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MOULT AND BREEDING IN THE COMMON NODDY *Anous stolidus* ON CHRISTMAS ISLAND INDIAN OCEAN

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Common noddies on Christmas Island in the Indian Ocean were captured at a social roost during the breeding season and their primary moult and brood-patch condition was examined. Early in the attendance period at the roost (May), few noddies showed evidence of either breeding or primary moult, and very few individuals were engaged in both activities. Most noddies had started to moult by June and many were incubating and moulting simultaneously. The number of noddies incubating peaked in early July when almost all breeding birds showed active wing moult. Moult was not completed during the main laying period. Although moult overlapped with breeding, it did not advance beyond the third primary in pre-laying or incubating noddies. However, it had resumed in birds with re-feathering brood-patches, many of which were rearing chicks. The extensive overlap between moult and breeding in July presumably corresponds to a period when the nutritional and/or energy requirements for both activities can be met by the food resources. However, moult was arrested in pre-laying and incubating birds, possibly because of the nutritional and/or energy cost of the early stages of the nesting cycle.

INTRODUCTION

In most populations of lariform seabirds, the basic moult and the nesting cycle take place in different seasonal periods or at different stages in a periodic cycle of moult and breeding. It is not uncommon for moult to overlap the beginning or end of the breeding season but, normally, individuals are not involved in both activities simultaneously (Ashmole 1962, 1968, Harris 1971, Dunlop 1985). However, there are a number of populations of gulls and terns in which moult occurs extensively in birds engaged in breeding. These populations include the Bridled Tern *Sterna anaetheta* in the Seychelles (Diamond 1976) and the Least Tern *Sterna antillarum* in Texas, U.S.A. (Thompson and Slack 1983). In populations of the Common Noddy *Anous stolidus*, both overlapping and alternating patterns of moult and breeding have been inferred from limited data. On Ascension Island (7°S., 14°W.) the replacement of some primary feathers occurred during the nesting cycle (Dorward and Ashmole 1963) and this is also thought to be the situation on Aldabra (9°S., 46°E.) (Diamond 1971). Dorward and Ashmole (1963) suggested, from very little data, that moult alternated with breeding on some islands in the North Atlantic. There are conflicting views about the situation on the Galapagos (2°N., 92°W.) (Dorward and Ashmole 1963, Diamond 1971). On Christmas Island, in the Pacific (2°N., 157°W.), moult and breeding were more or less separate activities early in the breeding season but were frequently concurrent in individuals breeding towards the end of the season (Schreiber and Ashmole 1971).

At Christmas Island in the Indian Ocean (10° 25'S., 105°42'E.) the common noddy nests from early April to the end of September (Nelson 1972, Gibson-Hill 1947). The earliest date recorded for an incubating bird during the year of study (1985) was 1 April. However, most laying appears to be concentrated between May and July.

The sites chosen for nesting by common noddies on Christmas Island are ledges on the precipitous sea-cliffs and inland cliffs and the forks of tall, monsoon forest trees on the coastal terraces. Such sites are different from those used by the species elsewhere in its range and presumably are the result of predation pressure from the immense populations of land crabs. The inaccessibility of the breeding site makes the capture of birds on the nest impractical. However, during the middle of the breeding season, between May and August, noddies form small flocks or clubs, in which mating displays occur, on one of the small beaches of coral fragments around the island (Lily Beach). Here the birds engage in courtship displays, including courtship feeding and copulation. Noddies are also attracted to this beach to ingest small pebbles which are presumably swallowed as an aid to digestion. Under suitable conditions, it was possible to capture noddies at the club using mist nets.

METHODS

Lily Beach was visited in daylight at least twice each week from February to early September 1985. Attempts to trap the noddies began when the birds started to roost on the beach in May. Noddies were captured in mist-nets set just above the tide line at Lily Beach. Most birds were captured in the first 2 hours of daylight, during the peak period of arrival at the club. The beach was not used for roosting at night.

The primary moult on both wings was scored using the methods of Ashmole (1962, 1963). This is similar to the method used on the Australian Bird Banding Scheme moult cards but permits better notation of discontinuities in feather replacement in birds without actively growing primaries, using (N) for newish feathers, (O) for old, worn feathers and (.) for intermediate wear and age.

The state of the paired, thoracic brood-patches was recorded as follows:

0 — no brood-patches
1 — brood-patches defeathering
2 — brood-patches completely defeathered
3 — brood-patches refeathering (pinfeathers emerging from the area).

Standard bill measurements were taken for most birds handled. However, there was no evidence of marked dimorphism in these characters and the sex of the birds examined is unknown.

RESULTS

The Lily Beach club was occupied by common noddies from May to August 1985. An attempt was made to capture birds every 2 to 3 weeks, netting over several days where necesary to provide an adequate sample. Table 1 shows the numbers of adults, second year birds (1+) and juveniles (year 1) handled during five different catching periods. Second year (1+) birds were distinguished from adults by their whiter and less defined cap, their paler orange gape colour, by their voice and from juveniles (year 1) by larger bill measurements and moult in the primaries.

There were no recaptures or sightings of banded noddies within the 1985 season.

The percentage of adults captured remained around 90 per cent in May, June and July, declining in the last sample during August. Most of the birds using the beach at this time were young from that year and the club was no longer being visited by early September. The only two adults captured in August were not used in the following analysis. Second year birds were present in May, June and early July but were not recorded towards the end of the season.

TABLE 1

The number of adult, second year (1+) and juvenile (year 1) noddies captured during five sampling periods from May to August 1985. Sample proportions in parenthesis.

	May 10-12	June 21-24	July 12-14	July 27	August 24	Total
Adults	32	24	42	8	2	108
2nd Year (1+)	1	1	2	0	0	4
Juveniles (Yr 1)	1	2	2	1	5	11
Total	34	27	46	9	7	123

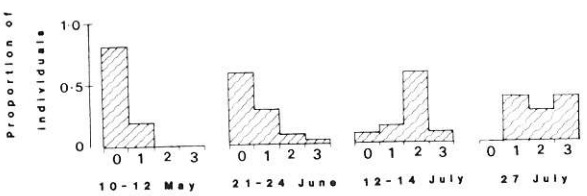

Figure 1. *The proportions of adult Common Noddies in four samples caught on Christmas Island between May and July which had no brood patches (0), defeathering brood patches (1), fully defeathered brood patches (2) or refeathering brood patches (3).*

Defeathered brood-patches are generally indicative of birds engaged in incubation and brooding. Dorward and Ashmole (1963) found that in common noddies the brood-patches were well-developed in incubating birds but had begun refeathering in one bird with a newly hatched chick. Noddies with older chicks had advanced refeathering of the brood-patches. Thus birds with brood-patches defeathering (condition 1) or completely defeathered (condition 2) can be assumed to be incubating. Noddies with refeathering brood-patches may be either rearing chicks or have completed an unsuccessful breeding attempt.

Figure 1 shows the state of the brood-patches in noddies caught on four different occasions through the season. In May, 71 per cent of adult noddies had yet to develop brood-patches, whilst the remainder had defeathering brood-patches and were presumably in eary incubation. Towards the end of June, nearly half of the adults had laid eggs and by mid-July the majority of birds studied were engaged in incubation or chick care. In the last sample, at the end of July, all adults had brood-patches which were defeathering, completely defeathered or refeathering, indicating post-laying stages in the reproductive cycle. Many birds had also completed incubation at this time. There was no evidence of non-breeding adults using the Lily Beach club (i.e. all noddies with adult plumage had developed brood patches). On the basis of brood-patch development, peak laying in 1985 was apparently around eary July.

Figure 2 shows the proportions of birds which were breeding (i.e. with brood-patch condition 1 or 2), in moult (i.e. growing fresh primaries), or engaged in both activities. About 18 per cent of adults were involved in breeding or moult in May, at which time only 6 per cent were engaged in both activities concurrently.

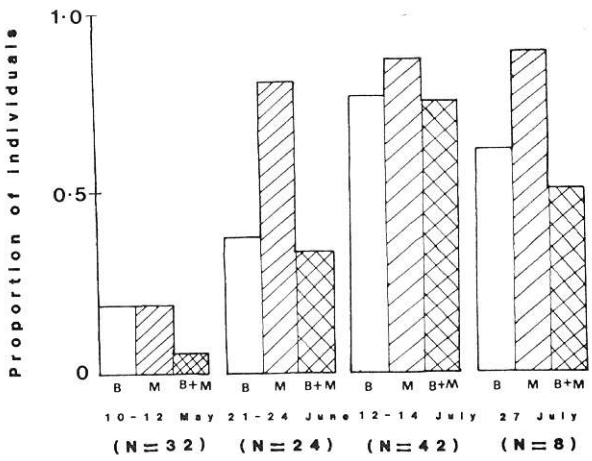

Figure 2. *The proportions of adult Common Noddies in four samples caught on Christmas Island between May and July which were breeding (B), moulting (M), or both (B + M).*

The proportion of birds breeding increased to a peak in the mid-July catch and then declined as more birds moved into the post-breeding (brood-patch condition 3) category. By the end of July about 90 per cent of adults, including most breeding noddies, were in wing moult. Thus in common noddies on Christmas Island in the Indian Ocean, the early basic moult almost completely overlaps the breeding season. At the beginning of the period, breeding and active moult in the same individual was uncommon but, as the season progressed, all birds commenced moult, including those engaged in the nesting cycle. In the mid-July sample, close to the peak in laying, almost all breeding noddies were also in primary moult.

The influence of the stage in the nesting cycle, as indicated by brood-patch condition, on the progress of primary moult is shown schematically in Figure 3. In addition to a seasonal influence on the proportion of noddies concurrently breeding and moulting, the following pattern emerges. Primary moult in pre-breeding or incubating birds (brood-patch condition 0, 1 and 2) only advances to the completion of the third primary (P3). If P3 is replaced early in the season or early in the nesting cycle the moult is arrested. Two examples of this were recorded.

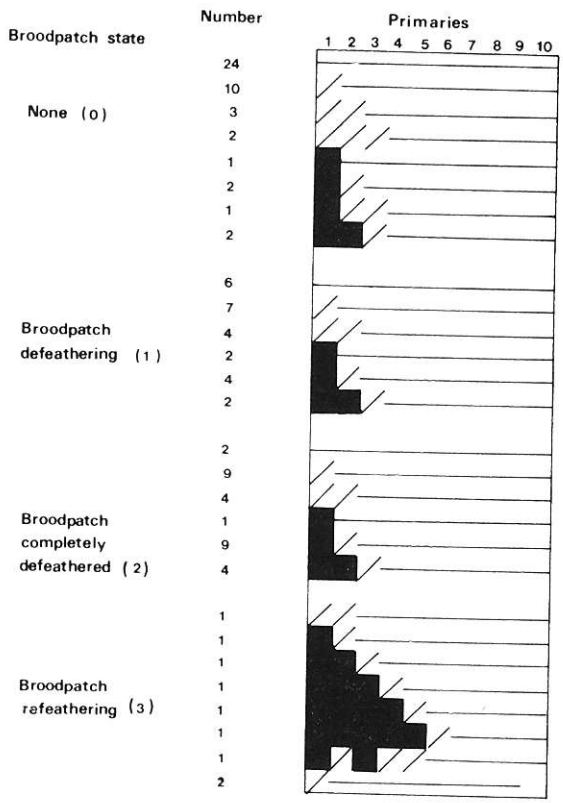

Figure 3. *The primary moult states (generalised for both wings) of noddies with no brood patches (0), defeathering brood patches (1), completely defeathered brood patches (2) and refeathering brood patches (3), fully grown fresh primaries are cross-hatched, actively grown primaries hatched, and primaries replaced in the previous moult cycle indicated by a horizontal line.*

One pre-breeding bird in May had the following pattern on both wings:

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
0	0	0	.	.	.	.	.	.	.

This probably indicated a period of arrest in the primary moult of the previous season. Another bird with a defeathered brood-patch, captured in June, showed the converse pattern on both wings:

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
N	N	N	.	.	.	.	.	.	.

This discontinuity indicates arrested primary replacement in the current season.

In birds with refeathering brood-patches (condition 3), which may include failed breeding birds or those rearing chicks, primary moult advances beyond the third primary. The highest moult score was 54 for a bird captured in June. Three birds captured in July showed moult which departed from the general serially descendent pattern (Figure 3). These adult terns with refeathering brood-patches had actively growing primaries at two points on the wing. Two individuals had P1 and P10 being replaced on both wings and the other was growing P2 as well as P4 and P5.

Only the single bird with a primary moult score of 54 was recorded as replacing secondaries. This is consistent with the normal pattern in gulls and terns, in which most of the basic moult coincides with the replacement of the outer primaries (Ashmole 1963). The remainder of the basic moult in noddies on Christmas Island apparently takes place late in the breeding season. Confirmation of this would necessitate other methods of study.

DISCUSSION

Both breeding and the basic moult impose increased nutritional and/or energy costs (Rahn and Whittow, 1984). Probably for this reason, the two activities rarely occur in the same seasonal period or concurrently in the same individuals. Only under unusual ecological conditions could moult-breeding overlap confer selective advantages.

In common noddies on Christmas Island, the early basic moult almost completely overlaps the breeding period, and pre-breeding and incubating birds will moult the inner three primaries. The replacement of the outer primaries takes place once the brood-patches are refeathering and probably begins soon after the hatching of chicks. Reaching this stage may release both parents from the nest for longer periods, allowing them to forage freely and improve their nutritional status. In the Bridled Tern on the Seychelles, the onset of the primary moult was synchronised with the time of hatching (Diamond 1976). In this species-population, however, the breeding cycle was aseasonal and sub-annual.

The ability to replace the inner three primaries early in the season and whilst engaged in incubation may relate to the relatively small size of the feathers and the low nutritional cost involved. Alternatively, it may be possible to shed these primaries without affecting flight and foraging ability. The replacement of the larger outer primaries may only occur when the breeding adults are free from the most nutritionally demanding parts of the nesting cycle, namely egg production and incubation.

There are marked seasonal changes in sea surface temperatures around Christmas Island. An analysis by the Abbott's Booby Monitoring Programme suggests that the period from December to March, the monsoon period, is characterised by high temperatures and, presumably, low marine productivity. During the season of the trade winds, from about April to October or November, there is an intrusion of cooler water, presumably from deeper layers. The decline in sea surface temperature is progressive, normally with a sharp drop to the lowest point in October or early November (J. Tranter, pers. comm.). If the observed intrusion of cooler, more nutrient rich water into the surface layers increases productivity then it might be related to the seasonal timing of moult and breeding. Both activities may depend on food resources such that, early in the season (May), the majority of birds neither breed nor moult and very few engage in both cycles concurrently. As the season progresses, food availability may increase and more noddies produce clutches and commence primary moult presumably because they can now support both activities. Presumably it is advantageous to complete both the nesting cycle and the moult during this favourable period. However, moult is constrained by the nutritional demands of the early stages of the nesting cycle. If the peak in laying during early July reported in this study is consistent from year to year, then most fledging would take place in late September and early October, close to the suspected period of highest marine productivity. This would maximise the probability of post-fledging survival, a critical period in the biology of most terns. The July peak, however, differs from the May timing suggested by Nelson (1972) and Gibson-Hill (1947).

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