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DIEL CHANGES IN NUMBERS OF SEABIRDS OCCUPYING CAYS ON THE SWAIN REEFS, GREAT BARRIER REEF, AUSTRALIA

BY

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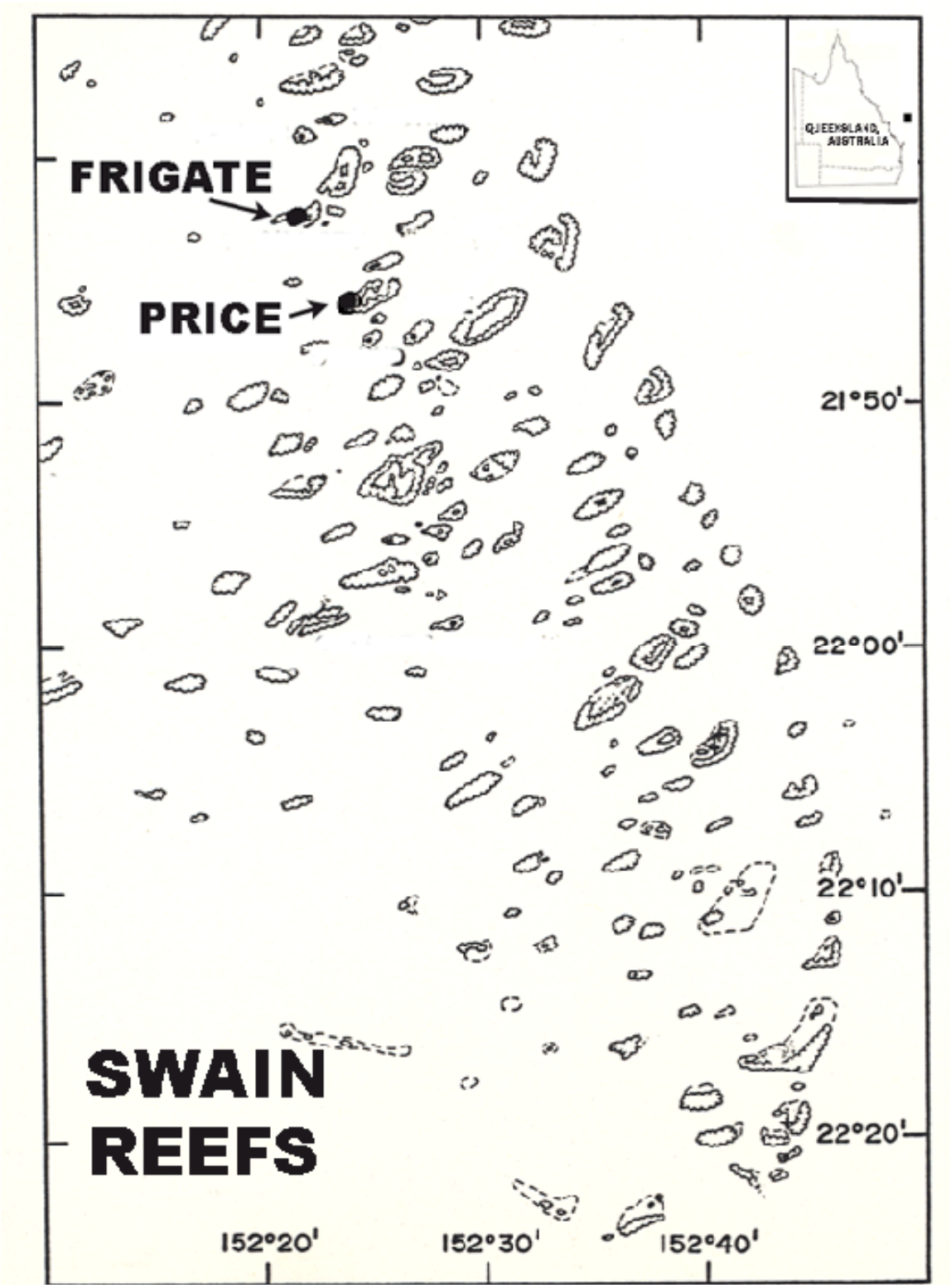

Figure 1. Map of the Swain Reefs showing Frigate and Price Cays. The black rectangle in the small inset in the upper right hand corner shows the location of the Swain Reefs in relation to Australia.

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ABSTRACT

Seabirds were counted during four 24-hour periods, two in summer and two in winter, on each of two cays (Price Cay and Frigate Cay) in the Swain Reefs, Great Barrier Reef, Australia. There were six breeding species of seabirds and 13 nonbreeding ones. Each species showed its own pattern of diel change in number of individuals on the islands, some being more numerous by day, others by night. For a given species, there were differences between seasons and between islands.

INTRODUCTION

There is a kaleidoscope of both positive and negative ecological interactions between seabirds and coral cays on the Great Barrier Reef (Heatwole, 1976, 1989, 1990, 1994; Heatwole and Saenger, 1989; Heatwole and Walker, 1989). Islands provide roosting and nesting platforms, and the structural variability of insular vegetation meets the nesting requirements for an array of bird species of varying habitat requirements (Heatwole *et al.,* 1981).

Seabirds are a major link in the nutrient cycling of coral cays. They capture organic matter in the form of fish and marine invertebrates over a wide expanse of sea and concentrate it, as guano, carrion and food scraps, on the cays thereby permitting the establishment of a scavenger-based food chain of terrestrial animals (Heatwole, 1971) and enriching the soil to levels allowing establishment of plants not otherwise able to colonize. Birds also act as agents for dispersal of many plant species to cays. Finally, birds destroy plants by trampling and overenrichment with nutrients. Because of this multiplicity of interactions, assessment of the size and variability in bird populations is an important contribution toward an understanding of insular ecosystems. Such assessment is an essential ingredient in the formulation of management plans for the coral cays of the Great Barrier Reef, many of which are threatened with ecological deterioration due to escalating encroachment by humans.

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As part of a long-term investigation of the community ecology of the Swain Reefs, Great Barrier Reef, periodic daytime counts of seabird populations were conducted on seven islands over a number of years (Heatwole *et al*., 1996; O'Neill *et al.,* 1996). These were thought to be underestimates because at any one time a proportion of the population would be foraging at sea. Furthermore, some seabirds forage by night (Martin, 1990) and interspecific differences in foraging schedules could lead to variation in species composition and/or relative abundances among species over the diel cycle and seasonally. Appropriate corrections may need to be applied to data obtained diurnally. Indeed, Hunter and Morris (1976) suggested that restriction of observations to diurnal periods was inappropriate for studies of seabird colonies in view of the probable importance of nocturnal events. The present study was designed to: (1) describe the diel pattern of change in numbers of seabirds occupying two cays; and (2) assess whether that pattern changed seasonally.

STUDY AREA AND METHODS

Counts of all species of birds were carried out at varying intervals, but usually every four hours over part or all of the diel cycle. Two islands, Frigate Cay and Price Cay, each were investigated both in summer (January) and in winter (July). Observations on 28 January 1988 were carried out five days before the full moon, and those on 22 January 1987 seven days after the full moon. The two observation periods in July were conducted on nights two-to-three days from the dark of the moon.

Both islands are small, oblong cays of coral sand, each located on its own patch reef in the Swain Reefs, a complex lying in the Coral Sea at the southern end of the Great Barrier Reef about 200 km northeast of Cape Clinton on the central Queensland coast (Fig. 1). Frigate Cay is the second largest of the seven major cays in the Swain Reefs and has an area of 35,100 m^2 with a vegetated center of about 16,900 square meters. Price Cay lies 6 km to the southeast of Frigate Cay. It is 29,700 m^2 in area with the vegetated part 10,800 m^2. Except for a few shrubs of Octopus Bush, *Argusia argentea*, the vegetation mostly is low (30 cm or less) and consists primarily of *Boerhavia diffusa,* a perennial herb, and the grasses, *Lepturus repens* and *Thuarea tomentosa*. Plant cover on the vegetated part of Frigate Cay is 60-90%; plants are more sparsely distributed on Price Cay (cover 50-60%).

Upon arrival at an island, before anyone else was allowed ashore, a party of four persons circled the island in a dinghy, one person to operate the motor, one to record data, and two with binoculars to make independent counts of birds on the beaches. When those counts were completed, the party landed and completed the census by walking slowly from one end of the island to the other and counting the birds in the central, vegetated part. Counts for each section of beach or central area were compared between the two observers. Small differences between them were averaged. Large discrepancies (rare) resulted in a recount. Nocturnal censuses differed only by use of headlights to make counts and birds on the beach were counted from the island rather than from a dinghy.

RESULTS AND DISCUSSION

Total bird counts (Fig. 2) represent the composite of the patterns of abundance of the various component species. Total numbers were higher on both cays in the Austral summer than in winter and for both seasons higher on Frigate than on the smaller island, Price. The same applies to some of the counts of individual species described below. In summer, the total number of birds was highest at night or in early morning and decreased during the day. The changes were less marked in winter. On Frigate there was a decrease from the earliest count, but for the rest of the day numbers fluctuated at levels below 1000 birds. On Price, numbers remained relatively stable all day.

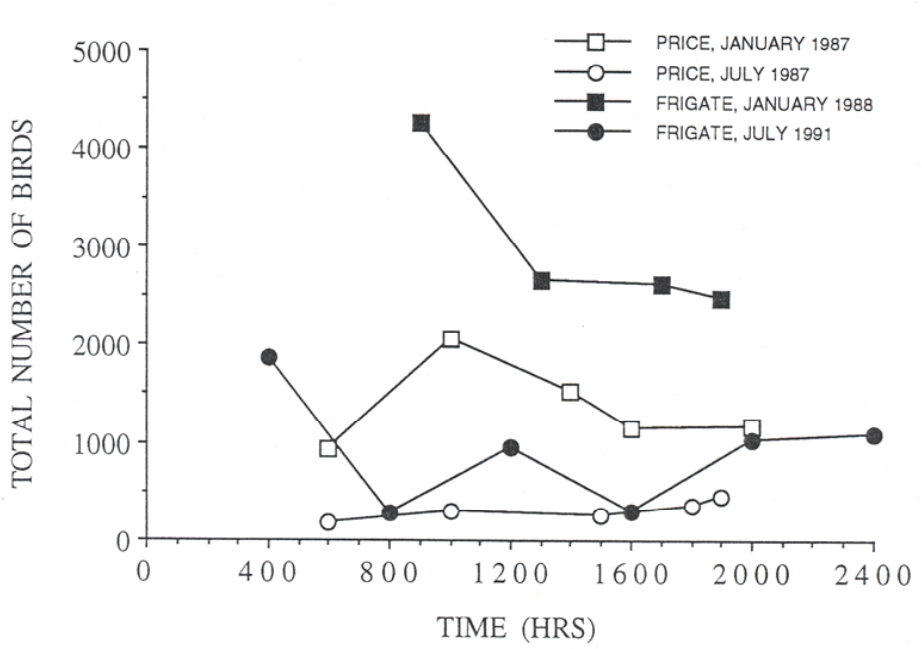

Figure 2. Total numbers of seabirds counted at different times of day and at different seasons on Price Cay and Frigate Cay.

The contributions to these patterns of each of the six species that nested during one or both seasons are now examined individually.

The Brown Booby (*Sula leucogaster*)

The numbers of Brown Boobies showed marked diel changes in summer (Fig. 3), their time of peak nesting in the Swains (Table 1). Numbers on Frigate were relatively low during the day as partners shared nesting duties, alternating between tending eggs of young and fishing at sea. With the return of many of the foraging birds in the evening, including unmated individuals that aggregated on the beach, and occupancy of the nest site by both members of mated pairs, numbers more than doubled (Fig. 3). In the winter, the resident population was smaller and the nocturnal increase was slight. On Price, there was even a decline in numbers in late evening. The decrease in numbers of Brown Boobies at night on Price Cay may be linked to the unusually high nocturnal increase

Table 1. Number of birds of breeding species roosting on vegetation compared to total numbers on cays during 24-hour censuses. Data on number of nests derived from Jones and Heatwole (in preparation).

LOCATION/DATE	SPECIES/TIDE	NO. OF NESTS	NUMBER OF BIRDS ROOSTING ON VEGETATION /TOTAL NUMBER OF BIRDS														
			0400	0600	0800	0900	1000	1200	1300	1400	1500	1600	1700	1800	1900	2000	2400
PRICE CAY	Brown Booby	200		119/210			219/416			212/290		121/135				144/356	
22 Jan. '87	Masked Booby	5		258/299			23/62			11/22		6/9				7/159	
	Silver Gull	0		0/22			2/32			3/19		14/26				1/1	
	Crested Tern	0		0/57			300/354			353/456		404/536				1/56	
	Common Noddy	85		250/295			400/580			310/332		92/236				600/660	
	Bridled Tern	8		5/5			40/40			24/26		18/18				156/156	
	STATE OF TIDE			Falling			Low			Rising		High				Falling	
PRICE CAY	Brown Booby	0		1/109			6/11				2/114			55/165	13/45		
23 July '87*	Masked Booby	24		51/53			26/31				19/19			54/82	49/92		
	Silver Gull	1		0/12			0/7				10/14			5/5	0/0		
	Crested Tern	0		0/0			0/120				0/48			0/18	0/0		
	Common Noddy	2		6/6			7/37				2/13			0/6	315/315		
	Bridled Tern	0		0/0			0/0				0/0			0/0	0/0		
	STATE OF TIDE			Rising			High				Low			Rising	High		
FRIGATE CAY	Brown Booby	79				119/232			96/261				86/357		66/766		
28 Jan. '88	Masked Booby	11				15/30			10/16				6/14		0/20		
	Silver Gull	0				0/15			2/30				0/19		0/0		
	Crested Tern	0				0/68			0/81				0/46		0/118		
	Common Noddy	603				930/1159			1123/1496				657/1006		370/1390		
	Bridled Tern	19				171/542			73/148				99/285		394/394		
	STATE OF TIDE					High			Falling				High		Falling		
FRIGATE CAY	Brown Booby	56***	172/258		130/149			96/184				103/219				197/297	198/306
14 July '91**	Masked Booby	42***	117/129		91/95			68/74				28/66				82/124	113/120
	Silver Gull	***	0/1		2/12			2/7				2/2				0/0	0/0
	Crested Tern	***	0/3		0/0			0/57				0/5				0/1	0/18
	Common Noddy	***	0/1353		0/0			0/311				0/0				571/572	3/543
	Bridled Tern	***	0/0		0/0			0/0				0/0				0/0	0/0
	STATE OF TIDE																

*Observations at 0600 and 1000 hours were made on 24 July.
**Observations at 0400 and 0800 hour smade on 15 July.
***Search for nests was not as thorough as on previous occasions because of gulls following humans and threatening nests. Where values are listed, they are minimum ones.

on nearby Frigate Cyhigh nocturnal increase on nearby Frigate Cay. Perhaps for this species, Frigate has better nocturnal roosting habitat for nonbreeding birds, e.g., broader beaches, and therefore at night attracts some of the individuals from Price.

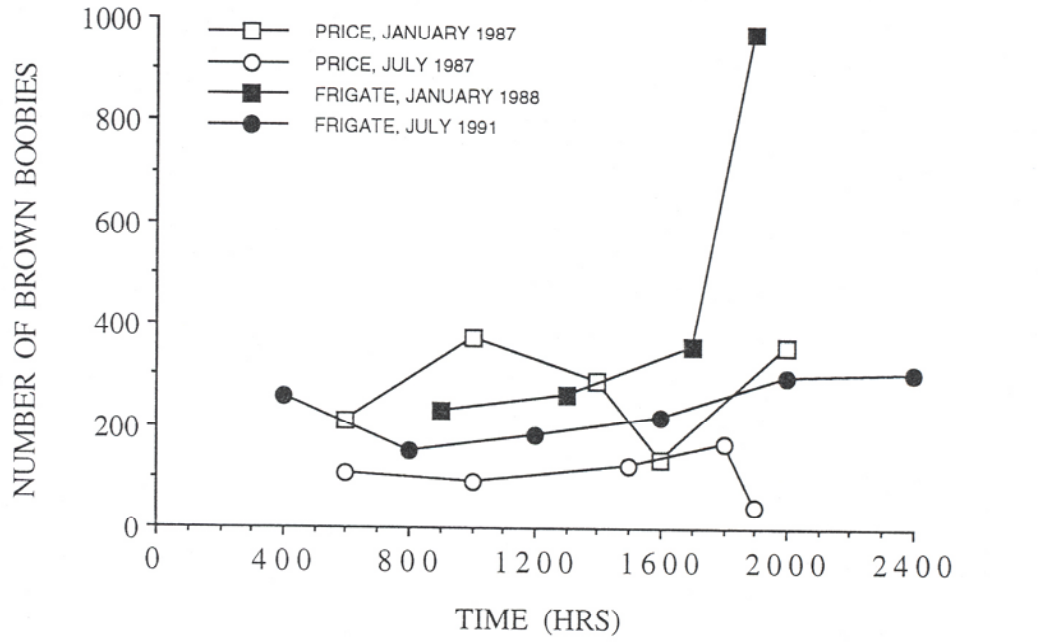

Figure 3. Numbers of Brown Boobies counted at different times of day and at different seasons on Price Cay and Frigate Cay.

The Masked Booby (*Sula dactylatra)*

The numbers of Masked Boobies were higher on Price during the Austral summer than in winter but the opposite was true for Frigate. In winter, Frigate had more birds than did the smaller island, Price, but this was reversed in summer. In both seasons the total number of birds tended to be higher at night and dwindle during the day to rise again after 1600 hours. These changes were less marked in the season with the lesser number of birds (winter on Price and summer on Frigate). Breeding of the Masked Booby in the Swains peaks in winter rather than in summer (Table 1; note that these results differ from those of King, 1993). A large number of nonbreeding individuals had assembled on Frigate in summer and, because few of them were attending nests at that time of year, numbers were low on the island by day but many returned in the evening from foraging at sea and were on the island at night (Fig. 4). Frigate had more Masked Boobies during the season of lowest breeding (summer) than during the winter peak of breeding, suggesting it may be more suitable as a roosting station than as a breeding ground. The opposite is true for Price where numbers were highest at the winter breeding peak. This species favors bare sand for nesting and the more open vegetation on Price may make a better breeding habitat than the denser vegetation on Frigate.

When Masked Booby chicks are small, one parent attends them during the day while the other forages. Radiotracking shows that adults do not forage at night although part of the return trip may take place after dark (Anderson and Ricklefs, 1992). Most delivery of food to young by returning adults occurs during the two-hour period preceding nightfall or just after dark (Anderson and Ricklefs, 1992). Accordingly, adults returning with food and then remaining on land accounted for the net accumulation of birds on the islands after 1600 hrs (Fig. 4).

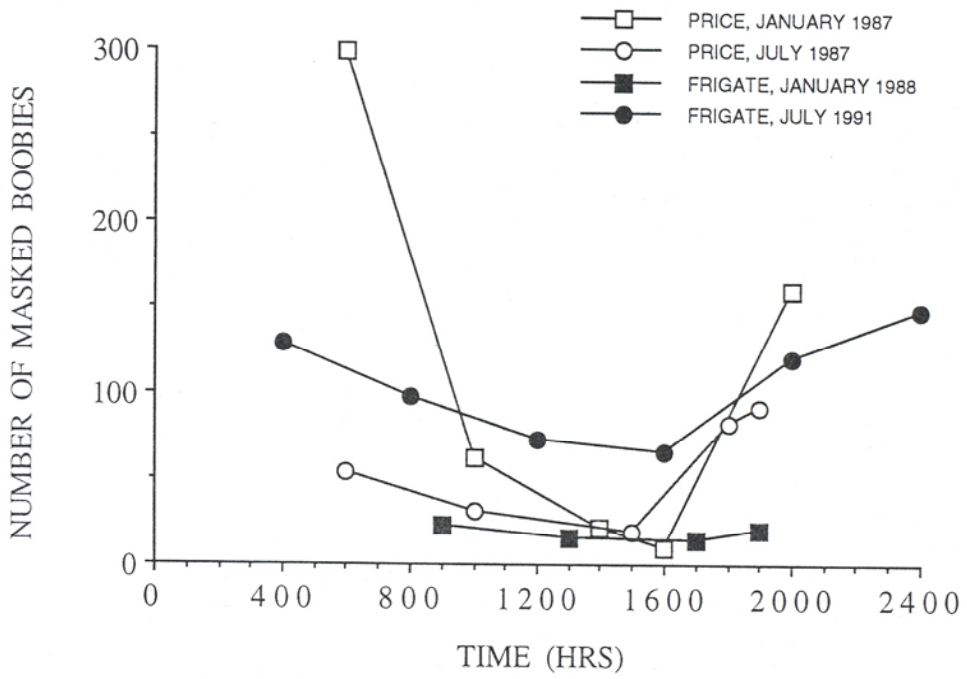

Figure 4. Numbers of Masked Boobies counted at different times of day and at different seasons on Price Cay and Frigate Cay.

An accumulation of birds at night in summer questions the validity of the migratory and/or seasonally dispersive behavior usually reported for the species (Marchant and Higgins, 1990). Analysis of 10 years of mark-recapture data for both Masked and Brown Boobies at the Swain Reefs (O'Neill *et al*., 1996) suggests that it is largely the young birds that disperse and that fidelity to breeding sites is strong.

Bird numbers were not related to the state of the tide in either summer or winter (Table 1), probably because Masked Boobies forage at greater distances at sea (Nelson, 1970; Anderson and Ricklefs, 1987) and would be less affected by tides than would inshore feeders such as some terns (see Hulsman and Smith, 1988; Domm and Recher, 1973). Birds left the island progressively during the day so numbers reached their lowest value just prior to the mass return after 1600 hrs (Fig. 4).

The Silver Gull (*Larus novaehollandiae*)

Gulls were present on the islands in greater numbers by day than by night. Indeed, during much of the night no gulls were present at all and must either have gone to sea or moved to a different island to roost. Alternatively, they may have been disturbed by the researchers before detection and may have flown to another island. Silver Gulls were found to be very sensitive to human disturbance at night during banding activities (M. Jones, personal observations).

Generally, numbers gradually increased during the day and then declined again toward evening (Fig. 5). The gulls were exceptional in consistently having as large a population on Price Cay as on Frigate Cay. On both cays, numbers in winter were lower than in summer, perhaps reflecting differences in their general abundance in the Swains at these times of year. Silver Gulls move among islands and between mainland and islands, tracking temporary food sources (Walker, 1988). They are predators of eggs and small chicks at tern and booby colonies (Walker, 1988) and consequently may have been attracted to these cays by the summer peak of breeding of terns and Brown Boobies (Table 1; Figs. 3, 5-7).

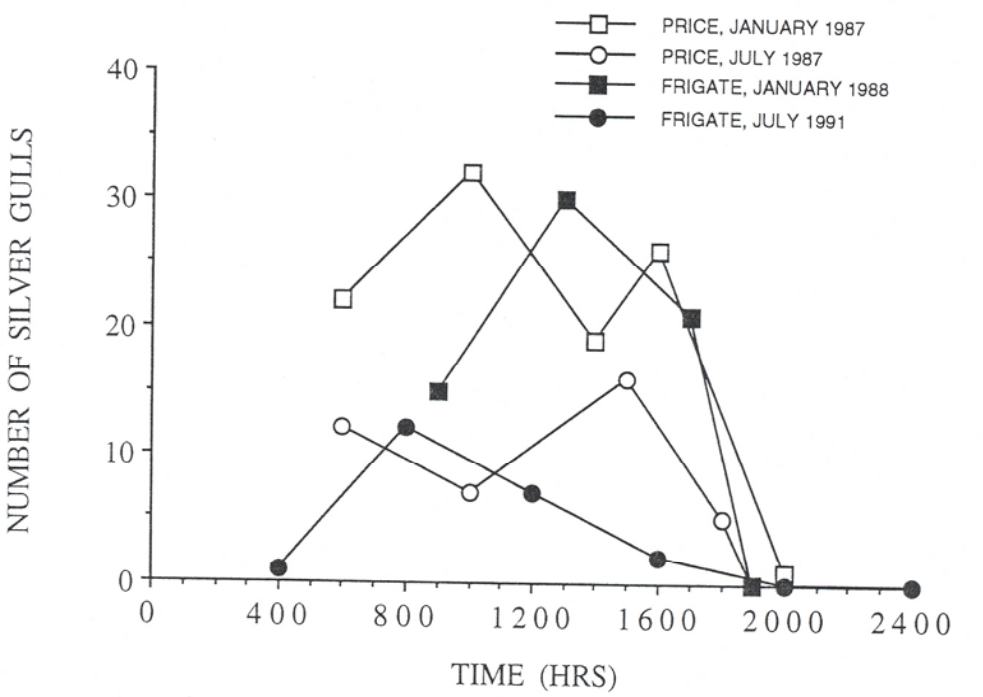

Figure 5. Numbers of Silver Gulls counted at different times of day and at different seasons on Price Cay and Frigate Cay.

Gulls were mostly scattered around the beach, singly or in twos and threes. This distribution may have provided them good vantage points from which to view birds returning with fish to feed their chicks (Hulsman, 1976). The exceptions were aggregations of gulls in the vegetated zone in the middle of the afternoon, the hottest

part of the day (Table 1). On Price in January and July 1987 and on Frigate in January 1988, such aggregations coincided with nesting species (Brown Boobies and Common Noddies in summer and Masked Boobies in winter) (Figs. 3-5, 7) having large numbers away from nests while foraging at sea. All eggs and small chicks of all nesting seabirds and the older chicks of small larids are vulnerable to predation by gulls.

The Crested Tern (*Sterna bergii*)

Unlike the other breeding species, Crested Terns nested in dense, localized colonies and roosted in large aggregations. They, like the gulls, were present during the day but absent, or in low numbers, at night (Fig. 6). Again, this may be because nonbreeding terns leave an island in response to disturbance by lights. The roosting pattern closely followed the tidal cycle with terns resting on the island during high tide. Hulsman (1974, 1977) found similar behavior in Crested Terns on One Tree Island. Crested Terns forage on shallow reefs close to the islands (Diamond and Prys-Jones, 1986). The resident population was much larger on Price Cay in January than at other times or places because about 500 terns were establishing a breeding colony. They were settling tenaciously in one patch on the edge of the vegetated zone but no eggs had been laid. Crested Terns will nest year-round in the Swains although fewer nest in winter (Walker and Jones, 1986). Gulls are an ever-present threat to eggs and nestlings by day and the terns may tend to feed at night when it is safer to leave their nests.

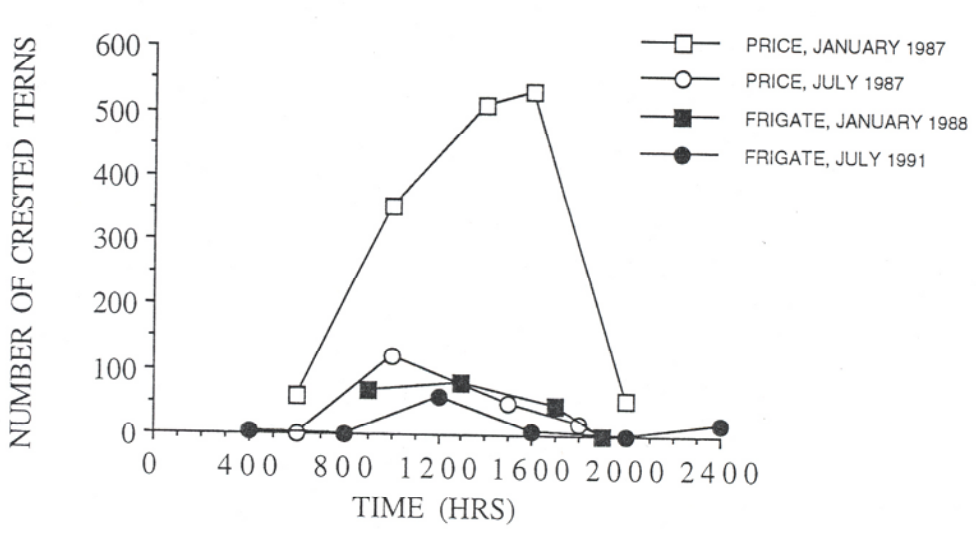

Figure 6. Numbers of Crested Terns counted at different times of day and at different seasons on Price Cay and Frigate Cay.

The Common Noddy (*Anous stolidus*)

Common Noddies are especially easy to count at night. Unlike many other larids, they do not fly away when spotted with dim light. Numbers were higher on both cays during summer breeding (peak nesting is November to March) than in winter, with many more birds and nests on Frigate than on Price during both seasons (Fig. 7), probably because Frigate provides denser vegetation in which nests can be concealed (Jones, unpublished). Common Noddies foraged in the early morning and afternoon and rested on the island in the hot, middle part of the day (Fig. 7). In contrast to many terns (Hulsman, 1974, 1977), numbers during the day were not related to the tidal cycle. This pattern of activity is similar to that of the closely related Black Noddies (*Anous minutus*) on One Tree Island (Hulsman, 1977). Common Noddies showed a distinct preference for roosting in the vegetation zone. For daylight roosting, this trend was more marked in the summer nesting season than in winter. Nearly all birds present at night on Price roosted in the vegetation during both seasons. Large numbers of nonbreeding Common Noddies roosted on the beach on Frigate in summer, although all breeding birds roosted at their nests (Table 1).

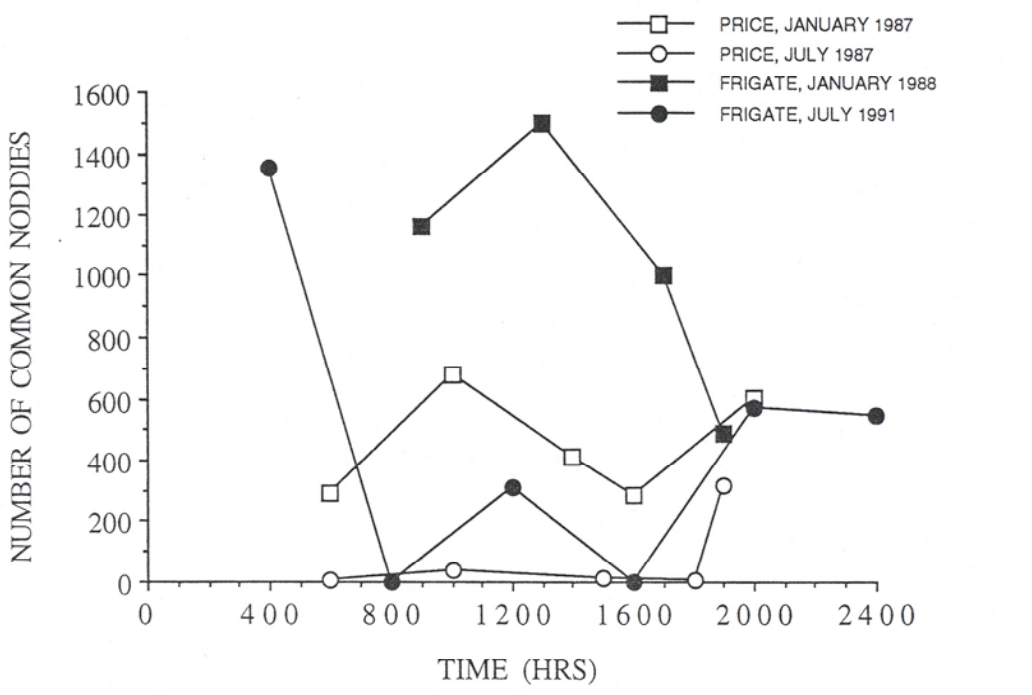

Figure 7. Numbers of Common Noddies counted at different times of day and at different seasons on Price Cay and Frigate Cay.

The Bridled Tern (*Sterna anaetheta*)

Bridled Terns were not present in winter but bred on both islands during summer (Fig. 8). Like Common Noddies, they were easy to see at night and generally stayed still when spotted by dim light. There were relatively few nests on either island but the large number of roosting birds on Frigate in summer (Table 1) suggests that they were preparing to nest there. In the absence of other shelter commonly used by this species for nesting elsewhere (e.g., rock crevices, under dead turtles), Bridled Terns on the cays of the Swain Reefs create small blind tunnels under the dense vegetation and lay their eggs there. This habit could significantly reduce the chance of gulls finding the nests. The denser vegetation on Frigate provided more suitable nesting habitat than occurs on Price. Numbers on Frigate were lower during the day when birds were away foraging, but increased dramatically at night. Numbers on Price were low at all times and actually decreased at night. Perhaps birds use Price as a daytime roost while fishing but roost at night on Frigate where they are preparing to nest. However, with only one exception, there were always more birds present in the vegetated zone of both islands than there were on nests (Table 1). There was a distinct preference for roosting in the vegetated zone regardless of island or time of the diel cycle.

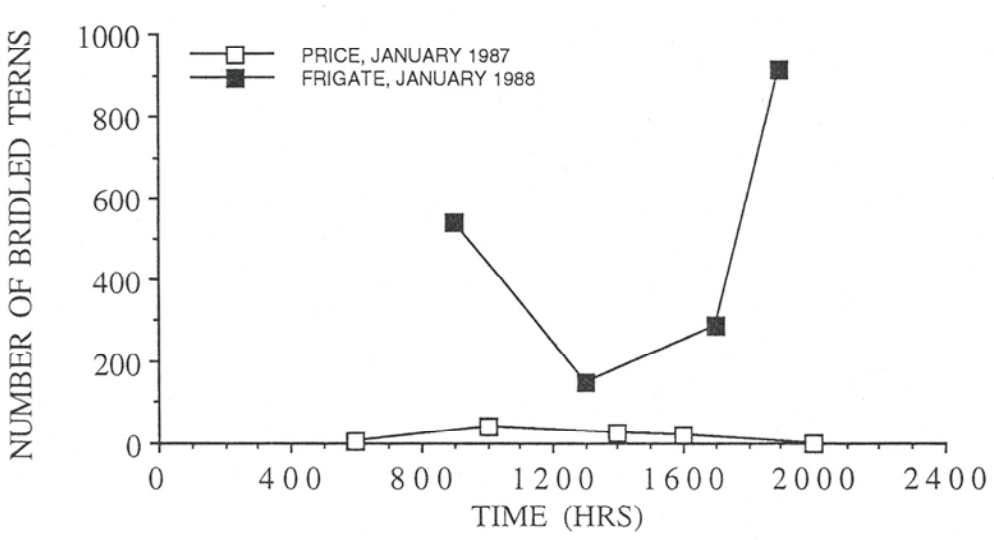

Figure 8. Numbers of Bridled Terns counted at different times of day in summer on Price Cay and Frigate Cay.

Nonbreeding Species

Counts of species that were present on these islands but did not nest there are presented in Table 2. Unlike other species, the Least Frigatebird (*Fregata ariel*) was found at night but not by day. In winter there were momentary influxes of groups of particular species that otherwise were usually absent or in low numbers. Most of these visits were by small numbers, although two (on Frigate) involved more than 100 birds:

Roseate Terns (*Sterna dougalli*) at noon and Black Noddies at 0400 hrs. In summer, counts of nonbreeders of several species were higher and some of the species maintained a more constant association with the island.

Lesser Golden Plovers (*Pluvialis dominica*), Ruddy Turnstones (*Arenaria interpres*), Black-naped Terns (*Sterna sumatrana*) and Little Terns (*Sterna albifrons*) were only recorded during the day. The lack of nocturnal observations may result from the sensitivity of these species to disturbance by lights at night. They may have flown to another island before they were detected. While not breeding during the time of these counts, Black-naped Terns do occasionally nest on the cays of the Swain Reefs (Limpus and Lyon, 1981; Moverley, 1985; Walker, 1986). Roseate Terns occurred on the island in greater numbers by day than by night in both seasons (Table 2). This pattern is opposite to that displayed by this species when wintering in Guyana where they feed offshore by day and come to land mainly at night (Nisbet, 1984). As the numbers of Roseate Terns in all surveys fluctuated dramatically from count-to-count, they were probably quite mobile, roosting on a number of the nearby cays in this part of the Swains. This pattern also has been observed in the longer-term counts on Swain Reef islands (Heatwole *et al*., 1996). In summer, Black Noddies were found on the islands only by day. However, in winter on Frigate they were present in greater numbers by night than by day. The greater numbers of Black Noddies on Frigate and their almost complete absence on Price is probably because only Frigate had shrubs (two sizable *Argusia* bushes); Black Noddies prefer trees or shrubs for nesting and roosting.

Nonbreeding species were relatively constant in number throughout a particular diel cycle on only one island and during only one season; otherwise, they occurred merely as sporadic visitors (e.g., Lesser Crested Tern, *Sterna bengalensis*; Great Frigatebird, *Fregata minor*; Whitefaced Heron, *Ardea novaehollandiae*). Whereas Lesser Crested Terns were only recorded as sporadic visitors in this survey, it should be noted that they do breed occasionally in small numbers on the Swain Reefs in mixed colonies with Crested Terns (M. Jones, unpublished data). Finally, there were species that seldom occurred and then in very low numbers (Least Frigatebird, *Fregata ariel*; Sooty Tern, *Sterna fusca*; Eastern Reef Egret, *Egretta sacra*).

There was no clear relationship between the numbers of roosting birds and tidal cycles for any of the nonbreeding tern species or between numbers of nonbreeding Black Noddies and time of day, such as Hulsman (1974, 1977) found. Perhaps these nonbreeding birds, not being attached to a particular nest site, were moving frequently between islands so that tidal and diel patterns of roosting were obscured.

A total of 13 nonbreeding species was recorded during the counts of which 11 species occurred in summer on the two islands collectively and nine species in winter. In summer, there were nine species on each island, seven in common between the two islands and two species unique to each (Table 1). In winter, Price had five species and Frigate seven, with three species in common between them and two unique to Price and four unique to Frigate.

The higher number of Bar-tailed Godwits (*Limosa lapponica*), Lesser Golden Plovers and Ruddy Turnstones in summer than in winter is because populations overwintering in Australia are supplemented in summer by migrants from the northern hemisphere (Cayley, 1970).

Table 2. All other (non-breeding) bird species recorded during the three 24 hour count periods. Note observations at 0600 and 1000 hours in July 1987 were made on July 24, and observations at 0400 and 0800 hours in July 1991 were made on July 15.

		BIRDS COUNTED THROUGH 24-HOUR PERIOD													
Location/Date	Species	0400	0600	0800	0900	1000	1200	1300	1400	1500	1600	1700	1800	2000	2030	2400
Price Cay	Great Frigatebird		2			2			0		1			0		
22 Jan. 1987	Bar-tailed Godwit		1			1			1		0			0		
	Lesser Golden Plover		0			1			3		0			0		
	Ruddy Turnstone		15			12			23		7			0		
	Roseate Tern		14			452			170		105			0		
	Black-naped tern		7			35			22		27			0		
	Little Tern		0			9			21		9			0		
	Lesser Crested Tern		1			5			6		1			0		
	Black Noddy		0			0			2		0			0		
Price Cay	White-faced Heron		4			1				8			0		0	
23 July 1987	Bar-tailed Godwit		1			0				1			0		0	
	Ruddy Turnstone		2			13				1			0		0	
	Roseate Tern		0			0				3			0		0	
	Black-naped Tern		0			0				22			80		0	
Frigate Cay	Least Frigatebird				0			0				0			1	
28 Jan. 1988	Lesser Golden Plover				1			6				5			0	
	Ruddy Turnstone				1			46				17			0	
	Roseate Tern				2194			506				470			900	
	Black-naped Tern				0			27				1			0	
	Sooty Tern				3			0				0			0	
	Little Tern				0			9				10			0	
	Lesser Crested Tern				0			2				0			0	
	Black Noddy				35			34				94			0	
Frigate Cay	Eastern Reef Egret	0		10			0				0			4		0
14 July 1991	Lesser Golden Plover	0		5			1				0			0		0
	Ruddy Turnstone	3		12			2				0			1		3
	Roseate Tern	0		0			300				0			30		35
	Black-naped Tern	0		0			6				0			0		0
	Lesser Crested Tern	0		0			10				0			0		0
	Black Noddy	112		0			6				0			11		30

In general, seabirds on Frigate and Price Cays roosted in mixed-species aggregations, mostly small and scattered around the beach, but with some large aggregations consistently in one spot. Nonbreeding species roosted almost exclusively on the beach. Exceptions to this generalization were Common Noddies and Bridled Terns which roosted in the vegetation regardless of whether they were nesting or not, and Black Noddies which showed a preference for roosting in the only bushes available, the two *Argusia* shrubs on Frigate. Black-naped Terns showed a preference for roosting on spits and nonbreeding Brown Boobies often roosted on exposed beachrock at night regardless of the direction and strength of the wind. When nesting, birds of all species roosted near their nests in the vegetated zone of the island, both by day and night. An exception occurred during the storm on the night of the summer count on Frigate. All nesting adult boobies, except those directly involved in brooding eggs or small chicks, congregated on the beach on the lee side of the island.

Diel patterns of activity are not well documented for seabirds. It is known, however, that various species of terns engage in "social flights" at twilight during the breeding season (Marshall, 1942). Desertion of nests for all or part of the night (when the risk of predation on eggs is lower) while maintaining nest attentiveness during the day has been recorded in several gull species, e.g., Ring-billed Gulls (*Larus delawarensis*), Chardine and Morris, 1983) and Black-headed Gulls (*L. ridibundus*) (Beer, 1962). In a review of nocturnal nest desertion by colonially nesting seabirds, Chardine and Morris (1983) found that desertion is most common early in the breeding season, both before and after egg-laying, and involves numbers ranging from a few individuals to nearly all of the colony. In the latter case, movements often were synchronous with virtually all birds departing and returning simultaneously. Such nocturnal nest desertion is thought to function in promoting synchrony in hatching. This type of nocturnal nest desertion must be distinguished from that caused by the risk of predation to the brooding adults. Nest desertion has been recorded in Ring-billed Gulls threatened by predation (Emlen *et al*., 1966) and in Common Tern (*Sterna hirundo*) colonies (Hunter and Morris, 1976; Nisbet and Welton, 1981; Shealer and Kress, 1991) in response to threat of predation by owls or Night Herons. In the study by Nisbet and Welton (1981), nests were deserted for 6.5 to 8 hours each night throughout the nesting season. Clearly, nocturnal desertion can be an important factor affecting diel changes in numbers of seabirds on islands. Differences in the extent of nest desertion at different stages of the nesting cycle could introduce a seasonal effect as well.

A number of other factors need to be taken into account when counting seabirds. It is important to conduct surveys at a consistent time of the year when bird species are at a similar stage of the nesting cycle. Even a few weeks can make a large difference in numbers if birds are just arriving to breed or if chicks are just fledging (del-Nevo *et al*., 1993). As the present study has shown, it is possible to obtain reliable counts of Brown and Masked Boobies, Common and Black Noddies and Bridled Terns at night, but gulls, charadriid waders and some species of terns are highly sensitive to lights and human activity at night and are likely to fly away before being counted; they are much more sensitive to disturbance at night than during the day and are particularly sensitive on moonlit nights. Schreiber and Chovan (1986) found that a census 10 minutes after

sunset gave an accurate count of the numbers of Redfooted Boobies (*Sula sula*) and Great Frigatebirds that roosted on an island for the night. This time-frame does not apply to all species, however. In the present study, Brown and Masked Boobies and Common Noddies continued to increase in numbers for several hours after sunset and, in the case of the Black Noddy, all night long. Finally, weather conditions at the time of the count can influence the number of birds roosting. Wind has a major influence on foraging activity of oceanic birds. Calm conditions reduce the area covered and may prolong the time away from the nest (Jouventin and Wiemerskirch, 1990). By contrast, species that forage inshore, such as terns, seek shelter in high wind (Hulsman, 1977). Long periods of severe weather, such as cyclones, can dramatically reduce breeding success in colonies because strong winds prevent adults from foraging or reduce their foraging success and chicks starve (Hulsman, 1984). The present study found that, in strong winds, nonbreeding birds, partners of brooding or incubating adults, and parents of large chicks congregated on the leeward beach where some shelter could be obtained. On calmer nights, birds were distributed more evenly around the island, even on the windward side, and remained near their brooding mate or large chick wherever located.

In summary, it is clear that on the cays of the Swain Reefs numbers of birds change both during the diel cycle and seasonally. Any measure of the impact of birds on islands should take such changes into consideration. The variation in numbers, even during the daytime, means that counts on different islands at different times of day are not strictly equivalent and techniques for taking censuses need to be standardized if precise comparative information is to be gleaned. The confounding factors of nocturnal desertion, differences between species in sensitivity to human disturbance at night, and weather conditions need to be recognized.

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