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# The reproductive capacity of Monk Parakeets *Myiopsitta monachus* is higher in their invasive range

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**Running head: Reproductive capacity of invasive Monk Parakeets**

## Abstract

We provide detailed breeding parameters for the population of monk parakeets, *Myiopsitta monachus*, in Barcelona, Spain, based on data collected for 651 nests over five breeding seasons. This invasive population has a high reproductive capacity compared to the native range: fledging success was double, the percentage of pairs attempting second broods three times higher, and 55% of one-year old birds bred compared to almost zero in South America.


**Keywords:** Myiopsitta monachus, breeding parameters, clutch size, productivity, reproductive potential, invasion range, juvenile breeding

An understanding of population dynamics is critical for the control of pest species. Measurement of productivity, recruitment and survival rates allows population growth forecasts and permits changes in population size under different control scenarios to be modelled (Williams *et al.* 2002; Conroy & Carroll 2009; Rockwood & Witt 2015). Monk parakeets (*Myiopsitta monachus*) are among the most invasive bird pest species (Carrete & Tella 2008; Menchetti & Mori 2014; Carrete & Tella 2016). Some effort has been made to model their population growth and spread within their invasive range (Pruett-Jones *et al.* 2007), but these simulations were based entirely on information obtained from their native populations in South America. Data on survival rates from invasive populations is now available (Conroy & Senar 2009), but equivalent data on breeding parameters is almost non-existent, apart from some incomplete information from Florida, USA, on brood size and fledgling success derived from a small sample of pairs (Avery *et al.* 2012). There is also some limited data based on only two nests in Brazil, where the species has recently spread (Viana *et al.* 2016). Information from Europe, where Monk Parakeets are a widespread invasive species with significant negative economic impacts on ornamental vegetation, human facilities and agriculture (Menchetti & Mori 2014; Senar *et al.* 2016), is totally non-existent.

The aim of this study is to quantify breeding parameters for the Monk Parakeet within its invasive European range. Our results are based on data from almost 500 pairs over five breeding seasons between 2002 and 2018.

## MATERIAL AND METHODS

The study was carried out in Barcelona city, Spain (N 41.39, E 2.17). The first Monk Parakeet nests were detected in Barcelona in the early 1970s (Batllori & Nos 1985). Since then, the population has increased exponentially (Domènech *et al.* 2003; Rodriguez-Pastor *et al.* 2012), becoming one of the largest populations in Europe that comprises in excess of 5,000 birds (Molina *et al.* 2016; Senar *et al.* 2017).

Nests were sampled in the breeding seasons of 2002-2003 and 2016-2018. Observations were conducted from 1st March to the end of September in 2002 and 2016, and to the end of June in the other years. Monk Parakeets are unique amongst the *Psittacidae* in building their own nests from twigs rather than nesting in cavities. They build communal nests containing from 1 to 60 separate nest chambers (1-12 recorded in our study area) (Burger & Gochfeld 2005), each occupied by a different pair. Communal nests are usually clustered in loose colonies in the same or adjacent trees. Nest inspections were conducted using a cherry-picker, and our sample unit was the chamber. In 2002, we focused on colonies in six locations within the city limits (Ciutadella, Lluïs Companys, Diagonal, Jardí Infantes, Tetuán, Institut Montserrat). In 2003, we focused on the same colonies except for those at the Institut Montserrat. In 2016, sampling was carried out on 28 colonies all over Barcelona (see figure 1 in Mori et al. (2019)). In 2017, sampling was focused on Ciutadella, Lluïs Companys, Marina and Tetuán. In 2018, we monitored colonies only in Ciutadella. For the majority of locations, each nest was visited a minimum of three times, with the final visit timed so that the chicks were 35 days or older and could be ringed. Some adults and juveniles

from colonies in Ciutadella Park were captured using a walk-in trap baited with food in the summer of each year of the study. Both juveniles and adults, when captured, and chicks in the nests, were marked with numbered aluminum rings and with unique medals attached to neck collars that allowed identification of the birds at distance (Senar *et al.* 2012).

Clutch size was determined from the total number of eggs and/or chicks found in the two first chamber inspections. The date of clutch initiation was estimated for each nest chamber by back-dating, based on a 2-day interval between successive eggs and a 24-day incubation period (Bucher *et al.* 1991; Navarro *et al.* 1992). The age of nestlings was also used for back-dating when necessary, age being calculated from appearance and body size measurements, according to Carrillo-Ortiz (2009). In about 50 clutches, no laying date could be estimated, for instance if it was found as a completed clutch and the eggs failed to hatch, giving no reference date. This resulted in differences in sample sizes between different breeding parameters. We provide detailed data on phenology for 2016 only, because the greatest number of nests was inspected over an extended time span during that breeding season. We also think that 2016 was a representative year for the phenology estimates. Overall productivity of the population was calculated as the number of fledglings per pair monitored, including pairs whose nests failed. The number of fledglings was determined in the final visit, when the chicks were ringed.

We refer to first clutches as the number of eggs laid by the female in her first breeding attempt in the season. Some first clutches failed for a variety of reasons and replacement clutches were laid; in our analyses we did not distinguish between replacement clutches (started following failure of the first clutch), and second clutches (laid after a successful first brood), referring to both as second broods. Thus, first brood productivity included both successful and failed first clutches, and any second clutches, either replacement or true second brood, were used to determine second brood productivity. For all the parameters we provide the mean value ± standard deviation.

## RESULTS

We found a total of 651 nests with eggs. Mean clutch initiation date for 2016 was 25th April (N = 316; range 5 March – 8 August), notably, there was clear bimodality in the frequency distribution of laying dates (Figure 1). Based on Figure 1, we defined 1st May as the last date for first clutches and the start of second clutches. Mean clutch initiation date for 2016 first clutches was 27th March (N = 189), and for second clutches was 6th June (N = 127). The distribution of lay dates in 2016 (Figure 1) reflected those recorded in other years. The earliest initial egg laying date was recorded on 2nd March 2012 and the latest on 18th August 2016.

Mean clutch size for the first brood in Barcelona across years was estimated as 5.0 ± 1.90 eggs (N = 468; Table 1). The maximum clutch size was 16; large clutches are not unusual in our Monk Parakeet population (see Table 1). Average clutch size for the

second brood was significantly smaller than first clutch size (3.6 ± 1.63 eggs, N = 183; two-sample t-test: t = 8.44, df = 649 , $P < 0.001$; Table 1). Clutch size did not differ between Europe and their native range, both for first and second clutches (1st: 5.0 ± 0.94 vs. 5.8 ± 0.90; t-test: t = 1.30, df = 7, $P = 0.24$; 2nd: 3.5 ± 0.28 vs. 4.0 ± 1.88, $P = 0.62$; Table 1).

Fledging success (i.e. productivity) for the first brood was estimated to be 3.3 ± 2.10 chicks per pair across all years of the study (N = 323; Table 1), with considerable variation across years (range: 1.6 – 4.3 fledglings per pair; Table 1). The maximum number of fledglings produced by a pair from a single breeding attempt was 11. Fledging success from second broods was significantly lower (1.5 ± 1.61 chicks, N = 59) compared to that of first broods (t-test: t = 6.40, df = 380, $P < 0.001$; Table 1). ǂ Fledging success during the first brood in Europe was substantially larger than in their native range (3.3 ± 1.08 vs. 1.6 ± 0.53; t-test: t = 2.97, df = 6, $P=0.02$; Table 1; we were unable to investigate this in second broods because data from South America were not available). The percentage of pairs engaged in second broods, estimated from sampling in 2002, 2016 and 2018 was 56% ± 9.93 (Table 1).

Detailed monitoring in 2018 of the breeding activity of juveniles previously ringed as nestlings in 2017, showed that 18 out of 33 yearlings (55%) observed at colonies in our study site in Ciutadella Park occupied chambers in which breeding attempts were made (with eggs and/or chicks) during their first year of life. The remaining 15 juveniles used roosting chambers where no breeding was attempted (n = 9) or formed part of a trio (n= 6) and were not computed as breeders. There were other juveniles present in our study site but that their nests were not checked and therefore we can draw no conclusions on their breeding status.

## DISCUSSION

Our results provide the first breeding parameters for the Monk Parakeet in Europe, and aside from data on clutch size and breeding success in Florida and Brazil for a small number of birds (Avery *et al.* 2012, Viana *et al.* 2016), we provide the first comprehensive data on breeding parameters in the invasive range of the species.

Cutch size did not differ between Europe and their native range. However, fledging success in Europe was the double than in South America. The lower fledgling success in the native compared to the invasive range could be due to the greater incidence of nest predation in their native range (Navarro *et al.* 1992). In North America, despite predation being possible, no direct observations of nest predation have been recorded (Avery & Shiels 2018). In Europe, black rats, *Rattus rattus,* have been observed depredating Monk Parakeet nests (Scortecci 1953), and black rats have been observed entering Monk Parakeets nests on several occasions (Hatchwell & Senar pers. obs.). Grey herons, *Ardea cinerea,* have also been occasionally observed to predate on Monk Parakeets chicks (Garcia & Tomas 2006). In addition, red squirrels, *Sciurus vulgaris,* could potentially be nest predators, since they have been observed depredating ring-necked parakeet, *Psittacula krameri,* nests (Mori *et al.* 2013). However, it is clear that

these predators, at least in the city of Barcelona, are not as active as snakes and opossums in the native range in South America (Navarro *et al.* 1992).

Clutch size and fledging success of second (and replacement) broods was approximately 50% lower than those of first brood attempts. This pattern was also observed in the native range in South America (Navarro *et al.* 1992), and it also appears in other ~~is generally true across~~ bird species (Deeming & Reynolds 2015). However, the percentage of pairs engaged in second broods, either true second broods or replacement broods, was far larger in the invasive range than in the native range (56 ± 9.93% vs. 15%) (Navarro *et al.* 1992). Despite the productivity of second broods being lower than that of first broods, the higher frequency of second broods could have a marked effect on yearly productivity of the species within their invasive range. Our data also demonstrates how long the breeding season can be in European populations, spanning from the start of March to the end of September; close to seven months of breeding activity *per annum*. In South America breeding spans six months from October to March (Navarro *et al.* 1992).

In relation to the age of first reproduction and although data is limited, we found that compared to the native range where breeding by yearling birds is seemingly extremely rare (Bucher *et al.* 1991~~;~~, Martín & Bucher 1993), in the invasive range about 50% of juveniles fledged the previous year were engaged in breeding activities during their first breeding season. This early onset of reproduction is also likely to increase the breeding output of the species within their invasive range.

Overall, our observations in Barcelona, where the Monk Parakeet is present at one of the highest population densities in Europe, reveal the high potential reproductive rate of the species in their invasive range. Given the economic damage that this species can cause in its invasive range (Conroy & Senar 2009~~;~~, Kumschick & Nentwig 2010~~;~~, Menchetti & Mori 2014~~;~~, Senar *et al.* 2016~~;~~, Avery & Shiels 2018), action to control their population growth is becoming increasingly necessary, especially in Mediterranean areas (Postigo *et al.* 2019). The results presented here can help to improve models of population growth for this species in invasive areas and contribute to designing effective management strategies.

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**Table 1.** Breeding parameters recorded in Barcelona Monk Parakeet population. Second brood refers to true second broods (when the first was successful) and replacement broods. We provide, for comparison, data from South and North America. The literature sources from our review appear in the author column.

| Parameter / Year | Mean | SD | N | Min | Max | Location | Author |
|---|---|---|---|---|---|---|---|
| **Cluth size (1st brood)** | | | | | | | |
| 2002 | 4.1 | 1.45 | 18 | 2 | 6 | Europe | This work |
| 2003 | 5.1 | 1.39 | 48 | 1 | 8 | Europe | This work |
| 2016 | 4.8 | 1.67 | 189 | 1 | 11 | Europe | This work |
| 2017 | 4.6 | 1.69 | 149 | 1 | 10 | Europe | This work |
| 2018 | 6.6 | 2.54 | 64 | 1 | 16 | Europe | This work |
| 1993-94 | 4.8 | | 15 | 3 | 7 | South America | Eberhard (1998) |
| 1998-99 | 6.9 | 2.10 | 13 | 5 | 12 | South America | Peris & Aramburú (1995) |
| 1982 | 6.0 | 1.75 | 52 | 1 | 11 | South America | Navarro et al. (1992) |
| 1983-88 | 5.4 | 2.30 | 313 | 1 | 9 | South America | Navarro et al. (1992) |
| 2006-07 | 4.2 | 4.81 | 50 | | | North America | Avery et al. (2008) |
| **Cluth size (2nd brood)** | | | | | | | |
| 2002 | 3.3 | 1.39 | 24 | 1 | 6 | Europe | This work |
| 2016 | 3.8 | 1.54 | 127 | 1 | 7 | Europe | This work |
| 2018 | 3.4 | 2.06 | 32 | 1 | 8 | Europe | This work |
| 1982-88 | 4.0 | 1.88 | 33 | | | South America | Navarro et al. (1992) |
| **Fledgling success (1st brood)** | | | | | | | |
| 2002 | 3.1 | 1.92 | 18 | 0 | 6 | Europe | This work |
| 2003 | 4.2 | 2.36 | 48 | 0 | 7 | Europe | This work |
| 2016 | 4.3 | 1.74 | 84 | 0 | 11 | Europe | This work |
| 2017 | 3.2 | 1.78 | 110 | 0 | 9 | Europe | This work |
| 2018 | 1.6 | 1.80 | 63 | 0 | 6 | Europe | This work |
| 1982 | 2.2 | | 52 | | | South America | Navarro et al. (1992) |
| 1983-88 | 1.4 | | 313 | | | South America | Navarro et al. (1992) |
| 1998-99 | 1.2 | | 13 | | | South America | Peris & Aramburú (1995) |
| 2006-07 | 3.1 | 1.41 | 14 | 1 | 6 | North America | Avery et al. (2012) |
| **Fledgling success (2nd brood)** | | | | | | | |
| 2002 | 1.8 | 1.40 | 12 | 0 | 4 | Europe | This work |
| 2016 | 1.4 | 1.66 | 47 | 0 | 5 | Europe | This work |
| **% pairs engaged in 2nd broods** | | | | | | | |
| 2002 | 50 | | | | | Europe | This work |
| 2016 | 67 | | | | | Europe | This work |
| 2018 | 50 | | | | | Europe | This work |
| 1982-88 | 15 | | | | | South America | Navarro et al. (1992) |

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312 **Figure 1**. Frequency distribution for Monk Parakeet clutch initiations in Barcelona city during
313 2016 (N= 316).

314

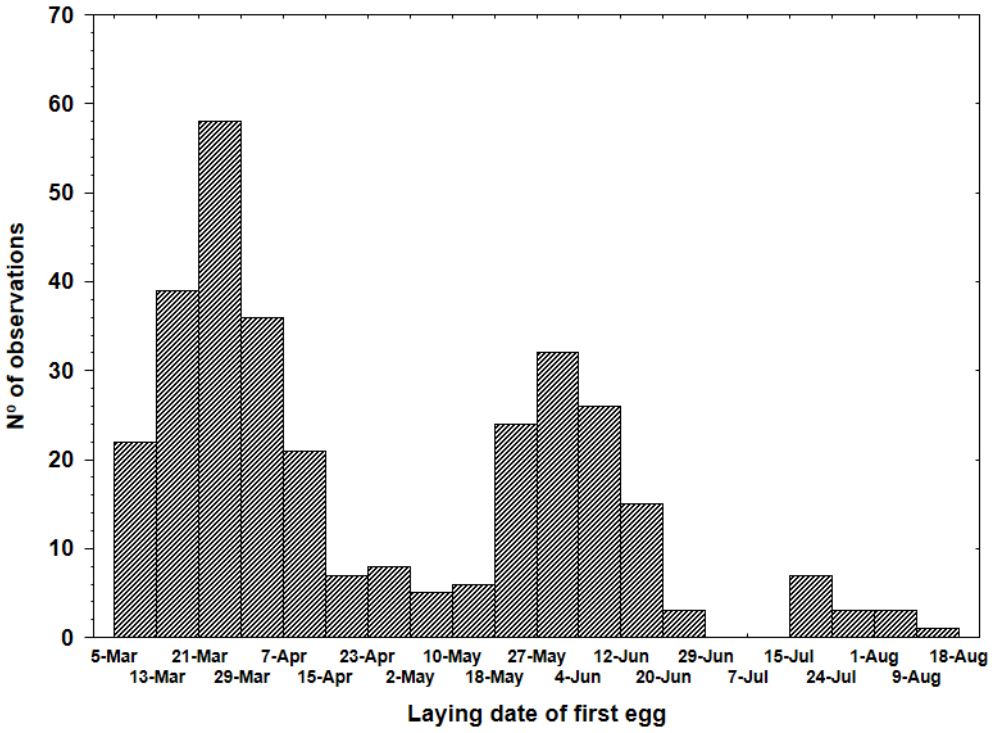


Figure 1. Frequency distribution for Monk Parakeet clutch initiations in Barcelona city during 2016 (N= 316).

206x154mm (96 x 96 DPI)