Long–distance dispersal of monk parakeets

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Abstract
Long–distance dispersal of monk parakeets. Invasive species threaten biodiversity all around the world and for this reason, identifying the causes and mitigating their effects is a priority in conservation biology. One of the most important factors when dealing with invasive species is dispersal, because the distribution of dispersal distances among members of a population can greatly affect the rate of spread of these invasive populations. Long–distance dispersal events have a disproportionately large influence on dispersal kernel estimations, but because of restricted spatial sampling scales they are difficult to detect. Here we use an extensive database of 3,039 monk parakeets ringed in Barcelona city since 2002 with an extensive control program across Catalonia where 3,460 birds have been captured since 2013, with the aim of describing these long–distance movements of monk parakeets. We recorded dispersal distances of over 10 km for a total of eight individuals. Long–distance dispersions were in all directions and both males and females were involved. While some individuals moved in their first year, others delayed dispersal several years. Given that long–distance dispersal events can have a large influence on the rate of range expansion of invasive species this information can be of great utility when modeling the dispersal and spread of the species.

Key words: Monk parakeet, Long–distance dispersal, Spread, Invasive species

Resumen
Dispersión a larga distancia de las cotorras argentinas. Las especies invasivas amenazan la biodiversidad en todo el mundo y, por ello, en el ámbito de la biología de la conservación se considera prioritario determinar las causas y mitigar los efectos de este fenómeno. Uno de los factores más importantes en relación con las especies invasivas es la dispersión, ya que la distribución de las distancias de dispersión entre los miembros de una población puede incidir notablemente en la velocidad de propagación de estas especies invasivas. Los episodios de dispersión a larga distancia tienen una influencia desproporcionadamente alta en las estimaciones de la dispersión de densidad de kernel, pero resultan difíciles de detectar debido a que las escalas de muestreo son restringidas. En el presente artículo utilizamos una extensa base de datos de 3.114 ejemplares de cotorra argentina que han sido anillados en la ciudad de Barcelona desde el año 2002, junto con los datos de un amplio programa de control en toda Cataluña gracias al cual se han capturado 3.460 aves desde 2013, con la finalidad de describir estos desplazamientos a larga distancia de las cotorras argentinas. Ocho de los ejemplares recorrieron distancias de más de 10 kilómetros. La dispersión a larga distancia se produjo en todas direcciones y tanto en machos como en hembras. Algunos ejemplares se desplazaron en su primer año de vida, mientras que otros tardaron varios años en hacerlo. Habida cuenta de que los episodios de dispersión a larga distancia pueden tener una gran influencia en la velocidad de expansión de la distribución de las especies invasivas, esta información puede ser muy útil para elaborar modelos de la dispersión y la propagación de la especie.

Palabras clave: Cotorra argentina, Dispersión a larga distancia, Propagación, Especies invasivas

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Introduction

Invasive species are one of the most important current threats to biodiversity (Swanson, 1995; Bellard et al., 2014). Dispersal, defined as the movement of organisms, their propagules, or their genes away from the source (Stenseth and Lidicker, 1994; Clobert et al., 2001; Petit, 2004), is a major ecological issue when dealing with invasive populations. It makes intuitive sense that dispersal is critical to colonization of new areas and that the distribution of dispersal distances among members of a population can greatly affect the rate of spread of invasive species over time (Paradis et al., 1998). Therefore, the rate at which ranges expand (i.e. the invasion speed) is the critical parameter in understanding invasion dynamics (Neubert and Caswell, 2000).

In both terrestrial and marine ecosystems, the general shape of dispersion curves is almost universally irregular: at one end of the distribution there is usually an abundance of relatively short dispersal distances, while at the other end there is a paucity of relatively long–distance dispersal (LDD) events (Kot et al., 1996; Cain et al., 2000; Nathan, 2001). Thus, LDD is typically an extreme event of propagule movement in any plant or animal population, usually occurring with extremely low probability but potentially reaching an extremely long–distance (Nathan, 2001; Jordano, 2017). Despite their rarity, LDD has a disproportionately high influence on population dynamics, genetic structure, and biogeographical history of species. It determines the ability to colonize new habitats (Nathan et al., 2008; Schurr et al., 2009) and the rate of population spread, which becomes even more important with invasive species because this exceptional dispersal of elements foreign to the ecosystem can threaten the survival of other (native) species (Kot et al., 1996; Clark et al., 1999; Shigesada and Kawasaki, 2002; Levin et al., 2003).

Therefore, LDD is highly relevant to the most pressing biodiversity issues facing us today, and is likely to become even more important as the impacts of global climate change intensify. Indeed, extensive literature addresses the importance of dispersal of invasive species in biodiversity conservation (Ellstrand, 1992; Strykstra et al., 1998; Sweanor et al., 2000; Cooper and Walters, 2002; Honnay et al., 2002; Haddad et al., 2003). However, although implementation of LDD assessment as a standard routine in conservation practice would lead to better management decisions, measurement of this important population parameter is notoriously challenging because of spatially constrained sampling regimes (Koenig et al., 1996; Reynolds et al., 2017).

The monk parakeet *Myiopsitta monachus*, native to South America, is considered the most invasive parrot species, having invaded with great success numerous areas across North America, Europe and Asia (Postigo et al., 2019). Studying the dispersal of monk parakeets is crucial because knowledge of LDD can be used in constructing biologically meaningful population models for directing management decisions. Previous work had shown that dispersal distance of monk parakeets is quite short, with a median natal dispersal of 45 m, but extreme values of 1,795 m (Dawson–Pell et al., 2021). Bucher et al. (1991) found an extreme value of 2,000 m, and Carrillo–Ortiz (2009) found an extreme value of 5,530 m. However, as described above, avian natal dispersal distance distributions often have long tails that are difficult to detect because of restricted spatial sampling scales (Greenwood and Harvey, 1982; Koenig et al., 1996; Paradis et al., 1998). Alternative methods, such as genetic approaches, have been used to infer such movements, finding LDD values for the monk parakeet as far as 100 km (Gonçalves da Silva et al., 2010). However, for verification of LDD on this scale, genetic and other alternative methods should be complemented with intensive capture–recapture efforts like the one used in this work (Nathan et al., 2003; Alcaide et al., 2009). Therefore, the objective of this work was to describe these long–distance movements of monk parakeets from Barcelona to various localities in Catalonia. To achieve this, we used an extensive database of 3,114 monk parakeets that were ringed in Barcelona city during the last 20 years with an extensive control program across Catalonia where 3,460 birds have been captured since 2013. These data reveal a limited but highly important number of long–distance movements for the monk parakeet.

Material and methods

This study was conducted in Catalonia, Spain, on the northeast coast of the Iberian Peninsula. Monk parakeets were ringed as adults or chicks in Barcelona city, with the majority of fieldwork conducted in Ciutadella Park, a large (30 ha) central park in the city that contains the city's zoological gardens and a large public access area of highly managed native and exotic vegetation (Postigo et al., 2021). Ciutadella Park is the site of the first record of monk parakeet nests in Barcelona (Batllori and Nos, 1985) and now contains a high density of monk parakeet nests. Birds were captured as adults since 2002 with a Yunick platform trap at the Natural Sciences Museum of Barcelona at Ciutadella Park, and as chicks, using a cherry picker machine for access to nests, in the same area. Each bird was ringed with an aluminum leg ring and was also marked with a unique neck collar for visual identification in the field without having to recapture them (Senar et al., 2012). From May 2002 to January 2023 a total of 3,114 individuals were marked.

Since 2013, efforts to control the species in various counties across Catalonia allowed the capture of 3,460 monk parakeet individuals. Capture efforts were conducted in all terrestrial directions from Barcelona, although the location of the efforts could change from year to year. We captured birds at night in the nests using a specially designed butterfly net with a long handle, and a database was built, including the georeferenced location, date, and ring and neck collar numbers for all marked birds captured.

We determined the dispersal distances of all marked birds from Ciutadella Park as the distance between the original ringing area and the site of

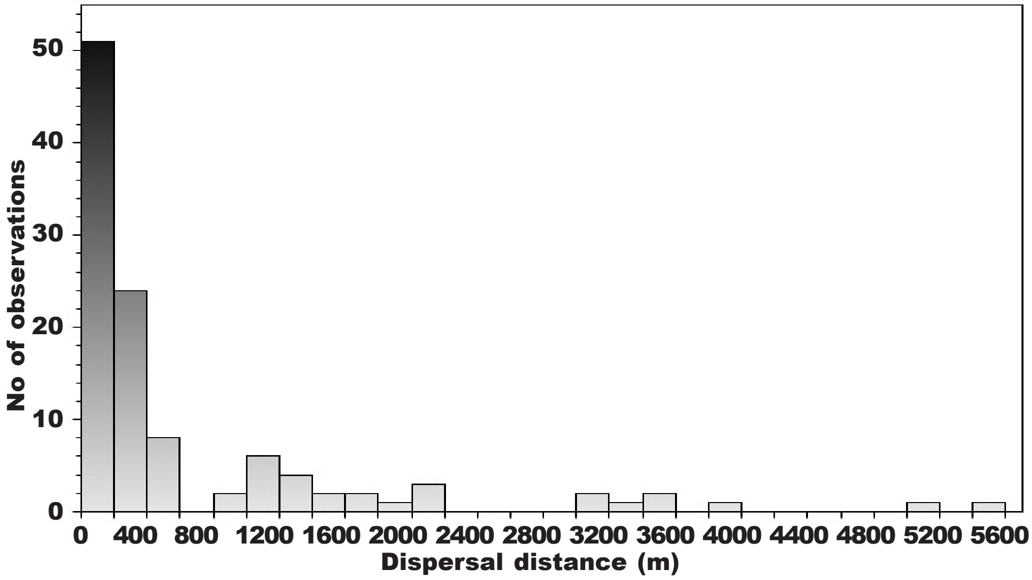

Fig. 1. Frequency distribution of dispersal distances of monk parakeets *Myipsitta monachus* in the study area, according to raw data from previous work by Carrillo–Ortiz (2009) and Dawson–Pell et al. (2021). Carrillo–Ortiz (2009) includes movements detected in the first year and in subsequent years; Dawson–Pell et al. (2021) included only movements carried out in the first year after fledging. The longest dispersal movement was of 5,530 m.

Fig. 1. Distribución de la frecuencia de las distancias de dispersión de la cotorra argentina Myiopsitta monachus *en la zona del estudio, según los datos sin elaborar de estudios anteriores de Carrillo–Ortiz (2009) y Dawson–Pell et al. (2021). En Carrillo–Ortiz (2009) se incluyen los movimientos detectados en el primer año y en años posteriores; en Dawson–Pell et al. (2021) solo se incluyen los movimientos realizados en el primer año posterior al emplumecimiento. El movimiento de dispersión más largo fue de 5.530 m.*

capture. We defined a long–distance movement when the dispersal distance was > 10 km because this is approximately double the maximum dispersal distance previously recorded for the population (fig. 1; Carrillo–Ortiz, 2009; Dawson Pell et al., 2021). Whenever blood samples were available, birds were sexed molecularly according to Dawson Pell et al. (2021).

Results

We recorded a total of eight out of a total of 3,114 ringed individuals that dispersed more than 10 km and hence were considered long–distance dispersers (table 1). The initial capture point is the place where the bird was ringed for the first time. Thereafter, several locations for the same bird correspond to resightings. The shortest long–distance movement recorded was 10.5 km and the longest was 73.9 km (mean = 33.2 km; median = 22.5 km). LDD events were in all directions (fig. 2) and involved both males and females (table 1). Some individuals moved in their first year (e.g. individual number 1, table 1), whereas some others delayed dispersal several years (e.g. individuals 3 and 7, table 1).

Discussion

The long–distance dispersal distances of monk parakeets recorded in this study are considerably larger than those documented in their native range (median = 1,230 m, maximum = 2,000 m; Bucher et al., 1991; Martín and Bucher, 1993) or in invasive habitats, with maximum values of 1,795 m (Dawson–Pell et al., 2021) and 5,530 m (Carrillo–Ortiz, 2009) (see also fig. 1). Dispersal distances based on genetic analyses have suggested that long range movements of > 100 km could be 'frequent' (Gonçalves da Silva et al., 2010). However, given our extensive sampling (fig. 2), we do not think that this suggestion is realistic, at least for our study population. While our data suggest that this distance could be reached, such events would clearly be rare. Instead, the results of this and previous studies in Catalonia suggest that dispersal by monk parakeets is characterized by very short dispersal distances (< 400 m; Dawson–Pell et al., 2021; fig. 1), although longer movements reaching localities as far away as 10 km, and exceptionally, locations at a distance of 50–100 km, have been reported. The two anecdotal movements of about 10 km described in Senar et al. (2016) add to the evidence.

Table 1. Information of capture events of monk parakeets *Myiopsitta monachus* performing long–distance dispersals (≥ 10 km) in Barcelona: Dd, dispersal distance (in km).

Tabla 1. Información de las cotorras argentinas Myiopsitta monachus *capturadas que realizaron desplazamientos a larga distancia (≥ 10 km) en Barcelona: Dd, distancia de dispersión (en km).*

ID	Ring	Sex	Dd	Date	Locality	Capture (Y)	Capture (X)
1	AX00781	F	10.5	25/09/2020	Ciutadella Park, Barcelona	41,388213	2,183081
				13/10/2020	Ciutadella Park, Barcelona		
				22/11/2020	Ciutadella Park, Barcelona		
				06/06/2021	Cornellá de Llobregat	41,356708	2,064361
2	AX04189	M	10.7	19/12/2016	Ciutadella Park, Barcelona	41,388213	2,183081
				26/01/2017	Ciutadella Park, Barcelona		
				05/05/2017	Ciutadella Park, Barcelona		
				23/05/2017	Ciutadella Park, Barcelona		
				09/06/2017	Ciutadella Park, Barcelona		
				19/07/2017	Ciutadella Park, Barcelona		
				04/12/2017	Plaça de Pau Vila, Barcelona	41,381476	2,184514
				20/03/2018	Pg. Lluís Companys, Barcelona	41,390189	2,181767
				20/03/2018	Plaça de Pau Vila, Barcelona		
				17/04/2018	Ciutadella Park, Barcelona		
				08/05/2018	Ciutadella Park, Barcelona		
				16/07/2018	Ciutadella Park, Barcelona		
				27/05/2021	Sant Joan Despí	41,378906	2,055313
3	4124445	–	10.7	03/01/2005	Ciutadella Park, Barcelona	41,388213	2,183081
				04/10/2005	Ciutadella Park, Barcelona		
				24/01/2006	Ciutadella Park, Barcelona		
				15/06/2007	Ciutadella Park, Barcelona		
				06/07/2007	Ciutadella Park, Barcelona		
				16/02/2008	Ciutadella Park, Barcelona		
				28/06/2008	Ciutadella Park, Barcelona		
				18/03/2009	Ciutadella Park, Barcelona		
				19/03/2009	Ciutadella Park, Barcelona		
				20/04/2009	Ciutadella Park, Barcelona		
				11/05/2009	Avda. Meridiana 88, Barcelona	41,406912	2,187220
				15/11/2010	Ciutadella Park, Barcelona		
				09/05/2015	Cornellá de Llobregat	41,346583	2,067333
4	AX04221	M	16.5	24/05/2017	Plaza Tetuan, Barcelona	41,394863	2,175811
				21/06/2017	Ciutadella Park, Barcelona		
				13/07/2017	Ciutadella Park, Barcelona		
				16/05/2019	Viladecans	41,311809	2,011705
5	AX05587	M	28.6	12/02/2019	Ciutadella Park, Barcelona	41,388213	2,183081
				29/11/2020	Ciutadella Park, Barcelona		
				21/12/2020	Ciutadella Park, Barcelona		
				29/12/2020	Ciutadella Park, Barcelona		
				20/01/2022	Les Franqueses del Vallés	41,631411	2,294086
6	AX05733	–	55.8	21/01/2021	Ciutadella Park, Barcelona		
				26/01/2023	c/ Mallorca, Calafell	41,188787	1,570507
7	AX00799	M	59.1	01/10/2020	Ciutadella Park, Barcelona	41,388213	2,183081
				13/11/2020	Ciutadella Park, Barcelona		
				25/01/2021	Ciutadella Park, Barcelona		
				01/02/2021	Ciutadella Park, Barcelona		
				05/02/2021	Ciutadella Park, Barcelona		
				18/11/2021	El Vendrell	41,182753	1,530116

Table 1. (Cont.)

ID	Ring	Sex	Dd	Date	Locality	Capture (Y)	Capture (X)
8	4060258	–	73.9	18/12/2003	Ciutadella Park, Barcelona	41,388213	2,183081
				27/12/2003	Ciutadella Park, Barcelona		
				25/06/2004	Ciutadella Park, Barcelona		
				27/07/2004	Ciutadella Park, Barcelona		
				03/08/2004	Ciutadella Park, Barcelona		
				28/12/2004	Ciutadella Park, Barcelona		
				18/01/2005	Ciutadella Park, Barcelona		
				12/02/2005	Ciutadella Park, Barcelona		
				17/08/2005	c/ Bac de Roda 258, Barcelona	41,415150	2,194150
				22/04/2016	Torelló	42,050037	2,264045

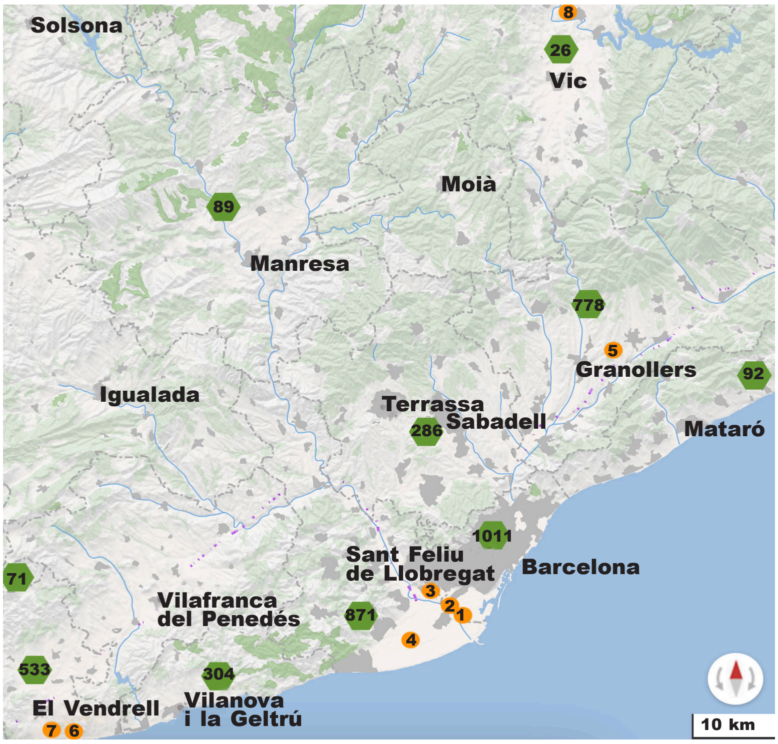

Fig. 2. Map of long–distance dispersals (orange points) of monk parakeets *Myiopsitta monachus* in Barcelona city. Numbers associated with orange points correspond to the number of each bird (ID) in table 1. Green hexagons are counties sampled across Catalonia, with the number of birds trapped in each of them across the control operations (n = 3,460). The map displays urbanized areas in dark grey. The division lines of the different counties are marked with a dashed line. Main cities are also labeled.

Fig. 2. Mapa de los desplazamientos a larga distancia (puntos de color naranja) de las cotorras argentinas Myiopsitta monachus *en la ciudad de Barcelona. Los números asociados a los puntos naranjas corresponden al número asignado a cada ave (ID), que se puede consultar en la tabla 1. Los hexágonos verdes indican las comarcas estudiadas de Cataluña y los números, la cantidad de ejemplares capturados en cada una de ellas en el marco de las operaciones de control (n = 3.460). En el mapa las zonas urbanizadas se muestran en gris oscuro. Las líneas discontinuas delimitan las comarcas. También se indican las principales ciudades.*

Monk parakeets in our study dispersed in various directions, and individuals appeared to have no specific inherent directional preferences (fig. 2). This is consistent with the general view that natal dispersal is a unidirectional movement in which individuals, after becoming independent from their parents, disperse in various directions to settle and reproduce at some distance from their natal sites (Jordano, 2017). This can simplify future models on the spread of the species (Méndez et al., 2014).

Both males and females were involved in these movements even though it is known that both natal and breeding dispersal in birds is more extensive among females (Greenwood and Harvey, 1982; Pusey, 1987; Trochet et al., 2016). Previous work on monk parakeets, at a smaller spatial scale, supported this view, with females having significantly longer (144 m) natal dispersal distances than males (15 m) (Dawson Pell et al., 2021). However, our data show that both sexes can exhibit long–distance dispersal movements, which could have important impacts on demographic and genetic population structure models (Trochet et al., 2016).

Despite the majority of animals dispersing after becoming independent from their parents (i.e. natal dispersal), our data show that some individuals delayed dispersal for several years, during which time some may have bred. Breeding dispersal movements may be caused by desertion, predation of the eggs or nestlings, or by the poor quality of the food supply in the territory (Greenwood and Harvey, 1982). In Barcelona, another cause of prompt dispersal may be nest destruction, conducted as a management strategy. However, dispersal events by birds older than one year are not necessarily instances of breeding dispersal because a proportion of birds in our population delay natal dispersion beyond their first year. About 50 % of monk parakeets do not breed in their first spring (Senar et al., 2019), and about 20 % engage in helping behavior (Dawson–Pell et al., 2021). Therefore, birds dispersing after their first year may be delayed natal dispersers (Brown, 1987; Ekman et al., 2009). However, in this dataset we are unable to distinguish these events from breeding dispersal.

Undoubtedly, dispersal ability strongly affects how quickly any organism spreads across the landscape. This dispersal is of critical importance for the study of colonization and range expansion (Paradis et al., 1998). Moving long–distances may not only increase the average dispersal distance but may also lead to the formation of satellite populations, and these satellites greatly increase the rate of spread by creating new sources of colonists. Simulations that contrast the effect of removing either the expanding edge of large populations or the more easily controlled small, nascent populations, generally find that control of these satellites is the better way to manage the spread of invasive species (Moody and Mack, 1988; Shigesada and Kawasaki, 1997; Taylor and Hastings, 2004). Long–distance dispersal movements are therefore very important to define the velocity of species expansion. Consequently, the inclusion of data on long–distance dispersal can guide the choice between the management options for controlling the dispersal and spread of the species.

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References

Alcaide, M., Serrano, D., Tella, J. L., Negro, J. J., 2009. Strong philopatry derived from capture–recapture records does not lead to fine–scale genetic differentiation in lesser kestrels. *The Journal of Animal Ecology,* 78(2): 468–475, Doi: 10.1111/j.1365-2656.2008.01493.x

Batllori, X., Nos, R., 1985. Presencia de la Cotorrita gris (*Myiopsitta monachus*) y de la Cotorrita de collar (*Psittacula krameri*) en el área metropolitana de Barcelona. *Miscel·lània Zoològica,* 9: 407–411, https://other.museucienciesjournals.cat/other/mz/mz-volum-09-1985/presencia-de-la-cotorrita-gris-myiopsitta-monachus-y-de-la-cotorrita-de-collar-psittacula-krameri-en-el-area-metropolitana-de-barcelona

Bellard, C., Leclerc, C., Leroy, B., Bakkenes, M., Veloz, S., Thuiller, W., Courchamp, F., 2014. Vulnerability of biodiversity hotspots to global change. *Global Ecology and Biogeography,* 23(12): 1376–1386, Doi: 10.1111/geb.12228

Brown, J. L., 1987. *Helping Communal Breeding in Birds: Ecology and Evolution*. Princeton University Press. Available online at: http://www.jstor.org/stable/j.ctt7zvrhd [Accessed on 17 July 2022].

Bucher, E. H., Martin, L. F., Martella, M. B., Navarro, J. L., 1991. Social behaviour and population dynamics of the monk parakeet. In: *Acta XX Congressus Internationalis Ornithologici, 2–9 December 1990*: 681–689 (B. Bell, R. Cossee, J. Flux, B. Heather, R. Hitchmough, C. Robertson, M. J. Williams, Eds.). Ornithological Congress Trust Board, Christchurch, New Zealand.

Cain, M. L., Milligan, B. G., Strand, A. E., 2000. Long–Distance Seed Dispersal in Plant–Populations. *American Journal of Botany,* 87(9): 1217–1227, Doi: https://doi.org/10.2307/2656714

Carrillo–Ortiz, J., 2009. Dinámica de poblaciones de la cotorra de pecho gris (*Myiopsitta monachus*) en la ciudad de Barcelona. PhD thesis, University of Barcelona, Barcelona.

Clark, J. S., Silman, M., Kern, R., Macklin, E., HilleRisLambers, J., 1999. Seed Dispersal near and Far: Patterns across Temperate and Tropical Forests. *Ecology,* 80(5): 1475–1494, Doi:10.1890/0012-96

58(1999)080[1475:SDNAFP]2.0.CO;2
Clobert, J., Danchin, E., Dhondt, A., Nichols, J. D. (Eds.), 2001. *Dispersal*. Oxford University Press.
Cooper, C. B., Walters, J. R., 2002. Experimental Evidence of Disrupted Dispersal Causing Decline of an Australian Passerine in Fragmented Habitat. *Conservation Biology*, 16(2): 471–478, Doi: 10.1046/j.1523-1739.2002.00346.x
Dawson–Pell, F. S. E., Senar, J. C., Franks, D. W., Hatchwell, B. J., 2021. Fine–scale genetic structure reflects limited and coordinated dispersal in the colonial monk parakeet, *Myiopsitta monachus*. *Molecular Ecology*, 30(6): 1531–1544, Doi: 10.1111/mec.15818
Ekman, J., Dickinson, J. L., Hatchwell, B. J., Griesser, M., 2009. Delayed dispersal. In: *Ecology and Evolution of Cooperative Breeding in Birds*: 35–47 (D. K. Walter, J. L. Dickinson, Eds.). Cambridge University Press, Cambridge.
Ellstrand, N. C., 1992. Gene Flow by Pollen: Implications for Plant Conservation Genetics. *Oikos,* 63(1): 77–86, Doi: 10.2307/3545517
Gonçalves da Silva, A., Eberhard, J. R., Wright, T. F., Avery, M. L., Russello, M. A., 2010. Genetic evidence for high propagule pressure and long–distance dispersal in monk parakeet (*Myiopsitta monachus*) invasive populations. *Molecular Ecology*, 19(16): 3336–3350, Doi: 10.1111/j.1365-294X.2010.04749.x
Greenwood, P. J., Harvey, P. H., 1982. The Natal and Breeding Dispersal of Birds. *Annual Review of Ecology and Systematics,* 13: 1–21, https://www.jstor.org/stable/2097060
Haddad, N. M., Bowne, D. R., Cunningham, A., Danielson, B. J., Levey, D. J., Sargent, S., Spira, T., 2003. Corridor use by diverse taxa. *Ecology,* 84(3): 609–615, https://www.jstor.org/stable/3107855
Honnay, O., Verheyen, K., Butaye, J., Jacquemyn, H., Bossuyt, B., Hermy, M., 2002. Possible effects of habitat fragmentation and climate change on the range of forest plant species. *Ecology Letters,* 5(4): 525–530, Doi: 10.1046/j.1461-0248.2002.00346.x
Jordano, P., 2017. What is long–distance dispersal? And a taxonomy of dispersal events. *Journal of Ecology,* 105(1): 75–84, Doi: 10.1111/1365-2745.12690
Koenig, W. D., van Vuren, D., Hooge, P. N., 1996. Detectability, philopatry, and the distribution of dispersal distances in vertebrates. *Trends in Ecology and Evolution,* 11(12): 514–517, Doi: 10.1016/S0169-5347(96)20074-6
Kot, M., Lewis, M. A., van den Driessche, P., 1996. Dispersal Data and the Spread of Invading Organisms. E*cology,* 77(7): 2027–2042, Doi: 10.2307/2265698
Levin, S. A., Muller–Landau, H. C., Nathan, R., Chave, J., 2003. The ecology and evolution of seed dispersal: A theoretical perspective. *Annual Review of Ecology Evolution and Systematics* 34: 575–604, Doi: 10.1146/annurev.ecolsys.34.011802.132428
Martín, L. F., Bucher, E. H., 1993. Natal dispersal and first breeding age in monk parakeets. The *Auk,* 110(4): 930–933, Doi: 10.2307/4088651
Méndez, V., Campos, D., Bartumeus, F. (Eds.), 2014. *Stochastic Foundations in Movement Ecology*. Springer Series in Synergetics, Springer Berlin, Heidelberg, Doi: 10.1007/978-3-642-39010-4
Moody, M. E., Mack, R. N., 1988. Controlling the Spread of Plant Invasions: The Importance of Nascent Foci. *Journal of Applied Ecology,* 25(3): 1009–1021.
Nathan, R., 2001. Dispersal: Biogeography. *Encyclopedia of Biodiversity, Elsevier*: 127–152, Doi: 10.1016/B0-12-226865-2/00073-0
Nathan, R., Perry, G. C., James, T., Strand, A. E., Cain, M. L., 2003. Methods for estimating long–distance dispersal. *Oikos,* 103(2): 261–273, Doi: 10.1034/j.1600-0706.2003.12146.x
Nathan, R., Schurr, F. M., Spiegel, O., Steinitz, O., Trakhtenbrot, A., Tsoar, A., 2008. Mechanisms of long–distance seed dispersal. *Trends in Ecology and Evolution,* 23(11): 638–647, Doi: 10.1016/j.tree.2008.08.003
Neubert, M. G., Caswell, H., 2000. Demography and dispersal: calculation a sensitivity analysis of invasion speed for structured populations. *Ecology,* 81(6): 1613–1628, Doi: 10.1890/0012-9658(2000)081[1613:DADCAS]2.0.CO;2
Paradis, E., Baillie, S. R., Sutherland, W. J., Gregory, R. D., 1998. Patterns of natal and breeding dispersal in birds. *Journal of Animal Ecology,* 67(4): 518–536, Doi: 10.1046/j.1365-2656.1998.00215.x
Petit, R. J., 2004. Biological invasions at the gene level. *Diversity and Distributions,* 10(3): 159–165, Doi: 10.1111/j.1366-9516.2004.00084.x
Postigo, J. L., Strubbe, D., Mori, E., Ancillotto, L., Carneiro, I., Latsoudis, P., Menchetti, M., Pârâu, L. G., Parrott, D., Reino, L., Weiserbs, A., Senar, J. C., 2019. Mediterranean versus Atlantic monk parakeets *Myiopsitta monachus*: Towards differentiated management at the European scale. *Pest Management Science*, 75: 915–922, Doi: 10.1002/ps.5320
Postigo, J. L., Carrillo–Ortiz, J., Domènech, J., Tomàs, X., Arroyo, L., Senar, J. C., 2021. Dietary plasticity in an invasive species and implications for management: the case of the monk parakeet in a Mediterranean city. *Animal Biodiversity and Conservation,* 44(2): 185–194, Doi: 10.32800/abc.2021.44.0185
Pusey, A. E., 1987. Sex–biased Dispersal and Inbreeding Avoidance in Birds and Mammals. *TreeNote,* 2(2): 295–299, Doi: 10.1007/978-3-319-55065-7_859
Reynolds, C., Cumming, G. S., Vilà, M., Green, A. J., 2017. Birds as key vectors for the dispersal of some alien species: Further thoughts. *Diversity Distribution,* 23(5): 577–580, Doi: 10.1111/ddi.12549
Schurr, F. M., Spiegel, O., Steinitz, O., Trakhtenbrot, A., Tsoar, A., Nathan, R., 2009. Long–Distance Seed Dispersal. *Annual Plant Reviews,* 38: 204–237, Doi: 10.1002/9781444314557.ch6
Senar, J. C., Carrillo–Ortiz, J., Arroyo, L., 2012. Numbered neck collars for long–distance identification of parakeets. *Journal of Field Ornithology,* 83(2): 180–185, https://www.jstor.org/stable/23256482
Senar, J. C., Carrillo–Ortiz, J., Ortega–Segalerva,

A., Dawson–Pell, F. S. E., Pascual, J., Arroyo, L., Mazzoni, D., Montalvo, T., Hatchwell, B. J., 2019. The reproductive capacity of monk parakeets *Myiopsitta monachus* is higher in their invasive range. *Bird Study,* 66: 136–140, Doi: 10.1080/00063657.2019.1585749

Senar, J. C., Domènech, J., Arroyo, L., Torre, I., Gordo, O., 2016, An evaluation of monk parakeet damage to crops in the metropolitan area of Barcelona. *Animal Biodiversity and Conservation*, 39.1: 141–145, Doi: 10.32800/abc.2016.39.0141

Shigesada, N., Kawasaki, K., 1997. Biological invasions: theory and practice. Oxford: Oxford University Press. Available online at https://global.oup.com/academic/product/biological-invasions-theory-and-practice-9780198548515?cc=es&lang=en&

Shigesada, N., Kawasaki, K., 2002. Invasion and the range expansion of species: Effects of long–distance dispersal. In: *Invasion and the range expansion of species: effects of long–distance dispersal*: 350–373 (N. Shigesada, K. Kawasaki, Eds.). Blackwell Science.

Stenseth, N. C., Lidicker, W. Z., 1994. Animal Dispersal: Small Mammals as a model. *Journal of Mammalogy,* 75(2): 553–556, Doi: 10.2307/1382582

Strykstra, R., Pegtel, D., Bergsma, A. (Eds.), 1998. Dispersal distance and achene quality of the rare anemochorous species *Arnica montana* L.: implications for conservation. *Acta Botanica Neerlandica*, 47(1): 45–56.

Swanson, T. (Ed.), 1995. *The Economics and Ecology of Biodiversity Decline: The Forces Driving Global Change*. Cambridge University Press, Melbourne, Australia.

Sweanor, L. L., Logan, K. A., Hornocker, M. G., 2000. Cougar Dispersal Patterns, Metapopulation Dynamics, and Conservation. *Conservation Biology,* 14(3): 798–808, Doi: 10.1046/j.1523-1739.2000.99079.x

Taylor, C. M., Hastings, A., 2004. Finding optimal control strategies for invasive species: a density–structured model for Spartina alterniflora. *Journal of Applied Ecology,* 41(6): 1049–1057, https://www.jstor.org/stable/3505781

Trochet, A., Courtois, E. A., Stevens, V. M., Baguette, M., Alexis, C., Schmeller, D. S., Clobert, J., Irschick, D. J., Wiens, J. J., 2016. Evolution of Sex–Biased Dispersal. *The Quarterly Review of Biology,* 91(3): 297–320, Doi: 10.1086/688097