From European priority species to characteristic apophyte: Epipactis tallosii (Orchidaceae)

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From European priority species to characteristic apophyte: *Epipactis tallosii* (*Orchidaceae*)

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Abstract: *Epipactis tallosii* is considered as one of the highly threatened European orchid species due to its local distribution and small isolated populations that are characterized by decreasing trends. The species is now enlisted in the endangered (EN) category of the Red List. Nevertheless, during the last decade, multiple new populations of the species were found in Hungary, while our field surveys indicated that *E. tallosii* populations regularly occur in poplar (*Populus*) plantations. Here we conducted a thorough field survey of poplar plantations, by visiting 182 plantations in Hungary and surrounding countries in the Pannonian Biogeographic Region. We found *E. tallosii* in 23% of the visited plantations, and counted a total of c. 4000 generative shoots. Moreover, we documented the occurrence of the species to four countries, where it has not been reported before: Croatia, Romania, Serbia and Ukraine. Alien and indigenous/mixed poplar plantations were similarly likely to harbour populations of *E. tallosii*. Our study suggests that the distribution area and number of populations of *E. tallosii* is much larger than previously assumed, and that poplar plantations serve as suitable habitat islands in the agricultural landscapes for this orchid. In the light of our results, we suggest the reassessment of the IUCN category of *E. tallosii* and to re-categorize it as Near Threatened (NT).

Key words: apophytism, Croatia, *Epipactis*, *Epipactis tallosii*, Hungary, hybrid poplar clones, IUCN Red List, *Orchidaceae*, orchids, *Populus* ×*canadensis*, Romania, Serbia, Ukraine

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Introduction

The majority of European orchids are of significant conservation importance, due to their specific ecological and biological requirements (for example: due to their dependence on mycorrhiza, their special lifestyles, or their extreme and unique pollination strategies). Many of the orchids have restricted, or scattered distribution ranges (Jacquemyn & al. 2005; Kull & Hutchings 2006; Molnár V. 2011). Even within the family, terrestrial orchids appear to be more prone to extinction than epiphytic or lithophytic species. Almost half of the extinct orchid species are terrestrial herbaceous perennials, while two-thirds of species within the orchid family are represented by epiphytes and lithophytes (Swarts & Dixon 2009). According to the most recent IUCN Red List (Bilz & al.

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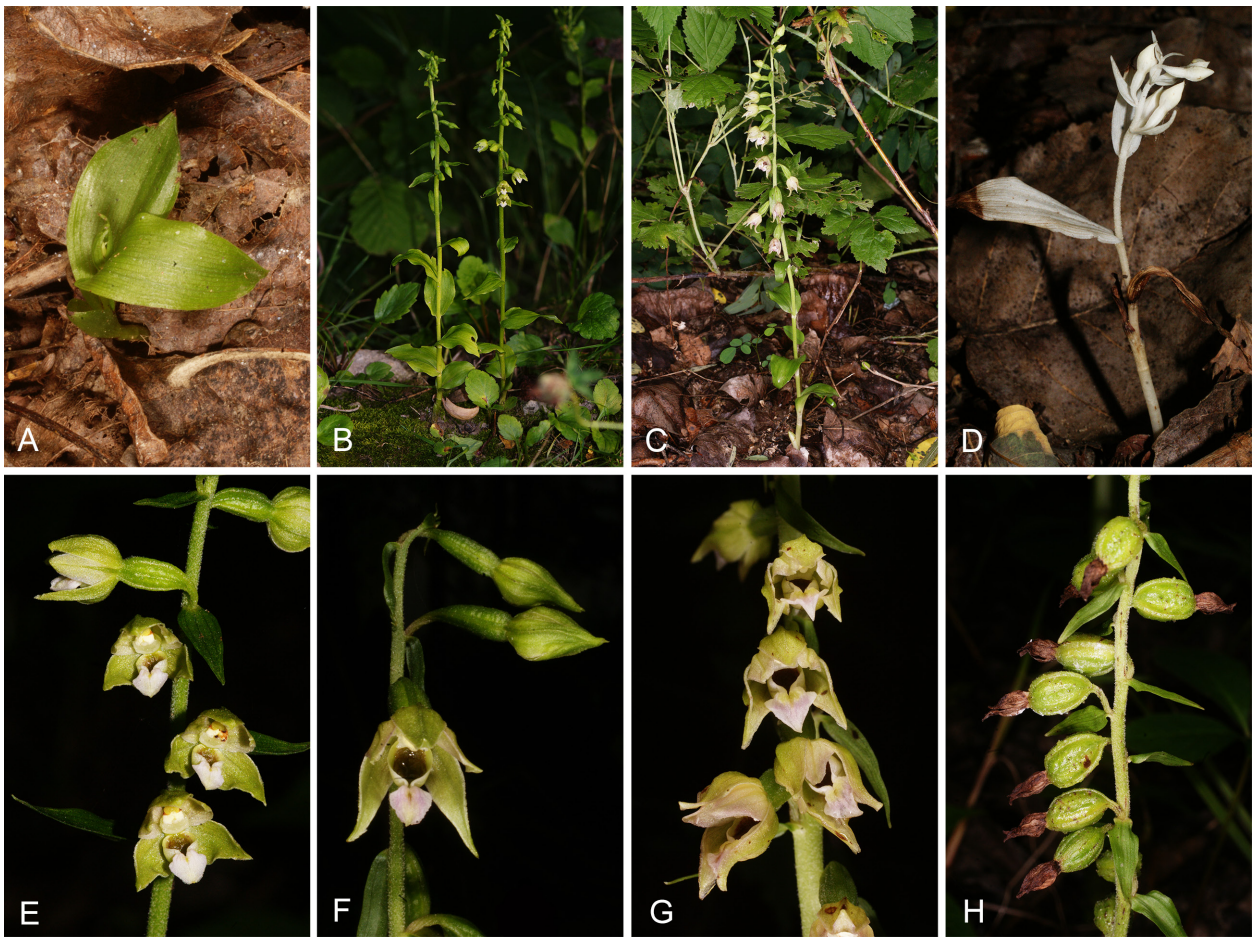

Fig. 1. *Epipactis tallosii* – A: young sprout (Ukraine: Nove Selo); B: habit (Hungary: Debrecen); C: habit (Serbia: Martonoš); D: achlorophyllous individual (Romania: Valea lui Mihai); E: inflorescence (Romania: Valea lui Mihai); F: inflorescence (Croatia: Baranjsko Petrovo Selo); G: inflorescence (Serbia: Martonoš); H: fruiting stem (Serbia: Kanjiža). – Photographs: A–H by A. Molnár V.

2011), one of the highly threatened European orchid species is *Epipactis tallosii* A. Molnár & Robatsch (Fig. 1). This orchid was discovered and described relatively late (in 1997), based on a single Hungarian population at the SW foot of the Bakony mountains, near the village of Nyirád. The species was named after a Hungarian botanist, Pál Tallós (Molnár & Robatsch 1997). *Epipactis tallosii* is currently enlisted in the Endangered (EN) category of the Red List (Bilz & al. 2011), and is considered very rare, mostly represented by very small and isolated populations over its scattered distribution area. The area of occupancy of this orchid is estimated to be roughly 37 km² and according to recent assessments the population exhibits a decreasing trend (Fay 2011). However, the distribution area of the species is much larger (Gügel & al. 2010). In the comprehensive book of *Orchids of Europe, North Africa and the Middle East* (Delforge 2006) it is stated that the distribution of the *E. tallosii* is "poorly known, but apparently endemic to the Danube valley and the interfluve between the Danube and Tisza, very rare and local". In terms of its biology, *E. tallosii* is an autogamous (self-pollinated) and mixotrophic, rhizomatous species and can be found in a wide range of habitat types. For instance, it was found in various types of forests: in gallery forests (poplar gallery forests and riparian mixed forests of oak, elm and ash) in birch bogs, furthermore in oak and oak-hornbeam forests both on the lowlands and in more hilly regions, as well as in poplar plantations (Fig. 3) (Molnár V. & al. 2012; Molnár V. 2009). Some of these habitats were periodically flooded (Borhidi 2003), and it can be concluded that the *E. tallosii* can tolerate a certain degree of periodical inundation. The latter characteristic is not unique in this genus. For example *E. albensis* Nováková & Rydlo, *E. nordeniorum* Robatsh or *E. exilis* P. Delforge in Europe (Delforge 2006), as well as *E. flava* Seidenf. in Asia are also tolerant to periodic flooding (Pedersen & al. 2013). *Epipactis tallosii* is one of the latest flowering orchid of its genus, with a flowering period that usually lasts from July to August (Delforge 2006), but flowering specimens were observed as late as October (Molnár V. 2011).

Besides Hungary, the presence of *Epipactis tallosii* has so far been known from two further C European countries (Gügel & al. 2010). The occurrence of *E. tallosii* in Slovakia was known from the mid-1990s (Vlčko 1997; Mereďa 2002; Kolnik & Kucera 2002), but it was not identified until 1997. The presence of the species is also known in the Czech Republic (Průša 2005; Batoušek

Table 1. Summary of literature data on orchid occurrence in European poplar plantations.

Species	Country	Source
Cephalanthera longifolia (L.) Fritsch	Poland	Jakubska & al. (2005, 2006)
Dactylorhiza incarnata (L.) Soó	Poland	Adamowski & Conti (1991)
Epipactis albensis Nováková & Rydlo	Czech Republic	Těšitelová & al. (2012)
Epipactis albensis	Ukraine	Ljubka & al. (2014)
Epipactis atrorubens (Hoffm.) Besser	Poland	Adamowski (1995)
Epipactis atrorubens × *E. helleborine*	Poland	Adamowski (1995); Adamowski (2004)
Epipactis helleborine (L.) Crantz	Netherlands	Vonk (2008)
Epipactis helleborine	Poland	Adamowski & Conti (1991); Adamowski (2004); Jakubska & al. (2006)
Epipactis helleborine	Ukraine	Ljubka & al. (2014)
Neottia ovata (L.) Bluff & Fingerh.	Poland	Adamowski (2004)
Platanthera bifolia (L.) Rich.	Poland	Adamowski & Conti (1991); Adamowski (2004)

Table 2. Summary of *Epipactis tallosii* occurrences with respect to composition of *Populus* species in the studied plantations.

Nativity status of poplar taxa in the studied plantations	Number of plantations with *E. tallosii* (poplar species composition)	Number of plantations without *E. tallosii* (poplar species composition)
Only native	4 (*P. alba*: 1; *P.* ×*canescens*: 3)	14 (*P.* ×*canescens*: 9; *P. alba*: 4; *P. nigra*: 1)
Mixed	5 (*P. alba* & *P.* ×*canadensis* agg.: 2; *P.* ×*canescens* & *P.* ×*canadensis* agg.:1; *P. tremula* & *P.* ×*canadensis* agg.: 1; *P. alba*, *P. nigra* & *P.* ×*canadensis* agg.: 1)	2 (*P.* ×*canescens* & *P.* ×*canadensis* agg.:1; *P. alba* & *P.* ×*canadensis* agg.: 1)
Only alien	38 (*P.* ×*canadensis* agg.)	119 (*P.* ×*canadensis* agg.)
Altogether	47	135

& Kežlínek 2012). Additionally, a population of *E. tallosii*, originally described as a subspecies, was found in N Italy (*E. tallosii* subsp. *zaupolensis* Barbaro & Kreutz; Barbaro & Kreutz 2007). In 2010, the latter taxon was treated as a separate species, named *E. zaupolensis* Bongiorni & al. (Bongiorni & al. 2010). Nonetheless, according to Batoušek & Kežlínek (2012) this taxon as well as *E. autumnalis* D. Doro are conspecifics with *E. tallosii*.

Epipactis tallosii has been classified by the IUCN as Critically Endangered (C1) in the Czech Republic (Holub & Procházka 2000; Grulich 2012). Although formerly it was listed as Endangered (EN) in Slovakia (Vlčko & al. 2003), currently it is classified as near threatened (NT) in both Slovakia (Eliáš & al. 2015) and in Hungary (Király 2007).

It is well known that Eurasian temperate terrestrial orchids are able to colonize secondary and anthropogenically strongly influenced habitats, including mines (Esfeld & al. 2008; Shefferson & al. 2008), roadside verges (Fekete & al. 2017) and cemeteries (Löki & al. 2015; Molnár V. & al. 2017). Poplar monocultures are also known as suitable habitats for at least seven orchid taxa (including three *Epipactis* species) in four European countries (Table 1). During the last decade it has become increasingly evident that *E. tallosii* is widespread in Hungary and numerous populations of the species were found in poplar plantations (Molnár V. 2011). Poplar plantations are fast growing woody crops, thus they have been in focus of both economic and environmental interest in recent decades (Heilman 1999). The conservation value of poplar monocultures is poorly known, probably due its secondary nature and therefore a lack of thorough botanical surveys. For instance, in Hungary poplar plantations were referred to as "tree plantations in a regular network, with characterless understory, their conservational value is low" (Bölöni & al. 2011). Poplar plantations are evidently most widespread in potential habitats of willow-poplar forests. Areas formerly covered by natural vegetation are currently subject to large scale agricultural cultivation (Király & al. 2008), while the existing riverine and swamp woodlands are generally affected by invasions of alien species (e.g. *Acer negundo* L., *Amorpha fruticosa* L., *Fraxinus pennsylvanica* Marshall, *Vitis vulpina* L., etc.) (Bölöni & al. 2011; Csiszár 2012).

The presence of *Epipactis tallosii* in poplar monocultures was detected at multiple locations throughout Hungary and data on these occurrences was mostly published in local journals (Molnár V. & al. 1998; Csiky 2006; Tóth 2009; Nagy 2011; Csábi & al. 2015). Based on these data and our preliminary observations we hypothesized that

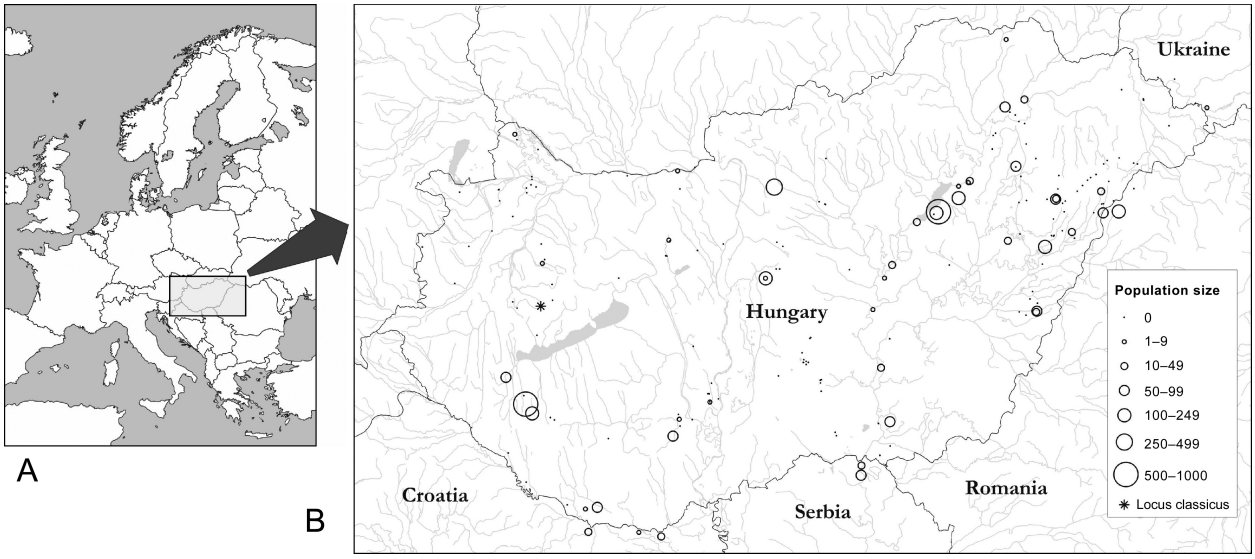

Fig. 2. A: position of the studied area within Europe; B: location of the studied poplar plantations with *Epipactis tallosii* in the Pannonian Biogeographic Region. The size of the circles indicates the size of the *E. tallosii* populations, assessed based on the number of generative shoots.

(1) the species is more widespread in poplar plantations in the Pannonian Biogeographic Region than previously thought, and (2) the occurrence of the species is highly presumable in further countries within the Pannonian Biogeographic Region. In this article, we present the results of a systematic field survey of poplar plantations conducted within the Pannonian Biogeographic Region with the central aim to document the distribution of *E. tallosii* in these secondary, man-made habitats. Over the last few years, several new *Epipactis* species were found as new to countries' flora in this region, for example: *E. purpurata* Sm. in Serbia (Đorđević & al. 2010), *E. muelleri* Godfery in Ukraine (Fateryga & al. 2013), *E. pseudopurpurata* Mereďa, *E. futakii* Mereďa & Potůček, *E. komoricensis* Mereďa in Slovakia (Mereďa 1996a, 1996b; Mereďa & Potůček 1998), *E. pontica* Taubenheim (Batoušek 1996), *E. pseudopurpurata* and *E. nordeniorum* (Batoušek 1999) in the Czech Republic, *E. greuteri* H. Baumann & Künkele and *E. albensis* in Romania (Ardelean 2011; Molnár V. & Sramkó 2012) etc., highlighting the need for further research into the distribution of species belonging to this genus. Moreover, the first population of *E. albensis* that was found in Ukraine was situated in a poplar plantation (Ljubka & al. 2014), indicating the need to also focus on anthropogenic habitats during these surveys.

Material and methods

The nomenclature used throughout this article follows Király (2009). Identification of *Epipactis tallosii* and separation from similar taxa (e.g. *E. moravica* and *E. nordeniorum*) was performed following Molnár V. (2011). We visited 182 poplar plantations in the Pannonian Biogeographic Region (EEA 2015), between June 2012 and August 2016. Fieldwork was mainly carried out within the borders of Hungary, but adjacent areas of Croatia, Romania, Serbia and Ukraine were also visited (Fig. 2). At each visited plantation we recorded the present poplar taxa and the orchid flora. Native poplar taxa (*Populus alba* L., *P.* ×*canescens* (Aiton) Sm., *P. nigra* L., *P. tremula* L.) were identified following Bartha (2009). Note that in this paper we use the name *P.* ×*canadensis* Moench agg. for all other planted, hybridogenous (non-indigenous) taxa. Originally the parent species of *P.* ×*canadensis* are *P. nigra*, a native species in Hungary, and *P. deltoides* W. Bartram ex Marshall, a North American species (Marron & al. 2003). We counted or estimated the number of individuals of all detected orchid taxa in each visited plantation. At each surveyed site we recorded the geocoordinates (recorded in WGS84 format) using a Garmin E-Trex Legend handheld GPS device. Statistical analyses were carried out in the R 3.5.1 statistical and computing environment (R Core Team 2018). In order to test whether the occurrence of *E. tallosii* is dependent on the presence of native poplar taxa, we used a Chi-squared test. Using the latter test we compared the proportion of plantations with and without *E. tallosii* between plantations containing native poplar species (i.e. native or mixed plantations) and plantations with only alien poplar species.

Results

We surveyed a total of 182 poplar plantations and we found *Epipactis tallosii* (Fig. 1) in 47 of them, representing nearly a quarter of the examined plantations (c. 23%) (Appendix 1, supplemental content online). Given that the emergence of flowering stems of terrestrial orchids fluctuates across years (especially due to variation in precipitation, Nagy & al. 2018), it is likely that even more sites harboured populations of *E. tallosii*, but remained

Fig. 3. Habitats of *Epipactis tallosii* in hybrid poplar monocultures. – A: Croatia: Baranjsko Petrovo Selo, plantation surrounded by agricultural cropfields; B: Croatia: Čađavica; C: Serbia: Kanjiža; D, E: Hungary: Vácegres. – Photographs: A–E by A. Molnár V.

undetected during the surveys. The species was found in poplar plantations of all five visited countries (Fig. 2). In the territory of Croatia, Romania, Serbia and Ukraine the occurrence *E. tallosii* was formerly unknown.

Altogether 27 occurrences of four co-occurring rhizomatous orchid taxa were also proved (*Cephalanthera damasonium* (Mill.) Druce, ten plantations; *C. longifolia* (L.) Fritsch, eight plantations; *Epipactis helleborine* (L.) Crantz, eight plantations; *Neottia nidus-avis* (L.) Rich., one plantation; Appendix 1, supplemental content online).

Populations of *Epipactis tallosii* were found in plantations of indigenous *Populus* taxa in four cases (*P. alba*: one, *P. canescens*: three), in mixed plantations of indigenous *Populus* taxa and *P.* ×*canadensis* agg. in five cases (*P. alba* & *P.* ×*canadensis* agg. : two, *P. canescens* & *P.* ×*canadensis* agg.: one, *P. tremula* & *P.* ×*canadensis* agg.: one, *P.* ×*canadensis* agg. & *P. nigra* & *P. alba*: one), moreover, it was found in 38 *P.* ×*canadensis* agg. monocultures (Table 2) (Appendix 1, supplemental content online), which is the most widespread type of poplar plantation in the Pannonian Biogeographic Region, but especially in Hungary. 24.84% of the alien and 33.33% of native or mixed plantations contained *E. tallosii*. The statistical analysis indicated that this difference was not significant between alien and indigenous/mixed plantations regarding the likelihood of occurrence of *E. tallosii*

(Chi-squared test, $X^2 = 0.40$, p- value= 0.5262). In the 47 checked populations, we found altogether c. 4000 generative shoots of *E. tallosii*, but the size of populations shows remarkable variability (mean±SD = 84±170) (Fig. 2). All of the almost four thousand individuals of the species detected during our survey were found on altitudes between 85–194 meters above see level and none were found in the 8 visited plantations above 194 m (altitudinal range of visited plantations: 85–378 m).

Discussion

Poplar plantations appear to represent suitable habitat "islands" for orchids in the agricultural landscape. This is probably explained by the composition of the root zone (presumably even in case of the *Populus* ×*canadensis* agg. plantations), which provide a diverse ectomycorrhizal environment in poplar plantations (Danielsen 2012). Rhizomatous mixotrophic orchids, such as the *Epipactis tallosii* usually show various degree of fungal dependence and specificity, often using multiple fungal partners (Ouanphanivanh & al. 2008). A recent study conducted in North America has shown that native and non-native poplar plantations have similar mycological diversity (Royer-Tardif & al. 2018). The results of the latter article are also supported by our observations. The sites inspected within the framework of our research were mostly man-made forests of Canadian poplar (*P.* ×*canadensis* agg.), while the presence of *E. tallosii*, often in high abundances, suggests that the ecological needs of this species, as well as of other orchids, are met in these "half-alien" hybrid plantations. Colonization of these often remote, scattered habitat islands may be easily accomplished by the anemochorous dust-seeds of orchids (Sonkoly & al. 2016), making these habitats not only suitable, but also easily accessible.

It was previously shown that plants of *Epipactis helleborine* produce more seeds per fruit in anthropogenic than in natural habitats (Rewicz & al. 2015). This study also highlights that in the anthropogenic habitats, *E. helleborine* individuals were much taller than in natural habitats, while taller plants are known to produce more seeds than shorter ones (Rewicz & al. 2015). These studies together indicate that anthropogenic habitats are often superior to the natural habitats, at least in the case of orchids.

Importantly, our results highlight that the area of occupancy of *Epipactis tallosii* is much larger than previously assumed and extends far beyond the previously estimated 37 km² (Fay 2009). Moreover, based on the data presented here, the occurrence of this species can be extended to four countries (i.e. Croatia, Romania, Ukraine and Serbia), in which no occurrence of this species was previously documented. Although populations of *E. tallosii* are sporadic and often isolated through most of the species' range, in some regions, such as along the river Tisza or in some areas of the Transdanubia (W Hungary), the populations are close to each other. Moreover, the number of individuals is also high, local population sizes can often reach hundreds or even thousand individuals.

We have shown that *Epipactis tallosii* readily colonizes and proliferates in poplar plantations, the latter representing a typical and common habitat type in almost all of Hungary. According to the data of the Central Statistical Office of Hungary (KSH 2017), in 2017 poplar forests – with spatial extension of 1972 square kilometre – represent the fourth largest forest type (10.6%) in terms of area in this country. Consequently, we can not declare that the number and the size of suitable habitats or potentially suitable habitats shows a decreasing tendency or would be on the verge of disappearance. Moreover, due to the reproductive biology of this species (i.e. self-pollinated), it is not affected by the worldwide pollination crisis either (Ghazoul 2005; Steffan-Dewenter & al. 2005; Biesmeijer & al. 2006). Based on this information, we recommend reviewing the IUCN Red List categorization of *E. tallosii* and changing its category from Endangered (EN) to Near Threatened (NT).

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