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EFFECTS OF MOTORBOATS AND PERSONAL WATERCRAFT ON FLIGHT BEHAVIOR OVER A COLONY OF COMMON TERNS

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Abstract. I examined the flight behavior of Common Terns (*Sterna hirundo*) over a nesting colony in Barnegat Bay, New Jersey in 1997. I used the number of birds flying over the colony to test the hypothesis that there were no differences in flight behavior as a function of presence and type of craft (motor boat, personal watercraft). For the overall model, 66% of the variation in the number of terns flying over the colony was explained by breeding period, type of craft, speed, route (established channel or elsewhere), the interaction of route and speed, and time of day. However, for the early stage of the reproductive cycle, type of craft, speed, and route explained 95% of the variation. Boats that raced elicited the strongest response, as did boats that were outside of the established channel. Boats traveling closer to the nesting colonies elicited stronger responses than those that remained in the channel. Personal watercrafts elicited stronger responses than motor boats. These data suggest that personal watercraft should be managed to reduce disturbance to colonial-nesting species, by eliminating them within 100 m of nesting colonies and restricting speed near such colonies.

Key words: boats, Common Terns, disturbance, personal watercraft, Sterna hirundo.

INTRODUCTION

With increasing development of our coastal regions for residential, industrial, and recreational uses, estuarine birds are exposed to increasing levels of human disturbance. Both the qualitative and quantitative effects of human disturbance have been studied extensively in birds that breed in colonies (Kury and Gochfeld 1975, Erwin 1989). Human disturbance can increase egg and chick mortality, cause premature fledging, and result in reduced body mass or slower growth of nestlings (Veen 1977, Schreiber 1979, Parsons and Burger 1982).

Colonially-nesting species often reduce their interactions with humans and other predators by nesting on remote islands (Burger and Gochfeld 1991). However, even while nesting on coastal islands, birds can be disturbed by people passing in boats or by people who actually land on the islands. Several investigators have examined the effects of passing or approaching canoes, sailboats, or motor boats on foraging (Kaiser and Fritzell 1984, Bamford et al. 1990) and breeding birds (Bratten 1990, Mikola et al. 1994, Rodgers and Smith 1995). In general, mobile birds move away from areas of high boating activity, whereas nesting birds show behavioral, growth, or reproductive effects, with varying degrees of habituation.

Recently, however, there has been a great increase in the number and use of personal watercraft (PWC) such as jet skis and wave runners. These boats can travel as fast as conventional motor boats in extremely shallow waters, and can go many places that motor boats cannot. In this paper I examine the effect of motor boats and personal watercraft on the flight behavior of Common Terns *Sterna hirundo* nesting on an island in Barnegat Bay, New Jersey. In 1996, while making regular colony checks of 15 Common Tern colonies in the bay, I noticed that those with frequent intrusions by personal watercraft suffered lower reproductive success (even complete colony failures) than did those with no personal watercraft activity nearby. However, such effects can be due to many different causes (inclement weather, storms, high tides, predators, Burger and Gochfeld 1991). The present observations were undertaken to observe behavioral responses to the boats themselves.

The conflicts between different types of outdoor recreation are just beginning to be examined in detail (Schneider and Hammitt 1995). There are many conflicts over the use of personal watercraft (PWC) among residents and a variety of recreational users, including other boat-

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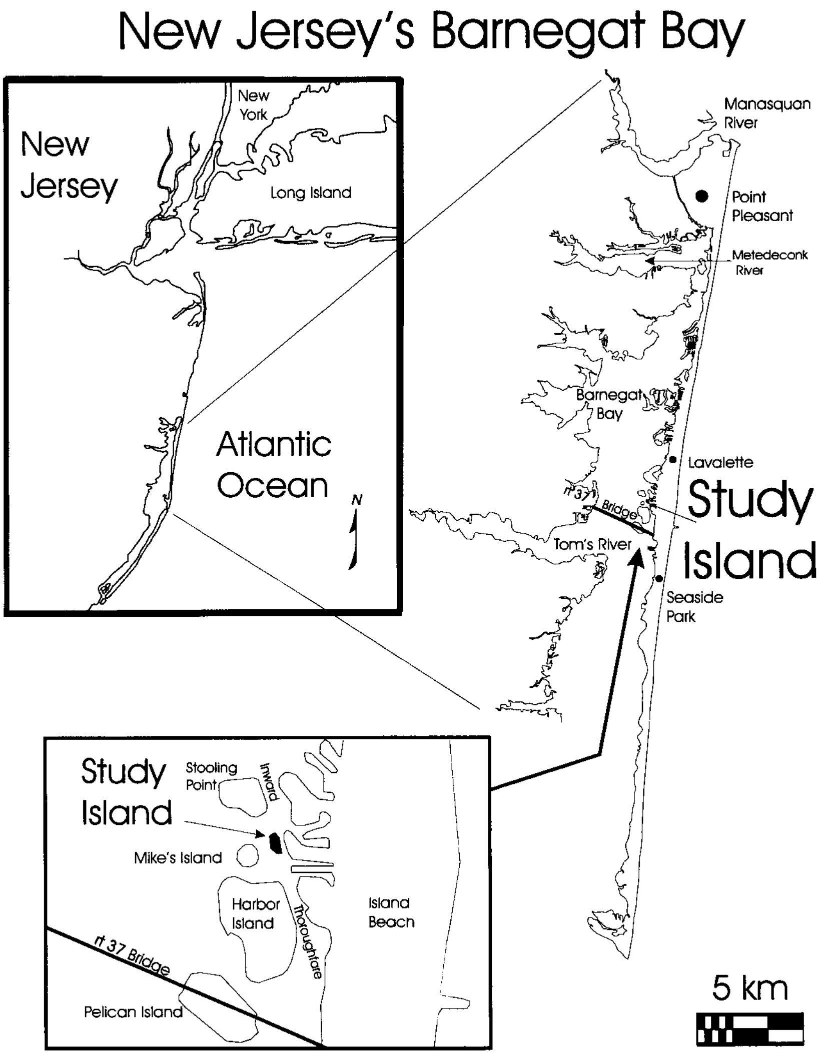

FIGURE 1. Map showing the study site on Mike's Island in Barnegat Bay.

ers, swimmers, and clammers. Not only are PWCs responsible for a large number of boating accidents (Shattuck 1997), but the noise and other disturbances have caused them to be banned (National Parks 1996) or severely restricted (National Parks 1997, Whiteman 1997) in a number of places. It is clear that there must be environmental planning to avoid user conflicts in general, as well as to deal with PWC issues (Inskeep 1987, Butler 1991, Whiteman 1997). However, such debate requires data on specific effects that can be attributed to PWCs. The present research was designed to examine the flight behavior of Common Terns in response to different types of boats. Recreation and nesting birds can surely coexist, but careful management is required to do so (Burger et al. 1995).

METHODS

Observations were made from mid-June until 2 August 1997 on Common Terns nesting on Little Mike's Island in northern Barnegat Bay, New Jersey (Fig. 1). This small, low, salt marsh island (*Spartina alterniflora,* with about 10% *S. patens*) is 45 m from the nearby barrier island, and 60 m from Mike's Island. There is a designated boat channel between Little Mike's Island and the barrier island, which is regularly used by motor boats. However, the channel is posted for "no wake." While motor boats and larger craft regularly move through the channel, PWCs can go completely around the nesting island, close inshore.

Since the early 1990s, Little Mike's Island has contained one of the largest nesting colonies of Common Terns in the bay (250–500 pairs), and prior to 1996, this colony was highly successful (birds fledged over 1 young/nest, Burger 1997). In 1996 there was an upsurge in the number of PWCs around the island, probably due to new rental concessions, and I observed that the birds were often flying overhead, rather than incubating. In some cases, the PWCs actually skimmed over the edge of the island, running over some nests with eggs or chicks.

In 1997 the following observations were made to determine whether the response of the terns varied with the different types of boats. I recorded the flight behavior of Common Terns as a function of whether there were craft present, and the type of craft present. Three classes of boats were distinguished: motor boats, personal watercraft where the driver stands up, and personal watercraft where the driver (and riders) sits down. In the early development of PWCs, the former type was more common, but at present, PWCs where the driver sits down predominate (they are larger and more stable). Observations were made every 10 min, and whenever a boat was present, for up to 8 hr a day. Data recorded included date, time of day, type of observation (no craft, motor boat, stand-up PWC, sit-down PWC), location (channel side or outside of island), distance from island (near third, middle third, and far third of the waterway), speed (slow with no wake, fast, or racing with a large wake), number of birds flying over the colony per min, and the number of birds flying over the colony in the second min and in the third min. It became clear that it was difficult to distinguish behavior when many boats came by at once. That is, at time 10:10, there might be no boat present, but if one had gone by 3 min earlier the birds might still be reacting to that event. Therefore, in the analysis I eliminated from the "no craft" category any observation when a boat had passed within the preceding 5 min. Although this was arbitrary, usually the birds had settled down within this period if there was no other disturbance.

One other confound was present: high storm tides and heavy rains in early July. At the start of the breeding season there were 490 pairs of Common Terns nesting on the island (early incubation), after the storm tides this dropped to about 150 pairs (early chick phase). During the late chick phase the number breeding dropped to about 123. The mean number of birds flying over the colony when there were no disturbances dropped as well. Thus, for the analyses I present models and some of the data by early, mid and late nesting. It is because of these natural effects on the breeding population that I felt it was important to use immediate behavior as a measure of disturbance due to boats.

These observations normally required two observers: one to take information on the craft type (speed, location) and one to observe the birds. Observations were made with binoculars, either from a dock on the barrier island or from the side of a nearby salt marsh island. The birds were not affected by our presence. The data on flight behavior in the second and third minute after passing of a boat did not differ in pattern from the first minute after a boat passed (correlations of over 0.90), and thus I present only data from the first minute.

The sampling unit for analysis was the response of the terns during the 1 min following the passing of a craft, or the 1 min following the "no craft" sample (every 10 min if no craft was present). Sample sizes for the various variables were: period (early = 170, middle = 441, late = 477), route (no craft = 269, boat channel = 486, other side of island = 333), speed (no craft = 269, slow = 293, fast = 240, racing = 286), craft type (no craft = 269, stand-up PWC = 43, motor boat = 295, sit-down PWC = 481).

I used multiple regression procedures to determine if period, craft type (including no craft), speed, or route accounted for differences in the number of birds flying over the island. The procedure determined the R^2 for the initial variable, and then determined the additional R^2 contributed by the next variable (SAS 1986, 1988). I used Wilcoxon χ^2 tests to examine differences between groups, ANOVA to determine whether there were differences among variables as a function of the dependent variables, and Duncan Multiple Range Test to determine differences between them (SAS 1988).

RESULTS

PATTERNS OF BOATS

The number of boats moving around Little Mike's Island was not constant throughout the

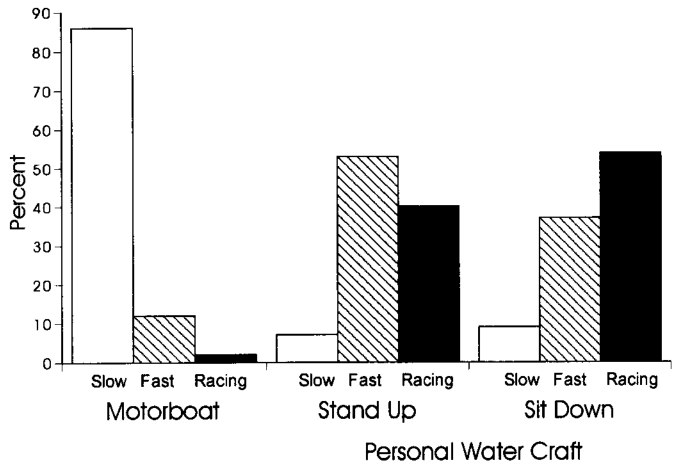

FIGURE 2. Speed of different types of crafts. Shown are percent of total number of crafts of each type.

day. Both motor boats and PWCs were more common in the middle of the day, and again toward evening (40% of boats were present from 11:30–13:30 and another 22% were present from 17:30–18:30). Thus, birds were potentially most disturbed during these time periods. PWCs came in bouts, both temporally and spatially. That is, two or three often came by the tern nesting island together, and when one PWC went by, there was more likely to be another one within the next 5 min than when none went by during the sample period (χ^2_1 = 4.3, $P < 0.04$). This was not true for motor boats (χ^2_1 = 1.0, P = 0.3).

The speed of boats was not independent of the type of boat (Fig. 2): motor boats normally followed maritime law and passed slowly through the appropriate channel (although some left a wake). PWCs did not seem constrained by maritime law, and were generally ignored by the marine police. However, only the PWCs raced, and sit-down PWCs went especially fast (Fig. 2).

COMMON TERN BEHAVIOR

The best overall model explained 66% of the variation in number of birds flying over the colony as a function of breeding period, craft type, speed, route, the interaction of route and speed, and time of day (Table 1). Similar factors accounted for the variation in the early compared to the middle-late phases of the breeding cycle (Table 1).

TABLE 1. Factors entering the best regression models explaining variation in the number of birds flying over a Common Tern nesting colony in a 1-min period. F is the statistic for the model, df is the degrees of freedom, and P is the probability level (* = <0.01, ** = <0.001, *** = <0.0001, ns = not significant).

	Overall model	Early stage	Middle/late stages
Model			
F	83.5	173.2	6.7
df	26, 1,086	16, 168	25, 919
R^2	0.67	0.95	0.16
P	0.0001	0.0001	0.0001
Factors entering (F, P)			
Period	145***	—	112***
Craft Type	45***	9**	2.7*
Speed	44***	16***	ns
Route	62***	7*	ns
Craft Type × Route	ns	ns	ns
Craft Type × Speed	ns	ns	ns
Route × Speed	80***	5*	ns
Time of Day	5.0***	ns	4.7***

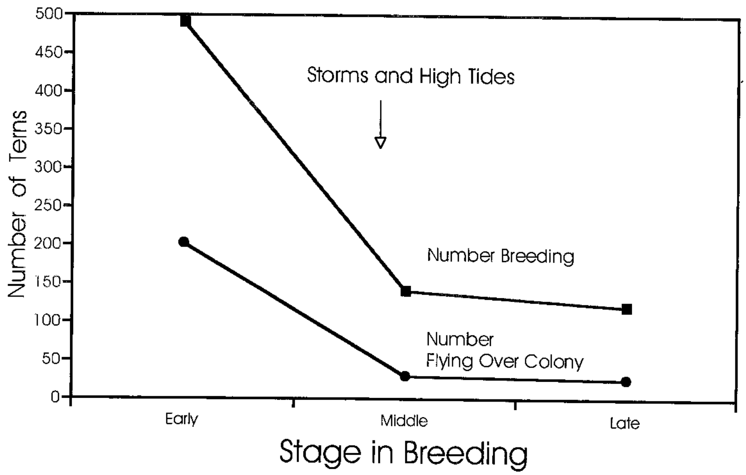

FIGURE 3. Number of birds breeding, and number of birds flying over when PWCs passed, by season.

The number of birds flying over the colony varied significantly by breeding period (χ^2_3 = 145, $P < 0.001$, Fig. 3), distance from the colony ($\chi^2_3 = 100$, $P < 0.001$), location relative to the colony ($\chi^2_2 = 92$, $P < 0.001$), speed (χ^2_2 = 128, $P < 0.001$), and craft type ($\chi^2_3 = 160$, $P < 0.001$, all shown in Fig. 4). Results were similar for the second and third minute after a boat passed (all $\chi^2_2 > 79$, $P < 0.001$): that is, Common Terns did not immediately settle down after a boat passed.

Duncan Multiple Range tests for the number of birds flying over the colony for the entire data set showed that: (1) all three breeding periods differed significantly from one another, (2) PWCs and motor boat/no craft differed significantly from one another, (3) all three speeds differed significantly from one another, and (4) the routes taken differed significantly from one another.

Time of day was a significant variable in the overall model, and the model for the middle-late periods (it was not for the early period because observations during this period only were taken in the morning). More birds flew over the colony at mid-day and in the late afternoon, largely because there were more boats during these time periods, and birds were kept in the air.

DISCUSSION

Colonially nesting birds are particularly vulnerable to human disturbances because of high nest density; when one bird is disturbed enough to respond, others often follow (Rodgers and Smith 1995). This also is true for Common Terns (Burger and Gochfeld 1991). Experimental studies on the effects of human disturbance have usually involved tests where the investigator disturbed the colony using some prescribed protocol (Anderson and Keith 1980, Safina and Burger 1983, Rodgers and Smith 1995). The responses examined are usually distance to flush or some other behavior that varies as a function of disturbance. This type of research makes two assumptions: (1) behavior in response to the investigator is similar to other human disturbances, and (2) these changes in behavior have significant biological effects, such as lowering reproductive success. The first assumption is problematic because terns can learn to recognize individual investigators and respond differentially to them (Burger et al. 1993). The second assumption is more difficult because a number of factors affect breeding success in any given colonial waterbird colony, including inclement weather, food supply, and predators (Wittenberger and Hunt 1985, Burger and Gochfeld 1991, Brown and Brown 1996).

Rather than disturb the colony with a protocol that involved using different types of boats to disturb the birds, I relied on the behavior of people engaged in operating motor boats and PWCs. Thus, the responses of the Common Terns were not subject to habituation to any particular human or any particular craft. This has the advantage of providing data on their responses to real conditions. However, using this opportunistic methodology has the disadvantage of not being

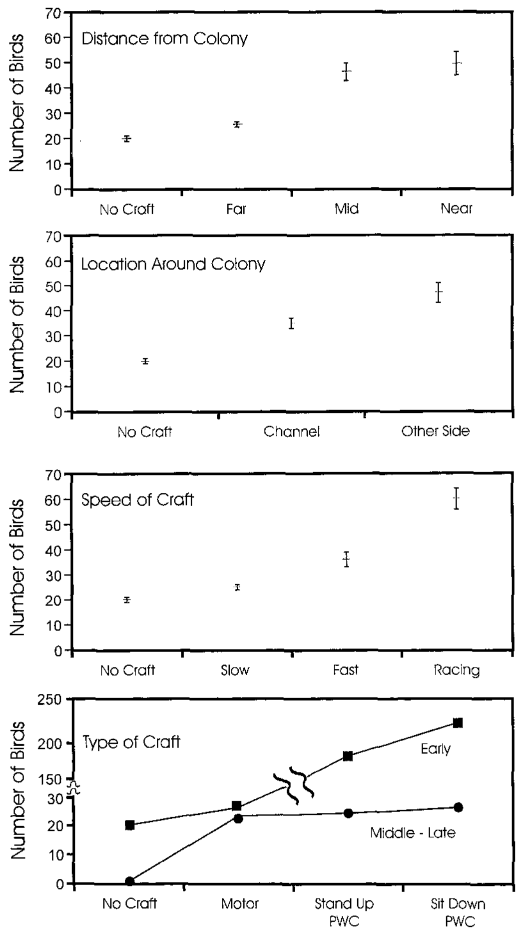

FIGURE 4. Number of Common Terns flying over Little Mike's Island (overall) as a function of distance from colony, location around colony, speed of craft, and type of craft.

able to determine the sample size within each category of craft type, speed, or location; but remarkably, over the course of these observations, sample sizes were similar for the different categories. Exceptions were period (there were fewer observations in the early period due to the timing of flood tides that ended that period for the purposes of this study) and craft type (there were fewer stand-up PWCs than sit-down PWCs). This latter fact suggested the possibility of combining all PWC into one category, and such an analysis did not change the results of any statistical analyses.

The second assumption, that the behavior measured in a human disturbance study has some relationship to reproductive success, bears examination. However, with colonial birds, several authors have noted that frequent disturbances requiring upflights from colonies eventually cause either reproductive losses or colony desertions (Southern and Southern 1979, Brown and Brown 1996). Further, the present research was stimulated by my observation that the Common Tern colonies that had the lowest reproductive success in 1996 were those that were exposed to PWCs, that PWCs sometimes ran up on the edge of nesting islands and over nests, and that in most colonies the entire breeding population flew up when a PWC came near the island.

Overall, these observations clearly indicate that the birds responded negatively to the presence of boats, and that they responded significantly more to PWCs than to motor boats. The factors that affected their flight behavior were the distance from the colony, whether the boat was in an established channel, and the speed of the craft. To some extent their response to the speed of the craft may relate to a noise factor (which I did not measure): craft of any type that raced made more noise than ones that moved slowly, and PWCs made more noise than motor boats in any speed category. This was true even when comparing motor boats to PWCs that were both traveling slow or fast. The noise factor is one that humans are particularly sensitive to, and is one of the factors most responsible for PWCs being banned in some National Parks (National Parks 1997). These data suggest that speed regulations for PWCs could serve as a surrogate for noise, and would decrease the disturbance to the birds markedly.

Finally, the data can be used to help design regulations and laws that could reduce the impact of PWCs on nesting colonial birds. From past studies on human disturbance, most species of colonial birds respond similarly, only the degree of response may vary. The terns clearly responded most strongly early in the season, to racing boats, and to those that came the closest to the island. However, it is likely that the damage was already done early in the season, but even without such early disturbance, PWC movement later in the season would be just as devastating.

These data suggest that enforcing regulations to keep PWCs at a specified distance from nesting islands, and to slow down when passing these islands, would reduce the adverse affects to nesting terns. From watching the behavior of the terns, I suggest that PWCs should not be allowed closer than 100 m from nesting islands. This is critical, particularly early in the season when pairs are setting up territories and courting, and when they have very young chicks that are vulnerable to cold stress. Moreover, speed restrictions would reduce the noise level so that it does not disturb nesting birds. Regulations must be strictly enforced throughout the nesting season.

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