

Short Communication

Conservation assessment of *Aquilegia pauti* (Ranunculaceae): a case study of an extremely narrow endemic

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Abstract The extremely rare *Aquilegia pauti* (Ranunculaceae) was described in 1920 but was not found again until 1999, when it was discovered in the Parc Natural dels Ports in Tarragona Province, Spain. This species had been confused with the widespread *A. vulgaris* and consequently its taxonomic and conservation status had been misinterpreted. Based on the limited range of *A. pauti* and the level of disturbance of its habitat we recommend that it is categorized as Endangered on the IUCN Red List. We summarize the conservation actions available for such extremely narrow endemic plant species and make appropriate recommendations for the conservation of *A. pauti*.

Keywords *Aquilegia pauti*, extremely narrow endemic, Iberian Peninsula, Ranunculaceae, Spain

Taxonomic assessments and research are often under-emphasized in conservation programmes and consequently some threatened species may escape attention. However, plant taxonomic and herbarium research can help conservation practitioners take appropriate action (Krupnick et al., 2009; Saad et al., 2009). The recent rediscovery of *Aquilegia pauti* (Ranunculaceae) in north-east Spain shows how much taxonomic research is still needed even in a country with a well-known flora (Bolòs & Vigo, 1984; Castroviejo, 1986–2010). The example of this species is representative of other restricted range plant species of isolated, impacted areas of Europe.

The genus *Aquilegia* L. includes nearly 70 species of perennial herbs distributed throughout temperate regions of the Northern Hemisphere. *A. pauti* was described by Font Quer (1920) from plants collected in the Ports de Tortosa mountain range of Tarragona Province, Catalonia, Spain.

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Cullen & Heywood (1968) recognized the species but Bolòs & Vigo (1984) and Díaz González (1986) treated *A. pauti* as a synonym or subspecies of *A. vulgaris* L. However, Aymerich & Sáez (2001) and Sáez & Guàrdia (2003) later tentatively accepted *A. pauti* and assessed it as Critically Endangered (IUCN, 2001) because of its narrow geographical distribution and low number of reproductive individuals. Finally, after the discovery of original herbarium type material, Martinell et al. (2007) demonstrated that the taxonomic debate arose from a mistake, when mixed specimens of *A. pauti* and *A. vulgaris*, both occurring in the same area in Els Ports massif, were included in Font Quer's exsiccata *Flora Iberica Selecta*. They concluded that *A. pauti* (Plate 1) is a distinct, well-defined species restricted to a limited area.

Recent fieldwork resulted in the rediscovery of the single known population of *A. pauti*, enabling us, after comparisons with herbarium specimens, to confirm the specific status of this extremely narrow endemic and to assess its conservation status. We conducted 20 surveys in Els Ports massif during 1999–2008, visiting all localities in which *A. pauti* had been reported by previous authors, and other areas in this mountain range potentially suitable for this species. We surveyed a total of 31 1-km² UTM squares but found *A. pauti* in only two, in the Montcaro area, the highest summit of the Els Ports massif, where the species was originally found by Font Quer (Fig. 1). It grows in a narrow altitudinal zone (990–1,390 m) on calcareous shady cliffs and scree, mainly with northern exposures. Populations in other localities reported for *A. pauti* contained only *A. vulgaris*.

We counted all reproductive and vegetative individuals. As two non-adjacent rosettes may come from a common underground stem, thus obscuring the difference between ramets and genets, we considered as different entities those rosettes that were separated by more than 20 cm. We identified four subpopulations (Table 1). The distribution of the species is very restricted, with an extremely low area of occupancy (0.12 km²; the area within the extent of occurrence, EOO, that is occupied by a taxon, where EOO is the area contained within the shortest continuous imaginary boundary that can be drawn to encompass all the known sites of occurrence of a taxon, excluding cases of vagrancy; IUCN, 2001) and extent of occurrence (0.60 km²). A decline



PLATE 1 *Aquilegia pawi* Font Quer growing in the Montcaro area of the Els Ports Massif. Photo: L. Sáez.

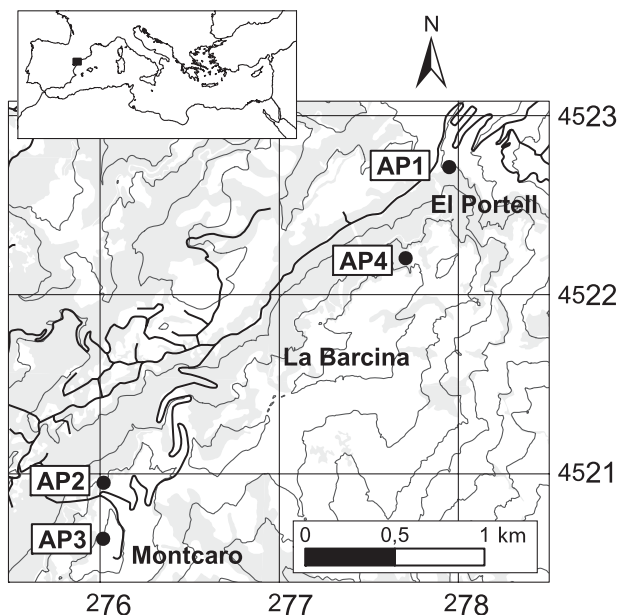


FIG. 1 Location of the four subpopulations (AP₁–4) of *Aquilegia pawi* in the Montcaro area. Dark lines are roads and contour lines are at 100 m intervals; coordinates are UTM (European Datum 1950, Zone 31T). The black rectangle on the inset indicates the location of the main figure in north-east Spain.

TABLE 1 For the populations AP₁–3 of *Aquilegia pawi* (Fig. 1, Plate 1) the area of occupancy (AOO) and number of mature individuals (and in parentheses the number of reproductive individuals achieving fruit ripening, excluding aborted flowers and predated fruits) located during surveys in 2005–2008. Surveys of subpopulation AP₄ (Fig. 1), discovered in 2008, are ongoing.

Population	AOO (m ²)	2005	2006	2007	2008
AP ₁	110.2	182 (29)	211 (37)	259 (20)	256 (39)
AP ₂	2.9	unknown	24 (5)	23 (3)	23 (1)
AP ₃	21.4	unknown	53 (11)	57 (3)	59 (0)
<i>Total</i>	134.5	182 (29)	288 (51)	339 (25)	338 (40)

in the population is inferred by the quality of the habitat, and we also recorded fluctuations in the number of mature individuals. We therefore recommend that *A. pawi* is categorized as Endangered based on the criteria (IUCN, 2001) B1ab (iii) c (iv) +B2 ab (iii) c (iv).

The vulnerability of this species is high, with extremely low levels of genetic diversity and low recruitment rates (Blanché et al., 2005). *A. pawi* appears to reproduce well by rhizomes (not by seed) in situ although it is not easily cultivated ex situ. The conservation of the endemic wild goat *Capra pyrenaica* subsp. *hispanica*, which may be overgrazing subpopulations AP₂ and AP₃, in Parc Natural dels Ports may be in conflict with the conservation of *A. pawi*, as in other mountain areas in which plant conservation programmes and hunting reserves coexist (Simon et al., 2001).

The impact of human activities on *A. pawi* does not currently appear to be particularly significant, although two subpopulations are located next to a road and may be affected by climbers and trekkers. Rock-climbing is increasingly popular on the cliffs at Montcaro and plant cover is reduced near the base of climbing routes, where *A. pawi* grows. Recent regulations issued by Parc Natural dels Ports authorities prohibit this activity where *A. pawi* occurs.

The summit of Montcaro has been severely altered by the construction of telecommunications facilities, including an access road, and the peak is frequented by visitors and maintenance staff. Such disturbances may have affected one subpopulation of *A. pawi*, which experienced a reduction in the number of individuals and area of occupancy during 1999–2007 (J.C. Baiges & L. Sáez, unpubl. data), mainly because of the deposition of waste in the construction of the telecommunications devices. A further potential threat is forest fires. A fire in north-west Parc Natural dels Ports in July 2009, near the village of Horta de Sant Joan, destroyed 1,000 ha and killed five firemen. This area, < 10 km from the populations of *A. pawi*, had already been burnt 20 years earlier.

The conservation of *A. pawi* is an example of the difficulties of designing appropriate conservation strategies for such species in the Mediterranean and, particularly, the Iberian Peninsula, where there are many threatened plant

taxa (Moreno, 2008) and a high percentage of endemics, many extremely restricted (Bañares et al., 2003). Management of narrow endemic plant species in Spain has mostly been addressed with recovery plans for individual species. However, the available resources and the pace at which these legal instruments and their implementation function are too slow to halt the loss of populations.

It is not uncommon for extremely narrow endemics to exist in only 1–5 subpopulations, as with *A. pauti*. There are five conservation steps that can be considered for such species, described here in increasing order of complexity and cost.

Habitat protection Passive habitat protection is not a guarantee of long-term conservation. Some of the now extinct species that formerly survived in only 1–2 known populations (e.g. *Kunkelliella psitoclada*, *Normania nava* and *Aeonium mascaense* in the Canary Islands; *Thymus funkii* in southern Spain) were lost despite growing in areas with some protection (Bañares et al., 2003). Reinforced habitat protection is required. An example is the small and actively managed area in Magalluf (Balearic Islands) where several point endemic *Limonium* species are conserved by a multi-species recovery plan focused on a few square metres in an urban area (Govern de les Illes Balears, 2009).

Diversification of risk Occurrence in only 1–2 subpopulations, even if there are no immediate threats and plants seem well adapted to estenoic (i.e. very narrow range) ecological conditions (such as rocky places, as for many Mediterranean narrow endemics; cf. Lavergne et al., 2004), will not counteract stochastic events. Establishment in at least a third site and ex situ measures are required. In Spain, in addition to Protection zones under EU law (Sites of Community Importance, SCI), each Autonomous Government developed a variety of legal measures to protect such small sites (so-called Microreserves, Espais d'Interès Natural or Reserves Naturals). A realistic objective, although it depends on the biology of each species, is to maintain a minimum viable population greater than the cut-off point for the Endangered category (250 individuals; IUCN, 2001) for each of a minimum of three subpopulations. The minimum size of such small reserves needs to be carefully planned (Albert et al., 2001; Colas et al., 2001).

Field research Although there is good floristic knowledge for some of the Mediterranean countries, intensive plant surveys are required in remote and/or unexplored locations to facilitate the location of currently unknown subpopulations of narrow endemic plant species. The relocation of *A. pauti* is an example of the value of such surveys.

Monitoring Monitoring, including population viability analysis, population genetics and reproductive biology, can be used to adapt long-term conservation strategies for

individual species. For long-lived, demographically stable species creation of additional new populations close to the original can be effective (e.g. *Borderea chouardii* in the Pyrenees; García et al., 2007). However, for demographically unstable species or those undergoing severe declines (e.g. annuals or short-lived monocarpic species such as *Seseli farrenyi* on the Mediterranean coast; López-Pujol et al., 2010), both in situ (reinforcement, reintroduction, establishment of new populations) and ex situ (germplasm preservation, propagation techniques) measures may be required.

Reintroduction For non-viable natural populations or species extinct in the wild reintroduction may be the only option but requires careful consideration. The attempts to reintroduce *Lysimachia minoricensis* to its natural habitat in Minorca failed because of lack of knowledge of the species' ecological requirements and the low genetic diversity of the ex situ population (Ibáñez et al., 1999). Efforts to establish new populations of the extremely narrow endemic *Diploaxis siettiana* on Alboran Island, southern Spain, managed, at the third attempt, to establish a population of 50 individuals (Mota, 2003), which is at the threshold for a minimum viable population. As the probability of success in such cases is low, such reintroduction can probably only be justified if sufficient new knowledge will be obtained to help future reintroductions (Colas et al., 2001; Krauss et al., 2002).

In the case of *A. pauti*, in accordance with these five steps, we propose the following conservation measures: (1) monitoring and surveys, as well as additional field exploration in suitable sites, in Parc Natural dels Ports; (2) preventive management (limiting overgrazing and climbing activities); (3) research on population genetics and demography, and seed germination and multiplication techniques, and to evaluate the results after 3 years and then prepare a long-term recovery plan if necessary.

If the distinctiveness of *A. pauti* had not been assessed it would have remained unidentified, immersed amongst the forms of the widely distributed, non-threatened *A. vulgaris*. However, *A. pauti* was identified in time to be included in a new list of the protected plants of Catalonia (DOGC, 2008). The case of this species is an example of the plight of other potentially neglected rare species that are facing extinction in anonymity because their taxonomic status has been misunderstood or overlooked.

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References

- ALBERT, M.J., ESCUDERO, A. & IRIONDO, J.M. (2001) Female reproductive success of narrow endemic *Erodium paularense* in contrasting microhabitats. *Ecology*, 82, 1734–1747.
- AYMERICH, P. & SÁEZ, L. (2001) Dades sobre l'estatus d'algunes plantes endèmiques, amenaçades o rares a Catalunya. *Orsis*, 16, 47–70.
- BAÑARES, A., BLANCA, G., GÜEMES, J., MORENO, J.C. & ORTIZ, S. (eds) (2003) *Atlas y Libro Rojo de la Flora Vasculare Amenazada de España*. Ministerio de Medio Ambiente, Madrid, Spain.
- BLANCHÉ, C., MOLERO, J., ROVIRA, A.M., SIMON, J., BOSCH, M., SÁEZ, L. et al. (2005) *Estudi bàsic sobre l'estat de conservació, biologia de poblacions i propostes de protecció per a Aquilegia pau*. Conveni entre el DMAH-Generalitat de Catalunya i la Universitat de Barcelona (Projecte FBG-303608), Barcelona, Spain.
- BOLÒS, O. & VIGO, J. (1984) *Flora dels Països Catalans*. Vol. 1. Ed. Barcino, Barcelona, Spain.
- CASTROVIEJO, S. (coord.) (1986–2010) *Flora Iberica*. 14 vols. CSIC, Madrid, Spain.
- COLAS, B., OLIVIERI, I. & RIBA, M. (2001) Spatio-temporal variation of reproductive success and conservation of the narrow-endemic *Centaurea corymbosa* (Asteraceae). *Biological Conservation*, 99, 375–386.
- CULLEN, J. & HEYWOOD, V.H. (1968) *Aquilegia* L. In *Flora Europea* Vol. 1 (eds T.G. Tutin, V.H. Heywood, N.A. Burges, D.H. Valentine, S.M. Walters & D.A. Webb), pp. 238–240. Cambridge University Press, Cambridge, UK.
- DÍAZ GONZÁLEZ, T.E. (1986) *Aquilegia* L. In *Flora Iberica* Vol. 1 (eds S. Castroviejo, M. Lainz, G. López González, P. Montserrat, F. Muñoz Garmendia, J. Paiva & L. Villar), pp. 376–387. CSIC, Madrid, Spain.
- DOGC (2008) Decret 172/2008, de creació del Catàleg de flora amenaçada de Catalunya. *Diari Oficial de la Generalitat de Catalunya-DOGC*, 5204, 65881–65895.
- FONT QUER, P. (1920) Contribució al coneixement de la flora catalana occidental. *Treballs del Museu de Ciències Naturals de Barcelona*, 5, 193–233.
- GARCÍA, M.B., GOÑI, D., GUZMÁN, D., IRIONDO, J.M., COSCULLUELA, J., PUENTE, J. et al. (2007) Cómo gestionar una planta prácticamente inaccesible y en peligro de extinción? *Ecosistemas*, 16, 155–162.
- GOVERN DE LES ILLES BALEARS (2009) Pla de recuperació de les saladines endèmiques del Prat de Magaluf. In *Quaderns de Natura* 22. Servei de Protecció d'Espècies, Palma de Mallorca, Spain.
- IBÁÑEZ, O., CALERO, C., MAYOL, M. & ROSSELLÓ, J.A. (1999) Isozyme uniformity in a wild extinct insular plant, *Lysimachia minoricensis* J.J. Rodr. (Primulaceae). *Molecular Ecology*, 8, 813–817.
- IUCN (2001) *IUCN Red List Categories and Criteria v. 3.1*. IUCN Species Survival Commission, IUCN, Gland, Switzerland.
- KRAUSS, S.L., DIXON, B. & DIXON, K.W. (2002) Rapid genetic decline in a translocated population of the endangered plant *Grevillea scapigera*. *Conservation Biology*, 16, 986–994.
- KRUPNICK, G.A., KRESS, W.J. & WAGNER, W.L. (2009) Achieving Target 2 of the Global Strategy for Plant Conservation: building a preliminary assessment of vascular plant species using data from herbarium specimens. *Biodiversity and Conservation*, 18, 1459–1474.
- LAVERGNE, S., THOMPSON, J.D., GARNIER, E. & DEBUSSCHE, M. (2004) The biology and ecology of narrow endemic and wide-spread plants: a comparative study of trait variation in 20 congeneric pairs. *Oikos*, 107, 505–518.
- LÓPEZ-PUJOL, J., MARTINELL, M.C., MASSÓ, S., BLANCHÉ, C. & MOLERO, J. (2010) *Seseli farrenyi*: un endemisme empordanès en vies d'extinció? *Collectanea Botanica (Barcelona)*, 29, 51–58.
- MALLARACH, J.M. (coord.) (2008) Protegits de fet o de dret: primera avaluació del sistema d'espais naturals protegits de Catalunya. *Treballs de la Institució Catalana d'Història Natural*, 15, 1–359.
- MARRERO-GÓMEZ, M.V., OOSTERMEIJER, J.G.B., CARQUÉ-ÁLAMO, E. & BAÑARES-BAUDET, A. (2007) Population viability of the narrow endemic *Helianthemum juliae* (Cistaceae) in relation to climate variability. *Biological Conservation*, 136, 552–562.
- MARTINELL, M.C., SÁEZ, L. & MOLERO, J. (2007) *Taxonomic assessment of the Critically Endangered narrow endemic Aquilegia pau* Font Quer. XII OPTIMA Meeting, Pisa, Italy.
- MORENO, J.C. (coord.) (2008) *Lista Roja 2008 de la flora vascular española*. Dirección General de Medio Natural y Política Forestal (Ministerio de Medio Ambiente y Sociedad Española de Biología de la Conservación de Plantas), Madrid, Spain.
- MOTA, J.F. (2003) Vicisitudes de la reintroducción del jaramago de Alborán. *Conservación Vegetal*, 8, 19–20.
- SAAD, L., TALHOUK, S.N. & MÁHY, G. (2009). Decline of endemic *Oncoclycus irises* (Iridaceae) of Lebanon: survey and conservation needs. *Oryx*, 43, 91–96.
- SÁEZ, L. & GUÀRDIA, L. (2003) *Aquilegia vulgaris* subsp. *pau* (Font Quer) O. Bolòs & Vigo. In *Atlas y Libro Rojo de la Flora Vasculare Amenazada de España* (eds A. Bañares, G. Blanca, J. Güemes, J.C. Moreno & S. Ortiz), pp. 104–105. Dirección General de Conservación de la Naturaleza, Madrid, Spain.
- SIMON, J., BOSCH, M., MOLERO, J. & BLANCHÉ, C. (2001) Conservation biology of the Pyrenean larkspur *Delphinium montanum*: a case of conflict of plant vs animal conservation? *Biological Conservation*, 98, 305–314.

Biographical sketches

The authors belong to a research group (GREB, <http://www.greb.org.es/joomla/>) with more than 20 years of interest in the systematics and conservation of Mediterranean flora. The group's current projects are devoted to the systematics of Campanulaceae, Ranunculaceae and Compositae, to conservation biology, including demography, reproduction, pollination biology and population genetics of narrow endemics, and to studies of the origin of the endemic flora of the Mediterranean, Asia and South America.