

## AN EXPERIMENTAL STUDY OF NEST SITE SELECTION IN COMMON TERNS

BY MIRIAM H. RICHARDS AND RALPH D. MORRIS

Several studies have examined the nesting habitat of Common Terns (*Sterna hirundo*; e.g., Blokpoel et al. 1978, Burger and Lesser 1978, Stelfox and Brewster 1979). Most were descriptive and compared the number of pairs nesting on different types of substrate. To our knowledge, only one experimental study of nest site selection in Common Terns has been published (Severinghaus 1982). Both types of study report similar preferences of nesting substrate among widely separated populations of Common Terns, which suggests a combination of factors preferred by terns seeking a nesting site.

On the Canadian Great Lakes, numbers of Common Terns are declining, with major reductions in numbers of breeding adults at some sites and entire colony desertions at others (Morris and Hunter 1976, Courtney and Blokpoel 1983). The reasons are multiple and include (1) generally lower reproductive success of terns at Great Lakes colonies compared to that of individuals on the eastern seaboard of North America (Nisbet and Drury 1972, Morris et al. 1976), (2) limited immigration of breeding birds to Great Lakes colonies from elsewhere (Haymes and Blokpoel 1978), and (3) earlier occupancy of tern nesting sites by Ring-billed Gulls (*Larus delawarensis*; Morris and Hunter 1976). In addition, it is possible that in some parts of their winter range, Great Lakes Common Terns face food shortages similar to those experienced by Atlantic Coast terns in Trinidad, Guyana and Suriname (Blokpoel et al. 1982). In view of these problems, management procedures that improve breeding recruitment at selected tern colonies seem appropriate.

The second largest Common Tern colony on the Canadian Great Lakes (Blokpoel and Fetterolf 1978) is on an artificial breakwall near the Lake Erie terminus of the Welland Canal. Nesting substrate along the flat breakwall surface ranges from vegetated areas containing small rocks and debris (western end) to areas of bare concrete (eastern end). During each breeding season, Common Terns occupy the breakwall from west to east as the preferred western portion becomes fully occupied by nesting terns. Early nesting terns at this colony have traditionally realized a higher reproductive success than later nesting terns (Morris et al. 1976), an observation also reported elsewhere (e.g., Nisbet and Drury 1972). Management procedures that have a potential for improving the reproductive success of terns nesting late in a breeding season, when success is generally low, may be of value in reversing the decline trends noted above. Our purpose therefore was to investigate the nesting substrate preference of late-nesting Common Terns by providing them with a choice of substrate types. We provided 2 new sub-

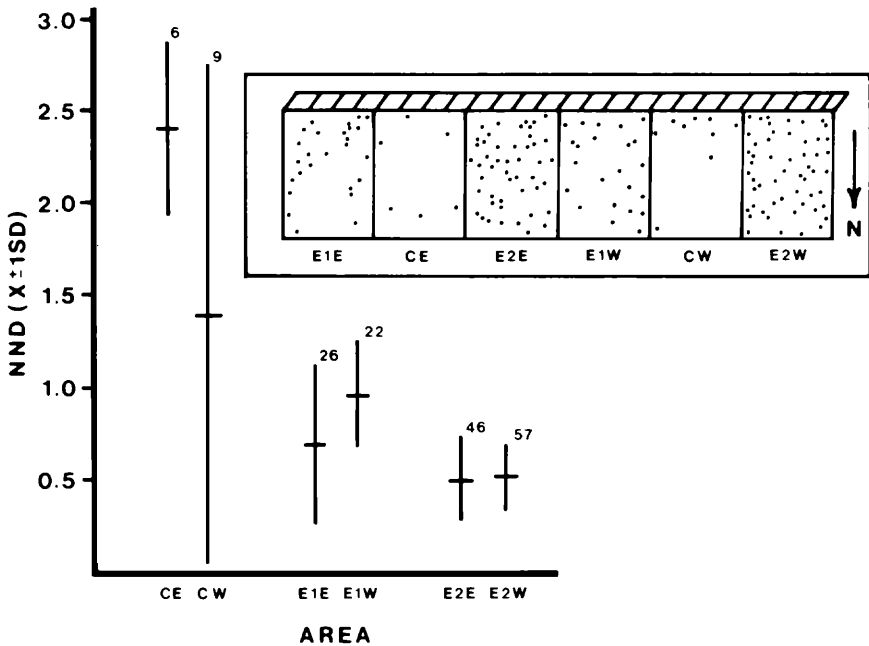


FIGURE 1. Nearest-neighbor distances for Common Tern nests within each of the 3 substrate types. East (E) and west (W) replicates are shown separately. The inset shows the relationships of replicates to each other. Each of the 6 areas is  $5 \times 7$  m. Dots indicate nest locations. The cross-hatched portion represents the vertical wall at the south edge of the breakwall.

strate types at the east end of the breakwall where only bare concrete is normally available. Our intentions were (1) to measure differential occupancy by late-nesting terns on these areas, and (2) to compare the reproductive success of late-nesting birds settling on the experimental areas with that of control pairs (those occupying existing bare concrete sites).

#### STUDY AREA AND METHODS

The horizontal breakwall shelf (approximately  $9 \times 200$  m) is bordered on the south by a vertical wall about 1.4 m high. Our study site was about 100 m from the east end of the shelf, in an area occupied by terns after the west end has become saturated with nests (see Morris et al. 1976). The study site measured  $7 \times 30$  m and was partitioned into 6 equal sections, each  $5 \times 7$  m (inset, Fig. 1). We prepared 3 types of nesting substrates with 2 replicates of each. The substrate in the control areas (C) was bare concrete with scattered concrete chips, exactly the same as that along the east end of the shelf. Enhanced areas (E-1) were

TABLE 1. Measures of nesting substrate selection by Common Terns. The east and west replicates of each substrate type are combined.

| Substrate type <sup>a</sup> | Total clutches (n) | Nest density (nests/m <sup>2</sup> ) | Date range of first eggs (1982) | Date when 50% of total clutches were initiated |
|-----------------------------|--------------------|--------------------------------------|---------------------------------|--|
| C                           | 15                 | 0.21                                 | 29 May–2 July                   | 16 June  |
| E-1                         | 48                 | 0.69                                 | 30 May–2 July                   | 17 June  |
| E-2                         | 103                | 1.47                                 | 30 May–29 June                  | 7 June   |

<sup>a</sup> C = bare concrete, E-1 = gravel and small rocks, E-2 = gravel and small rocks, logs, and plants.

covered with a layer of small rocks and gravel, raked level to a depth of about 5 cm. Super-enhanced areas (E-2) were also covered with a layer of small rocks and gravel, but in addition, clumps (15–40 cm diameter) of Mossy Stonecrop (*Sedum acre*) and driftwood logs of various shapes and sizes were randomly distributed on top of the gravel. We prepared the study site from 24–29 May 1982.

We visited the study site daily in early morning or late afternoon from 29 May to 11 August 1982. The location of each new clutch was marked with a numbered tongue depressor and eggs were marked as they were laid. Laying and hatching data were obtained by walking to each nest, a procedure continued until the earliest hatched chicks became mobile. Thereafter, hatching and fledging dates were determined by nest checks from an elevated blind adjacent to the study site. On 7 July, 30 cm high chicken-wire fencing was erected along the borders of each substrate type to prevent chicks in the different areas from wandering among them. Chicks were counted as fledged if they were known to survive to 21 days of age (Morris et al. 1976).

## RESULTS

*Nest site selection.*—Although 171 clutches were laid on all three substrate types during the summer of 1982, most clutches ( $n = 166, 97.1\%$ ) had first eggs between 29 May and 2 July. We report here on these 166 pairs. The number of clutches on each substrate type was a principal measure of nest site selection by parents. The largest number of clutches was in the E-2 areas, followed by the E-1, and C areas respectively (Table 1). As all areas were exactly the same size, nest density varied directly with the number of clutches in each.

Nearest-neighbor distances (NND's) were measured for all nests within each of the 6 areas. NND's varied inversely with nest density (Fig. 1) but also reflected nest spacing (inset, Fig. 1) especially in C areas. There were no differences between NND's in the east and west replicates of the enhanced substrate types (Mann-Whitney U tests; E-1:  $z = .95, P = .17$ ; E-2:  $z = .23, P = .41$ ). In C areas, NND's in the east replicate were

greater than in the west replicate ( $U = 6, P < .05$ ). NND's in the pooled E-1 replicates were greater than those in the pooled E-2 replicates ( $z = 4.70, P < .001$ ).

To determine whether terns nesting on the E-2 substrates chose nest sites based on topographical variety, nests were scored according to location (i.e., within 15 cm of a log, within 15 cm of a plant, or on open ground). Nests in ambiguous locations (e.g., against the vertical wall or on the boundary between areas,  $n = 7$ ) were excluded from this analysis. The distributions of nests among the 3 locations were similar within each of the E-2 replicates (Chi-square  $r \times k = .32, df = 2, P > .8$ ). Pooled data from the 2 replicates revealed no preference for any of the nest site locations (Chi-square = 2.69,  $df = 2, P > .2$ ).

A further measure of nest site preference among the 3 substrate types was the timing of first eggs in clutches (clutch start). To examine the distribution of clutch starts within the various areas, we divided the laying period into 2 portions (early: 29 May–14 June, 17 days; late: 15 June–2 July, 18 days; Fig. 2). There were no differences in the distributions of early and late clutch starts in the east and west replicates of any of the 3 substrate types (Fisher and Chi-square tests,  $P > .1$ ). When east and west replicates of each substrate type were pooled, there was no difference between the clutch start distributions in C and E-1 areas ( $P > .1$ ). However, there were significant differences between the distributions in C and E-2 areas ( $P < .05$ ) and between the distributions in E-1 and E-2 areas ( $P < .001$ ). In other words, the majority of terns on E-2 substrates nested earlier than on E-1 or C substrates (Fig. 2). The timing of clutch starts was also assessed by the date when 50% of the total number of first eggs appeared in each of the 3 substrate types (Table 1). Half of the total number of first eggs in clutches were present in the E-2 areas by 7 June 1982, 9–10 days before a comparable proportion of first eggs in clutches appeared in the C and E-1 areas.

*Reproductive success.*—The modal clutch size in all areas was 3 eggs (Table 2). Clutches smaller than 3 eggs occurred in all areas, but larger clutches (4–5 eggs,  $n = 5$ ) were found only on the E-2 substrates. The relatively few 4- and 5-egg clutches are not included in comparisons of clutch size which follow.

As there were no differences between the distributions of clutch size in the east and west replicates of any of the substrate types (Fisher and Chi-square tests,  $P > .05$ ), the replicate data were pooled. The mean clutch size in the pooled E-2 replicates (Table 3) was larger than in either the pooled C or pooled E-1 replicates although the differences were short of the required level of significance in both cases ( $z = 1.32, .1 > P > .05$ ). The distribution of clutch sizes in E-1 compared to E-2 areas was different (Chi-square = 5.51,  $df = 2, .1 > P > .05$ ) with a greater proportion of 1- and 2-egg clutches on the E-1 substrates. These smaller clutch sizes, taken together as a proportion of all 3 clutch sizes, were 33.0% (C), 33.0% (E-1), and 25.5% (E-2).

The hatching success of 3-egg clutches was contrasted among the

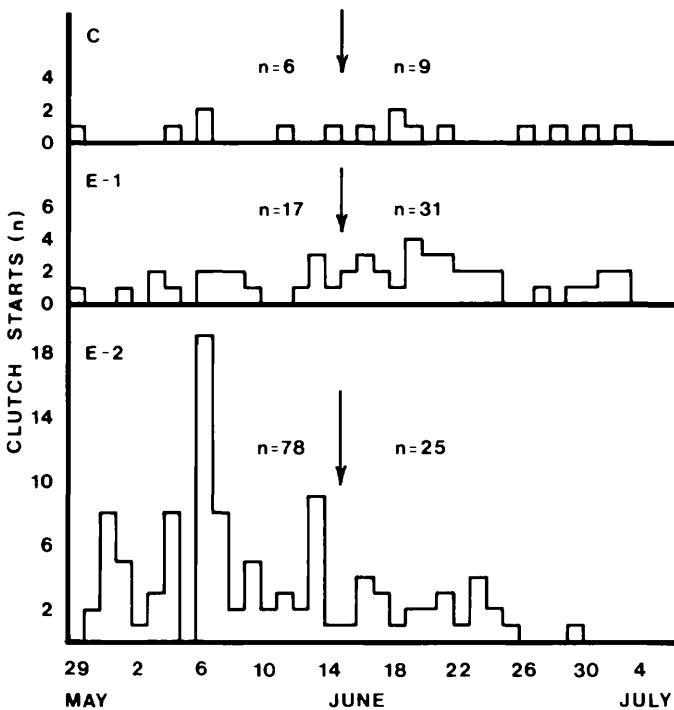


FIGURE 2. The distribution of clutch starts on the 3 substrate types between 29 May and 2 July 1982. Data from the 2 replicates of each type are pooled. The arrows show the date of separation of the laying period into 2 portions.

areas by comparing the number hatching no eggs against those in which at least one egg hatched. This procedure recognizes that eggs within a clutch are not independent units. There were no differences in hatching success of 3-egg clutches among the 3 substrate types. However, the same treatment of 1- and 2-egg clutches pooled revealed a significantly greater failure of whole clutches on the E-1 compared to the E-2 substrate types (Chi-square = 4.2,  $df = 1$ ,  $P < .05$ ). Numbers of clutches in the C areas were too small for testing. Whole 1- and 2-egg clutches failed to hatch in E-1 and E-2 areas due to the disappearance, desertion, or breakage of eggs. In E-1 areas, 8 of the 16 (50%) 1-egg or 2-egg clutches failed for these reasons compared to 6 of 25 (24%) in E-2 areas. A combination of these factors (disproportionate number of small clutches with a higher whole clutch disappearance rate) likely accounted for the lower hatching success of eggs in the E-1 egg pool compared to the other two substrate types (Table 3).

The number of chicks fledged per egg hatched was highest in E-2 areas, lower in C areas, but less than half these values in the E-1 areas (Table 3). On the basis of chicks fledged per pair, there was no difference

TABLE 2. The distribution of Common Tern clutch sizes in control and enhanced areas.

| Area             | Clutch size |    |    |   |   | Mean<br>( $\pm 1$ SD) |
|------------------|-------------|----|----|---|---|-----------------------|
|                  | 1           | 2  | 3  | 4 | 5 |                       |
| C-E <sup>a</sup> | 1           | 2  | 3  | 0 | 0 | 2.33 $\pm$ 0.75       |
| C-W <sup>b</sup> | 2           | 0  | 7  | 0 | 0 | 2.56 $\pm$ 0.83       |
| E-1-E            | 6           | 3  | 17 | 0 | 0 | 2.42 $\pm$ 0.84       |
| E-1-W            | 5           | 2  | 15 | 0 | 0 | 2.45 $\pm$ 0.84       |
| E-2-E            | 4           | 5  | 33 | 3 | 1 | 2.69 $\pm$ 0.64       |
| E-2-W            | 5           | 11 | 40 | 1 | 0 | 2.63 $\pm$ 0.64       |

<sup>a</sup> East replicate.

<sup>b</sup> West replicate.

in fledging success between the C and E-2 areas although the difference was just short of the required level of significance ( $z = 1.36$ ,  $.1 > P > .05$ ). Fledging success was higher in both C and E-2 areas than in E-1 areas (C vs E-1:  $z = 2.25$ ,  $P = .01$ ; E-2 vs E-1:  $z = 5.57$ ,  $P < .0001$ ).

Chick loss prior to fledging was due to known death or disappearance. Chicks which disappeared accounted for the majority of chick loss in all areas (C = 84.6%; E-1 = 93.3%; E-2 = 86.2%). Whole broods were never lost in any of the areas due to the known deaths of all chicks. However, a significantly greater number of whole broods of all brood sizes disappeared from the E-1 areas than from either the C (Fisher test,  $P = .04$ ) or the E-2 (Chi-square = 7.35,  $df = 1$ ,  $P < .01$ ) areas. There was no difference in the disappearance rates of whole broods from the C compared to the E-2 areas (Fisher test,  $P > .1$ ).

#### DISCUSSION

Both the total number and timing of clutches in the various areas indicated that late-nesting Common Terns favored the E-2 substrate followed by the E-1 and C substrates. This finding of a preference by terns for high relief or vegetated areas is neither new nor surprising. Each year at the Port Colborne colony, terns begin nesting on the western end of the shelf where grassy areas and debris predominate (Morris et al. 1976). In another experimental study at Oneida Lake, New York, Severinghaus (1982) examined nest site selection by Common Terns presented with 5 types of nesting substrate in parallel strips with 2 replicates of each type. The usual tern-nesting substrate at Oneida Lake is dried grass interspersed with stones of various sizes. Experimental substrates added were dried grass, small rocks, medium rocks, and large rocks. Common Tern nest densities were highest on the experimental dried grass sites followed by the usual nesting substrate. Relatively few nests were in areas with rocky substrates. Burger and Lesser (1978) found that about 80% of terns in New Jersey nested on piles of dried grass produced by wind action, although this substrate

TABLE 3. Reproductive statistics for Common Tern pairs nesting on each of the 3 substrate types. The east and west replicates of each substrate type are combined as are all clutch sizes. Four and 5-egg clutches ( $n = 5$ ) are removed from analysis of the E-2 data.

|   | Substrate type <sup>a</sup> |                 |                 |
|---|-----------------------------|-----------------|-----------------|
|   | C                           | E-1             | E-2             |
| Clutches (n)                              | 15                          | 48              | 98              |
| Clutch size (mean $\pm$ 1 SD)             | 2.46 $\pm$ 0.81             | 2.44 $\pm$ 0.84 | 2.65 $\pm$ 0.64 |
| Eggs hatched (n)                          | 32                          | 89              | 216             |
| Percent of eggs hatched                   | 0.86                        | 0.76            | 0.82            |
| Chicks fledged (n)                        | 19                          | 29              | 157             |
| Chicks fledged per egg hatched            | 0.59                        | 0.33            | 0.73            |
| Chicks fledged per pair (mean $\pm$ 1 SD) | 1.27 $\pm$ 1.09             | 0.62 $\pm$ 0.91 | 1.60 $\pm$ 1.05 |

<sup>a</sup> See footnote, Table 1.

accounted for only about 4.6% of that available. Finally, in a newly established Common Tern colony at the Eastern Headland (Toronto, Ontario), the majority of terns nested in or near broad bands of vegetation parallel to bare beaches (Blokpoel and Fetterolf 1978, Blokpoel et al. 1978). The attraction for terns of high relief, vegetated nesting sites is most likely related to the benefits of enhanced nest site recognition by chicks and adults, protection of chicks and adults against predators, and/or shelter from harsh weather conditions (Blokpoel et al. 1978, Burger and Lesser 1978).

Nearest-neighbor distances (NND's) and the timing of clutch starts were similar between replicates of each substrate type. The only case in which NND's were different between replicates was in the C areas. The greater NND's in the east replicate were a reflection of the different nest distribution patterns in the two locations (inset, Fig. 2). In the west replicate, most nests were in the southern half of the area adjacent to the vertical wall. This pattern prevailed along the entire shelf with nests established closer to the wall than to the water. The lower number and widely scattered pattern of nests in the east replicate was a consequence of the first 3 nests in this area being situated closer to the edge of the water.

The modal clutch size of Common Terns is 3 eggs and, at least at this colony, 2-egg clutches outnumber 1-egg clutches (Morris et al. 1976). This type of distribution was observed in the E-2 areas. However, in both C and E-1 areas, 1-egg clutches outnumbered 2-egg clutches and represented a greater proportion of the clutch size distribution than in the E-2 areas (Table 3). Courtney (1977), also working at the Port Colborne colony, found that in low nest density areas of gravel substrate with no vegetation cover, 1-egg clutches were more numerous than 2-egg clutches. The proportionately higher number of smaller clutch sizes on the C and E-1 areas in our study may be explained as follows. Two of the 3 (66.7%) 1-egg clutches in C areas and 7 of the 11 (63.7%) 1-egg clutches in the E-1 areas were never incubated and thus most likely

represent "dumped" eggs. Conversely, only 1 of the 9 (11.1%) 1-egg clutches in the E-2 areas was never incubated. More eggs may have been dumped in the C and E-1 areas because of the lower nest densities there. Since nesting Common Terns are able to recognize their neighbors (Austin 1940), the risk of attack for a strange female would be greater in more densely occupied areas.

Mean clutch size declines with season in Common Tern colonies (Nisbet and Drury 1972, Morris et al. 1976). The trend likely reflects a tendency for late nesters to be either younger birds or those renesting after first clutches (broods) were lost earlier in the season. In our study, birds nesting on all substrates laid first eggs on 29–30 May 1982, almost 1 month after first nesters at this colony (5 May 1982). In previous years, such later nesting birds had lower clutch sizes than earlier nesters (Morris et al. 1976). In 1982 however, the mean clutch size of birds nesting on the E-2 substrate was higher than those on the C and E-1 substrates. Furthermore, the mean clutch size of birds nesting on the E-2 substrates ( $2.65 \pm .64$ ) was statistically indistinguishable from a randomly chosen sample of clutches ( $n = 27$ ) produced between 8–15 May 1982 at the western (optimal) end of the colony (clutch size =  $2.69 \pm .68$ ). Although the E-2 areas were clearly preferred by late-nesting terns, none of the birds in the study area was marked. We are thus unable to comment on whether the larger clutch sizes in the E-2 areas resulted from the type of substrate there, or the type of bird (older, more experienced) which produced them.

It is equally difficult to determine the influence of nesting substrate on hatching success. We are unable to satisfactorily account for the lower hatching success of clutches started on the E-1 substrate type but note that a greater proportion of whole 1- and 2-egg clutches disappeared from E-1 than from E-2 areas. One possibility was the presence of Ruddy Turnstones (*Arenaria interpres*) observed in the study area in early June. Individuals of this species are known to break open Common Tern eggs (Parkes et al. 1971). We noted that disappearance of tern eggs was especially common following diurnal "panic flights" by adult terns which were most frequent on days following the presence of an owl in the colony on the previous evening. The greater exposure and visibility of tern clutches on the E-1 compared to the E-2 substrate types (i.e., no rocks, logs, ground cover) may have made them more susceptible to Ruddy Turnstone damage and have lowered the overall hatching success accordingly.

The majority (89.1%) of chick losses prior to fledging was due to disappearance, usually of chicks less than 5 days old. Disappearance rates were highest in the E-1 areas. While the obvious presence of high relief materials on the E-2 substrates provided cover for chicks, such material was not present on either the C or E-1 substrates. Differential disappearance rates of chicks on the E-1 compared to C substrates may have been caused by differential visibility of chicks on the two substrates. Tern chicks appeared to us to contrast more with the gray gravel substrates



in E-1 sites than with the bare concrete substrates in C sites. Herring Gulls (*L. argentatus*) prey on tern chicks and some individuals appear to specialize on tern chick prey (Hatch 1970). Although we observed only one incident of chick predation in our study area, predation on tern chicks elsewhere along the shelf was seen every 2–3 days after mid-June 1982 (pers. observ., V. Wai-Ping, D. Wiggins). We believe that predation by gulls and the attacking of wandering chicks by other Common Tern parents after departure of the gulls were responsible for the majority of chick disappearances at the study site. Such predation may have been especially damaging to chicks on the E-1 substrates.

Our experimental substrate enhancement procedures at the Port Colborne ternery resulted in an active selection of the enhanced sites by late nesting terns. Furthermore, pairs nesting on the E-2 substrates in 1982 realized a fledging success rate equal to that of earlier nesting terns in most other years (cf. Morris et al. 1976). We suggest that enhancement procedures, based on knowledge of preferred substrates at a particular colony, are valuable management tools for improving productivity of late-nesting Common Terns.

#### SUMMARY

The Port Colborne Lighthouse-breakwall complex supports the second largest breeding colony of Common Terns (*Sterna hirundo*) on the Canadian Great Lakes. Birds nesting early in a breeding season traditionally occupy a preferred substrate area (logs, rocks, ground cover) at the western end of the linear colony site. Later nesting birds occupy remaining, open concrete substrate sites to the east. An experimental study area was established at the eastern end of the breakwall in late May 1982. The area contained 2 replicates each of 3 substrate types (control—bare concrete; enhanced—small rocks only; super-enhanced—small rocks, logs, plants). Late nesting terns which occupied the area preferred vegetated, high relief nesting substrate (super-enhanced) similar to that at the western end of the colony. Few terns nested on the control sites (bare concrete), the traditional nesting substrate of late breeders at this colony. Mean clutch size, hatching, and fledging success were all higher on the super-enhanced substrate. Eggs and chicks disappeared at higher rates on the enhanced than on the super-enhanced substrates. We suggest that greater visibility of both eggs and chicks on the enhanced substrates (small rocks only) contributed to a greater loss rate due to predation than was the case on the super-enhanced substrates. Suitable substrate enhancement procedures, based on knowledge of preferred substrates at a particular colony, is a valuable management tool for improving productivity of late nesting terns.

#### ACKNOWLEDGMENTS

We are thankful for the logistic assistance and summer comradeship of John Chardine, Virginia Wai-Ping, and David Wiggins. Jack Boni-

stele (Lighthouse keeper) and Chuck Rutledge (Marina operator) were constantly available for advice and security. We thank Hans Blokpoel for comment on the manuscript. Financial support from the Natural Sciences and Engineering Research Council of Canada and the Canadian National Sportsmen's Fund (to RDM) is gratefully recognized. This paper derives from an Honors (B.Sc.) thesis completed by MHR.

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*Department of Biological Sciences, Brock University, St. Catharines, Ontario, L2S 3A1.* Received 18 July 1983; accepted 27 Mar. 1984.