Dating daffodils to save species

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In previous yearbooks we have written about the PhD research that makes up the *Narcissus* Monograph project (Könyves, David, and Culham, 2011; Könyves and Bilsborrow, 2016). Following on from two previous PhD projects which focused on *Narcissus* sections *Bulbocodii* and *Meridionalis*, and part of subsection *Pseudonarcissi*, the RHS is co-funding a third *Narcissus* PhD project at the University of Reading. In this PhD project, Zoë will investigate the effect of past climatic changes on *Narcissus* evolution and distribution patterns to better understand modern diversity. The aim is to enhance our understanding of current day species distributions and provide insights into the effect of future climate change on *Narcissus* distributions and habitat availability following the construction of species distribution models.

The Mediterranean basin (sensu IUCN, 2021) is a major centre of plant diversity (Heywood, 1999) and has a range of ecosystems, with high levels of endemism. This is attributed to several climatic and geological events in the region over the past 30 million years. Future projected increases in aridity and temperature in the Mediterranean Basin with rapid human-induced climate change, is expected to negatively impact the survival of the Mediterranean flora (Yesson, Toomey, and Culham, 2009). With 90% of wild daffodil species native to the Iberian Peninsula including many endemics, understanding the impact of past climatic events on *Narcissus* evolution will enable us to assess how wild daffodil species may respond to future climate change.

Narcissus is thought to have arisen some ~24 MYA (Santos-Gally *et al.*, 2012) when it diverged from the common Amaryllidaceae ancestor with *Sternbergia* in the western Mediterranean. Since then, climatic and geological events in the Mediterranean Basin are thought to have significantly impacted *Narcissus* evolution with changes in environmental conditions and sea level affecting species distributions through alternating periods of isolation resulting in speciation and shared distributions enabling hybridisation (Fig. 1). These processes are thought to have resulted in a myriad of natural hybrids and initiated lineage divergence. Lineage divergence occurs due to the accumulation of genetic and phenotypic differences between individuals and results in the division of evolutionary lineages into two or more lineages (Vaux *et al.,* 2016). *Narcissus* diverged during a period of cooler and drier climate, following the collision of the African plate and the Iberian microplate (30 – 27 MYA) which resulted in the break-up of the continuous mountain range between the Iberian Peninsula and northern Africa. This has also been found to be important in the evolution of other geophytic genera including *Acis* Salisb. Additionally, during this period a land bridge between the Iberian Peninsula and Northern Africa enabled the dispersal of *Narcissus* species between the two continents until ~12 MYA, at which point the land bridge ceased to exist preventing dispersal of *Narcissus* taxa along that route.

The closure of the Strait of Gibraltar approximately 6 MYA, again enabled dispersal between the Iberian Peninsula and Northern Africa by providing a land bridge between the two continents. The closure of this Strait initiated a period of increasingly arid and saline conditions (known as the Messinian Salinity Crisis) which may have played an important role in *Narcissus* evolution. During the Messinian Salinity Crisis, the Mediterranean Basin consisted of a series of unconnected salt lakes, and continuous land that aided dispersal between what is now known as the Iberian Peninsula and northern Africa. Following the reopening of the Strait of Gibraltar (~5 MYA) and the refilling of the Mediterranean, aridity diminished which is thought to have led to climate-driven extinctions and speciation events across the Mediterranean. The loss of this land bridge which connected the Iberian Peninsula to northern Africa again isolated *Narcissus* populations resulting in genetic divergence between lineages.

The onset of the Mediterranean climate ~3.2 MYA and repeated glacial and interglacial periods (the Pleistocene glaciations) between 2.5 MYA – 11,700 years ago have been deemed important periods of *Narcissus* evolution, with the majority of diversification occurring after the reopening of the Strait of Gibraltar (Fig. 2). During glacial periods sea level declined by 100–140 m below present level in some areas (Gracia *et al.*, 2008; Rodríguez-Sánchez *et al.*, 2008). This resulted in a series of small islands and islets between the Iberian Peninsula and Northern Africa aiding dispersal and inducing diversification of several *Narcissus* species. This could explain the current distribution of *Narcissus* species on both sides of the Strait of Gibraltar.

As part of the PhD project, Zoë will use models of past climates and vegetation and a *Narcissus* phylogeny to predict drivers of divergence for all *Narcissus* sections. This will aid in understanding how past climatic changes influenced *Narcissus* evolution in the Mediterranean. The phylogeny will include all *Narcissus* sections and be dated using an Amaryllidaceae phylogeny which we are also constructing as part of this PhD project. Molecular data will be used to estimate timing of diversification in the Amaryllidaceae and *Narcissus* phylogenies. She will use the dates of divergence of all *Narcissus* sections to attribute past climatic and geological events to the divergence of *Narcissus*, *Narcissus* sub-genera and sections. Zoë will also construct species distribution models to predict distributions of daffodil taxa under various future climate change scenarios. To enhance our understanding of how *Narcissus* taxa may respond to future changes in climate, we will combine the insights acquired from the dated phylogeny and species distribution models. This will help identify which taxa may become threatened or extinct as a consequence of human-induced climate change and will be used to inform conservation management.

Figures

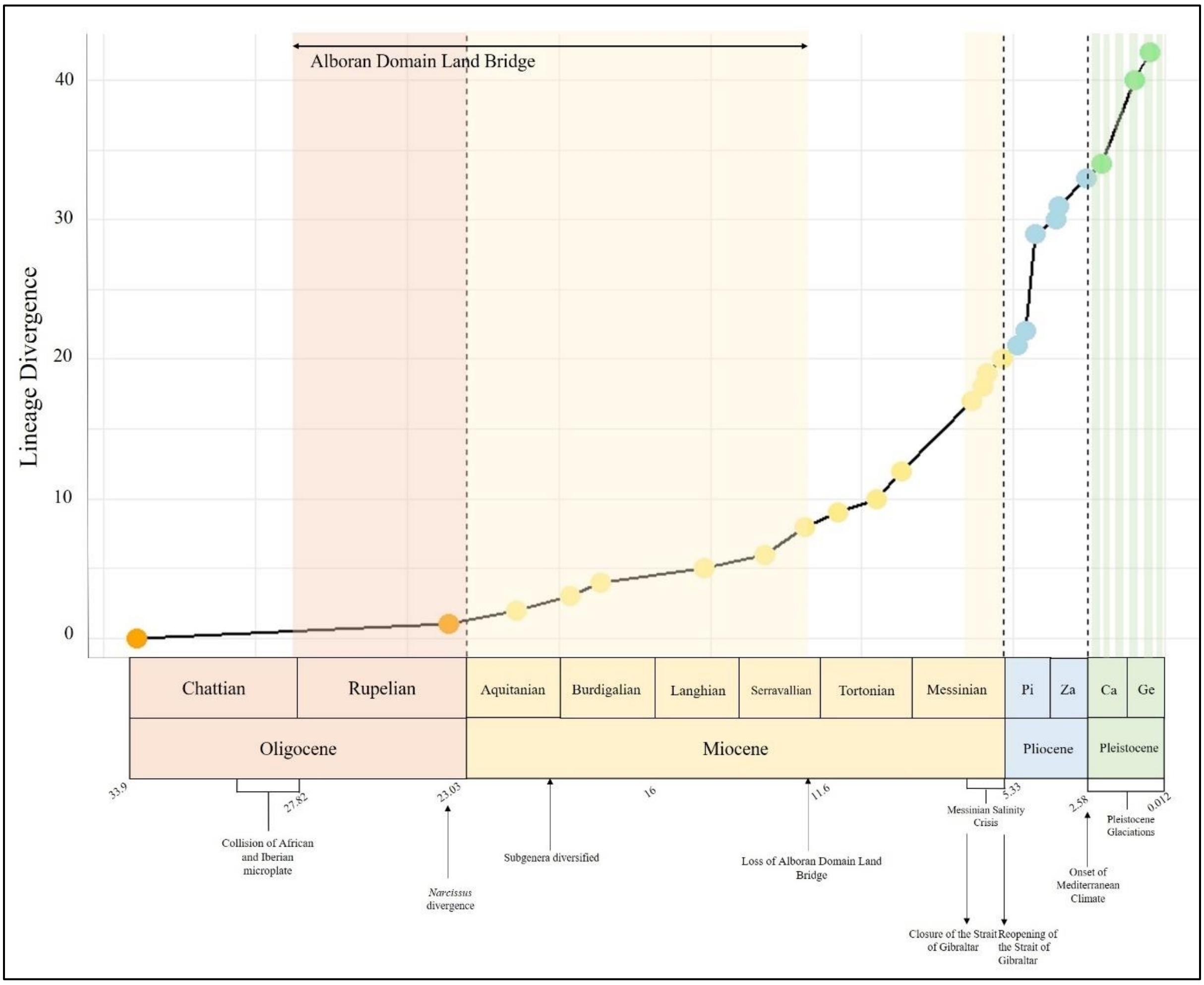

Figure 1 – Lineage divergence of *Narcissus* from 34 Million Years Ago to present day, based on age estimates provided by Santos-Gally *et al.*, (2012) with a timeline of key climatic and geological events which influenced *Narcissus* evolution from the Oligocene to Pleistocene. Timings of epochs and ages were acquired from Geological Society of America Geological Time Scale v. 5.0 (Walker et al., 2018). Orange circles represent divergence in the Oligocene, yellow circles for the Miocene, blue circles for the Pliocene and green circles for the Pleistocene. Pi = Piacenzian; Za = Zanclean; Calabrian = Ca; Gelasian = Ge. Shaded regions represent land bridges connecting the Iberian Peninsula and Morocco.

Figure 2 here

Figure 2 – Palaeographic map from Krijgsman *et al.*, (2018) showing the evolution of the Mediterranean between the late Tortonian until the Zanclean.

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