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Experiences of historical introductions in Majorca: the case of *Ranunculus weyleri* (Ranunculaceae)

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Abstract. Conservation translocations did not begin to be documented until the late decades of the twentieth century in Spain. However, there is evidence that some endemic species were translocated in 1958 in Majorca (Balearic Islands) because the blasting of the highest mountain peak on the island for the installation of an American radar station could have endangered the survival of these endemic species. This is the case for *Ranunculus weyleri* Marès ex Willk., a threatened plant that consists of a few subpopulations with disjoint distribution. The aim of this study was (i) to search the personal documents of the botanist Jeroni Orell Casasnovas (1924-1995) —delegate of the *Societat d'Història Natural de les Balears* for the protection of the Puig Major flora before the blasting in 1958— to obtain information about this introduction and (ii) to perform a demographic census of its current conservation status. After the introduction in 1958, monitoring of the translocated plants in the following years 1963 and 1964 confirmed that the establishment was successful; currently, this subpopulation consists of 63 adult plants. Overall, the conservation translocation of *R. weyleri* sixty years ago was successful. Finally, we underline the utility of field notebook data for historical botanists who gathered valuable information but did not publish it elsewhere and the importance of publishing the results of current translocation actions, whether they succeed or not.
Keywords: Conservation translocation; historical introduction; threatened species; narrow endemics; Balearic Islands; Mediterranean Basin.

Experiencias de introducciones históricas en Mallorca: el caso de *Ranunculus weyleri* (Ranunculaceae)

Resumen. Las translocaciones con objetivos conservacionistas no comenzaron a documentarse hasta las últimas décadas del siglo XX en España. Sin embargo, hay evidencia de que algunas especies endémicas fueron translocadas en 1958 en Mallorca (Islas Baleares) porque la voladura del pico más alto de la isla para la instalación de una estación de radar estadounidense podría haber puesto en peligro la supervivencia de estas especies endémicas. Este es el caso de *Ranunculus weyleri* Marès ex Willk., una planta amenazada con unas pocas subpoblaciones de distribución disjunta. El objetivo de este estudio fue (i) buscar en los documentos personales del botánico Jeroni Orell Casasnovas (1924-1995), el delegado de la Societat d'Història Natural de les Balears para la protección de la flora del Puig Major antes de la voladura en 1958, para obtener información sobre esta introducción y (ii) para realizar un censo demográfico de su estado de conservación actual. Después de la introducción en 1958, el monitoreo de las plantas translocadas en los años siguientes 1963 y 1964 confirmó que el establecimiento fue exitoso; actualmente, esta subpoblación consiste en 63 plantas adultas. En general, la translocación para la conservación de *R. weyleri* hace sesenta años fue exitosa. Finalmente, subrayamos la utilidad de los datos del cuaderno de campo de los botánicos históricos que recopilaron información valiosa pero no la publicaron en otro lugar y la importancia de publicar los resultados de las acciones de translocación actuales, tengan éxito o no.
Palabras clave: Translocación de conservación; introducción histórica; especies amenazadas; endémicas estrechas; Islas Baleares; Cuenca Mediterránea.

Introduction

In recent decades, introductions and reintroductions have become widely used tools for the conservation of threatened plants (Maunder, 1992; Hodder & Bullock, 1997; Heywood & Iriondo, 2003; Godefroid & *al.*, 2011; Liu & *al.*, 2015), and the relevant criteria and methods have been analysed by different authors (Fiedler & Laven, 1996; Guerrant & Pavlik, 1998; IUCN/SCC, 2003; Escudero & Iriondo, 2003; Guerrant & Kaye, 2007; Godefroid & *al.*, 2011). A "conservation translocation" is the deliberate movement of organisms from one site to another for conservation purposes and consists of (i) reinforcement and reintroduction within a species' indigenous range, and (ii) conservation introductions, comprising assisted colonisation and ecological replacement, outside the indigenous range (IUCN/SCC, 2013). However, conservation translocations entail risks, and their success is difficult to evaluate. Indeed, manuals and published best practices recommend this tool as the last option and only for threatened taxa, with a plan that provides an accurate analysis of risks and

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feasibility, and with precise selection of both sites and plants (Escudero & Iriondo, 2003; IUC N/SCC, 2013).

Successful translocations require an in-depth understanding of species ecology, e.g., plant-pollinator interactions and mycorrhizal relationships (Reiter & *al.*, 2016; Reiter & *al.*, 2017), microsite preferences (Wendelberger & Maschinski, 2016), climatic conditions (Draper & *al.*, 2016), or host preference for parasitic plants (Holzapfel & *al.,* 2016). Moreover, monitoring is of crucial importance, and translocations should be fully documented to inform future conservation planning (Godefroid & *al.* 2011; IUCN/SCC, 2013).

There is a long history of reintroductions in Spain, although documentation of these processes did not begin until the last decades of the twentieth century (see, for example, Sainz-Ollero & Hernández-Bermejo, 1979; Escudero & Iriondo, 2003). The first cases of reintroduction in Spain were *Lysimachia minoricensis* J. J. Rodr. (Primulaceae) in 1959, *Vella pseudocytisus* L. (Cruciferae), *Silene hifacensis* Rouy (Caryophyllaceae), *Hutera rupestris* Porta (Cruciferae), *Antirrhinum charidemi* Lange (Scrophulariaceae) and *Artemisia granatensis* Boiss. (Compositae) (Sainz-Ollero & Hernández-Bermejo, 1979). Furthermore, much of the experience gained in Spain remains unpublished, as in the rest of the world (Godefroid & Vanderborght, 2011).

In the Balearic Islands (western Mediterranean basin), a notable case is that of *Lysimachia minoricensis*, a plant endemic to Minorca Island which became extinct in the wild, and which, from 1959 to the present, has been successively reintroduced but with little success (Bolòs, 1962; Fraga, 2000; Valdés, 2011). More recently, the environmental authority of the Balearics (Govern de les Illes Balears) has attempted several reintroductions of threatened species, such as the introduction of *Euphorbia margalidiana* Kuhb. & Lewej. (Euphorbiaceae), which is endemic to a single islet north of Ibiza, to a new location (Mayol & *al.*, 2011); the introduction of *Pinus pinaster* Aiton (*Pinaceae*) to new localities in Minorca from a small local subpopulation that disappeared after a fire; the reinforcement of several endangered species of the genus *Limonium* in Majorca (PlumbaginaceaeL; Moragues & Mayol, 2013); the reinforcement and creation of several new subpopulations of *Helosciadium bermejoi* (L. Llorens) Popper & MF Watson (Umbelliferae), a threatened plant endemic to Minorca with only one locality (Rita & Cursach, 2013); and *Thymus herba-barona* Loisel. subsp. *bivalens* Mayol, L. Sáez & Rosselló (Labiatae) and *Euphorbia fontqueriana* Greuter (Euphorbiaceae), both endangered plants endemic to Majorca with only one locality each (Rita & *al.*, 2017).

Here, we present the case of *Ranunculus weyleri* Marès ex Willk. (Ranunculaceae), a threatened plant endemic to Majorca (the largest of the Balearic Islands). There is evidence that one of the five currently known subpopulations was introduced in 1958. In that year, the scientific community was concerned about the conservation of the flora of Puig Major —the highest mountain in Majorca, located in the centre of the Serra de Tramuntana— due to the blasting of its peak for the construction of a military base, and thus, a few specimens of *R. weyleri* from Puig Major were translocated to the Font des Coloms— a location less than 2 km away in linear distance but at a lower elevation of 500 m asl. This conservation action was performed by Jeroni Orell Casasnovas (J. Orell, hereafter) and now represents the first known introduction for conservation purposes documented in Spain.

J. Orell (Sóller 1924-Barcelona 1995) was a teacher and a great enthusiast of botany: he was a founding member of the *Museu Balear de Ciències Naturals* and collaborator on the botanical garden (Sóller), he was an active part of the *Societat d'Història Natural de les Balears* (SHNB), and he made important herbarium collections throughout his life (Garcias & Pons, 2011). He collaborated with other contemporary botanists, such as Antoni de Bolòs i Vaireda (Olot 1889-1975) and his son Oriol de Bolòs i Capdevila (Olot 1924-2007), M. Àngels Cardona i Florit (Ferreries 1940-1991), Llorenç Garcias Font (Artà 1885-1975) and Francesc Bonafè Barceló (Biniamar 1908-1994; Garcias & Pons, 2011). He also maintained contact with foreign botanists, such as Tadeus Reichstein (Włocławek, Poland, 1897-1996; J. Orell, pers. com.).

Years later, the reproductive biology and demography of this species were broadly studied by Cursach & Rita (2012) and Cursach & *al.* (2013). The aims of the present study were (1) to perform a demographic census of the introduced subpopulation of *R. weyleri* to determine its current conservation status, and (2) to search through the personal documents of the botanist J. Orell, both his field notebook and his letters with other contemporary botanists, to obtain graphical and written information about this introduction.

Material and Methods

Study species

Ranunculus weyleri is an endemic plant of Majorca, catalogued as Vulnerable (Moreno, 2008) and legally protected both at the National level (RD 139/2011) and the European level (Berna Convention 1991 and Habitat Directive of the European Council, 1992). This species is distributed in only five locations, with a disjoint distribution: two subpopulations in Serra de Tramuntana, a protected region catalogued as a Cultural Landscape and declared as World Heritage by UNESCO, and three subpopulations in the Serra de Llevant, located approximately 48 km away (Figure 1) (terms are defined according to the IUCN guidelines (IUCN, 2012)).

It is a small perennial herb with a small rosette of leaves 3-7 cm in diameter, depending on the subpopulation and the environmental factors (Cursach & *al.*, 2013), and a short vertical rhizome with creeping stems and ascendant apex (Figure 2). Occasionally, plants may grow additional lateral rosettes, although there is no asexual reproduction. It flowers in spring, and each individual produces 6-14 flowers; the species is predominantly allogamous, and pollination is both by insects (mainly *Diptera*, *Hymenoptera* and *Coleoptera*) and the wind (Cursach & Rita, 2012). Each reproductive plant produces a few dozen seeds per flowering season; achenes are mature in late June-early July and disperse by barochory, and most seeds germinate in early autumn (Cursach & Rita, 2012; Cursach & *al.*, 2013).

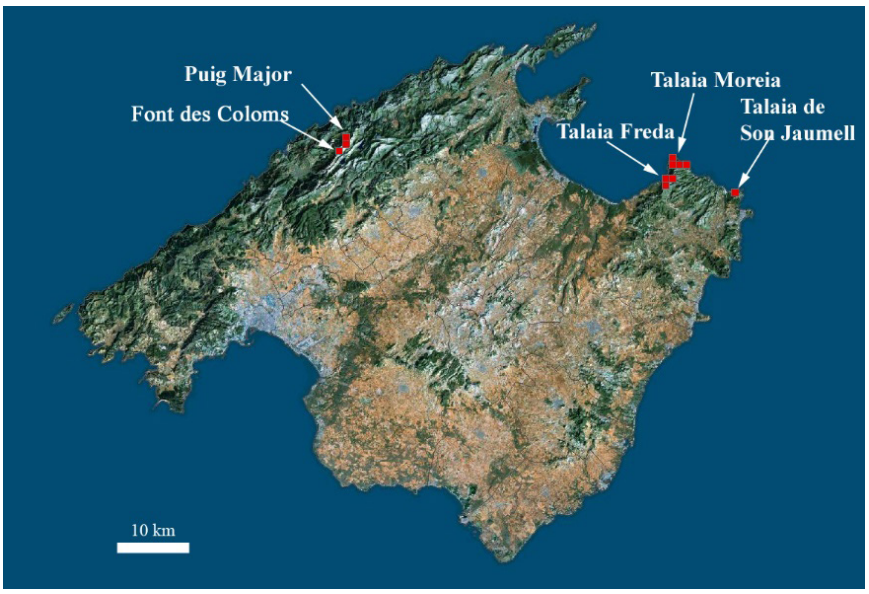

Figure 1. Map of Majorca Island (western Mediterranean basin) with the geographical distribution of *Ranunculus weyleri*. The species occurs in eleven UTM 1 × 1 km squares (in red) (source: BioAtles Project, available at http://www.ideib.es), and five subpopulations can be identified. Font des Coloms and Puig Major are located in Serra de Tramuntana, and Talaia Freda, Talaia Moreia and Talaia de Son Jaumell are located in Serra de Llevant.

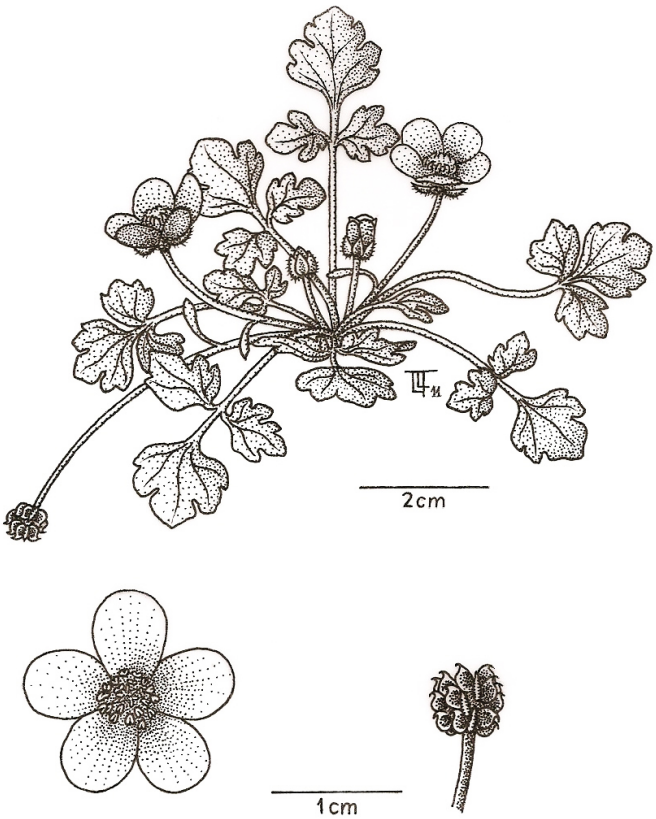

Figure 2. Habit, flower and fructified peduncle of *Ranunculus weyleri* (drawing's author: Lluís Fiol)

The habitat is restricted to cracks and bases of limestone rocks in shady areas, and occasionally mountain scrublands (Bibiloni & *al.*, 1996; Sáez & *al.*, 2017). The species occurs in the *Arenaria balearici* alliance communities consisting of caespitose, recumbent, phanerogamic plants, many of which (up to 40%) are endemic, and dense mossy lawns (Llorens & *al.*, 2007). That is, comophytic vegetation that lives on skeletal lithosols in shady locations, in which habitats are formed at the bases of walls and rocky slopes, especially those facing north (Gil & Llorens, 2017). In addition to intrinsic threats from the reduced and disjoint geographical

distribution, and the reduced number of isolated subpopulations, the species is threatened by habitat loss and deterioration and by the herbivory of goats (Cursach & Rita, 2012).

Study site and demographic census

The Font des Coloms (FC) subpopulation is located in Coma de n'Arbona (39°47'N, 2°46'E) (Serra de Tramuntana) at 940 m asl and constitutes a small subpopulation, with less than 50 reproductive individuals each year distributed over an area of a few square metres at the base of a fountain with water that flows almost year-round (Cursach & *al.*, 2013). Other caespitose, recumbent, phanerogamic plants endemic to the Balearic Islands inhabiting this site are *Bellium bellidioides* L. (Compositae), *Scutellaria balearica* Barceló (Labiatae), *Sibthorpia africana* L. (Scrophulariaceae), and *Carex rorulenta* Porta (Cyperaceae). Integral Projection Models (IPMs) using demographic data collected from 2007 to 2010 showed that this subpopulation was stable ($\lambda = 1.026$, $CI_{95\%} = 0.965\text{-}1.093$) and that the plant survival and growth component had the largest impact on λ ($CI_{95\%} = 0.77\text{-}0.83$; Cursach & *al.*, 2013). To the best of our knowledge, no other census has been performed since then.

In February 2017, an exhaustive demographic survey was carried out in the FC subpopulation. Because most seeds germinate in autumn, the survey was performed at this season in order to collect information about seedlings. For each plant, we recorded the state (seedlings with cotyledons, seedlings (<1 year), one-rosette plants, two-rosette plants, and three-rosette plants), number of leaves, and the size as determined by averaging the maximum diameter of the basal leaves and its perpendicular diameter. We compared these data with those of the last census, which was performed in February 2010 by Cursach & *al.* (2013). We used generalised linear models (GLMs) to test for differences in number of leaves and plant size among the plant states and between the years (2010 and 2017). We used the error distribution and link function that best fit the data, that is, a Poisson distribution for number of leaves and a Gaussian distribution for plant size. Plant size was previously log10-transformed to meet the assumptions of normality. We used n-1 contrasts to detect pairwise differences between the years through multiple comparisons using the LSD (least significant difference) statement of the GENLIN procedure. All statistical analyses were performed with SPSS (v. 24.0).

Results

The FC subpopulation was composed of 105 plants in February 2017 compared to 211 plants in February 2010. However, the main differences were in the youngest plant state (plants < 1 year old; Figure 3A). The number of leaves differed significantly among the plant states (χ^2-Wald = 739.102, df = 1, $p < 0.001$), and there were no differences between 2010 and 2017 (χ^2-Wald = 0.725, df = 1, $p = 0.395$; Figure 3B). Plant size differed significantly among the plant states (χ^2-Wald = 5.216, df = 1, $p = 0.022$) and between the years (χ^2-Wald = 8.986, df = 1, $p = 0.003$) (Figure 3C). The average diameter of one-rosette individuals increased from 3.48 ± 0.20 (n = 74) in 2010 to 4.04 ± 0.16 in 2017 (n = 56).

J. Orell was fascinated by the plants endemic to the Balearic Islands, and he repeatedly visited Puig Major (Figure 4). Shortly before the blasting of the peak of Puig Major, he visited the zone at least twice (February and summer 1958) with other prominent island naturalists —Llorenç Garcias i Font, Guillem Colom Casasnovas, and Juan Cuerda Barceló —who formed the board of the SHNB at that time, and two engineers belonging to the 880ACW Squadron W.7 of the US Army, Mr. Tomhson and Mr. Buck (Figure 5). After these visits, it seems that the project of blasting the top of the mountain was modified to preserve the best botanical areas (J. Orell, pers. com.). Nevertheless, J. Orell collected some species to translocate them in the field and into his own garden. We have only been able to document the translocation of *R. weyleri* in the field. Other species were cultivated in gardens and some years after were donated to the Botanical Garden of Sóller (J. Orell, pers. com.).

Fortunately, J. Orell included in his field notebook information about the translocation of some plants of *R. weyleri* from Puig Major to the Font des Coloms in 1958, and he verified that those plants had taken root in successive years (1963 and 1964; Figure 4). Other new and intriguing information is the citation in his field notebook of the presence of *R. weyleri* in Torrent de Pareis, a north-oriented canyon situated in the middle of the Serra de Tramuntana (Figure 6). In light of this information, in the flowering timing of the species during the spring of 2017, M. Capó and J. Cursach prospected in that area but had no success.

Discussion

The last few hundred metres of Puig Major encompasses the highest concentration of endemic, endangered and singular vascular flora of Majorca Island (Moragues & *al.*, 2015), and *Ranunculus weyleri* is one of those emblematic species. Although the greatest conservation and exploration efforts have been made in the last twenty-five years, plant translocations for conservation purposes were performed in 1958 by G. Colom and J. Orell. These conservation translocations were performed because the blasting of the peak for the installation of an American radar station could have threatened the survival of endemic species (Moragues & *al.*, 2008). This translocation was made in a context in which a group of very relevant and enthusiastic Majorcan naturalists sought to reduce the impact on the flora of the construction of an American military tracking station on the summit of Puig Major, the highest mountain in Majorca. A few years before (1954), these people had formed the SHNB, so contact with the US Army was not made individually but through this association, which

gave them and their concern much greater credibility. Surprisingly, the SHNB, which was dedicated to the study of nature, was created only six years after the founding of the International Union for the Conservation of Nature (IUCN) in 1948, which shows that Majorca was connected to the currents of international thinking on nature conservation at that moment. This fact indicates that there was a high sensitivity to flora conservation in the most advanced minds of the island society at the time.

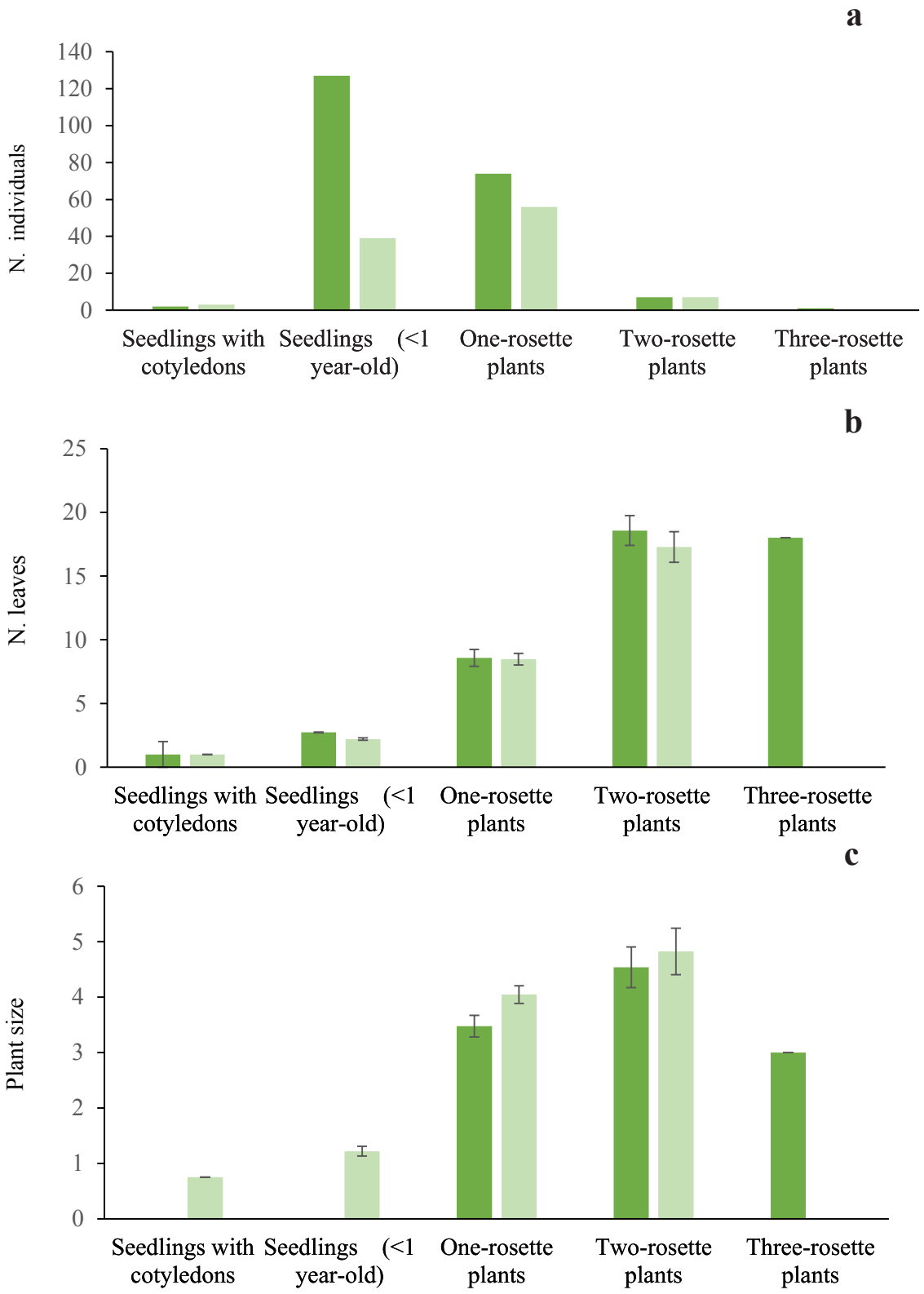

Figure 3. Number of individuals (a), average number of leaves (b) and average plant size (c) in the FC subpopulation in 2010 (dark bars) and 2017 (green bars). Plant size was recorded by averaging the maximum diameter of the basal leaves and its perpendicular diameter. Data of seedlings are presented separately depending on the presence of cotyledons, and those of adult plants are separated by their number of rosettes.

Figure 4. J. Orell at the geodesic point at the peak of Puig Major, the highest point of Majorca Island. (Source: J. Orell archive).

Figure 5. Visit to Puig Major. From left to right: Llorenç Garcias i Font, Guillem Colom Casasnovas, Mr. Tomhson, Juan Cuerda Barceló, Mr. Buck and J. Orell. (Source: J. Orell archive).

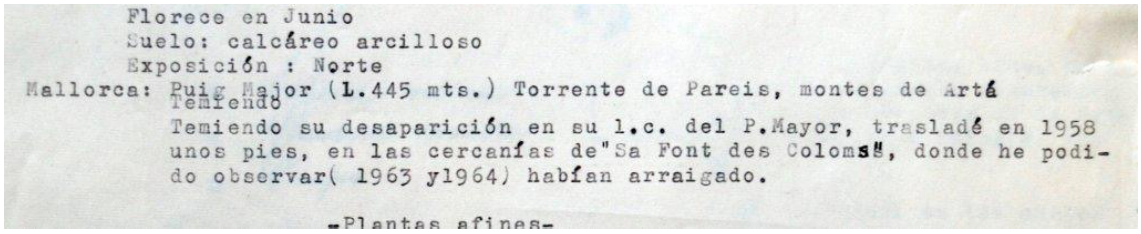
Florece en Junio
Suelo: calcáreo arcilloso
Exposición : Norte
Mallorca: Puig Major (L.445 mts.) Torrente de Pareis, montes de Artá
Temiendo
Temiendo su desaparición en su l.c. del P.Mayor, trasladé en 1958
unos pies, en las cercanías de"Sa Font des Colomsª, donde he podi-
do observar(1963 y1964) habían arraigado.
-Plantas afines-

Figure 6. Piece of the field notebook of J. Orell including information about the distribution and translocation of *Ranunculus weyleri.* (Source: J. Orell archive).

To the best of our knowledge, the introduction of *R. weyleri* to Font des Coloms is the oldest documented introduction in Spain, one year earlier than that of *Lysimachia minoricensis* by P. Montserrat, A. and O. de Bolòs, and A. López (Bolòs, 1962), which was the oldest known until now. After the introduction in 1958, J. Orell confirmed the establishment of the translocated plants in 1963 and 1964. However, no updated data were gathered until 2007 (Cursach & *al.*, 2013). These authors performed a demographic study of data collected between 2007-2010, which demonstrated that this introduced subpopulation was stable. Although the number of plants in 2017 was half of that in 2010, the most important difference was in the number of seedlings, which is the most variable stage in perennial plants across different years (Pfister, 1998; Caswell, 2001). Indeed, the IPM for *R. weyleri* showed that the fecundity function had a very small contribution to the elasticity pattern compared to the survival-growth function.

The successful of plant translocations can be assessed in the short term −e.g., assessing survival (establishment), reproduction and dispersal ratios− but ultimate success, i.e., autonomous maintenance of the subpopulation, can be determined only after many years of monitoring (from 10 years to several decades, depending on the generation time of the species) (Maunder, 1992; Pavlik, 1996; Milton & *al.*, 1999; Guerrant & Key, 2007; Menges, 2008; Godefroid & *al.*, 2011). Hence, given that this subpopulation persists 60 years after its introduction and presents autonomous maintenance, as revealed by the demographic study (Cursach & *al.*, 2013), we can affirm that this conservation introduction was successful.

Many conservation translocations have been performed in Spain, mainly in the last decade. Recently, García-Fernández & *al.* (2017) have created a database of all documented conservation translocations performed in Spain. Overall, 330 conservation translocations were compiled: 53% of them were published, 205 involved some kind of posterior monitoring programme with a duration average of 5 years, and just 78 achieved a certain degree of success. However, a great deal of information remains undocumented, as in the case of *R. weyleri*. In this vein, we highlight the utility of the field notebook data of those historical botanists who gathered valuable information and did not publish it elsewhere. Moreover, in light of the results of García-Fernández & *al.* (2017), we also underline the need for long-term monitoring and the importance of publishing the results of translocation actions whether they succeed or not.

Finally, knowledge of the genetic variation of the target species positively influences conservation translocation outcomes (Godefroid & *al.*, 2017). Unfortunately, there is no information available regarding the genetic variation of the translocated subpopulation, nor that of the other four subpopulations. Not even information about the number of plants used in the translocation of *R. weyleri* exists, nor the number of surviving original plants. On this topic, it is widely known that the introduction of few individuals can lead to loss of genetic diversity due to inbreeding depression or post-introduction genetic drift (e.g., Barret and Kohn, 1991; Frankham & *al.*, 2002). Given the conservation status of this species, we strongly recommend future research focused on the genetic diversity of the species, not only of the translocated subpopulation but also of the other subpopulations.

Acknowledgements

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