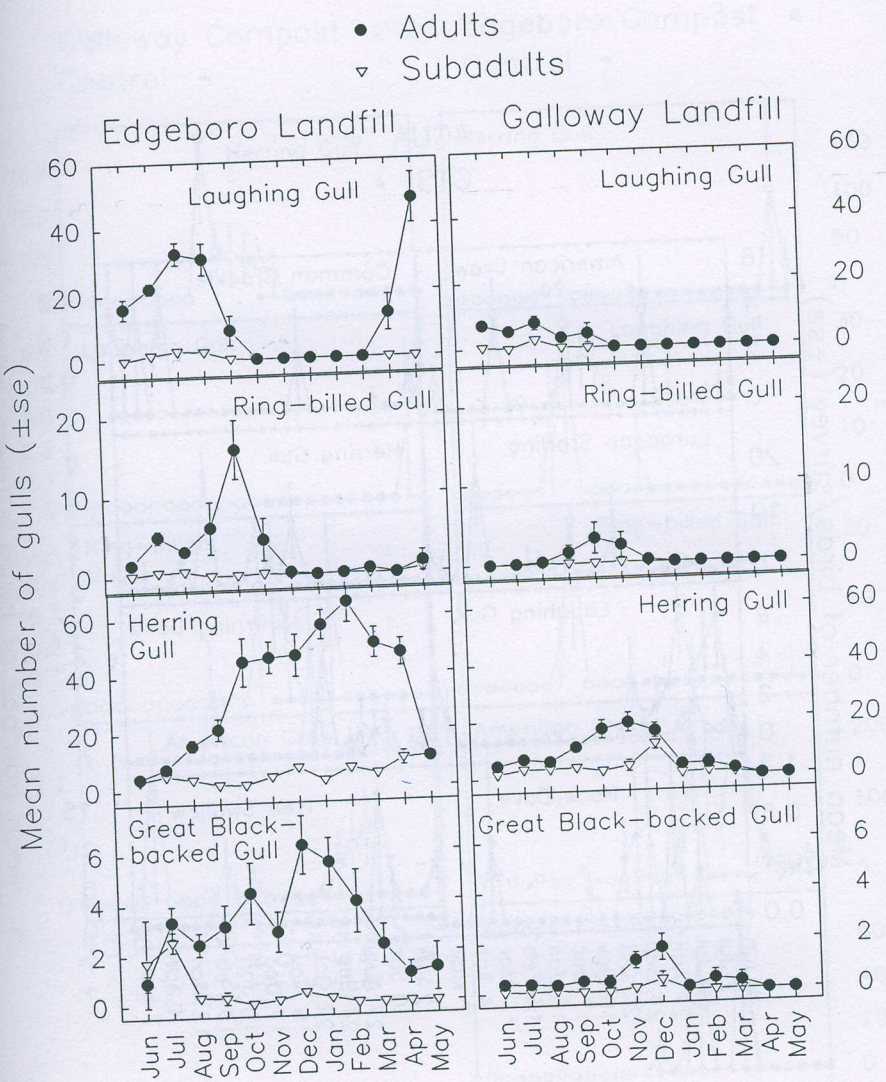
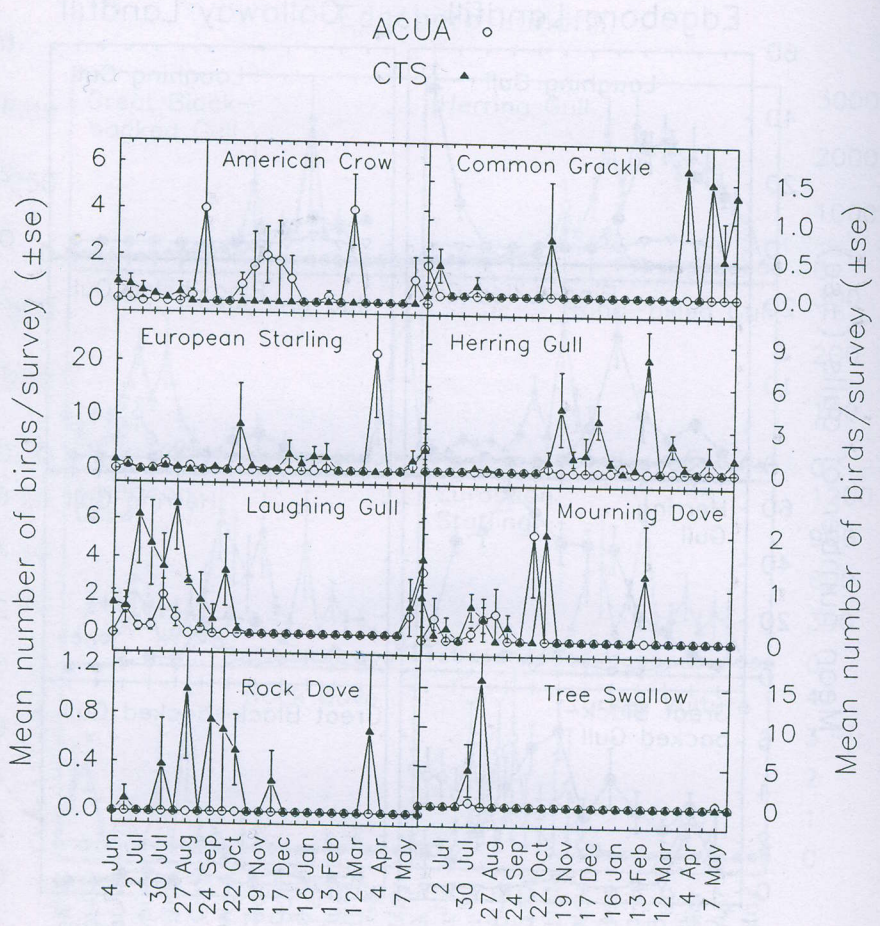
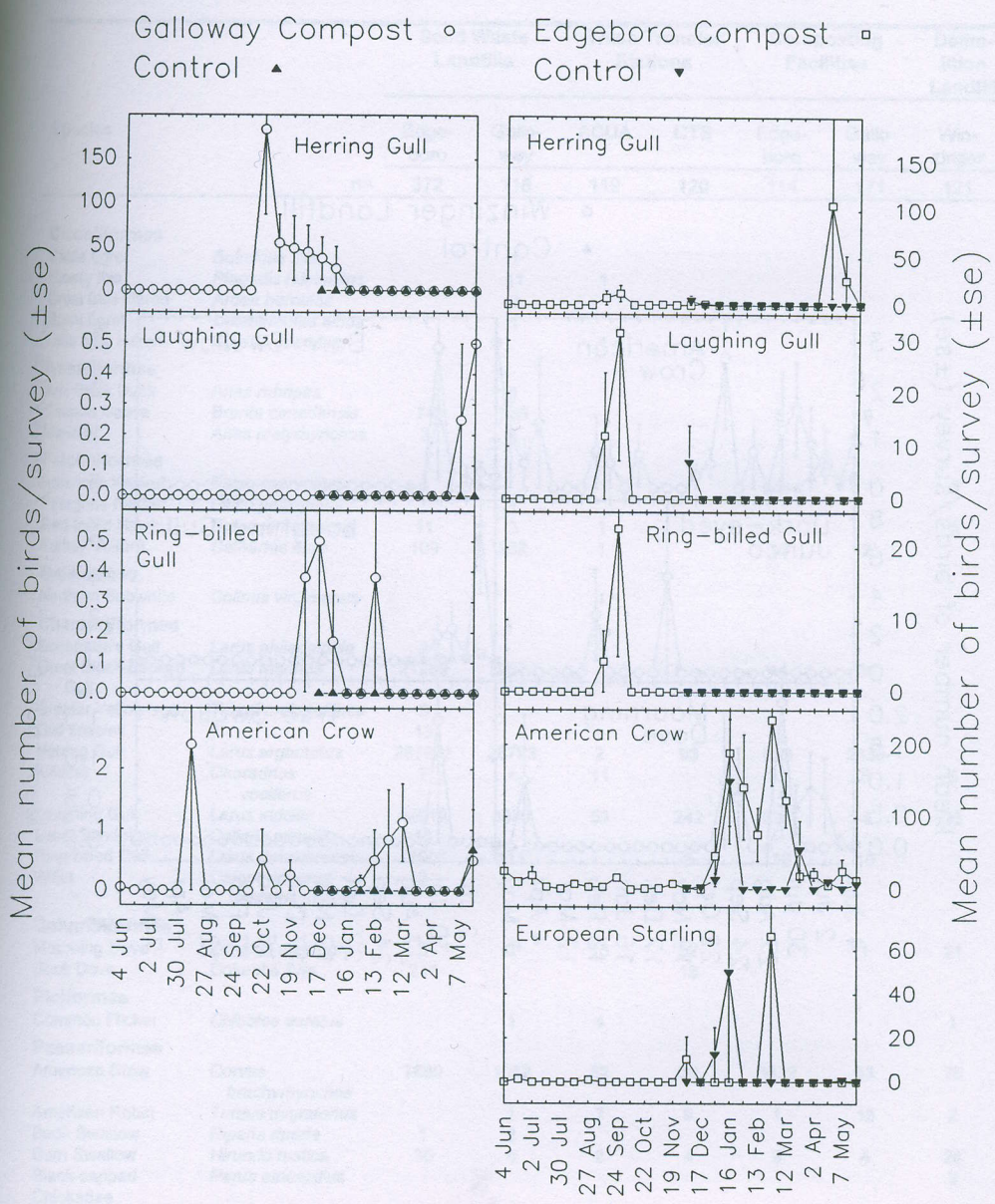

Central New Jersey Sites
Kilometers
0 1 2 3 4 5
1,2,3,4 Edgeboro Landfill
5 Edgeboro Compost
6 Edgeboro Compost Control
7 Reservoir
Staten Island
Raritan River
New Brunswick
Atlantic Ocean
6,5
1,2,3
4 7
N
N.J.
Southern New Jersey Sites
Kilometers
0 1 2 3 4 5
8 Galloway Landfill
9,10 Galloway Compost
11 Galloway Compost Control
12 Wetlands at Galloway
13 ACUA Transfer Station
14 Cardiff Transfer Station
15 Winzinger Landfill
Great Bay
12 8
9
10 11
15
14
13
Atlantic Ocean
Atlantic City


Galloway Landfill
Edgeboro Landfill
Great Black–backed Gull
Herring Gull
Laughing Gull
Ring–billed Gull
American Crow
European Starling
Rock Dove
Turkey Vulture
Mean number of birds/survey (±se)
Mean number of birds/survey (±se)
4 Jun
2 Jul
30 Jul
27 Aug
24 Sep
22 Oct
19 Nov
17 Dec
16 Jan
13 Feb
12 Mar
9 Apr
7 May


Adults
Subadults
Edgeboro Landfill
Galloway Landfill
Laughing Gull
Ring–billed Gull
Herring Gull
Great Black–backed Gull
Mean number of gulls (±se)
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May


ACUA ○
CTS ▲
American Crow
Common Grackle
European Starling
Herring Gull
Laughing Gull
Mourning Dove
Rock Dove
Tree Swallow
Mean number of birds/survey (±se)
Mean number of birds/survey (±se)
4 Jun
2 Jul
30 Jul
27 Aug
24 Sep
22 Oct
19 Nov
17 Dec
16 Jan
13 Feb
12 Mar
4 Apr
7 May


Galloway Compost ○
Control ▲
Edgeboro Compost □
Control ▼
Herring Gull
Laughing Gull
Ring-billed Gull
American Crow
European Starling
Mean number of birds/survey (±se)
4 Jun
2 Jul
30 Jul
27 Aug
24 Sep
22 Oct
19 Nov
17 Dec
16 Jan
13 Feb
12 Mar
2 Apr
7 May

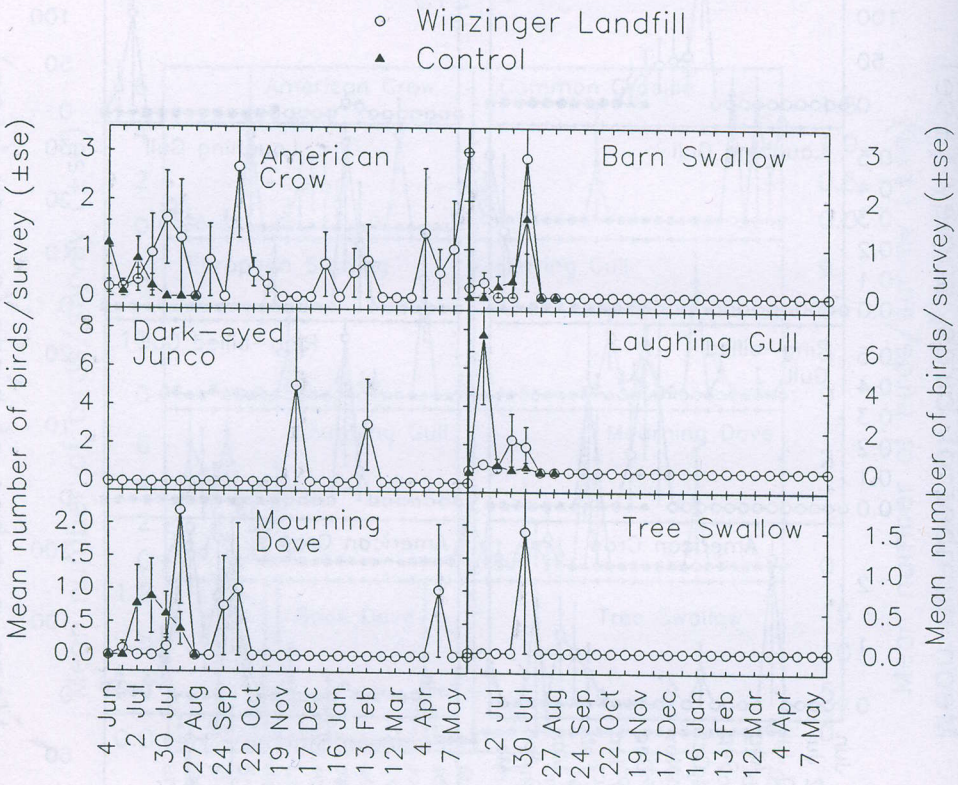

Winzinger Landfill
Control
American Crow
Barn Swallow
Dark-eyed Junco
Laughing Gull
Mourning Dove
Tree Swallow
Mean number of birds/survey (±se)
Mean number of birds/survey (±se)
4 Jun
2 Jul
30 Jul
27 Aug
24 Sep
22 Oct
19 Nov
17 Dec
16 Jan
13 Feb
12 Mar
4 Apr
7 May

Table 1. List of species occurring at seven solid waste management facilities in New Jersey from June 1991 to May 1992. Values given are total number of birds seen at the site; n refers to the number of surveys at each site.

Species		Solid Waste Landfills		Trash Transfer Stations		Composting Facilities		Demolition Landfill
		Edgeboro	Galloway	ACUA	CTS	Edgeboro	Galloway	Winzinger
	n=	372	116	119	120	114	171	121
Ciconiiformes								
Cattle Egret	*Bubulcus ibis*		1					
Glossy Ibis	*Plegadis falcinellus*		11	1				
Great Blue Heron	*Ardea herodias*		2					
Great Egret	*Casmerodius albus*	1	1					
Little Blue Heron	*Egretta caerulea*			1				
Anseriformes								
Am. Black Duck	*Anas rubripes*		1			5	9	
Canada Goose	*Branta canadensis*	74	266					
Mallard	*Anas platyrhynchos*	3	2					
Falconiformes						1		3
American Kestrel	*Falco sparverius*							
Peregrine Falcon	*Falco peregrinus*		1					3
Red-tailed Hawk	*Buteo jamaicensis*	11	3	1				
Turkey Vulture	*Cathartes aura*	109	262	1		10	2	
Galliformes								
Northern Bobwhite	*Colinus virginianus*			1				
Charadriiformes								
Bonaparte's Gull	*Larus philadelphia*	2						
Great Black-backed Gull	*Larus marinus*	21289	987			44	30	
Greater Yellowlegs	*Tringa melanoleuca*	3						
Gull species	?	13						
Herring Gull	*Larus argentatus*	287622	28793	2	93	639	2639	
Killdeer	*Charadrius vociferus*	7	4	11		52	6	5
Laughing Gull	*Larus atricilla*	44519	8386	53	242	334	4	33
Least Sandpiper	*Calidris minutilla*	13						
Ring-billed Gull	*Larus delawarensis*	11007	111		6	158	10	
Willet	*Catoptrophorus semipalmatus*	2						
Columbiformes								
Mourning Dove	*Zenaida macroura*	5	3	15	32		1	21
Rock Dove	*Columba livia*	217			18			
Piciformes								1
Common Flicker	*Colaptes auratus*		1	4				
Passeriformes								
American Crow	*Corvus brachyrhynchos*	7669	1052	62	26	3839	53	75
American Robin	*Turdus migratorius*		1	7	9	1	13	2
Bank Swallow	*Riparia riparia*	1	2					
Barn Swallow	*Hirundo rustica*	30	6	8	4	9	4	28
Black-capped Chickadee	*Parus atricapillus*							3
Blue Jay	*Cyanocitta cristata*			8	8		3	7

Table 1 (continued)

Species		Solid Waste Landfills		Trash Transfer Stations		Composting Facilities		Demolition Landfill
		Edgeboro	Galloway	ACUA	CTS	Edgeboro	Galloway	Winzinger
	n=	372	116	119	120	114	171	121
Carolina Wren	*Thryothorus ludovicianus*							3
Chipping Sparrow	Spizella passerina							1
Common Grackle	*Quiscalis quiscala*	21	1009	4	21	2	1	4
Crow species	*Corvus ?*			1				
Dark-eyed Junco	*Junco hyemalis*			1				32
Eastern Kingbird	*Tyrannus tyrannus*		1	2				7
Eastern Meadowlark	*Sturnella magna*			3	2			
Eastern Tufted Titmouse	*Parus bicolor*							2
European Starling	*Sterna vulgaris*	62596	282	108	119	250	5	6
Field Sparrow	*Spizella pusilla*			2				5
Finch species	?					6		
Fish Crow	*Corvus ossifragus*		98		1	1		
Grasshopper Sparrow	*Ammodramus savannarum*			1				
Gray Catbird	*Dumetella carolinensis*				1			2
Great Crested Flycatcher	*Myiarchus crinitus*							3
House Sparrow	*Passer domesticus*				14			
Northern Cardinal	*Cardinalis cardinalis*				1			1
Northern Mockingbird	*Mimus polyglottis*		3	12	4	1	7	2
Ovenbird	*Seiurus aurocapillus*				1			1
Purple Martin	*Progne subis*	3			1			
Red-winged Blackbird	*Agelaius phoeniceus*	9	1	4	2		1	7
Rufous-sided Towhee	*Pipilo erythrophthalmus*							1
Song Sparrow	*Melospiza melodia*						1	11
Sparrow species	?			1	8	3		13
Tree Swallow	*Tachycineta bicolor*		4	6	117			12
Wood Thrush	*Hylocichla mustelina*							2