HUMAN IMPACTS ON BEACH USE BY WINTERING AND MIGRATING BIRDS IN THE LOWER CHESAPEAKE BAY

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Dedicated to my parents
for their unwavering support and encouragement
throughout the entire process.

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ABSTRACT

With the increased movement of humans to coastal areas and the industrial, developmental and recreational activity that has followed, the use of coastal beaches by wintering and migrating birds has appeared to decline. Different species of bird can be affected by human-related disturbances depending on the type, scope and duration of the disturbance. Disturbances interfere with the foraging efficiencies of birds by forcing greater numbers into less profitable foraging sites, making them expend energy to avoid molestation or by decreasing the numbers or availability of prey species. Indirectly, the temporary presence of humans at foraging sites can make an area inhospitable to foraging. The concentrations and distributions of birds on relatively disturbed (public access) and undisturbed (military base) coastal beaches in southeastern Virginia was compared during the winter and spring of 1992.

Total birds, gulls and terns, and Ring-billed Gulls were more common during the early half of the study and disturbances were more common during the later half. Shorebirds showed no such seasonal differences. Total birds, gulls and terns, shorebirds and Ring-billed Gulls were more common at low human-use beaches. Disturbances were more common at high human-use beaches. Within beache at different resolutions, the mean numbers of birds when alone and when in conjunction with disturbances was statistically the same although all categories of birds appeared to avoid segments of beach with disturbances. At 100 and 200 meter segments of the beach, all categories of birds significantly overuse segments of beach with the fewest numbers of disturbances present. Ring-billed Gulls show this same pattern of overuse at 300 meter segments and shorebirds show the same pattern at both 300 and 600 meter segments. In addition to the stresses of environmental conditions such as temperature, tidal and wind factors, birds can be adversely impacted by the presence and activity of humans on coastal beaches. Protected lands along coastlines should be monitored and managed for wintering and migrant species. Major coastal staging areas, considered especially critical for migrant species, should continue to be protected.

HUMAN IMPACTS ON BEACH USE BY WINTERING AND MIGRATING BIRDS IN THE LOWER CHESAPEAKE BAY

INTRODUCTION

Historically, human activity has been shown to have extensive impacts on wildlife resources. Development of frontiers, alterations of habitats and exploitation of wildlife for food, clothing and shelter can drastically change communities and whole ecosystems. Animal species of particular use to humans for meat, fur or ornamentation are particularly subject to overexploitation. Similarly, species seen to be competitors for resources are persecuted to some extent. Steadman (1993) showed how a decline in the species richness of a Polynesian island coincided with the arrival of humans to that area when previously there had been little or no turnover in the number of species.

Coastal areas in particular are subject to heavy development due in large part to their attractiveness to humans. By 1977, migration to the coastal zone had resulted in a population of over 130 million people living within 100 miles of United States coastlines (Knecht 1977). To accommodate the residential, commercial and recreational needs of the increasing population, a wave of land development has followed. This growth has gone unchecked with little or no regard for the loss of wildlife habitat. As this growth trend is expected to continue well into the next century (Culliton et al. 1990), it appears that coastal habitats will be subjected to ever increasing human pressures.

Human activities along coastlines can affect both whole ecosystems and local concentrations of natural resources. Large oil spills can immediately reduce seabird numbers in the coastal areas directly affected by the spill (Chapman, 1984 in Larsen and Richardson, 1990). Pollution in the form of waste disposal, industrial runoff, water withdrawals and shipping activities can also have widespread detrimental effects on shoreline communities. At a more local level, human activity and development can affect bird concentrations and distributions along the coast. Shorebirds, in particular, seem to be especially sensitive to human intrusion and several studies have pointed to the sharp decline in shorebird numbers over the past several years (Myers, 1983; Burger, 1986). Depending on the time of the year and the degree of disturbance, humans can disrupt the reproductive, feeding and roosting behaviors of breeding, wintering or migrating birds.

The effect of human disturbance on non-breeding birds is more related to decreased feeding efficiency than to survival of young. Birds that winter along temperate beaches may experience difficulties in meeting winter energy demands. Shorebirds in particular have more specific dietary requirements and are not as flexible in their choice of food as gulls and terns may be (Burger, 1983). Metabolic energy requirements increase with decreasing temperature while at the same time, prey abundance and availability decline with temperatures (Evans, 1979; Goss-Custard, 1984). In order to balance energy budgets during the winter, birds in temperate areas must forage almost continuously throughout the day and occasionally at night (Evans 1976). As a consequence, these birds may be especially prone to small-scale human disturbance.

Birds that migrate from their breeding grounds in the North to wintering grounds in the South (and vice versa) face many of the same obstacles along their journey as wintering birds. As with any migrating animal, these birds must meet the extreme energetic demands associated with migration. In addition to general maintenance, the birds require additional energy to travel sometimes thousands of kilometers from southern wintering grounds or from northern breeding grounds. Shorebirds may use several times the energy accumulated as premigratory fat reserves during several hours of non-stop flight (Myers 1983). Dunlin in England were found to add an average of 26 grams of fat (corresponding to a 53% addition to their mid-winter lean weight) by late May (Pienkowski et al., 1979). This was calculated to be enough to arrive on the breeding grounds in Norway, but with no additional fat reserves. To compensate for this migratory depletion, long distance migrants often stop at areas along the migration route to build up fat reserves before continuing their journey. For many shorebirds, these "staging areas" are critical to their survival during migration. Species appear to use the same staging areas from year to year and recent studies have suggested that even slight disturbances at these areas can affect the ability of the birds to obtain enough energy to survive migration (Myers 1983, Burger 1988).

Presumably, birds that are not required to defend territories or protect chicks are less prone to human disturbances than breeding birds. Humans can, however, have long-term impacts on wintering and migrating birds through industrial, recreational or agricultural development of foraging or roosting areas. Even the presence of roads, buildings and other landscape features can disrupt feeding or roosting activities (Madsen, 1985). For birds that may already have difficulty finding enough to eat in a relatively short period of time, the consequences of human-related disturbances can be magnified. This also holds true for birds that migrate north in the spring through the interior of North America. In these case, wetland habitats such as marshes, prairie potholes, flooded agriculture fields and artificial reservoirs or impoundments are important stopover areas for migrants (Smith et al., 1991; Hands et al., 1991). Above all, staging areas, whether coastal or inland, are critically important to migrating birds, and human disturbance at these areas can be devastating to bird populations.

Along coastal beaches and mudflats, birds are not spread evenly over a particular feeding area. They will tend to concentrate in areas with highest densities of prey provided that these areas are not too distant from nighttime roosting sites and that the energetic cost of flying to and from the feeding ground does not exceed that acquired at the feeding site. In addition, different species will use different habitats depending on foraging strategies, environmental conditions and the availability of preferred prey species (Burger et al. 1977; Connors et al. 1979). Development of a foraging site could affect different species to varying degrees. Widespread development can force more birds to occupy less profitable feeding areas which can decrease profitability of foraging by decreasing the number of prey items of the preferred size, and decreasing the intake rate (and therefore the profitability) of foraging by the birds (Goss-Custard, 1979). Forcing greater numbers of birds into a smaller area also makes them more susceptible to disturbance, competition and predation than smaller flocks (Burger, 1984; Pfister et al., 1992).

On a smaller scale, transient disturbances can displace individual birds from foraging areas and continually make them expend energy by moving from one place to another to avoid molestation. Walkers, swimmers, joggers, picnickers, boaters and recreationists can dislodge birds from preferred feeding areas. Disturbances such as dogs, horses, all terrain vehicles and bicycles can have the same effect. To complicate matters, the intensity and proximity of the disturbance as well as the species of bird being affected can alter the consequence of the disturbance. Burger (1981a) found that rapid-movement or close proximity disturbances such as jogging or lawn mowing was more disturbing to feeding or roosting birds than slow movement such as bird-watching or clamming. She also found in the same study that gulls and terns were less likely to flush away from a disturbance and responded when the disturbance was at a closer distance than shorebirds did. The feeding efficiencies of gulls were lowered, however, and gulls moved further out onto beaches or mudflats during high-disturbance demolition and beach clean-up activities (Burger 1988).

One aspect of human-bird interactions that has not been studied in detail is the local effect of humans on wintering and migrating bird populations. Most investigators have focused on seasonal patterns and long term distributions of birds at breeding sites or staging areas, and the influence of humans at these sites.

This study investigated the influence of transient human disturbance on migrant and wintering birds by comparing bird distribution on a series of low-disturbance (military) and high disturbance (public access) beaches. The goals of this study were to: (1) document the effect of transient human disturbance on the numbers and diversity of birds on sandy beaches, (2) determine at what spatial scale humans affect birds and (3) investigate interspecific differences in response to transient human disturbance.

METHODS

Study Areas

The study was conducted along a series of four public access and two military (private) beaches at the mouth the Chesapeake Bay and along the Atlantic Ocean in Virginia (Figure 1). Beaches were chosen for their location along the coast and the amount of human use they receive as well as for their physical characteristics. Two treatments were used. High human-use sites had greater than 500 human related disturbances observed over the course of the study and were located at Lynhaven Inlet beach, Chick's Beach and northern Virginia Beach (Figure 1: LI, CB, and VB respectively). Low human use beaches had less than 500 human related disturbances observed over the course of the study and were located at Ocean View beach, Fort Story Naval Base and Dam Neck Fleet Combat Training Center Atlantic (FCTCL) (Figure 1: OV, FS and DN respectively). All are wide, sandy beaches bordered by (or once bordered by) primary dunes and all are influenced by a regular tide cycle. The high human-use sites as well as Ocean View beach are developed with private residences set back approximately 50-100 m from the water line at the beach edge or on low primary or secondary dunes. Fort Story and Dam Neck are not developed and the dunes continue back from the beach face for approximately 200-300 m. The dunes at all the sites are intermittently or entirely reinforced with hurricane fencing along the census route.

Census routes consisted of 1800 meter segments of beach marked at 20m intervals with non-intrusive wooden markers placed along the dune or property line. The beach face from the surf line to the primary dune or property line was subdivided into four separate zones (surf zone, below the berm line, above the berm line, and dune zone) for the precise placement of birds or disturbance factors on the beach.

Data Collection

Sites were censused by walking along the dune or property line and mapping bird and human activity on the beach. Data was plotted on a grid map of the beach segment with the location of the birds known to within 10 meters parallel to the transect and within a specific zone along the beach face. Human-related disturbances, including passive (e.g. people sunbathing or playing in the sand) and active (e.g. joggers, volleyball players) disturbances, were plotted in the same manner, as were any other disturbances present on the beach (dogs, vehicles, etc.). Because of problems with estimation of distances and identification of bird species, birds and disturbances were counted only if they were present on the beach up to a distance of 100 meters ahead of the investigator. Birds offshore were counted if they were within 50 meters of the shore. Aircraft were not documented as they were generally high flying and did not appear to disturb the birds.

Data collection covered the late winter and spring of 1992 from 8 February through 11 June to include the spring migration of northern breeding species. Censuses were conducted in eighteen time blocks with each study site censused once in each block (with the exception of Dam Neck which was not censused during the first block). The order of sites to be censused within each time block was randomly determined. Censusing of all sites within one time block required from two to nine days (avg. = 5.7 days) to complete, with the time between censuses of individual sites ranging from 2 to 15 days (avg. = 7.3 days). All data was collected within the six hours around low tide when shorebirds are most active on beaches (Burger, 1984). The temperature, tide height and direction, wind speed and direction, and cloud cover were also collected during each census. Sites were not censused during heavy winds or rainfall.

Data Analysis

Between Beaches

On a broad scale, the seasonality of beach use by birds and humans was determined for all sites and general trends were described. Surveys one and eighteen for all sites were omitted from the majority of the analyses due to the absence of data from Dam Neck during the first time block and to the unusually large number of people at Virginia Beach during the last time block. This omission reduced the total number of surveys from 107 to 96, or sixteen for each of the six sites. To further facilitate analysis of differences between taxa, gull and tern numbers were combined into one category (Gulls and Terns) and plover and sandpiper numbers were combined into another (Shorebirds). In addition to being included in the gull and tern category, Ring-billed Gulls (*Larus delawarensis*), the most abundant species on the beaches (36% of all birds observed), were also considered separately in the analysis. Waterfowl were not abundant on the study beaches and were generally located too far offshore to be subject to human disturbance and so were excluded from the analysis.

It was obvious that the time of year would have an effect on when certain species were present on the study beaches due to the migration patterns of some species of birds. Therefore, based on abundance curves for the categories analyzed (gulls and terns, and shorebirds), the sixteen time blocks used in the analysis of seasonal and treatment patterns were broken up into two seasons to correspond to the movement of birds into and out of the area. "Early" refers to surveys 2 through 9, approximately mid-February through early April. "Late" refers to surveys 10 through 17, approximately mid-April through early June. The seasonal patterns of beach use over all the sites was compared using a non-parametric Kruskal-Wallis statistical test. Additionally, the difference in bird and human use at each of the two treatment types was determined using a one-way ANOVA, constraining the data by season where appropriate.

Within Beaches

At small scales, birds are disturbed by human activity by being displaced from foraging or roosting areas. Indirectly though, the presence of a disturbance can prevent the occupation of an area by birds altogether. In addition, the intensity and duration of a disturbance can affect the numbers and species of birds found near it. To assess this indirect effect of disturbance, and to determine at what spatial scale disturbances would have an effect, a subset of surveys was used to analyse patterns of beach use at distances less than the entire 1800 meter survey route. It was necessary to limit the number of surveys used in the analysis of indirect bird and human interactions within beaches because of the low amount of beach activity by birds and/or humans during many of the surveys. This analysis was limited to surveys with at least ten birds and ten human-related disturbances present on the entire 1800 m section of beach. This reduced the number of surveys analyzed from a total of 107 to 31. In addition, the different categories of birds were constrained in the same way, reducing the number of surveys for gull and tern analysis to 29, shorebirds to 16 and Ring-billed Gulls to 20. For these surveys, the beach was divided into cells (or segments - the two terms are used interchangeably) of 900, 600, 300, 200 and 100 meters in length. Regression analysis of the numbers of humans on the numbers of birds in each cell was performed for 1800 and 900 meter cells. For smaller cell sizes, the mean numbers of birds and humans in cells when alone and when in conjunction with one another were compared. The non-parametric Kruskal-Wallis test was used because the data at this level of analysis was not normally distributed.

Part of the difficulty with a broad-scale analysis of this type stems from the varied range of sample sizes due to sporadic beach use by birds and humans, and variation in numbers as the scale of the analysis decreases from larger to smaller segments of the beach. Common sense would dictate that the size of a cell and the number of humans occupying it would affect the number of birds present in the cell. To address this problem, the difference between the observed proportions of birds in cells and an expected number was determined in the following way. For each cell size (600, 300, 200 and 100 meters), the disturbance level (number of humans per cell) was divided into subcategories (the disturbance gradient) and a frequency distribution of the proportion of cells at each disturbance level was generated. These frequencies represent the availability of relatively disturbed and undisturbed sections of beach for bird occupation. The total observed number of birds at each disturbance level along the disturbance gradient was determined from collected data and expressed as a percentage of the total. The expected values were then subtracted from the observed values. This method gives an indication of over- or underutilization of relatively disturbed or undisturbed segments of beach (Bryan D. Watts, pers. comm.). Significance was determined by X^2 analysis.

RESULTS

A total of 10,066 birds representing 33 species were observed on the six study beaches over the five months of the study. Appendix A contains a list of species' common and scientific names. Of the 33 total species observed, there were six gull species (representing 50% of the total), 12 sandpiper species (38%), five tern species (10%), six waterfowl species (1%), and four plover species (1%). Eleven of the 33 species accounted for 97% of the observed birds and were the basis for the statistical analysis. Of these eleven species, there were four gull species (52%), four sandpiper species (38%), two tern species (9%), and one plover species (1%). Appendix B gives the abundance of each of the top 11 species by date for all sites combined. As mentioned earlier, for statistical purposes, these species were combined into two groups: gulls and terns, and shorebirds. Gulls and terns comprised 60% and shorebirds comprised 40% of the total birds seen. There were 3617 human-related disturbances observed on the study beaches over the course of the investigation.

Between Beaches

Figure 2 shows the abundance curves by date for each of the bird categories and for human-related disturbances totaled across the six sites. Table 1 gives the results of a 2-way ANOVA for seasonal and treatment effects. Total birds, gulls and terns, and Ring-billed Gulls were present on the beaches in significantly greater numbers during early surveys (F-ratio >9.843, $P < 0.02$ in all cases). Shorebirds showed no such seasonal pattern (F-ratio = 0.338, NS). All categories of birds were present in significantly humans only compared to the mean number in cells occupied by both humans and birds (Kruskal-Wallis test statistic < 3.693, $P > 0.06$ in all cases). The implication is that birds are not avoiding cells occupied by a greater number of disturbances. Total birds and Ring-billed Gulls in 100 m cells had significantly greater number of humans in human-only occupied cells (Kruskal-Wallis statistic = 10.606, $P = 0.001$ and 4.265, $P = 0.05$ respectively). Despite the lack of statistical significance, birds were almost always found in greater numbers in segments with no disturbances, and the number of disturbances in a segment was almost always less when birds were also present in the segment.

Finally, the analysis of the indirect effect of disturbances on birds showed that the size of a segment and the number of disturbances within a segment influenced the number of birds present. Figures 7 - 10 show the deviation of the observed percentage of birds from expected percentages across the disturbance gradient. A value greater than zero indicates overutilization of cells by birds at that disturbance level and a value less than zero indicates underutilization. For all categories of birds, there appeared to be an increasing tolerance for disturbances as the segment size increased. At 100 and 200 meter segments, all categories of birds significantly overused cells with few disturbances (X^2 statistic > 19.720, $P < 0.05$ in all cases). Only shorebirds and Ring-billed Gulls showed significant results at 300 meter segments (X^2 statistic = 14.310, $P < 0.001$ and 25.063, $P < 0.001$ respectively) and only shorebirds showed significant results at 600 meter segments ($X^2 = 27.942$, $P < 0.001$). These results are expected as 10 humans in 600 meters of beach would not likely have the same disturbance effect as the same 10 humans in 100 meters.

DISCUSSION

Disturbance Levels

The difference in human use at the treatment sites with respect to time of year suggests that human disturbance is more of a threat to birds later in the spring and at the high human-use sites. Unfortunately, the spring migration of many bird species often occurs concurrently with increased human use. Human use of a beach appears to be a function of its accessibility, its perceived attractiveness for use, and weather conditions at the time of use. Accessibility is a major consideration. Dam Neck is not open to the public although there were often military personnel walking or jogging along the beach. Fort Story is also closed to the public along the census route although access is not controlled as tightly as at Dam Neck. Though more accessible, Fort Story does require a short walk from the nearest street parking, making it unlikely to be used by casual sunbathers or beach walkers. Similarly, Ocean View is a wide sandy beach similar to the high human-use sites, but is located in an unsafe section of town with few parking areas so human use is limited.

Not only do beaches become more disturbed at the same time species begin to migrate through in the spring, but the types of disturbance also changes. In winter, disturbances (walkers, people with dogs and an occasional jogger) are present for only short periods of time and generally keep near the dunes for protection from wind and sea spray. The major types of disturbances as the weather gets warmer (walkers, joggers and dog walkers) stay out longer and often travel the length of beach along the prime foraging spots (water's edge). Climate and seasonal factors also influence the number and type of disturbances on beaches. The majority of people on beaches during early surveys were walkers or dog owners. Virginia Beach allowed dogs on the beach until the first of May. Late surveys saw many more active disturbances; children, joggers and sports activities in addition to a significant increase in the number of sunbathers. In a previous study, these active types of disturbances were found to be the most disruptive to birds on beaches (Burger, 1986). Furthermore, the scope of the disturbance (whether it is localized or widespread), the speed, and the duration of the disturbance can influence its effect on birds. Joggers for example were often counted twice during a survey as they moved up and down the beach. They also preferred to run along the firmer sand at the water's edge which is the preferred foraging spot for shorebirds. Although in these cases, the disturbance was of short duration, it was widespread along the beach, a problem for foraging birds. Sunbathers had little movement on the beach, but the sheer numbers present (especially on warm, sunny days) were a possible deterrent to foraging birds.

Disturbance Effects

Consistently, low human-use sites had a greater mean number of birds occupying the beach suggesting that birds are avoiding areas of high human concentration. In addition, the species richness at he low-use sites was greater than that at high-use sites. Although Ocean View was considered a low human-use site and had the greatest number of total observed birds (25% of all birds observed), only 16 different species used the beach. Fort Story, well known as a prime "birding" location, had 25 species, the greatest diversity of all sites.

Gulls and terns in general appear to adapt more readily to human presence than shorebirds. Burger (1981a) found that gulls were significantly less disturbed by human presence than shorebirds in the same area. In addition, Burger and Gochfeld (1983a) found that regular disturbance of breeding Herring and Great Black-backed Gulls reduced the response distance and return time to nests than birds at less frequently disturbed sites. The small-scale patterns of beach use presented here support this habituation hypothesis. Birds in 300 and 600 meter segments showed no significant preference for less disturbed areas and, in the case of gulls and terns, and Ring-billed Gulls, overutilized cells at intermediate disturbance levels (7 - 9 disturbances/cell). The presence of humans may be benefitting some gull species leading to a desensitization in gulls that is not seen in shorebirds. Laughing Gulls and Ring-billed Gulls, the two most common species of gull during the last two surveys, are known to be common around humans and at dumps. Gulls often feed on human garbage and may be drawn to large populations of humans for the potential food source they provide. During one survey at a high-use beach (Virginia Beach), two people with a loaf of bread were surrounded by over 50 Ring-billed and Herring Gulls.

Shorebirds were more disturbed than gulls and terns or Ring-billed Gulls and were disturbed at greater distances than the other categories. Burger (1986) noted the same difference at Jamaica Bay in New Jersey. This may relate to several factors. Shorebirds may not be as flexible in their dietary requirements as gulls and so have a limited habitat range in which to forage. In addition, migrant shorebirds may not be as habituated to the presence of humans and human-related disturbances as birds that winter in the area. Continual disruption of foraging birds has been shown to cause relocation (possibly to less profitable foraging sites) and/or abandonment of the area (Burger, 1981a; Burger, 1981b, Pfister, 1992).

Environmental Effects

In addition to human-related disturbances, distributions and feeding efficiencies of wintering and migrating birds are also subject to a variety of environmental pressures. Seasonal and climate factors are important mainly for their effect on the activity of prey species. These factors can cause energetic stress in birds by making prey less available to the birds or prey capture more difficult. This inhibition of foraging rates can come at a time when adequate energy uptake is of prime importance and; in the case of migrants, may be already difficult to obtain.

Time of year is important in determining the presence and numbers of birds on a coastal beach. There were significant seasonal effects for total birds, gulls and terns, and Ring-billed Gulls in this study. Shorebirds would likely have shown the same pattern except for the presence of Sanderling on the beaches during February and March. Four of the five species of shorebird (with the exception of Sanderling) arrived and disappeared from the beaches within a period of only five weeks (Appendix B). Ring-billed Gulls, which appeared in high numbers in the late winter and early spring, all but disappeared from the beaches by mid-April. Migrational and breeding patterns influence the presence and activity of birds in a particular area as well as influencing the activity of the their prey species. For example, many shorebirds migrate north following the migration of the Horseshoe Crab (*Limulus* sp.) and feed on the eggs of this species along the coast. Spring migration along the east coast, especially in shorebirds, is typically of shorter duration and has fewer birds than a Fall migration. Many birds follow a more inland route in the Spring and juvenile birds (less than a year old) are absent at this time reducing the numbers on beaches.

Seasonal and circadian rhythms mainly affect the amount of daylight available to the birds for foraging, unlike variations in temperature and other climate factors which affect actual foraging and prey intake rates of the birds. In conjunction with tidal factors which have been shown to influence foraging sites and intake rates (Burger, 1984; Burger, 1983; Burger and Galli, 1987), daylength is an important consideration during winter months and can be a critical factor at latitudes where daylength is greatly reduced. Behavioral responses of birds to a short day length include feeding for a longer period of time during the day or feeding at night. Goss-Custard (1970) found that Redshank on the Wash in Great Britain increase the amount of daylight spent foraging from 70% in the fall to 95% in the winter. Night foraging is generally not as profitable as daytime feeding, although waders that are able to hunt by touch will forage at night in the winter as needed to meet daily energy requirements (Evans, 1976; Goss-Custard, 1970). Surveys during this study were conducted only during the day and never during periods of extremely harsh weather. The great majority of birds, with the exception of terns, were observed foraging along the water's edge or in the wet sand along the tide line. Terns, which often feed on the open water (Bent, 1947), were also found at the water line, but were generally preening or roosting. This preference for daytime feeding and foraging at the water's edge would tend to increase the interactions of birds and people as these areas also appeared to be the preferred sites for human activity. It was interesting to note that some birds (usually gulls and terns) could often be found on exposed sandbars off the beach. These were seldom used by people, but also didn't appear (from casual observation) to receive the same invertebrate use as the water's edge. This may have accounted for the lack of shorebirds on these relatively protected "islands."

A behavioral response of birds to seasonal and circadian fluctuations in prey availability (due mainly to climatic factors) is to move from one foraging area to another during the day to maximize energy intake (Evans, 1979). This type of cyclic variation in foraging area has been observed in sanderling (Summers and Waltner, 1979), curlew sandpipers (Puttick, 1984), and a mixed assemblage of shorebirds (Burger and Gochfeld, 1983b). For East Coast shorebirds, this usually involves moving from sandy beaches and marshes to mudflats, and back again throughout the day. Gulls in New Jersey were found to switch foraging areas from a coastal bay to freshwater impoundments when the Bay was frozen during January and February (Burger, 1983). Numbers of birds at study beaches could have been influenced by this type of circadian foraging cycle although it is not clear from the collected data.

Temperature effects should be included in a discussion of seasonal effects as temperatures change with season and affect both human use of a beach and energy balances in birds. Temperature has a significant effect on the foraging efficiencies of wintering and migrating birds. Decreasing temperatures can directly increase energy demands on birds and indirectly change the activity patterns (and therefore the availability and detectability) of prey species. Invertebrates are less active, are found deeper in the substrate and emerge at the surface less frequently at lower temperatures (Pienkowski, 1983; Burger, 1983; Burger, 1984). Lower substrate temperature was shown to decrease the emergence rate of the amphipod *Corophium* sp., thereby affecting the foraging and intake rate of the redshank (Goss-Custard, 1970). Red Knots on the Wash in England were shown to have less capture success of their bivalve prey at lower temperatures (Goss-Custard, 1984). Pecking rates of redshank decreased at lower temperatures although it was unclear if the prey items were less visible or if they were deeper in the mud and not as available to the birds (Goss-Custard, 1984). In response to low temperatures, birds may switch prey items or change their foraging strategy from visual to tactile methods (Puttick, 1984; Pienkowski, 1982). In New Jersey, higher temperatures caused both gulls and ducks to abandon feeding on the Bay and move to freshwater ponds (Burger, 1983, Burger, 1984). Although temperature effects were not analyzed here, they, in conjunction with human-related disturbances, can add to the energy budget problems of birds.

Wind direction and velocity can directly affect birds by increasing the energy demands placed upon them via the windchill effect (Burger, 1984). In high winds, birds may change their foraging site to a more protected (albeit perhaps less profitable) location or conserve energy by roosting if more energy is expended in foraging. During set-up of the Chick's Beach site with a strong northeast wind blowing, a small flock of inactive Sanderlings were observed in a group on the beach facing into the wind. This was the only time Sanderlings was observed on the beach not engaged in any activity. Indirectly, high winds can affect tide height which can cover exposed mudflats and decrease foraging times for birds (Burger, 1984; Prater, 1981). Cloud cover and precipitation appear to have minimal effects on foraging rates although there is some evidence that precipitation can affect prey availability (Burger, 1984) or detectability due to agitation of the substrate (Goss-Custard, 1984).

It is likely that the patterns of beach use seen at the study sites are due to long-term exposure of the birds to human-related disturbances. Birds seen at these sites (especially shorebirds) are probably stragglers of migratory flocks or birds that have become habituated to the presence of humans. Additionally, the low numbers of birds throughout the course of the study may mask the true distances and effects of disturbances on the birds. As previous studies have suggested, repeated exposure to human-related disturbances often results in either movement of birds away from preferred feeding grounds followed by abandonment of the area, or habituation to the disturbances. The low numbers and patterns of beach use during this study may simply reflect long-term and persistent disturbance of birds at these sites. It is important, however, to note the increased numbers of birds on the military beaches. Management and protection of these areas could provide important habitat for migrant species in the future.

CONCLUSIONS

The data generally supports the hypothesis that birds are affected by the presence of humans at foraging sites and that spatial factors as well as interspecific differences in response to human related disturbance exists. Although large-scale differences in patterns of use at disturbed and undisturbed beaches are apparent, the presence of humans at these sites would most likely have only a superficial effect on the overall survival of the species. This is especially apparent when the numbers at the study beaches are compared to numbers on the Virginia barrier island chain or at other major staging areas. Areas such as the Copper and Berring River deltas in south-central Alaska can often be host to more than 20 million waterfowl and shorebirds during spring migration (Senner, 1979). In addition, the type of disturbance, its duration and scope, and associated environmental factors all have an impact on the local distributions of birds and their interaction with humans at coastal beaches.

Birds at these coastal beaches appear to be disturbed by human presence, but the overall low numbers point to abandonment of these beaches as major foraging sites. Alternatively, due to some unseen environmental, geological or disturbance factor, these beaches may never have been used extensively by migrants or winter residents. For birds that are found here, habituation to human presence appears to occur; the process would seem to happen more readily in gull and tern species than in shorebird species. With the lack of any serious harassment of birds, disturbance distances are reduced and birds continue to be active on beaches with disturbances present. The presence of humans may also be benefitting some species, especially gulls. It may be that the low numbers of birds on these beaches and the disparity of species richness between study sites can be attributed to a historical effect of human use at these beaches. That is, the birds have been so impacted by the presence of humans that only those species that can adapt to or benefit from human presence (Sanderling and Ring-billed Gulls, for example) will remain in any great numbers.

Table 1

2-way ANOVA between season and treatment effects. Season refers to early and late surveys, treatment refers to high and low human use.

Total Birds

Source	SS	df	MS	F-ratio	P
season	108004.167	1	108004.167	9.843	0.002
treatment	194940.375	1	194940.375	17.765	0.000
season x treatment	30104.167	1	30104.167	2.743	NS
error	1009517.917	92	10973.021		

Gulls and Terns

Source	SS	df	MS	F-ratio	P
season	73648.760	1	73648.760	14.613	0.000
treatment	45370.510	1	45370.510	9.002	0.003
season x treatment	10605.010	1	10605.010	2.104	NS
error	463668.208	92	5039.872		

Shorebirds

Source	SS	df	MS	F-ratio	P
season	2204.167	1	2204.167	0.338	NS
treatment	56940.042	1	56940.042	8.743	0.004
season x treatment	6501.042	1	6501.042	0.998	NS
error	599160.083	92	6512.610		

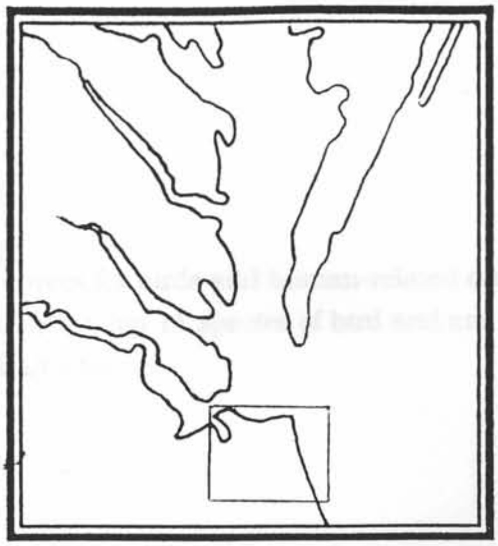
Ring-billed Gull

Source	SS	df	MS	F-ratio	P
season	59750.260	1	59750.260	31.669	0.000
treatment	10024.594	1	10024.594	5.313	0.022
season x treatment	5355.094	1	5355.094	2.838	NS
error	173574.958	92	1886.684		

Disturbance

Source	SS	df	MS	F-ratio	P
season	21122.667	1	21122.667	8.870	0.004
treatment	16120.167	1	16120.167	6.770	0.011
season x treatment	5520.667	1	5520.667	2.318	NS

Figure 1. Map of the lower Chesapeake Bay showing location of study sites.



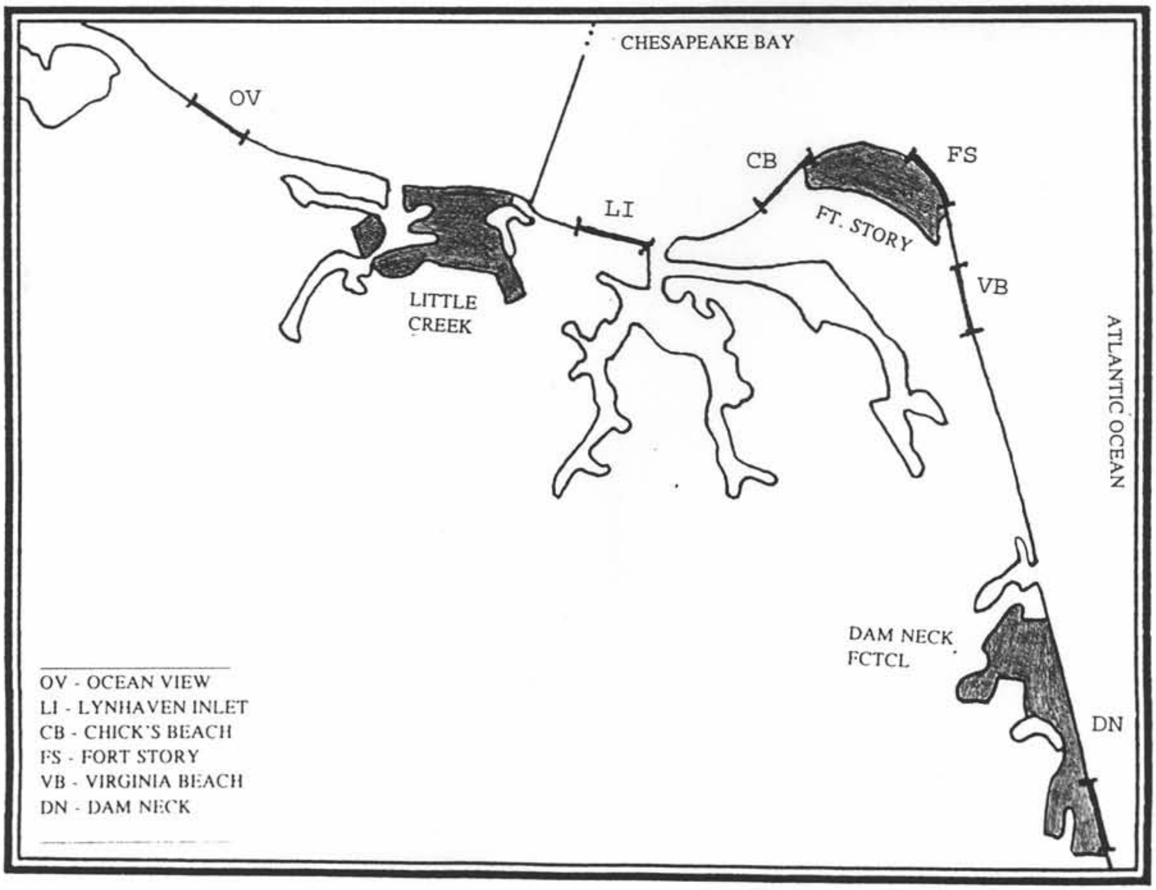
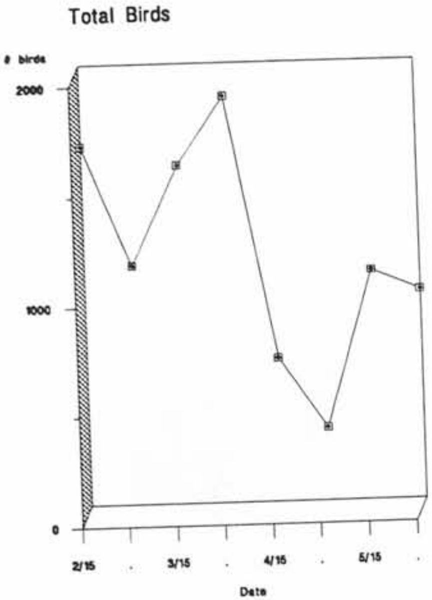
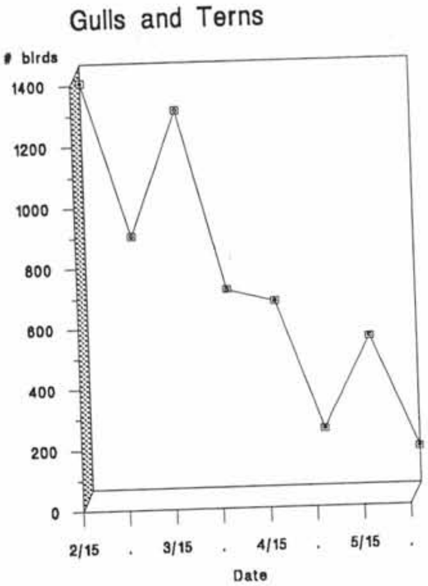
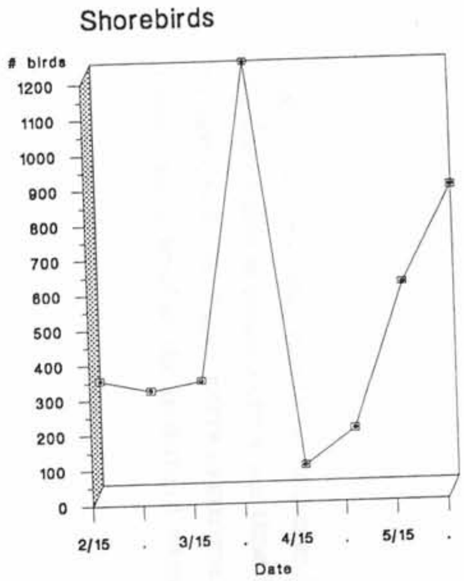
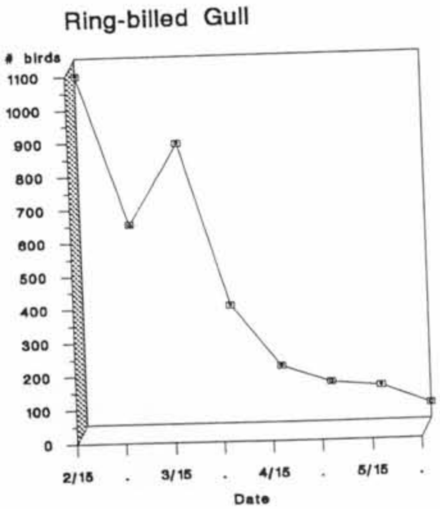

CHESAPEAKE BAY
OV
CB
FS
LI
FT. STORY
VB
LITTLE CREEK
ATLANTIC OCEAN
DAM NECK FCTCL
DN
OV - OCEAN VIEW
LI - LYNHAVEN INLET
CB - CHICK'S BEACH
FS - FORT STORY
VB - VIRGINIA BEACH
DN - DAM NECK

Figure 2. Abundance curves for birds and human-related disturbances by date. The numbers include only the top 11 species of bird and are the totals for two surveys totaled across all sites.


Total Birds
birds
2000
1000
0
2/15
3/15
4/15
5/15
Date


Gulls and Terns
birds
1400
1200
1000
800
600
400
200
0
2/15
3/15
4/15
5/15
Date


Shorebirds
birds
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
2/15
3/15
4/15
5/15
Date


Ring-billed Gull
birds
1100
1000
900
800
700
600
500
400
300
200
100
0
2/15
3/15
4/15
5/15
Date

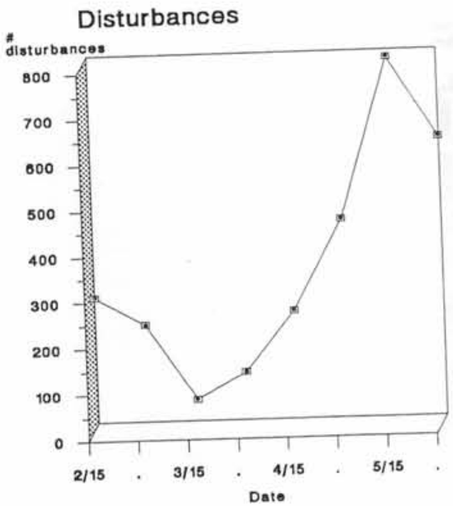

Disturbances
disturbances
800
700
600
500
400
300
200
100
0
2/15
3/15
4/15
5/15
Date

Figure 3. Seasonal effects on bird numbers at study beaches. Values represent the mean and standard error per time block (all sites combined). "Early" refers to surveys 2 - 9. "Late" refers to surveys 10 - 17. "Low" and "high" refer to the disturbance level at the treatment sites.

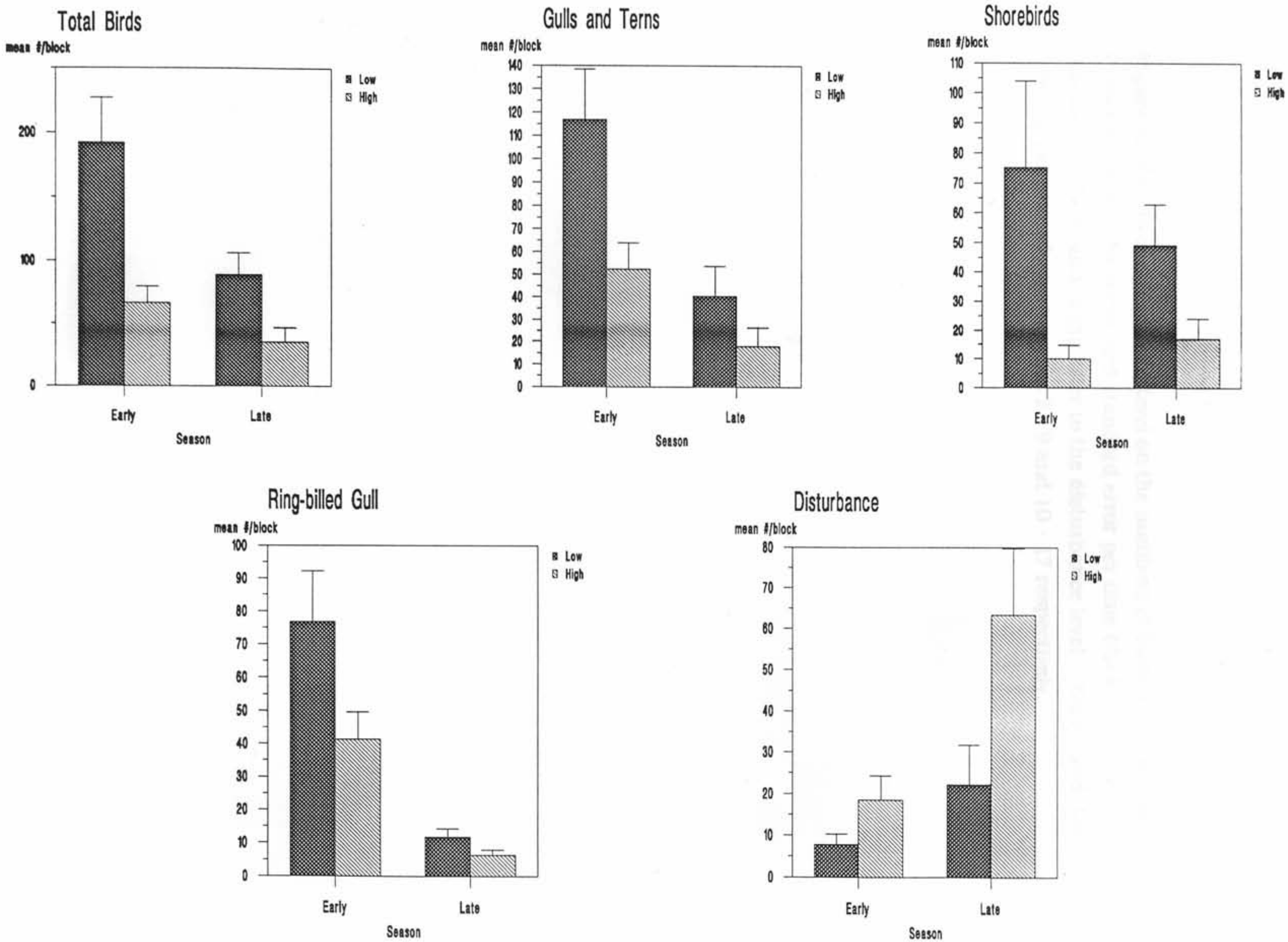
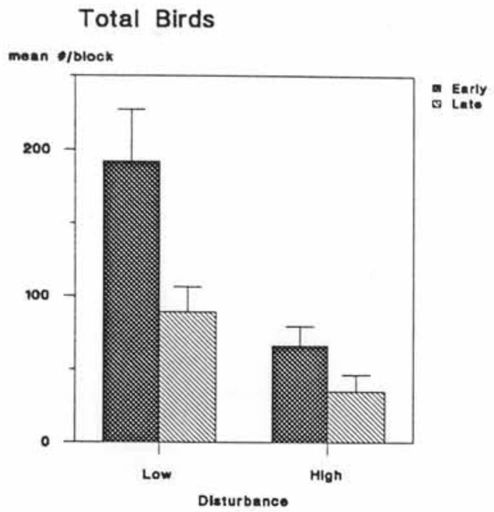
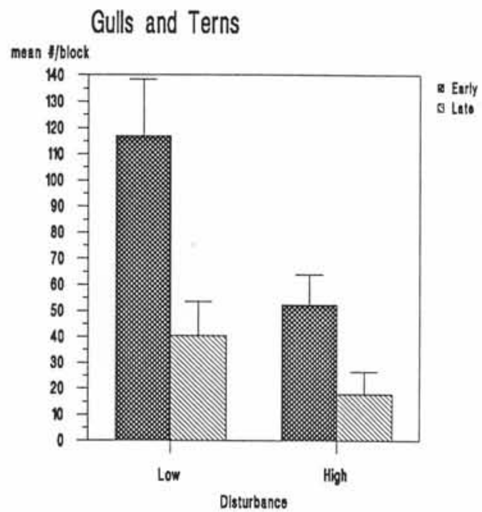
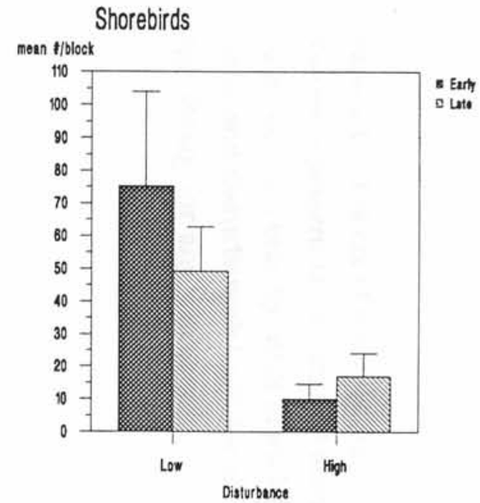
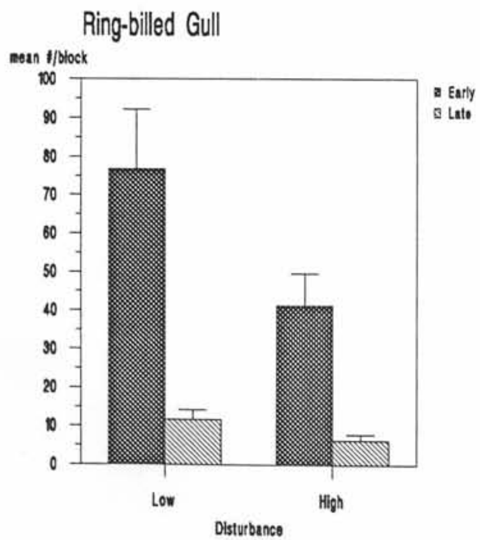

Total Birds
mean #/block
Low
High
Early
Late
Season
Gulls and Terns
mean #/block
Low
High
Early
Late
Season
Shorebirds
mean #/block
Low
High
Early
Late
Season
Ring-billed Gull
mean #/block
Low
High
Early
Late
Season
Disturbance
mean #/block
Low
High
Early
Late
Season

Figure 4. Effects of disturbance level on the numbers of birds at study beaches. Values represent the mean and standard error per time block (all sites combined). "Low" and "high" refer to the disturbance level. "Early" and "Late" refers to the time of year (surveys 2 - 9 and 10 - 17 respectively.


Total Birds
mean #/block
200
100
0
Early
Late
Low
High
Disturbance


Gulls and Terns
mean #/block
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Early
Late
Low
High
Disturbance


Shorebirds
mean #/block
110
100
90
80
70
60
50
40
30
20
10
0
Early
Late
Low
High
Disturbance


Ring-billed Gull
mean #/block
100
90
80
70
60
50
40
30
20
10
0
Early
Late
Low
High
Disturbance

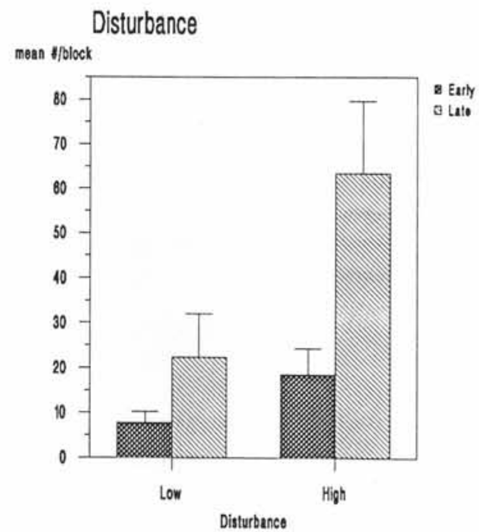
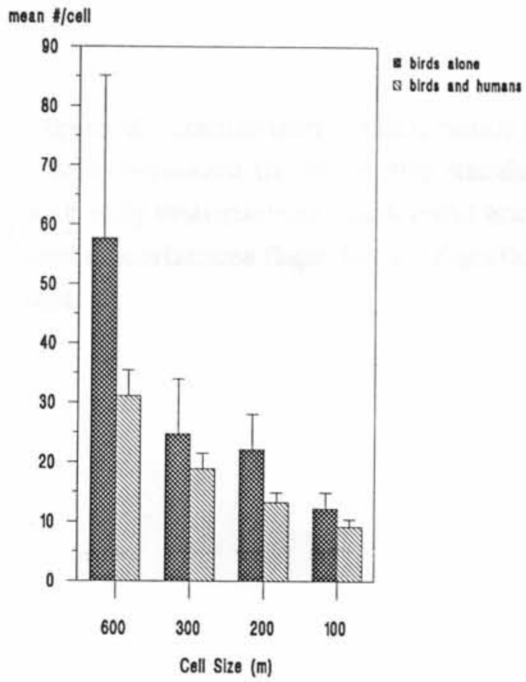
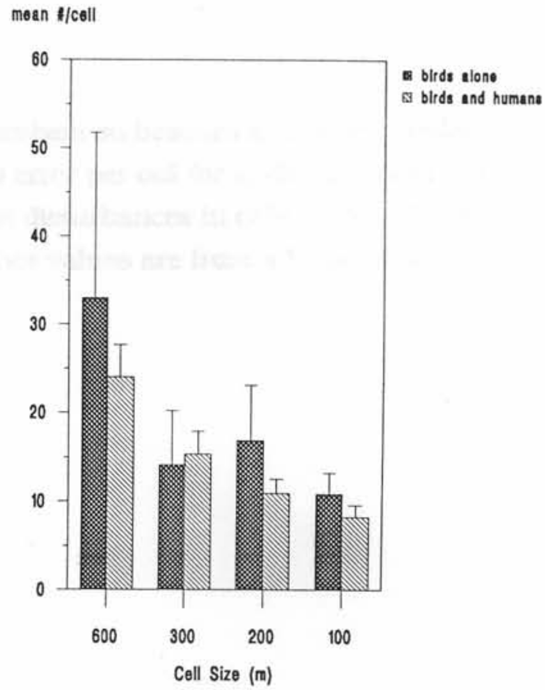

Disturbance
mean #/block
80
70
60
50
40
30
20
10
0
Early
Late
Low
High
Disturbance

Figure 5. Effects of disturbance at different scales on the numbers of birds. Values represent the mean and standard error per cell (segment) for a) birds in cells occupied only by birds (dark bars) and b) birds in cells occupied by both birds and disturbances (light bars). Results of a Kruskal-Wallis test were not significant for any category.

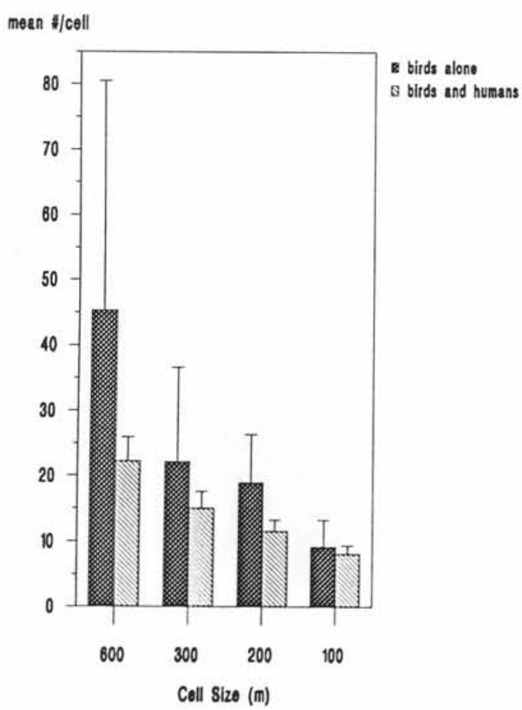
Total Birds



Gulls and Terns



Shorebirds



Ring-billed Gull

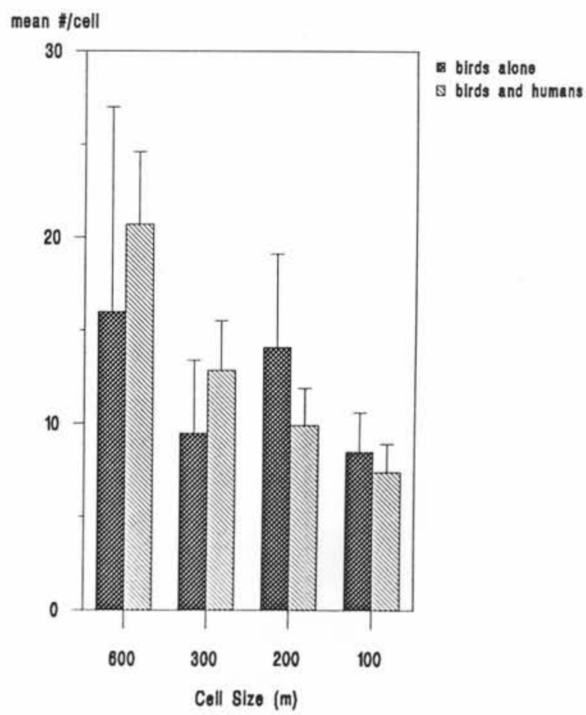
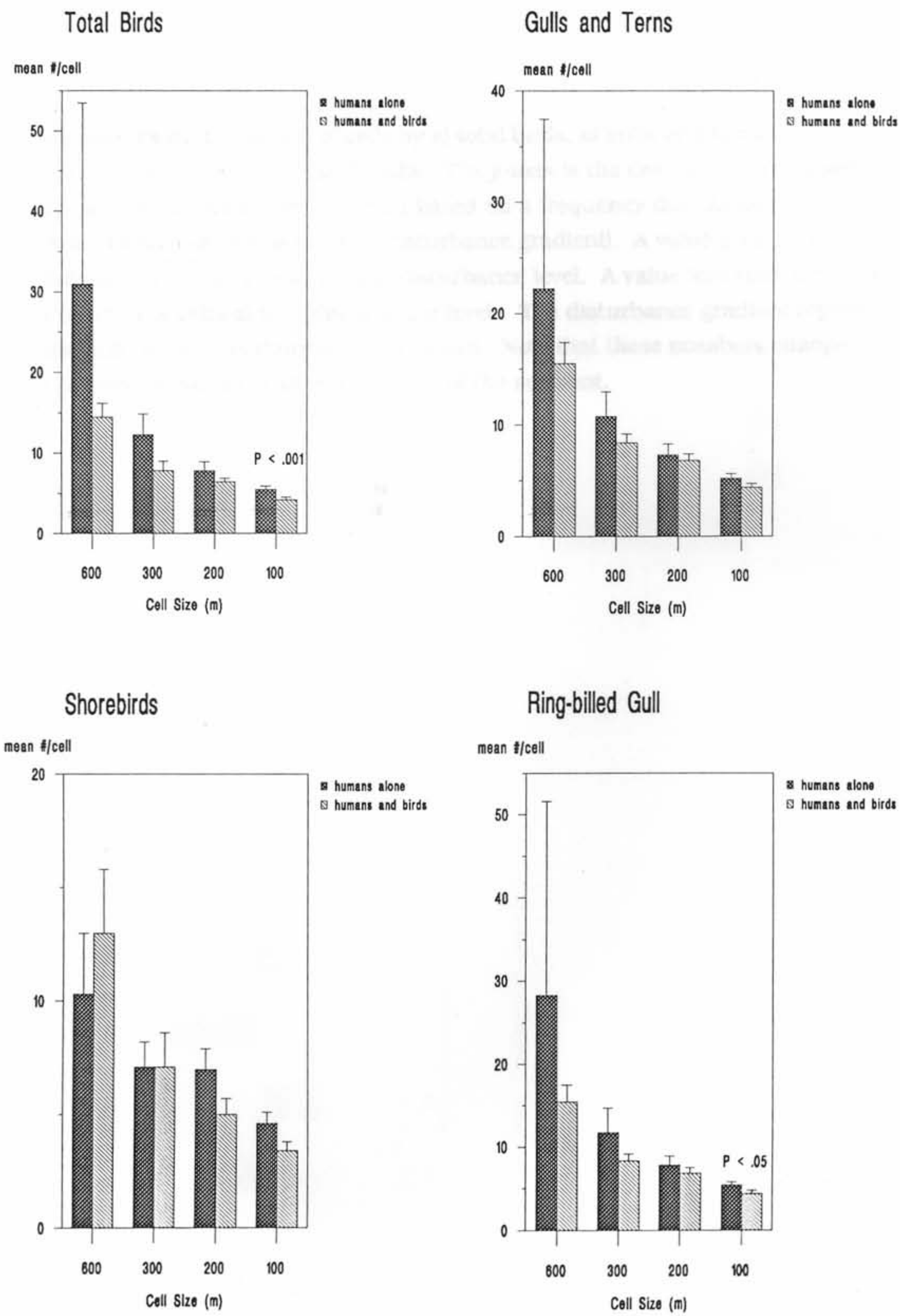
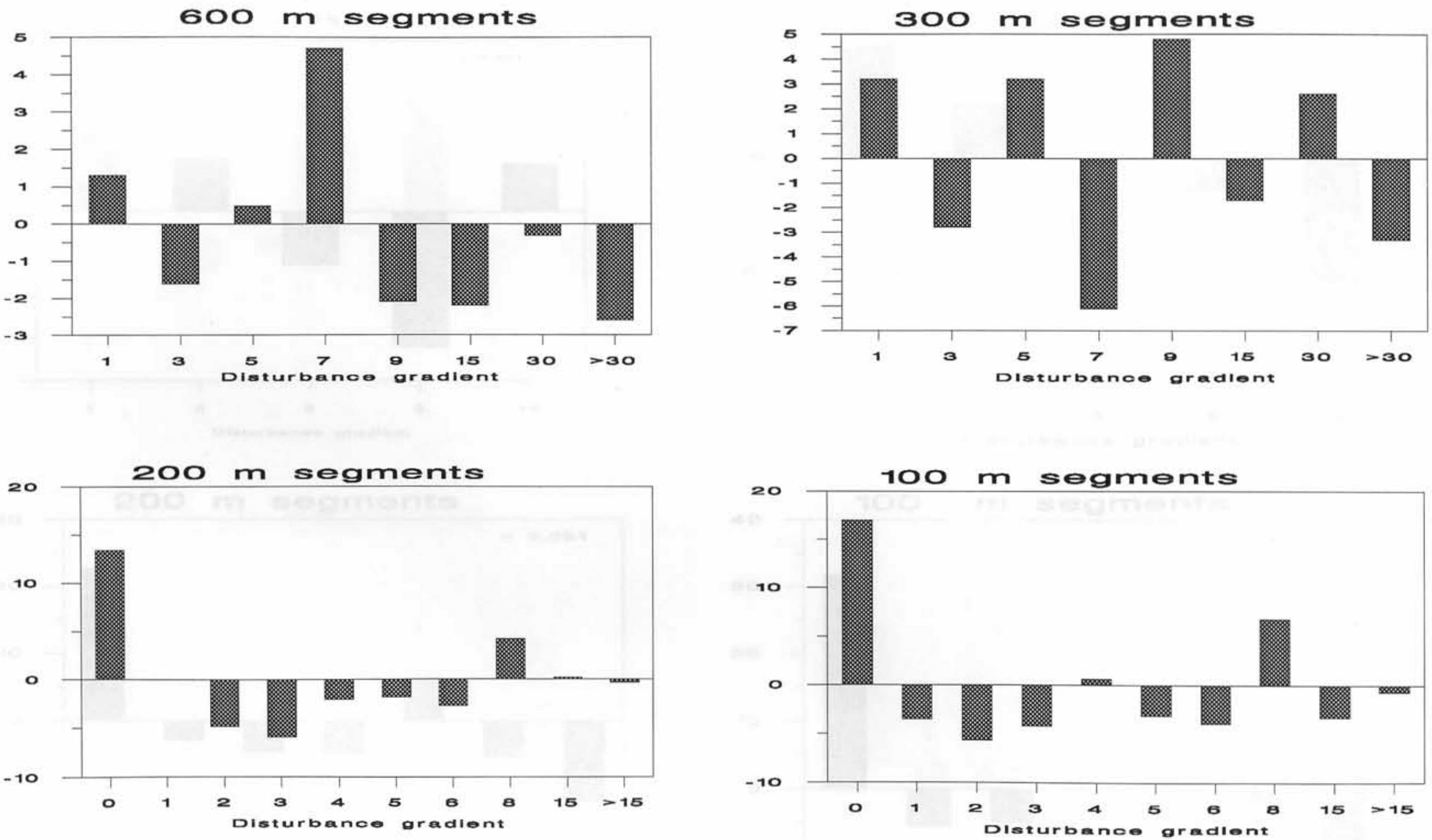


Figure 6. Comparison of disturbance numbers on beaches at different scales. Values represent the mean and standard error per cell for a) disturbances in cells with only disturbances (dark bars) and b) disturbances in cells with both birds and disturbances (light bars). Significance values are from a Kruskal-Wallis test.

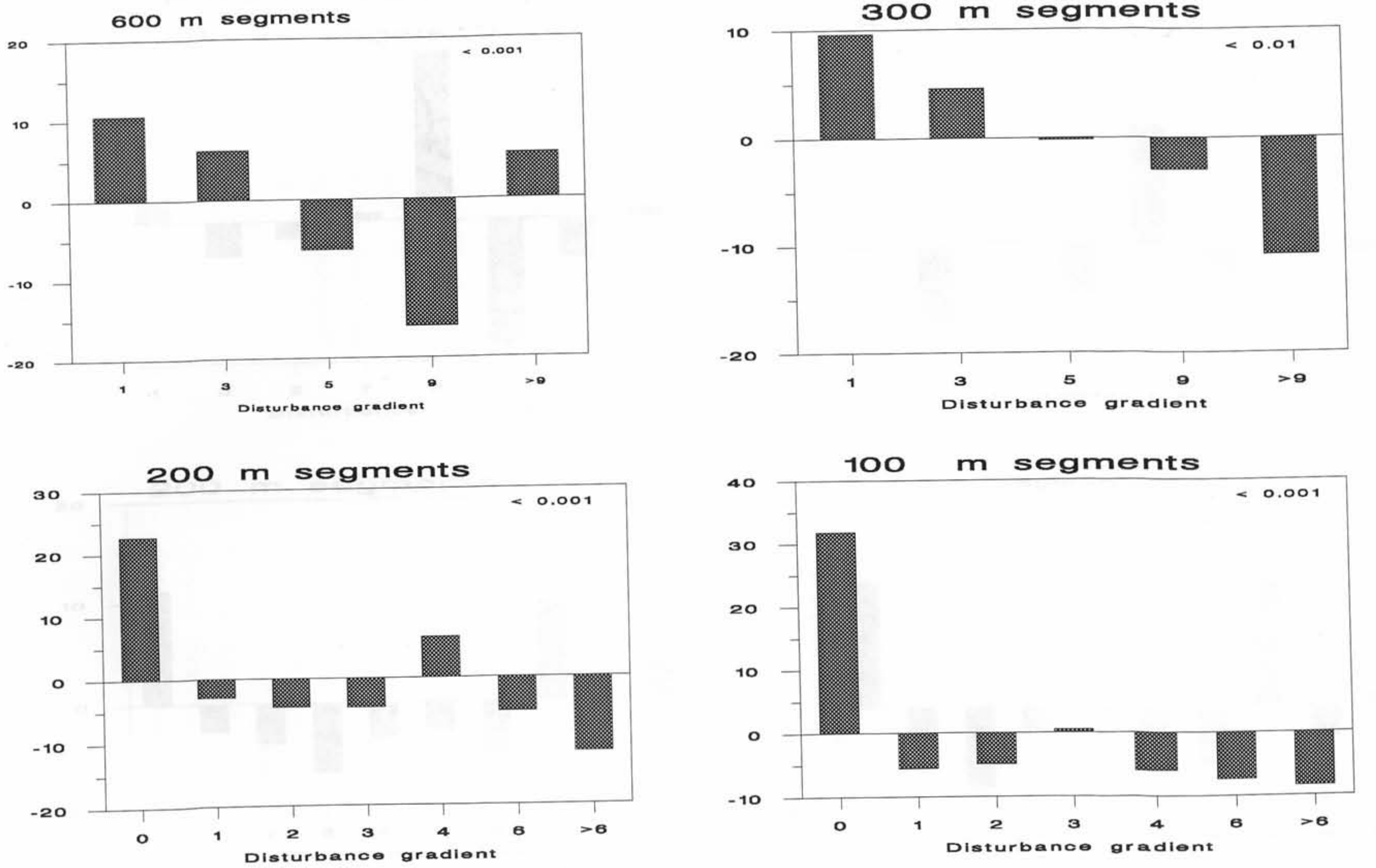

Total Birds
mean #/cell
humans alone
humans and birds
P < .001
Cell Size (m)
Gulls and Terns
mean #/cell
humans alone
humans and birds
Cell Size (m)
Shorebirds
mean #/cell
humans alone
humans and birds
Cell Size (m)
Ring-billed Gull
mean #/cell
humans alone
humans and birds
P < .05
Cell Size (m)

Figures 7a-d. Utilization of cells by **a)** total birds, **b)** gulls and terns, **c)** shorebirds and **d)** Ring-billed Gulls. The y-axis is the deviation of the observed proportion of birds from expected based on a frequency distribution of disturbances on the beach (the Disturbance gradient). A value greater than 0 indicates overuse of cells at that disturbance level. A value less than 0 indicates underuse of cells at that disturbance level. The disturbance gradient represents the number of disturbances in a segment. Note that these numbers change between categories, and with the size of the segment.

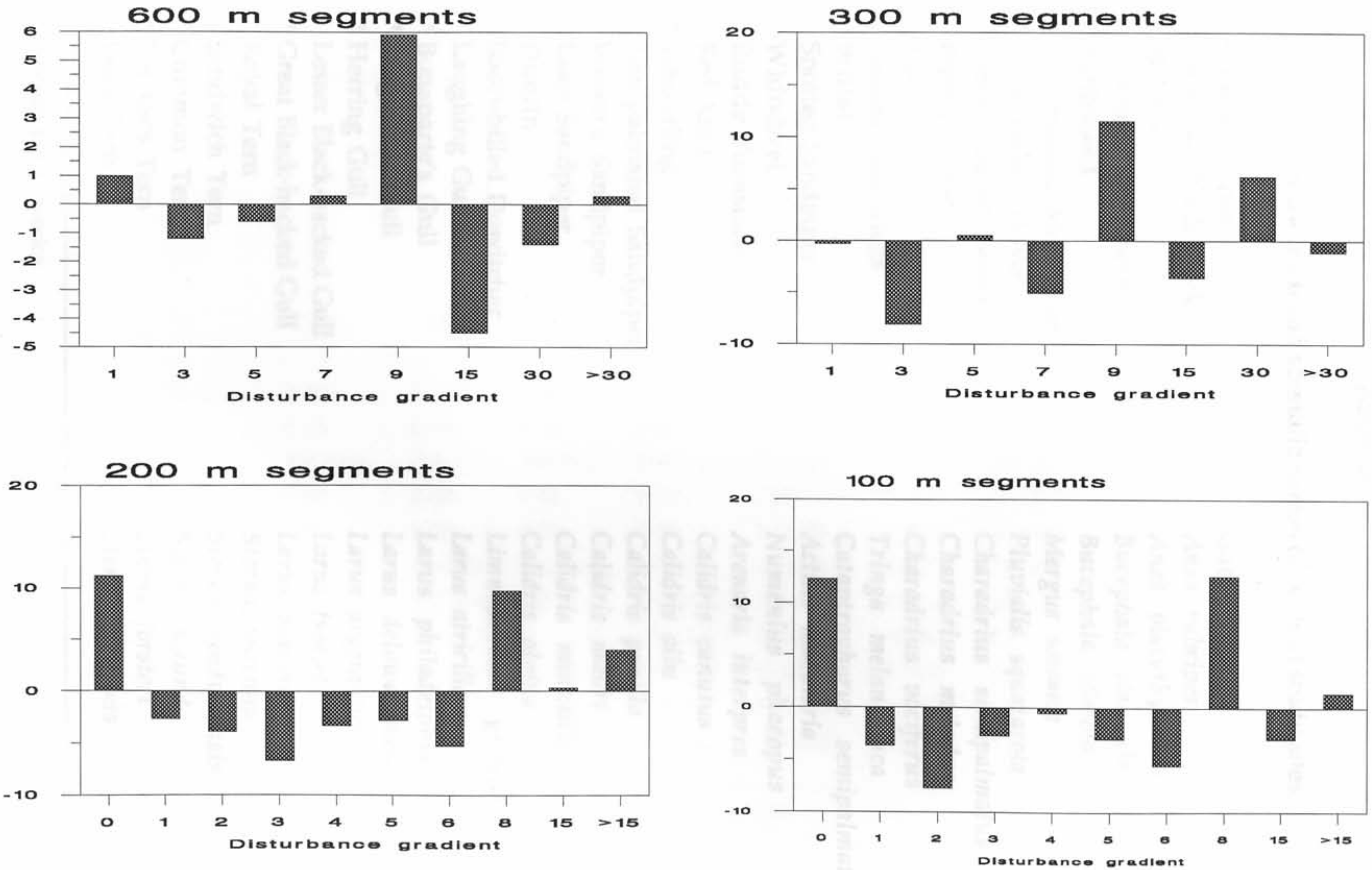
B. GULLS AND TERNS



C. SHOREBIRDS



D. RING-BILLED GULLS



Appendix A

List of common and scientific names of birds at study sites

Common Loon	*Gavia immer*
American Black Duck	*Anas rubripes*
Mallard	*Anas platyrhynchos*
Common Goldeneye	*Bucephala clangula*
Bufflehead	*Bucephala albeola*
Red-breasted Merganser	*Mergus serrator*
* Black-bellied Plover	*Pluvialis squatarola*
Semipalmated Plover	*Charadrius semipalmatus*
Piping Plover	*Charadrius melodus*
Kildeer	*Charadrius vociferus*
Greater Yellowlegs	*Tringa melanoleuca*
Willet	*Cataptrophorus semipalmatus*
Spotted Sandpiper	*Actitis macularia*
Whimbrel	*Numenius phaeopus*
* Ruddy Turnstone	*Arenaria interpres*
Red Knot	*Calidris canutus*
* Sanderling	*Calidris alba*
* Semipalmated Sandpiper	*Calidris pusilla*
Western Sandpiper	*Calidris mauri*
Least Sandpiper	*Calidris minutilla*
Dunlin	*Calidris alpina*
* Short-billed Dowitcher	*Limnodromus griseus*
Laughing Gull	*Larus atricilla*
* Bonaparte's Gull	*Larus philadelphia*
* Ring-billed Gull	*Larus delawarensis*
* Herring Gull	*Larus argentatus*
Lesser Black-backed Gull	*Larus fuscus*
* Great Black-backed Gull	*Larus marinus*
Royal Tern	*Sterna maxima*
Sandwich Tern	*Sterna sandvicensis*
* Common Tern	*Sterna hirundo*
* Forster's Tern	*Sterna forsteri*
Least Tern	*Sterna albifrons*

* indicates top 11 species

Appendix B

Beach use by date for the 11 most common species of bird.
Numbers represent the total of all sites combined for two surveys:
total numbers for all sites (percent of all birds seen).

Species	**Date**								**Total**
	15 Feb	1 Mar	15 Mar	1 Apr	15 Apr	1 May	15 May	1Jun	
Black-bellied Plover	0 (0)	0 (0)	0 (0)	0 (0)	15 (0.2)	23 (0.3)	13 (0.1)	13 (0.1)	**64**
Ruddy Turnstone	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	5 (0.1)	64 (0.7)	63 (0.7)	**131**
Sanderling	294 (3.2)	264 (2.9)	290 (3.2)	1197 (13.2)	26 (0.3)	38 (0.4)	248 (2.7)	543 (6.0)	**2901**
Semipalm. Sandpiper	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	63 (0.7)	199 (2.2)	216 (2.4)	**478**
Short-billed Dowitcher	0 (0)	0 (0)	0 (0)	0 (0)	3 (0.03)	17 (0.2)	38 (0.4)	0 (0)	**58**
Bonaparte's Gull	145 (1.6)	76 (0.8)	146 (1.6)	34 (0.4)	26 (0.3)	10 (0.1)	11 (0.1)	1 (0.01)	**449**
Ring-billed Gull	1046 (11.5)	597 (6.6)	838 (9.2)	350 (3.8)	168 (1.8)	117 (1.3)	104 (1.1)	47 (0.5)	**3267**
Herring Gull	29 (0.3)	109 (1.2)	117 (1.3)	106 (1.2)	22 (0.2)	1 (0.01)	0 (0.0)	0 (0.0)	**384**
Gr. Black-backed Gull	53 (0.6)	18 (0.2)	142 (1.6)	136 (1.5)	55 (0.6)	12 (0.1)	35 (0.4)	6 (0.1)	**457**
Common Tern	2 (0.02)	0 (0.0)	0 (0.0)	0 (0.0)	32 (0.4)	46 (0.5)	177 (1.9)	62 (0.7)	**319**
Forster's Tern	61 (0.7)	33 (0.4)	0 (0.0)	25 (0.3)	307 (3.4)	0 (0.0)	160 (1.8)	4 (0.04)	**590**
Total	**1631**	**1088**	**1542**	**1848**	**654**	**332**	**1048**	**955**	**9098**

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