NESTING BEHAVIOR OF HERRING GULLS: INVASION INTO *SPARTINA* SALT MARSH AREAS OF NEW JERSEY

JOANNA BURGER

The Herring Gull (*Larus argentatus*) has increased its numbers and expanded its breeding range substantially since the turn of the century. Populations in Sweden, North Germany, and Holland have doubled or tripled (Davis and Dunn 1976, Andersson 1970). In New England, populations have increased by a factor of 15 to 20 (Kadlec and Drury 1968, Drury and Kadlec 1974), and the species has extended its breeding range as far south as North Carolina (Hailman 1963, Parnell and Soots 1975). The increase in numbers has been attributed to the presence of garbage dumps which provide a constant and dependable food supply at all times of the year (Drury 1965, Harris 1970). The availability of ample and easily obtained food influences the survival of growing chicks in the breeding season, juveniles after the breeding season (Drury and Smith 1968), and all age groups during the winter months.

Yet the expansion of any breeding population of gulls depends not only upon available food reserves, but upon available nesting habitat(s) as well. Colonies in the northeastern United States are located on sandy or rocky barrier beach islands (Kadlec and Drury 1968). Further south, fewer such islands are available for colonization.

Herring Gulls have been found nesting under *Iva* bushes in high salt marsh at Stone Harbor, New Jersey. Laughing Gulls (*L. atricilla*) nested in nearby low marsh areas of *Spartina alterniflora*. Since the two species did not use the same habitat, Bongiorno and Swinebroad (1969:100) concluded that they were "not yet in direct competition."

In a colony of Laughing Gulls on Elder Island in the Brigantine National Wildlife Refuge, New Jersey, 15 to 30 pairs of Herring Gulls have nested under *Iva* bushes for the last four or five years. During the 1973 breeding season some of these nests were located in the high marsh *S. alterniflora* near the *Iva* bushes suggesting the possibility of expansion into new habitat and of direct competition with Laughing Gulls. Therefore, during 1974 and 1975 I censused and studied the Herring Gull colonies in and near the Refuge in order to determine the extent of their expansion into salt marsh areas. I investigated the adaptations of nesting Herring Gulls to salt marshes and compared the breeding success of pairs in *Spartina* areas with others nesting under the higher and drier *Iva* bushes.

STUDY AREA AND METHODS

The barrier beach and salt marsh islands studied extend from Absecon Is., Atlantic City (70°21′W) north to Little Egg Harbor, Holgate (74°16′W), New Jersey. The area (fig. 1) contains three larger barrier beach islands and numerous low marsh islands bisected by natural channels and mosquito ditches. The principal vegetation on the salt marsh islands is *Spartina alterniflora*. High marsh (Redfield 1972) areas contain *Distichlis spiccata*, *S. patens*, and *Salicornia* sp., while a few of the *Spartina* islands contained higher elevation areas with *Iva frutescens* bushes, *Phragmites*, bayberry (*Myrica pensylvanica*) and poison ivy (*Rhus radicans*).

I checked the barrier beach and salt marsh islands in 1974 and 1975 to determine the number of breeding Herring Gulls, the habitats they selected, and relative breeding success. Detailed observations were made from mid-March through June 1975 on Islajo and Big Heron islands, and two experiments were conducted. Both islands were checked for nests two or three times a week during March and April. During May and June, I lived on Islajo Island and made daily observations there, while similarly checking Big Heron Island every three days. I spent the same amount of time in each habitat to equalize the effect of my presence on breeding success. During the egg-laying period I searched the available habitat and all new nests were marked and measured. Data collected at each nest included the width and depth of the nest and cup, number of eggs, location of nest by habitat type, and the behavior of the adults. Thereafter, nests were checked and measured from 05:00 to 06:00. Eggs were considered to be preyed upon only if I observed the predator or found the eggshell pecked open.

RESULTS

ISLANDS AND HABITATS USED

Herring Gulls nested on six salt marsh islands, containing low and high *Spartina* with higher and drier areas of *Iva, Phragmites* and/or dune vegetation (colonies are numbered in fig. 1). The entire area contained many islands with only *Spartina* marsh, but these islands were not used by the gulls.

Colony 1 was on Elder Is., near Little Beach Is. and Brigantine Channel. In 1973, it contained 15 to 20 pairs nesting under the *Iva* bushes well above the storm tide level. In 1974, more nests were present, and some were located near the *Iva* bushes in high

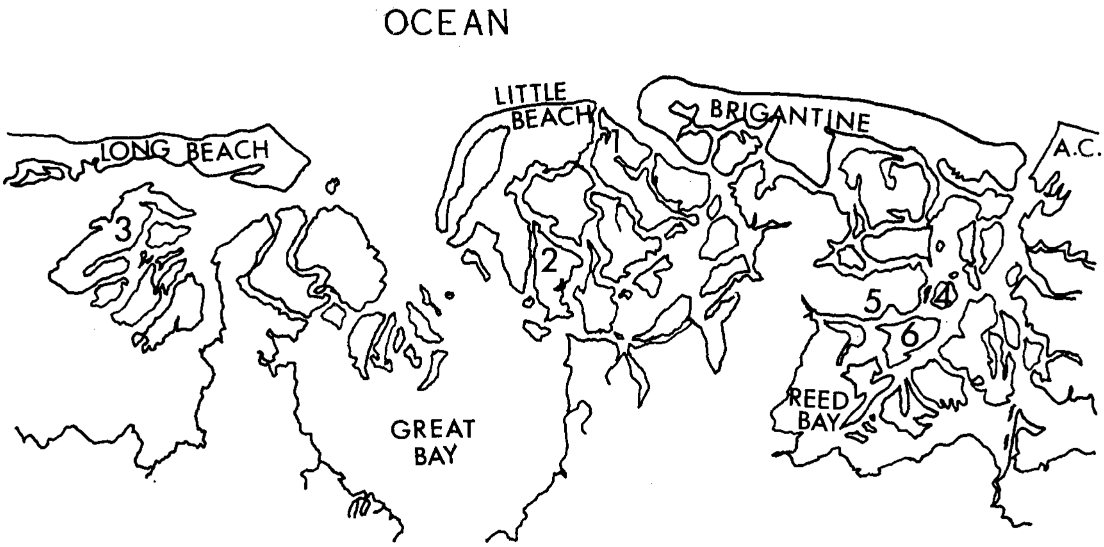

FIGURE 1. Map showing the locations of Herring Gull colonies. See text for colony names.

marsh *Spartina*. The nests in the bushes were relatively close together ($\bar{x} = 3.0$ m, SD = 1.6, $N = 21$), and since nests were distributed throughout the bushes, some pairs may have been forced to move into the surrounding *Spartina*. Very high tides combined with a northeastern storm destroyed some of the nests in the *Spartina*, but eggs in three or four nests hatched. No Laughing Gulls nested in this high marsh area, but a small colony of Common Terns (*Sterna hirundo*) that nested nearby lost all nests in the above mentioned high tide.

The second colony was on Egg Is. near Little Beach Is. About 20 pairs of Herring Gulls have nested under the *Iva* bushes for some years and raised young in the last three years.

Colony 3 was on Barrel Is., near Holgate. The vegetation consists largely of *Spartina* with a central area of *Iva* bushes. This central bushy area contains a colony of herons and egrets. From 100 to 120 Herring Gull pairs nested in the *Spartina* immediately surrounding the bushes. I checked this island only in late June of 1974 and 1975, when 25% of the nests contained eggs, and the rest contained one to three chicks. In 1974, this colony was also checked after very high storm tides, yet most nests still contained chicks and eggs.

Colony 4 was on Big Heron Is. (Island A 61c of Nordstrom et al. 1974) near Reed Bay. This island has a high dense central area with *Phragmites* containing a heron colony. High marsh surrounds the *Phragmites* and 58 Herring Gull pairs nested in the edge areas of the *Phragmites* as well as in the live *Spartina* of the high marsh.

The fifth colony was on Islajo Is. (Island A 61b of Nordstrom et al. 1974) near Reed Bay. This island has a high sand dune area of grasses (*Ammophilia*) and herbs, surrounded by dense *Phragmites* containing a heronry. The *Phragmites* were surrounded on various sides by an open mudflat, an area with *Iva*, and a protected area containing an expanse of dead *Spartina* mat as wide as 30 m. In 1974 and 1975, about 120 nests were located in all areas of the island.

The sixth colony, located on Little Gull Is. in Reed Bay, had a very small area of *Iva* bushes surrounded by *Spartina*. Twenty pairs of Herring Gulls nested in 1975 under the *Iva* bushes and in the surrounding *Spartina*. No gulls nested here in 1974.

Thus, Herring Gulls in the area nested in many small colonies of 15 to 124 pairs ($\bar{x} = 55$, SD = 49, $N = 6$), and all colonies were located in or near the point of highest elevation in *Iva* bushes. Herring Gulls did nest in the *Spartina* marsh areas surrounding *Iva* bushes when these bushes were not available to them (either because other gulls or herons nested there), and some pairs in *Spartina* succeeded in hatching eggs.

Islajo, Big Heron and Little Gull islands were examined in detail. I classified the nesting areas on these islands as wet, wet-dry, and dry habitats depending on the number of times that water reached an area during high tides (table 1, fig. 2). I defined the areas as follows: (1) Dry areas did not get wet during high or storm tides. (2) Wet-dry areas were intermediate in that water covered the area during up to half of the high tides. On Islajo Is. these habitats were the edge

TABLE 1. Herring Gull habitats studied in New Jersey.

Location	Habitat	Vegetation	% Nests having at at least one egg hatch (total nests)
Islajo Island	Dry	*Ammophilia* grass and *Phragmites*	100 (15)
	Wet-dry	Edge of *Spartina*	45 (42)
		Spartina mat (dead grass)	79 (42)
	Wet	Live *Spartina* (low marsh)	0 (25)
Big Heron Island	Wet-dry	Live *Spartina* (high marsh)	83 (6)
		Edge areas of *Ammophilia* grass and *Phragmites*	88 (32)
	Dry	*Phragmites*	95 (20)
Little Gull Island	Wet-dry	*Spartina* (high marsh)	70 (20)

areas between low marsh *Spartina* and *Phragmites*, and large areas of *Spartina* mat. Although both areas were water-covered at the same time, the *Spartina* mat floated in such a way that nests in this area did not get as wet as those placed on the ground in live *Spartina*. Unless specifically stated, wet-dry nests are those in live *Spartina*. (3) Wet areas were touched by water during half or more of the high tides.

TERRITORY ACQUISITION AND EGG LAYING

I first observed Herring Gulls on Islajo Is. on 10 April. The first territories defended were those in the dry area. The available dry sand dune area was occupied by 15 pairs, and all intruders were chased. A few additional pairs tried to establish territories in the nearby *Phragmites*, but all eventually abandoned this area. By mid-April territories were being formed and defended in the edge areas of live *Spartina* and on the *Spartina* mat.

The relationship between egg laying and habitat type is shown in table 2. The first eggs were laid significantly earlier in the dry habitat ($F = 13.2$; df = 2,120; $P < 0.005$). The mean date of egg laying was 15.5 May, and the total egg laying period on Islajo Is. was 26 days. Synchrony within any one area was greater than the synchrony in the entire colony ($\chi^2 = 24.0$, df = 3, $P < 0.001$). The synchrony within sub-areas varied from 11 to 13 days. In the mat area the egg laying period extended for 20 days. Most of the nests were begun from 11 to 22 May, no nests were begun from 23 to 27 May, and 10 nests were begun on 28 and 29 May. I believe these

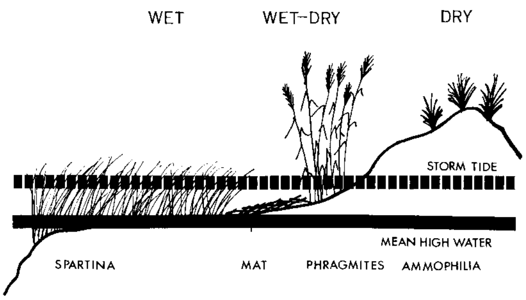

FIGURE 2. Schematic profile of Islajo showing vegetation and location of Herring Gull nest types.

later pairs had lost their nests in the very high tides of 24 May and were renesting.

NEST STRUCTURE

I gathered data on the width and depth of 15 (in dry area) or 20 (in the other areas) nests (fig. 3). There were significant overall differences among the habitats in initial nest widths ($F = 9.6$; df = 2,53; $P < 0.001$) and depths ($F = 11.2$; df = 2,53; $P < .001$). Nest widths in the dry area were significantly less than those in the wet-dry area ($t = 3.04$, df = 33, $P < 0.001$ a posteriori); nest widths in the wet-dry area were significantly less than those in the wet area ($t = 4.78$, df = 38, $P < 0.001$, a posteriori). Similarly, nest depths in the dry area were significantly less compared to those in the wet-dry area ($t = 4.06$, df = 33, $P < 0.001$, a posteriori); nest depths in the wet-dry area were significantly less than those in the wet area ($t = 7.18$, df = 38, $P < 0.001$, a posteriori).

The nest cup width also varied among habitats ($F = 8.32$; df = 2,53; $P < 0.001$). The cup in dry habitats was not wider than those in wet-dry habitats ($\bar{x} = 236$ mm, SD = 28 versus $\bar{x} = 23.0$ mm, SD = 10; $t = 1.11$, df = 38, not significant a posteriori). The cup in wet-dry habitats was not as wide as those in wet habitats ($\bar{x} = 230$ mm, SD = 10 versus $\bar{x} = 214$ mm, SD = 20; $t = 2.50$, df = 38, $P < 0.001$, a posteriori). There were no differences in the depths of the nest cups ($F = 0.04$; df = 2,53).

I also compared the size of nests during the first week with sizes during the second week (fig. 3). There were significant overall differences among habitats in increased nest depth ($F = 12.37$; df = 2,53; $P < 0.001$). Differences in added nest depth in dry and wet-dry habitats did not differ ($t = 1.01$, df = 33, a posteriori), but added nest depth did differ between wet-dry and wet nests ($t = 18.32$, df = 38, $P < 0.001$, a posteriori). Thus, birds in wet habitats did not increase their nest depth

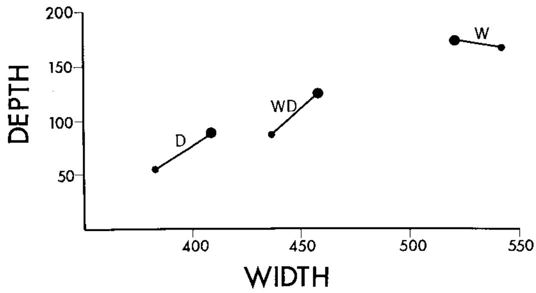

FIGURE 3. Nest depth and width (in mm) as a function of habitat type. D = dry area, WD = wet-dry area, and W = wet area. The small dot is the mean size during the first week of incubation, and the large dot is the mean from these same nests 10 days later.

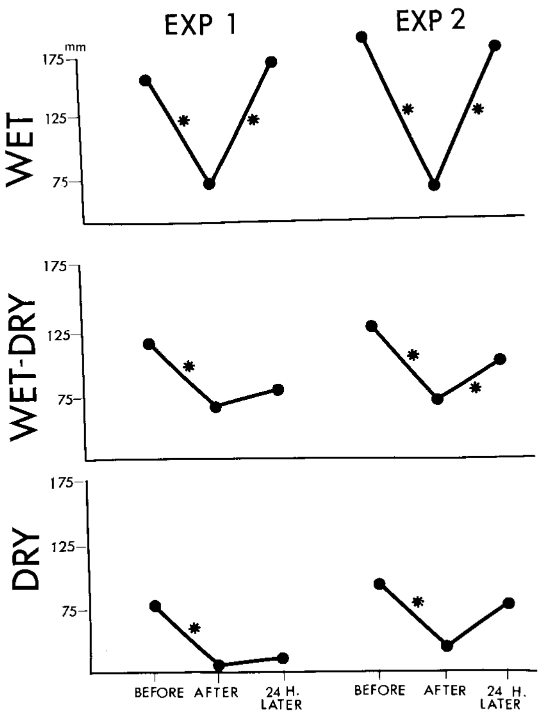

FIGURE 4. In experiment 1, material was removed from the entire circumference of the nest, while in experiment 2 it was removed from only one side of the nest. The first dot shows the mean nest depth (in mm) before treatment, the second dot the mean after treatment, and the third dot the mean 24 h later. A star indicates a significant difference.

significantly while those in dry and wet-dry habitats did. There were no differences in added nest widths among habitats ($F = 1.01$; df = 2,53), although nests generally increased in width (fig. 3).

NEST STRUCTURE EXPERIMENTS

Beer (1963) found that in Black-headed Gulls (*Larus ridibundus*) nest-building behavior before and during incubation was similar. Moore (1975) observed that nest-building behavior in salt marsh nesting Laughing Gulls is directed by feedback from the state of the nest. If Herring Gulls are to be successful in salt marsh, their nest-building behavior should be responsive to habitat differences and subsequent changes in nest size and structure due to tidal fluctuations. I designed two experiments to discover the differences (if any) in nest repair behavior of Herring Gulls in different habitats.

In Experiment 1, I removed one-half of the material from the entire surface of each of 10 nests per habitat during the second week of incubation. Nests still contained cups, and were the same width but the nest depth was less; thus, when incubating, the birds were closer to the ground. This removal resulted in nests similar in size to those nests suffering compaction during high tides (see below). An equal number of untreated control nests were measured in the wet and wet-dry areas. The dry habitat had only five controls since the area had so few nests.

In all habitats, of course, the mean nest depth immediately after treatment was significantly less than before treatment (fig. 4). Yet in the next 24 hours nest repair varied as a function of habitat. There were significant differences among habitats in nest repair with respect to depth ($F = 46.2$; df = 2,28; $P < 0.001$). The dry and wet-dry habitats did not differ significantly ($t = 1.05$, df = 18), whereas, the wet-dry and wet habitats were different ($t = 8.13$; df = 18, $P < 0.001$, a posteriori). There was no significant repair in the dry condition ($\bar{x}$ change = 1.25 mm, SD = 9.39, $t = 1.01$, df = 18; paired comparison) and in the wet-dry condition ($\bar{x}$ change = 16.1 cm, SD = 18.1, $t = 0.90$, df = 18; paired comparison), whereas, there was a significant difference in the wet condition nest depths ($\bar{x}$ change = 92.25 mm, SD = 8.53, $t = 14.3$, df = 18, $P < 0.001$; paired comparison). Similarly, there were overall differences with respect to habitat in the depth of nests before treatment compared to 24 hours after treatment ($F = 15.94$; df = 2,28; $P < 0.001$). Nests in the wet habitat were not significantly different ($\bar{x}$ change = 3.2 mm, SD = 6.3), but those nests in the wet-dry habitat ($\bar{x}$ difference = 41.3 mm, SD = 7.3, $t = 2.67$, df = 18, $P < 0.01$; paired comparison) and the dry habitat ($\bar{x}$ difference = 67.3 mm, SD = 13.3, $t = 2.35$, df = 18, $P < 0.05$; paired comparison) had significantly lower nest depths 24 hours after treatment compared to pre-treatment depths.

No differences in nest depths were recorded in any control nests.

In Experiment 2, I removed over half of the nest material from one side of each of 10 nests in each habitat during the third week of incubation. Thus, the nest cup was open on one side, but not on the other. This action produced noticeably damaged nests. An equal number of control nests in each habitat were measured during the same census times. The wet and wet-dry samples were from Islajo Is., and the dry nests were sampled on Big Heron Is.; no nest used in the first experiment was used. The initial nest depths were slightly higher, since this experiment was performed five days after Experiment 1.

There were significant overall differences between habitats in nest repair ($F = 45.3$; df $= 2{,}53$; $P < 0.001$; fig. 4). The amount of repair (i.e., increased nest depth 24 hours after treatment) in wet-dry nests was significantly more than in dry nests ($t = 6.32$, df $= 18$, $P < 0.001$, a posteriori), and significantly less than in wet nests ($t = 7.13$, df $= 18$, $P < 0.001$, a posteriori). There was no significant repair in the dry condition ($\bar{x}$ change $= 55.1$ mm, SD $= 53.2$, $t = 1.32$, df $= 18$; paired comparison), whereas, there was significant repair in the wet-dry ($\bar{x}$ change $= 45.1$ mm, SD $= 26.1$, $t = 2.1$, df $= 18$, $P < 0.05$; paired comparison) and wet areas ($\bar{x}$ change $= 112.1$ mm, SD $= 23$, $t = 11.3$, df $= 18$, $P < 0.001$; paired comparison).

BEHAVIOR AND A NATURAL EXPERIMENT AT HIGH STORM TIDES

On 25 May 1975, a very high tide combined with northeasterly winds to produce the highest tide of the breeding season. All of the *Spartina*, mud flat, and shrub areas on Islajo Is. were inundated during the peak, yet most of the *Phragmites* area and all of the interior sand dune areas remained dry. Gull behavior during this exceptionally high tide was similar to, although more intense than, that shown in lower high tides.

As the tide advanced, loafing gulls abandoned the mudflat for drier areas. Gulls incubating on nests on the mudflat and *Spartina* areas continued to incubate until the tidal water reached the height of the eggs; then they stood, gave alarm calls (*kow* calls), or flew before resetting. Adults abandoned their nests when the water was 5 cm over the top of the eggs. Their frequent flying and landing resulted in some eggs being broken, and intruding gulls ate the eggs of unattended nests. Nest owners often flew over their inundated nests and *kow*-called, or landed in the water nearby. The tidal water was as deep as 45 cm over nests in the *Spartina* area. Some nests remained anchored to the *Spartina* and others floated. Some nests in the wet-dry edge area (edge of *Spartina-Phragmites*) were inundated, most were partially wet, and a few were completely dry. The *Spartina* mat partially floated with the result that most eggs were dry, although five nests on the edge of the mat closest to the open bay were almost covered with water, and three were later abandoned.

I checked and measured all nests on this island between 05:30 and 06:30 the following day. All nests were destroyed or missing in the wet *Spartina* area. Of 42 nests in the wet-dry area, 18 were destroyed or missing, and 3 of 42 nests on the edge of the *Spartina* mat were missing. No nests had been destroyed in the dry area.

Before the flood, the mean sizes of the nests ($N = 16$) on the mat were: width $= 538$ mm, SD $= 28$; depth $= 132$ mm, SD $= 11$. Immediately after the flood water receded, nest depth was significantly less ($\bar{x}$ change $= 28$ mm, SD $= 9$, $t = 2.86$, df $= 30$, $P < 0.01$; paired comparison). Twelve hours later, nest depths were significantly greater than those immediately after the flood tide ($\bar{x}$ change $= 41$ mm, SD $= 13$, $t = 4.10$, df $= 30$, $P < 0.001$; paired comparison). All nests were deeper than they had been before the flood tide on the *Spartina* mat.

During the same time period there were no significant changes in the depths of nests in the dry habitat ($F = 0.32$; df $= 2{,}41$). Unfortunately, all the nests in the wet area were destroyed so a similar comparison could not be made.

These results are similar to those in Experiment 1. Under natural conditions high tide water compacted nests, and the gulls responded by adding material until nests were higher above the ground than before the tide.

All nests were checked on Big Heron and Little Gull islands. None were lost in the live *Spartina* on Big Heron Is., and eggs subsequently hatched. The rims of most nests in the *Spartina* were slightly above the tide water, since the area was slightly higher than the comparable *Spartina* on Islajo Is. Most nests in the *Spartina* on Little Gull Is. survived the storm and remained intact, and eggs subsequently hatched in 70% of the nests.

NEST SUCCESS AS A FUNCTION OF HABITAT

I observed 202 nests from laying until hatching on the three study islands. Of these nests,

TABLE 2. Synchrony in laying of the first egg within sub-areas on Islajo Island in 1975.

Habitat	Number of nests	Egg-laying period	Mean date (SD)	Length of period (days)
Dry	15	4–15 May	10.3 May (3.3)	11
Wet-dry				
Edge of *Spartina*	42	9–21 May	13.7 May (3.6)	13
Spartina mat	42	11–29 May	19.7 May (7.1)	20
Wet	25	9–21 May	14.2 May (2.6)	13
All nests	124	4–29 May	15.5 May (5.35)	26

67% (135) had at least one egg hatch. The percentage of nests in which at least one egg hatched was computed for each habitat on these islands (table 1). In the dry area, 95% of the nests had eggs hatch, between 45 and 88% ($\bar{x}$ = 70%) of the nests in the wet-dry area had eggs hatch, and none had eggs hatch in the wet areas. Hatching success varied in the live *Spartina* areas from 0 to 83% ($\bar{x}$ = 37%).

I examined the 1975 data from Islajo Is. to discover the fate of individual eggs (table 3). Clutch size did not vary significantly in the three habitat types ($\chi^2 = 0.04$, df = 3). A higher percentage of the eggs hatched in the dry areas, and no eggs hatched in the wet areas ($\chi^2 = 98.1$, df = 2, $P < 0.001$). Wet-dry edge areas had 40% of the eggs hatch compared to 75% on the *Spartina* mat which had floated during the storm. More eggs were preyed upon in the wet area (25%) than in the wet-dry areas (10 and 3%, $\chi^2 = 13.6$, df = 2, $P < 0.001$). No eggs were preyed upon in the dry area. However, flooding accounted for the loss of 75% of the eggs in the wet area and 25% of eggs in the wet-dry areas, respectively ($\chi^2 = 80.2$, df = 2, $P < 0.001$).

DISCUSSION

Herring Gulls nested in all three specific habitat types on Islajo Is. The gulls established territories first in the limited dry sand dune area, and the space appeared to be divided by the 15 pairs that nested there. A few gulls tried to establish territories in the adjacent *Phragmites*, but they eventually abandoned these sites, perhaps because of the behavior of the nearby nesting herons which often threatened the gulls. Territories were then established in the remaining areas, one to two weeks later.

The differences in the timing of territory acquisition were reflected in the egg laying periods. The total egg laying period on Islajo Is. was 26 days, which is shorter than that reported by other workers (e.g. Brown 1967a, 1967b, MacRoberts and MacRoberts 1972). However, the Islajo Is. colony had fewer breeding pairs than their colonies.

Nest structure also varied as a function of habitat; nests in wet areas were larger in width and depth than those in dry areas. In fact, dry area nests ranged only from a scrape with a few blades of grass to flimsy nest structures. General variability in initial nest structure was to be expected since Herring Gulls are known to build differently shaped and sized nests in other habitats. Yet the activity of nest repair seems to be responsive behavior. Whether the cause of the reduction in nest depth was natural (tidal effect compacting material) or experimental (removal of material), immediate repair occurred only in the wet areas. Moreover, while all pairs in the wet area completely repaired their nests, pairs in the wet-dry areas partially repaired their nests, and pairs in the dry area were variable in that some partially repaired nests and some made no repairs. Experimental removal of material from only one side of the nest resulted in some repair in all habitat types. These experiments showed that Herring Gulls have the ability to respond differentially to changes in their nests as a function of the type of nest damage. More importantly, gulls nesting in wet areas made immediate and complete repairs in their nests, suggesting responsive behavior, since in the wet habitats a

TABLE 3. Nesting characteristics on Islajo Island.

	Dry	Wet-dry: Edge of *Spartina*	Wet-dry: *Spartina* mat	Wet
No. nests	15	42	42	25
$\bar{x}$ clutch size	2.83	2.71	2.66	2.38
SD clutch size	0.39	0.40	0.64	0.79
No. eggs	42	114	112	60
Fate of eggs (%)				
Hatched	95	40	75	0
Predated[a]	0	10	3	25
Lost in flood	0	45	7	75
Rotten	0	3	10	0
Unknown	5	2	5	0

[a] Predation was by other Herring Gulls and occurred during high tides.

higher, more substantial nest can withstand some tidal inundation. The extreme tides destroyed all nests in the *Spartina* on Islajo Is. However, on Big Heron and Little Gull islands, nests in *Spartina* at slightly higher elevations withstood the tide and were rebuilt deeper so that a stronger tide could be withstood. Then too, nests in the wet-dry area were partially repaired under experimental conditions, and, under the flood conditions, these nests were completely repaired. Under both experimental and flood conditions, the heights of dry nests were never significantly changed after 24 h.

Clutch size on Islajo Is. was similar to that reported by Paynter (1949) in more established colonies in the United States and by Harris (1969) and others in Europe. This suggests that the Herring Gulls nesting in New Jersey are not competitively inferior or only first year breeders.

Hatching success on the three study islands varied as a function of habitat. I found that 67% of the 202 pairs that nested on these islands hatched young. Of the total eggs laid ($N = 523$), 59% hatched. This is lower than the 71% reported by Paynter (1949) for Kent Island Herring Gulls. Figures reported for Europe are also higher and range from 55 to 95% ($\bar{x} = 84\%$; see Harris 1964 for summary).

Tidal effects account for the lower hatching rate in the present study. The fate of 328 eggs laid on Islajo Is. was followed closely (table 3) and only about 5% of the egg loss is not attributable to tide-related phenomena. Flood tides not only affect nest success directly and immediately by destroying nests and eggs, but also latently by causing rotten eggs. The rotten eggs in the *Spartina* mat area had fallen out of nests into tide water or remained in nests completely inundated. Flood tides also influence nest success indirectly by increasing predation rates. For example, all nests lost to predation in the wet area (25%) were lost in the few hours around the very high tides of 12 and 25 May, when adults were agitated and frequently left nests unattended. Other adults landed and ate the eggs. Egg cannibalism is well documented in Herring Gulls (Parsons 1971, Burger 1974).

Egg hatching success is lower in my study area than in other Herring Gull colonies. Given the limited amount of available dry habitat, just how successful at raising young are gulls nesting in these marginal areas? On Islajo Is., 57% of the eggs hatched in the wet-dry areas and 80% of these chicks were still alive at 10 days of age, when the effects of high tide were minimized (since chicks could then move to higher and drier areas). Although no eggs in *Spartina* nests hatched on Islajo Is., a high percentage did hatch in the higher *Spartina* areas on other islands. I predict that these Herring Gulls will make increasing use of mat areas, where hatching success was very high.

SUMMARY

Herring Gulls have increased in numbers and expanded their breeding range since the turn of the century. They have begun nesting in *Spartina* salt marshes of southern New Jersey, where I examined nesting behavior and success in dry shrub areas, edge *Spartina* mat areas, and wet *Spartina* areas. Herring Gulls constructed larger and deeper nests in wet areas than in dry areas. Natural (tidal effect compacting nest material) and experimental (where I removed material) reduction of nest depth resulted in immediate repair only in the wet areas. Experimental removal of nest material from only one side of the nest resulted in some repair in all habitats. However, complete repair occurred only in the wet areas. Hatching success varied from 0 to 100%, depending on the habitat. Nests in dry areas had at least one egg hatch in 95 to 100% of the nests, in wet-dry areas hatching success varied from 45 to 88%, and in the wettest areas none of the eggs hatched. Gulls nesting in *Spartina* had eggs hatch in 0, 70, and 83% of the nests which directly related to the height of the marsh. Clearly, Herring Gulls can successfully hatch eggs in *Spartina* if they select high marsh areas.

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Department of Biology, Livingston College, Rutgers University, New Brunswick, New Jersey 08903. Accepted for publication 17 June 1976.