AFESC - TR - 80 - 02

ATTRACTIVENESS OF SHREDDED GARBAGE TO GULLS AND OTHER AVIAN SPECIES POTENTIALLY HAZARDOUS TO AIRCRAFT

DENNIS M. FORSYTHE
THE CITADEL
CHARLESTON, S C

FEBRUARY 1980

1 JANUARY TO 31 DECEMBER 1976
FINAL REPORT

DIRECTORATE OF ENVIRONMENTAL PLANNING
AIR FORCE ENGINEERING AND SERVICES CENTER
TYNDALL AIR FORCE BASE, FLORIDA 32403

NOTICE

PLEASE DO NOT REQUEST COPIES OF THIS REPORT FROM HQ AFESC. ADDITIONAL COPIES MAY BE PURCHASED FROM:

NATIONAL TECHNICAL INFORMATION SERVICE
5282 PORT ROYAL ROAD
SPRINGFIELD, VIRGINIA 22161

FEDERAL GOVERNMENT AGENCIES AND THEIR CONTRACTORS REGISTERED WITH DEFENSE TECHNICAL INFORMATION CENTER SHOULD DIRECT REQUESTS FOR COPIES OF THIS REPORT TO:

DEFENSE TECHNICAL INFORMATION CENTER
CAMERON STATION
ALEXANDRIA, VIRGINIA 22314

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFESC-TR-80-02	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* The Attractiveness of Shredded Gargabe to Gulls and Other Avian Species Potentially Hazardous to Aircraft.		5. TYPE OF REPORT & PERIOD COVERED Final Report January-December 1976 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Dr Dennis M. Forsythe		8. CONTRACT OR GRANT NUMBER(s) 14-16-ØØØ8-2Ø24
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Department of Interior, Fish and Wildlife Service Patuxent Wildlife Research Center Laurel, Maryland 20811		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS PE 91212F ØØDEVN21
11. CONTROLLING OFFICE NAME AND ADDRESS HQ AIR FORCE ENGINEERING AND SERVICES CENTER Tyndall AFB FL 32403		12. REPORT DATE February 1980 13. NUMBER OF PAGES 97
14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*
Approved for Public Release; Distribution Unlimited

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*
Bird/aircraft strike hazard, bird movement/population patterns, feeding habits, loafing/feeding sites.

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*
Bird activities were studied during January-December 1976 at the solid waste shredder at Romney Street, Charleston, South Carolina. At least 84 bird species were observed; Herring Gulls, Ring-billed Gulls, Laughing Gulls, Common Crows, Fish Crows, Boat-tailed Grackles, and Cattle Egrets were the major species. Up to 1,000 Herring Gulls, 300 Ring-bills, and 800 crows were present in winter. Greater proportions of immature Herring and Ring-billed Gulls were found at the shredder than in the greater study area; the reverse was true for

DD FORM 1 JAN 73 1473

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

Laughing Gulls. Gull and crow daily movement patterns showed peaks of abundance during midmorning and midafternoon. Similar peaks but reduced numbers were noted on weekends and at other times when refuse was not being processed. Daily movement patterns were not influenced by tidal or seasonal variations. All species but Ring-billed Gulls showed a preference for feeding on newly-dumped piles of shredded refuse on the landfill; Ring-bills fed primarily on unprocessed refuse at the mill. All gull species fed on shredded refuse, Cattle Egrets on insects obtained from the refuse, and crows and grackles on invertebrates in the nearby salt marshes as well as on some shredded garbage.

About 50 insect species representing 32 families and seven orders were found in the shredded refuse. The most abundant species were flies of the families Muscidae, Calliphoridae, and Scarcophagidae. Rats and feral dogs were present on the landfill.

During 1976, about 163,172 tons of solid waste were processed at Romney Street, with an average of 2,587 tons shredded per week. Lowest amounts were processed on Wednesdays, Saturdays, and Sundays, with peak amounts on Mondays and Fridays No correlations were found between daily gull numbers and amounts of refuse dumped or between bird numbers and shredded particle size. Results indicated that shredders attracted birds potentially hazardous to aircraft in about the same numbers as would be found at a sanitary landfill.

Gull numbers and habits were monitored in the 500 square mile greater Charleston area during 1976. Herring, Ring-billed, and Laughing Gulls were the main species present. Numbers of Herring and Ring-billed, but not Laughing gulls were significantly reduced from those of 1971-72; however, variations in weather between the years obscured this difference. Gull movement patterns and food sources also changed with the reduction in number of solid waste disposal sites in 1976. Most gulls remained along the coast, with few inland flights; and most birds fed on natural food sources. These habits were reflected in an 86 percent reduction in the number of bird strikes at Charleston Air Force Base for 1976 (only two strikes) when compared with 1971-72 (14 strikes). These data demonstrate the usefulness of solid waste zoning and consolidation as a technique for reducing the bird/aircraft collision problem.

PREFACE

This study was performed under Program Element 91212F, AFESC JON IEDEVN21. Inclusive dates of the study were 1 January-31 December 1976.

This report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nations.

This report has been reviewed and is approved.

Jeffrey J Short

JEFFREY J. SHORT, Capt, USAF
BASH Reduction Team Leader

William M. Kornman

WILLIAM M. KORNMAN
Chief, Natural Resources Division

Sterling E. Schultz

STERLING E. SCHULTZ, Colonel, USAF
Director of Environmental Planning

ACKNOWLEDGMENT

Thanks go to D. D. Terry, K. L. Touchton, R. Pop, and H. Fraser for assistance in the field. Capt G. Lyle, Flight Safety Officer, Charleston Air Force Base, provided data on bird strikes. Dr. L. Knutsen and the Insect Identification Section, U.S. Department of Agriculture, Agricultural Research Service, Beltsville, Maryland, kindly identified insect species. Mr L. Singletary, Plant Manager, Solid Waste Reduction Center, Romney Street, allowed access to the shredder and provided data on solid waste disposal in Charleston County. Dr T. R. Adkins, Dr W. B. Ezell, J. Adkins, A. Dill, and J. Vorgetts provided comments and suggestions used to improve the manuscript. Dr J. L. Seubert and J. Forsythe encouraged me in all aspects of this study.

CONTENTS

FIGURES

TABLES

SECTION I

INTRODUCTION

Objectives

The objectives of this study were: (1) to determine the attractiveness of shredded garbage as a food source for birds; and (2) to determine what changes have occurred in gull populations and movement patterns and the bird/aircraft strike hazard at Charleston Air Force Base now that solid waste, formerly deposited at open dumps and sanitary landfills, is being processed in a shredder prior to dumping at a landfill.

Statement of Problem

The bird/aircraft strike hazard is a worldwide problem resulting in human fatalities and aircraft damage. Although the exact cost of bird damage is difficult to obtain, United States commercial losses are estimated at several million dollars per year and annual cost to the Air Force runs over $10 million (Refs 1, 2).

Collision between birds and aircraft frequently occurs either enroute or when planes are landing or taking off at airports. Most of these collisions are caused by large flocks of birds attracted to the vicinity by food, shelter, or water (Ref 3). Solid waste disposal sites are sources of food for many of the hazardous bird species, especially gulls and blackbirds; and if these sites are located near airports, they constitute a major cause of potential bird/aircraft collisions (Refs 4, 5). Thus, information on the attractiveness of birds to solid waste disposal sites is important and may lead to a reduction in the number of bird/aircraft collisions.

To date, most studies have been conducted on open dumps and sanitary landfills because these were the most common methods of waste disposal (see Refs 6 and 7 for a review of these studies). However, the technique of milling or shredding solid waste has recently begun to replace the other methods; and this trend will probably continue. With the exception of a survey of 22 milling sites in Europe (Ref 8), little is known about the attractiveness of shredded material to bird species potentially hazardous to aircraft. Thus, data are needed on the attractiveness of shredded refuse to birds, so that a potentially hazardous bird/aircraft collision problem can be avoided when planning the placement of shredded solid waste sites near airports.

The Charleston, South Carolina area offered a unique opportunity to obtain information on the attractiveness of shredded garbage to birds. Data are available from a prior study (Ref 9) of avian populations and movement patterns (especially gulls)

related to waste disposal sites and the bird/aircraft strike hazard at Charleston AFB. Further, the Charleston County Health Department closed all dumps and landfills and replaced them with a solid waste shredder in June 1974. This study was conducted to obtain information about the attractiveness of shredded solid waste to birds, and about changes in bird populations and movement patterns that result when waste disposal sites are closed and replaced by a shredding plant.

SECTION II

STUDY AREA AND METHODS

General Study Area

Observations were made in a 500 square mile section of Charleston, Berkeley, and Dorchester Counties, South Carolina (Fig 1). About 15 percent of the area was coastal marsh or barrier island; 40 percent was urban habitat; and 45 percent was farmland, swamp or forest. The study area was part of the Coastal Plain; hence, it was flat and low, with the highest elevation 50 feet above sea level. The extent of the study area was large enough to include the majority of the gulls and other avian species that might be hazardous to aviation at Charleston AFB. Intensive field work was conducted within the Greater Charleston area (Fig 2).

Romney Street Solid Waste Reduction Center

Since July 1974, the only major solid waste disposal site was the Charleston County Solid Waste Reduction Center located at the east end of Romney Street adjacent to the Cooper River and Drum Island (Fig 2). This approximately 73-acre complex consisted of a shredding plant and adjacent landfill (Fig 3). The shredding plant, a corrugated steel structure with concrete floor, contained three Heil Company shredding units. Two units milled at the rate of 20 tons per hour and one at 40 tons per hour. Once milled, the material was carried on conveyor belts to trucks that transported the shredded refuse to the landfill. In May 1975, a ferrous-metal recovery unit was added to the complex.

The landfill was a former dredge-material disposal site whose last pumping operations terminated approximately 20 years ago. Initially, it was covered with a dense stand of vegetation, chiefly Red Mulberry (Morus rubra) and Groundselbush (Baccharis halimifolia) with an understory of Lamb's Quarters (Chenopodium album) and Pokeberry (Phytolacca americana). Most of the vegetation disappeared as the landfill was used.

Other Waste Disposal Sites

Although the Romney Street Shredder was the main disposal site used during this study, three others deserve mention. A 5-acre tract on Stromboli Street near the former Spruill Avenue landfill was used as an alternate site whenever the shredder broke down (Fig 2). The City also operated a 60-acre site on Azalea Avenue for the disposal of dry trash and construction material (Fig 2); no garbage was dumped at this landfill. In 1972, the county closed all sewer outlets and replaced them with a secondary treatment plant located on Plum Island (Fig 2).

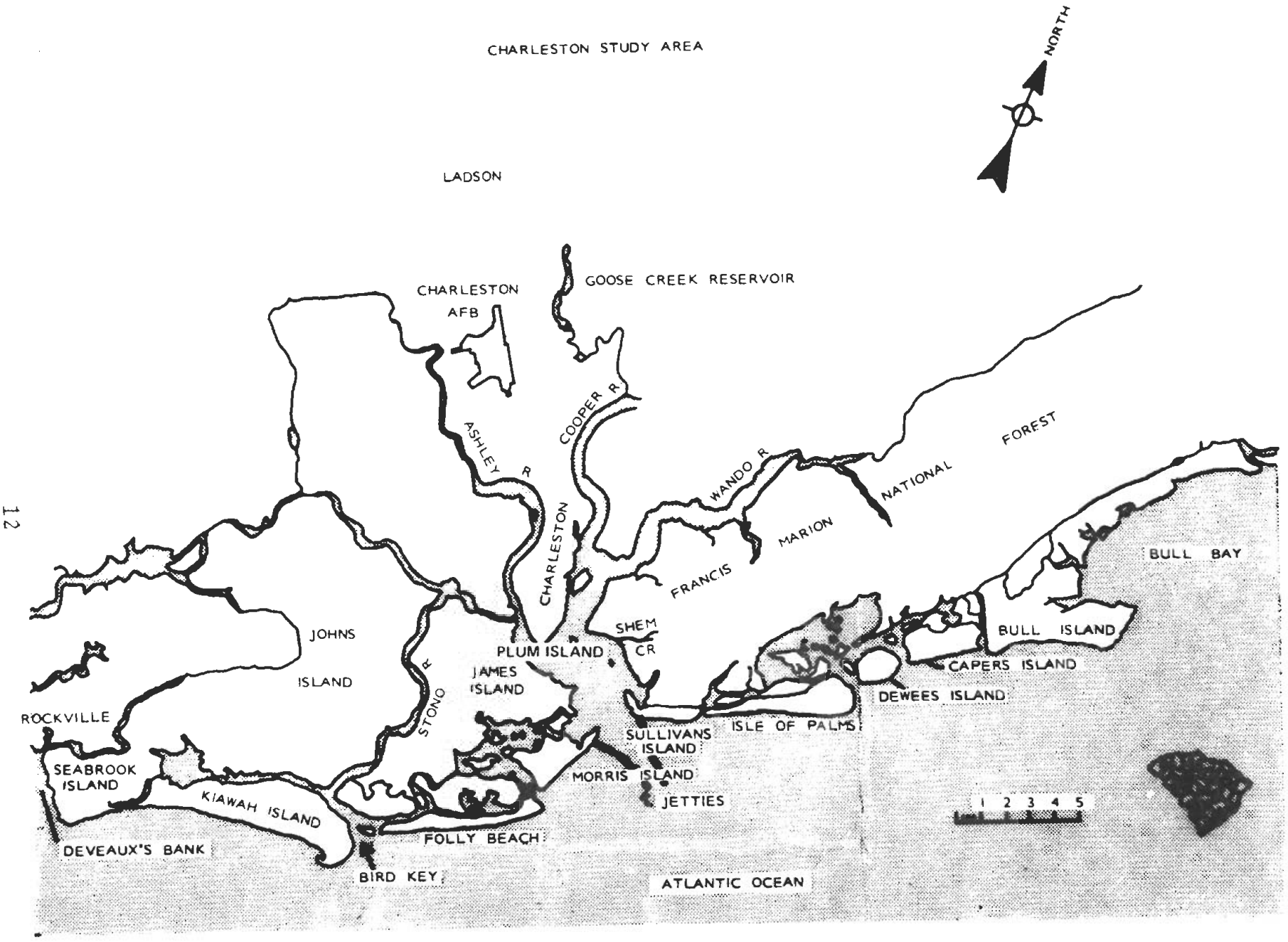


Figure 1

Charleston Gull Ecology Study Area

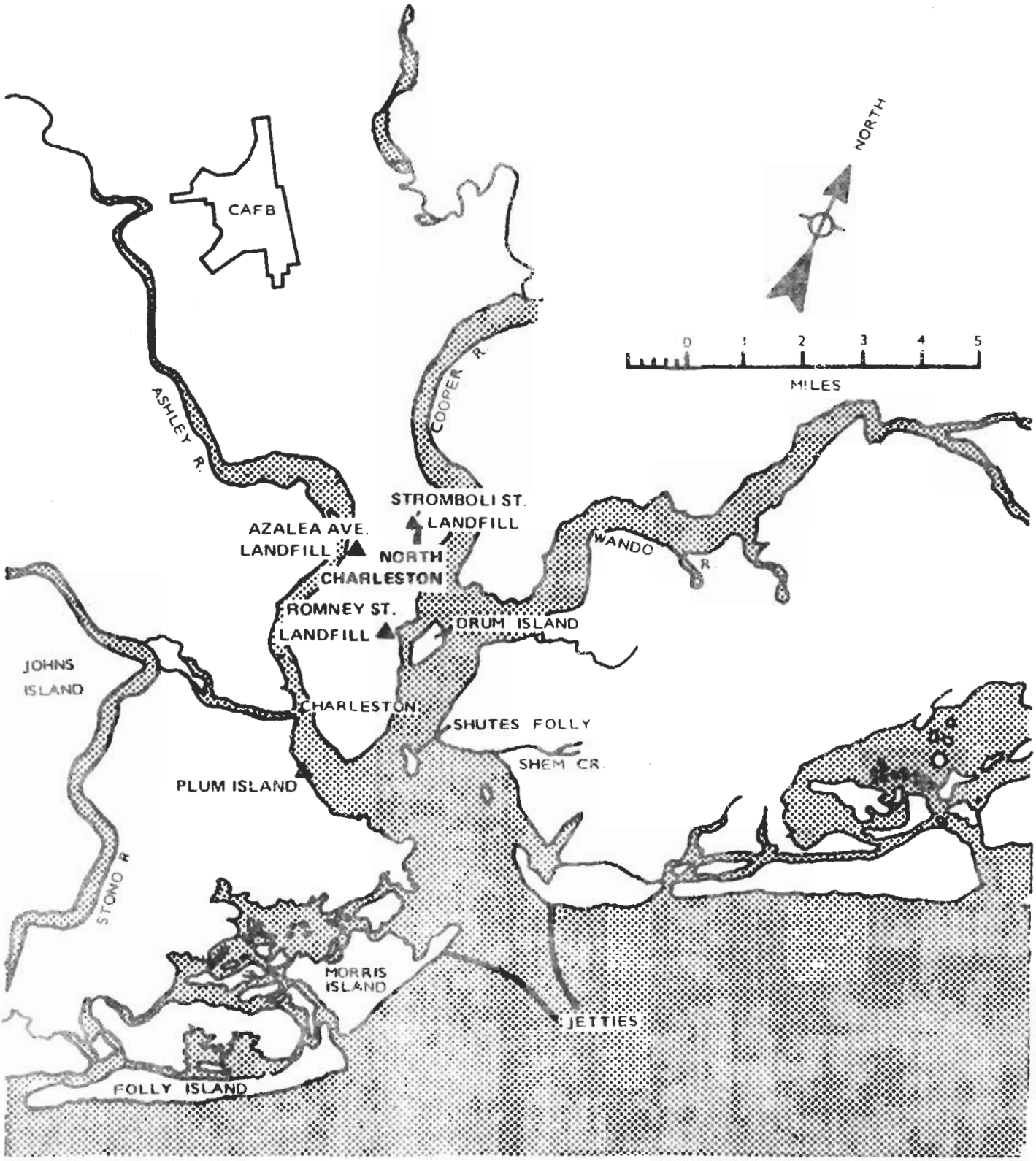


Figure 2

Metropolitan Charleston Area Within Which
Most Intensive Field Work Was Conducted

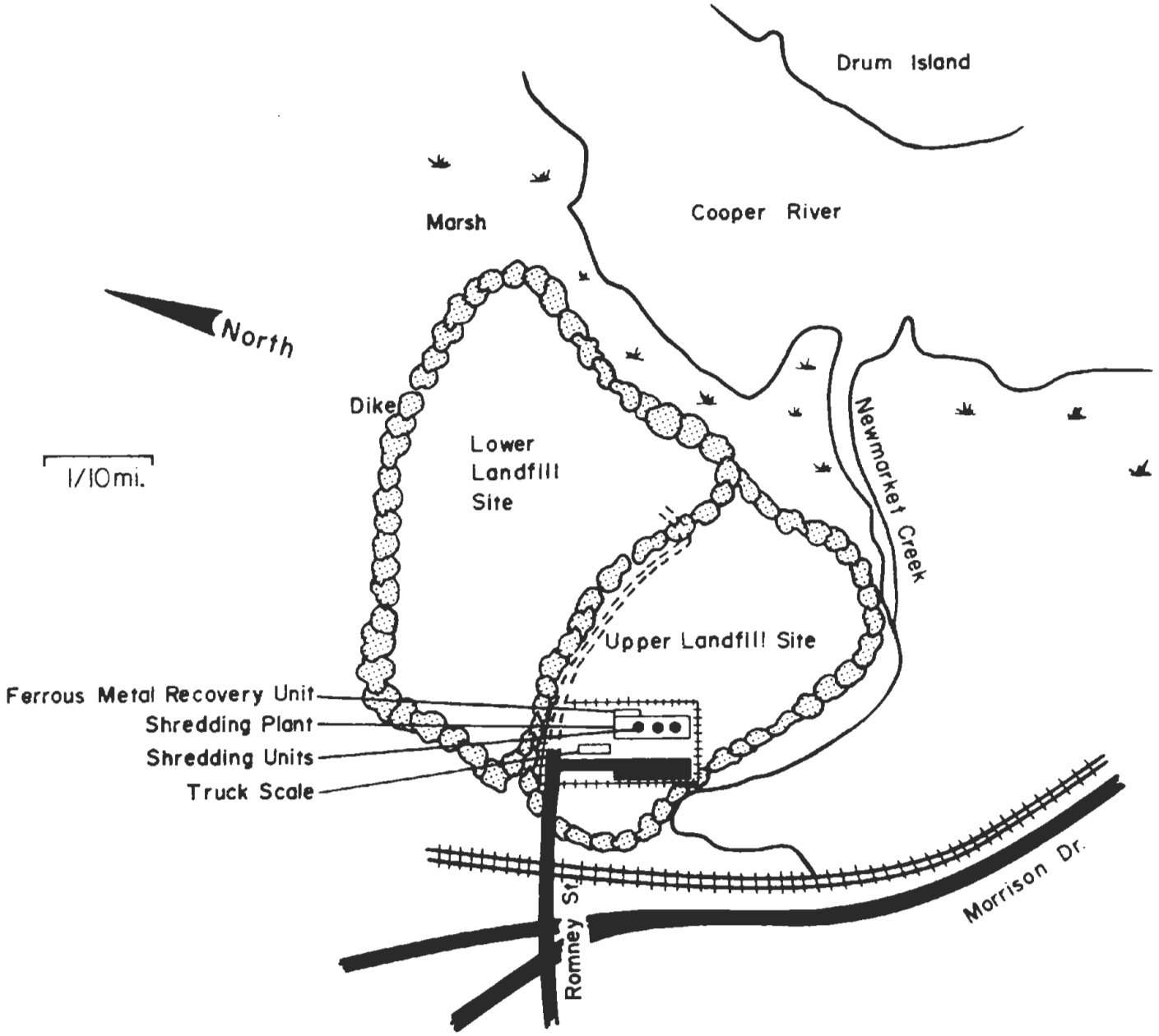


Figure 3

Charleston County Solid Waste Reduction Center, Romney Street
Charleston, S. C.

SECTION III

MATERIALS AND METHODS

Determination of the Attractivenss of Shredded Garbage to Birds

The study was conducted from 1 January through 31 December 1976 at the Charleston County Solid Waste Reduction Center, Romney Street, Charleston, South Carolina. A total of 26 dawn-to-dusk counts were made at the site to determine daily use patterns of birds. At least two counts were made each month, and the days were selected to determine what variables influenced daily use. In addition, hourly counts were made at the shredder a minimum of three days a week. Preliminary data indicated that peak numbers occurred in midmorning and midafternoon, so most counts were made during these times. Bird counts also were made at other times of day, both on weekdays and weekends. On each count, data was collected on species present, sex and age ratios, feeding behavior, and loafing sites. Area weather and tidal information also were recorded. Age ratios were determined by plumage characteristics as suggested by Poor (Ref 10) and Kadlec and Drury (Ref 11) for the Herring Gull (Larus argentatus) and by Dwight (Ref 12) for other gulls. Once a week, particle size of shredded refuse was measured by taking samples in a pre-weighed 10-gallon garbage pail and processing them through a series of wire sieves which discriminated among 6-inch, 4-inch, and 2-inch size particles. From these, the proportion, by weight, of each particle size class in the sample was determined. The amount of solid waste processed daily was obtained from the records of the reduction center. Unlike the previous study (Ref 9), accurate figures could be obtained as each load brought to the center was weighed on truck scales.

Several procedures were used to determine if birds fed on shredded garbage and/or invertebrates associated with the shredded material. At least five birds of each important species were collected during January, April, July, and October. The species included: Herring Gull, Ring-billed Gull (L. delawarensis), Laughing Gull (L. atricilla), Boat-tailed Grackle (Quiscalus major), Cattle Egret (Bubulcus ibis), Common Crow (Corvus brachyrhnchos), and Fish Crow (C. ossifragus). Attempts were made to collect birds when they were feeding in the vicinity of shredded refuse on the landfill. Individuals were taken to the laboratory, where they were measured and weighed and their crops and gizzards removed and stored in 70 percent ethanol. Gut contents were analyzed, and food items were separated and catalogued by volume and frequency of occurence (Ref 13).

To determine if invertebrates were present in the shredded refuse, five random 10 m^2 sweeps were made with a sweep net over

the shredded garbage once a week. All sweep samples were made during midafternoon on weekdays when peak bird numbers were present. To determine if invertebrates lived and bred in the shredded material and were available as food for birds, ten samples (0.1 m^2) of milled material were collected at the same time as sweep net samples. Five of these samples were processed through Berlese funnels (Ref 14), and five were placed in emergence traps. The samples were left in the funnels for 48 hours, the trap samples for two weeks. The invertebrates obtained were identified to species when possible, and their density and frequency of occurence were determined.

Determination of Current Gull Populations and Movement Patterns in the Charleston Area

Gull populations and movement patterns in the general study area were determined by aerial surveys conducted monthly during May-September, and bi-weekly during January-April and October-December. Emphasis was placed on Herring Gull and Ring-billed Gull populations, as these were the main hazardous species (Ref 9). In all, 19 surveys were flown in a Cessna 150 or 172 single-engine aircraft. Flights averaged four hours and were made in the morning, over the same course, at altitudes of 500-800 feet. Clear weather with light winds and good visibility but variable tidal conditions occurred on all censuses. On each count, the species, numbers, locations, and movement patterns of all gulls were recorded. Aerial photographs, taken with a 35-mm camera using fine-grain, black-and-white film, were made on the first three counts. These were compared with the results of ground counts and of the aerial surveys. They showed that the counts underestimated gull numbers by about 11 percent, which was better than the 25 percent underestimation experienced in the 1971-72 study. The only identification problem was differentiating between immature Herring and Great Black-backed Gulls (L. marinus), but there were so few Black-backs that the error was negligible. Ground censuses were made in conjunction with each aerial survey. Additional ground counts were made at areas of gull concentrations when necessary, but at least once a month. Bird/aircraft strike records for Charleston AFB were obtained from the Flight Safety Officer. The population counts obtained from these censuses and the related bird/aircraft strike data were compared with those of the previous study (Ref 9) to evaluate the changes that occurred since 1971-72. To facilitate this comparison, the methods of the previous study (Ref 9) were used whenever possible.

SECTION IV

RESULTS AND DISCUSSION

Species Present and Population Size at the Charleston County Solid Waste Reduction Center, Romney Street

At least 84 species of birds were observed at Romney Street during 1 January - 31 December 1976 (Table 1). Of these, nearly 50 percent (41 species) were passerines, chiefly species associated with the shrub- and tree-covered dikes bordering the landfill. The 11 species of long-legged waders were present because of the site's proximity to Drum Island (Fig 2), location of a major rookery containing an estimated 44,000 ibises, egrets, and herons. Only seven species occurred in large enough numbers and high enough frequencies to be considered the principal components of the Romney Street avian community; these species probably would be a major hazard to aircraft if the landfill were near an airport. They included: Herring Gull, Ring-billed Gull, Laughing Gull, Common Crow, Fish Crow, Boat-tailed Grackle, and Cattle Egret. Their seasonal abundance is shown in Figures 4-9. For each species, a weekly population average was determined by finding the mean number observed for at least three weekday counts during periods of peak bird activity. Only counts taken when the shredder was operating were used for these figures. Because of the difficulty in separating the two crow species, their numbers were pooled and reported as crow species.

Herring Gull numbers ranged from 700 in early January to zero during the summer (Fig 4). January-March numbers averaged about 350 birds, with increases to 600-700 in the first weeks of January and February. These peaks were associated with cold fronts and other adverse weather conditions in the Charleston area. A rise of 550 during the first two weeks of March was related to migratory movements. In April-May, numbers declined to about 50-60, with a weather-related increase to 110 at the end of April. An additional drop to 3-4 birds in June was followed by a complete lack of gulls during July-September. Numbers increased to 50-60 in late October, 150 in November, about 300 by early December, and 600 by the end of 1976. No migrational movements were seen in the fall.

Ring-billed Gulls exhibited seasonal population trends similar to those found in Herring Gulls, with peaks in the winter and lows in the summer (Fig 5). However, differences between the two species were observed. Ring-bill members were more constant, averaging about 180 during January-May and October-December, and fewer weather-induced fluctuations were noted. Also, their population remained high during April, after Herring numbers had declined; and during late October-early November before Herring Gulls had reappeared. During these periods and in June-August,

TABLE 1. OCCURRENCE OF BIRD SPECIES AT THE CHARLESTON COUNTY SOLID WASTE REDUCTION CENTER (ROMNEY STREET), 1 JANUARY - 31 DECEMBER 1976

Species	Abundance	Location
Great Blue Heron	1-3 birds, all year	marshes adjacent to landfill
Green Heron	1-2 birds, April-Sept.	brushy edges of temporary ponds
Little Blue Heron	5-8 birds, all year	marshes adjacent to landfill
Cattle Egret	1-81 birds, Feb.-Oct.	on landfill
Great Egret	1-5 birds, all year	marshes adjacent to landfill
Snowy Egret	1-8 birds, all year	marshes adjacent to landfill
Louisiana Heron	1-5 birds, all year	marshes adjacent to landfill
Black-crowned Night Heron	1-3 birds, summer	trees on dikes
Yellow-crowned Night Heron	1 bird, summer	trees on dikes
Glossy Ibis	5-20 birds, March-Sept.	flying over landfill
White Ibis	1-3 birds, March-Sept.	on landfill
Turkey Vulture	4-8 birds, all year	on landfill
Black Vulture	1-3 birds, all year	on landfill
Sharp-shinned Hawk	1 record, Sept.	trees on dikes

TABLE 1 (continued)

Species	Abundance	Location
Cooper's Hawk	2 records, November	flying over landfill
Red-tailed Hawk	1-3 birds, winter	flying over landfill
Marsh Hawk	1 bird, winter	marshes adjacent to landfill
Peregrine Falcon	1 record, November	flying over landfill
American Kestrel	1-3 birds, winter	trees on dikes, landfill
Clapper Rail	5-15 birds, all year	marshes adjacent to landfill
Sora	1 bird, March	marshes adjacent to landfill
Killdeer	1-5 birds, all year	on landfill
Common Snipe	2-4 birds, winter	temporary ponds and ditches on landfill
Spotted Sandpiper	2-3 birds, all year	temporary ponds and ditches
Solitary Sandpiper	4 birds, March, Sept.	temporary ponds and ditches
Greater Yellowlegs	1 bird, March	temporary ponds and ditches
Least Sandpiper	1 bird, Sept.	temporary ponds and ditches
Great Black-backed Gull	1 adult, Dec.	on landfill
Iceland Gull	1 immature, Feb.	on landfill

TABLE 1 (continued)

Species	Abundance	Location
Herring Gull	up to 1000, all year; less numerous in summer	on landfill
Ring-billed Gull	up to 300 birds, all year; less numerous in summer	on landfill
Laughing Gull	1-250 birds, all year; most numerous in summer	on landfill
Mourning Dove	numerous flocks (1-80), all year	on landfill
Yellow-billed Cuckoo	1-3 birds, summer	trees along dikes
Barred Owl	1 record, June	trees on dikes
Common Nighthawk	1 pair, summer	breeds on landfill
Chimney Swift	3-8 birds, April-Sept.	flying over landfill
Belted Kingfisher	1 bird, all year	marshes adjacent to landfill
Common Flicker	2 birds, all year	landfill
Red-bellied Woodpecker	1-3 birds, all year	trees on dikes
Yellow-bellied Sapsucker	1-5 birds, winter	trees on dikes
Downy Woodpecker	1-3 birds, all year	trees on dikes
Eastern Kingbird	1 bird, June	brush along dikes

TABLE 1 (continued)

Species	Abundance	Location
Great Crested Flycatcher	1-4 birds, summer	trees on dikes
Eastern Phoebe	1 bird, Nov.	brush along dikes
Tree Swallow	small flocks, winter	flying overhead
Rough-winged Swallow	small flocks, summer	flying overhead
Barn Swallow	small flocks, summer	flying overhead
Purple Martin	small flocks, March-Sept.	flying overhead
Blue Jay	1-20 birds, all year	trees and brush on dikes
Common and Fish crow	30-800 birds, all year	landfill and dikes
Carolina Chickadee	1-3 birds, all year	trees and brush on dikes
House Wren	1-5 birds, winter	brush and trees on dikes
Carolina Wren	2-10 birds, all year	brush and trees on dikes
Long-bill Marsh Wren	common, all year	adjacent salt marshes
Mockingbird	1-4 birds, all year	trees and brush areas
Brown Thrasher	13 birds, all year	trees and brush on dikes
American Robin	small flocks, winter	trees on dikes

TABLE 1 (continued)

Species	Abundance	Location
Ruby-crowned Kinglet	4-20 birds, winter	trees and brush on dikes
Water Pipit	one flock of 25, Nov.	on landfill
Cedar Waxwing	numerous flocks, winter	trees adjacent to landfill
Loggerhead Shrike	1-3, all year	brush and trees on dikes
White-eyed Vireo	1-3 birds, summer	brush along dikes
Red-eyed Vireo	1-5 birds, summer	trees along dikes
Black-and-white Warbler	one bird, 11 Dec.	trees on dikes
Yellow-rumped Warbler	small flocks, winter	trees and brush along dikes
Palm Warbler	1-8 birds, winter	trees and brush along dikes
Northern Waterthrush	small flocks, spring and fall	brush along dikes
American Redstart	small flocks, spring and fall	brush along dikes
House Sparrow	1-30 birds, all year	mill and landfill
Eastern Meadowlark	5-20 birds, all year	on landfill
Red-winged Blackbird	1-15 birds, all year	on landfill

TABLE 1 (continued)

Species	Abundance	Location
Boat-tailed Grackle	7-250 birds, all year; most common in winter	trees on dikes and on landfill
Common Grackle	scattered individuals, Jan.-April and Sept.-Dec.	trees along dikes and on landfill
Cardinal	small numbers, all year	brush and trees on dikes
Painted Bunting	1-3 birds, April-Aug.	landfill and brushy areas
American Goldfinch	small flocks, winter	brushy areas on dikes
Rufous-sided Towhee	1-8 birds, all year	brush on dikes
Savannah Sparrow	up to 100 birds, winter	on landfill
Dark-eyed Junco	1-20 birds, winter	brushy areas
White-throated Sparrow	1-40 birds, winter	brushy areas on dikes
Swamp Sparrow	small flocks, winter	trees near water
Song Sparrow	small flocks, winter	brush along dikes

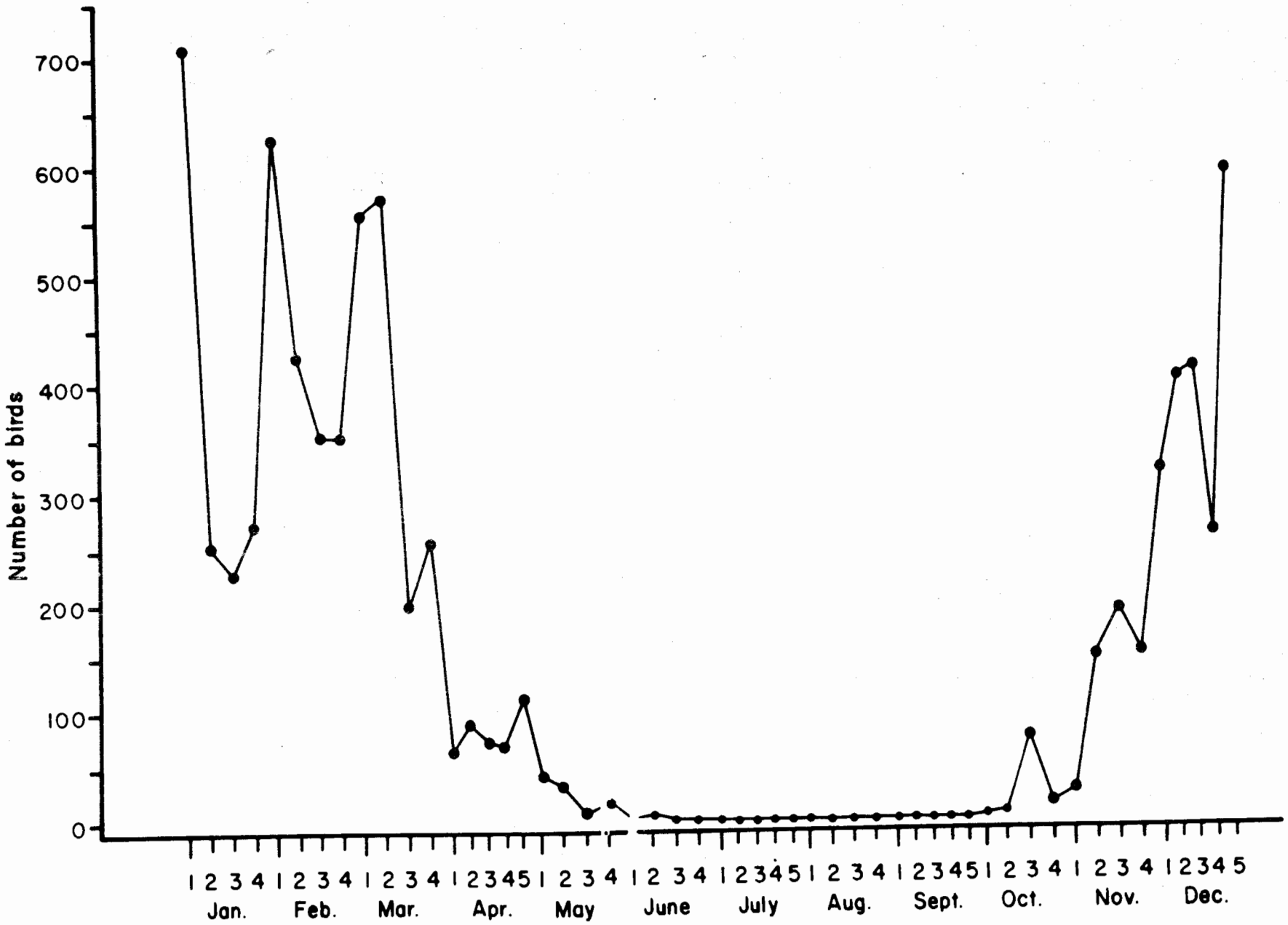


Figure 4

Number of Herring Gulls at the Charleston County Solid Waste Reduction Center, Jan. 1 - Dec. 31, 1976.

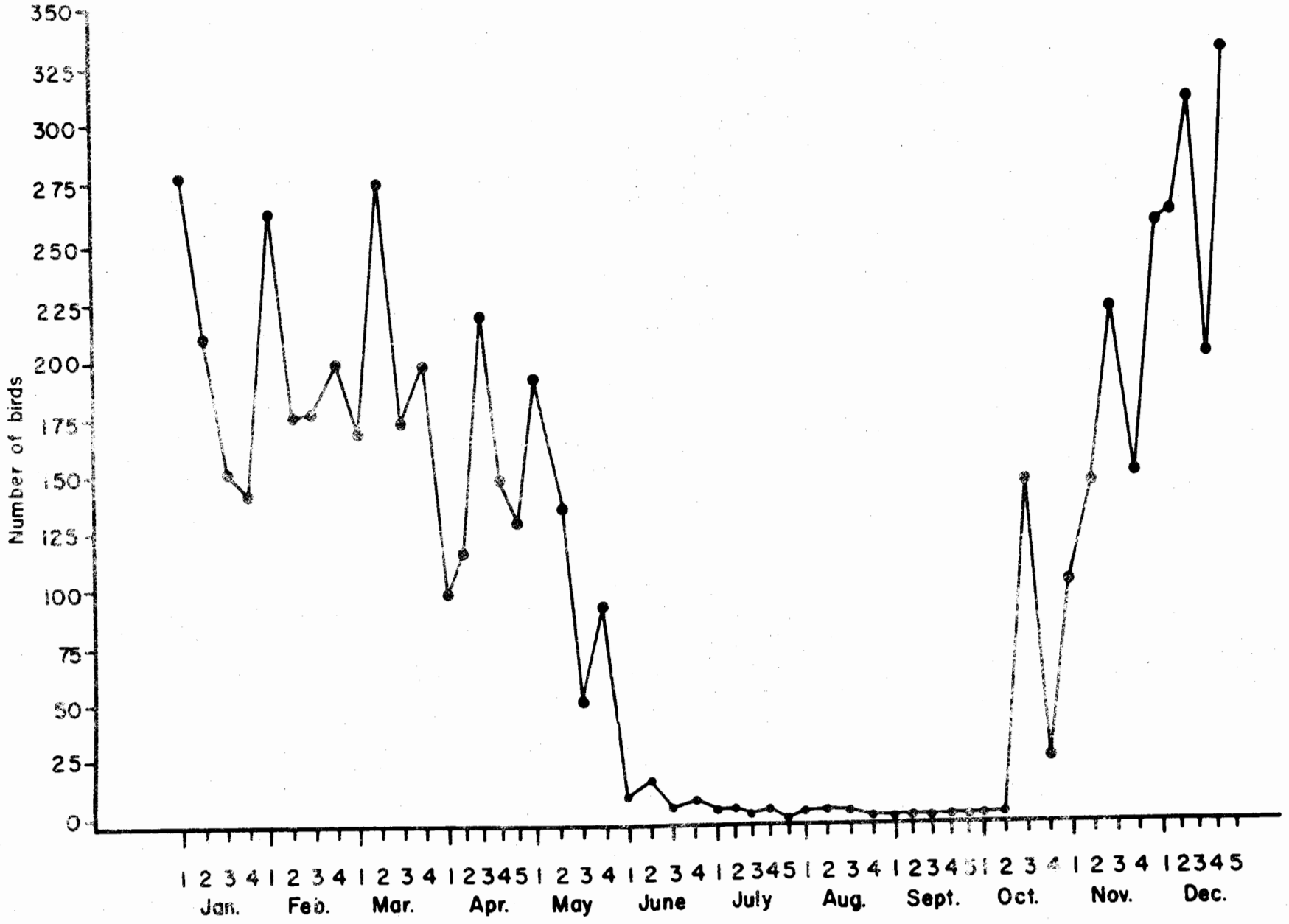


Figure 5

Number of Ring-billed Gulls at the Charleston County Solid Waste Reduction Center
Jan. 1 - Dec. 31, 1976

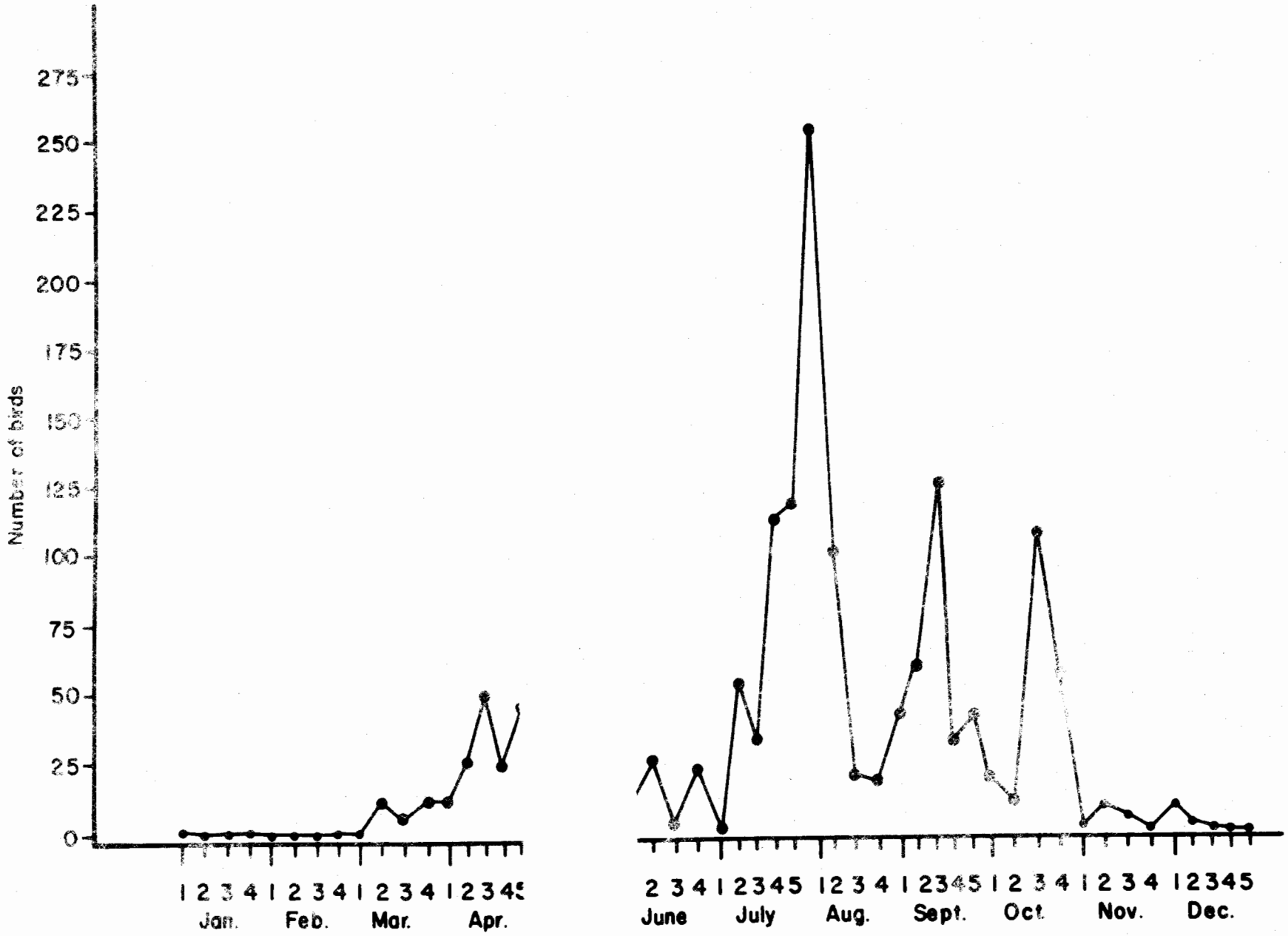
Ring-bills outnumbered Herrings only. Ring-billed Gulls were completely absent only in September.

Laughing Gulls were the least abundant of the three gulls commonly observed at Romney Street. They were present in small numbers throughout the year (Fig 6) with 10-40 consistently present in April-October. Increases to 100-250 were detected in the last week of May, late July-early August, and the third weeks of September and October. The spring and summer increases were associated with strong offshore winds, which drove the birds inland. The October peak was also associated with strong weather patterns, but the birds were clearly migrants from the North. Several color-marked birds banded in New Jersey were seen on the landfill during the October peak.

Crow population trends were similar to those for Herring and Ring-billed Gulls (Fig 7), with high populations in winter and low ones during spring and summer (April-July). Unlike gulls, crow numbers remained relatively constant for a given period without weather-induced fluctuations. The April-July low occurred at a time when flock break-up and breeding in Fish Crows was at its peak (Ref 15). The relative proportions and the seasonal distributions of the two crow species in the Romney Street population were impossible to determine directly. However, calling counts and samples taken for food analysis suggested that most of them were Fish Crows--probably 70-80 percent of the winter population, and almost 100 percent during June-August.

Boat-tailed Grackles were present in varying numbers throughout the year (Fig 8). The population averaged 250 birds in January-February, after which it declined to 15-30 in April-October. Numbers increased in October-November to 275, before declining to 125 in late December. The winter population consisted mainly of one or two large feeding flocks, chiefly composed of females and immatures (90-95 percent), while the summer population was primarily solitary individuals about equally divided between adult males and adult females that fed in the immediate vicinity of the landfill.

Cattle Egrets were present at Romney Street almost solely during the summer, arriving by early March and leaving by early October (Fig 9). Although over 1,000 birds bred on nearby Drum Island (Personal communication: 4 January 1976, Dr Thomas Custer, Wildlife Biologist, United States Department of the Interior, Patuxent Wildlife Research Center, Laurel, Maryland 20810), the Romney Street bird population was relatively low, with a range of 14-80 and an average of 35 birds. This gave a density range of 0.19-1.1 birds per acre (average 0.49). These figures are similar to those observed by Siegfried (Ref 16) for African Cattle Egrets feeding in their natural habitat (0.5-1.5 birds/acre). The similarity in feeding densities between the two



e 6

Number of Laughing Gulls at the
Jar

on County Solid Waste Reduction Center
. 31, 1976

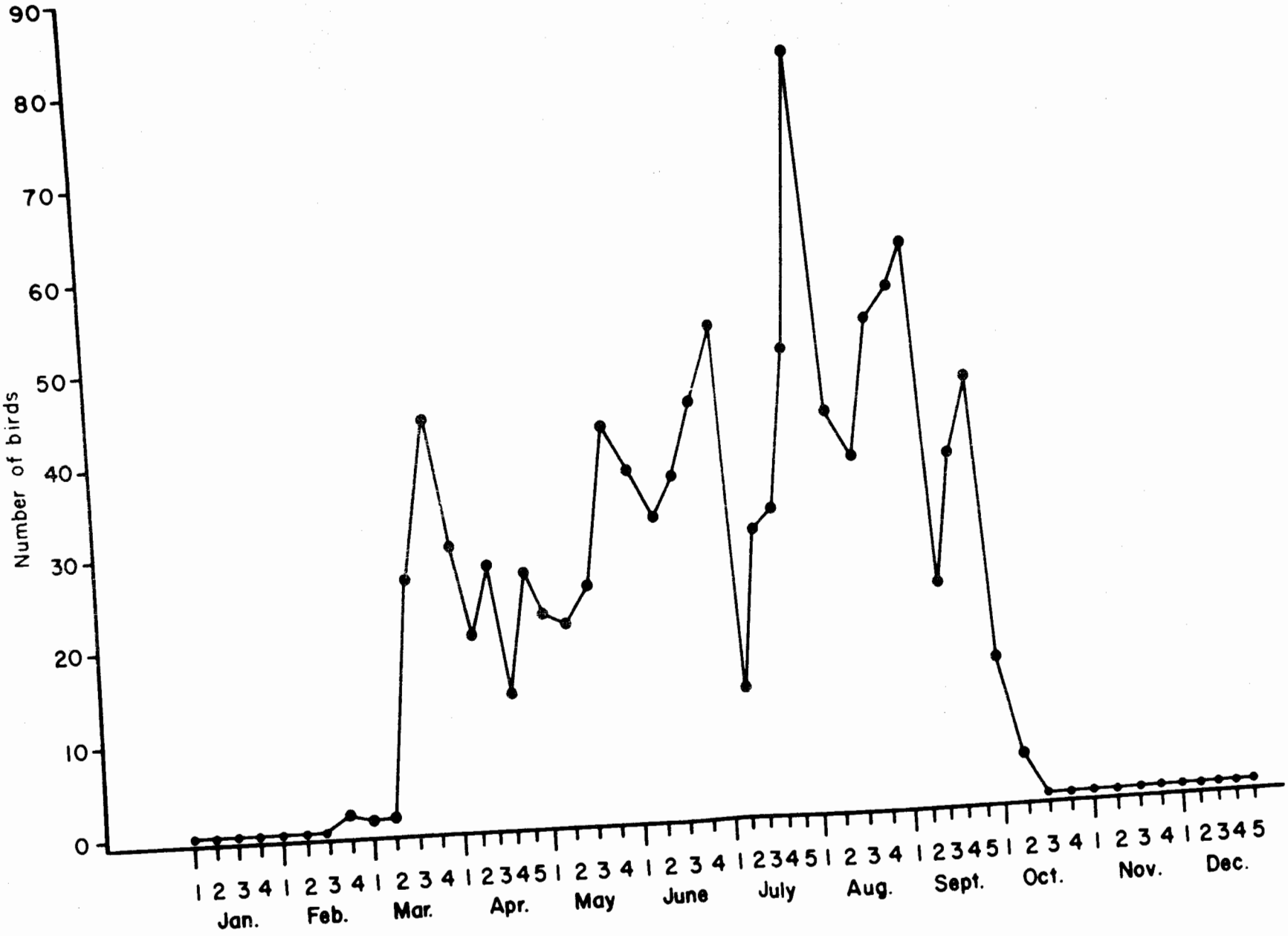


Figure 9

Number of Cattle Egrets at the Charleston County Solid Waste Reduction Center
Jan. 1 - Dec. 31, 1976

habitats suggest Cattle Egret populations were regulated by factors such as foraging behavior or intraspecific aggression, and that the food resources were similar in both habitats.

Influence of Geography and Topography on Species Composition

Clearly, the Romney Street shredder attracted a variety and abundance of bird species. Although data are lacking, shredders in other areas also probably attract numerous birds (Ref 17). Probably at all sites, the main hazardous species are the gregarious birds belonging to the following groups: crows, blackbirds and Starlings, House Sparrows, pigeons, Cattle Egrets, and gulls. The species composition, seasonal abundance and occurrence of these groups are determined mainly by two factors: geography and topography.

Four corvid species may frequent shredders, especially as flocks during the non-breeding season (August-March). Common crows are the most abundant and widespread species, occurring throughout Eastern North America. In the Southeast, their numbers are augmented and/or replaced by Fish Crows, especially in coastal areas such as Charleston. The Northwestern Crow (C. caurinus), occuring in the tidal zone from Alaska to Washington, may frequent sites in numbers large enough to be a hazard to aircraft, as may the Common Raven (C. corax) in the far North (especially Alaska) and West.

Blackbirds and Starlings (Sturnus vulgaris) are often present at dumps and shredders in numbers large enough to cause a bird/aircraft strike incident similar to that which occurred at the Dekalb-Peachtree Airport, Atlanta, Georgia (Ref 18). These species are especially a problem in the Southeast during winter when large flocks are present (Ref 19, 20). In inland locations such as Atlanta, blackbirds may replace gulls as the major hazardous group. In the Southeast, the most important species are: Starlings, Red-winged Blackbirds (Agelaius phoeniceus), Brown-headed Cowbirds (Molothrus ater), Common Grackles (Quiscalus quiscula), and (along the coast) Boat-tailed Grackles.

Small numbers of Rock Doves (Columba livia) may be found at shredders year round. Despite their presence in low numbers, these pigeons can be a major hazard to aircraft because of their size and flock density. In Europe, pigeons cause up to ten percent of all bird strikes (Ref 21), and they pose a similar hazard to North American aircraft. House Sparrows (Passer domesticus) also are found at disposal sites in small numbers, but they are a less threat to aircraft because of their small size.

Cattle Egrets, recent arrivals in North America, are undergoing a rapid population expansion in the East (Ref 22). They are most abundant in the Southeast, where groups of up to 100 may be seen feeding at disposal sites during the summer (Refs 23, 7).

They are known to frequent shredders in Charleston and Beaufort, South Carolina, as well as in Florida. Their presence at such sites, along with their habit of feeding in grassy areas near airports, make Cattle Egrets a potential hazard to aircraft, especially in the Southeast (Personal communication: 9 September 1977, M. Harrison, Capt, USAF, Air Force Civil Engineering Center, Tyndall AFB, Florida 32403).

Although most gulls are opportunistic feeders, not all regularly use garbage as their main food source. Those species that do feed on refuse, however, are involved in about 40 percent of the bird/aircraft strikes reported for Europe and North America (Ref 21). In the Northeastern United States, Iceland, and western Europe, the Herring and Great Black-backed Gulls are the principal refuse-feeding species (Refs 24, 25, 26). On the West Coast, Glaucous-winged (L. glaucescens), Western (L. occidentalis), California (L. californicus) Herring, and Ring-billed Gulls are the important species (Refs 27, 28, 29). In the Southeast, Ring-billed and Herring Gulls are the main species at sites in winter (Refs 5, 9), with Laughing Gulls present at coastal locations mainly in the summer.

Local topographic features influence the species composition and abundance of birds attracted to disposal sites. In the Southeast, Fish Crows and Boat-tailed Grackles are mostly restricted to coastal areas. They are replaced by Common Crows and Common Grackles at inland locations. In fact, the blackbird species seem to be more abundant away from the coast in the Southeast. All gulls seem attracted to areas near water (Refs 24, 27, 30). However, some species variation in habitat preference is present: Herring and Laughing Gulls prefer coastal locations, while Ring-bills prefer inland areas. The Romney Street landfill reflected this, as Herring Gulls outnumbered Ring-billed Gulls and the proportions of the two species were similar to those found in 1971-1972 at the Naval Base Dump, a dump located between the present shredder and landfill (Ref 9), and the Cooper River Estuary. The reverse trend in the proportion of these gulls could be expected if the shredder were located in a more inland site such as the former Ladson landfill (Fig 2 in Ref 9). Other topographical features attractive to gulls include: open areas with little or no vegetation, and large flat areas.

Age Structure of Gulls at Romney Street

Age-ratio data for gulls at the shredder are summarized in Figures 10-12. Herring Gulls (Fig 10) were divided into three age classes: chicks (1 year old or less); intermediate (2-3 years old); and adults (3 or more years old). The winter (January, December) population averaged 72 percent chicks, 3.5 intermediates, and 24.5 adults. After January, the proportion of chicks declined until none were present in May through early October. Adults, after an initial increase in February-March,

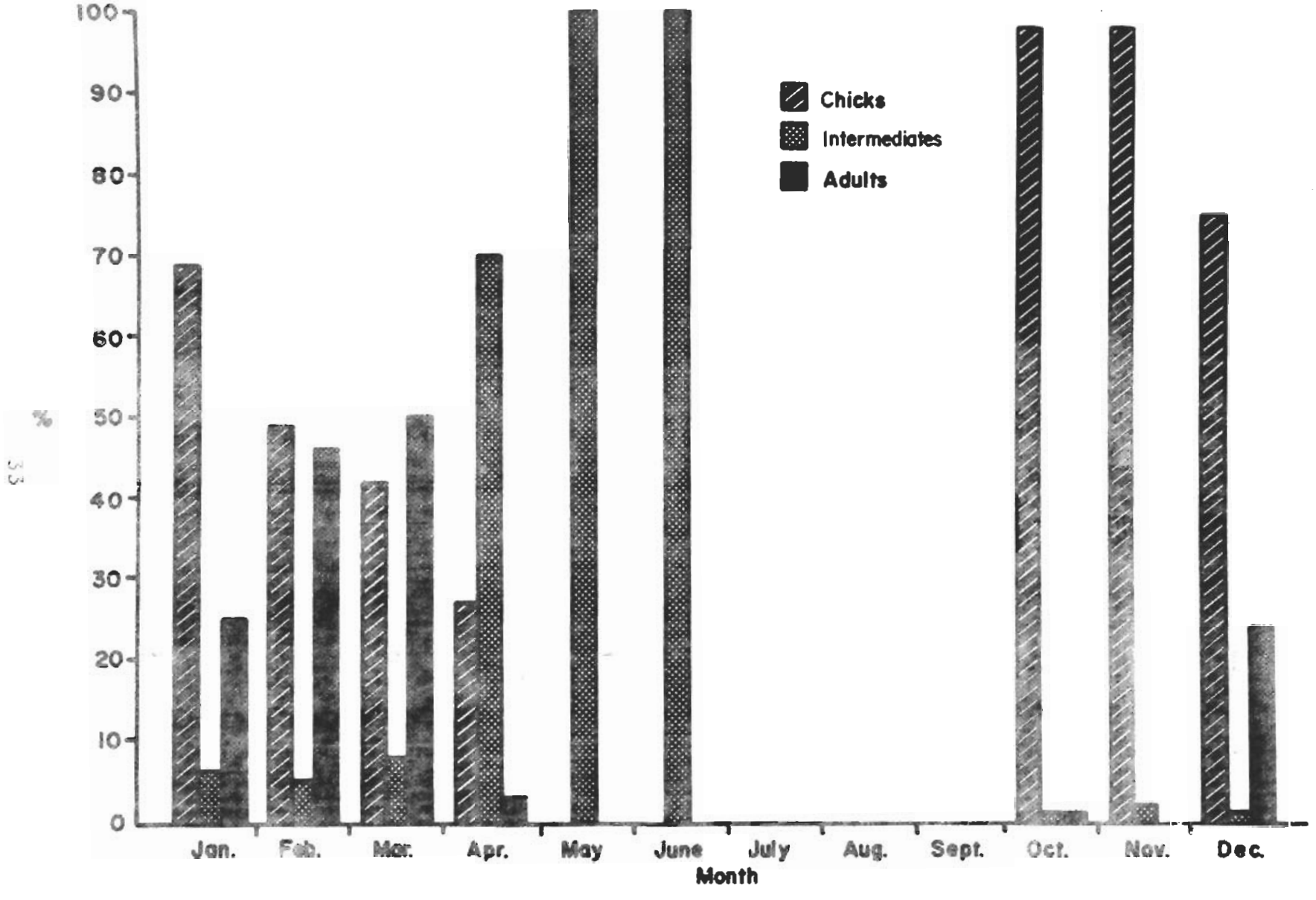


Figure 10

Age Ratio of Herring Gulls at Charleston County Waste Reduction Center, Romney Street, Charleston, S. C.

rapidly declined to zero in May. Intermdiates, on the other hand, increased to 100 percent in May-June. When gulls reappeared in late October, they were almost all chicks. The normal winter ratio was re-established in December. The age ratio and its seasonal trends were similar to those observed at the Charleston Base-Spruill Avenue dump in 1971-72 (Ref 9), but the reverse of those observed for Herring Gulls in their breeding range of Michigan, Maine, and Connecticut (Refs 31, 32, 33, 34).

The large majority (over 90 percent of Ring-billed Gulls were in immature plumage (chicks), less than one year old (Fig 11). The largest proportion of adults (10-17 percent) were present in February-April, the period when the highest concentration of post-breeding Ring-bills from the Great Lakes Region are present along the South Atlantic Coast (Ref 35). Similar age-ratio trends were observed at dumps and landfills in Charleston during 1971-72 (Ref 9).

Laughing Gull age-ratio trends (Fig 12) were the reverse of those for the previous two species. As is typical for a species in the northern part of its wintering range, all winter and early spring birds were adults, over one year of age. Immature birds (chicks) appeared in May, and reached a peak (70 percent) in the last week of May. The summer population averaged 22 percent immature, and a migration peak occurred in early October.

Observations suggest that immature gulls may concentrate at disposal sites and other artificial food sources. Thus, Drury (Ref 24) found that 90-95 percent of the immature Herring Gulls in the Boston area fed at dumps and pig farms; and I found large numbers of immature Herring and Ring-billed Gulls at dumps and landfills in Charleston (Ref 9), but was unable to determine if the numbers were significantly different from those for the rest of the Greater Charleston area. To determine if such age preferences did exist, I compared age ratios for gulls present at the shredder with those found elsewhere in the study area, using a Chi-Square test of independence (Ref 36). Herring, Ring-billed, and Laughing Gulls all showed significant differences in the proportion of birds in immature plumage present at the shredder as compared with the remainder of the Charleston area (Tables 2-4). Immature Herring and Ring-billed Gulls concentrated at the shredder (Tables 2 and 3). This may have been due to either an exclusion from natural areas by adults, as Drury and Smith (Ref 37) found for New England birds, or because immature gulls were inexperienced in food procuring. Thus, Cooke and Ross (Ref 30) found young gulls spent more time foraging for food on dumps than did adults. If immature gulls frequent disposal sites because of lack of feeding experience, they must be inexperienced in other areas, e.g., aircraft avoidance. Thus, positioning a solid waste disposal site near an airport may increase the potential bird/aircraft strike hazard because of inexperienced immature gulls being attracted to the area.

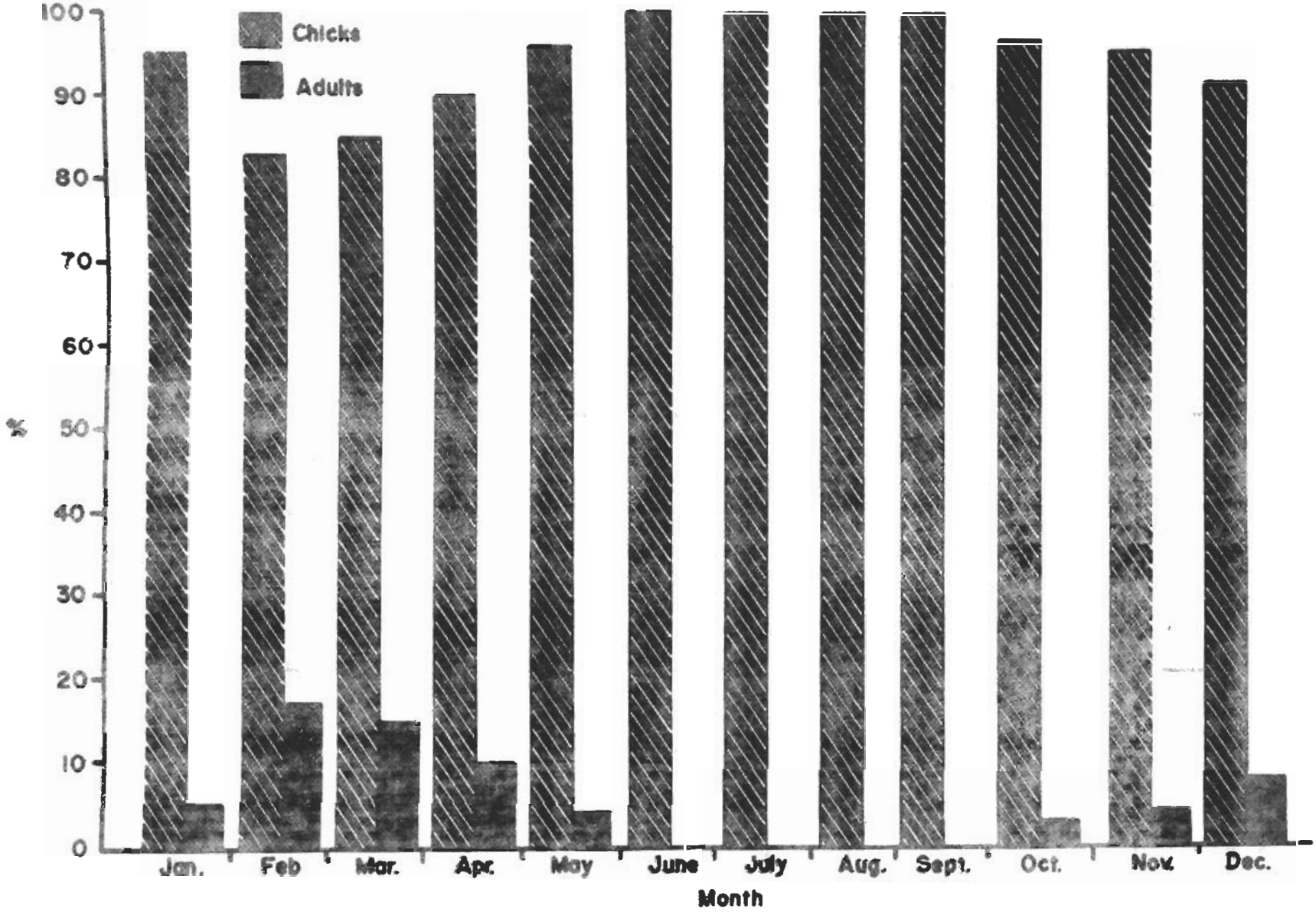


Figure 11

Age Ratio of Ring-billed Gulls at Charleston County Waste Reduction Center, Romney Street Charleston, S. C.

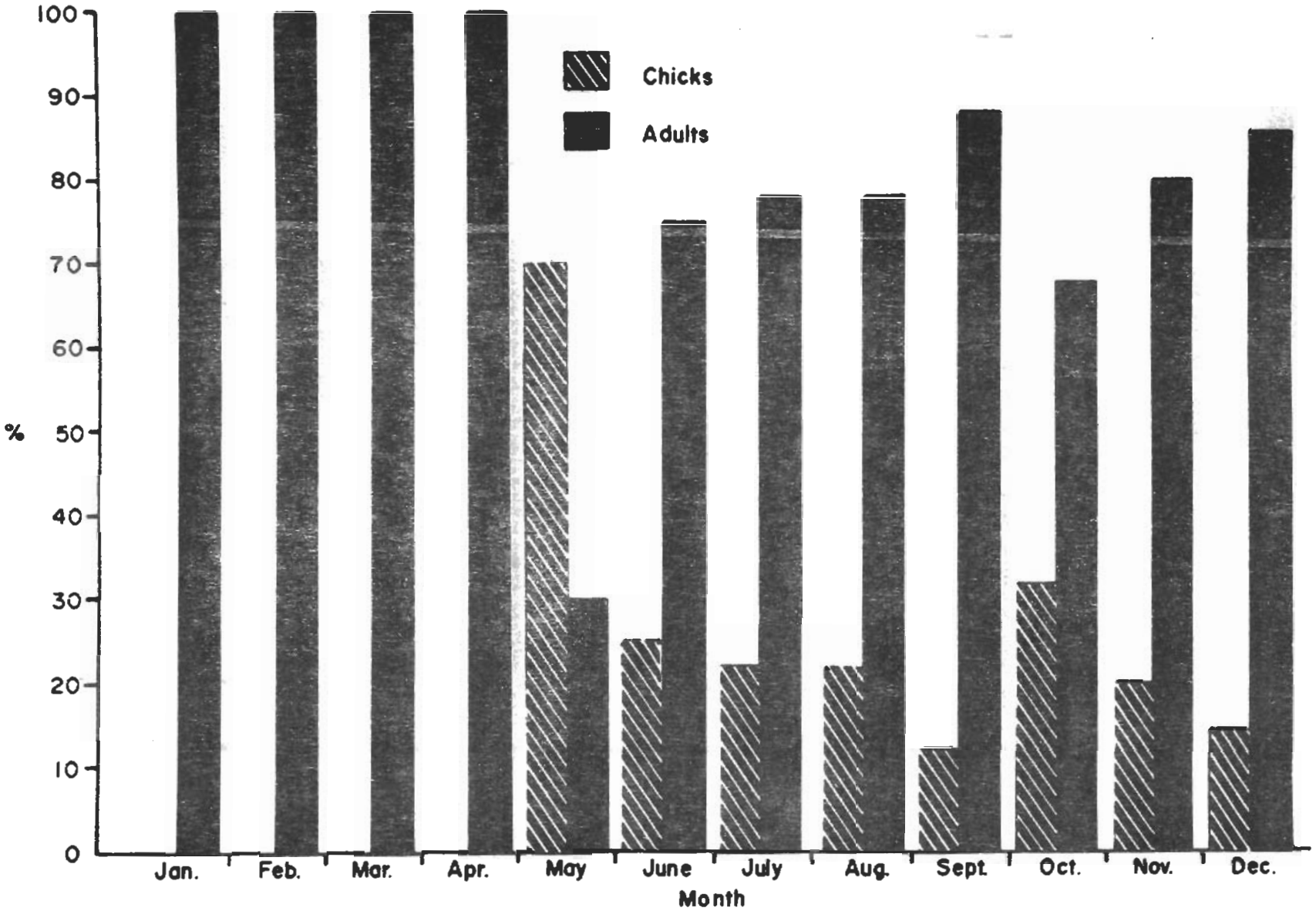


Figure 12

Age Ratio of Laughing Gulls at Charleston County Waste Reduction Center, Romney Street Charleston, S. C.

TABLE 2. COMPARISON OF AGE RATIOS OF HERRING GULLS BETWEEN THE ROMNEY STREET SHREDDER AND THE CHARLESTON STUDY AREA, USING A CHI-SQUARE TEST OF INDEPENDENCE

Month	Week		Age: Chicks	Age: Intermediates	Age: Adults	Totals
January	2.	Observed	202	12	38	252
		Expected	199.08	15.12	37.8	252
		Chi-square	0.043	0.644	0.01	0.697
	4.	Observed	211	11	333	555
		Expected	183.15	27.75	344.1	555
		Chi-square	4.234	10.11	0.358	14.702
February	2.	Observed	248	8	268	524
		Expected	199.12	10.48	314.4	524
		Chi-square	12.90	0.59	6.849	20.339
	4.	Observed	137	38	189	364
		Expected	145.6	40.04	214.76	400.4
		Chi-square	0.51	0.104	3.09	3.704
March	2.	Observed	270	11	282	563
		Expected	259.44	11.28	293.28	564
		Chi-square	0.43	0.07	0.44	0.94
	4.	Observed	170	8	76	254
		Expected	157.48	12.7	83.82	254
		Chi-square	0.99	1.74	0.73	3.46
April	2.	Observed	26	52	0	78
		Expected	11.7	62.4	3.9	78
		Chi-square	17.5	1.74	3.9	23.14
	4.	Observed	13	57	0	70
		Expected	11.9	56	2.1	70
		Chi-square	0.1	0.018	2.1	2.218
May		Observed	0	32	0	32
		Expected	0	31.04	0.96	32
		Chi-square	0	0.03	0.96	0.99
June		Observed	0	5	0	5
		Expected	0	5	0	5
		Chi-square	0	0	0	0

TABLE 2 (continued)

Month	Week		Age: Chicks	Intermediates	Adults	Totals
July		Observed	0	0	0	0
		Expected	0	0	0	0
		Chi-square	0	0	0	0
August		Observed	0	0	0	0
		Expected	0	0	0	0
		Chi-square	0	0	0	0
September		Observed	0	0	0	0
		Expected	0	0	0	0
		Chi-square	0	0	0	0
October	2.	Observed	5	0	0	5
		Expected	3.5	0.5	1.0	5
		Chi-square	0.65	0.5	1.0	2.15
	4.	Observed	14	1	0	15
		Expected	9.75	1.8	3.45	15
		Chi-square	1.85	0.36	3.45	5.66
November	2.	Observed	144	3	0	147
		Expected	110.25	7.35	29.4	147
		Chi-square	10.33	2.57	29.4	42.3
	4.	Observed	148	2	0	150
		Expected	120	7.5	22.5	150
		Chi-square	6.54	4.0	22.5	33.04
December	2.	Observed	282	0	115	397
		Expected	232.2	19.85	138.95	397
		Chi-square	8.05	19.85	4.13	32.03
	4.	Observed	450	1	134	585
		Expected	386.1	46.8	152.1	585
		Chi-square	10.57	44.82	2.16	57.55

Chi-square = 253.002 with 36 dmf, significant at the 0.05 level.

TABLE 3. COMPARISON OF AGE RATIOS OF RING-BILLED GULLS BETWEEN THE ROMNEY STREET SHREDDER AND THE CHARLESTON STUDY AREA, USING A CHI-SQUARE TEST OF INDEPENDENCE

Month	Week		Age: Chicks	Age: Adults	Totals
January	2.	Observed	198	10	208
		Expected	197.6	10.4	208
		Chi-square	0.008	0.015	0.023
	4.	Observed	137	7	144
		Expected	116	28	144
		Chi-square	3.937	15.75	19.687
February	2.	Observed	105	70	175
		Expected	113.75	61.25	175
		Chi-square	0.673	1.25	1.923
	4.	Observed	134	63	197
		Expected	110.32	86.68	197
		Chi-square	5.082	6.469	11.551
March	2.	Observed	291	96	387
		Expected	313.47	73.53	387
		Chi-square	1.610	6.867	8.477
	4.	Observed	179	18	197
		Expected	163.51	33.49	197
		Chi-square	1.467	7.164	8.631
April	2.	Observed	248	24	272
		Expected	149.6	122.4	272
		Chi-square	64.72	79.10	143.82
	4.	Observed	128	17	145
		Expected	139.2	5.8	145
		Chi-square	0.9	21.62	22.52
May		Observed	128	5	133
		Expected	127.68	5.32	133
		Chi-square	0.0	0.019	0.019
June		Observed	17	0	17
		Expected	17	0	17
		Chi-square	0	0	0

TABLE 3 (continued)

Month	Week		Age: Chicks	Age: Adults	Totals
July		Observed	4	0	4
		Expected	4	0	4
		Chi-square	0	0	0
August		Observed	3	0	3
		Expected	2.94	0.06	3
		Chi-square	0.001	0.06	0.061
September		Observed	0	0	0
		Expected	0	0	0
		Chi-square	0	0	0
October	2.	Observed	2	0	0
		Expected	1.9	0.1	2
		Chi-square	0.05	0.1	0.15
	4.	Observed	128	3	131
		Expected	120.62	10.38	131
		Chi-square	0.082	5.247	5.329
November	2.	Observed	240	8	248
		Expected	235.6	12.4	248
		Chi-square	0.082	1.56	1.642
	4.	Observed	186	2	188
		Expected	182.36	5.64	188
		Chi-square	0.073	2.34	2.413
December	2.	Observed	237	23	260
		Expected	221	39	260
		Chi-square	1.15	6.564	7.714
	4.	Observed	297	29	326
		Expected	211.9	114.1	326
		Chi-square	34.176	63.47	97.646

Chi-square = 331.606, 18 df, significant at the 0.05 level.

TABLE 4. COMPARISON OF AGE RATIOS OF LAUGHING GULLS BETWEEN THE ROMNEY STREET SHREDDER AND THE CHARLESTON STUDY AREA, USING A CHI-SQUARE TEST OF INDEPENDENCE

Month	Week		Age: Chicks	Age: Adults	Totals
January	2.	Observed	0	0	0
		Expected	0	0	0
		Chi-square	0	0	0
	4.	Observed	0	0	0
		Expected	0	0	0
		Chi-square	0	0	0
February	2.	Observed	0	0	0
		Expected	0	0	0
		Chi-square	0	0	0
	4.	Observed	0	1	1
		Expected	0	1	1
		Chi-square	0	0	0
March	2.	Observed	0	11	11
		Expected	0	11	11
		Chi-square	0	0	0
	4.	Observed	0	12	12
		Expected	0	12	12
		Chi-square	0	0	0
April	2.	Observed	0	28	28
		Expected	0	28	28
		Chi-square	0	0	0
	4.	Observed	0	24	24
		Expected	0	24	24
		Chi-square	0	0	0
May		Observed	0	2	2
		Expected	0	2	2
		Chi-square	0	0	0
June		Observed	12	13	25
		Expected	12	13	25
		Chi-square	0	0	0

TABLE 4 (continued)

Month	Week		Age: Chicks	Age: Adults	Totals
July		Observed	26	93	119
		Expected	37	82	119
		Chi-square	3.270	1.475	4.745
August		Observed	21	77	98
		Expected	44	54	98
		Chi-square	12.02	9.79	21.81
September		Observed	4	56	60
		Expected	18	42	60
		Chi-square	10.88	4.66	15.54
October	2.	Observed	7	53	60
		Expected	24	36	60
		Chi-square	12.04	8.03	20.07
	4.	Observed	14	40	54
		Expected	15	39	54
		Chi-square	0.07	0.025	0.095
November	2.	Observed	1	6	7
		Expected	0	7	7
		Chi-square	0	0.143	0.143
	4.	Observed	0	0	0
		Expected	0	0	0
		Chi-square	0	0	0
December	2.	Observed	1	3	4
		Expected	0	4	4
		Chi-square	0	0.25	0.25
	4.	Observed	0	0	0
		Expected	0	0	0
		Chi-square	0	0	0

Chi-square = 62.653, with 18 df, significant at the 0.05 level.

Laughing Gulls exhibited the reverse of the age-distribution pattern found for the other gull species (Table 4); fewer young were present at the shredder than in the region as a whole. Unlike the others, Laughing Gulls were summer residents breeding on islands in the Charleston area. The tendency for young gulls to remain near breeding colonies on the coast, along with this species' preference for feeding on marine organisms, accounts for the higher proportion of young observed away from the shredder.

Daily Movement Patterns of Gulls and Crows at the Romney Street Shredder

Thirty-three all-day counts were made: Four in November-December 1975, and 29 in 1976. Attempts were made in 1976 to divide the counts equally among the four seasons, with at least two counts each month. In all, 21 counts were made during opposite tides in consecutive weeks to see what influence tides had on daily movements; three paired counts were made on weekdays and two on Saturdays.

The typical weekday pattern in late fall and winter is shown in Figure 13. The three gull species were combined because Ring-bills and Herrings, which exhibited similar movement patterns, made up the majority of the population (74 and 25 percent) respectively; and Laughing Gulls, with a different pattern, occurred in such low numbers (less than one percent) as not to alter the dominant pattern.

Herring and Ring-billed Gulls began arriving, singly or in small groups, shortly after sunrise and continuing until a peak occurred in midmorning. After this, number declined until late afternoon when a second peak occurred. Numbers then declined until all birds had left prior to sunset (Fig 13).

Laughing Gulls showed a slightly different pattern. They arrived later in the morning, left earlier in the afternoon, and reached a single high at about noon.

Crow patterns were similar to those of Herring and Ring-billed Gulls with a morning and afternoon high and a midday low. However, crows arrived more quickly in the morning; the majority arrived in one large flock within 20 minutes of sunrise. The population peaked earlier in the morning and later in the afternoon than did the gulls. Crows quickly left in large flocks just prior to sunset, after most gulls had departed for their roosts (Fig 13). This basic bimodal pattern was characteristic of gulls and crows at Romney Street throughout the year; however, some variations in the size and timing of the peaks were seen.

Daily movement cycles on Saturdays and Sundays differed in some details from those seen during the week. Gull numbers were reduced by 50-60 percent on Saturdays and 70-90 percent on

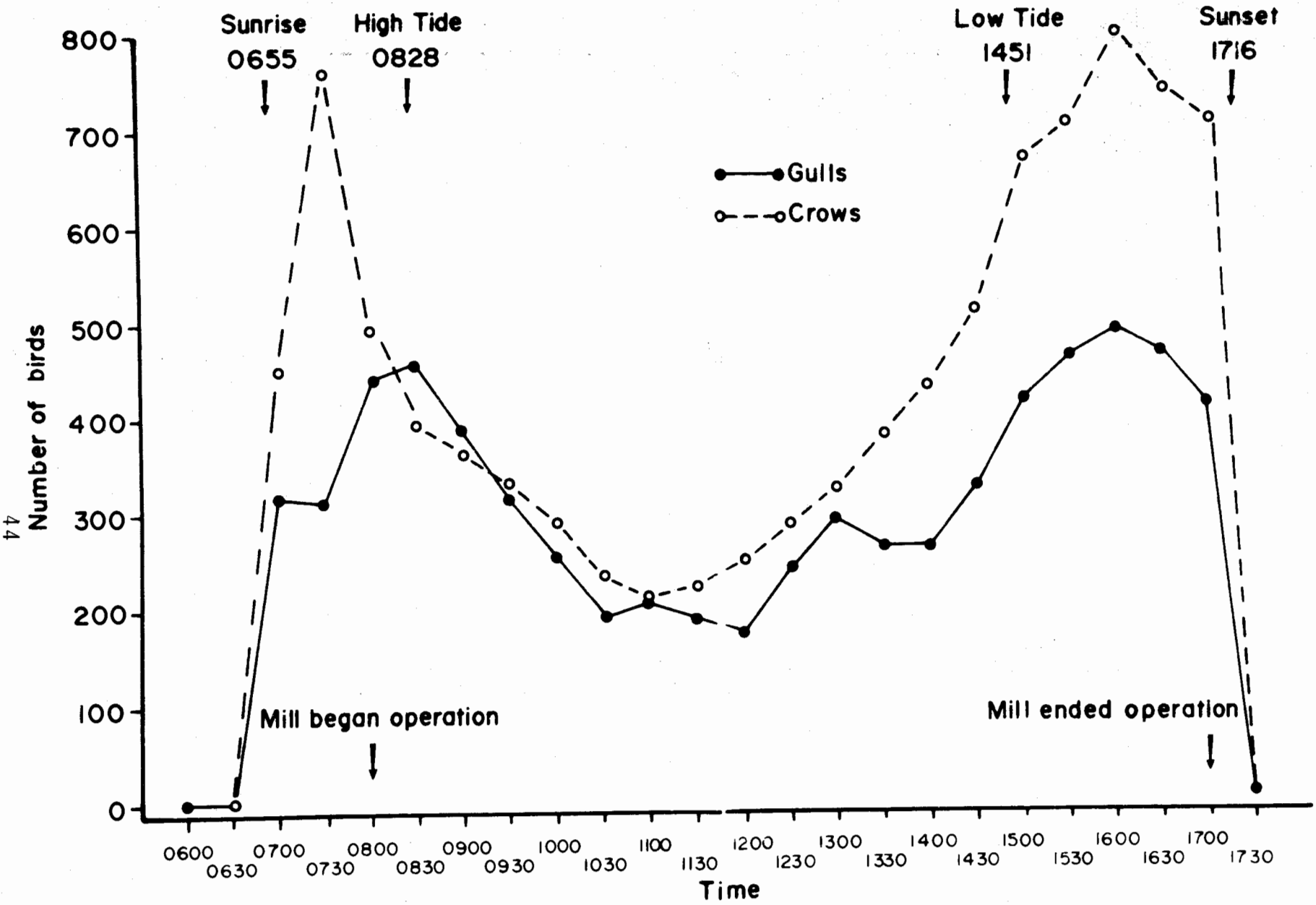


Figure 13

Normal Weekday Movement Pattern of Crows and Gulls at Charleston County Waste Reduction Center, Romney Street, Charleston, S. C., Nov. 20, 1975.

Sundays from those present on weekdays. Morning and afternoon peaks were observed on Saturdays, with the afternoon peak being lower. This trend continued for Sundays, with the afternoon peak even lower or, in spring and fall, absent altogether. Crow populations were less influenced by the lack of dumping on weekends. Saturday and Sunday numbers were usually within 10-15 percent of weekday levels, and the morning and afternoon peaks were not noticeable reduced. Thus, dumping activities did not influence the numbers present; however, gulls were more sensitive to changes in dumping patterns than were crows.

Some seasonal variations in movement patterns existed, but they were difficult to determine exactly because few or no gulls were present in summer. Gulls seemed to arrive closer to sunrise and leave closer to sunset in winter. Schreiber (Ref 38) indicated there was a specific light-intensity threshold for roosting in individual gulls, but it was modified by numerous environmental factors. He also found, in Maine Herring Gulls, that light intensity influenced roosting behavior more in fall and winter. Surprisingly, no shift in the morning or afternoon peaks at Romney Street was seen with changing seasons. During the summer, crows arrived and departed more gradually and in smaller groups than those seen in winter or fall.

Tidal rhythms had no observable influence on movement patterns. There was a trend toward higher numbers during high tide, but the results were too variable to be predictable. No opportunities occurred to compare patterns on overcast and clear days. Indirect observations suggested populations were higher on overcast days. If Schreiber's (Ref 38) observations are applicable, gulls would probably roost earlier on overcast days. Additional studies on the influence of weather on daily movement patterns are needed.

Gull and crow loafing sites changed during the course of the study as dumping patterns changed. In July 1974-March 1976, birds used roof tops and parking lots of buildings on nearby Morrison Drive (Fig 14). Gulls also used the mud flats of the Cooper River; and crows, trees on Drum Island. During April-December 1976, birds used areas on the upper dump near the shredder as more of the landfill was cleared of brush (Fig 15). Gulls still used the Cooper River mud flats and bare areas on Drum Island, while crows used the tree-covered dikes around the landfill (Fig 15).

Gulls feeding at Romney Street roosted on Shutes Folly, Morris Island, and the Charleston Jetties, and other protected sites in Charleston (Fig 2). Crow roosting areas were not located precisely, but most birds seemed to roost near Magnolia Gardens and Bear Swamp, about 15 miles west of Romney Street on the Ashley River (Fig 2). Crows have been known to roost in these areas since the 1700's (Ref 39).

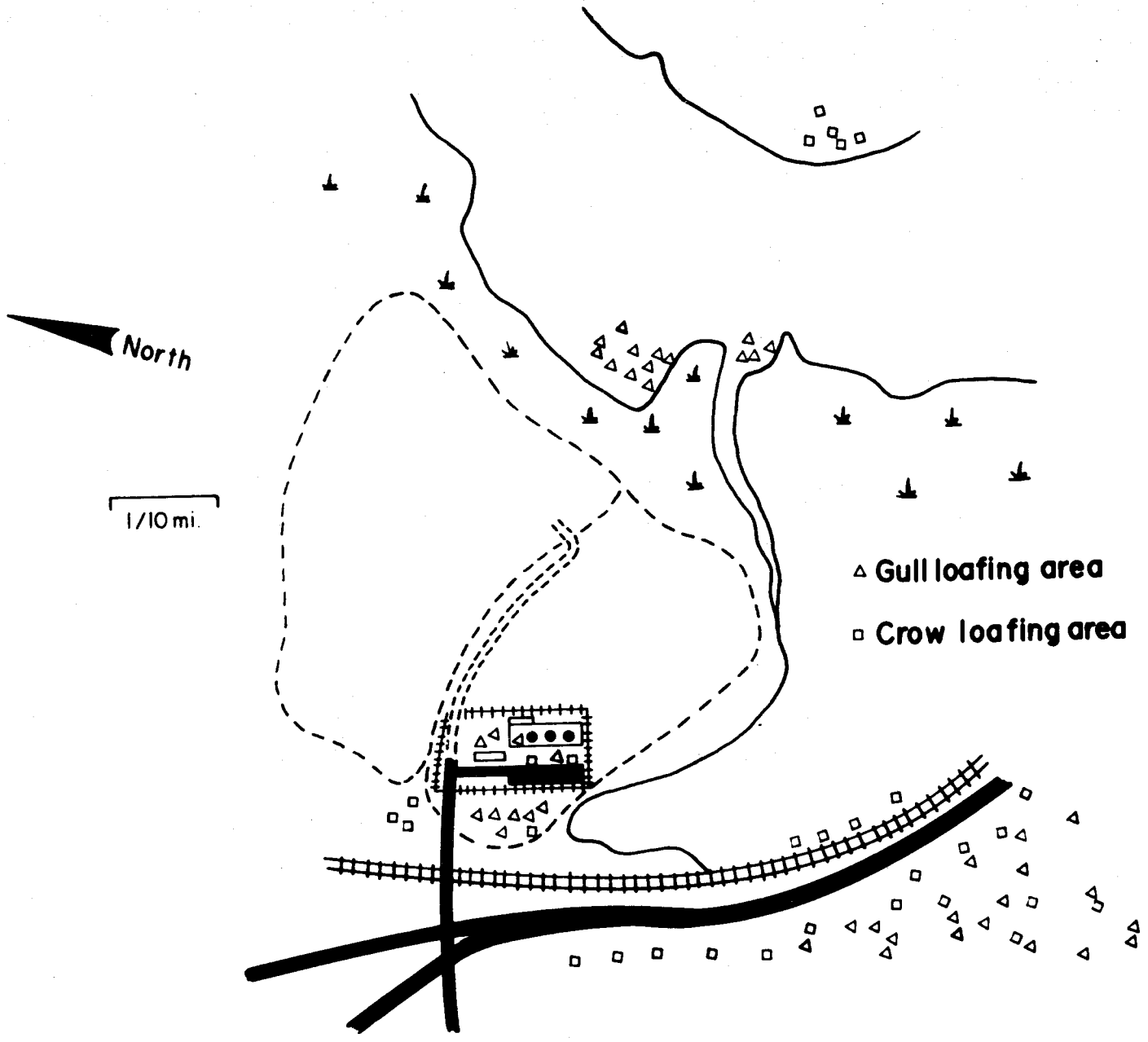


Figure 14

Gull and Crow Loafing Areas at Charleston County Solid Waste Reduction Center, Romney St., During July 1974-March 1976.

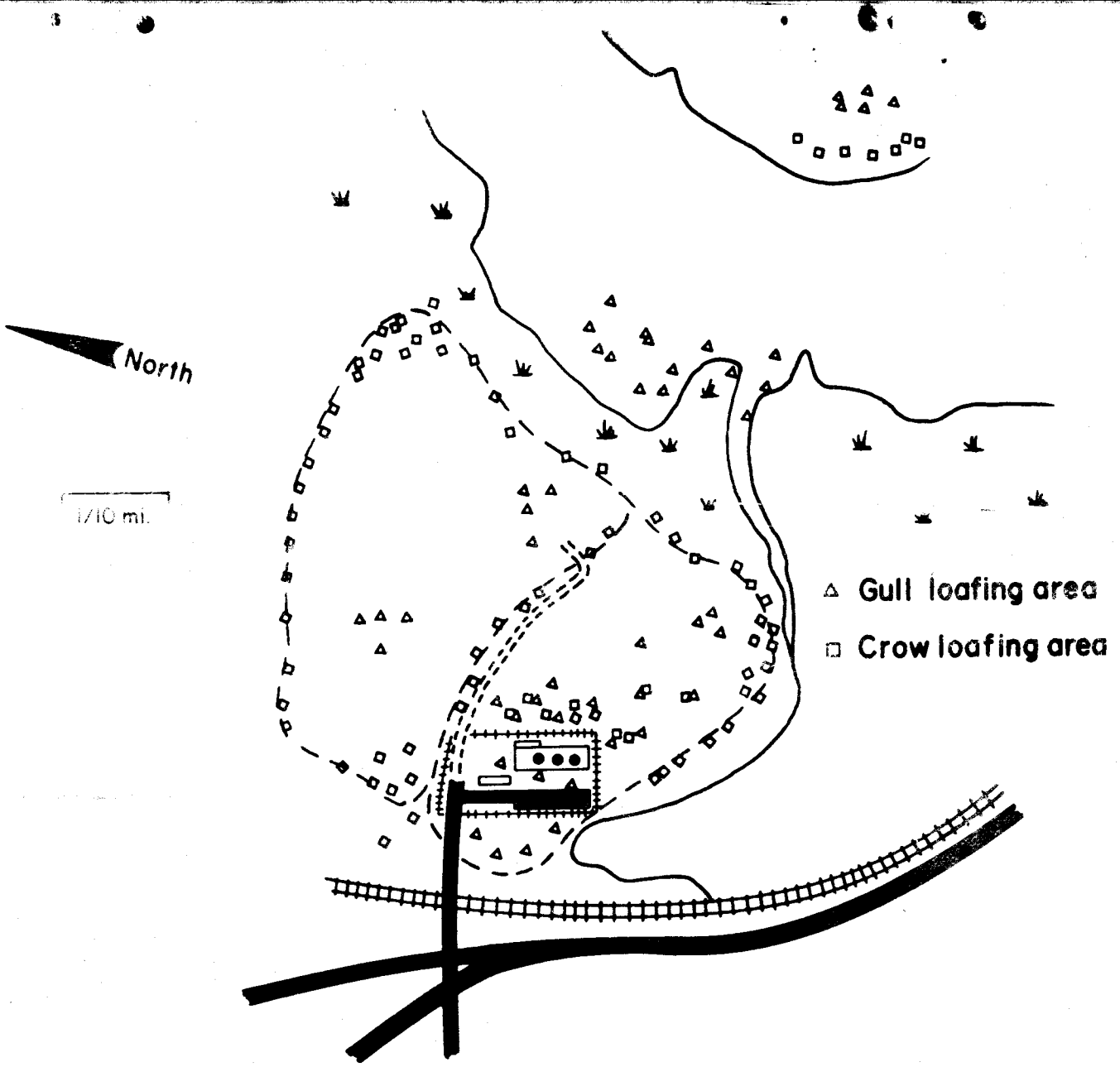


Figure 15

Gull and Crow Loafing Areas at Charleston County Solid Waste Reduction Center, Romney St., During April - Dec. 1976.

Feeding Behavior of Avian Species at Romney Street

All gulls fed using similar foraging techniques. Most birds would pick and glean all food items from the ground, often in compact flocks. In such flocks, birds exhibited considerable aggressive behavior. Aerial chases and food stealing were common. In interspecific encounters, Herring Gulls were dominant over the other two species, and both Herring and Ring-billed Gulls dominated Laughing Gulls. Although all gulls used similar feeding techniques, they showed different habitat preferences (Table 5). Herring and Laughing Gulls preferred piles of freshly shredded garbage when it had been dumped on the landfill; however, Ring-billed Gulls preferred to feed on unprocessed refuse in and around the shredder. Although shredded refuse was not covered when dumped on the landfill, no gulls fed on it after about 24 hours. Shredded material was unattractive to birds after it had remained on the landfill for a day; probably most of the available food had been removed in this period either by feeding birds or by bacterial decomposition (Ref 17).

Boat-tailed Grackles and crows used feeding techniques similar to those of gulls. They often fed in large single-species flocks, and numerous aggressive interactions and aerial food chases occurred. Like Herring Gulls, these species preferred feeding on freshly-dumped shredded refuse on the landfill. But, unlike the Herring Gull, they often fed on older piles of refuse.

Cattle Egrets foraged in loose flocks with considerable intraspecific distance. They fed on live prey, would slowly stalk an organism, capturing it with a rapid stabbing motion of the bill. They fed on freshly-dumped as well as old shredded waste. They were the only species to feed on piles of sludge dumped on the landfill from sewage treatment lagoons (Table 5). Similar feeding behavior has been described for garbage dumps in Uganda (Ref 40) and the Seychelles (Ref 41).

Ham and Reinhardt (Ref 8) indicated that, although birds were present at all European shredder sites surveyed, there was no evidence of birds feeding at the shredders. To test if birds were feeding on shredded refuse at Romney Street, 101 individuals of seven species were collected during 1976 and their crop and gizzard contents examined. The total included: 16 Herring Gulls, 17 Ring-billed Gulls, 15 Laughing Gulls, 22 Boat-tailed Grackles, 21 Fish and Common Crows, and 10 Cattle Egrets. At least five of each species, when present, were collected during January-February, March-April, June-July, and October-November. The results are shown in Tables 6-11.

All three gulls fed almost exclusively on garbage (Tables 6-8). Behavioral observations and analysis of gut contents show most garbage was obtained from shredded refuse on the landfill; however, Ring-bills obtained some from unprocessed refuse around

TABLE 5. FEEDING PREFERENCE OF AVIAN SPECIES AT THE CHARLESTON COUNTY SOLID WASTE REDUCTION CENTER

Species	Percent of species feeding in habitats				No. in sample
	Unprocessed refuse	Newly-dumped shredded refuse	Old shredded refuse	Liquid sludge	
Herring Gull	6.6 ± 8.3	93.4 ± 8.3	0	0	48
Ring-billed Gull	74.9 ± 6.8	25.1 ± 6.8	0	0	54
Laughing Gull	5.3 ± 6.4	94.3 ± 6.4	0	0	23
Boat-tailed Grackle	0.7 ± 1.3	67.3 ± 24.8	34.3 ± 21.1	0	54
Cattle Egret	7.3 ± 1.2	63.0 ± 32.5	6.1 ± 10.7	29.4 ± 33.3	23
Crows	1.2 ± 0.5	67.3 ± 24.8	34.3 ± 21.1	0	67

TABLE 6. ANALYSIS OF FOOD HABITS OF HERRING GULLS BY PERCENT VOLUME AND FREQUENCY OF OCCURRENCE

Food	Winter	Spring	Fall	Total
Shredded garbage	95(100)	94.3(100)	96.3(100)	95.2(100)
Plant material	0(0)	0 (0)	0 (0)	0 (0)
Invertebrates	0(0)	3.5(20)	0 (0)	1.2(6.6)
Grits and misc.	5(100)	3.0(100)	3.7(100)	3.9(100)
n:	6	5	5	16

TABLE 7. ANALYSIS OF FOOD HABITS OF RING-BILLED GULLS BY PERCENT VOLUME AND FREQUENCY OF OCCURRENCE

Food	Winter	Spring	Fall	Total
Shredded garbage	73.1(100)	66(100)	70(100)	69.7(100)
Plant material	0 (0)	0(0)	0(0)	0 (0)
Invertebrates	0 (0)	0(0)	0(0)	0 (0)
Grits and misc.	26.9(80)	44(100)	31(90)	34.0(90)
n:	6	5	6	17

TABLE 8. ANALYSIS OF FOOD HABITS OF LAUGHING GULLS BY PERCENT VOLUME AND FREQUENCY OF OCCURRENCE

Food	Winter	Spring	Fall	Total
Shredded garbage	82.8(100)	67.3(100)	62.4(100)	71(100)
Plant material	0 (0)	0 (0)	0 (0)	0(0)
Invertebrates	9 (0)	30.5(20)	0 (0)	10(6.7)
Grits and misc.	17.2(100)	3.0(100)	37.6(100)	19(100)
n:	5	5	5	15

the mill. As no other solid waste source was operating in Charleston during 1976, the results show that gulls could and did obtain sufficient food from shredded refuse and were attracted to the Romney Street landfill to feed on the shredded material.

Invertebrates were a minor part of the spring diet of Herring Gulls (Table 6), but made up 30 percent of the spring diet of Laughing Gulls (Table 8). The main species was Cochliomyia macelleria (DIPTERA: CALLIPHORIDAE), a widespread and abundant fly on the landfill (K. L. Touchton, unpub. data). Ring-bills did not feed on invertebrates (Table 7). This is surprising in view of the preference for terrestrial feeding sites and insect diets on the breeding grounds (Refs 42, 43, 44). Insect eating in spring by Herring and Laughing Gulls was the only seasonal variation in diet seen in gulls.

Boat-tailed Grackles fed mainly on plant materials and invertebrates (Table 9). Most of the plant materials were annual seeds that grow on the landfill or in the adjacent Spartina Salt Marsh. The amount of plant material and the variety did not vary seasonally. The invertebrates were either salt water species or insects from the landfill. Three intertidal crabs (Uca minax, U. pugnax, and Rhithroporopeus harrisii) made up 50 percent of the species eaten. The proportion did not vary seasonally. Insects were the remaining invertebrates eaten. The main species were four flies: the muscid (Musca domestica), and the calliphorids (C. macellaria, Phaenicia cuprina, and Phormia regina). All were species common on shredded refuse where they were probably obtained by foraging flocks. Only M. domestica numbers varied seasonally, with the population reduced in the winter sample but increased in the summer and fall. Grackles did not depend upon shredded refuse for food; the small amounts found in food samples were probably picked up incidentally while foraging on the landfill. Only in summer samples did refuse make up as much as 10 percent of the diet (Table 9). Few grackles were present during the summer, and these were breeding birds with established territories around the landfill. The grackle's food habits were similar to those described for birds in the Charleston area and the rest of this species Atlantic Coast range (Ref 45).

In all, 21 Fish and Common Crows were examined (Table 10). Sample sizes of the two species were not large enough to see if interspecific differences in diet existed. Crows had the most varied diets of the species studied. Shredded garbage was the principal food, averaging 51 percent by volume. Some seasonal differences were found; the highest amount of refuse was in spring and the lowest in winter. The differences might not have been significant because of the low sample size and the mixture of the two species. Invertebrates were also an important food item, except in spring; the chief species was the fly (M. domestica). The only intertidal invertebrate was the Spartina-eating snail (Littorina irrorata) found in the winter sample.

TABLE 9. ANALYSIS OF FOOD HABITS OF BOAT-TAILED GRACKLES BY PERCENT VOLUME AND FREQUENCY OF OCCURRENCE

Food	Winter	Spring	Summmer	Fall	Total
Shredded garbage	3.6(28)	1.7(40)	12.9(60)	3.8(30)	5.5(39.5)
Plant material	47.6(100)	54.4(100)	55.5(100)	52.4(80)	52.4(95)
Invertebrates	41.1(100)	36.7(100)	18.5(60)	36.3(60)	33.3(80)
Grit and Misc.	8.2(92)	6.2(100)	13.5(80)	7.8(60)	8.8(82)
n:	6	5	5	6	22

TABLE 10. ANALYSIS OF FOOD HABITS OF CROWS BY PERCENT VOLUME AND FREQUENCY OF OCCURRENCE

Food	Winter	Spring	Summmer	Fall	Total
Shredded garbage	39.5(80)	79 (100)	44.2(60)	43.5(100)	51 (85)
Plant material	3.1(20)	5.3(33)	10.5(16)	18.8(30)	9.4(25)
Invertebrates					
insects	20.6(60)	0.0(0)	39.5(67)	34.9(100)	25 (61)
snails	9.0(20)				
Grit and misc.	32.8(100)	16 (100)	12.1(100)	2.6(60)	14.8(90)
n:	6	5	5	5	21

Plant material was a small, but increasingly important, food item as the year progressed. Mostly, the plant materials were fruits and berries of trees such as mulberry (Morus sp.) and Wild Cherry (Prunus sp.) that grew on the dikes around the landfill. Except for the inclusion of shredded refuse, the diet of crows at Romney Street was similar to that described by Bent (Ref 46).

Although primarily insectivorous, Cattle Egrets are opportunistic feeders and take a variety of food items. On the landfill, they fed mainly on insects (Table 11), about 98 percent of which were C. macellaria, the remaining 2 percent being M. domestica. Only in spring did they eat shredded refuse, and even then it was a minor part of the diet. In more natural areas, egrets are mainly insect eaters (Refs 16, 47, 48), but feed mostly on orthopterans, with dipterans the next most important group. Presumably, egrets observed feeding at African dumps were also eating insects; but they might have been feeding on garbage as no food analysis was made (Ref 40).

Insects Present in Shredded Solid Waste

About 50 insects species representing 32 families and seven orders were collected from shredded solid waste at Romney Street during the study (Table 12). The majority of families and species were flies (16 families and 28 species), and beetles (nine families and 12 species). The families with the most species included: Calliphoridae, with five; Nitidulidae, and Formicidae, with four each; and Otitidae, Muscidae and Sarcophagidae, each three. All but the Nitidulidae (beetles) and Formicidae (ants) were flies.

Species were classified into arbitrary abundance categories based on the total number of individuals caught with all three collecting techniques. Species with a total of 100 or more individuals were termed abundant; 50-99, common; 10-49, uncommon; and 9 or less, rare. Only three species (Bradysia sp., Phormia regina, and Euxesta notata) were abundant. The abundance of the first two species was due to large numbers of individuals taken in small number of emergence trap samples. Bradysia sp. and E. notata were regularly collected almost every week with either sweep nets or Berlese funnels, whereas P. regina was not and therefore would be considered uncommon judging from the rest of the samples.

Only two species were classed as common: Phaenicia curprina, and Musca domestica. The abundance of cuprina was due to high counts from two emergence trap samples, and it was only encountered incidentally during other sampling. Musca domestica populations were consistent and fairly regular, and this fly was collected throughout the year.

Six species, Phaenicia sericata, Chochliomyia macellaria, Calliphora vicina, Drosophia melanogaster, D. repleta, and

TABLE 11. ANALYSIS OF FOOD HABITS OF CATTLE EGRETS BY PERCENT VOLUME AND FREQUENCY OF OCCURRENCE

Food	Spring	Summer	Total
Shredded garbage	13.4(23)	0 (0)	6.7(11)
Plant material	0 (0)	0 (0)	0 (0)
Insects	86.6(100)	99.1(100)	92.8(100)
Grit and misc.	0 (0)	0.9(10)	0.4(5)
n:	5	5	10

TABLE 12. INSECTS COLLECTED AT CHARLESTON COUNTY SOLID WASTE REDUCTION CENTER, ROMNEY STREET, DURING 1976

Insect species	Collection method		
	Sweep net	Berlese funnel	Emergence trap
ORTHOPTERA			
Blattidae			
Periplaneta americana	+*	+	
PSOCOPTERA			
ECTOPSOILIDAE			
Sctopsocopsis cryptomeriae	+		
HEMIPTERA			
REDUVIIDAE			
Species undetermined	+	+	
HOMOPTERA			
Psyllidae			
Pachypsylla sp.	+	+	
COLEOPTERA			
Staphlinidae			
Unidentified species	+	+	
Cleridae			
Necrobia rufipes		+	
Cryptophagidae			
Anchicera ochracea	+		
Nitidulidae			
Carpophilus hemipterus		+	
Carpophilus humeralis	+		
Carpophilus freemani	+		
Haptoncus luteolus	+		
Lathridiidae			
Cartodere constricta	+		
Mycetophagidae			
Typhaea sterocorea	+		
Coccinellidae			
Diomus terminatus	+		
Anthicidae			
Anthicus floralis	+	+	
Scolytidae			
Hypothenemus georgiae		+	
DIPTERA			
Psychodidae			
Telmatoscopus	+		
Ceratopogonidae			
Culicoides hollensis	+		
Biblionidae			
Plecia nearctica	+		

*Insects were present in collections by this technique.

TABLE 12 (continued)

Insect species	Collection method		
	Sweep net	Berlese funnel	Emergence trap
DIPTERA			
Mycetophilidae			
Leia sp.	+		
Sciaridae			
Bradysia sp.	+	+	+
Scatopsidae			
Scatopse fuscipes	+	+	
Stratiomyidae			
Hermeta illuscens	+		
Phoridae			
Dohrniphora cornuta	+	+	
Megaselia scalaris	+		
Micropezidae			
Taeniaptera trivittata		+	
Otitidae			
Chaetopsos apicalis	+		
Euxesta notata	+	+	
Physiphora aenea	+	+	
Sphaeroceridae			
Leptocera sp.	+		
Milchiidae			
Milichiella lactipennis	+		
Drosophilidae			
Drosophilia melanogaster	+		+
Drosophilia repleta group	+		+
Muscidae			
Graphyomya maculata	+		
Musca domestica	+	+	
Ophyra aenescens	+	+	
Calliphoridae			
Cochliomyia macellaria	+	+	+
Calliphora vicinia	+	+	+
Phaenicia cuprina	+	+	+
Phaenicia sericata	+	+	
Phormia regina	+	+	+
Sarcophagidae			
Helicobia rapax	+	+	
Sarcophaga johnsoni	+	+	
Sarcophaga sp.	+	+	
HYMENOPTERA			
Braconidae			
Hypomicrogaster sp.	+		

TABLE 12 (continued)

Insect species		Collection method		
		Sweep net	Berlese funnel	Emergence trap
HYMENOPTERA				
Diapriidae				
Trichopria sp.		+		
Formicidae				
Iridimyrmex humilis		+	+	
Iridimyrmex prunosus		+		
Monomorium pharaonis		+	+	
Solenopsis invicta		+		
TOTAL	50	46	26	7

Reduviidae sp. were not uncommon. The Reduviidae occurred regularly in May-June, but was not encountered during the rest of the year. The remaining 39 species, 78 percent of the total, were rare.

The abundance categories described above were biased by the appearance of large numbers of individuals found in a small number of emergence trap samples. Emergence traps gave a poor picture of the insect community as only seven of the 50 species were found in traps. Also, the frequency of encounter was not considered in the above discussion. To overcome these biases, densities and frequencies for each insect species were calculated using only the sweep net and Berlese funnel data. The most abundant species, as determined by these techniques, are shown in Table 13. In general, the results of the two methods were in agreement, and flies (especially Muscidae and Calliphoridae were prominent members of the insect community. Allowing for regional differences in insect fauna, similar results were reported for garbage dumps in other regions of the United States. Thus, in Charleston, West Virginia, School and Mial (Ref 49) found M. domestica and Phaenicia sericata to be among the most important species. In urban areas of Michigan, New York, North Carolina, Kansas, and Arizona, P. sericata, M. domestica, and Phormia regina were the most abundant species at dump sites (Refs 50, 51). In all studies of refuse sites, refuse-feeding flies of the families Muscidae, Calliphoridae, and Sarcophagidae dominated the insect community.

At Romney Street, the most important refuse-feeding flies (M. domestica, C. macellaria, P. sericata, and P. regina) also were the most numerous species large enough to provide a significant food source for birds. And, as expected, these were the only insects found in food samples taken from birds feeding on the landfill. However, only in crows, grackles, and especially Cattle Egrets, were they a major food item. All other bird species were more dependent on shredded refuse as a food source.

It was difficult to compare the relative abundance of insects on shredded refuse with that at regular garbage dumps, but numbers (especially of refuse-feeding flies) seemed lower on the shredded material. Ham and Reinhart (Ref 8) made similar observations for European milling sites. Emergence trap and Berlese funnel data showed that few larvae, pricipally Muscidae and Calliphoridae, were produced in the shredded material. All were associated with large particles of organic material; these larvae probably were present in the garbage prior to shredding. Also, larval development was inhibited by the high subsurface temperature occuring in the shredded material ($\bar{x}$ = 43.5% C± 10.5) (Ref 52). Ham and Reinhart (Ref 8) commented on the few flies produced in shredded material at European sites. However, refuse-feeding flies did breed at Romney Street, mostly in uncovered piles of dead cats and dogs disposed of on the landfill by the

TABLE 13. THE MOST ABUNDANT AND FREQUENTLY ENCOUNTERED INSECT SPECIES IN SWEEP NET AND BERLESE FUNNEL SAMPLES AT CHARLESTON SOLID WASTE REDUCTION CENTER, ROMNEY STREET, DURING 1976

Insect species	Density individuals/m^2	Frequency of occurrence
COLEOPTERA		
Staphylinidae		
Unidentified species	30-10	12.5%
DIPTERA		
Sciaridae		
Bradysia sp.	0.16-0.02	54.2%
Otitidae		
Euxesta notata	0.02-0.02	12.5%
Muscidae		
Musca domestica	0.16-0.02	45.8%
Calliphoridae		
Cochliomyia macellaria	0.34-0.02	12.5%
Phaenicia cuprina	300-200	4.2%
Phormia regina	0.10-0.02	10.4%
HEMIPTERA		
Reduviidae		
Unidentified species	0.54-0.02	29.2%

county canine patrol, and in piles of sludge from oxidation ponds. The fly population at Romney Street, an attraction for avian species potentially hazardous to aircraft, could be reduced by covering these breeding sources.

Rats and Dogs at the Romney Street Landfill

Although no systematic censuses were taken, numerous Norway Rats (Rattus norvegicus) were present on the Romney Street landfill. Most had dens in dirt piles used to cover the landfill or on the dikes surrounding the landfill. Rats were often seen on piles of shredded refuse, but it is not known if they were feeding on the material. No rodents were seen by Ham and Reinhart (Ref 8), but they were known to be present on several of the sites visited.

About 10-18 feral dogs (Canis familiaris) inhabited the landfill, feeding on refuse, rodents, and rabbits. Their numbers were reduced with the clearing of the landfill and the resultant disposal of shredded material on it.

Influence of Shredding on Avian Species Abundance and Behavior

During 1976, approximately 163,172 tons of solid waste were brought to the Solid Waste Reduction Center, Romney Street. About 127,144 tons (78 percent) were shredded; the remaining 36,028 (22 percent) consisting of dry trash and non-garbage too large to be shredded, were dumped directly on the landfill. A total of 4,272.94 tons of ferrous material was recovered by the metal separator and recycled. This represented about 2.62 percent of the total solid waste brough to Romney Street, or 3.36 percent of the waste that was shredded.

The plant experienced a number of mechanical difficulties. Out of a total of 256 working days, one or more shredders were shut down on 55 (21 percent). Usually the breakdowns were because of mechanical problems; but on three occasions they were caused by explosions in the shredders, and by fire, twice. Shredder hammers were replaced about once every two weeks. The metal separator was inoperable on 15 days, mainly because of mechanical problems with the magnets or conveyors; on five days, the packers malfunctioned, and the truck scales did not work on two days. Despite the problems, the Reduction Center was able to store or process most of the solid waste received. Garbage had to be diverted to the Stromboli Street sanitary landfill without being shredded on only eight of the 256 working days.

Little variation was seen in the amount of refuse shredded weekly (Fig 16). Amounts averaged 2,587 tons per week, with a normal range between 2,000-2,900 tons. Amounts below this range occurred on several occasions, and were associated either with short work weeks (as during the weeks of 22 November and 20

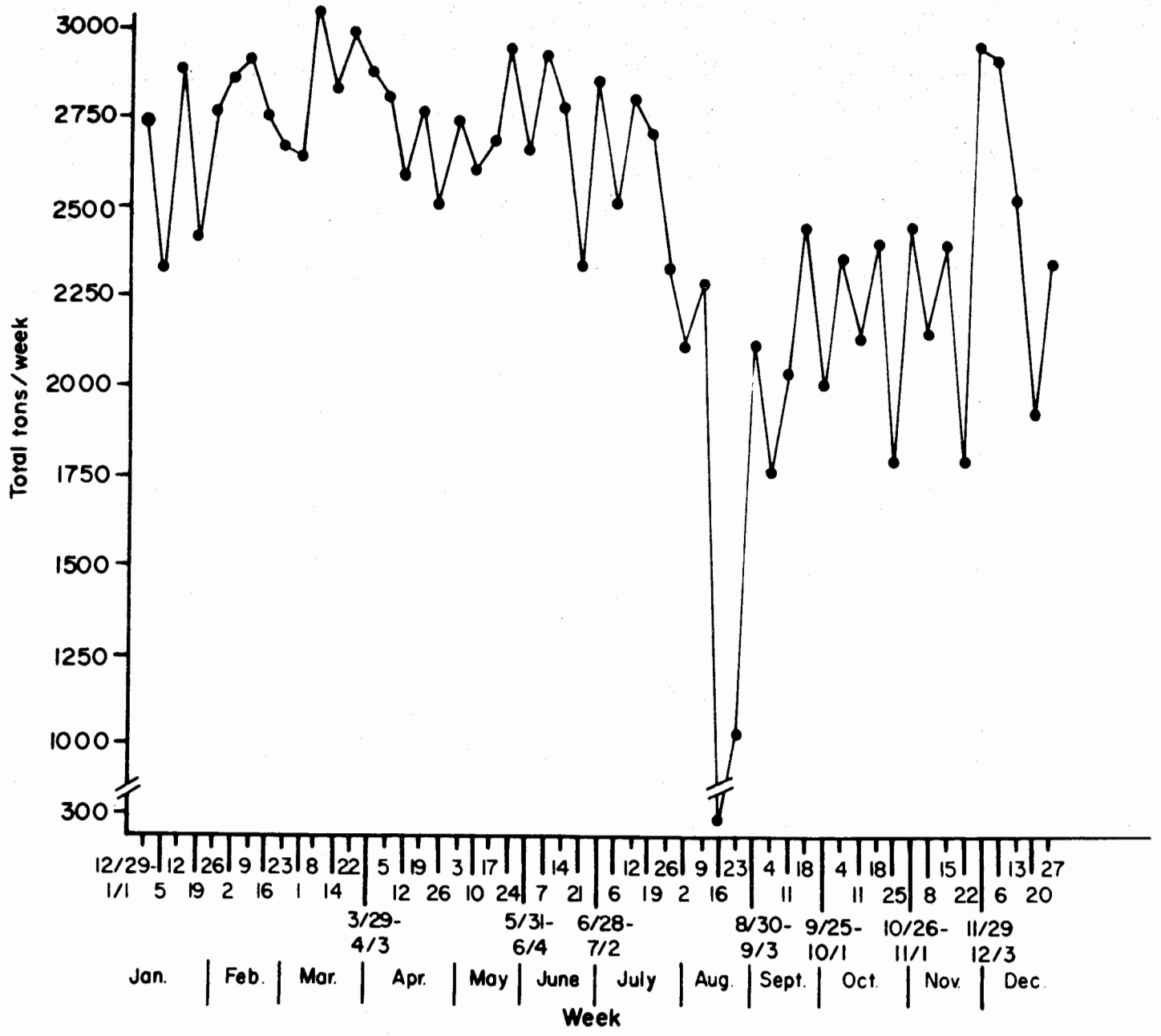


Figure 16

Total Number of Tons Solid Waste Shredded per Week at the Charleston County Solid Waste Reduction Center, Romney St., in 1976

December) or with mechanical breakdowns (as during the weeks of 16 and 23 August).

The amounts of solid waste received and processed varied with the days of the week (Table 14). Lowest amounts were processed on Sundays, Saturdays, and Wednesdays. This pattern was related to the waste-collecting schedule of the Cities of Charleston and North Charleston, two of the major sources of refuse for Romney Street. Neither city collected anything but dry trash on Wednesdays. The high amounts on Mondays and Tuesdays resulted from garbage accumulated over the weekend. No refuse was collected on Sundays or Saturdays. The few occasions when refuse was shredded on Saturdays occurred when there was a backlog from the preceding Friday.

The dumping patterns for the landfill from June 1974 to December 1976 are shown in Figure 17. By February 1976, all but the southeastern corner of the upper landfill had been covered. In April, dumping started on the lower landfill. The eastern one-half was covered by June; and the western one-half by December. Additional refuse was dumped on the upper landfill in June-October 1976. Originally, the Romney Street site was estimated to be able to last for six years. At the present dumping rate, it will be filled within four years. Charleston County has contracted to use about 60 acres near the lower landfill. This should prolong the life of the Romney Street complex about four years. After that, the county is planning to build a refuse-burning electrical generating plant at the Romney Street site. This should provide a long-term solution to the problem of finding landfill sites.

An attempt was made to correlate bird numbers with the volume of shredded refuse. For this comparison, the average daily populations of Herring Gulls, Ring-billed Gulls, and crows were compared with the average daily tons of shredded refuse dumped in a given week. The results showed no relationship existing between bird numbers and volume of solid waste for any of the species considered (Fig 18). Other attempts to correlate gull members with either the amount of solid waste dumped or the surface area covered by refuse have been inconclusive (Ref 28).

There does seem to be a correlation between shredded-particle size and food availability for birds (Ref 17). Ham (Ref 17) suggested that if material was ground up so at least 90 percent passed through a 3-inch screen, little or no food would be available for refuse-feeding birds. However, birds were present and fed on refuse at Romney Street when an average of 81 percent (S.D. = $\pm$ 4 percent) of the refuse passed through a 2-inch sieve. No correlation between particle size and the number of birds present was found (Fig 19). Some correlation might have been present if particle size was larger or if it varied more. However, both particle size and variation in size were regulated by the Charleston County Health Department.

TABLE 14. VARIATION IN WEEKDAY DUMPING PATTERNS AT THE CHARLESTON COUNTY SOLID WASTE REDUCTION CENTER, ROMNEY STREET, IN 1976

Day	Average number of tons processed	Sample size
Monday	597.4 ± 135.73	47
Tuesday	613.1 ± 152.8	53
Wednesday	294.0 ± 155.1	52
Thursday	470.9 ± 125.4	53
Friday	571.9 ± 87.5	53
Saturday	106.9 ± 73.41	13
Sunday	0.0	0
Total tons processed for 1976: 127,144 tons		

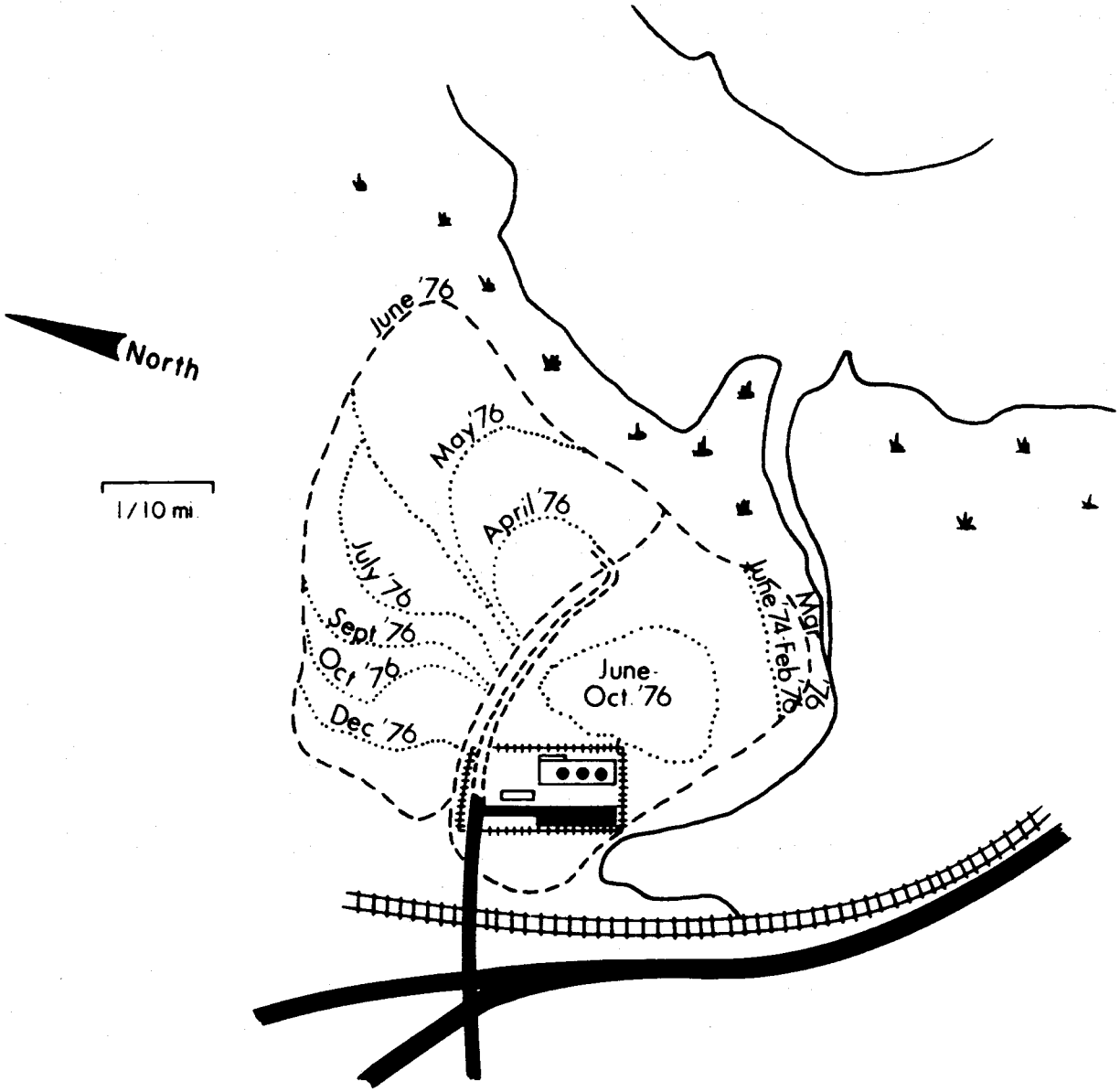


Figure 17

Pattern of Disposal of Shredded Solid Waste at the Romney St. Landfill, June 1974 - Dec. 1976.

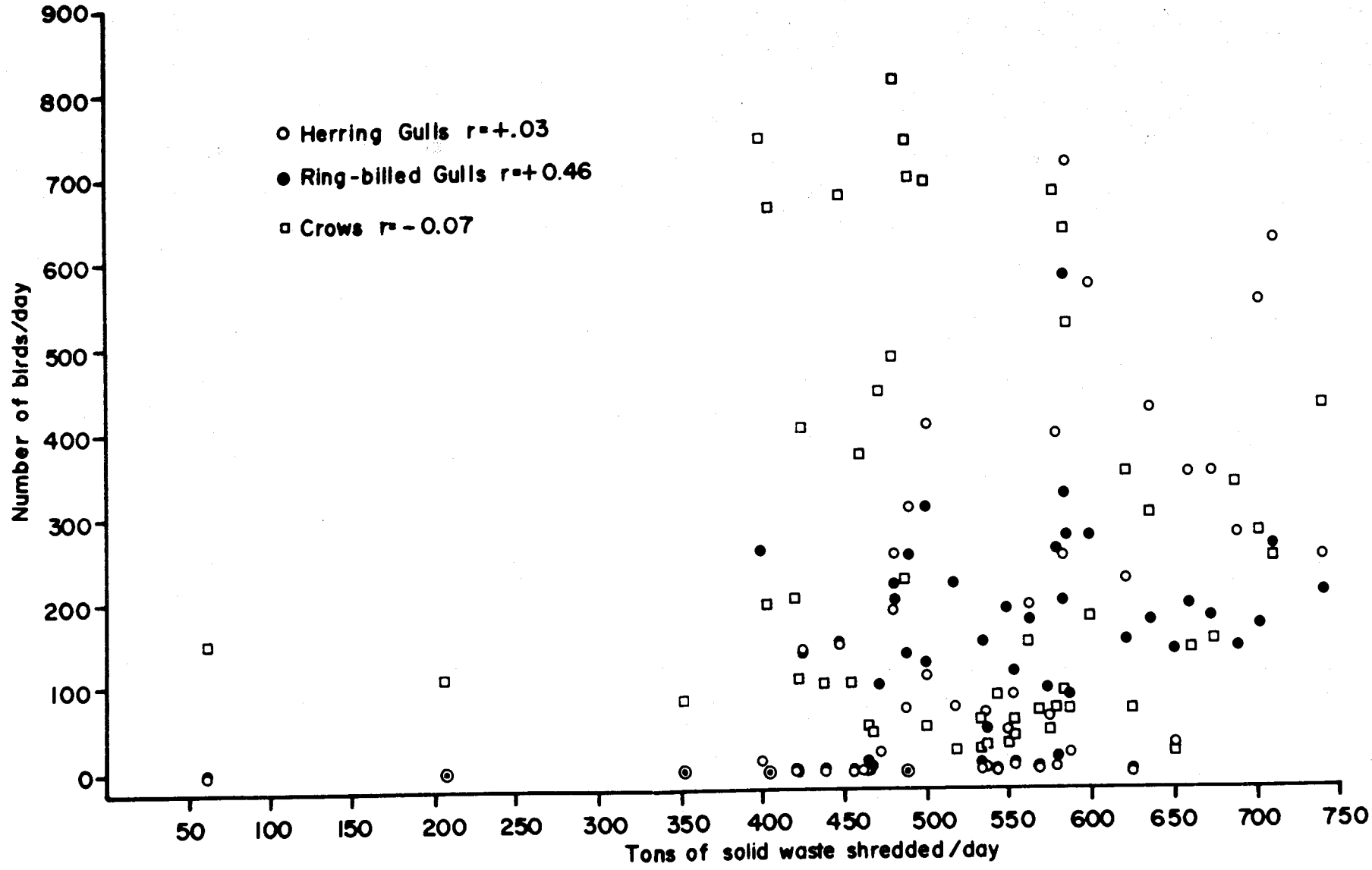


Figure 18

A Comparison of Number of Birds Present with Respect to Volume of Solid Waste Processed at the Charleston County Solid Waste Reduction Center in 1976.

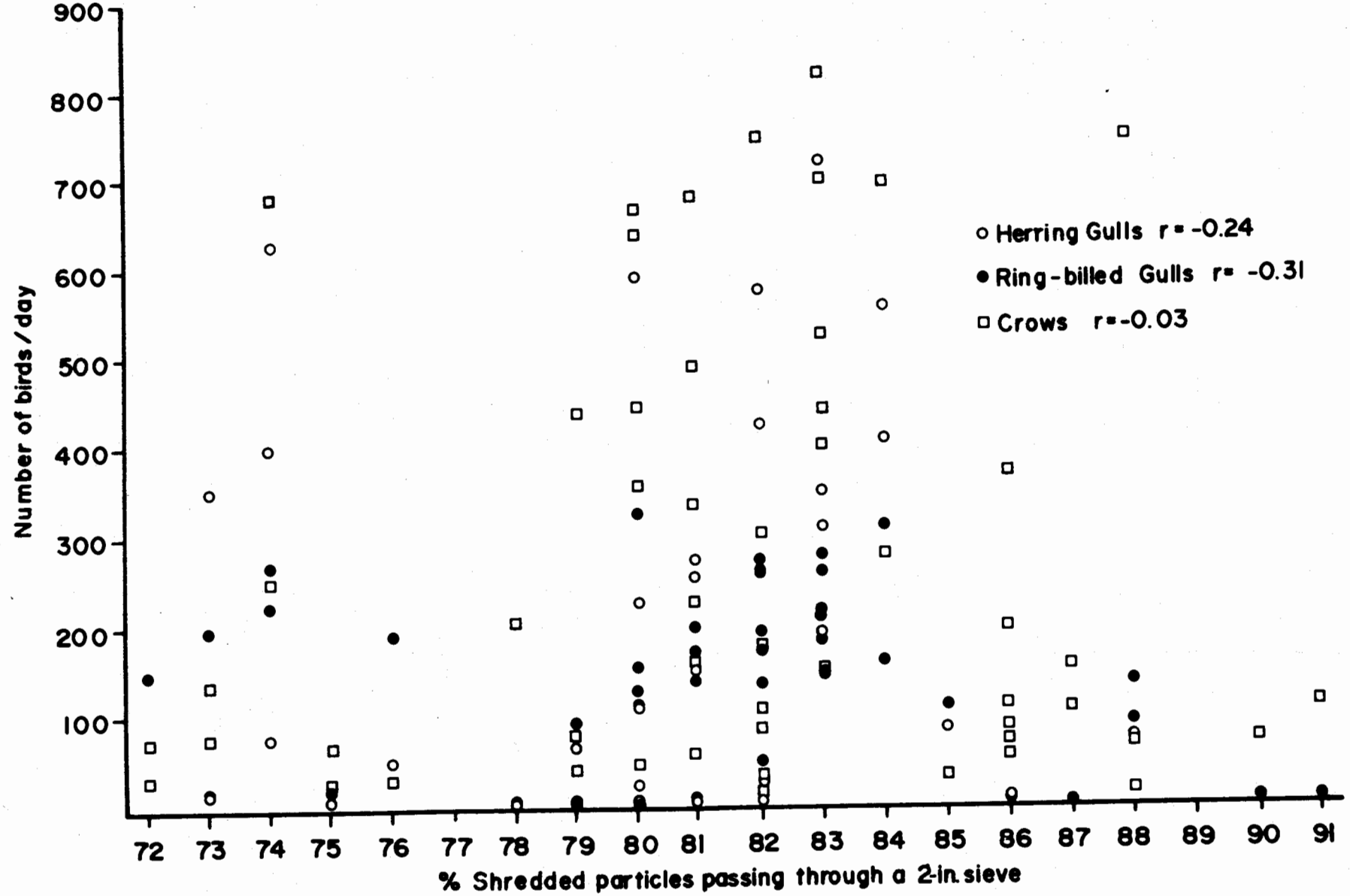


Figure 19

A Comparison of Number of Birds Present and Shredded Solid-Waste Particle Size at the Charleston County Solid Waste Reduction Center in 1976.

Relative Attractiveness of Various Solid Waste Disposal Techniques to Potentially Hazardous Bird Species

At this time, solid waste is disposed at either open dumps or sanitary landfills. At open dumps, the material is piled and left uncovered, or it may be burned; at sanitary landfills, the waste is placed in trenches, and then covered with dirt. Several techniques are used to reduce the volume of material prior to disposal, including: metal recovery, compression, baling, and shredding. Shredding increases the density of refuse, so more may be disposed of in a given volume.

All techniques presently used attract birds potentially hazardous to aircraft except perhaps baling, which has not been evaluated and is not in wide use. Direct comparisons of the relative attractiveness of the various techniques were not possible because they were not all operating during the same time period in Charleston. Also, comparisons were difficult because a variety of other factors influenced the attractiveness of a site. If all other factors were constant, however, my studies indicated that open dumps in Charleston attracted about 50 percent more gulls than did sanitary landfills. The shredder also attracted gulls and other birds, and seemed as attractive as a sanitary landfill. Different species seemed to prefer different disposal techniques, with Ring-bills preferring landfills, and Herring Gulls, open dumps.

Charleston Weather Patterns During the 1971-72 and 1976 Studies

As weather patterns influence gull populations and migrations, weather patterns for 1971-72 and 1976 periods were compared. The Charleston climate is temperate, modified by the nearness of the ocean. Winter temperatures are as much as 10-15°F higher, and summer temperatures, about 3°F lower than comparable inland sites. Prevailing winds are northerly in fall and winter, southerly in spring and summer.

Summers are warm and humid, but temperatures of 100°F and above are infrequent. Summer is the season with the highest amount of precipitation, about 41 percent of the annual total. Rain is generally in the form of showers, thundershowers, or an occasional tropical storm producing the variable amounts of rainfall over scattered areas. Fall passes from a warm period to prewinter cold spells beginning in late November. From late September to early November, the weather is mostly sunny, and extremes of temperature are rare. The winter months, December-February, are mild, with rainfall averaging 18 percent of the annual total. Winter rainfall is generally uniform, with few thunderstorms. Snow flurries are rare. An average winter experiences less than one cold wave and severe freeze; temperature of 20°F or less are unusual. Spring is a period of rapid changes from windy and cold in March to warm and pleasant in May. Spring rainfall represents

about 20 percent of the yearly total. The average date of the first freeze in fall is 10 December, and the last before spring is 19 February (Ref 53).

During the 1971-72 period, weather conditions were relatively normal except that precipitation levels were below average, especially in July-October 1971 and June-July 1972. The 1971-72 winter was normal, with few cold fronts and no snowfall or extremely low tempertures (Refs 53, 55). That winter also was normal in the northeastern and Great Lakes states, areas which produce the majority of Herring and Ring-billed Gulls that winter in the Charleston area (Refs 11, 55, 56). Extreme winters in these regions would tend to increase the winter gull population in Charleston.

The 1976 weather conditions were characterized by drought and low temperatures during most of the year. Water conditions were normal in May, September, and November. The fall and winter were among the coldest on record, and measurable snowfall was recorded on five occasions (Ref 57). In September-December, the Northeast and Great Lakes experienced one of the worst winters in recent times, with abnormally cold temperatures and abundant snow. With such weather, one would predict above average numbers of wintering gulls in Charleston as compared with the more normal winter of 1971-72.

Gull Populations for the Charleston Study Area in 1976

Seven species of gulls, Herring, Ring-billed, Laughing, Bonaparte's (L. philadelphia), Great Black-backed, Lesser Black-backed (L. fuscus), and Iceland (L. glaucoides) were found during this study. In addition, the Glaucous (L. hyperboreus), Franklin's (L. pipixcan), and Black-headed (L. ridibundus) Gulls have been reported for South Carolina on one to four occasions in the past (Ref 15, 39, 58). Of these ten species, only the Herring, Ring-billed and Laughing Gulls were common.

Herring Gull numbers peaked in February. After this, they declined until midsummer lows were reached in June-August. Fall migration started in October, and by late December, the population again reached the February peak (Fig 20). Seasonal trends were similar in the general study area and the Romney Street landfill (Fig 4), except the fall population increase was earlier in the general area. Also, the seasonal trends were similar to those observed in 1971-72 (Fig 4 in Ref 9).

Ring-billed Gull population trends were similar to those found for Herring Gulls, with high numbers in winter and lows in summer (Fig 21). Unlike Herring Gulls, the Ring-bill population peak occurred later in February, exceeding the December peak. Also, more Ring-bills summered in Charleston. Both the general study area and the Romney Street landfill exhibited similar seasonal

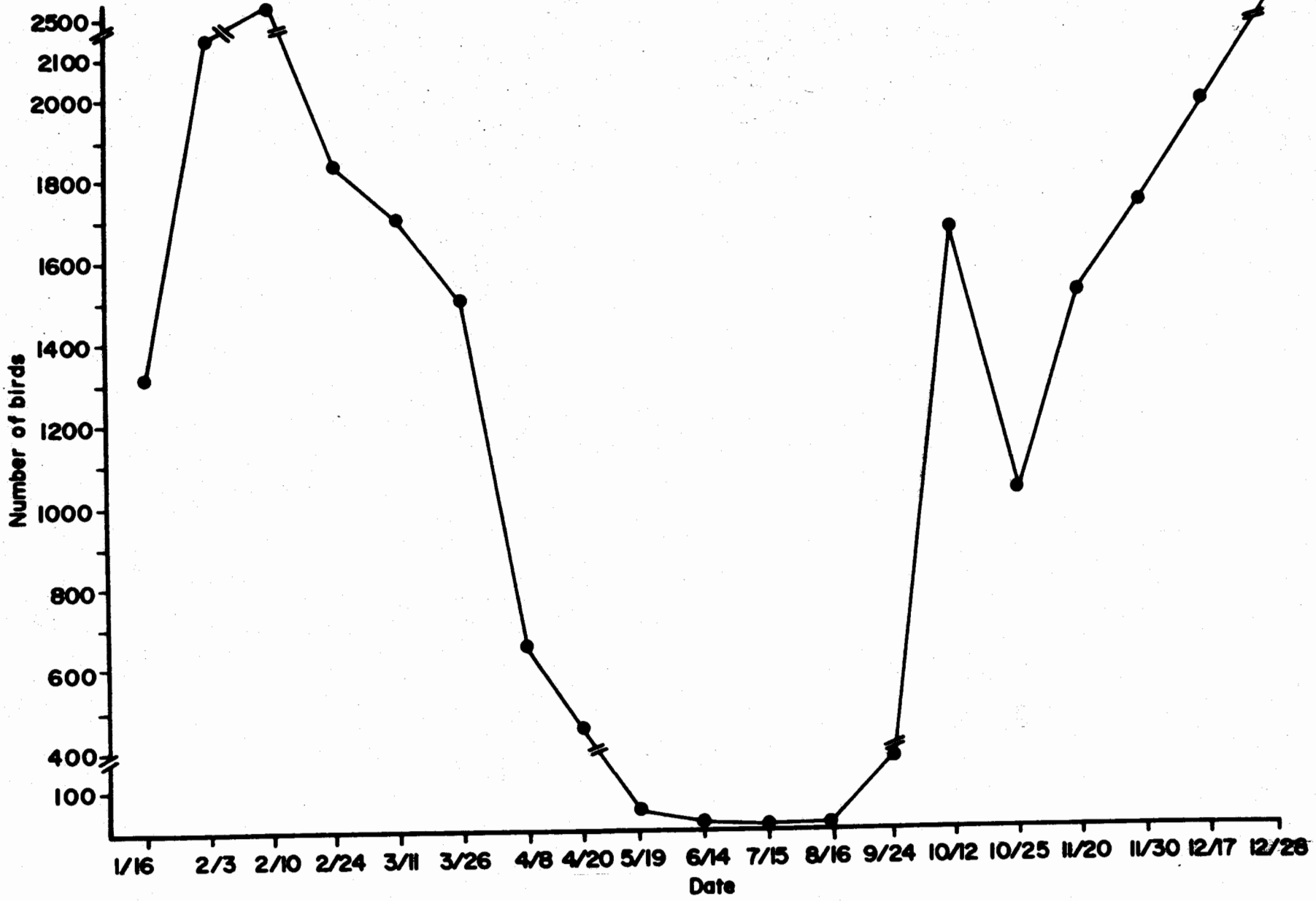


Figure 20

Number of Herring Gulls within the Charleston Study Area During 1976.

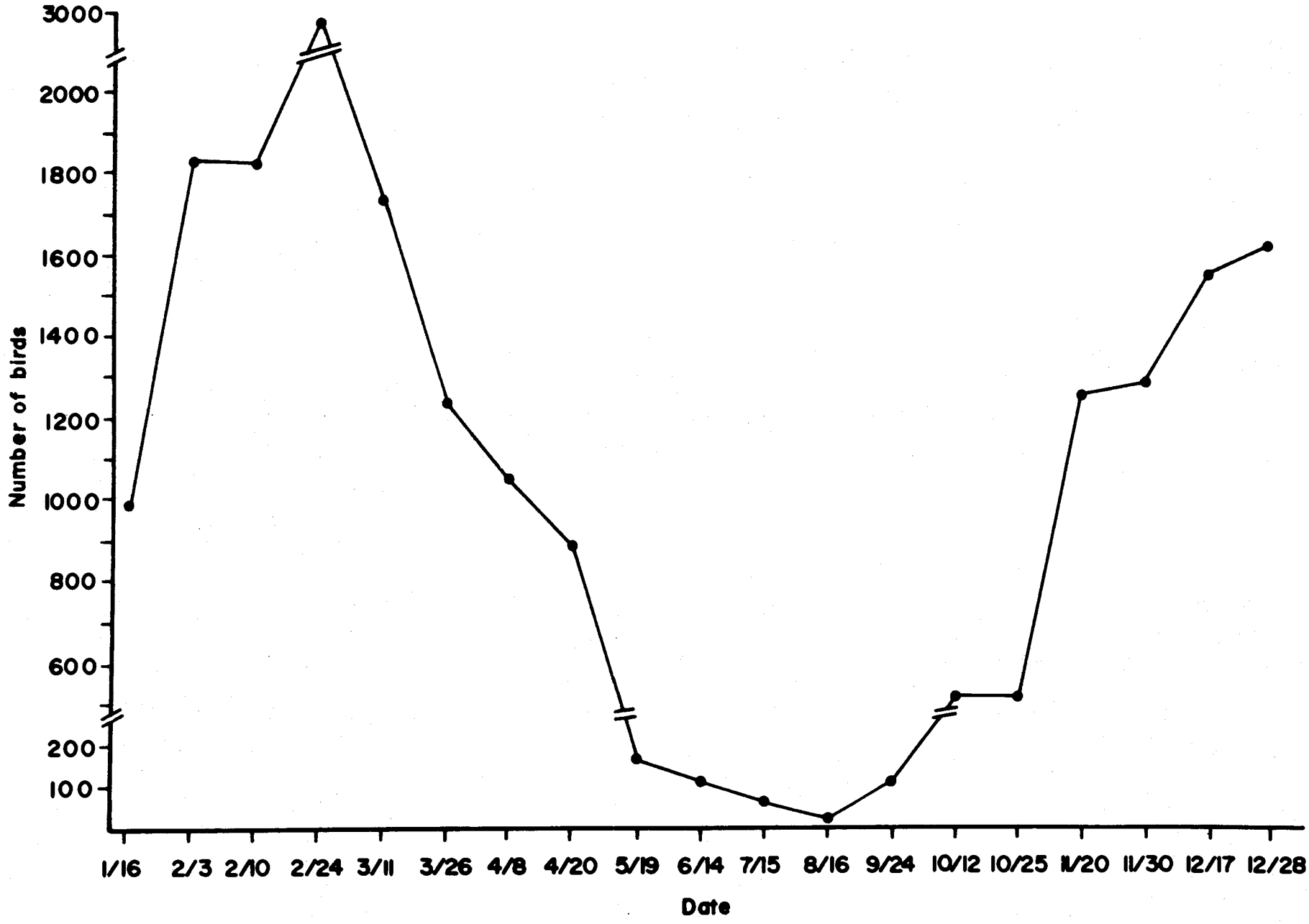


Figure 21

Number of Ring-billed Gulls within the Charleston study area during 1976

population trends. Ring-bill seasonal trends in 1976 were like those of 1971-72 (Fig 3 in Ref 9).

Laughing Gull population trends, with lows in winter and highs in summer and early fall, were the reverse of those found for the previous two species (Fig 22). The small wintering population was augmented by returning migrants in April-May. The breeding population of about 2,000 increased to over 3,000 by September with the addition of newly-independent young. Laughing Gulls reached their yearly peak (over 4,000) in early October when migrants passed through the area; after that, numbers declined rapidly to 800 in late November and one in December. Although population trends at Romney Street were erratic (Fig 6), major peaks corresponded to those in the study area as a whole. Also, seasonal trends were similar in 1976 and 1971-72 (Fig 5 in Ref 9).

Bonaparte's Gulls were observed from January through April, and from 25 October through December. These dates were within the normal period of occurrence for South Carolina (Ref 59). Peak numbers (400-800) were found in January-February, and November-December. The 1976 population was about double of that of 1971-72. This higher number may have been due to the abnormally cold winter in the North reducing the availability of feeding sites for this aquatic species. About 98 percent of the birds seen were adults.

The Great Black-backed Gull is a rare winter visitor along the South Carolina coast, occuring from 12 November to 12 May (Ref 60). During 1976, Black-backs were seen on 3-10 February, and 20 November-28 December. On all occasions except 3 February and 28 December, only one individual was present; two were seen on 3 February, and five on 28 December. All birds were adults. The high of five was much lower than the peak of 20 seen during February 1972.

A two-year old Iceland Gull was observed for about ten minutes on 15 February at Romney Street. It was not seen again, nor were any others seen during 1976 in Charleston. A single bird was seen at Clemson, South Carolina, during February by Harry LeGrand (Ref 61). Iceland Gulls have been observed on two other occasions in South Carolina; both records were by E. M. Burton at Charleston (Ref 62). There is one specimen record from the Savannah River; it was collected by I. Tomplins on the Georgia side of the river (Ref 15).

To see if the consolidation of disposal sites reduced gull populations, Herring and Ring-billed Gull numbers for 1971-72 were compared with those for 1976 by a paired t-test (Ref 36). For each species, January-June 1972 populations were compared with those for 1976, and July-December populations with those for 1976. The results (Tables 15-18) showed numbers of both species

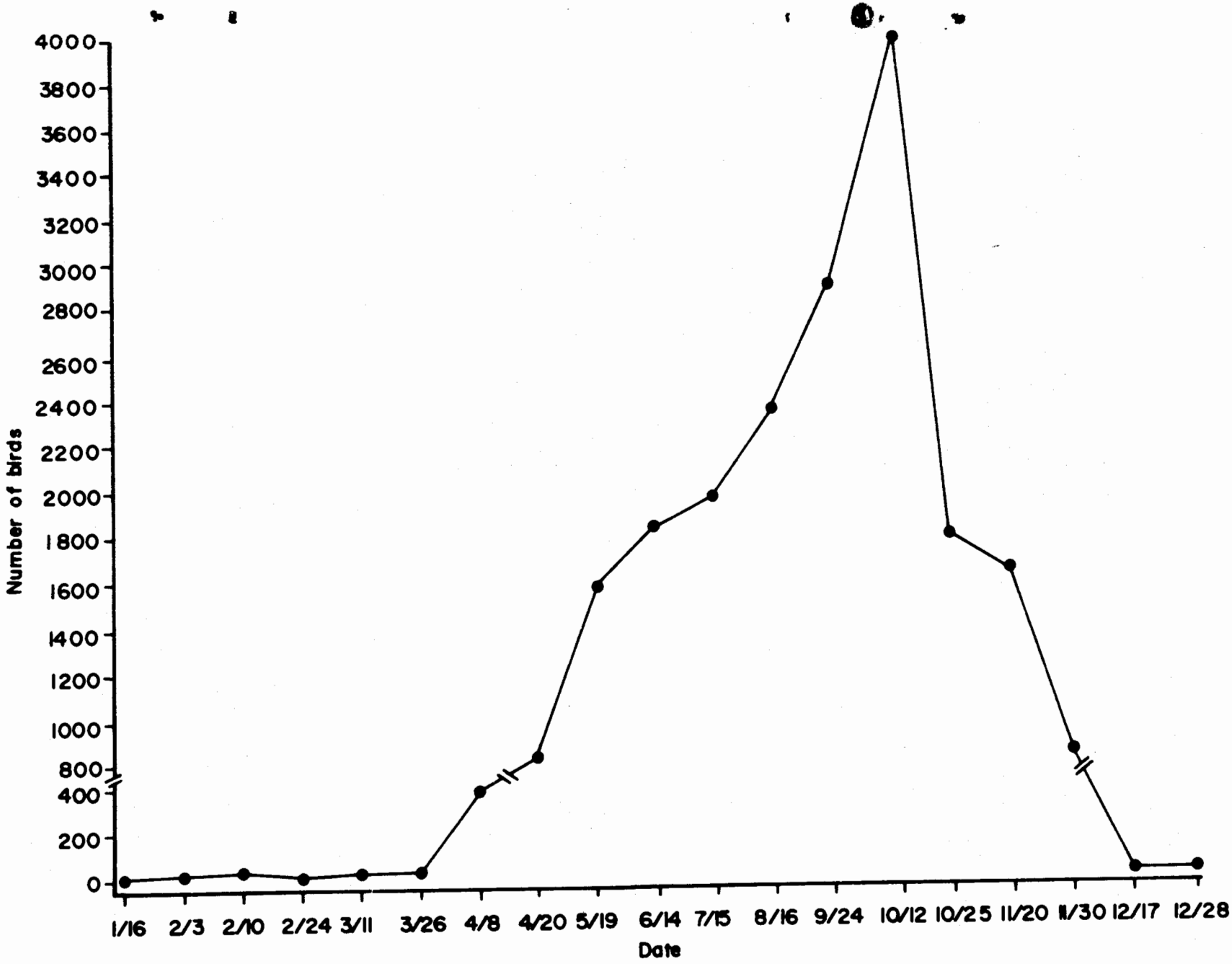


Figure 22

Number of Laughing Gulls within the Charleston Study Area During 1976.

TABLE 15. COMPARISON OF HERRING GULL POPULATIONS IN THE CHARLESTON STUDY AREA, 1972 and 1976

Month	Number of birds present 1972*	1976**
January	2780	1300
February 1-15	2900	2100
16-28	2600	1900
March	3200	1700
April	1100	650
May	300	60
June	75	24

* During 1972, there were eight active dumps and landfills.

** During 1976, there was only one active landfill.

t = 3.47 with 6 df, significant at the 0.05 level.

TABLE 16. COMPARISON OF HERRING GULL POPULATIONS IN THE CHARLESTON STUDY AREA, 1971 and 1976

Month	Number of birds present	
	1971*	1976**
July	75	14
August	80	14
September	100	166
October	700	1345
November	2590	1627
December	2720	2256

* During 1971, there were eight active dumps and landfills.

** During 1976, there was only one active landfill.

t = 0.64 with 5 df, not significant.

TABLE 17. COMPARISON OF RING-BILLED GULL POPULATIONS IN THE CHARLESTON STUDY AREA, 1972 and 1976

Month	Number of birds present 1972*	1976**
January	2400	900
February 1-15	3400	2700
16-28	3100	2500
March	3200	1735
April	1900	900
May	600	200
June	50	118

* During 1972, there were eight active dumps and landfills.

** During 1976, there was only one active landfill.

t = 3.72 with 6 df, significant at the 0.05 level.

TABLE 18. COMPARISON OF RING-BILLED GULL POPULATIONS IN THE CHARLESTON STUDY AREA, 1971 and 1976

Month	Number of birds present 1971*	1976**
July	100	68
August	100	26
September	120	110
October	600	519
November	3700	1257
December	2100	1576

* During 1971, there were eight active dumps and landfills.

** During 1976, there was only one active landfill.

t = 2.78 with 5 df, not significant.

reduced in 1976 from the 1972 levels, but no similar trends were seen between 1976 and 1971. The weather in 1971 and 1972 was normal and similar for both years; however, the winter of 1976 was abnormally severe. (See preceding section on weather.) These data suggest that the reduction in numbers of disposal sites did reduce the gull population, but severe weather could cause short-term population increases. Similar reduction in birds with the removal of dumps and landfills was observed by Van Tets (Ref 63) in Australia. Clearly, one of the most effective means of reducing a bird/aircraft collision problem resulting from the presence of dumps and landfills is by an active participation in efforts for the consolidation and removal of such sites.

Gull Roosting Sites and Daily Movement Patterns in the Charleston Study Area in 1976

The main Herring, Ring-billed and Laughing Gull roosting sites are shown in Figure 23. All sites were isolated islands or beaches along the coast, with little or no vegetation and few ground predators. A few gulls roosted on water in the harbor, rivers, inlets, and the leeward side of the jetties. Similar roosting sites have been described by Bent (Ref 64). No noticeable differences in roosting site selection or behavior between the two Charleston studies were found (Fig 24).

Herring and Ring-billed Gull daily movement patterns are shown in Figure 23. Gulls left roosts near sunrise and flew singly or in small groups to feeding and loafing areas. In the evening, birds returned to the roosting area, using the same pathways that were used in the morning. Around the roosts, individuals fed and loafed, flying the short distance to the roost just prior to sunset. No differences in flight paths were observed between January-April and September-December 1976. However, differences were noted between 1971-72 and 1976 (Figs 23, 24): during 1976, most gull movements were along the coast, with few short-distance flights up the major estuaries, and no overland flights or long-distance flights up rivers were observed, as was seen in 1971-72. This concentration of gulls along the coast and the lack of inland flights in 1976 was the direct result of the elimination of inland dumps and landfills.

Gull Loafing and Feeding Sites in the Charleston Study Area During 1976

Figure 25 shows the main loading and feeding sites for gulls in the metropolitan Charleston region during 1976. Most feeding areas were on beaches or mudflats along the coast, except for the Romney Street site and the Plum Island Sewage Treatment Plant. All loafing areas were within 1/2 mile of feeding or roosting sites. In contrast to 1971-72, few gulls were seen in 1976 at sewer outlets because the county had eliminated all open sewers in 1972, when the Plum Island Plant was started (Fig 26). There was

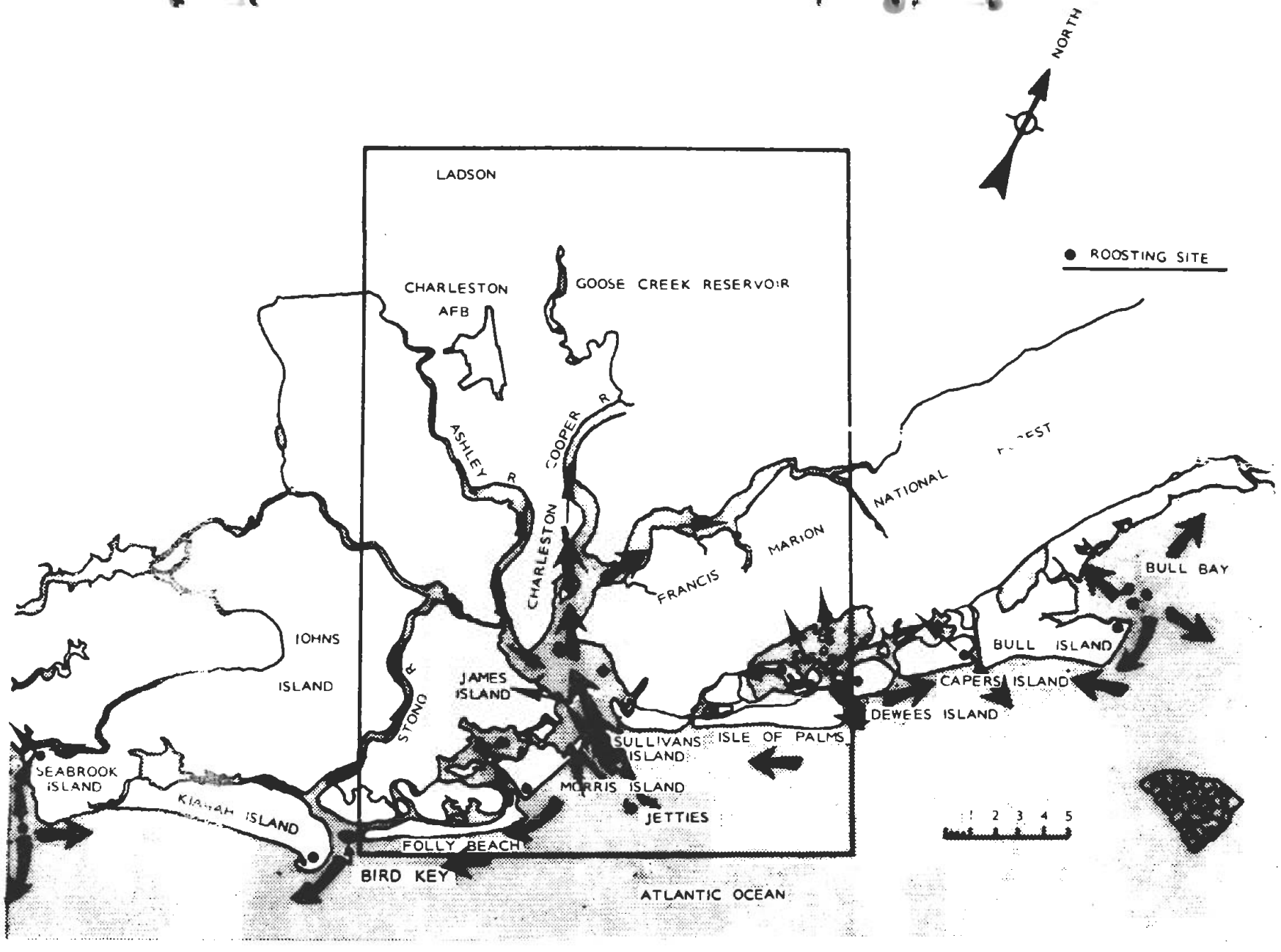


Figure 23

Roosting Sites and Daily Movement of Gulls, Jan. - April and Sept. - Dec. 1976.
Heavier Arrows Indicate Greater Number of Gulls.

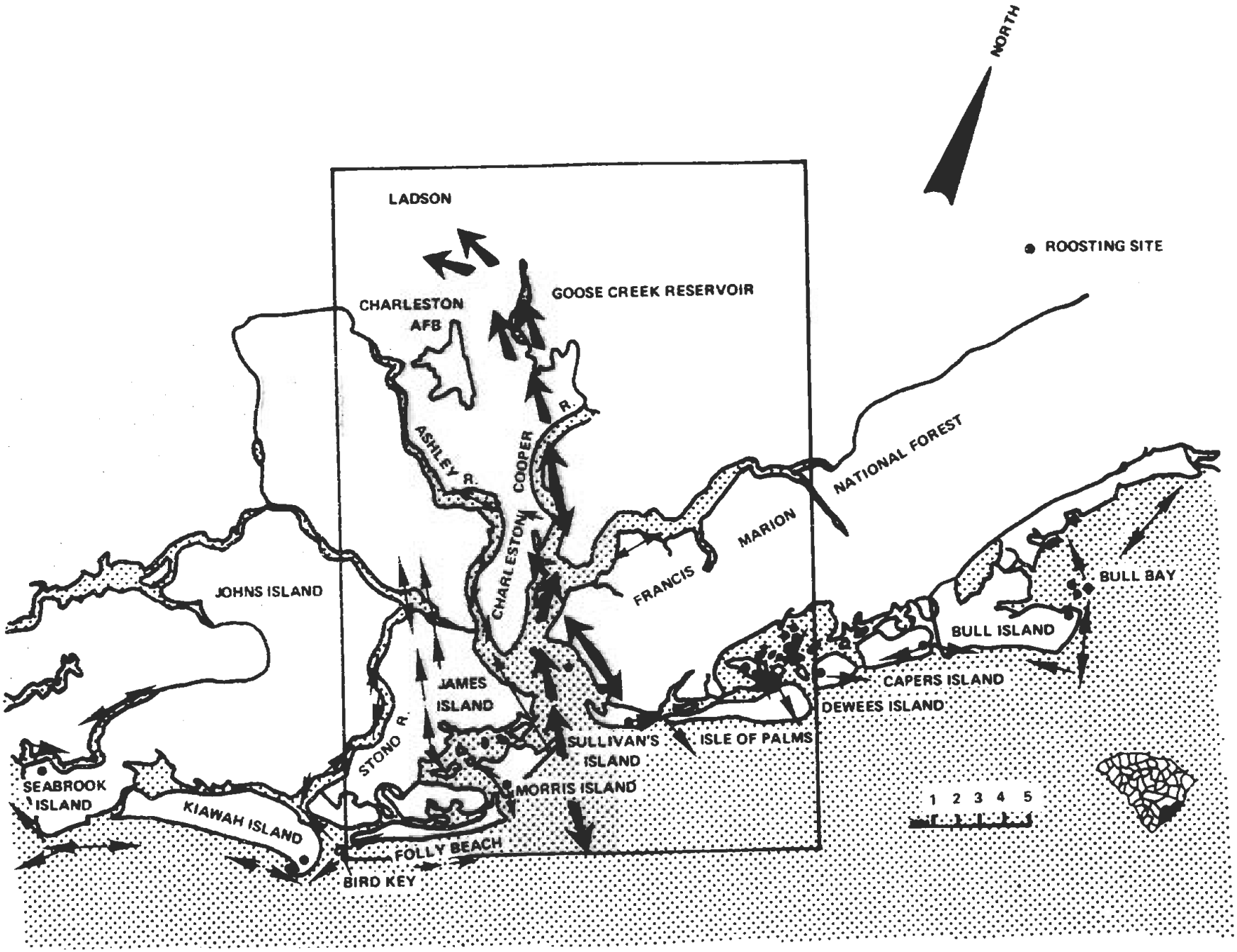


Figure 24

Roosting Sites and Daily Movement of Gulls, Oct. 1971 - April 1972

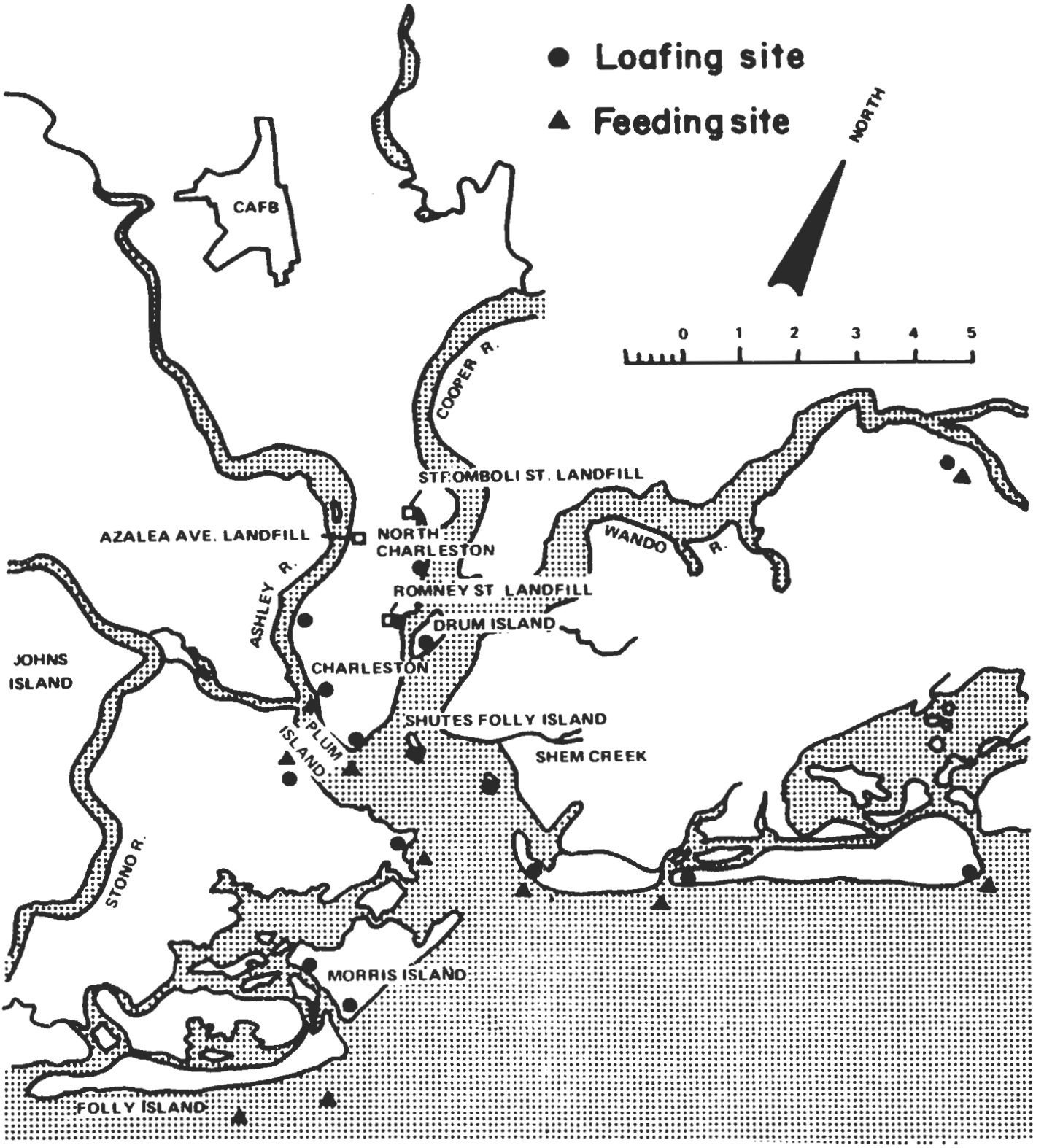


Figure 25

Major Loafing and Feeding Sites of Herring and Ring-billed Gulls during Jan. - April and Sept. - Dec. 1976. Each Dot Represents a Minimum of 30 Gulls.

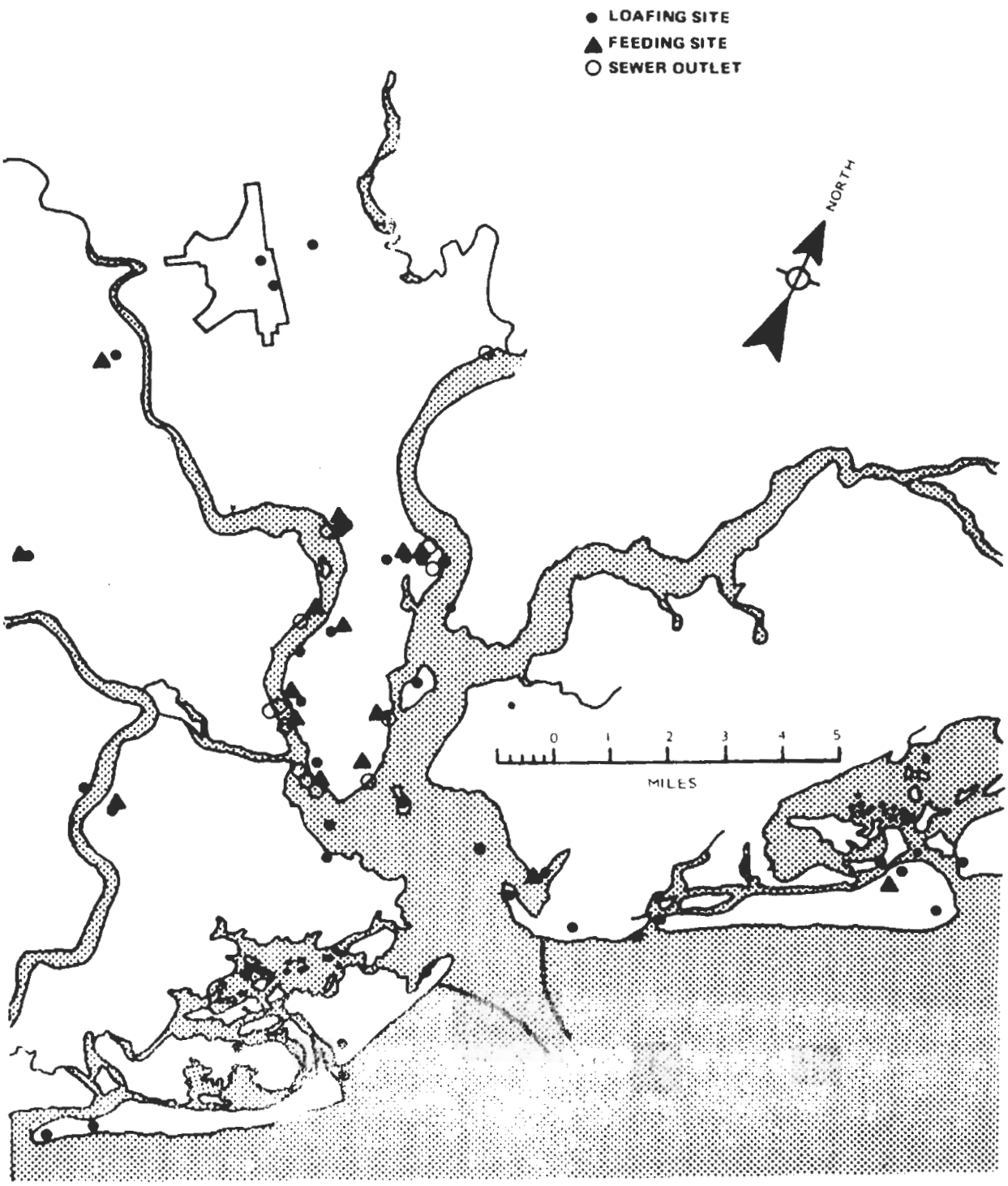


Figure 26

Major Loafing and Feeding Sites of Herring and Ring-billed Gulls during October 1971 - April 1972

a marked reduction in the number of birds feeding in inland areas, and no birds were present at disposal sites closed since 1974. The results of these changes were a reduction in the number of gull feeding areas within metropolitan Charleston and a concentration of gulls at natural sites along the ocean and Charleston harbor.

Changes in Gull Feeding Patterns in Charleston Between 1971-72 and 1976

Gulls are an ecologically successful group, with morphological and behavioral adaptations allowing them to exist in a variety of geographic locations and habitats. Part of their success is due to their ability to use a wide variety of natural and artificial food sources. In most cases, gull distributions and movements are influenced by food abundance (Refs 24, 65, 66). This was true for the Charleston gull population.

During 1971-72, Herring, Ring-billed, Laughing, Great Black-backed, and Bonaparte's Gulls used a variety of artificial food sources. These included: sewer outlets, sewage treatment lagoons, refuse from the shrimping and crabbing industries and from restaurants, and (most importantly) garbage dumps and landfills. During 1976, the relative importance of these artificial food sources was reduced because of changes in waste-disposal patterns.

In 1971-72, sewer outlets (Fig 26) attracted feeding assemblages of gulls, terns, and shorebirds. About 12 percent of the wintering Ring-billed Gulls fed at outlets, about 10 percent of the summer and fall Laughing Gulls used such sites, and about 60 percent of the population of Bonaparte's Gulls were heavily dependent on sewers for food. Herring Gulls, however, did not feed at sewer outlets. All the sewers were closed in 1972, thus, during 1976, no significant numbers of gulls of any species were observed feeding at sewer outlets.

Several primary sewage treatment ponds were located in the Charleston area. In 1971-72, these were used as feeding areas for small flocks of Herring, Ring-billed, and Bonaparte's Gulls. These species also used the oxidation pond at The Baptist College at Charleston. Ring-bills were observed using such ponds near Charleston AFB and these ponds were a major food source for Bonaparte's Gulls.

In 1976, only Bonaparte's Gulls frequented oxidation ponds, and no gulls were present at The Baptist College pond, primarily because of the closing of the adjacent Ladson landfill. In 1976, however, the Plum Island sewage treatment plant was an important food source, especially for Ring-billed Gulls. About 200 Ring-bills, ten percent of the population, fed at that plant in winter. Plum Island was one of the few areas where wintering

Laughing Gulls were present. In 1976, most Bonaparte's fed in aquatic situations on natural foods.

During both studies, shrimp trawlers were major feeding locations for Herring and Laughing Gulls. Some Bonaparte's Gulls also fed around trawlers, but Ring-bills rarely did. The proportion of Laughing Gulls using trawlers was about the same during both studies, consisting of about 80 percent of the July-November population. However, the proportion of Herring Gulls increased in 1976 from about 30 percent in 1971-72 to about 80 percent. This increase was related to the reduction in solid waste disposal sites initiated in 1974. Herring Gull populations at Romney Street (Fig 4) reflected their dependence on shrimp trawlers, as the population decreased in mid-March with the opening of the commercial shrimping season and did not increase until the season closed at the end of November.

In 1971-72, sanitary landfills and dumps were the main food source for wintering Herring and Ring-billed Gulls. About 70 percent of the Herrings, and 73 percent of the Ring-bills fed at disposal sites. Solid-waste sites were still important in 1976, but were not the predominant food source, as 25 percent of the Herrings, and 35 percent of the Ring-bills fed at Romney Street. Most Herring Gulls fed around trawlers and in the intertidal zone during 1976, and the intertidal zone was the main feeding location for Ring-bills.

A small percent of Ring-billed Gulls fed around restaurants and shopping centers in 1971-72; the percentage was even more reduced in 1976. Few birds were present at inland sites.

Bird/Aircraft Strikes at Charleston Air Force Base, 1971-1976

A serious bird/aircraft strike hazard existed at Charleston AFB during June 1970 through May 1971, with at least 33 reported strikes (Table IX in Ref 9). Strikes were reduced to 14 (42 percent of those in 1970-71) during June 1971-May 1972 (Table X in Ref 9), with the closing of the Reward Street dump next to the air base. No bird/aircraft strike records are available for the period June 1972-December 1973, but records are available for 1974 through 1976 (Table 19), and these show an additional reduction in bird strikes from the 1970-71 high. In 1974, when all dumps were closed and replaced with the Romney Street shredder, four strikes were recorded -- a 71 percent reduction from the 1971-72 level. Six strikes were reported in 1975 and only two in 1976. These results show that solid-waste site consolidation and effective zoning of solid-waste sites (Fig 24 in Ref 9) can minimize the bird/aircraft strike hazard at airports.

TABLE 19. SURVEY OF BIRD STRIKES, CHARLESTON AFB, SOUTH CAROLINA (1 JANUARY 1974 THRU 31 DECEMBER 1976)
(Data from Capt. Lyle, USAF, Flight Safety Officer, Charleston AFB)

	1974			1975			1976		
Month	Military airport operations	Bird strikes	Bird species	Military airport operations	Bird strikes	Bird species	Military airport operations	Bird strikes	Bird species
Jan	4454			5500			4979	1	Unknown
Feb	5804			5446	1	Unknown	4810	1	Suspected Seagulls
Mar	5480	1	Unknown	5277			5512		
Apr	6199	1	Unknown	5270	1	Unknown	5271		
May	6607			5236			6120		
June	5276	1	Unknown	5931			5394		
July	7850			5475			5549		
Aug	6657	1	Unknown	5621	1	Unknown	5613		
Sep	5804			5594	1	Unknown	5641		
Oct	5519			5329	1	Unknown	5401		
Nov	5438			4919	1	Unknown	5510		
Dec	5643			4890			5330		
Total	70731	4		64488	6		65130	2	

Note: The number of takeoffs and landings are not maintained on record per se; however, a record of overall operations is maintained; by using the following formula, a close approximation of the takeoffs and landings may be obtained: $[(2 \times \text{Military Airport Operations}) - (\text{Military Airport Operations} \times 2 \times 10\%)] \div 2 = \text{Takeoffs and landings}$

SECTION V

CONCLUSIONS

This study showed that shredded solid waste attracted a variety of avian species in large enough numbers to create a bird/aircraft strike hazard if the site were situated near an airport. The major species present were Herring Gulls, Ring-billed Gulls, Laughing Gulls, Common Crows, Fish Crows, Boat-tailed Grackles, and Cattle Egrets, and were the same species one would expect at an open dump or sanitary landfill located in a topographically similar area to Charleston. The population levels were about the same as those of a similarly-located sanitary landfill. Seasonal and daily movement patterns, as well as loafing and feeding sites were similar to those observed previously at dumps and landfills in Charleston (Ref 9).

Gulls fed almost exclusively on shredded refuse at Romney Street, thus showing that these species could feed on shredded refuse even when milled so that 85 percent passed through a 2-inch sieve. This disproves Ham's hypothesis (Ref 17) that no food would be available for birds if garbage were milled so that 90 percent passed through a 3-inch sieve. Cattle Egrets, and, to a lesser extent, crows and Boat-tailed Grackles fed on insects produced from the shredded refuse.

Surprisingly, no relationship was found between gull numbers and either amount or particle size of shredded refuse dumped, even though numerous studies have shown that gulls rapidly abandoned refuse sites when garbage is no longer dumped (Refs 25, 26, 30, 67). Gulls probably respond to the presence of refuse in all-or-none fashion. They are known (Ref 68) to have visual and acoustical signals which communicate to other gulls not only the presence of food but also if the amount is enough for more than one individual. Thus, gulls are attracted to shredded refuse by behavioral clues. These clues, however, are not precise enough to provide information on variations in the amount of food available, except in a general way. These facts indicate gulls would be attracted to shredded refuse if it were used as a landfill material. A bird/aircraft strike hazard could be created if borrow pits near Charleston AFB were being filled with shredded material from Romney Street.

The elimination of all dumps and landfills and their replacement with a shredder greatly changes gull populations and movement patterns. Both Herring and Ring-billed Gull populations were reduced significantly after consolidation, although variations in weather obscured the magnitude of the reduction for July-August 1976. Inland movements were reduced, and most birds remained close to the coast. The proportion of refuse-feeding birds in the population also was reduced, with most birds feeding

around shrimp trawlers and on natural foods in the intertidal zone. All these changes were reflected in an average yearly reduction in 1974-76 of 71 percent from the 1971-72 level in the number of bird strikes experienced at Charleston AFB. This reduction supported the previous recommendations (Fig 24 in Ref 9) for the zoning of dump sites in Charleston to reduce the bird/aircraft strike hazard at Charleston AFB.

This study indicates that no solid waste disposal technique now used is bird-proof. Therefore airport managers and flight safety officers must be concerned and involved with solid waste disposal programs of their communities if they wish to reduce the possibility of bird/aircraft collisions. Present guidelines for considering when landfills are incompatible with airport safety requirements, such as those of Vitale (Ref 69), must be considered the minimum needed by airport personnel in reducing the bird/aircraft collision problem. A more positive approach would include participation by airport personnel in the establishment of county- and regional-wide solid waste disposal zoning plans. Such plans (Fig 24 in Ref 9) can locate disposal sites so that they not only keep birds away from airports, but also may concentrate birds in regions away from airports, thus reducing the hazard (Ref 21). In such programs, guidance should be obtained from biologists knowledgeable in both the bird/aircraft strike hazard and the biology of the hazardous avian species. Airport personnel also should cooperate with solid waste disposal personnel in programs of landfill and dump consolidation, in recycling plans, and in any other technological improvement that would reduce the attractiveness of disposal sites to potentially hazardous birds.

SECTION VI

RECOMMENDATIONS

General Recommendations

1. Because shredded solid waste attracts birds potentially hazardous to aircraft, shredders should not be placed so as to create a bird/aircraft strike hazard on an airbase.

2. No shredded solid waste should be used as fill material at or near airports.

3. Airport and solid waste personnel should coordinate efforts to reduce the problems of dumps and landfills at airports.

4. Solid waste personnel and government agencies should encourage the consolidation and zoning of disposal sites to reduce the bird/aircraft collision hazard. A biologist knowledgeable in the behavior of hazardous species and in the bird hazard problem should be consulted.

5. Shredding plants should be combined with shredded refuse-burning electrial generating plants when possible.

6. Recycling of solid waste and any other technological improvements that would reduce the attractiveness of disposal sites to potentially hazardous birds should be encouraged.

7. The process of baling solid waste should be investigated to see if it would be attractive to birds.

Specific Recommendations

1. No shredded refuse should be dumped at Charleston other than in the approved zone as designated in my previous study (Ref 9, Fig 24). Especially no shredded refuse should be dumped at or near Charleston AFB.

2. Charleston County should be encouraged to add a refuse burning electrical generating plant at the Romney Street shredder.

3. Charleston County should be encouraged to continue using the present landfill or the area near Romney Street. No other location should be used without consulting the personnel at Charleston AFB.

4. Dead animals brought to the landfill should be covered with dirt immediately.

5. Sludge from sewage treatment lagoons should be covered with dirt immediately after placement on the landfill.

6. Care should be taken to keep the amount of loose garbage around the mill to a minimum.

7. The application of bird control techniques at Charleston AFB should be maintained at least at current levels. These techniques should include a full-time person responsible for the program, and a mobile bird patrol operating daily throughout the year.

8. Extra care should be taken at the airbase to patrol the airport during cold fronts in the fall, winter, and spring.

9. Aircraft should not be permitted to take off or land when birds are present on the airfield.

10. All pilots should be routinely advised of bird hazards on the airfield, in approach or departure zones, or at other areas where bird concentrations occur.

11. Care should be taken to keep the population of pigeons, House Sparrow, and other hazardous species found at the airport reduced to levels not hazardous to aircraft.

REFERENCES

1. Seubert, J. L., Birds and Airport Safety, Environmental Planning Conference, Airport Operators Council Inter., New Orleans, Louisiana, 24 March 1971, 6 pp., typescript, 1971.

2. Harrison, M. J., "The Bird/Aircraft Strike Hazard (BASH) Program in the United States Air Force," pp. 15-22 in S. A. Gauthreaux, Jr., ed., Proc. Bird Hazards to Aircraft Training Seminar and Workshop, FAA, East Point, Georgia, 1976.

3. Solman, V. E. F., How We Reduce Bird Hazards to Aircraft, Tenth Nat. Conf. Environ. Effects on Aircraft and Propulsion Systems, Trenton, N. J., 11 pp., mimeo, 1971.

4. Solman, V. E. F., Influence of Garbage Dumps Near Airports on the Bird Hazard to Aircraft Problem, Nat. Conf. Urban Engineering Terrain Problems, Montreal, Quebec, Canada, 8 pp., mimeo, 1973.

5. Davidson, G. R., Jr., T. V. Degeare, Jr., T. J. Sorg, and R. M. Clark, Land Disposal Sites Near Airports Reporting Bird/Aircraft Hazard, U.S. Environ. Prot. Agency, Solid Waste Manage. Office (Open-file Report: TSR 1.6.004/0), 33 pp., 1971.

6. Forsythe, D. M., "Gulls, Solid Waste Disposal, and the Bird-Aircraft Strike Hazard," pp. 17-25 in S. A. Gauthreaux, Jr., ed., Proc. Conf. on the Biological Aspects of the Bird/Aircraft Collision Problem, Clemson Univ., Clemson, South Carolina, 1974.

7. Forsythe, D. M., "Avian Biology Related to Solid Waste Disposal Techniques and the Bird-Aircraft Strike Hazard," pp. 77-92 in S. A. Gauthreaux, Jr., Proc. Bird Hazards to Aircraft Training Seminar and Workshop, FAA, East Point, Georgia, 1976.

8. Ham, R. K., and J. J. Reinhardt, "Refuse Milling in Europe," Nat. Center Res. Recovery Bull., 3:2-11, 1973.

9. Forsythe, D. M., An Ecological Study of Gull Populations to Reduce the Bird-Aircraft Strike Hazard at Charleston Air Force Base, AFWL-TR-73-42, Air Force Weap. Lab., Kirtland AFB, NM, 88 pp., 1974.

10. Poor, H. H., "Plumage and Soft-Part Variation in the Herring Gull," Auk 63:135-150, 1946.

11. Kadlec, J. A., and W. H. Drury, Jr., "Structure of the New England Herring Gull Population," Ecology 49:644-676, 1968.

12. Dwight, J., "The Gulls (Laridae) of the World: Their Plumages, Moults, Variations, Relationships and Distribution," Bull. Am. Mus. Nat. Hist. 52:62-401, 1925.

13. Korschgen, L. J., "Procedures for Food-habits Analysis," pp. 233-250, in R. H. Giles, Jr., ed., Wildlife Management Techniques, The Wildl. Soc., Washington, D.C., 1969.

14. Borror, D. J., and D. M. Delong, An Introduction to the Study of Insects, Holt, Rinehart, and Winston, New York, N.Y., 1964.

15. Sprunt, A., Jr., and E. B. Chamberlain, South Carolina Bird Life, rev. ed., Univ. of South Carolina Press, Columbia, 1970.

16. Siegfried, W. R., "The Food of the Cattle Egret," J. Appl. Ecol. 8:447-468, 1971.

17. Ham, R. K., "The Role of Shredded Refuse in Landfilling," Waste Age (Dec.):25-38, 1975.

18. Jones, R. R., "The Southern Region Bird Hazard Prevention Program," pp. 55-60, in S. A. Gauthreaux, Jr., ed., Proc. Bird Hazards to Aircraft Training Seminar and Workshop, FAA, Dept. of Transportation, East Point, Georgia, 1976.

19. Meanley, B., Blackbirds and the Southern Rice Crop, U.S. Dept. Interior, Res. Publ. 100, Washington, D.C., 64 pp., 1971.

20. Dyer, M. I., "Spatial Patterns and Problems of Resource Utilization in Winter Populations of Blackbirds and Starlings: A Theoretical View," pp. 191-223, in S. A. Gauthreaux, Jr., ed., Proc. Bird Hazards to Aircraft Training Seminar and Workshop, FAA, Dept. of Trans., East Point, Georgia, 1976.

21. Blokpoel, H., Birds Hazards to Aircraft, Books Canada, Inc., 1976, Buffalo, N. Y.

22. Bystrak, D., Breeding Bird Survey Newsletter, No. 4. U.S. Dept. Interior, Migratory Bird and Habitat Res. Lab., Patuxent Wildl. Res. Lab., Laurel, Maryland, 2 pp., mimeo., 1976.

23. Buckley, P. A., "The Changing Seasons," Am. Birds 25:541-546, 1971.

24. Drury, W. H., Jr., "Results of a Study of Herring Gull Populations and Movements in Southeastern New England," pp. 207-219 in R. G. Busnel and J. Giban, eds., Le Probleme des Oiseaux sur les Aerodromes, Instit. National De La Recherche Agronomique, Paris, France, 1965.

25. Ingolfsson, A., The Feeding Ecology of Five Species of Large Gulls (Larus) in Iceland, Ph.D. Thesis, Univ. of Michigan, 186 pp., 1970.

26. Hunt, G. L., Jr., and M. Hunt, "Habitat Partitioning by Foraging Gulls in Maine and Northwestern Europe," Auk 90:827-839, 1973.

27. Cogswell, H. L., "Gulls and Solid Waste Disposal in the San Francisco Bay Area, California," pp. 423-438 in Proc. World Conf. Bird Hazards to Aircraft, Queen's Univ., Kingston, Ontario, Canada, 1969.

28. Cogswell, H. L., "Ecological Factors in the Hazard of Gulls to Aircraft in a Bayside Complex of Airports and Solid Waste Sites," pp. 27-108 in S. A. Gauthreaux, Jr., ed., Proc. Conf. Biol. Aspects Bird/Aircraft Collision Problem, Clemson University, Clemson, South Carolina, 1974.

29. Wooten, R. C., Jr., Evaluation of the Bird-Aircraft Strike Hazard at Shemya Air Force Base, Alaska, DE-TN-71-037, Air Force Weapons Laboratory, Kirtland AFB, New Mexico, October 1971.

30. Cooke, F., and R. D. Ross, "Diurnal and Seasonal Activities of a Postbreeding Population of Gulls in Southeastern Ontario," Wilson Bull. 84:164-172, 1972.

31. Southern, W. E., "Dispersal Patterns of Subadult Herring Gulls from Rogers City, Michigan," Jack Pine Warbler 46:2-6, 1968.

32. Schrieber, R. W., "Seasonal Populations Fluctuations of Herring Gulls in Central Maine," Bird-Banding 39:81-106, 1968.

33. Haeni, F. R., "An Evaluation of Gulls Using the Milford, Connecticut Solid Waste Landfill Area," Unpub. report to C. E. Maguire, Inc., Wethersfield, Conn., 26 pp., 1974.

34. Haeni, F. R., "The Ethology of Utilization of Sanitary Landfill Areas by Southern New England Herring Gull Populations," Unpub. M.S. Thesis, Southern Connecticut State College, Groton, Conn., 70 pp., 1975.

35. Southern, W. E., "Seasonal Distribution of Great Lakes Region Ring-billed Gulls, " Jack Pine Warbler 52:154-179, 1974.

36. Steel, R. G. D., and J. H. Torrie, Principles and Procedures of Statistics with Special Reference to the Biological Sciences, McGraw-Hill Book Co., Inc., New York, N.Y., 1960.

37. Drury, W. H., Jr., and W. J. Smith, "Defense of Feeding Areas by Adult Herring Gulls and Intrusion by Young," Evolution 22:193-201, 1968.

38. Schreiber, R. W., "Roosting Behavior of the Herring Gull in Central Maine," Wilson Bull. 79:421-431, 1967.

39. Burton, E. M., Supplement, pp. 573-642 in A. Sprunt, Jr., and E. M. Burton, South Carolina Bird Life, rev. ed., Univ. of South Carolina Press, Columbia, 1970.

40. Pomeroy, D. E., "Birds as Scavengers of Refuse in Uganda," Ibis 117:69-81, 1975.

41. Feare, C. J., "Scavenging and Kleptoparasitism as Feeding Methods of Seyhelles Cattle Egrets Bubulcus ibis," Ibis 117:388, 1975.

42. Hailman, J. P., "Ring-billed Gulls Follow the Plow," Raven 21:105, 1960.

43. Vermmer, K., Breeding Biology of California and Ring-billed Gulls: A Study of Ecology Adaptation to the Inland Habitat, Can. Wildl. Serv. Rep. 12, Ottawa, Ontario, Canada, 1970.

44. Jarvis, W. L., and W. E. Southern, "Food Habits of Ring-billed Gulls Breeding in the Great Lakes Region," Wilson Bull. 88:621-631, 1976.

45. Sprunt, A., Jr., "Eastern Boat-tailed Grackle, Cassidix mexicanus torreyi Harper," pp. 365-374 in A. C. Bent, Lift Histories of North American Blackbirds, Orioles, Tanagers, and Allies, U.S. Nat. Mus. Bull 211, Washington, D.C., 1958.

46. Bent, A. C., "Life Histories of North American Jays, Crows and Titmice," U.S. Nat. Mus. Bull. 191, Washington, D.C., 1946.

47. Fogarty, M. J., and W. M. Hetrick, "Summer Foods of Cattle Egrets in North Central Florida," Auk 90:268-280, 1973.

48. Jenni, D. A., "Regional Variations in the Food of Nesting Cattle Egrets," Auk 90:821-826, 1973.

49. Schoof, H. F., and G. A. Mail, "Dispersal Habits of Phormia regina in Charleston, West Virginia," J. Econ. Ent. 46:258-262, 1953.

50. Schoof, H. F., and R. E. Siverley, "Urban Fly Dispersion Studies with Special Reference to Movement Pattern of Musca domestica," Am. J. Trop. Med. Hyg. 3:539-547, 1954.

51. Cranford, E. C., "Survey of Synanthropic Flies in Wake County, North Carolina," unpublished paper, Dept. Entomology, North Carolina State Univ., Raleigh, 1973.

52. Sacca, G., Comparative Bionomics in the Genus Musca, Annual Review of Entomology 1964, Vol. 9:341-358.

53. U.S. Dept. Commerce, Climatological Data, South Carolina Annual Summary, Environmental Data Service, NOAA, Vol. 74, No. 13, 1971.

54. U.S. Dept. Commerce, Climatological Data, South Carolina Annual Summary, Environmetnal Data Service, NOAA, Vol. 75, 1972.

55. Forsythe, D. M., "Ring-billed and Herring Gull Band Returns from South Carolina," Bird-Banding, Vol. 43, pp. 276-281, 1972.

56. Southern, W. E. and L. K. Kinkel, "Computer Generated Migrational Phenograms as Indicators of the Potential Hazard of Gulls to Aircraft," pp. 93-164 in S. A. Gauthreaux, Jr., ed., Proc. Bird Hazards to Aircraft Training Seminar and Workshop, FAA, East Point, Georgia, 1976.

57. U.S. Dept. Commerce, Climatological Data, South Carolina Annual Summary, Environmental Data Service, NOAA, Vol. 79, No. 13, 1976.

58. Probst, F. M., "A First Record for South Carolina: Black-headed Gull Photographed," Chat 35:109-110, 1971.

59. Neugent, P., Check-list of South Carolina Birds, Charleston Nat. Hist. Soc., 4 pp., mimeo, 1976.

60. Forsythe, D. M., "Aves," in R. Zingmark, ed., Checklist of the Coastal Zone Biota, Univ. South Carolina Press, Columbia, in press.

61. Teulings, R., "South Atlantic Region," Am. Birds 30:705-707, 1976.

62. Forsythe, D. M., "Gull Populations at Charleston, S. C., June 1971 to June 1972," Chat 37:57-62, 1973.

63. van Tets, G. F., Australian Airport Bird Problem Investigation, Div. Wildl. Res., CSIRO, 9 pp., mimeo, 1965.

64. Bent, A. C., "Life Histories of North American Gulls and Terns," U.S. Nat. Mus. Bull. 113:1-337, 1921.

65. Lack, D., The Natural Regulation of Animal Numbers, Oxford Univ. Press, Oxford, England, 1954.

66. Drury, W. H., Jr., and I. C. T. Nisbet, "Strategy of Management of a Natural Population: the Herring Gull in New England," pp. 441-454, in Proc. World Conf. Bird Hazards to Aircraft, Queen's Univ., Kingston, Ontario, Canada, 1969.

67. Kihlman, J. and L. Larsson, On the Importance of Refuge Dumps on a Food Source for Wintering Herring Gulls, Larus argentatus, Pont. Arvis. Scan. Vol. IV, pp. 63-70, 1974.

68. Frings, H., M. Frings, B. Cox, and L. Peissner, "Auditory and Visual Mechanisms in Food-Finding in the Herring Gull," Wilson Bull. 67:155-170, 1955.

69. Vitale, W. V., FAA Guidance Concerning Sanitary Landfills on or Near Airports, Dept. of Transportation, Fed. Aviat. Admin, (report: 5200.5), 3pp.