Sources of variation in success of tern colonies on Sable Island: implications for management

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Summary

We conducted censusses, watched nests, and measured reproductive success at the colonies of nesting terns on Sable Island in the 2000 breeding season, to assess the health of the tern population and to see which sorts of colonies had higher reproductive success. We found that the number of breeding birds on the island was similar to the numbers reported since the early 1970s, suggesting that the population of breeding adults is relatively stable. Reproductive success varied among different colony sites. Colonies with more nesting pairs and on consolidated terrain tend to be more successful, but other factors are probably also important, since even these colonies varied in their success. We recommend further study of variation in nest success within the island's most successful colony near East Light, and a study of how terns might avoid storm wash-out and gull predation in some colonies on the west end of the island.
Sable Island now has one of the largest breeding populations of terns (Common, *S. hirundo,* and Arctic, *S. paradisaea)* in Atlantic Canada (Lock et al. 1993), and formerly contained much of the Canadian population of the endangered Roseate Tern, *Sterna dougallii* (Boates and Sam 1996). The total tern population declined drastically during the first half of the century, coincidentally with a general decline in tern populations throughout the northeast (Nisbet 1973, Lock 1989). Over the last two decades, the Sable Island population of terns has been stable, although reproductive success may be low and not self-sustaining. Roseate Terns, in particular, have

declined sharply, from about 60 pairs in 1969 to fewer than six by the 1990s (Horn and Shepherd 1999).

The reasons for these declines, and hence management options, are unclear. Predation from large gulls, *Larus* spp., may be a key factor, as it is elsewhere in the northeast (Nisbet 1973). However, the limited data available for Sable Island show strong variation in levels and sources of chick mortality among different colonies on the island, perhaps because of differences in vegetation, topography, or proximity to gull colonies (Horn and Shepherd 1999, A. Lock pers. comm.). Identification of favorable colony features will allow managers to enhance those features on Sable Island. It win also be useful for tern conservation efforts throughout Atlantic Canada, because inter-colony variation in success have only been studied on a state- or province-wide scale elsewhere, in situations where data are difficult to collect and experimentation is impossible (e.g., Burger 1984, Howes and Montevecchi 1993, Kirsch 1996).

The main goals of this study were to census the terns on Sable Island, identify sources of chick mortality, and attempt to explain variation in nesting success among colonies across the island, in order to develop recommendations for an experimental management program for the 2001 breeding season.

Methods

In order to avoid disturbance of breeding adults, we entered colonies no more than once every three days, never during heavy fog, rain, or cold weather, and never for more than 20 min (as recommended in Bibby et al. 1992).

Censuses

On 22-25 June, we visited colony sites that were known from previous years (Horn 1998) and conducted flush counts by walking slowly to the edge of the colony and waving our arms, repeatedly counting the number of birds in the air. Flush counts through the breeding season on Sable Island in 1998 (Horn and Shepherd 1999), as well as at other study sites (Bibby et al. 1992), show that a census at this stage of the breeding cycle (late incubation) yields the highest count of breeding adults. Videotaped flush counts of this kind on Sable Island in 1998 showed a median error (film count-field count/field count) of -6 % (range - to +31% per colony).

Particular emphasis was placed on locating Roseate Terns at the colonies, both by scanning specifically for roseates during flush counts and by visiting each colony at least three times spaced through the study, specifically to scan for incubating roseates. All individual terns loafing on the shoreline of the entire island were also censussed and aged during the count period.

One colony (4 in Fig. 1, near East Light) was too large for an accurate flush count, and covered too wide an area for the photographic flush count that has been used at that site in previous years (e.g., Horn and Shepherd 1999). Instead we conducted a nest count of this area by marking all nests in two 10 in wide strip transects across the colony, then recounting marked and unmarked nests on a repeat count of each strip to derive a mark-recapture estimate of the true number of nests in the transect (using the Lincoln-Peterson index; Bibby et al. 1992). The location of the transects was selected to reduce disturbance of the colony (edge of colony) and to be readily identifiable on aerial photos (along a fence line).

Previous studies have used various conversion factors to convert the number of adults counted during flush counts to a number of breeding pairs, usually ranging from 1.5 to 2 (Bibby et al. 1992). At three colonies, we were able to count incubating adults from a high dune overlooking the colony, and to compare that figure with the number of adults we counted using a flush count (Bibby et al. 1992). The ratios of flying adults to sitting birds were 160/87 (1.84), 40/20 (2.00), and 20/12 (1.67), suggesting that the correct conversion factor is between 1.5 and 2. Since we suspected that we did not see all the nests in these colonies, we use the more widely recommended factor (e.g., Bibby et al. 1992, Boates et al. unpubl. ms) of 1.5 here.

We searched for new colonies throughout the study period.

Measurement of *reproductive success*

Our central concern in measuring reproductive success was to cause as little disturbance to the terns as possible. In particular, the standard method of measuring tern reproductive success, i.e., fencing of nest sites to contain chicks (Nisbet and Drury 1972) does not work on Sable Island because the fencing trips up horses and may harm both horses and terns (A. Lock, Z. Lucas pers comm). Therefore we marked 6-10 nests with tongue depressors placed 15 cm. away and labelled with numbers that could be read from a vantage point at least 50 m outside the colony. In three colonies with particularly high grass, we marked nests with 50 cm. surveyor stakes placed 1 m away from the nest, although for future studies we do not recommend this method since at one colony horses appeared to use them as scratching posts.

When we marked the nests, we noted their clutch size and determined their age by flotation (Hays and LeCroy 1971). Clutch size data are included only for clutches that were between five and 17 days into incubation, since other clutches might be incomplete or partly hatched.

The observation nests were watched for one hour every three days during late incubation and early chick rearing to obtain the following data: nest contents (if visible), number of feeding visits by parents, prey species provided (if visible), parental nest attendance, number of gulls within 20 m of the colony edge at the start of the watch, number of gull flights over the colony and hunting in the colony ("overflights"' and "hunting flights"), number of intrusions by horses, and number of upflights (either "panics" or "dreads"; Burger and Gochfeld 1991) by the colony.

Results

Censuses

We censussed a total of 1494 pairs of terns from 19 colonies (Fig. 1). Approximately 10 % of the birds (142 pairs) were Arctic Terns, and four were Roseate Terns. Most colonies ranged from 4 to 83 pairs, except for two larger colonies that contained 103 and 785 pairs each, the first just north of Wallace Plain and the second near East Light.

We counted 559 individuals loafing on the beaches, 64% of which were first summer Arctic Terns, and one of which was an adult Roseate Tem.

Reproductive success

Mean clutch size for the entire island was 2.6±0.06 (N=91) for Common Terns and 2.1±0.18 (N=10) for Arc-tic Terns. There was no difference in the proportion of two versus three egg clutches between the colonies on the sand or marram-dominated habitats on the east and west ends of the island versus the heath or fescue dominated habitats in the more consolidated areas toward the middle of the island (Common Terns only; G=0.01, df=1, P=0.92).

Ten out of the 19 colonies are likely to have successfully fledged young. Of the rune colonies that failed, six failed during incubation and three within the first five days after hatching (Table 1). Predation was not directly observed at these colonies, however other evidence strongly suggests they were depredated by gulls. Three of the failed colonies had gull intrusions above the 0 to 2 intrusions per h seen at most colonies *(3, 5.5,* and 12 intrusions per h), and searches of focal nest sites in these colonies immediately after they failed revealed no dead chicks or abandoned eggs (Burger 19%).

We obtained success data on eight of the partially successful colonies (Table 2). Nest success (i.e., percentage of nests raising at least one chick to five days) ranged from 20-100 % (Table 2). Abandoned eggs or dead chicks found in most of the nests in these colonies, together with the tendency of predation to sweep through entire colonies (Horn and Shepherd 1999), suggested that nest failures in these partially successful colonies were not due to predation. Exposure is a more likely cause of total nest failure in most of the colonies, because 58 % of failed nests (N=31) failed during the last half of incubation or the first two days after hatching. A likely cause of partial, as opposed to total, nest failures was starvation, because many large chicks were found in the final walkthrough of the colonies, especially in the largest colony, where 16 large (>10 d old) dead chicks were found in the core area (which had contained 58 nests).

We did not observe establishment of any new colonies after initial colonies failed, although this may have been because we left the study site relatively soon after the failures. In two colonies (8 and 12; Fig. 1), numerous new clutches within the colony suggested that colony members renested within the colony after nest failure.

Foraging

Nearly all the food that adults brought to chicks and mates was sand lance (161 out of 162 deliveries', or 99.4%; the single exception was an unidentified fish). Observed provisioning rates were generally low (1.8+0.22 feeds per h, N=32 nests with > 0 feeds per h), and the range of variation in the data was too low to test for associations between provisioning rates and other variables, such as colony success.

Intrusions by gulls and horses

Gull intrusion rate varied from 0 to 12 intrusions per watch; on average, 40 % (±0.9 %, N=29 watches with intrusions) were hunting flights (i.e., zig zag flights over nest sites, within 10 m of the ground; Horn and Shepherd 1999). The mean number of gulls present at colonies at the beginning of watches did not correlate with the mean number of intrusions at that colony (r_s=0.34, df=18, P=0.26), suggesting that the number of gulls present at a colony may be a poor predictor of the likelihood of intrusions.

Horses entered colonies on only four occassions at three colonies, when one or two horses passed through the edge of the colony without staying more than five minutes and without treading on any nests. This rate of intrusion was too low to justify relating horse intrusion rate to reproductive success.

At another colony, outside our regular watch schedule, we saw horses knock over surveyor stakes that we had used to mark nests, apparently trying to scratch themselves against them. They had deviated their route toward the stakes as they approached the colony, suggesting they may have been attracted into the colony by the presence of these scratching posts.

Relationship between colony characteristics and reproductive success

Colony success did not appear to vary consistently with vegetation type (Table 1). For example, 4 out of 10 colonies in sand or marram were successful, compared with 6 out of 9 in heath or mixed vegetation ($X_{corr}2=0.5$, P=0.48). Also, a subjective vegetation density score (O=sand, 1=sparse fescue or marram, 2=dense marram/beach pea, 3=mixed marram & heath, 4=heath, 5=dense mixed with a deep mat of dead vegetation) did not correlate with the percentage of nests raising at least one chick to five days ($r_s=0.26$, df=18, P=0.32; Fig. 2).

The percentage of nests successful to day 5 also did not correlate with lay date ($r_s=-0.20$, df=16, P=0.48) or rate of gull intrusions ($r_s=-0.23$, df=13, P=0.42; Fig. 2). This measure of colony success did, however, increase significantly with colony size (i.e., number of breeding pairs; $r_s=0.77$, df=18, P=0.0003; Fig. 2).

Discussion

Population size

The census of both breeding and loafing terns was similar to other similar censusses conducted in the 1990s, supporting Horn and Shepherd's (1999) conclusion that Sable Island's population of breeding terns has remained stable since the 1970s, at between 1300 and 1700 pairs, including about 10 % Arctic and fewer than six pairs of Roseate Terns.

Depending on the error of these population estimates, a population decline might have to be substantial before it is detected. We did not formally evaluate the error in our estimate, but it is likely to be similar to that of Horn and Shepherd (1999), who used similar methods, and had a measurement error of at least 10 % and a sampling error of at least 5 %. Thus, using present methods, the population would have to drop by at least 15 %, or about 200 pairs, before a decline would be detected. This low sensitivity of population counts, combined with the long life span of breeding adults, mean that censusses alone are likely to be a poor measure of the health of this population of terns.

Variation in colony success

Reproductive success was higher in 2000 than dunng a similar study in 1998 (Horn 1998, Horn and Shepherd 1999). Low reproductive success in 1998 was attributed to storms and gun predation in 1998; in 2000, the weather appeared to us to be less severe, and we could not attribute any nest failures to storm wash-outs. In turn, because fewer colonies failed completely, there was more variation in reproductive success within colonies caused by other factors, such as starvation or exposure. As at other study sites (Burger and Gochfeld 1991), reproductive success across Sable Island probably varies dramatically from year to year, so that any generalizations about reproductive success from one year's data should be made cautiously.

In 1998, Horn and Shepherd (1999) found a strong association between colony placement and success. Colonies on the east and west spits all failed due to storm wash-out and gull predation. Of the remaining colonies, colonies with some heath vegetation were the only successful colonies. Horn and Shepherd (1999) hypothesized that successful colonies were those that offered firm substrate against storm wash-outs and high vegetation for hiding from predators.

Our data from 2000 partially support this hypothesis. Most colonies in marram, sandwort, or sand on the east and west spits failed, most likely due to gull predation. However, a large colony in marram grass on the west spit was one of the most successful colonies on the island, and four out of the 12 colonies on consolidated terrain failed completely. Overall, we found no clear relationship between vegetation or location and colony success in 2000. Part of the difference between years may be that 1998 was particularly severe for terns; losses to gull predation and storms were high across the province in that year (Horn and Shepherd 1999). Variation in colony success may be easier to explain in years when colony success is an all or nothing phenomenon.

The one variable consistently associated with colony success in both 1998 and 2000 is colony size. This may be because more birds settle where their success is likely to be higher, or because colony size has a direct positive effect on reproductive success. Larger colonies have been shown elsewhere to improve foraging success and protection against predators, with both benefits outweighing the costs of increased aggressive interactions and food stealing (Burger and Gochfeld 1991).

Implications for management

The main decline in the number of breeding terns on Sable Island occurred in the first half of the 20th century, paralleling the decline of terns throughout the northeastern United States. Stable numbers of breeding adults over at least the last two decades suggest that the population on Sable is not currently in crisis. Any management effort would therefore presumably be directed at restoring tern numbers to their pre-1970s levels; i.e., enhancing the island's suitability for terns, rather than maintaining its current population. Sable Island, with its isolation from the mainland and formerly high population of terns, would seem to be an ideal location for creating a tern refuge (Lock 1989), provided its suitability can be enhanced without damage to the other components of Sable Island's ecosystem. Given the terns' relatively specific habitat requirements and localized distribution on the island, this should be possible. Two management options discussed, but not necessarily recommended, here are gull control and habitat management.

Gull control

Gull control has been an essential feature of tern restoration programs throughout the northeast, and was prescribed for Sable Island by CWS in the early 1990s. Current CWS guidelines require that tern populations be in crisis before gull control is implemented (Canadian Wildlife Service 1992). On Sable Island, however, the number of breeding terns appears to have been stable over the last two decades, despite the presence of gulls and high levels of predation in some years. The gull population on Sable also appears to have been stable on the island during that time (Horn 1998). Indeed, in the decade since gun control for Sable Island was originally proposed, the demographic surge of gull populations in the northeast appears to have reversed, due to the decline of fisheries and to new landfill regulations (e.g., Howes and Montevecchi 1993, Chapdelaine 1995). Thus the population of terns on Sable Island may have reached a new equilibrium that, because of gulls, is lower than the tens of thousands of terns known in the last century, but is nevertheless stable.

One factor that may have contributed to the tern's survival in the face of gull predation is the presence of colony sites that are relatively safe from predators. The consistent success of the large colony at East Light in the face of heavy losses elsewhere, suggests that, given the right conditions, terns may be able to avoid heavy gull predation. Here and at some of the other partially successful colonies, reproductive success may be low in some years (e.g., 1998), but chicks are safer from predation than they are on either spit Two factors that likely enhance safety from predation are large colony size, which increases vigilance and group defense (Burger and Gochfeld 1991), and dense vegetation in which chicks can hide. Both of these factors are amenable to further observation and experimental manipulation. The success of one colony in marram-beach pea on the west spit (colony 19, Fig- 1), however, suggests that other habitat factors may also enhance protection for gulls, and are worth further study.

Habitat enhancement

We have not identified all the features that lead to reproductive success on Sable Island, but dearly large colonies on established terrain are preferable to small colonies on shifting sand, because they reduce the likelihood of predation or exposure or for some as yet undetermined reason. Because of the importance of colony size to reproductive success, increasing the size of colonies at a few preferred sites seems a better management option than attempting to establish several new colony sites.

In choosing these few sites, yearly settlement patterns should be considered. Several colony locations on Sable Island, particularly some in the central, consolidated terrain, have been fairly constant over the last two decades (Horn 1998). Given this strong effect of "tradition" on settlement patterns, any attempt to attract terns to other locations seems unlikely to succeed. At the same time, some of these "traditional" locations vary both in their popularity with the birds and their success, once chosen. The birds may be responding to their success in the previous year, moving locations if they had poor success in previous years, as has been found for other populations of Common Terns (Burger 1984) and for Least Terns (S. antillarum, Kirsch *1996).* Thus the most promising sites for attracting nesters are those which are not only "traditional" sites, but have also had high success in the year immediately before enhancement.

Of all the colonies on the island, the large colony at East Light seems to be the only one to fit these criteria for a program of habitat enhancement It is the only colony to be consistently successful in *1998* and 2000, and to have been occupied consistently since at least *1983.* It is also the only colony in which gull predation was not detected in *1.998* or 2000. Even without any management intervention, between *1998* and 2000, the terns expanded the area of the colony beyond the fenced exclosure that contained almost the whole colony in 1996-1998 suggesting that they may settle there again in large numbers in 2001. Indeed, in its currently expanded form, the colony provides a wide range of nest sites that would provide data on the relationship between nest site selection and reproductive success, and may be large enough to allow manipulative experiments, albeit on a small scale.

Conclusion

PartiaI success of colonies on consolidated terrain with at least some dense vegetation suggests that a study of variation in success among nest sites within one of these colonies would be useful. At the same time, factors that might allow evasion of gull predation in marram-dominated terrain on the west end of the island deserve more study, since encouraging vegetation growth (as dense as found, say, in the East Light enclosure) across the whole island is clearly an impractical management option.

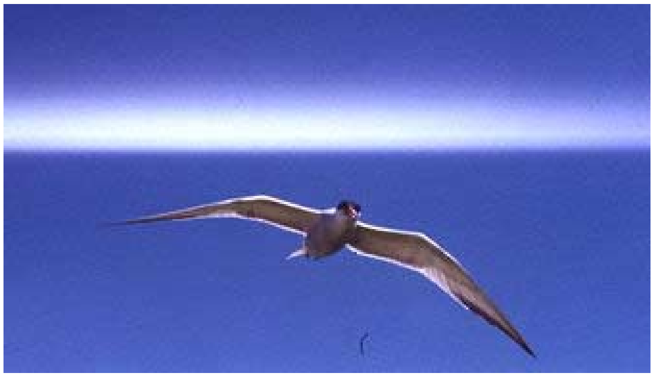

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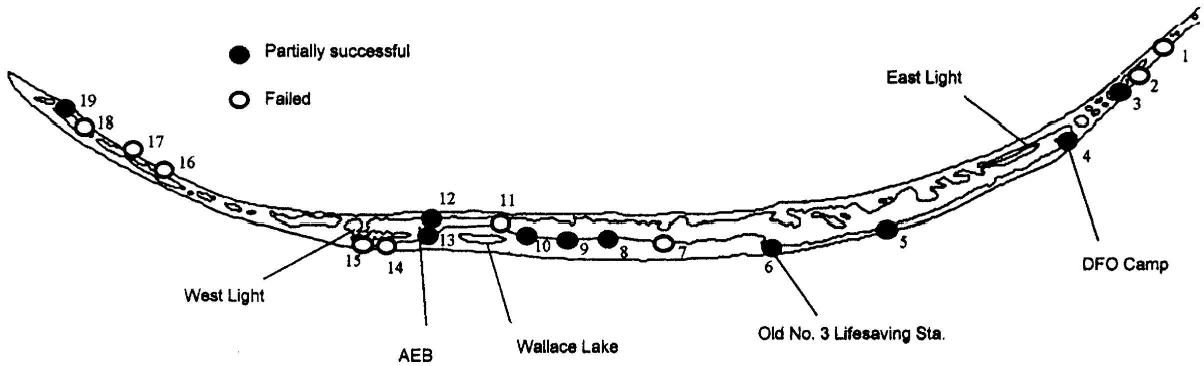
Table 1. Fate of colonies in relation to vegetation and colony size.

Colony	Vegetation (and density rank)	Breeding pairs	Success/fail	Stage of failure
East spit				
1	Sand	17	Fail	Incubation
2	Pea-marram	33	Fail	Hatch
3	Pea-marram	27	Success	--
Middle				
4	Marram	785	Success	--
5	Heath	29	Success	--
6	Marram	67	Success	--
7	Mixed	17	Fail	Incubation
8	Mixed	77	Success	--
9	Mixed	103	Success	--
10	Mixed	40	Success	--
11	Mixed	27	Fail	Hatch
12	Fescue	83	Success	--
13	Fescue	67	Success	--
14	Heath	13	Fail	Hatch
15	Pea-marram	4	Fail	Incubation
West spit				--
16	Marram/sand	11	Fail	Incubation
17	Marram/sand	10	Fail	Incubation
18	Marram	47	Fail	Incubation
19	Marram	37	Success	--

Table 2. Fate of nests in partially successful colonies.

		% depredated during:		% successful (to day 5)
Colony	N	Incubation	Nestling	
4	28	3 %	7%	90%
6	5	0 %	80%	20%
8	8	37 %	38%	25%
9	11	0 %	36%	64%
10	9	0 %	11 %	89%
12	16	31 %	25 %	44%
13	10	40 %	0%	60%
19	7	0 %	0%	100 %

Fig. 1. Map Of Sable Island showing distribution of tern colonies.



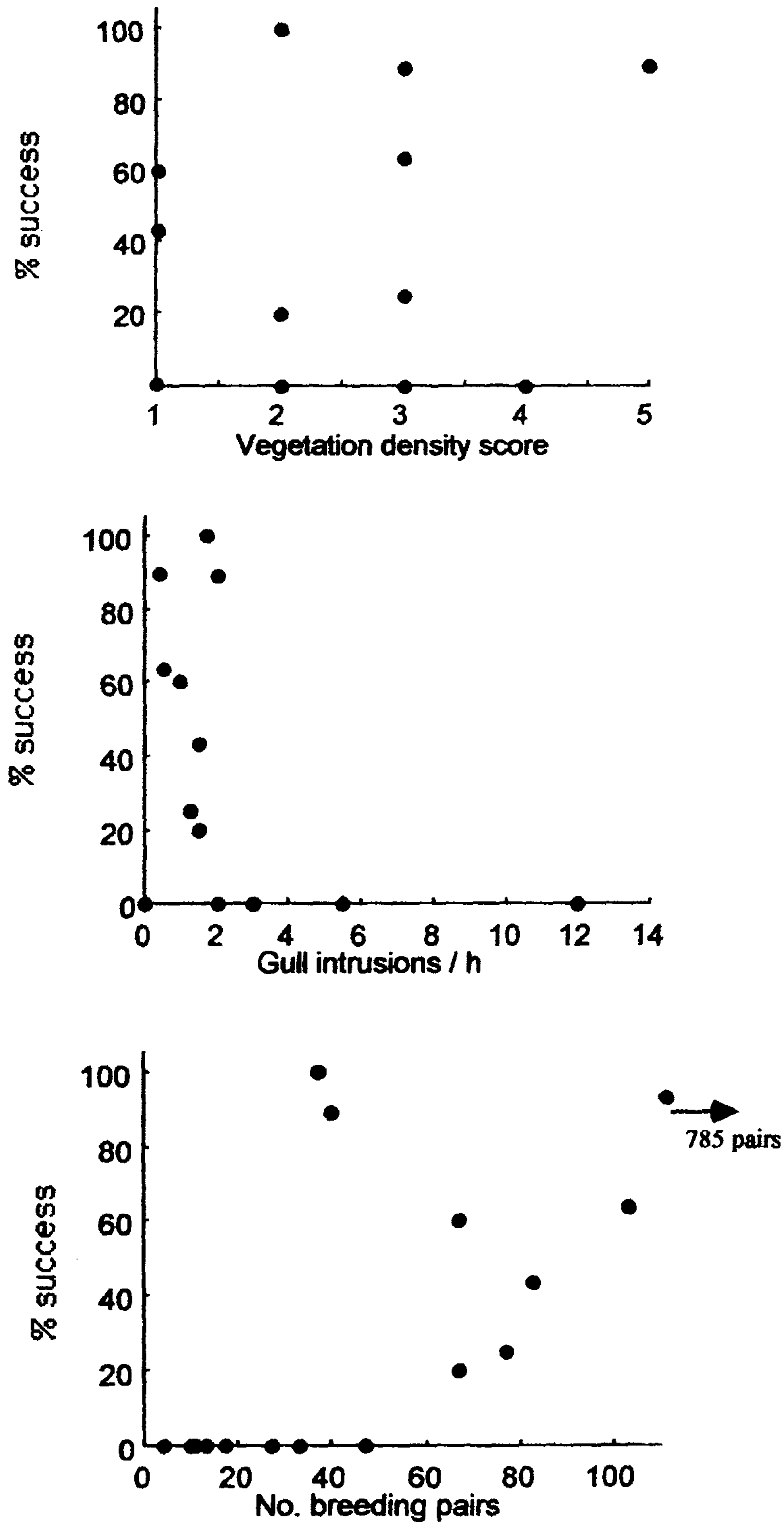


Fig. 2. Relationship between percentage of nests that raised Young to the age of five days and vegetation density score, mean gull intrusion rate, and colony size.