Corella, 2013, 37(2): 36–40

Analysis of breeding data of the Welcome Swallow *Hirundo neoxena* near Manjimup, Western Australia

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Received: 31 July 2012

Breeding data on the Welcome Swallow *(Hirundo neoxena)* collected by Dick and Molly Brown at the Middlesex Field Study Centre, near Manjimup, Western Australia, were analysed and compared with data from Sydney, Tasmania and New Zealand. The mean clutch size in Middlesex (3.06) was considerably lower than in Sydney (3.86), Tasmania (4.03) and New Zealand (4.49). The long, dry Western Australian summer and migration factors may account for the difference between Middlesex and Sydney but migration factors cannot account for those differences with New Zealand. Lack of competition in New Zealand, where the Welcome Swallow is a recent immigrant, may be the explanation for the differences. There was no correlation between latitude and clutch size from the four study sites. The hatching and fledgling success rates were noticeably higher in Middlesex than in the other three studies. Nesting sites close to water were preferred, possibly because they provided the birds with mud for nest building and a rich foraging place. Man-made nesting sites were used much more commonly than natural sites across all studies, perhaps because they were convenient and provide protection. There was no correlation between rainfall and breeding success. There was no evidence that pulli return to breed at the location in which they were reared.

INTRODUCTION

The Welcome Swallow *Hirundo neoxena* was studied for over 20 years by Dick and Molly Brown at the Middlesex Field Study Centre, near Manjimup, Western Australia (Brown and Brown 1991; Brown *et al*. 2005). Between 1974 and 2000, they collected detailed nest records of Welcome Swallows breeding behaviour around Middlesex. The study area covered 22 breeding sites, all within a five kilometre radius of the Centre. The detailed records for the Welcome Swallow cover 894 nests and, in addition, there are data from mist netting and banding of 2260 birds (Brown *et al.* 2005).

Many of the breeding birds and their young were banded with bands supplied by the Australian Bird and Bat Banding Scheme (ABBBS). After the Browns died the data were transferred by their executor Lee Fontinini, to Alma and Perry de Rebiera who released it to the Department of Environment and Agriculture, Curtin University, for detailed analysis by SS. This paper examines the mean clutch size, number of eggs hatched and the number of fledglings in first and second nesting attempts from 1974 to 2000 from the Middlesex area. The hatching and fledging success between each of the nesting sites for clutch one and two and between the years 1974 to 2000 are compared to determine differences between the sites and between the years. In addition the hatching success data are compared between man-made and natural nesting sites and with the rainfall data for the region to examine the effect of an important environmental variable. These results are compared with the results of studies from Sydney, Tasmania and New Zealand and the relationship between clutch size and latitude is investigated.

METHODS

Study sites

The Middlesex Field Study Centre is located eight kilometres south of Manjimup, Western Australia (34° 30' S, 116° 18' E). It was established in 1972 by Molly and Dick Brown on their two hectare property where they recorded every bird that they saw on their land from 1974 to 2000 (Brown *et al.* 2005).

Land use of the district

The Centre is located near the main forest reserves of south-western Australia, where the Karri (*Eucalyptus diversicolor*) forests merge into Jarrah (*Eucalyptus marginata*) and Marri (*Corymbia callophylla*) forests. Much of the large timber has been logged and the area cleared for farming, initially for cattle and sheep grazing, with remnant bushland left for shelter. Later orchards were established. During the period 1972 to 1989, the area experienced much clearing of remnant bush as well as a decrease in orchards and a significant increase in vegetable crops, especially potatoes and cauliflowers. During the following decade, many vineyards were added to these vegetable crops. This change from grazing to horticulture was accompanied by the building of many dams on the streams to ensure water was available for irrigation (Brown *et al*. 2005).

Climate

Manjimup experiences a Mediterranean climate, with cool wet winters and warm, dry summers. From 1971 to 2000, Manjimup recorded a mean maximum temperature 20.4°C, a mean minimum temperature 10.1°C and a mean annual rainfall 963.9mm (Bureau of Meterorology 2011) (Table 1). Unlike

Table 1

Total annual rainfall for Manjimup, W.A, from 1974 to 2000

Year	Annual Rainfall (mm)
1974	1040.8
1975	945.5
1976	1021.5
1977	896.6
1978	1052.1
1979	893.9
1980	923.8
1981	1153.2
1982	815.7
1983	967.6
1984	1029.2
1985	915.2
1986	792.4
1987	699.4
1988	1140.7*
1989	887.6*
1990	1053.7*
1991	985.2
1992	1024.7
1993	897.4
1994	724.3
1995	930.8
1996	1092.4
1997	890
1998	996.4
1999	1059.4
2000	1000.9*

*Some rainfall data for Manjimup missing. Missing months were replaced with data from Yanmah, 11km northwest of Manjimup. Data source: (Bureau of Meterorology 2011)

Sydney, Tasmania and New Zealand little summer rain fell during the period of the study.

Collection of data

The following data were recorded for the nest records: date, location of nest, clutch number, number of eggs, number hatched, number of fledglings, fate of the egg (if known), fate of the young (if known) and first egg date. All birds were banded using metal bands supplied by ABBBS and some were colour-banded. For each banded bird, the following data were recorded: band number, date, age, sex, weight, wingspan, colour of the band, shortest tail feather, longest tail feather, whether it was banded as a nestling and whether it was a re-trap.

Hatching Success

The hatching success for each year/nesting sites was calculated as: mean number hatched/mean number of eggs multiplied by 100. To account for the large variation in sample size, the hatchling success rate was added to the count and the highest numbers selected as the most successful. Third and fourth clutches were not included in the analysis due to their small sample sizes.

Statistical analysis

Independent samples t-test was used to determine if the first and second clutches were statistically different. Due to uneven sample sizes, Mann-Whitney U tests were used to determine whether there was a significant difference between man-made and natural nesting sites in each of the size of clutches, the mean number hatched and the mean number of fledglings. This test was also used to determine if there was a difference between the lowest and highest mean size of clutches, mean number hatched and mean number of fledglings. A Pearson Correlation test was carried out to determine whether there was a significant correlation between total annual rainfall for Manjimup and the hatching success of each clutch. This test was also used to determine whether there was a correlation between mean size of clutches and latitude. All tests were conducted with a 95 percent confidence interval.

RESULTS

Data from 894 nests, collected from 1974 to 2000, showed a 78.4 percent success rate to fledging at least one chick. 62 percent of the clutches occurred on the first nesting attempt, considerably more than the second nesting attempt (36.2%). The third and fourth nesting attempts were only recorded six times and once respectively and these were most likely replacement clutches for failed second nesting attempts (Brown and Brown 1991).

Eggs

The incubation period ranged from 14 to 24 days, with an average of (mean ± *sd*) 17.4 ± 0.2 days. (mode=18, *n*=125). Nesting occurred between August and December with the majority of first clutches occurring in September and the majority of second clutches in November.

Clutch size varied between one and six eggs (mode= 3; mean ± *sd* = 3.06 ± 0.023; *n*= 889). The lowest mean clutch size for the first clutch occurred in 1974 (2 ± 0.58, *n*=3) and the highest in 1976 (3.5 ± 0.5, *n*=2) however these were not significantly different (*P*=0.139). The second clutch had the lowest clutch size in 1978 (2.38 ± 0.38 n=8) and the highest in 1975 (4 ± 0, *n*=2), however these were not significantly different (*P*=0.06). There was no significant difference in mean clutch size between first and second nesting attempts for the different nesting sites (df= 30, t=0.21, *P*= 0.833).

Young

An overall mean ± *sd* of 2.44 ± 0.04 hatchlings was calculated from 894 nesting attempts. Brood size at hatchling varied between one and five (mode= 3; mean ± *sd*= 2.93 ± 0.027; *n*= 746). The lowest mean number of hatchlings for the first clutch occurred in 1985 (1.44 ± 0.66, *n*=7) and the highest occurred in 1979 (3.13 ± 0.23, *n*=8), with the 1979 clutches being significantly higher than those in 1985 (*P*=0.04). The second clutch had the lowest mean number of hatchlings in 1983 (1.75 ± 0.67, *n*=5) and the highest number in 1975 (4 ± 0.0, *n*=2), with the 1975 clutches being significantly higher than the 1983 clutches (*P*=0.018). There was no significant difference in the mean brood size at hatchling between first and second nesting attempts for each of the nesting sites (df= 30, t=-0.19, *P*= 0.849).

Table 2

Summary of mean clutch size, hatching success, fledgling success and incubation periods of the Welcome Swallow in four locations from Australia to New Zealand

	Mean clutch size	Hatching success (%)	Fledging success (%)	Mean incubation (days)
Middlesex	3.06	80.2	72.6	17.4
Sydney	3.86	74.65	56.22	16
Tasmania	4.03	nd.	59.4	15.6
New Zealand	4.49	nd.	46.3	16.7

Source of data: Middlesex Field Study Area: this study; Sydney: Marchant and Fullagar (1983); Tasmania: Park (1981b); New Zealand: Tarburton (1993); nd: no data available

An overall mean ± *sd* of 2.21± 0.05 fledglings was calculated from 894 nesting attempts. Fledging rate varied between one and five (mode= 3; mean ± *sd*= 2.83 ± 0.029; *n*= 699). The lowest mean number of fledglings for the first clutch occurred in 1974 (1 ± 0.71, *n*=2) and the highest in 1992 (3 ± 0.31, *n*=21), with 1992 clutches being significantly higher than 1974 (*P*=0.002). For the second clutch, 1983 had the lowest mean number of fledglings (1.38 ± 0.75, *n*=4) and 1975 had the highest (4 ± 0.0, *n*=2), with 1975 clutches being significantly higher than 1983 clutches (*P*=0.028). There was no significant difference in the number of fledglings between first and second broods for each of the nesting sites (df= 30, t=-0.99, *P*= 0.326).

Breeding success

Looking at breeding localities over all years for the first clutches, taking into account both the hatching success and the number of nests, Keegan's Brook (77.02%, n=108) and Bob's old house (84.05%, *n*=81) were the most successful localities.

In the second clutches, taking into account both the hatching success and the number of nests, Home Dam (91.6%, *n*=40) and Bob's old house (80.51% n=63) were the most successful.

Looking at individual years for the first clutch, years 1975 (*n*=2), 1977 (*n*=4), 1979 (*n*=8) and 1992 (*n*=27) had the highest hatching success rate (100%). Years 1988 (hatching success rate 86.72%) and 1989 (hatching success rate 74.14%) had the highest number of nests at 40 each. Taking into account both the hatching success and the number of nests, 1988 (86.72%, *n*=40) and 1992 (100%, *n*=27) were the most successful years.

In the second clutch, years 1974 (*n*=1), 1975 (*n*=2) and 1980 (*n*=4) had a 100 percent hatching success rate. 1988 (80.73%) had the highest number of nests with 34 recorded. Taking into account both the hatching success and the number of nests, 1999 (97.50%, *n*=12) and 1988 (80.73%, *n*=34) were the most successful years.

Environmental effects

There was no significant correlation between total annual rainfall for Manjimup and the hatchling success for clutch one (*P*=0.476, r=-0.143) or clutch two (*P*=0.99, r=0.003). However, the years with the highest hatchling success for clutch one and two (1988, 1992 and 1999) all received above average rainfall (1140.7mm, 1024.7mm and 1059.4mm respectively).

The majority (96%) of the nests were found on man-made sites. There was no significant difference in the clutch size (*P*=0.172), number hatched (*P*=0.324) or the number of fledglings (*P*=0.473) between natural and man-made sites.

DISCUSSION

In discussing these results it is useful to make comparisons with previously published studies from Sydney, Tasmania and New Zealand (Table 2) (Marchant and Fullagar 1983; Park 1981b; Tarburton 1993).

The average incubation period for Middlesex was higher than Sydney, Tasmania and New Zealand (Table 2). The average incubation period for Welcome Swallows is 16 days (Frith H. J. (ed.) 1997; Marchant and Fullagar 1983; Sindik and Lill 2009) with the Sydney, Tasmania and New Zealand studies recording similar incubation times (Marchant and Fullagar 1983; Park 1981b; Tarburton 1993). The difference may be due to different recording and calculating methods (i.e. recording from first egg or last egg laid).

The mean clutch size at Middlesex was considerably below the average of four (Beruldsen 2003). The mean clutch size of this study was lower than that of Sydney and considerably lower than that of Tasmania and New Zealand (Marchant and Fullagar 1983; Park 1981b; Tarburton 1993) (Table 2).

The smaller clutch size found in the Middlesex population compared to Sydney populations may be due to their sedentariness (Brown and Brown 1991). Since the population does not migrate, they are not exposed to some of the dangers associated with migration such as disorientation and predation while *en route* (Alerstam 1990). The migratory populations, such as those in Sydney, may have evolved larger clutch sizes to make up for those individuals lost on migration (Brown and Brown 1991; Hindwood 1934; Tarburton 1993). It is also possible that the long dry Western Australian summers have an effect on clutch size, by limiting the period when food is readily available.

Both the Middlesex and New Zealand population is sedentary so migration cannot account for the considerable difference in clutch sizes. Welcome Swallows have only recently colonised New Zealand and the population has not yet reached the threshold where density limits the breeding success (Evan *et al.*

2003; Higgins *et al.* 2006). There may be a lack of competitors for resources such as nesting sites and food and an increase in food supply can lead to larger clutches (Lack 1947; Tarburton 1993). Disney's (1988) study into Welcome Swallows breeding in captivity (with food provided) found it not uncommon for birds to have four clutches. A good food supply may increase the clutch size of Welcome Swallows breeding in Australia and New Zealand.

There is a recognised trend in the Northern Hemisphere that clutch size, within the same species, increases with latitude (Lack 1947), however there is little evidence that this trend is present within Australia (Marchant and Fullagar 1983). There was no significant correlation between latitude and the mean clutch sizes of the four locations looked at in this paper. This may be due to the lower climatic and photoperiod variation across the four locations compared to studies in Europe and in the tropics.

There was no significant difference in mean clutch size between the years (when comparing the highest and lowest years) which is consistent with Lack (1947), who states that in most species the mean clutch size does not vary between years.

This study found no significant difference between the clutch size of first and second nesting attempts, however there were considerably more first nesting attempts (62% compared to 36.2%). The Sydney study found a small difference between clutch size in first and second nesting attempts (96 for first clutch and 105 for the second clutch) (Marchant and Fullagar 1983).

The majority of the nesting attempts occurred as first or second clutches, with only 0.8 percent occurring in third or fourth nesting attempts, indicating that, at Middlesex, Welcome Swallows have very few clutches after their second.

The hatching success of this study is considerably higher than the study in Sydney (Marchant and Fullagar 1983) (Table 2). There was no significant difference in the number hatched in clutches one and two, similar to the Sydney study where first and second clutches were not considerably different (71 and 77 respectively) (Marchant and Fullagar 1983). As expected, the years with the lowest clutch size were significantly different from the highest years (for clutch one and two).

The fledgling success of this study is considerably higher than that of Sydney, Tasmania, and New Zealand (Marchant and Fullagar 1983; Park 1981b; Tarburton 1993) (Table 2). This study found no significant difference between the number of fledglings in the first and second clutches. In Sydney, there was a considerable difference, with clutch one having 38 fledge and clutch two having 71 (Marchant and Fullagar 1983).

The Browns listed the nesting sites by local names that will be meaningless to most readers. However, if any follow-up work is undertaken it may be useful to have them published because they will be recognised by local people, so they have been used in the following comments. Two of the most successful nesting sites (Keegan's Brook and Home Dam) were located at a major water source. Water sources, such as dams, provide the swallows with mud for nest building (Boehm 1957; Brown and Brown 1991) as well as excellent feeding grounds, attracting many insects, particularly mosquitoes (Boehm 1957). Swallows also use a large amount of energy during foraging which subsequently leads to a large amount of water loss (Bartholomew and Cade 1963). It would therefore be advantageous to the birds to breed near a large dam.

Bob's old house was also a very successful breeding location, most likely used by the swallows because of convenience and the level of protection it provided (Sharland 1943). However it is difficult to conclude as to why certain sites were preferred due to the little data available on each location.

Lack (1947) states that year generally has little effect on the breeding parameters of most species of birds. In the Middlesex study, several years had 100 percent hatchling success rates but these years generally had very small sample sizes. The most successful years were 1988, 1992 and 1999, which had a high hatchling success as well as relatively large sample sizes. From 1986, much more time was devoted to monitoring the swallows, therefore the years following generally had a larger sample size (Brown and Brown 1991).

There was no significant correlation between annual rainfall and hatchling success at Middlesex. Tarburton (1993) also found no correlation between rainfall and breeding success. Serventy and Marshall (1957) found out-of-season rainfall events have no effect on bird breeding patterns in the southwest. The present analysis confirms their view for the Welcome Swallow.

There were substantially more nests built on man-made structures compared with natural sites, as reported in other studies (Brown and Brown 1991; Evan *et al.* 2003; Higgins *et al.* 2006; Marchant and Fullagar 1983). Tarburton(1993) found no natural nesting sites in the study in New Zealand. The clearing of land for agriculture may account for the lack of natural nest sites in Middlesex. Swallows are known to nest in man-made structures for convenience and protection (Sharland 1943) and depend on man for their wide-spread distribution (Boehm 1957; Marchant and Fullagar 1983).

Re-trap data were investigated to determine if individuals banded as pulli returned to breed in the same location. There did not appear to be any trend in the data to support this. Likewise Park (1981a) banded 213 pulli and only one returned to breed in the area.

ACKNOWLEDGEMENTS

We acknowledge with gratitude the tireless work of Dick and Molly Brown at the Middlesex Field Study Centre who collected all the data, and Lee Fontinini, the Executor of their estate who gave us access to the data for analysis. Jared Pedro gave much help and support, especially during the lengthy analysis process. We thank Peter Fullagar and Michael Tarburton for helpful comments on a draft of this article.

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