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EFFECTS OF HUMAN DISTURBANCE ON REPRODUCTIVE SUCCESS IN THE BLACK SKIMMER

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ABSTRACT.—We subjected Black Skimmers (*Rynchops niger*), nesting in six subcolonies within a tern colony, to either daily or weekly nest checks in order to study the effects of human activity on reproduction. Many prelaying adults left subcolonies that were disturbed daily and settled in relatively undisturbed subcolonies; some pairs in these areas deserted nests early in incubation. Nest density, late nesting, hatching success, and fledging success were inversely correlated with disturbance. In consequence of disturbance, a few chicks ate younger conspecifics. Low fences placed around groups of nests depressed fledging in areas disturbed weekly, but enhanced it in subcolonies disturbed daily.

The activities of researchers themselves at waterbird colonies may reduce the birds' reproductive success. Disturbance by biologists has been deemed a major threat to seabirds because their activities have caused desertion and mortality of eggs and young (Nisbet 1978, Schreiber 1979). Determining the effect of observers is important, because the validity of conclusions drawn from scientific investigation is diminished when an observer unintentionally and unknowingly influences the results. Knowledge of the phenomenon can also help to minimize adverse effects on the birds.

Natural losses of eggs and chicks cannot be wholly separated from artificial ones because the presence of observers may increase losses. However, the stage at which losses are most likely to occur can be determined (Ollason and Dunnet 1980), and this information can be used to minimize disturbance. Furthermore, the reproductive success of seldom disturbed birds can be compared to that of birds that have been disturbed more often. We designed a study to examine the effect of our field activities on all phases of the breeding season of Black Skimmers (*Rynchops niger*). We subjected subcolonies of skimmers to different disturbance schedules in order to determine when the birds were most affected by human disturbance.

We chose Black Skimmers for this study because they usually nest in clusters or subcolonies on sandy patches within tern colonies (Gochfeld 1978, Erwin 1979), allowing for different treatments of various nesting groups within the same colony. We wanted to quantify the effects of human disturbance, identify stages of the breeding season when skimmers are most sensitive to disturbance, and test the feasibility of enclosing groups of nests in fences to reduce chick mortality.

STUDY AREAS AND METHODS

We studied Black Skimmers at Cedar Beach on the Jones Beach (Long Island, New York; 40°N, 73°W) barrier island from early May to early August 1980. The colony contained 2,500 pairs of Common Terns (*Sterna hirundo*), 200 pairs of skimmers, and 80 pairs of Roseate Terns (*S. dougallii*). Several pairs of Willets (*Catoptrophorus semipalmatus*), Killdeer (*Charadrius vociferus*), and Piping Plover (*Charadrius melodus*) also nested in the colony. Most of the birds nested between the primary and secondary sand dunes, where the predominant vegetation was beach grass (*Ammophila breviligulata*) and seaside goldenrod (*Solidago sempervirens*). Several pairs of skimmers and Common Terns, however, nested on the ocean beach near the primary dunes where the predominant vegetation was sea rocket (*Cakile edentula*). Within the colony, we selected six subcolonies of skimmers for study, choosing areas that were roughly equivalent in size, substrate, and vegetative cover. To compare the effects of different amounts of disturbance on the birds' reproductive success, we monitored these subcolonies on one of three schedules. Nest checks were made either: (1) daily beginning 22 May, soon after the onset of laying; (2) weekly until hatching and daily thereafter (also referred to as "weekly/daily"); or (3) weekly throughout the study.

In order to check the nests in a subcolony, one or two persons walked through it marking new nests (with numbered tongue depressors), recording numbers of eggs and chicks, and color-banding all new chicks with colors coded to the above disturbance schedules. Color-banding allowed us to compare the relative fledging success of various subcolonies when flying young later gathered in groups on the beach. Time spent within each subcolony depended on the number of nests to mark or chicks to color-band, but seldom exceeded 1/2 h. Distances between nests (from center of nest) were measured after all young had fledged. The date of laying of the first egg of clutches in areas that were disturbed weekly during incubation was obtained by extrapolation from the hatching date, based on a 22-day incubation period (M. Gochfeld, pers. comm.).

One adverse effect of disturbance is that chicks tend to run from the nest and have difficulty finding their way back. To test the hypothesis that human disturbance substantially increases the mortality of chicks that run from the nest and become lost, we enclosed about one-third of the nests in each subcolony by 0.3-m high, 2.5-cm hexagonal mesh wire fences so as to prevent chicks from traveling far from the nesting territory. Each fence enclosed an average of 10 nests (range = 1–17). All fenced areas contained 5–15% vegetative cover, which was used by chicks for hiding and shade.

After fledging, chicks often gathered on the outer sand beach. To assess fledging success, we counted the number of color-banded young from each subcolony in these gatherings each day using a telescope. We then determined the ratio of banded chicks hatched to banded chicks fledged in each treatment group, using the formula:

$$\frac{\text{No. chicks banded in a treatment group} \times (\text{No. banded fledglings of all treatments sighted})}{(\text{Total no. chicks banded in all treatments}).}$$

This gave the expected fledging success if there were no mortality; we compared these values among treatment groups (i.e., fenced vs. unfenced nests; disturbed daily vs. disturbed weekly) using χ^2 analyses.

RESULTS

Throughout the nesting season, when humans entered the subcolonies, adult skimmers usually took flight as a group, circled the subcolony area and the intruder for several minutes, and then left briefly (usually going to the beach). Individual skimmers sometimes flew toward the observer, as if to attack, but always veered away before getting closer than about 3 m. During the late incubation and early hatching periods, nesting birds did not flush as readily as they had earlier; they returned to the colony sooner, and occasionally performed distraction displays, presumably to lure observers from their nests.

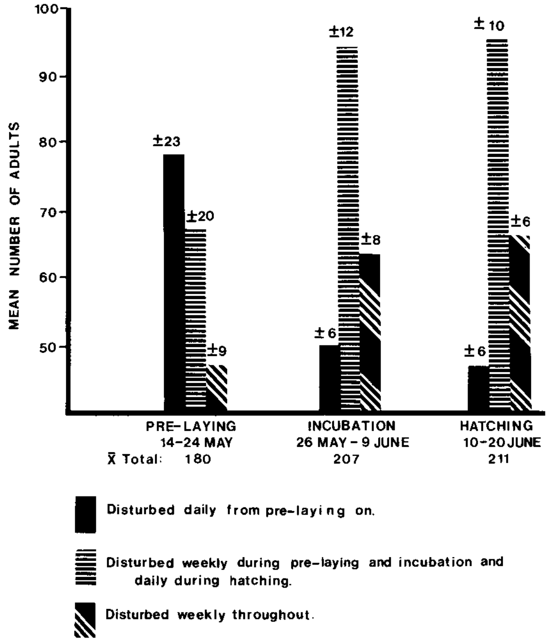

FIGURE 1. Mean numbers of adult skimmers in areas subjected to different amounts of human disturbance during various phases of the reproductive season. $\bar{x}$ total = mean number of adult skimmers in the entire colony during the same phases of the cycle. Numbers above each bar are ± SD.

The number of adults in areas checked daily fell precipitously during egg-laying and continued to fall throughout the hatching period (−37% and −6%, respectively). However, they increased in areas disturbed only once per week during these same periods (+43% and +4%, respectively). Compared to the colony-wide net change, the decrease in numbers of adults was statistically significant during the egg-laying period ($\chi^2 = 26.40$, $P < 0.001$), but not during hatching ($\chi^2 = 0.36$). During the prelaying to incubation period, those areas disturbed weekly that were closest to the areas disturbed daily had a higher recruitment rate than areas farther away (40% vs. 34%). Although not statistically significant ($\chi^2 = 0.42$), these data suggest that individuals leaving disturbed areas tended to move into the nearest undisturbed areas. Adults continued to move into areas in which daily disturbance began at hatching ("weekly/daily" areas), but at a lower rate (2% vs. 5%; $\chi^2 = 0.034$, n.s.) than into areas disturbed weekly. The total number of adults in the subcolonies increased 11% through the incubation period, but was generally constant thereafter (+2% overall; Fig. 1).

Clutch sizes were not significantly affected by the amount of disturbance (2 × 3 contin-

TABLE 1. Breeding characteristics of Black Skimmers as a function of disturbance.

	Disturbance schedule			
	Daily	Daily/Weekly	Weekly	All skimmers
Number of nests	45	85	60	190
Clutch size ($\bar{x}$ ± SD)	3.5 ± 0.21	3.6 ± 0.83	3.9 ± 0.52	3.7 ± 0.85
Hatch rate (% of eggs laid)	76	93	90	88

gency table: $\chi^2 = 0.66$, df = 2), although they were slightly larger in subcolonies that were disturbed less frequently (Table 1). However, hatching success (the proportion of eggs that hatched) was significantly lower in areas disturbed daily during incubation (2 × 2 contingency table: $\chi^2 = 28.3$, $P < 0.001$).

Although vegetative cover and substrate were similar in all of the subcolonies, nests were significantly closer together in areas disturbed weekly than in those entered daily. Several skimmer colonies on salt marsh islands, which are disturbed less frequently than barrier beach colonies due to their remote location, have been found to have nests even closer together (Burger and Gochfeld, unpubl. data; Fig. 2, Table 2). These salt marsh islands varied in size, and were all smaller than the barrier beach island, yet none of the colonies occupied all of the available habitat.

Although egg-laying started earlier and was more synchronous in areas disturbed daily than in areas disturbed weekly, the number of clutches started dropped abruptly after 22 May, the date when we began daily nest checks (Fig. 3). We had a strong impression that other birds who intended to lay in subcolonies that were disturbed daily moved into the less disturbed subcolonies. Late nesting was inhibited in subcolonies that were disturbed on a daily basis, as indicated by the relatively protracted pattern of laying in subcolonies disturbed weekly in contrast to those disturbed daily (Fig. 3).

More nests were abandoned in daily disturbed subcolonies. Eight of nine abandoned nests were in areas receiving daily disturbance at the time of abandonment.

In fenced areas, we repeatedly saw adults attempting to call chicks through the wire. Many unfenced chicks were probably lured

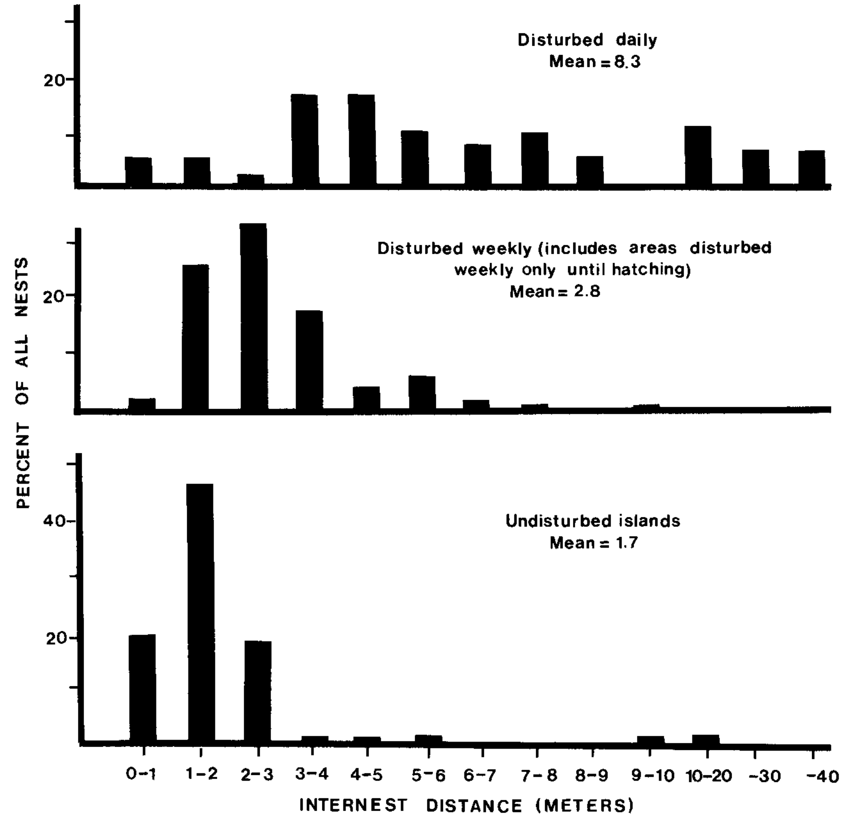

FIGURE 2. Internest distances in colonies of Black Skimmers subjected to different amounts of disturbance.

TABLE 2. Internest distances of Black Skimmers as a function of human disturbance. Values in the table are mean distances ± SD.

	Number of nests	Internest distance* (m)
Areas disturbed daily throughout the breeding cycle	45	8.3 ± 8.8 a
Areas disturbed weekly until hatching and daily thereafter	85	2.8 ± 1.6 b
Areas disturbed weekly throughout the breeding cycle	60	2.7 ± 1.2 b
Undisturbed areas (salt marsh islands)†	90	1.7 ± 1.3 b

† Burger and Gochfeld (unpubl.). See description in text.
* Values followed by the same letter are not significantly different ($P > 0.05$); other differs significantly ($P < 0.01$), Student Newman-Keuls test.

away from the hatching area by their parents, and we occasionally found young chicks up to 100 m from their hatching area. Small chicks were always dead when found farther than about 40 m from their subcolony, but larger ones (over 14 days in age) were sometimes found alive at such distances. Many large chicks from all subcolonies began to appear on the beach before they could fly.

Chicks more than a few days old often ran from approaching observers. Chicks found crouching cryptically sometimes ran long distances after being picked up and banded. Older ones sometimes began to flee when we were still 100 m away from a subcolony, and we seldom found them again. Running chicks were occasionally struck by diving terns as they crossed tern territories, but we did not see any killed in this way. Older chicks inside our fences also tried to run, and were often bruised at the base of the bill from the wire. The severity of such abrasions was related to the amount of vegetation within the fenced areas: chicks that could hide in enclosed vegetation were injured less seriously. None of these injuries appeared to be fatal.

We saw three instances of cannibalism in subcolonies that were disturbed on a daily basis. In each case, we found skimmer chicks trying to swallow smaller conspecifics, at least two of which were probably siblings. One of them had died while swallowing its meal.

Because young chicks frequently leave nesting areas when disturbed, we were unable to determine the actual number that fledged in our study sites. Nevertheless, since these chicks were color-banded, we were able to determine the *relative* fledging success of birds from each disturbance type by observing ratios of color-banded birds in groups of fledged chicks on the outer beach (Fig. 4). The relative proportion of chicks fledged per hatched egg (Fig. 4) was higher in subcolonies disturbed weekly ($\chi^2 = 8.31$, df = 1, $P < 0.01$). Fencing reduced fledging success in those areas ($\chi^2 = 8.03$, df = 1, $P < 0.01$), but enhanced it in areas disturbed daily ($\chi^2 = 7.17$, df = 1, $P < 0.01$).

DISCUSSION

PRELAYING PHASE

Skimmers and many other colonial waterbirds are particularly sensitive to disturbance when

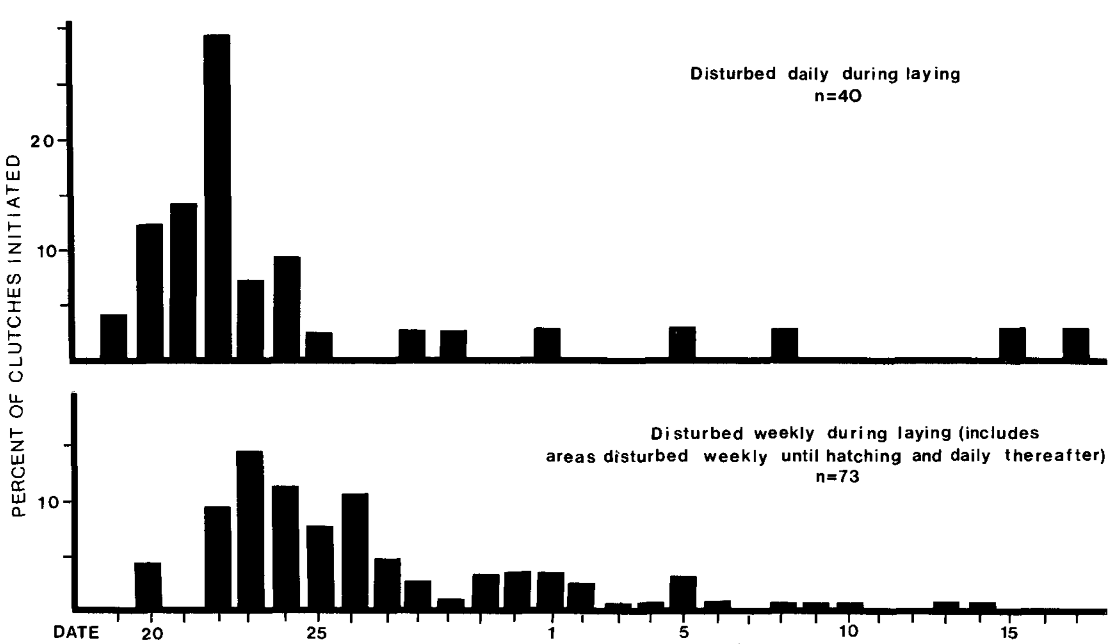

FIGURE 3. Initiation of skimmer clutches as a function of amount of disturbance.

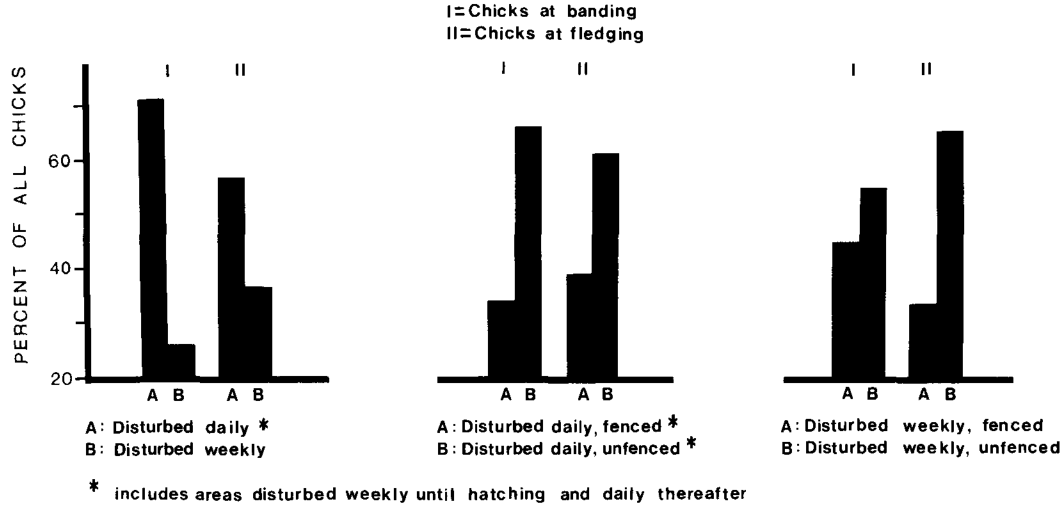

FIGURE 4. Relative proportions of chicks at banding and at fledging. Changes in ratios of A to B from banding to fledging are statistically significant within each of the three groups. "Percent of all chicks" = percent of all chicks in treatment groups defined by A and B for each panel.

it occurs early in the breeding season. When Ring-billed Gulls (*Larus delawarensis*) first return to breeding islands, they will not come ashore during the entire day if a human is present on the island in the morning (Conover and Miller 1978). Early season disturbance of American White Pelicans (*Pelecanus erythrorhynchos*) by low-flying aircraft lowered mean productivity from 0.80 young/nest to 0.22, whereas similar disturbance later in the nesting season reduced their productivity only slightly, to 0.74 (Bunnel et al. 1981).

Since many colonial birds nest in dynamic places (i.e., barrier beaches), which are subject to rapid change, it is adaptive for these species to be sensitive to changes in the site, including the presence of predators. Thus, if a traditional colony site were unsafe at the beginning of the season, the birds could move to a more suitable area. Desertion of an area by adults has also been noted as a response to early disturbance in Franklin's Gulls (*Larus pipixcan*; Burger 1981a), Black-crowned Night-Herons (*Nycticorax nycticorax*; Tremblay and Ellison 1979), and Caspian Terns (*Sterna caspia*; Fitch and Shugart 1981). In our study skimmers that deserted early-disturbed subcolonies apparently moved to relatively undisturbed subcolonies nearby. Daily disturbance throughout the entire colony might discourage some birds from attempting to nest there. Since skimmers apparently do not nest in pure colonies except in high numbers (>200 pairs; Erwin 1979), it is unlikely that individuals sensitive to disturbance would colonize new, unused areas.

In our study, early disturbance reduced nesting density in daily-disturbed subcolonies (Tables 1 and 2), but increased it in surrounding, less disturbed areas. Since skimmer subcolonies are limited to sandy patches and often cannot expand outward into the surrounding vegetated areas, birds moving to less disturbed subcolonies cause the density there to be higher than it would otherwise be. This may lower the productivity of less disturbed areas because, at least in some species, intraspecific aggression becomes more frequent and more intense with increased density (e.g., Hunt and Hunt 1975, 1976). Since trespassing skimmer (and tern) chicks may be killed by territorial adults (Burger 1981b), chick mortality may increase because of alterations in nest density caused by disturbance before egg laying.

INCUBATION PHASE

In our study, skimmers also were sensitive to disturbance during the egg-laying and early incubation phases (Fig. 3). Thus, they deserted their nests most often before they had invested much time and energy in their reproductive efforts. Other colonial waterbirds have also been found to abandon their nests or attempt less late nesting in response to observer intrusion (Buckley and Buckley 1972, Nisbet and Drury 1972, Conover and Miller 1978, Ellison and Cleary 1978, Manuwal 1978, Tremblay and Ellison 1979).

As incubation progresses, skimmers and other colonial waterbirds become less sensitive to human intrusion, desert less often, flush less easily, and return sooner when flushed (Johnson and Sloan 1975, Conover and Miller 1978, Manuwal 1978). Once birds have invested much time and energy in their eggs or young, it is advantageous for them to continue since to abandon and renest elsewhere lowers their chances of reproductive success (Davis and Dunn 1976, Ollason and Dunnet 1978, 1980, M. Gochfeld, pers. comm.).

The hatching success of skimmers was significantly reduced in daily disturbed subcolonies (Table 1). Disturbance often makes it easier for gulls to steal or destroy eggs (e.g., Harris 1964, Johnson and Sloan 1975, Kury and Gochfeld 1975, Robert and Ralph 1975, Davis and Dunn 1976, Ellison and Cleary 1978, DesGranges and Reed 1981). We have no evidence, however, that predation by gulls increased because of our presence at Cedar Beach. Decreased hatching success in disturbed colonies has also been attributed to thermal stress caused by exposure of unattended eggs and chicks to heat and cold (Teal 1965, Hunt 1972, Ollason and Dunnet 1980), and eggs being crushed or knocked from nests by adults (Schreiber 1979). However, the significance of such factors is poorly documented (Cairns 1980). The most likely causes of egg mortality at Cedar Beach were heat stress and altered parental behavior. Teal (1965), for example, reported that a 30-min exposure to the sun was lethal to White Ibis (*Eudocimus albus*) eggs, and during our nest checks, adults were occasionally away for periods of time approaching this.

CHICK PHASE

Disturbance can affect the survival of chicks by increasing their vulnerability to predators and conspecific adults and by altering their behavior and that of adults. Gulls, for example, are often quick to devour exposed chicks (Harris 1964, Johnson and Sloan 1975, Kury and Gochfeld 1975, Davis and Dunn 1976, Ellison and Cleary 1978, DesGranges and Reed 1981).

Young birds in colonies are often killed by cannibalistic conspecifics (see Parsons 1971) or by adults defending their territories against chicks that wander from their own nests. Gillett et al. (1975) noted the importance of chick mortality caused by observer-induced trespass. In areas of Western Gull (*Larus occidentalis*) colonies subjected to different degrees of disturbance, Robert and Ralph (1975) found that survival of chicks was inversely proportional to disturbance because chicks that habituated, and did not flee from humans, were not killed by territorial adults. Nonetheless, chick survival was highest in completely undisturbed areas.

Skimmers at Cedar Beach sometimes kill trespassing skimmer and tern chicks (Burger 1981b). We have not seen adults eat chicks, but Safina found a color-band in a regurgitated skimmer pellet and several severed legs with color-bands. However, we did see skimmer chicks swallowing younger conspecifics. Two of the three cannibalistic chicks were similar in age and close to one another, suggesting a specialist parent. They were in an area of low density, whereas the third was in an area of high density.

Chick mortality is also caused by thermal stress when parents leave in response to human intrusion (Gillett et al. 1975, Tremblay and Ellison 1979). Very young skimmer chicks often begin to gular flutter if exposed to sun for more than a few minutes on hot days.

Disturbance also causes chicks to leave their nests early. For skimmer chicks, human intrusion alone increases the distance that they move from the nest, and handling them increases it even more (Gochfeld 1981). Since skimmers nest in open patches of sand, such chicks often must cross through the territories of conspecifics or terns to reach the safety of vegetation. Chicks of Franklin's Gull and the Brown-hooded Gull (*Larus maculipennis*) also flee from observers and become lost or tangled in aquatic vegetation. In a study of Herring Gulls, chicks who were handled daily moved much farther than chicks handled weekly. They also ran immediately when approached, in contrast to those that were not handled, which did not flee until they were 20 days old (Burger 1981a). Teal (1965) found that ardeid chicks also left the nest abnormally early and moved farther away than otherwise if they were subjected to weekly disturbance.

Adults often exacerbate nest-leaving by calling chicks from disturbed areas, as noted in Sandwich Terns (*Sterna sandvicensis*; Veen 1977), Ring-billed Gulls (Conover and Miller 1978), Black Skimmers (Gochfeld 1981 and this study), and Caspian Terns (Fitch and Shugart 1981). One result of early departure from the nest is that smaller chicks may straggle behind their parents and become lost because they are so young (Veen 1977). Gochfeld (1981) reported that skimmers may lead three-week-old chicks up to 1.5 km away from the nest.

In our study, daily disturbance greatly depressed fledging success, unlike the case in certain other colonial waterbirds. Such disturbance, for example, did not prevent Herring Gulls, Black-crowned Night-Herons, or Black Guillemots (*Cepphus grylle*) from successfully rearing young (Hunt 1972, Tremblay and Ellison 1979, Cairns 1980). We think that the main factor contributing to observer-induced mortality in skimmer chicks at Cedar Beach was their running from the nest at our approach.

Fences are often used by researchers to prevent chicks from leaving the vicinity of the nest so that daily observations can be made. In our study, direct fence-induced mortality was very low, a similar finding to that reported by Nisbet and Drury (1972) for Common and Roseate terns. Langham (1968), however, found that Roseate Tern chicks were injured by such fences, as did we. Such injuries did not cause death among our birds, although they were almost universal among large chicks. Survival of chicks in fenced areas of weekly-disturbed subcolonies was slightly lower than that of chicks in unfenced areas of the same subcolonies, perhaps because fences cause parents to desert their nests. We saw skimmers repeatedly attempt to call their chicks through the wire, and found several chicks dead with their heads through the mesh (but not stuck). These observations suggest that chicks that did not follow were abandoned, especially if their siblings were able to get through the wire. The higher survival of fenced chicks in daily-disturbed areas may mean that early departure from the nest surpassed fence-related deaths as a mortality factor under such conditions.

MITIGATION OF OBSERVER EFFECTS

Our study suggests that human activity reduces the breeding success of Black Skimmers, even in undisturbed areas, because it artificially increases the density of breeding birds there. Skimmers are sensitive to human intrusion both early and late in the breeding season. Disturbances during egg-laying and early incubation caused adults to leave subcolonies and abandon nests, and also reduced hatching success. Disturbance later in the season caused chicks to run long distances and consequently they were killed by territorial adults or became lost. To minimize observer-induced losses while assessing reproductive activity, we recommend that biologists who are documenting the number of breeding pairs and their success rate should visit nesting areas only once during late incubation (when adults are least likely to desert and will return to the nest soon after the disturbance), and count fledged young at nearby loafing sites with the aid of a telescope. Several other investigators have made similar suggestions (Johnson and Sloan 1975, Kury and Gochfeld 1975, Ellison and Cleary 1978, Tremblay and Ellison 1979).

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RECENT PUBLICATIONS

Visual and Vocal Signals in Penguins, their Evolution and Adaptive Characters.—Pierre Jouventin. 1982. Advances in Ethology 24, Supplement to Journal of Comparative Ethology, Verlag Paul Parey, Berlin. 149 p. Paper cover. No price given. Source: Verlag Paul Parey, Lindenstrasse 44–47, D-1000 Berlin 61, Germany. This monograph describes and analyzes the sexual and aggressive behavior of penguins, based on studies of 15 species in zoos and in the wild over a span of many years. It begins by describing, interpreting, and classifying the visual signals (mostly sexual) of all six genera in order to gain insight into the biological meaning of ritualized postures. The vocalizations are then described in detail and experimental results are presented, these showing that individual recognition is not visual but vocal. Lastly, in a long and intensive analysis, Jouventin discusses the evolution of penguin behavior, relating it to the birds' distribution, speciation, breeding habits, and environment. His findings on vocalizations, combined with ecological and morphological data, lead to several conclusions on the systematics of the group. In closing, he briefly discusses three theoretical problems in ethology. This work makes an important contribution to our understanding of the evolution and adaptive features of avian behavior. Essential reading for penguin specialists, it offers lessons for those who study other colonial waterbirds. Illustrated with many photographs, drawings, charts, and sound spectrograms. References, brief index.

Lek Behavior in the Golden-headed Manakin, *Pipra erythrocephala* in Trinidad (West Indies).—Alan Lill. 1976. Advances in Ethology 18, Supplement to Journal of Comparative Ethology. 83 p. Source: as before. A technical paper on the unusual group-mating system of a tiny forest-dwelling, fruit-eating bird. Covers in detail the unusual territory relationships among members of the same species, the closely-related White-bearded Manakin, and other birds. Factors affecting visits by females and other males to the communal display ground (lek) occupy most of the paper. Nest behavior, nest biology, reproductive success and post-fledging behavior are included. A thorough documentation of lek behavior in a passerine bird. Well suited to the ethologist or even the curious, but informed, reader. Summaries in English and German, literature cited, subject index.—J. Tate.