Wilson Bull., 99(4), 1987, pp. 673–687

NEST-SITE SELECTION BY MEW GULLS (*LARUS CANUS*): A COMPARISON OF MARSH AND DRY-LAND COLONIES

JOANNA BURGER[1] AND MICHAEL GOCHFELD[2]

ABSTRACT.—We examined nest-site selection in 13 Mew Gull (*Larus canus*) colonies in south-central Alaska to compare characteristics used in wet versus dry-land colonies. We distinguished three types of colonies that experience different selection pressures: (1) dry-land colonies surrounded by dry land, (2) dry-land colonies surrounded by water, and (3) marsh colonies. The former probably experienced greater mammalian predation than the latter two. Nests in dry-land colonies on the mainland were in dense cover with low nest visibility from 1 and 5 m, except at colonies that were protected by fences or by being on a roof. All colonies were exposed to aerial predators, and in all but one colony cover over nests was significantly greater than for random sites. Dry-land colonies on islands and marsh colonies exposed to flooding had nests that were higher above water than were the random sites. Our results indicate that Mew Gulls' choice of nest sites reflects habitat constraints and predation pressures. *Received 17 Nov. 1986, accepted 26 May 1987.*

Selection of a particular nest site is critical for reproductive success, thus the factors affecting nest-site selection should vary depending on specific environmental features (Lack 1968, Partridge 1978, Cody 1985, Burger 1985). Colonial species often nest in places that are inaccessible to mammalian predators, such as islands or tree tops. Colonies on dry land may also be free from mammalian predators if there are other predator barriers. Despite the emphasis on the differences between marsh, cliff, and dry-land nesting in the literature on colonial birds (Cullen 1957; Burger 1974, 1981; Montevecchi 1978), there are few studies comparing nest-site selection in both marsh and dry-land colonies of the same species (but see Storey 1978, Gotmark 1982). Here we do so for Mew Gulls (*Larus canus*).

Mew Gulls in Alaska use a wide diversity of habitats for colony sites (Burger and Gochfeld, unpubl. data) in a small geographical area. They nest on river bars, tops of spruce trees, in marshes, and on dry land (Grinnell 1900, Murie 1963, Isleib and Kessel 1973, Armstrong 1983). Vermeer and Devito (1986) recently examined several Mew Gull colonies on Vancouver Island and provide additional habitat-use information. Overall, Mew Gulls nest in habitats where they can minimize slope, distance to vegetation, and cover from above; and where they can max-

[1] Biological Sciences, Rutgers Univ., Piscataway, New Jersey 08855.
[2] Environmental and Community Medicine, UMDNJ-Robert Wood Johnson Medical School, Piscataway, New Jersey 08854.

imize distance above water and cover around the nest. Thus they provided the opportunity to (1) examine and compare nest-site selection in dry-land and marsh colonies, and (2) compare nest-site selection in dry-land colonies surrounded by other dry land with those surrounded by water. We hypothesized that visibility of the nest would be low and cover around nests would be high in dry-land colonies compared to marsh colonies (and dry-land colonies surrounded by water) that are less vulnerable to mammalian predators. As avian predators have access to all colonies, cover directly over nests should be similar in all habitats.

METHODS AND STUDY COLONIES

We studied 13 colonies of Mew Gulls within 250 km of Anchorage, Alaska, from 26 June to 24 July 1985, during the late incubation and chick phase. We distinguished three types of colonies:

Dry-land colonies surrounded by dry land.—These included (1) the Anchorage military base containing 20 pairs nesting on earthen dikes (or roads), (2) the Anchorage landfill adjacent to the airport with 25 pairs nesting on soil and rock, and (3) the roof top colony with 13 pairs nesting on the Anchorage Port Authority building.

Dry-land colonies surrounded by water.—These included (4) Hood Lake (400 pairs) within Anchorage, a large grassy island surrounded by a lake, (5) Sullivan Park with 24 gull nests on individual grassy islands with small birch trees, (6) a gravel Island in the Nenana River (A) near Denali Park (30 pairs), (7) a rocky island in the Nenana River (B) near Denali Park (75 pairs), (8) a sand bar colony (80 pairs) in the middle of Snow Creek at milepost 18 on the Seward-Anchorage highway, and (9) a man-made rock dike adjacent to the Anchorage Harbor (30 pairs).

Marsh colonies.—These included (10) a wet marsh near the Shell Oil Company plant in the Anchorage Port area (3 floating nests), (11) a creek bog near Anchorage Airport with 12 nests built on the top of marsh grass tussocks, (12) two nests in a moss muskeg bog near the Anchorage Post Office, and (13) a salt-marsh colony (30 nests) at Portage marsh, at milepost 40 south of Anchorage.

At each colony we collected data on all nests (if under 30) or a random sample of 30 nests including slope (in degrees from the horizontal); distance to nearest rock, tree or vegetation; distance to edge of colony; height above water; height of nearest tree, rock or vegetation; percent cover directly over the nest; percent cover in a 1- and 5-m radius around the nest; and visibility of the nest from above the nest and from 1 and 5 m. We distinguished ground cover (herbs less than 5 cm tall), herb cover (taller than ground cover, but shorter than trees), and tree cover.

At each colony we selected a number of random sites equal to the number of nests sampled, or 15 sites (if there were fewer nests) with which to compare to nests characteristics. Random sites were chosen by selecting X and Y coordinates for each site from a table of random numbers (Burger and Gochfeld 1986). Similar characteristics were measured at the random sites and the nests. We compared nest-site characteristics with those of random sites with Kruskal-Wallis χ^2 tests.

RESULTS

Dry-land Colonies Surrounded by Dry Land

Dirt dike on military base.—Port Anchorage has a military installation enclosed by chainlink fences, immediately inside of which is an earthen

dike about 2 m high × 2.5 m wide, beside a ditch or moat. The dikes were devoid of vegetation except for a few small willows or tall herbs that grew on the shoulder. Mew Gulls nested on these dikes, close to the vegetation, on the top or gently sloping sides, where they built up one side of the nest so the nest was level. They nested in sites with low vegetation cover (high visibility), but within 0.5 m of vegetation (Table 1). Their choice of nest sites differed significantly from the random sites with respect to slope, percent rock cover, vegetation cover (but not vegetation height), and visibility above the nest.

Airport landfill.—Adjacent to the Anchorage airport a landfill (coarse spoil sand) with scattered low herbs contained 25 pairs of Mew Gulls and about 40 pairs of Arctic Terns (*Sterna paradisea*). One edge of the colony was bordered by willow and birch trees and a creek, and the other was bordered by a jogging trail and a six-lane highway. Overall, vegetation cover in 5-m^2 plots on the site ranged from none to 40%. Mew Gulls nested on flat areas away from rocks (Table 1). Cover over nests was greater than in the 5-m^2 areas around nests, indicating that gulls choose to nest close to vegetation (small herbs and *Lupinus*), although the area around the nest was open and visibility of the nest was high. The nest sites differed significantly from random sites in having more cover, being closer to vegetation, with greater visibility, and with taller herbs and vegetation.

Anchorage port roof.—Less than 100 m from the rock dike was a large harbor warehouse with a flat, fine-gravel roof. The roof was crisscrossed with electrical conduits with 4-cm high junction boxes situated at intervals. Only one side of the warehouse was exposed to boats and cranes, which operated only 5 m from this edge. Because the birds were entirely exposed on the roof, we were worried about young running over the edge, and we mapped the location of the cables and junction boxes for later generation of random site data (Monte Carlo simulation, Ricklefs and Lau 1980). We took data at nest sites and left immediately. While we were there, the young formed a group on the farthest side of the roof. Nests were significantly closer than expected to the edge of the roof farthest from the harbor activity. All nests were placed adjacent to conduit cables, and many were adjacent to the junction boxes (Table 2). Many gulls also nested next to vertical objects (but not next to tall chimneys).

Dry-land Colonies Surrounded by Water

Hood Lake.—Most of the periphery of the grassy island was covered with short grass. Scattered around the edge of the island were short willow trees, and at one end there was a small stand (5 × 20 m) of willow and birch trees. Gulls nested over the entire island, except in the tall grass on the central ridge. Mew Gulls generally nested on flat sites in grass that

TABLE 1

CHARACTERISTICS OF NESTS AND RANDOM SITES ($\bar{x} \pm$ SD) FOR MEW GULLS NESTING ON DRY-LAND COLONIES

Characteristics	Hood Lake			Airport landfill		
	Nests	Random sites	χ^2 (*P*)	Nests	Random sites	χ^2 (*P*)
Height above water (cm)						
Distance to water or edge (cm)					685 ± 32	
Slope (°)	2 ± 0.5	4 ± 0.5	3.75 (0.05)	4 ± 0.8	6 ± 3	3.3 (NS)
% rock cover	0	0	—	0.4 ± 0.2	1 ± 0.3	4.03 (0.05)
Rock height (cm)	—	—	—	—	2 ± 0.3	
% cover over nest	98 ± 0.1	94 ± 1	9.65 (0.001)	91 ± 3	45 ± 6	14.71 (0.0001)
% cover within 1 m	98 ± 0.2	94 ± 1	5.74 (0.02)	84 ± 4	48 ± 6	11.20 (0.0008)
% cover within 5 m	99 ± 0.1	95 ± 1	4.82 (0.03)	77 ± 4	48 ± 5	8.60 (0.003)
Distance to vegetation (m)	0.5 ± 0.2	4.0 ± 0.7	25.1 (0.0001)	0.5 ± 0.4	6 ± 3	6.7 (0.01)
Distance to willows (m)	4.4 ± 1.1	4.1 ± 8.2	1.2 (NS)			
Distance to birch (m)	1.1 ± 0.2	1.5 ± 3.8	0.8 (NS)			
Distance to *Lupinus* (cm)	37 ± 0.5	49 ± 6.5	1.4 (NS)	48 ± 14[a]	154 ± 34	5.94 (0.01)
Nest visibility from over nest	94 ± 3	99 ± 2	10.5 (0.001)	90 ± 2	94 ± 2	5.14 (0.02)
Nest visibility from 1 m	94 ± 3	98 ± 4	7.70 (0.005)	88 ± 4	97 ± 0.7	13.23 (0.0003)
Nest visibility from 5 m	95 ± 2	99 ± 2	7.91 (0.004)	85 ± 4	97 ± 1	11.08 (0.0009)
Vegetation height (cm)	57 ± 3	38 ± 4	14.3 (0.0002)	68 ± 7	43 ± 5	6.74 (0.009)
Herb height (cm)	12.8 ± 1	9.4 ± 1	8.38 (0.003)	32 ± 6	9 ± 1	15.01 (0.0001)
Nearest neighbor nest (cm)	283 ± 29			1147 ± 201		

[a] Distance to grass.
[b] For the 10 nests close to birch.

TABLE 1
CONTINUED

Characteristics	Military base dirt dike			Sullivan Park		
	Nests	Random sites	χ^2 (*P*)	Nests	Random sites	χ^2 (*P*)
Height above water (cm)				38 ± 5		
Distance to water or edge (cm)	110 ± 19	90 ± 10	1.2 (NS)	101 ± 24		
Slope (°)						
% rock cover	25 ± 2	32 ± 3	5.62 (0.03)	0.7 ± 0.3		
Rock height (cm)	14 ± 6	3 ± 2	83 (0.001)	0		
% cover over nest						
% cover within 1 m	5 ± 3	0.1 ± 0.2	2.1 (NS)	94 ± 3	80 ± 10	12.3 (0.0001)
% cover within 5 m	15 ± 7	0.3 ± 0.2	12.2 (0.001)	87 ± 6		
Distance to vegetation (m)	6 ± 3	0.2 ± 0.1	9.3 (0.003)	64 ± 5		
Distance to willows (m)	3 ± 0.1	5.2 ± 1.6	11.2 (0.001)	1.2 ± 0.5		
Distance to birch (m)						
Distance to *Lupinus* (cm)						
Nest visibility from over nest	96 ± 3	99 ± 0.1	11.6 (0.001)	72 ± 8	86 ± 7	16.1 (0.0001)
Nest visibility from 1 m	99 ± 0	99 ± 3	0.0 (NS)	71 ± 8		
Nest visibility from 5 m	99 ± 0	99 ± 2	0.0 (NS)	63 ± 11		
Vegetation height (cm)	55 ± 7	51 ± 6	0.6 (NS)	73 ± 5	56 ± 6	7.21 (0.005)
Herb height (cm)	65 ± 63 ± 6	63 ± 6	0.2 (NS)	21 ± 11		
Nearest neighbor nest (cm)	1280 ± 60			374 ± 72		

TABLE 2

CHARACTERISTICS FOR NESTS AND RANDOM SITES ($\bar{x} \pm$ SD) FOR MEW GULLS NESTING ON A ROOF AND ON A ROCK DIKE

Characteristic	Roof			Rock dike		
	Nests	Random sites	P^a	Nests	Random sites	χ^2 (P)
Distance to edge (cm)	222 ± 401	1038 ± 190	0.005			
Distance to water (cm)				610 ± 19	547 ± 15	3.43 (0.06)
Height above water (cm)	—	—		23 ± 18	27 ± 12	1.2 (NS)
Slope (°)	0	0	NS	3 ± 5	7 ± 0.6	4.57 (0.03)
% cover over nest	0	0	NS	5 ± 1	16 ± 6	5.71 (0.02)
% cover within 1 m	0	0	NS	65 ± 2		
% cover within 5 m	0	0	NS	4 ± 2		
% rock				11 ± 5		
Herb height (cm)				41 ± 5		
Vegetation height (cm)				46 ± 7		
Distance to bush or trees (cm)				127 ± 25		
Distance to vegetation (cm)				244 ± 87		
Nest visibility from over nest	99 ± 0	99 ± 0	NS	96 ± 2		
Nest visibility from 1 m	99 ± 0	99 ± 0	NS	98 ± 1		
Nest visibility from 5 m	99 ± 0	99 ± 0	NS	99 ± 0		
Distance to junction box (cm)	309 ± 15	462 ± 16	0.0005			
Distance to vertical rock (cm)	3.8 ± 1.8			13 ± 4	14 ± 3	0.2 (NS)
Height of vertical object (cm)	42 ± 38			31 ± 5	30 ± 3	0.3 (NS)
Distance to cliff edge (cm)				36 ± 5	47 ± 5	3.80 (0.06)
Height of cliff drop (cm)				13 ± 2	19 ± 2	5.42 (0.04)

[a] From Monte Carlo simulation.

averaged 57 cm tall, and that had scattered low herbs (12 cm high) around them (Table 1). Grass cover around the nest was 98%, but the grass did not cover the nest, and visibility estimates averaged about 95%. Nest sites differed significantly from the random sites in being flatter, with more cover, lower visibility, and taller vegetation, but not with respect to the distance to trees or bushes (Table 1).

Sullivan Park.—Located within Anchorage, Westchester Lagoon in Sullivan Park has 31 small grassy islands (2–4 m × 3–12 m), and is used extensively for canoeing. Due to the large number of people on the lake, we landed on nesting islands only to take nest measurements, and we recorded only limited data from random sites. Most of the smaller islands had only one pair of nesting gulls; however, five of the larger islands had two (one nest at each end of the island). Mew Gulls nested on flat sites well above water, but usually at the edge of islands (Table 1). Cover over the nest was denser than in the 5-m area around the nest. Gulls did not nest close to birch trees, but they nested close to other vegetation and herbs. They selected to nest on sites with more cover, lower visibility, and near taller vegetation than occurred at the random sites (Table 1).

Nenana River site A.—The first Nenana River colony we examined was just outside Denali Park, on a low, tear-shaped island with black sand, gravel, and small rocks. The river was wide and swift-moving at this point. In the center, dead logs deposited by high water formed shelters for some chicks. Small plants (*Lupinus*) and herbs grew on the edges of the island. Thirty pairs of gulls nested on the island, although they concentrated on the downriver end where the land was slightly higher in elevation. A 0.5-m rise in river elevation would have flooded all of the nests. Mew Gulls nested on the higher parts of the island, on slight slopes on sites with little cover, close to herbs and willow bushes (Table 3). Their choices of nest sites differed from the random points with respect to distance to water (they nested farther away), slope (flatter spots), rock cover (more rocks), and vegetation height (they chose taller vegetation) (Table 3).

Nenana River site B.—Nenana B colony, located about 5 km downriver from Nenana A where the river widens, was much larger and was covered (90%) with dense trees and shrubs, which were avoided by nesting gulls. The leading edge of the island exposed to the swift currents was a 5–60 m wide section with boulders and small rocks where most gulls nested. On these beaches sand was deposited on a few higher places which supported small willows, but otherwise there was little vegetation cover. The average gull nest was 28 cm above the water, over 30 m from the water's edge, and on flat sites with intermediate cover (Table 3). Cover over nests was greater than in the 1 and 5 m areas around the nest, indicating selection

TABLE 3

CHARACTERISTICS AT NESTS AND RANDOM SITES FOR DRY-LAND MEW GULL COLONIES SURROUNDED BY WATER IN ALASKA

Characteristics	Snow Creek			Nenana River A			Nenana River B		
	Nests	Random sites	χ^2 (*P*)	Nests	Random sites	χ^2 (*P*)	Nests	Random sites	χ^2 (*P*)
Height above water (cm)	18 ± 3	13 ± 1.5	2.8 (NS)	24 ± 3			28 ± 4	18 ± 3	21.2 (0.001)
Distance to water (m)	15.1 ± 2.3	15.9 ± 2.3	0.2 (NS)	7.2 ± 2.1	2.8 ± 3.7	28.9 (0.0001)	34 ± 6	28 ± 2	29.6 (0.0001)
Distance to edge (m)	14.8 ± 2.4	19.5 ± 2.5	1.2 (NS)	28.2 ± 7					
Slope (°)	0.5 ± 0.2	1.6 ± 0.5	4.5 (0.03)	5 ± 2	8 ± 1	4.7 (0.03)	10 ± 7	20 ± 6	5.82 (0.02)
% rock cover	0	0		24 ± 3	1 ± 1	31.2 (0.0001)			
Rock height	—	—	—	3 ± 0.6	2 ± 0.8	0.8 (NS)			
% cover over nest	45 ± 4	11 ± 4	19.8 (0.0001)	3 ± 1	16 ± 5	7.41 (0.006)	46 ± 6	16 ± 5	9.84 (0.001)
% cover within 1 m	37 ± 4	11 ± 3	18.1 (0.001)	15 ± 4	15 ± 5	0.0 (NS)	39 ± 6	15 ± 5	10.07 (0.001)
% cover within 5 m	24 ± 2	12 ± 2	10.9 (0.001)	18 ± 5	12 ± 3	1.1 (NS)	26 ± 5	13 ± 5	4.43 (0.03)
Distance to vegetation (m)	10 ± 3	47 ± 15	5.0 (0.05)	28 ± 6	44 ± 12	5.7 (0.03)	5 ± 3	44 ± 12	8.05 (0.004)
Distance to willows (m)	0.7 ± 0.3	1.1 ± 5.9	2.1 (NS)	1.2 ± 2.5	35.6 ± 6.7	21.6 (0.0001)	1.4 ± 3.6	3.6 ± 6.7	6.0 (0.01)
Willow height (m)	1.2 ± 0.7	0.8 ± 1.3	6.1 (0.01)	0.8 ± 0.1	0.56 ± 3.1	0.8 (NS)	0.7 ± 0.1	0.5 ± 0.7	0.2 (NS)
Distance to *Lupinus* (cm)	2.9 ± 0.6	2.8 ± 6.7	0.1 (NS)						
Nest visibility from over nest	80 ± 6	88 ± 5	4.3 (0.03)						
Nest visibility from 1 m	90 ± 1	93 ± 4	0.6 (NS)						
Nest visibility from 5 m	92 ± 3	95 ± 3	0.4 (NS)						
Vegetation height (cm)	45 ± 5	41 ± 9	0.5 (NS)	78 ± 13	47 ± 7	12.1 (0.001)			
Herb height (cm)	15 ± 3	3 ± 0.5	13.8 (0.0002)						
% bushes	24 ± 4	7 ± 3	5.8 (0.01)						
Nearest neighbor nest (cm)	1097 ± 140			992 ± 136			817 ± 120		

of herbs or shrubs. Gull nests were on higher sites, farther from water, on flatter slopes in greater cover, and closer to vegetation than were the random sites (Table 3). Nests tended to be clustered in favorable areas, where two pairs nested near the same vegetation or driftwood clump.

Snow Creek.—At milepost 18 (about 100 km south of Anchorage toward Seward), the highway crosses Snow Creek and a low lying, partly vegetated sand bar (over 500 m long) that has a high, central portion, which supports a dense stand of willow and birch trees. The gulls nested on the upstream portion of the island on black sand among scattered short willows (<2 m tall). The nesting substrate was only 18 cm above the river level. Gulls nested close to vegetation with intermediate cover and high visibility (Table 3). They nested closer to willow than to *Lupinus,* and they selected flatter sites with more cover (and less visibility), that were next to taller willow and herbs when compared to the random sites (Table 3).

Rock dike.—The rock dike at the Anchorage harbor is a boulder embankment about 100 m × 10 m, which shores a heavily used road and parking lot. The rocks were placed at a 30° slope, and at the bottom was a tidal mudflat. On the top margin some willow trees grew between the dike and the parking lot. About 30 pairs of gulls nested among the rocks, and they were vigorously protected by the port personnel that had adopted the colony. Gulls were limited to a narrow range of sites because if they nested close to the bottom they were exposed to tidal flooding, whereas nesting close to the top exposed them to people from the parking lot. Gulls nested on flat rocks, usually well above the high water (Table 2). There was almost no cover over the nests (except rock overhangs), and visibility of the nests was high. Nests were placed on flat rocks, with small "cliffs" below the nest and upright rock faces above. There were no differences in the height of the rocks above nests, but the cliffs below the nests were shorter than for the random sites (Table 2). Nests were farther from water than were random sites.

Marsh Colonies

Anchorage port marsh.—A small pond on Shell Oil property at the Port of Anchorage had 3 pairs of nesting gulls. The water in the marsh was deeper than 1.5 m, and had cattails and emergent vegetation in the center. The pond was fringed with oil storage tanks and upland areas supporting 10-m tall trees. The gulls built floating platforms that were 35–50 cm wide and extended 30–60 cm below the water surface. The dead, emergent vegetation around the nest extended only 16.0 ± 4.4 cm [SD] above the water surface, suggesting extensive flooding since the previous growing season. Cover over the nests ranged from 2 to 5%, and visibility ranged

TABLE 4

CHARACTERISTICS OF NESTS AND RANDOM SITES ($\bar{x} \pm$ SD) FOR MEW GULLS NESTING IN MARSHES

Characteristics	Portage marsh			Moss muskeg			Creek bog		
	Nests	Random sites	χ^2 (*P*)	Nests	Random sites	χ^2 (*P*)	Nests	Random sites	χ^2 (*P*)
Distance to grass or trees (m)	0.12 ± 0.03[a]			1.45 ± 0[b]	3.0 ± 9	1.5 (NS)	3.1 ± 1.1[b]	2.0 ± 0.6	0.9 (NS)
Tree height (m)				122 ± 18	67 ± 3	48 (0.03)			
Height above water (cm)	2.0 ± 1	0.1 ± 0.4	4.6 (0.01)	38 ± 12	−12 ± 2	4.82 (0.02)	27 ± 4	12 ± 10	7.57 (0.005)
Slope	0.1 ± 0.1	0.1 ± 0.1	0.0 (NS)	0	0		0.4 ± 0.4	3 ± 0.6	6.08 (0.01)
% cover over nest	95 ± 2	89 ± 1.3	5.6 (0.01)	97 ± 2	65 ± 7	4.48 (0.03)	98 ± 1	91 ± 6	1.6 (NS)
% cover within 1 m	96 ± 3	75 ± 4	5.30 (0.02)	90 ± 0	78 ± 2	1.4 (NS)	83 ± 7	95 ± 2	1.9 (NS)
% cover within 5 m	95 ± 2	80 ± 8	9.97 (0.001)	85 ± 5	81 ± 2	0.9 (NS)	68 ± 6	94 ± 2	5.80 (0.01)
% bushes				27 ± 3	15 ± 7	3.38 (0.06)	22 ± 10	17 ± 6	1.2 (NS)
Herb height (cm)							21 ± 4	20 ± 2	0.1 (NS)
Vegetation height (cm)	38 ± 5	43 ± 1	0.3 (NS)	35 ± 1	24 ± 3	3.36 (0.05)	50 ± 6	38 ± 4	2.1 (NS)
Nest visibility from over nest	97 ± 1	98 ± 3	0.1 (NS)	80 ± 4	92 ± 6	6.48 (0.01)	86.7	80 ± 6	1.2 (NS)
Nest visibility from 1 m	91 ± 1	87 ± 3	1.4 (NS)	94 ± 4	92 ± 6	0.1 (NS)	87 ± 7	77 ± 6	2.2 (NS)
Nest visibility from 5 m	70 ± 4	82 ± 4	1.2 (NS)	90 ± 0	92 ± 7	0.1 (NS)	87 ± 7	72 ± 8	2.4 (NS)
Distance to vegetation (cm)	0	0		0 ± 0	0.6 ± 0.4	0.6 (NS)	2 ± 1	15 ± 6	3.28 (0.07)
Nearest neighbor distance (cm)	1450 ± 1525			350 ± 350			858 ± 108		

[a] Grass.
[b] Alder trees.

from 90 to 99% ($\bar{x} = 96 \pm 3\%$). In this habitat gulls nested where they could attach their nests to the emergent vegetation, and avoided open water. This restricted them to an 8 × 10 m section in the middle of the pond.

Anchorage creek bog.—The creek-bog colony (27 m × 85 m) was between the airport and a slow moving creek within 100 m of the airport landfill colony. The site was grass and sphagnum moss adjacent to the creek with dense birch, willow, and alder trees on the other side. The gulls nested on top of the grass hummocks about 1 m above water, on flat spots with higher cover around the nest and high visibility overhead (Table 4). Nest sites differed from random sites with respect to height above water, slope, cover within 5 m, and distance to vegetation. Nests were significantly farther from birch trees (5.7 ± 1.2 m) than were random points (2.9 ± 6.9 m, $\chi^2 = 4.37$, $P < 0.03$), and were closer to water (4.4 ± 1.8 m) than were random points (9.3 ± 2.6 m, $\chi^2 = 4.59$, $P < 0.03$). These two characteristics placed them farther from the dry land, and may have discouraged access by the dogs we saw walking among the birch trees.

Moss muskeg.—Two pairs of gulls nested in the muskeg colony across from the Anchorage Post Office. The extensive marsh was primarily sphagnum moss with occasional hummocks where spruce trees and dead bushes provided higher places for nests. While walking in the marsh we sank kneedeep in water. The nests, 350 cm apart, were well above the water on hummocks near tall trees with dense cover and high visibility (Table 4). The nest sites differed from the 15 random sites with respect to tree height, height above water, cover over nests, percent bushes, and visibility from the nest (Table 4).

Portage marsh.—The Portage marsh, located along the road to Seward, 64 km south of Anchorage, is an extensive grassy marsh where about 30 pairs of gulls nested on the ground amid the grass. The gull colony was adjacent to an Arctic Tern colony of about 25 pairs. Gulls nested around a small pond, placing their nests on extensive platforms of dead grass, presumably constructed to raise them above flood levels. The gull nests were on the highest available part of the marsh (Table 4). Nest sites were on flat ground in dense cover but with high visibility overhead. Nest sites differed from random sites with respect to cover.

DISCUSSION

Nest-site Selection

Mew Gull nest sites differed from random sites with respect to several physical and biotic factors at all colony sites. The same features, however,

were not necessarily important in each colony (Table 5). Comparisons of the characteristics recorded at colonies indicate that for some colonies many environmental features were important, whereas at other sites (roof top, marsh colonies) few characteristics differed (see below).

Colonies ranged from dense vegetation (Hood Lake, Sullivan Lake, creek bog, moss muskeg, Portage marsh), to sparse vegetation (military base, landfill, Nenana River A and B, Snow Creek), to being nearly (rock dike) or completely devoid of vegetation (roof). All colonies, however, had some cover. Although in most colonies cover was provided by vegetation, cover was also provided by rocks (rock dike) and junction boxes (roof). Vegetation and rocks clearly provided protection from both predators and inclement weather, as chicks could hide almost completely from view. The junction boxes, however, provided only shade and protection from the wind.

Marsh Versus Dry-land Colonies

Predators.—In this study we divided the colonies into three types: dry-land colonies surrounded by land, dry-land colonies surrounded by water, and marsh colonies. One method of protecting nests from mammalian predators is to have nest sites invisible from the ground (low visibility from 1 and 5 m). Only the landfill colony, however, where we saw both dog and cat tracks, had lower visibilities from 1 and 5 m than did random sites. Gulls nesting on the military base and roof did not have low visibility of their nests, but they were protected from some mammalian predators by chain-link fences (military base) or by being 9 m above ground (roof). Mammalian predators could not approach either colony.

As all colonies (regardless of habitat) were exposed to aerial predators, we expected cover over nests to be greater than for the random points, and this was the case except at the creek-bog colony. At this colony nesting on the tops of hummocks (away from flooding) appeared to override selection for vegetative cover (see below).

Inclement weather.—Inclement weather can provide stress for eggs and chicks during hot or cold spells, or during heavy rains (Austin 1933, Burger 1974, Burger and Lesser 1978). This stress should be similar regardless of habitat type. Weather stresses can be reduced by having hiding places for chicks, or by providing cover over the nests. In all colonies the gulls nested in cover whenever it was available.

Floods.—The marsh colonies and dry-land colonies surrounded by water were subject to flood conditions. Two of the colonies examined (Hood Lake, Sullivan Park) were on high and dry islands that would rarely, if ever, flood. The other colonies, however, probably experienced regular flooding. The riverine colonies were particularly vulnerable to flooding

TABLE 5

COMPARATIVE NEST CHARACTERISTICS OF MEW GULL COLONIES THAT DIFFERED FROM RANDOM (X), DID NOT DIFFER (NS), OR WERE NOT MEASURED (—[a])

	Dry land			Dry land surrounded by water								
	Anchorage military base	Anchorage landfill	Roof top	Hood Lake	Sullivan Park	Nenana River A	Nenana River B	Snow Creek	Rock dike	Creek-bog	Moss muskeg	Portage marsh
Slope	X	NS	—	X	—	X	X	X	X	X	—	NS
% rock cover	X	X	—	—	—	X	—	—	—	—	—	—
Rock height	—	—	—	—	—	—	—	—	—	—	—	—
% cover over nest	X	X	—	X	X	X	X	X	X	NS	X	X
% cover within 1 m	X	X	—	X	—	NS	X	X	—	NS	NS	X
% cover within 5 m	X	X	—	X	—	NS	X	X	—	X	NS	X
Distance to vegetation	X	X	—	X	—	X	X	NS	—	NS	X	—
Distance to willow	—	—	—	NS	—	X	X	NS	—	—	—	—
Distance to birch	—	—	—	NS	—	—	—	—	—	—	—	—
Distance to *Lupinus*	—	X	—	NS	—	—	—	NS	—	—	—	—
Willow height	—	—	—	—	—	NS	NS	X	—	—	—	—
Vegetation height	—	X	—	X	—	X	—	NS	—	NS	X	NS
Herb height	X	X	—	X	X	—	—	X	—	NS	—	—
Nest visibility over nest	X	X	NS	X	—	—	—	X	—	NS	X	NS
Nest visibility from 1 m	NS	X	NS	X	—	—	—	NS	—	NS	NS	NS
Nest visibility from 5 m	NS	X	NS	X	—	—	—	NS	—	NS	NS	NS
% bushes	NS	—	—	—	—	—	—	X	—	NS	X	—
Distance to water	—	—	—	—	—	X	X	NS	X	—	—	—
Height above water	—	—	—	—	—	—	X	NS	NS	X	X	X
Distance to junction box	—	—	NS	—	—	—	—	—	—	—	—	—

[a] Usually because they were not relevant. Data summarized from Tables 1–4.

because they were located on low sand or gravel islands that were completely washed over by flood waters. In all three riverine colonies, the gulls nested on the highest available sites that provided some vegetative cover. We also observed (unpubl. data) that gulls nesting on these colonies moved chicks to higher ground after hatching.

Some marsh colonies were vulnerable to flooding because nests were on vegetation just above the water level (Shell Oil marsh, moss muskeg, creek bog). Indeed, the nests at the moss muskeg colony had recently been flooded out, and the gulls were in the process of relaying eggs. In all marsh colonies nests were significantly higher above water than were random sites.

Our results indicate that protective cover at nests is critical for Mew Gulls, and that cover can be provided by vegetation, rocks, or man-made structures. Nest visibility from 1 or 5 m, which would act to reduce nest detection by ground predators, was more important for dry-land than for marsh colonies. For marsh colonies, height above water was more important in affecting nest-site selection. Overall, gulls used different physical features in the different colonies to provide protection from predators, inclement weather, and floods.

ACKNOWLEDGMENTS

We thank D. J. and D. A. Gochfeld for field assistance, R. Steidl for computer assistance, W. A. Montevecchi and E. J. Tramer for helpful comments on the manuscript, and the Charles and Johnson Busch Fund for partial support. D. W. and T. Sonneborn provided hospitality, advice, and logistical assistance throughout our stay.

LITERATURE CITED

ARMSTRONG, R. H. 1983. Guide to the birds of Alaska. Alaska Northwest, Anchorage, Alaska.

AUSTIN, O. L., JR. 1933. The status of Cape Cod terns in 1933. Bird-Banding 4:190–198.

BURGER, J. 1974. Breeding adaptations of Franklin's Gull (*Larus pipixcan*) to a marsh habitat. Anim. Behav. 23:521–567.

———. 1981. A model for the evolution of mixed-species colonies of Ciconiiformes. Quart. Rev. Biol. 56:143–167.

———. 1985. Habitat selection in temperate marsh-nesting birds. Pp. 253–281 *in* Habitat selection in birds (M. L. Cody, ed.). Academic Press, New York, New York.

——— AND M. GOCHFELD. 1986. Nest site selection in Sooty Tern in Puerto Rico and Hawaii. Colonial Waterbirds 9:31–45.

——— AND F. LESSER. 1978. Selection of colony sites and nest sites by Common Terns *Sterna hirundo* in Ocean County, New Jersey. Ibis 120:433–449.

CODY, M. L. 1985. An introduction to habitat selection in birds. Pp. 3–56 *in* Habitat selection in birds (M. L. Cody, ed.). Academic Press, New York, New York.

CULLEN, E. 1957. Adaptations in the Kittiwake to cliff-nesting. Ibis 99:275–303.

GOTMARK, F. 1982. Coloniality in five *Larus* gulls: a comparative study. Ornis. Scand. 13:211–234.

GRINNELL, J. 1900. Birds of the Kotzebue Sound region, Alaska. Pacific Coast Avifauna. 1:1–80.

ISLEIB, M. E. P. AND B. KESSEL. 1973. Birds of the North Gulf Coast-Prince William Sound Region, Alaska. Biol. Paper 14, Univ. Alaska, Fairbanks, Alaska.

LACK, D. 1968. Ecological adaptations for breeding in birds. Methuen, London, England.

MONTEVECCHI, W. A. 1978. Nest site selection and its survival value among Laughing Gulls. Behav. Ecol. Sociobiol. 4:143–161.

MURIE, A. 1963. Birds of Mount McKinley, Alaska. Mt. McKinley Nat. History Soc., Fairbanks, Alaska.

PARTRIDGE, L. 1978. Habitat selection. Pp. 351–376 *in* Behavioural ecology: an evolutionary approach (J. R. Krebs and N. B. Davies, eds.). Sinauer, Sunderland, Massachusetts.

RICKLEFS, R. E. AND M. LAU. 1980. Bias and dispersion of overlap indices: results of some Monte Carlo simulations. Ecology 61:1019–1024.

STOREY, A. E. 1978. Adaptation in Common Terns and Forster's Terns for nesting in the salt marsh. Ph.D. diss., Rutgers Univ., Newark, New Jersey.

VERMEER, K. AND K. DEVITO. 1986. Habitat selection of nesting Mew Gulls (*Larus canus*) on Vancouver Island, and Glaucous-winged Gulls (*L. glaucescens*) in the Gulf Islands: a comparative report. Colonial Waterbirds 9:95–103.