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A compilation of common crossbill *Loxia curvirostra* L., 1758 ring-recovery data from the Iberian Peninsula and other European regions.

Recopilación de datos de anillamiento y recaptura de piquituerto común *Loxia curvirostra* L., 1758 entre la península ibérica y otras regiones europeas.

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Abstract

In November 2021, a female common crossbill ringed in Switzerland was found in the Sistema Central mountain range, within the administrative border of the Community of Madrid (Spain). This is an unusal record due to the lack of data on irruptions of this species from central or northern Europe in the centre of the Iberian Peninsula. In this study, we have compiled all the existing common crossbill ring-recovery data from Iberia and other European regions. Our results show that common crossbill populations in the Iberian Peninsula are mainly sedentary, with limited movements across the different pine forest masses in search of food. In contrast, northern European common crossbill populations develop long distance migratory movements that may involve a large number of individuals following a NE-SW axis that, in an irregular manner and depending on the year, can arrive in the Iberian Peninsula in mid-August or September, where they may remain for several years before returning to their places of origin. In the Iberian Peninsula, these crossbills seem to use the pine species available as a trophic resource according to their ecological speciation, including species not present in their regions of origin.

Key words: common crossbill, *Loxia curvirostra*, nomadism, migration, centre Iberian Peninsula.

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Resumen

En noviembre de 2021, una hembra de piquituerto común anillada en Suiza fue encontrada en el Sistema Central dentro del límite administrativo de la Comunidad de Madrid (España). Se trata de un registro peculiar debido a los pocos datos sobre las irrupciones de individuos de la especie con origen/destino entre el centro o norte de Europa y el centro de la península Ibérica. Se recogen en este trabajo los registros de recuperaciones de piquituerto común extra-ibéricos hasta la fecha. Nuestros resultados muestran que las poblaciones de piquituerto común en la península ibérica tienen un carácter principalmente sedentario, con movimientos limitados a través de las diferentes masas forestales de pinos en busca de alimento. En cambio, las poblaciones de piquituerto común del norte de Europa realizan movimientos migratorios de larga distancia que pueden involucrar a un gran número de individuos siguiendo un eje NE-SO que, con carácter irregular según años, pueden alcanzar la península ibérica a partir de mediados de agosto o septiembre, donde pueden permanecer durante varios años antes de regresar a sus lugares de origen. Estos piquituertos parecen emplear como recurso trófico en la península ibérica las especies de pinos disponibles según su especiación ecológica, incluyendo especies no presentes en sus regiones de origen.

Palabras clave: piquituerto común, *Loxia curvirostra*, nomadismo, migración, centro península Ibérica.

Laburpena

2021eko azaroan, Suitzan eraztundutako mokoker eme ale bat topatu genuen sistema Zentralean, Madrilgo Erkidegoko (Espainia) mugen baitan. Erregistro bitxia da; izan ere, Europa erdialdea edo iparraldea jatorri edo helmuga duten espezie honetako aleen Iberiar penintsulan zeharreko bat-bateko sartzeen datu gutxi daude. Lan honetan, Iberiar penintsulan eta gaur egunera arte jasotako penintsulaz kanpoko berreskurapenen erregistroak biltzen dira. Gure ondorioen arabera, Iberiar penintsulako mokoker populazioek eskuarki jokabide sedentarioa dute eta elikagaiak bilatzeko pinu-baso batzuetatik besteetara mugatutako mugimenduak egiten dituzte. Europa iparraldeko mokoker populazioek, ordea, distantzia handiko migrazio mugimenduak egiten dituzte; IE-HM ardatza jarraitzen dute, taldeak ale askokoak izan daitezke, urteen arabera izaera irregularra dute eta iberiar penintsulara abuztu erdialdean-irailean hasita iristen dira. Gainera, jatorrizko eremuetara itzuli aurretik penintsulan hainbat urte eman ditzakete. Mokoker hauek, Iberiar penintsulan eta beren espezializazio ekologikoaren arabera, elikatzeko eskuragarri dituzten pinu espezie desberdinak erabil ditzakete (beren jatorrizko eremuetan ez dauden espezieak barne).

Gako hitzak: mokokerra, *Loxia curvirostra*, nomadismoa, migrazioa, Iberiar penintsulako erdialdea.

Introduction

The common crossbill *Loxia curvirostra* L., 1758 is a finch of Holarctic distribution of a genus specialised in feeding on coniferous seeds before the cone that contains them opens and are naturally dispersed, taking advantage of a resource out of the reach for other birds (Cramp and Perrins, 1994; Shirihai and Svensson, 2018). The distinct cone designs of the different coniferous species have caused morphological adaptations in the animals that feed on them. In the case of crossbills, feeding on different types of cones produces small biometric differences among populations, which leads to ecological isolation due to specialisation in the use of these trophic resources (Alonso *et al.*, 2006, 2020; Borras *et al.*, 2008; Edelaar and Terpstra, 2004; Edelaar *et al.*, 2012).

Feeding basically on coniferous seeds produces deficiencies of minerals that common crossbills compensate by licking certain rocks in search of their salts. They also consume small stones that, as in other birds, help them to crush the food in the gizzard. In humanised areas, they frequently occur around blocks of salt used as a nutrition complement for cattle, and stone facades of buildings where they lick the mortar for the same reasons. This need also leads them to consume the salt used in winter as flux on roads, where they are often accidentally run over by vehicles.

On November 21st, 2021, during a regular ringing session in Robregordo (41º 09' N, 03º 36' O) in an area adjacent to a Scots pine (*Pinus sylvestris*) wood, a female common crossbill carrying a metal ring around her right leg was found perched on the wall of a house (Fig. 1). The size of the ring did not correspond to our own and after a series of photographs and videos some characters could be read. Our colleague Sergio Sanz of the Alula Ringing Group, determined that the ring corresponded to the Swiss Ornithological Institute under EURING scheme Sempach-Helvetia (Switzerland), later confirmed by them. Unfortunately, we could not obtain the entire code, which makes it impossible to know the exact place and time of marking. The bird was not re-sighted in subsequent ringing sessions. This casual finding pushed us to investigate the migration and origin of extra-Iberian common crossbills.

Northern European common crossbill populations are forced to and can make nomadic movements in search of food due to the variable productivity of common spruce (*Picea abies*). It represents their main food source in these regions during the breeding season that occurs from January to April. Chicks are typically growing from February to April, the time when the spruce seeds are most easily accessible. This spruce species is an alternate bearing tree, with bad crop years typically followed by a moderate or good cone crop, and vice versa, usually on a pluriannual basis. In the years with poor spruce crops over wide areas, common crossbills make long-distance movements after the breeding season (from late May to October, mainly in June-July), at the same time as the nomadic annual movements described above, being able to reach thousands

Fig. 1.- Female common crossbill (*Loxia curvirostra*) ringed in Switzerland, perched on the wall of a building in the Sierra Norte of Madrid (Spain), November 2021 (Autor: EB).

Fig. 1.- Hembra de piquituerto común (*Loxia curvirostra*) anillada en Suiza, encaramada a la pared de un edificio en la Sierra Norte de Madrid (España), noviembre 2021 (Autor: EB).

of kilometres away mainly southwestward through Europe. These large scale movements are known as irruptions (Marquiss *et al.*, 2012; Newton, 2006). These southwestward movements are not evident in the Northeast of Europe until August, September and October according to migration counts at Falsterbo and Ottenby in Sweden, Rybachi in the Russian Federation, and other bird observatories near the southern edge of the boreal zone (Marquiss *et al.*, 2012). These irruptions generally take place in years with poor or moderate spruce productivity in Scandinavia that force crossbills from northern Russia to extend their migration to other parts of Europe in search of alternative food sources. Bird ringing recovery data in the Col de Bretolet has reflected that these common crossbill individuals cross Switzerland and often continue on to the southernmost part of France and up to Spain and Portugal in the Iberian Peninsula (Alerstam, 1993; Newton, 1972). They remain in the southwest of Europe from one to several years, in terms of spruce annual cycle taken as June to May, since this multiannual movement is linked to new cycles of northern Europe spruce crop loads after pluriannual alternate bearing. In the meantime, they are able to breed before returning to the regions where they were born (Newton, 2006), which can imply a certain genetic exchange among subpopulations. The use of stable isotope analysis from feathers suggests that irruptive common crossbills in Britain, Iceland and

Faeroes are originate from different parts of the western Palearctic boreal zone each year, and when several origins are denoted in the same irruptive year, birds arriving later come from further east (Marquiss *et al.*, 2012, 2008). Interestingly, it has been found that, in areas where alien coniferous species have been artificially planted by humans, the crossbill subpopulations adapted to feed on them, due to the similarity to natural conifers in their original breeding areas, are even able to colonize these coniferous plantations (Marquiss *et al.*, 2012; Massa *et al.*, 2022; McNab *et al.*, 2019; Newton, 1972).

Traditionally, it was considered that the Iberian populations of common crossbills are mainly sedentary due to the more regular seed/cone annual productivity of southern Europe pine species (*Pinus* spp.) (Borrás and Senar, 2003; Senar *et al.*, 1993). However, records using ring-recovery data (Mazuelas *et al.*, 2015), as well as the findings of studies using stable isotopes and geolocators (Alonso *et al.*, 2017; Arizaga *et al.*, 2014, 2015), reflect that Iberian populations follow a pattern of nomadism similar to that documented in northern Europe although on a smaller scale. These movements can take place within and between different mountain ranges in search of patches with an abundance of cones of the different coniferous species on which each population has specialised, and/or in search of the better annual productivity of the conifers depending on their fruiting cycles.

Added to these intra-Iberian movements, there are irruptions of crossbills that come from northern latitudes. These birds are more flexible in the selection of conifers they use for feeding in the Iberian Peninsula, different from those of their breeding or birth areas. These irruptions present a greater number of individuals in years with low productivity of the coniferous species with which they are associated.

The extent of these long-distance movements is still poorly known (Alonso and Arizaga, 2013; Alonso *et al.*, 2017; Newton, 2006). The ringing and recovery records of common crossbills are collected in this study for assessing their different movements with origin or destination in the Iberian Peninsula.

Material and methods

Historical data on ringing and recovery of common crossbills with origin or destination in the Iberian Peninsula was collected from SEO/BirdLife, 2021; OAA, 2021; ICO, 2021; and CEMPA, 2021.

Data was processed to unify formats among the different ringing schemes, discarding records with errors due to the inconsistency between ringing and recovery dates, duplicates, or recoveries with absence of ringing data. Validated records were treated using R (R Core Team, 2017) with the help of package *ggplot2* (Wickham *et al.*, 2020) for graphical representations, and the package *geosphere* (Hijmans *et al.*, 2021) for

the representation of loxodromic curves and the calculation of distances between ringing and recovery locations. The predominant coniferous species on each capture site were obtained from the EU-Forest dataset (Mauri *et al.*, 2017) in the interception of a 5 km buffer around the ringing and recovery locations of the extra-Iberian common crossbills. These analyses were made using the program QGIS (QGIS Development Team, 2020).

As a cautionary note, the interpretation of these data should have taken into consideration the potential heterogenous ringing effort among European countries. Additional ringing data and other complementary survey methods (see discussion) will be necessary in the future for a better understanding of the common crossbills long distance movements and their ecological requirements.

Results

We obtained a total of 2,307 validated ring-recovery records of common crossbill with the origin and/or destination in the Iberian Peninsula spanning from 1930 to 2021. Out of these, 96.5% (n=2,227) of the recoveries corresponded to locations less than 25 km from its original ringing site, and 97.9% (n=2,259) at distances less than 100 km. For the evaluation of extra-Iberian movements, the records corresponding to birds ringed and recovered between the Iberian Peninsula and other European regions were filtered, obtaining a total of 41 records (Appendix 1; Fig. 2).

To date, the ring-recovery records of common crossbills marked in central or northern Europe and recaptured in the Iberian Peninsula (n=38) were from: Austria (1), Belgium (1), Germany (9), Italy (10), Netherland (1), Poland (2), Russian Federation (3), Sweden (2) and Switzerland (9). Ring-recovery records of common crossbills ringed in the Iberian Peninsula and recovered in other European countries (n=3) corresponded to: Austria, Switzerland and United Kingdom.

The longest movements registered corresponded to, a juvenile ringed in September 1983 in Múrmansk (Russian Federation) recaptured in Cardona-Barcelona (Spain) only 67 days later, after traveling at least the 3,548 km that separate both localities; two females ringed as adults in Kaliningrad (Russian Federation) in June 1986 and July 1990 were found in Huesca (2,114 km) and Granada (2,711 km), after 134 and 207 days, respectively; or an adult male ringed in June 1962 in Gotland (Sweden) recovered 2,477 km away in January 1964 in Atienza-Guadalajara (Spain).

All these movements follow a S-SW to SW direction, and NE when homing to their breeding or birth areas, except a record of a juvenile ringed in Sevilla (Spain) in 2011 and recovered six years later on the northeast coast of England.

The fastest migration records correspond to three adult specimens ringed in August 1930 in Brescia (Italy) and recovered in Spain in Infiesto-Asturias (1,295 km),

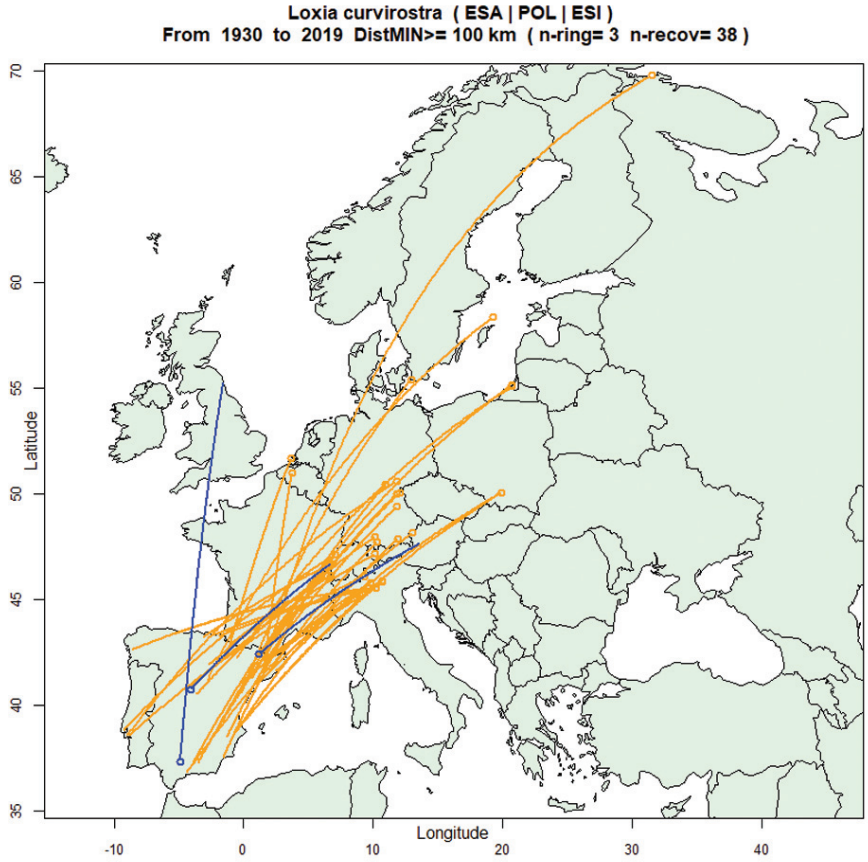

Fig. 2.- Map of common crossbill ringing and recovery records (*Loxia curvirostra*) ringed (blue lines) or recovered (orange lines) in the Iberian Peninsula and other European regions. Circles represent ring locations; and lines represent loxodromic curves to the recovery location.

Fig. 2.- Mapa de representación de registros de anillamiento y recuperación de piquituerto común (*Loxia curvirostra*) anillados (líneas en azul) o recuperados (líneas en naranja) en la península ibérica y otras regiones europeas. Los círculos representan las localidades de anillamiento; y las líneas representan las curvas loxodrómicas a las localidades de recuperación.

Marquina-Vizcaya (1,040 km) and Hernani-Guipúzcoa (999 km) after 15, 39 and 54 days, respectively. A juvenile ringed in July 1983 in Oost-Vlaanderen (Belgium) was recovered 17 days later 1,026 km away in Barcelona (Spain).

Monthly distribution of birds ringed in northern Europe and recovered in the Iberian Peninsula (n=38) shows several recovery differences between the first and the subsequent Spruce-years (defined from 1st June to 31st May; Fig. 3 and Appendix 1). For the first, the second, and the third and later Spruce-years, the recoveries were 29, 5 and 4, respectively. Most of the birds within the first Spruce-year, were ringed from

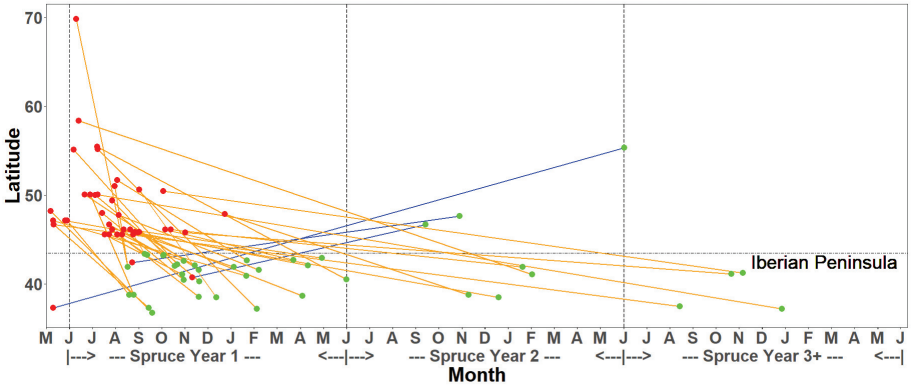

Fig. 3.- Relationship between latitudinal distribution of common crossbills (*Loxia curvirostra*) ringed (red points) and recovered (green points), and the month per "Spruce-year" (from 1st of June to 31th of May), up to three consecutive years, where the first year included the ringing month and the third year included all subsequent years after the second year, following Newton (2006). Orange lines indicate movements into the Iberian Peninsula, and blue lines homing to breeding or birth sites outside the Iberian Peninsula.

Fig. 3.- Relación entre la distribución latitudinal del piquituerto común (*Loxia curvirostra*) anillado (puntos rojos) y recuperado (puntos verdes), y el mes de "Anualidad de Pícea común" (desde 1 de junio a 31 de mayo), hasta 3 tres años consecutivos, donde el primer año incluir el mes de anillamiento y el tercer año incluye todos los años después del segundo año, siguiendo a Newton (2006). Las líneas naranjas indican movimientos hacia la península Ibérica y las líneas azules el retorno a las zonas de reproducción u origen fuera de la península Ibérica.

May to November, and recovered in the Iberian Peninsula from mid of August to the end of April of the same Spruce-year.

The predominant coniferous species on each ringing and recovery site of the extra-Iberian common crossbill records are included in Appendix 1. The ringed crossbills in non-Iberian countries (n=38) were made in areas with a predominance of common spruce (27), silver fir (*Abies alba*; 1), Scots pine (4) and black pine (*Pinus nigra*; 6), and were recovered in the Iberian Peninsula on areas with abundance of Scots pine (8), black pine (6) and more frequently on Aleppo pine (*Pinus halepensis*; 17). It is notable that the four recoveries in Iberia over Monterey pine (*Pinus radiata*; 4) correspond to crossbills ringed on forest grounds with the dominance of black pine. The three birds ringed in the Iberian Peninsula and recovered in other European countries were first captured in forest masses of Aleppo pine, mountain pine (*Pinus uncinata*) and Scots pine, with two recoveries in areas with prevalence of common spruce and silver fir, and one crossbill ringed in Sevilla over Aleppo pine was recaptured on the northeast coast of England in an area with prevalence of Scots pine.

Discussion

The high number of recoveries recorded at distances less than 25 km between the ringing and recovery locations (96.5%, n=2,227), even in time intervals greater than eight years, reinforces the idea of the sedentary character of common crossbill populations in the Iberian Peninsula (Senar *et al.*, 1993; Edelaar *et al.*, 2012). Nevertheless, intra-Iberian recoveries of specimens between the different coniferous enclaves distanced from each other from 15 to 60 km (Mazuelas *et al.*, 2015), and even the few records inside the Iberian Peninsula with distances greater than 100 km (n=7), suggests a pattern of nomadic movements between the different mountain ranges in search of food in a similar way to other European populations. Among other causes, these nomadic movements in the common crossbill populations associated to Scots pine, are correlated with the low availability of pine seeds from May to the next autumn-winter. Other research in the Pyrenees and the Ebro valley associate these movements as a result of the variations in the utilization patterns of the different forest masses (Alonso *et al.*, 2017; Arizaga *et al.*, 2015) and/or different types of pines depending on their fruiting cycles (Borrás *et al.*, 2011).

The recoveries in the Iberian Peninsula of extra-Iberian common crossbills are scarce and correspond to birds ringed as juveniles (n=17), adults (n=14) or with unknown age (n=7), with the date of ringing from May to the end of September inversely related to the latitude, and the monthly distribution of the recoveries, within the same Spruce-year, from mid August (Appendix 1; Fig. 2), supports the theory about the origins of Iberian irruptions as post-breeding and post-juvenile movements of the northeast populations from other European regions in different waves. It is noteworthy that the only three records obtained to date of birds ringed in the Spanish Iberian Peninsula (Sevilla, Madrid and Lleida) and recovered in other European countries (United Kingdom, Switzerland and Austria, respectively), correspond to two individuals ringed in their first calendar year, and one adult male ringed in the Catalonian Pyrenees. This could support the hypothesis about a possible post-juvenile dispersion of specimens with Iberian natal origin whose parents come from Central European irruptions in previous years (Newton, 2006), but it cannot be considered as conclusive. These ring recovery data confirm that most outward and return movements occur on a roughly NE to SW axis, with arrivals to the Iberian Peninsula from mid-August, mainly from September or October, in a time as short as two weeks from Central Europe or just over two months from northeastern Europe (Appendix 1; Fig. 2; Fig. 3).

When common crossbills arrive to southern Europe in irruptive years, the different individuals need to select the most suitable pine species according to their ecological and morphological speciation for feeding (Newton, 2006; Alonso *et al.*, 2006; Edelaar *et al.*, 2012). Based on ring-recovery records, the populations of common crossbills from northern Europe associated to the alternate bearing common spruce, silver fir, or Scots pine, in the Iberian Peninsula select the same (Scots pine) or other coniferous

species (black pine and Aleppo Pine). However, is not clear if, due to the differences in the bill morphology of each population, they are able to take seeds from closed or open cones (McNab *et al.*, 2019), or the impact of wrong selection on the starvation of a specialist population of crossbills in the Mediterranean areas using same (Mezquida *et al.*, 2018) or different coniferous species for feeding. For example, during the 1990 influx in Sicily (Italy) some common crossbill individuals from northern populations were observed feeding on seeds of eucalyptus (*Eucalyptus* sp.) plantations in an area with an abundance of black pine and a patch of Aleppo pine. These birds likely starved to death, a few pairs from this irruption settled and were able to feed on an afforestation patch of Aleppo pine up to 2005, when probably they migrated back to their original region (Massa *et al.* 2022). Our results indicate a positive selection in Iberia, probably facultative, of extra-Iberian crossbills over Aleppo pine forest masses for the birds coming from Central or northern Europe where they use spruces or Scots pines as primary food resource. This contrasts with the resident Iberian crossbills having limited movements between forest patches of Scots pine and Aleppo pine (Edelaar *et al.*, 2012), or the results from stable isotopic analysis of Arizaga *et al.* (2014, 2015), who found that birds from a forest of Aleppo pine did not seem to come from nearby areas with Scots pine, and vice versa. One of the advantages for crossbills feeding on the Aleppo pine in the Mediterranean areas is that some cones open as early as September, when extra-Iberian crossbills arrive to Iberia, while other cones remain in plants longer and their seeds are released by drying atmospheric conditions (xeriscence) or by fire (pyriscence) (Daskalakou and Thanos, 2010), so the seeds are available all the time. In general, the food availability for Mediterranean crossbills feeding on seeds of *Pinus* spp. is more regular than in Central and North Europe, where they feed on less regularly seed producing *Picea* spp. and *Larix* spp. species (e.g., Martin *et al.*, 2020), but see Mezquida *et al.* (2018) for Scots pine. For the interpretation of this forest masses data one must take into consideration the accuracy limitations of the provided capture coordinates, the available European forest maps (Mauri *et al.*, 2017) and, as in the case of the Iberian Peninsula, the frequent presence of small experimental patches of exotic pine plantations, so the obtained predominant coniferous species may not be those used by the common crossbills to feed. This may be the case for recoveries in areas where the predominant coniferous species are umbrella pine (*Pinus pinea*) or maritime pine (*Pinus pinaster*), with seeds that are too large and hard, and hence not suitable for common crossbills.

Aligned with our finding in the Central Iberian Peninsula, some decades ago, a first-year crossbill ringed in July 1963 in Südwürttemberg (Germany) was recovered in Madrid (Spain) in October of the same year; and a first-year crossbill ringed in November 1970 in Cercedilla-Madrid (Spain) was recovered in Vaud (Switzerland) in October of the following year. The observation documented here would support this pattern of irruptive movements and the findings of the studies published to date.

The main origins of extra-Iberian common crossbills in Iberia are still unclear given the limited number of recoveries and the uncertainty on the exact breeding origin of the birds recovered in Iberia. Research developed to date in the Iberian Peninsula using geolocators, morphology and stable isotopic analyses (d^2H) have not documented the origin of these movements (Alonso *et al.*, 2017; Arizaga *et al.*, 2015) as well as in northwestern Europe (Marquiss *et al.*, 2012, 2008). Additional studies must be carried out using complementary techniques such as telemetry, stable isotopes and/or molecular markers, to evidence the origins of the different irruptive events of the common crossbill into the Iberian Peninsula.

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Supplementary Material - Annexes:
https:www.aranzadi.eus/fileadmin/docs/Munibe/mcn.2023.71.07_anexo.pdf

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