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Paul D. Curtis  
*Cornell University*

Charles R. Smith  
*Cornell University*

William Evans  
*Cornell University*

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# TECHNIQUES FOR REDUCING BIRD USE AT NANTICOKE LANDFILL NEAR E. A. LINK AIRPORT, BROOME COUNTY, NEW YORK

PAUL D. CURTIS, CHARLES R. SMITH, and WILLIAM EVANS, Department of Natural Resources, Cornell University, Ithaca, NY 14853-3001.

**ABSTRACT:** Human and wildlife conflicts have increased in importance in many suburban areas of the United States. Birds pose a serious hazard to air traffic, and 1,200-1,500 bird strikes are reported to the Federal Aviation Administration (FAA) annually. The location of a landfill near an airport may increase avian activity because landfills provide a food source for omnivorous birds. To reduce avian hazards at airports, FAA Order 5200.5A established a proximity criterion prohibiting the location of any runway used by turbojet aircraft within 3,048 m of a landfill. However, existing landfills within this proximity may be kept open if an acceptable bird management strategy is developed and maintained. The objectives of this study were to: (1) document bird use at Nanticoke Sanitary Landfill; (2) evaluate 3 potential techniques for reducing bird numbers at the landfill; and (3) develop bird management guidelines for the landfill environment. Avian numbers, species, and behavior patterns were monitored at the landfill for 11 months (December 1991 through October 1992) before control activities were initiated. The repellent effects of methyl anthranilate (MA, ReJeXIT®), Posi-shellR (PS) cover material, and pyrotechnics (PT) were evaluated during late October to December 1992. A surface MA application did not reduce avian numbers at the landfill, as birds quickly learned to tear open plastic refuse bags to obtain untreated food. PS treatment alone did not reduce numbers, as birds were able to forage through the thin surface covering. However, hazing birds with the spray equipment used to apply PS reduced the daily number of gulls (primarily herring gulls, *Larus argentatus*) foraging at the landfill by about 50%, from approximately 2,400 to 1,200 birds per day. PT was the most effective treatment, further reducing the gull numbers at the landfill to about 50-60 birds/day. Strategic use of PT to maximize its effectiveness, as part of a consistent bird-harassment program, should cost <\$ 10/day for shells during the peak months of bird activity at the landfill (July through January). Interchange of gulls between the landfill and airport was minimal, and has been effectively controlled with PT on a use-as-needed basis.

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The large expanses of paved and open vegetative areas at airports often attract large numbers of flocking birds including gulls (*Larus* spp.), American crows (*Corvus brachyrhynchos*), and European starlings (*Sturnus vulgaris*). Raptors may also use open airport habitats for hunting, loafing, or soaring. Birds with a large body mass, or large flocks of smaller birds, are particularly hazardous to turbojet aircraft (Martino and Skinn 1989). Between 1,200 and 1,500 bird strikes are reported annually to the Federal Aviation Administration (FAA), and the direct cost of these bird strikes in the United States is estimated to be \$25 to \$35 million (DeHaven et al. 1985).

The location of a landfill near an airport may increase avian activity, as landfills provide an important food source for omnivorous birds at certain times of the year, especially during fall and winter. To reduce this additional risk to air traffic, FAA Order 5200.5A (U.S. Dep. Transp. 1990) sets forth a "proximity" criterion for landfills and airports. This criterion prohibits the location of any runway used or planned to be used by turbojet aircraft within 3,048 m (10,000 feet) of a landfill. However, if the landfill cannot be closed and effective bird control procedures are implemented at both the landfill and airport, an existing landfill may be permitted to continue operation.

E.A. Link Field is located approximately 1,830-2,135 m (6,000 to 7,000 feet) from the Nanticoke Sanitary Landfill in Broome County, New York. The FAA was concerned that birds

using Nanticoke Landfill may be creating a hazardous situation at Link Field. This project was initiated to: (1) determine bird foraging patterns and activity at Nanticoke Landfill, (2) evaluate 3 techniques for reducing bird numbers at the landfill, and (3) develop bird management guidelines for the landfill environment.

During the first repellent trial, we evaluated the effectiveness of methyl anthranilate (MA, ReJeX® TP-40, PMC Specialties, Cincinnati, OH) for reducing bird numbers at Nanticoke Landfill. MA formulations have recently been tested for repelling ring-billed gulls (*Larus delawarensis*) from food sources and water (Belant and Dolbeer 1992, Dolbeer et al. 1992, Vogt 1992). MA is a GRAS-listed human food-flavoring (Jenner et al. 1964, Code of Federal Regulations 1988, Vogt 1992) that could serve as a bird repellent in a variety of situations (Cummings et al. 1991, Askham 1992). Large-scale field tests using MA at landfills have not been conducted previously.

During the second repellent experiment, we applied a thin surface coating of PosishellR (PS, Landfill Services Corporation, Albany, NY), a liquid formulation made from recycled cellulose, cement kiln dust, and water, to freshly-dumped refuse at intervals throughout the day. Anecdotal reports indicated that gulls did not like to forage through PS cover material at a landfill near Albany, New York. More recently, Belant and Dolbeer (1992) have had success reducing cowbird (*Molothrus ater*) and ring-billed gull foraging in pen

trials by applying ConCover 18® (Newwastecon, Inc., Perrysburg, OH) combined with MA to millet and gizzard shad (*Dorosoma cepedianum*, respectively). ConCover 18® is a blend of polymers, clay, and recycled cellulose. Similar to PS, it is sprayed as a slurry over exposed refuse at landfills. Again, field tests at active landfills evaluating the bird repellency of either PS or ConCover 18® had not occurred prior to this study.

During the final phase of the project, we examined the effectiveness of bird bangers and screamers (Reed-Joseph International Co., Greenville, Miss.) for reducing avian numbers at Nanticoke Landfill. Pyrotechnics (PT) have frequently been recommended for scaring birds from airports (USDOT 1988:64), and have also been used to reduce bird damage in agricultural situations. Avian reactions to PT may vary by species (USDOT 1988:70), and repeated use may lead to habituation. Consequently, we wanted to determine if PT would lower bird numbers initially, and if continued treatment would result in habituation and decreased effectiveness.

We thank T. Joseph and B. Zimpel for assistance with data collection and analyses. W. Finn provided access to the airport operations area and bird strike records from E. A. Link Field. J. Kowalchuk was instrumental in coordinating research activities with Nanticoke Landfill operations. R. Dolbeer and J. Belant provided helpful advice during field trials. Funding for this study was provided by Broome County Division of Solid Waste Management.

## METHODS

This study consisted of an 11-month period of observation (11 December 1991-27 October 1992) to determine the bird species involved, population levels, and behavior patterns. Once baseline data were collected, techniques for deterring birds from using the landfill were tested during 28 October through 15 December 1992.

## Bird Population Assessments

Bird patterns at the landfill were documented by making observations for at least one full day in each two week period during the 11 months prior to the repellent trials. Half-day counts usually alternated between sunrise to mid-day and mid-day to sunset. Observations at the landfill were made from a position on the active fill pile (Fig. 1). Counts at the airport were made primarily from 3 locations (Malzar shack, concrete pad, and CF parking lot; Fig. 1) which provided a good view of the airfield and/or airspace between the airport and the landfill. Birds observed were tallied by species and time of day. Pertinent weather data were recorded and avian behaviors which could pose a hazard for aircraft were noted.

During 8-9 January 1992, 40 gulls were captured with a rocket net at the landfill and fitted with wing tags (Curtis et al. 1983). In October 1992, 33 gulls were captured and their breasts were painted bright pink with a Rhodamine-B and isopropyl alcohol solution (J. Belant, USDA-APHIS-Wildlife Services, pers. commun.). The wing tags and breast dye enabled the identification of these individuals at other locations. Gull roosts on large bodies of water and other landfills in the region were checked for color-marked birds. An effort was made to determine the night-roosting locations of gulls and crows foraging at the landfill and their flight routes. Birds leaving the landfill were followed by automobile to locate their night roosts.

## Bird Repellent Experiments

During the first trial (28 - 31 October 1992), MA was applied to the active fill area to see if it would deter birds from feeding at the landfill. The New York State Department of Environmental Conservation had granted a permit to apply MA on up to 0.81 ha (2 ac.) of landfill surface/day at a maximum application rate of 30.3 l (8 gal.) of 40% a.i. solution/acre/day.

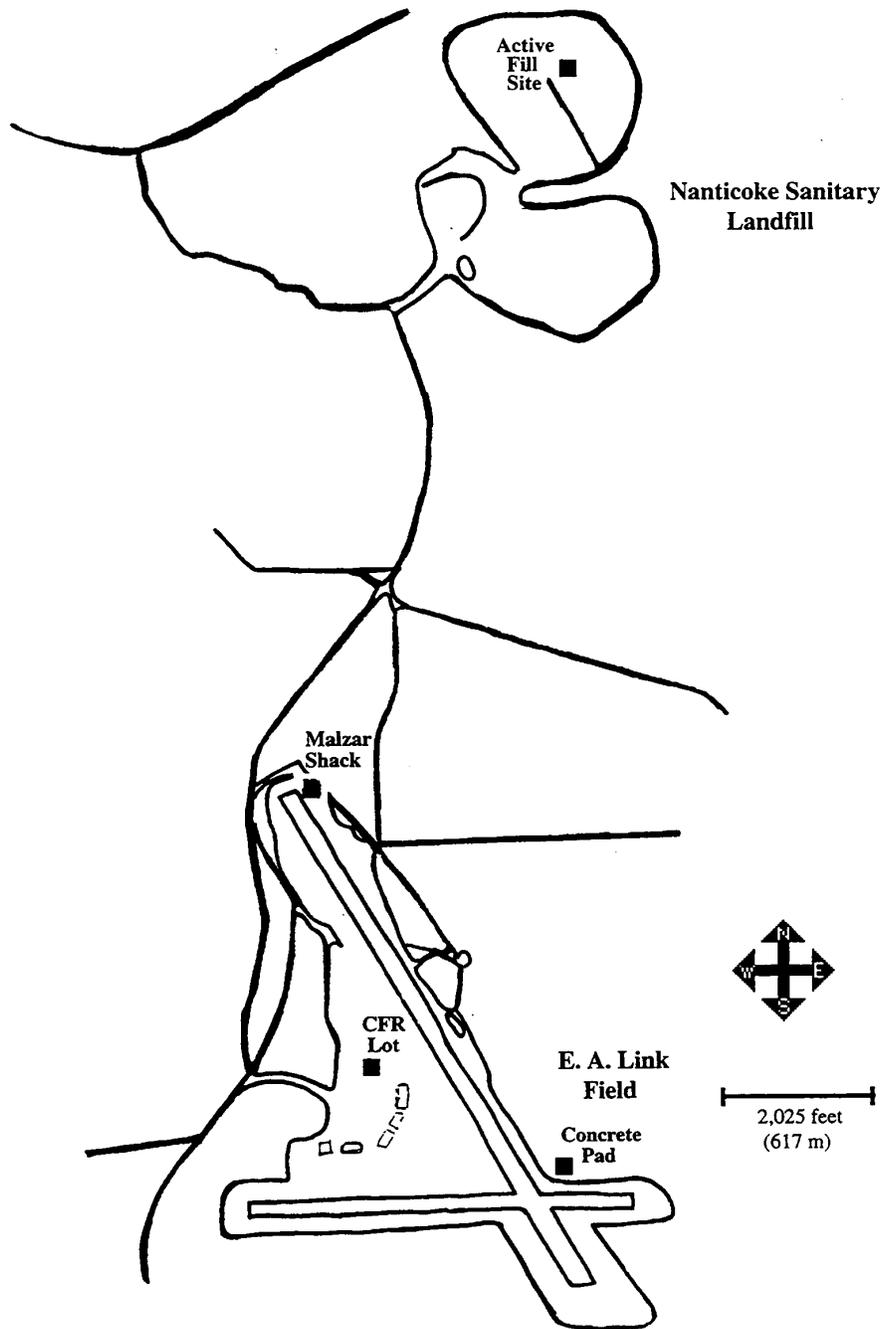


Fig. 1. Location of Nanticoke Sanitary Landfill and E. A. Link Field, Broome County, New York.

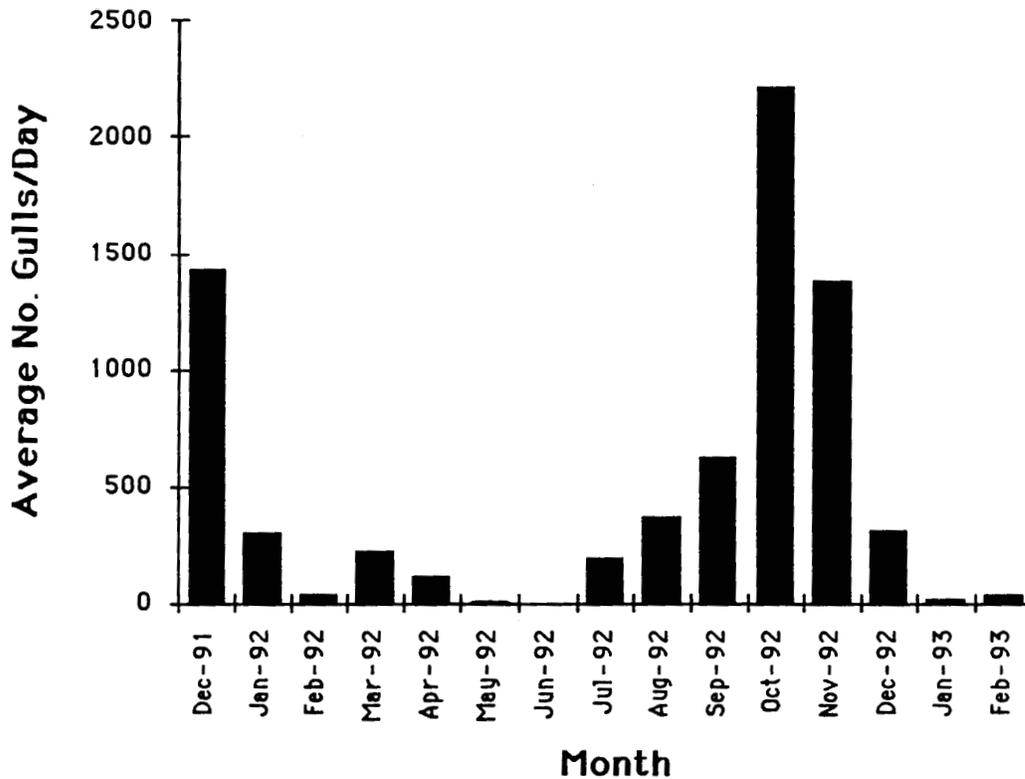


Fig. 2. Average number of gulls observed per day at Nanticoke Sanitary Landfill, Broome County, New York, December 1991 through February 1993.

Each day of the trial, the area of active fill was calculated, and the maximum allowable quantity of MA was applied in three spray applications. The first application occurred between 8:00 - 9:00 AM EST, the second between 10:00 - 11:30 AM, and the third between 1:30 - 2:30 PM. Applications were timed to occur immediately prior to typical gull feeding periods, after fresh refuse had been dumped and spread. Bird numbers and behavior were monitored during the trial. A one-week buffer period was scheduled between experiments to allow gull numbers to stabilize post-treatment.

The second trial occurred from 9-14 November 1992. PS was sprayed over the active fill after fresh refuse was dumped. Timing of applications were similar to those for the MA experiment.

The PT trial occurred from 8-15 December 1992, and 2 types of noise-creating projectiles were fired in the vicinity of birds as they attempted to feed and/or roost at the landfill. The projectiles were fired from a 6-mm, hand-held, single-shot, pistol launcher. Bird bangers flew 36-44m (120-145 ft) and produced a loud report. The screamer-sirens flew 55-73 m (180-240 ft) and made a sharp screaming sound. PT harassment was used to scare birds from the airport operations area as needed.

## RESULTS

### Birds Patterns at the Landfill

Four avian species comprised the majority of bird observations at Nanticoke Landfill. Ring-billed and herring gulls, European starlings, and American crows all were noted at some point during the study in peak numbers exceeding 400 individuals/day. Ten other species used the landfill for food in peak numbers of less than 30 individuals/day.

**Gull numbers.** When observations began in mid-December 1991, there was a maximum of approximately 2,500 gulls (primarily herring gulls), feeding at the landfill each day. This number declined, apparently due to normal migration once Whitney Point Reservoir was frozen over, to a daily average of around 1,000 gulls/day by late December (Fig. 2).

Following rocket-netting during 8-9 January 1992, <300 gulls were observed/day. By late January, peak daily counts were <50 gulls per day. In March, migrant gulls began to return and peak numbers at the landfill increased to nearly 400 gulls/day. Numbers then diminished through April. During May and June, few gulls were seen daily. At this time of year most herring gulls are on breeding grounds to the north of New York State (Blockpoel and Tessier 1992).

Gulls began returning in early July, and increased dramatically in late July and early August. Peak daily counts were 750 to 1,000 gulls/day by late August, and remained relatively constant through September. Ring-billed gulls were the predominant species in July and August. However, by late September, the proportion had shifted toward more herring gulls. Herring gulls typically arrive in the Finger Lakes Region later in the summer than ring-billed gulls (Bull 1974). In late September and early October an influx of herring gulls occurred, and by mid-October daily counts were ranging between 2,000-2,500 gulls/day.

**Gull flight patterns.** The majority (>90%) of gulls arrived from northerly directions, predominantly north to northwest. Observations indicated most gulls were roosting on Whitney Point Reservoir (when not frozen over) and Cayuga Lake in the evening. Whitney Point Reservoir was about 16 km (10 mi) north of the landfill, and Cayuga Lake was about 64 km (40 mi) northwest. Less than 10% of the gull flight each day would arrive at the landfill from southerly directions. Following gulls by automobile to determine their evening roosting sites was difficult because of the hilly terrain and paucity of roads. The results of the wingtagging study during early 1992 produced concrete evidence that gulls were traveling to Cayuga Lake. On 7 and 8 January 1992, 40 gulls were color-tagged at the landfill. On 10 January, two of these tagged gulls were observed feeding at the Spencer landfill approximately 48 km (30 mi) west of the Nanticoke Landfill and 36 km (22.5 mi) south of Cayuga Lake. Two tagged gulls, possibly the same ones noted at the Spencer Landfill, were seen at the south end of Cayuga Lake on 11 January. Other tagged gulls were observed on Cayuga Lake and at the Spencer Landfill through February 1992. No gulls tagged in the first year of the study were observed at the Nanticoke landfill after they were tagged. A surprising observation was one tagged gull which visited Seneca Meadows Landfill northwest of Seneca Falls, New York on 14 January. This landfill is 108 km (68 mi) northwest of the Nanticoke Landfill.

On 16 October 1992, 33 gulls were color-marked with Rhodamine-B dye, and up to a dozen of these gulls were seen feeding at the landfill during the following week. During the second week after the -color-marking, a daily total of only 5 color-marked gulls was noted. By the third week after color-marking, no more than 3 color-marked gulls were observed daily.

**Gull repellent trials.** During late fall 1992, 3 methods of deterring gulls from feeding at the landfill were tested. Applications of MA were sprayed over the fresh garbage from '8 through 31 October. Gull numbers at the landfill were not affected following these applications (Fig. 3). A total of 2,450 gulls were counted on 27 October. On 30 October, after three days of spraying, a total of 2,570 gulls were counted. During 1-8 November, no experimental control of gulls was attempted, and numbers remained high (approximately 2,400 on 4 November).

During 9 through 14 November, the second method for deterring birds was evaluated. Application of "Posi-shell" (PS) to the garbage intermittently during the day was to act as a physical barrier blocking bird consumption of the garbage. However, these treatments had no apparent effect on gull feeding. Gulls landed on the freshly-sprayed PS, foraged for, and found food. Because of the frequent spreading of garbage during the day, the PS did not have time to dry. However, the act of spraying PS frightened the gulls, and a brief application of PS could deter birds from feeding for an hour or more. The Landfill Services Corporation sprayer could shoot a stream of PS >30 m (100 ft). Gulls were too quick to get sprayed, but the disturbance was enough to prevent them from feeding. Once we observed this behavior, hazing the birds superseded the more-costly comprehensive spraying of the entire active landfill face where fresh garbage was spread. On 10 November when this modified trial began, we counted approximately 2,300 gulls.

After 4 days of being deprived of food via the harassment-spraying of PS, gull numbers were down nearly 50% (approximately 1,200 birds/day, Fig. 3). This trial proved so successful that the same technique was used during the following 2 weeks to see if numbers would continue to decline. By 27 November, only 400 to 500 gulls were visiting the landfill each day. Some progress was lost when the landfill was not capped thoroughly during the weekend of 28 and 29 November, and on 30 November > 1,000 gulls were counted. Continuing the harassment-spraying during the first week of December reduced gull numbers to approximately 300.

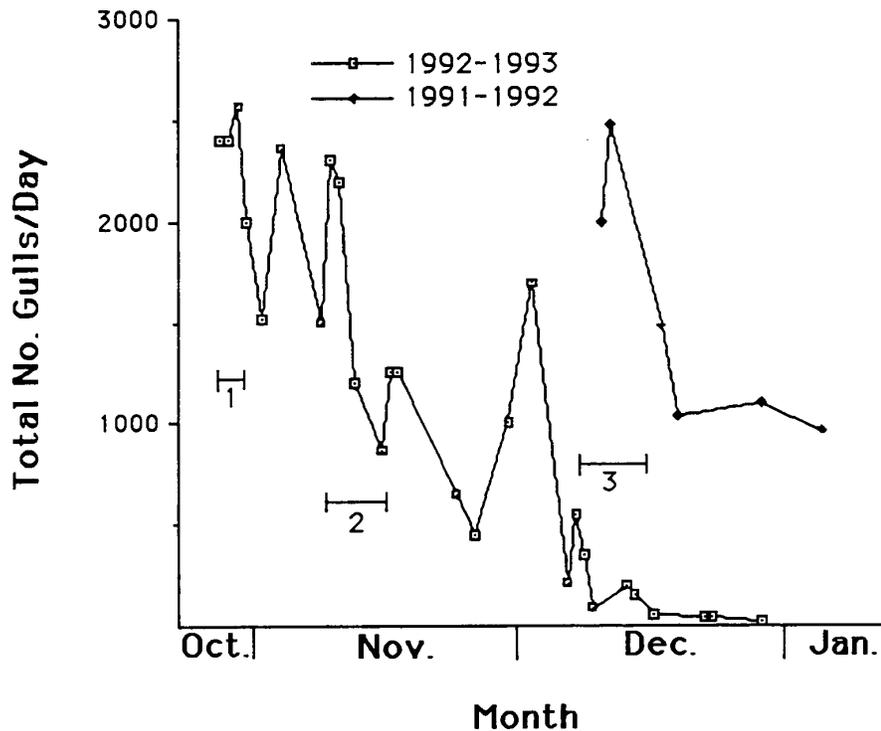


Fig. 3. Estimated number of gulls at Nanticoke Sanitary Landfill, Broome County, New York during repellent trials in 1992-93, and baseline counts in 1991-92. Numbered bars designate trial times (1 = Methyl Anthranilate, 2 = Posishell®, 3 = Pyrotechnics).

Though the PS harassment-spraying reduced gull numbers, a few hundred birds still visited the landfill each day. On 8 December the PT trial began, and this method was the most effective (Fig. 3). By 17 December, only about 50 gulls were visiting the landfill (compared with 1,500 on 18 Dec. 1991). After, a shot or two with the PT, these birds usually left for the day. Numbers declined to less than a dozen in early January. At this time employees of the landfill were operating PT on a use-as-needed basis. During late January and February, the landfill was being visited by 40 to 50 gulls early each week, and no deterrents were used on the weekends.

**Crow numbers.** Crows are abundant year-round residents in Broome County, and their foraging activity at the Nanticoke Landfill increased during the nonbreeding season (late July through March, Fig. 4). When observations began in early December 1991, crow numbers averaged around 100 individuals/day. By the end of December daily averages were > 200 birds/day. Crow numbers continued to increase at the landfill throughout winter, and peaked in February (300-400 birds/day). Numbers declined in late winter, with a March average of about 100 crows/day. On average, <50 crows/day were observed during April through mid-July. However, by late July numbers increased due to flocking of juvenile crows. During late July through October, crow numbers averaged between 100 to 200 individuals/day.

During November 1992, approximately 30 fish crows (*Corvus ossifragus*) were foraging at the landfill. The fish

crow, a smaller, much less common relative of the crow, is apparently increasing in numbers in central New York State. These birds roosted in the vicinity of the landfill at night and were not seen after the end of December.

**Crow flight patterns.** Crows were the first birds present at the landfill in the morning, often arriving a half-hour before sunrise. During the peak of crow activity at the landfill during December 1991 through March 1992, they were observed to arrive predominantly from the northerly and southerly directions. The first arrivals (approximately 60 crows) came in from the north and had probably roosted in conifer stands just north of the landfill. A second contingent numbering up to 130 individuals arrived later in the morning from the southwest. Other crows arrived throughout the day, predominantly from northerly directions. Crow populations fluctuated during the day as birds wandered to forage and/or socialize at other nearby sites. Their departure directions were similar to those of their arrival. By midafternoon pairs of crows steadily departed to the southwest. This contingent was followed by automobile numerous times to points in the Endwell area, 15-20 km (9-13 mi) south of the landfill. The crows that departed to the north remained at the landfill longer in the day and gradually dispersed into the conifer stands. During winter 1992-93, there was no crow contingent arriving from and departing to the southwest.

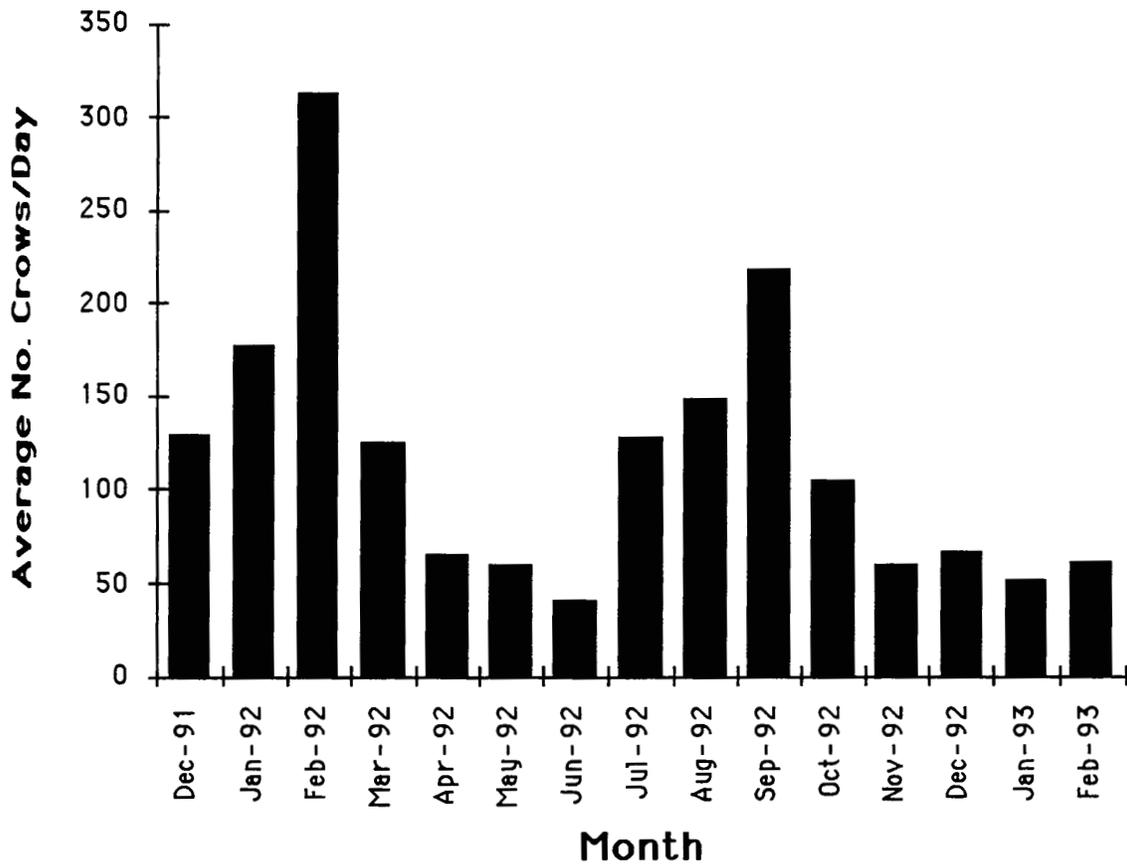


Fig. 4. Average number of crows observed per day at Nanticoke Sanitary Landfill, Broome County, New York, December 1991 through February 1993.

**Crow repellent trials.** Though the repellent trials were primarily focused at gulls, crow numbers responded as well. The MA trial from 28 through 31 October 1992 did not reduce crow numbers (Fig. 5). During the PS trial and the modified harassment-spraying technique, crow numbers began to decline from > 90 individuals on the first day of this trial, to a daily average of <50 individuals during the last 2 weeks of November (Fig. 5). Crow numbers to day in -early December 1992, equaling the quantity observed at this time during December 1991. On 8 December, the PT trial was initiated. From the second week of December 1992 through the end of field work in late February 1993, crow numbers averaged about 50 individuals/day. This compares with an average of nearly 200 crows/day during the same time Cod during winter 1991-92. PT use during 1992-93 reduced crow numbers up to 75% when compared to the previous winter.

**Starling numbers.** Starlings were the most difficult species to count because of their small size and habit of flying in large tightly spaced flocks. Estimated daily counts should be regarded as plus or minus 100 individuals. When observations began in early December 1991, daily totals for starlings averaged around 750 individuals (Fig. 6). This number continued to visit the landfill until February, when starling counts dropped to between 300-400 birds/day. Numbers remained similar to the end of April, when they dropped off sharply. This trend was associated with the onset of breeding season for starlings, and their numbers averaged <100 individuals/day from late April through mid-July. During the end of July, numbers increased because of the flocking of juveniles, and averaged of 100-150 individuals. By September and October, the daily count averaged between 200-400 starlings.

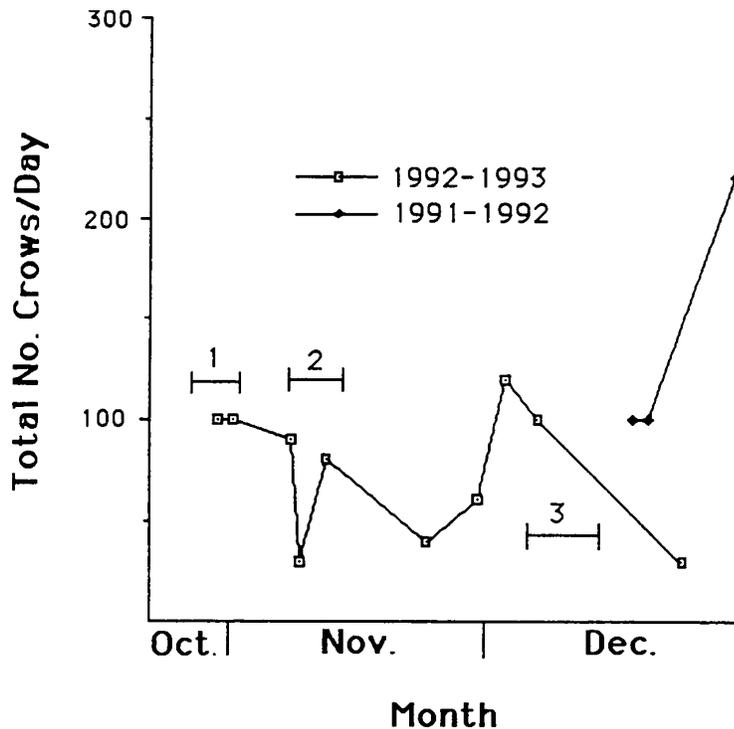


Fig. 5. Estimated number of crows at Nanticoke Sanitary Landfill, Broome County, New York, during repellent trials in 1992-93, and baseline counts in 1991-92. Numbered bars designate trial times (1 Methyl Anthranilate, 2 PosishellR, 3 Pyrotechnics).

**Starling flight patterns.** Typically, starlings arrived at the landfill later than the crows, but before the gulls each morning. The first individuals would appear by sunrise and numbers steadily increased until late morning. Peak numbers were noted between late morning and midafternoon and numbers gradually declined thereafter. About 90% of the starling flight each day arrived and departed north to northeast of the landfill. The remainder of each day's flight arrived from and departed in a diffuse pattern from the east to southwest. Starlings tended to aggregate in 1 or 2 large flocks that would perch in roosts to the north of the landfill when birds were not actively feeding. They would fly to and from the landfill from these roosts frequently during the day.

**Starling repellent trials.** Starling numbers were least affected by the 3 repellent treatments, however by December 1992, approximately 400 fewer starlings were visiting the landfill than during the same time period in 1991 (Fig. 7). It was difficult to the repellent trials because they occurred during times when starling numbers typically inch at the landfill

(based on the previous year's observations). During the 4 days of the MA trial, starling numbers remained consistently between 300-400 individuals/day (Fig. 7). During the 5-day PS trial, starling numbers remained consistently between 400-500 individuals/day (Fig. 7). Also, starlings were less intimidated by PT. When bird bangers were used, starlings would fly away with the gulls and crows. However, starlings were the first to return to feed. Similar to crows, starlings often foraged on areas of the landfill other than the active dumping sites. Harassing starlings was much more tedious than scaring gulls, and it should be noted that during the 3 weeks of the Cornell-operated PT trial, primary attention was directed toward harassing gulls and crows. By the end of November and early December 1992, starting numbers ranged between 600-800 individuals/day, similar to daily counts during December 1991 (when no repellent trials were conducted). However, after the PT trial was initiated, starling numbers averaged at least 400 birds (50%) fewer during mid-December (Fig. 7).

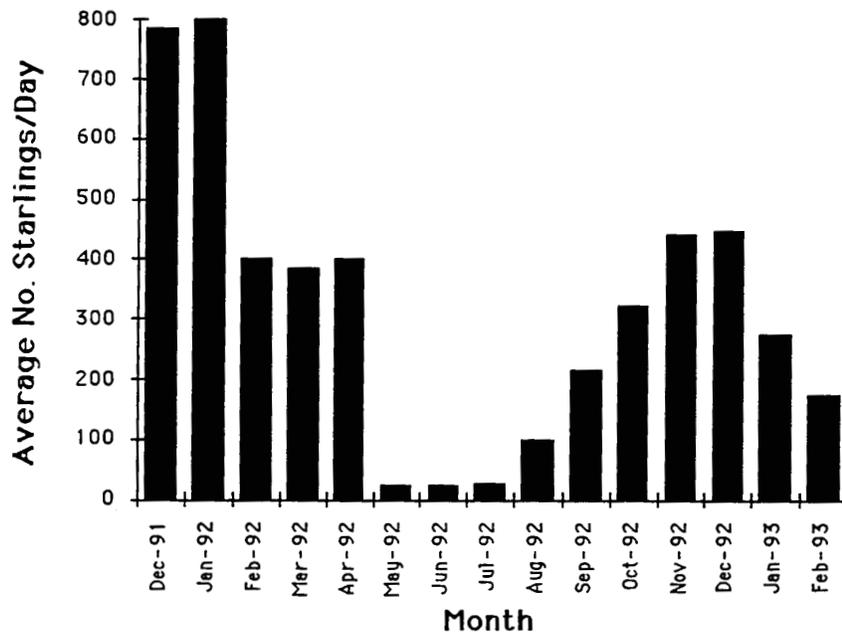


Fig. 6. Average number of starlings observed per day at Nanticoke Sanitary Landfill, Broome County, New York, December 1991 through February 1993.

**Other bird species observed at the landfill.** Four of landfill. Mourning doves were seen primarily in summer 10 other bird species observed at the landfill were gulls, and fall, feeding at the landfill in numbers averaging <12 Few great black-backed gulls (*L. marinus*) were present from December through February during both observation seasons. A peak daily count of 6 individuals was noted during January 1992. Three lesser black-backed gulls (*L. fuscus*) were observed during October and November 1992. In addition, a few Iceland gulls (*L. glaucooides*) and glaucous gulls (*L. hyperboreus*) were seen each winter.

Three species of hawks were observed hunting at the landfill throughout the year. A single red-tailed hawk (*Buteo jamaicensis*) was seen soaring over the landfill during nearly every afternoon observation session. Single Cooper’s hawks (*Accipiter cooperii*) and sharp-shinned hawks (*A. striatus*) were observed regularly hunting starlings. From late July through early October 1992, an average of less than 3 turkey vultures (*Cathartes aura*) per day were observed roosting in the trees around the landfill and attempted to feed on refuse in the afternoon. A peak count of 14 turkey vultures occurred in late September, corresponding with the peak migration period for this species (Bull 1974).

The 2 remaining avian species observed at the landfill were house sparrows (*Passer domesticus*) and the mourning doves (*Zenaida macroura*). A flock of up to 30 house sparrows was seen foraging at the landfill during 1992, and appeared to roost near the houses north of the landfill. Mourning doves were seen primarily in summer and fall, feeding at the landfill in numbers averaging < 12 individuals/day.

## DISCUSSION

The 4-day MA trial did not produce a noticeable reduction in the number of gulls foraging at the landfill. More gulls were observed washing and preening at several large puddles and a pond near the test area at the landfill after they had been foraging on MA-treated refuse. This behavior appeared to be a response to their encounter with the MA-treated garbage, and indicated their aversion to MA. However, gulls continued to forage on the fresh garbage, as the repellent effects of MA were not strong enough to overcome the gulls’ need for food. Also, MA only affected the surface of the garbage. By using their bills, gulls were able to obtain food underneath the MA-sprayed surface. On numerous occasions, gulls were observed removing food from plastic garbage bags by probing through holes in the plastic.

The effectiveness of PS in blocking gulls from obtaining food in the freshly-spread garbage was reduced because the PS never had time to dry and reach its maximum blocking potential. Fresh garbage is spread at least once per hour during the day at Nanticoke Landfill, and it takes approximately 15 minutes to cover the freshly-spread garbage with PS. The drying time of PS varies with weather conditions, but takes several hours to reach its minimum hardness. The quantity of labor and cost of the PS (estimated at \$500/day) to cover the continuously spread garbage cannot be justified given the relatively short time each barrier layer is in place.

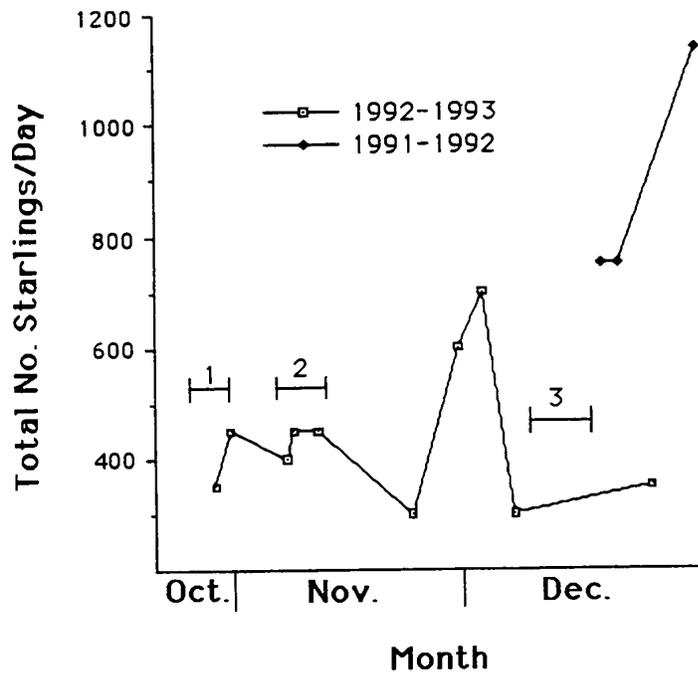


Fig. 7. Estimated number of starlings at Nanticoke Sanitary Landfill, Broome County, New York, during repellent trials in 1992-93, and baseline counts in 1991-92. Numbered bars designate trial times (1 = Methyl Anthranilate, 2 = Posi-shell®, 3 = Pyrotechnics).

The drop in bird numbers at the landfill during the PS trial was due to the repellent effect of spraying PS over the garbage. The PS trial was modified due to its high cost, and spraying (hazing) was carried out when birds attempted to feed. Birds would leave the active fill area during PS spraying, and would roost at other sites at or in the vicinity of the landfill. Each time birds attempted to feed, landfill personnel would spray a small amount of PS over the active fill area. Bird numbers at the landfill declined because their access to food was inhibited by this hazing effect. The modified PS trial was not as effective on crows and starlings as it was for gulls, because crows and starlings often foraged on other areas of the landfill other than the active dumping site. possibly they were searching for insects, and/or ingesting grit. Gulls only roosted on inactive parts of the landfill.

The effectiveness of PT in further reducing bird numbers after the modified PS trial can be attributed to the more mobile harassment that PT allows. The PS spray harassment could only be used at the active dumping site, whereas PT were used at the active dumping site, as well as bird roosting and foraging sites. This allowed for a more persistent and thorough harassment of birds, and PT were the most effective method for lowering bird foraging activity at Nanticoke Landfill.

In addition to being more flexible, were also less expensive. While water could potentially be used as a substitute for the more costly PS in the spray-harassment technique, the equipment and labor needed for this method is much more expensive than the portable pistol and shell crackers needed for FT harassment. Furthermore, the spray

merely deterred birds from eating and numbers declined because birds were deprived of food. PT not only kept birds from foraging, but also encouraged them to leave because the noise was a fear provoking stimulus.

PT appeared to be most effective on herring gulls, crows, and starlings in descending order. After 3 to 4 days of PT harassment herring gull numbers were drastically reduced. Typically, small groups of herring gulls would check the landfill during the days following intensive PT use, and it's possible that these were wandering individuals which had not been exposed to the scare devices. If these birds were not had' then gull numbers would increase during the next few days, as it seemed that "word" would spread that food was again available at the landfill. These observations are important because they suggest that harassment must continue on a oily basis throughout the gull migration period so that new arrivals can be aversively conditioned.

Crows numbers were reduced by PT, but not as completely as herring gulls. Crows present were easily dispersed with a few shots; however, between 30 to 40 individuals continued to visit the landfill after a month of harassment. These may have been local individuals that foraged at both the landfill and other areas nearby. The occasional lethal control of crows would likely enhance the effectiveness of PT. The lack of the winter flight path of approximately 130 crows that had come from Endwell to feed at the landfill during the preceding winter, may have been a result of harassment during 1992-93. The repellent trials began about the time this flight would have been forming, and possibly it was energetically too costly for

these crows to make the long flight if food was not guaranteed.

Starling numbers were reduced by the PT, but proportionally less than gulls or crows. Starlings seemed to recover from harassment faster than the other species. It should be noted however, that gulls and crows were higher priority targets than starlings, and it is possible that a more starling-focused harassment program could yield better results.

A varying response of different gull species to PT has been observed in other studies. Dolbeer et al. (1989), in a project aimed at reducing bird numbers at John F. Kennedy International Airport, noticed that laughing gulls (*Larus atricilla*), did not respond to harassment techniques. In fact, > 15,000 laughing gulls were shot while crossing runways at JFK by airport personnel in 1992, and a significant hazard still exists due to the nearby gull breeding colony. King-billed gulls may also be less sensitive to PT than herring gulls (R. Dolbeer, USDA-APHIS-Wildlife Services, pers. commun.). This may have implications for bird management at Nanticoke landfill. Ringbills are the predominant gull species at Nanticoke Landfill from August through September. Because the repellent trials were not initiated until late October, few data were gathered concerning the effectiveness of PT for scaring ring-billed gulls.

Once the effectiveness of PT was demonstrated, bird harassment was continued throughout the winter of 1992-93. Operation of the pyrotechnics was conducted by Nanticoke Landfill personnel on a use-as-needed basis, and the progress that had been made in reducing bird numbers was sustained.

**Bird Management at Nanticoke Landfill.** In order to maintain minimum bird activity at Nanticoke Landfill, 2 practices must be consistently followed by landfill personnel. First, the PT program should be continued. During much of the year, PT harassment could be adequately conducted by existing staff at the landfill, who are flexible enough in their normal responsibilities to confront minor bird population increases as they occur. However, from mid-July through mid-January, new migrant birds can arrive at the landfill each day. During this period either a specific landfill staff person, or a contracted nuisance wildlife control specialist, should have bird harassment as their primary responsibility. Even if bird populations appear low, bird numbers may quickly escalate if they are not harassed. If harassment only occurs sporadically, our observations indicate that birds will learn that they can sometimes obtain food at the landfill. Consequently, higher numbers will occur than if a consistent, daily harassment program existed.

PT harassment should be conducted with both banger and screamer shells to reduce the probability that birds will become accustomed to one shell type. Strategic use of the shells to maximize their effectiveness should result in an average usage of <20 shells per day during the peak months of activity. This translates to a cost of <\$10 per day for shells from July through January, and much less during the rest of the year. State and federal permits, should be obtained to use live shotgun fire for crows, gulls, and starlings, to occasionally reinforce the fear-provoking stimulus of the PT. We expect that a sustained PT program at Nanticoke Landfill from mid-July through February would greatly reduce bird hazards at E. A. Link Field.

The second bird management procedure which should be carried out at Nanticoke Landfill involves the proper capping of the active dumping area at the end of each day, especially before weekends and holidays. We noted that if the landfill is not capped thoroughly for the weekend, birds are attracted to the exposed food, and numbers can increase dramatically by the following Monday. This occurred because the birds fed without harassment during weekends. The same phenomenon occurred to a lesser extent if the landfill was not capped thoroughly at the end of each workday. This provided birds with an opportunity to forage for exposed food during late evening after work crews departed, and in early morning before landfill personnel arrived. Proper capping of the active pile at the end of each day will reduce the quantity of PT needed to repel birds.

**Bird Management at Link Field.** Current bird management procedures at E. A. Link Field include: (1) visual reporting of potential bird hazards by pilots, airport security, and control tower personnel; (2) bird harassment with PT as needed; (3) investigation and documentation of birdstrikes by aircraft, and (4) maintenance of the airport grounds to minimize their attraction to birds.

We recommend that Link Field personnel pay particular attention to the height of grass along the runways. The Federal Aviation Administration Airport Wildlife Hazard Management manual (U.S. Dep. Transp. 1988:30-34) outlines the advantages and disadvantages of different grass heights for discouraging bird use. Previous research indicated that a grass height between 15-25 cm (6-10 in) was optimal for reducing bird numbers feeding near airfields. Portions of Link Field seem to have grass lengths below the recommended level, possibly because of poor soil conditions. A review of the grass management policy at Link Field could result in fewer birds (i.e., crows and starlings) foraging at the airfield.

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