CORELLA

Journal of the Australian Bird Study Association

VOLUME 18 MAY, 1994 NUMBER 2

Corella, 1994, 18(2): 33–36

POPULATION DYNAMICS OF THE BRIDLED TERN *Sterna anaethetus* COLONY ON PENGUIN ISLAND, SOUTH-WESTERN AUSTRALIA

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Received 19 March 1993

The Bridled Tern breeding population on Penguin Island has increased steadily over the last decade as evidenced by an expansion in the area occupied by the nesting birds. In an established sub-colony area, individuals which were five to seven years of age or older made up most of the breeding pairs. Three-year olds, which were probably pre-breeders, were conspicuous in their established natal sub-colony but many were recruited later elsewhere. A recently occupied nesting area only contained young pre-breeding and breeding age terns, with four year olds being the most important age class. Adult survival was calculated to be 82.5 per cent. However, because of the effective emigration of some pre-breeding adults, this was concluded to be an underestimate.

INTRODUCTION

The Bridled Tern has expanded its breeding range southwards from the Houtman Abrolhos Islands since 1843. It was nesting on some of the Shoalwater Bay Islands by 1920. Between 1940 and 1942, nesting occurred near Penguin Island on Bird and Shag Islands (Serventy and White 1943). Then the breeding colonies expanded to Seal Island, 1.1 km north of Penguin Island, and to the rocks off Cape Peron (Serventy *et al.* 1971; Serventy and Whittell 1976). Penguin Island was clearly occupied later but the actual timing of colonization was not recorded. Presently approximately 1 000 to 1 200 breeding pairs nest in a number of sub-colonies on Penguin Island.

Bridled Terns return to their natal area, most doing so in their third year of life. Once established as breeding adults, individual terns will retain the same nest sites from year to year, although some will shift short distances within the original sub-colony (Dunlop and Jenkins 1992). Thus, the historical expansion of the area occupied by the breeding colonies in Shoalwater Bay must correspond to growth in the population.

The observed range extension of the Bridled Tern in south-western Australia is considered to be related to oceanographic factors. Specifically, the long-term trends in the behaviour of the Leeuwin Current have presumably expanded the distribution of the Bridled Tern's prey species (Dunlop and Wooller 1990; Wooller *et al.* 1991). However, little is known about the population biology underlying range extension. A banding study which began in the 1982/83 breeding season now provides some information on the expanding Bridled Tern colony on Penguin Island.

STUDY AREA AND METHODS

The location, physiography, vegetation and ornithology of Penguin Island was described in Dunlop *et al.* 1988. The Bridled Tern breeding season was analysed in some detail in Dunlop and Jenkins 1992 and that paper also included a description of the northern study colony.

Before the 1988/89 breeding season, the Bridled Tern colony was more or less confined to the northern and southern plateaux and the talus slopes. Since that time, the colony has expanded into sandier habitats, in particular the south-eastern dune slope and the tombolo area, which extends eastwards towards the adjacent mainland. The natural vegetation here is dominated by trailing Sea Spinach *Tetragonia decumbens* with scattered clumps of Spinifex *Spinifex longifolius* and Berry Saltbush *Rhagodia baccata*. Parts of the tombolo area were, until recently, covered with buildings or were grassed but are now at various stages of revegetation. Human disturbance in the area has been much reduced in recent years.

Banding of adult Bridled Terns, pulli and fledglings in the northern sub-colony study area (Fig. 1) began during the 1982/83 breeding season. It resumed in this area in the 1986/87 season (i.e. after a four year break) and has continued to the present (1992/93).

The capture and banding methods were described in Dunlop and Jenkins 1992. Banding of Bridled Terns in the southern sub-colony area within the tombolo (Fig. 1) began in the 1989/90 season when the first pair was observed holding a breeding territory within it. Since that time terns occupying this area have been captured routinely during banding operations. Most of the small number of terns in this area were captured in their year of arrival.

Bridled Terns within the northern sub-colony were captured at random, without reference to marked sites. As a result, only a proportion of the previously marked terns from within this area would be expected to be recaptured. Adult annual survival rates in the northern colony were estimated using the Method 2 calculation of Nicholls and Woinarski 1988. This uses the ratio of the percentage of individuals known to be alive (% KTBA) in successive yearly intervals after banding. The estimate of average annual percentage survival is obtained by the following:

$$\frac{100}{(x-1)} \times \left(\frac{\%\ \text{KTBA (yr 2)}}{\%\ \text{KTBA (yr 1)}} + \frac{\%\ \text{KTBA (yr 3)}}{\%\ \text{KTBA (yr 2)}} + \ldots + \frac{\%\ \text{KTBA (yr x)}}{\%\ \text{KTBA (yr x-1)}} \right)$$

The assumptions underlying this method are outlined in Nicholls and Woinarski 1988.

RESULTS

From the beginning of this study in the 1982/83 breeding season, the area occupied by the Bridled Terns has expanded progressively. Figure 1 shows three stages in the expansion of breeding area; delineating the situation in 1982/83, 1986/87 and 1992/93. All areas which have been occupied have remained so. The colonization of the southern sub-colony began in the 1989/90 breeding season, with the number of terns occupying territories increasing rapidly in the two years 1991/92 and 1992/93. Recently, about 25 pairs of Bridled Terns were observed on breeding territories, in two groups, within the southern study area (Fig. 1).

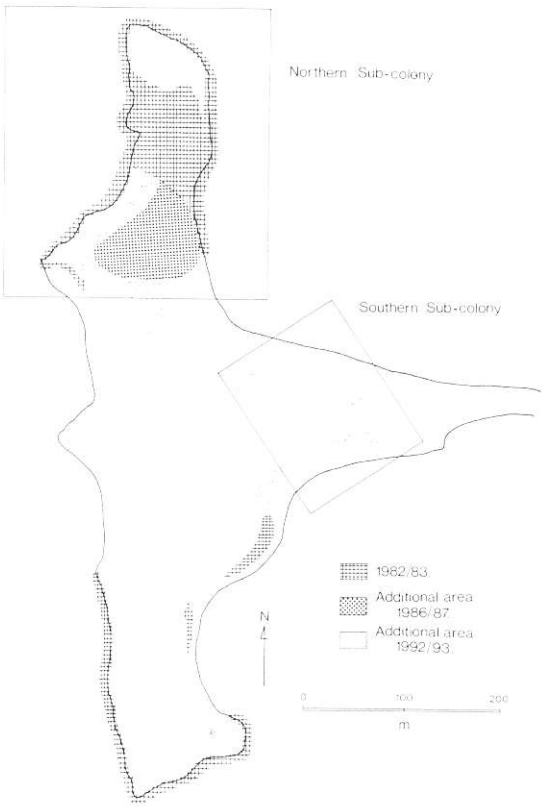

Figure 1. *Map of Penguin Island, showing the distribution of the Bridled Tern breeding colony in the 1982/83 season and the additional areas occupied up to 1986/87 and then 1992/93. Also shown are the locations of the two study areas; the Northern Sub-colony and the Southern Sub-colony.*

Forty-four of 603 Bridled Terns banded as pulli or fledglings in the northern study colony have been recaptured at least once in subsequent years within this area or from the southern study area. In total there were 53 known-age recaptures, because some terns were recaptured in more than one year. Terns from one to seven years of age were recaptured. In Figure 2, the bars represent the number of terns captured at each age standardized for the number banded and available for capture at that age, expressed as a

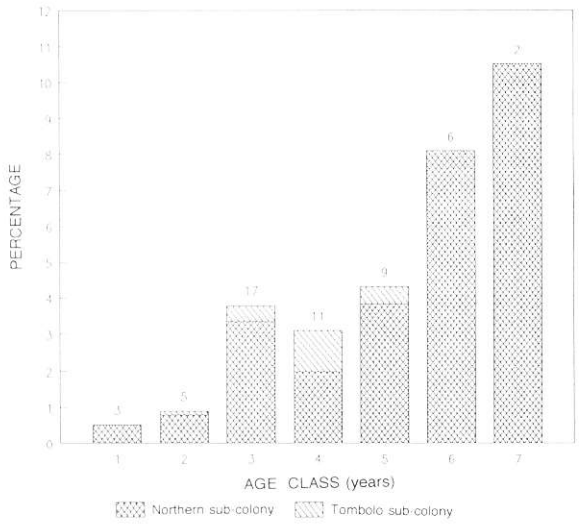

Figure 2. *Stack Bar Chart showing the relative importance of seven known-age classes in the Bridled Tern colony. The bars represent the number of Bridled Terns captured at ages 1 to 7 divided by the total number banded and available for capture at each age and expressed as a percentage. The layers in the bar chart distinguish the contribution of known-aged terns captured in the Northern Sub-colony and Southern Sub-colony. The totals captured at each age are given above the columns.*

percentage. This standardization does not allow for mortality and therefore the proportion of young birds in the study colony will be exaggerated.

Figure 2 shows that a small proportion of one and two-year old terns were present in the colonies. There was a marked peak with the influx of three-year old terns into the colony areas, particularly into the established northern sub-colony. Four-year olds were proportionately less important in the established sub-colony but they were an important age class amongst the terns establishing themselves in the recently occupied southern sub-colony. Known-age terns older than five years were not present in the southern sub-colony.

During the study, 1 438 adult Bridled Terns were captured in the northern sub-colony and were available for recapture, at least once, in subsequent years. Table 1 shows the number banded in each season and the number known to be alive in the years following the banding year. The data for the adults banded in the 1982/83 season are shown in the table but were not used int the calculation of mean annual survival because of the four year break.

The oldest terns presently known to be in the colony were banded as adults ten years ago (Table 1). It is unlikely that these birds were less than three years old at banding, so their minimum age would be thirteen. Using the results in Table 1 and the Method 2 calculation of Nicholls and Woinarski (1988), the average annual survival of adult Bridled Terns was 82.5 per cent. This would give a mean expectation of further life for banded adult terns of 5.2 years (Nicholls and Woinarski 1988).

DISCUSSION

The results from the recapture of known-age terns suggest differences in age structure between the long established northern sub-colony and the recently occupied southern sub-colony.

Most Bridled Terns appear to return to their natal sub-colony in their third year. Dunlop and Jenkins (1992) have shown that this generally happens late in the season and may not result in a breeding attempt. Four-year old terns were recorded from nests and this was effectively the first breeding year (Dunlop and Jenkins 1992). The three-year age class produced a marked peak in the northern sub-colony but four-year olds were proportionately less represented in this area. This suggests that there was a partial emigration of young breeding-age birds from the established northern sub-colony. The recapture of terns from these age classes in the recently occupied southern sub-colony confirmed that this local emigration was taking place. The dominant age classes in the established northern sub-colony were years six

TABLE 1

The number of adult Bridled Terns banded in the northern study colony each season and the number of these known to be alive in subsequent years.

Banding season	Number banded	Subsequent Years									
		1	2	3	4	5	6	7	8	9	10
1982/83	61	—	—	—	15	14	11	7	3	3	2
1986/87	188	104	89	55	27	18	16	—	—	—	—
1987/88	331	125	76	32	23	17	—	—	—	—	—
1988/89	252	75	35	24	17	—	—	—	—	—	—
1989/90	256	24	17	12	—	—	—	—	—	—	—
1990/91	245	24	18	—	—	—	—	—	—	—	—
1991/92	105	6	—	—	—	—	—	—	—	—	—

and seven, with still older terns probably also important.

Overall, these trends in age structure suggest that a proportion of the three and four-year old recruits which returned to the natal sub-colony were unable to secure breeding sites. Presumably, the established colony was producing more recruits than were necessary to compensate for adult mortality, leading to competition for nest sites and partial dispersal.

The estimate of the average annual adult survival assumes that none of the losses were due to emigration. In the latter seasons of the study, a significant proportion of the previously unmarked terns banded would have been pre-breeding age birds. Since some of these terns have been shown to settle ultimately outside the northern sub-colony study area, the calculated 82.5 per cent adult survivorship will be an underestimate.

The 1982/83 cohort of banded young was known to have a minimum survival to recruitment of 36.8 per cent (unpublished data). Using that figure for breeding output, an adult survival rate of 83.5 per cent would produce an average lifetime reproductive rate above replacement level.

The observed growth in the area occupied by breeding Bridled Terns would therefore have been driven by a surplus of young breeding age terns in an environment where food availability was not limiting population size. Although the colonization of the Shoalwater Bay Islands must have begun initially with immigration from another population, the present expansion could be sustained without the recruitment of terns from outside the natal region.

ACKNOWLEDGMENTS

We are grateful to the Western Australian Department of Conservation and Land Management for permission to undertake research on Penguin Island and for providing accommodation. The banding project was conducted under the auspices of the Australian Bird and Bat Banding Scheme. Peter Long, Michael Slack-Smith and Dee Margetts assisted with the preparation of the manuscript.

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