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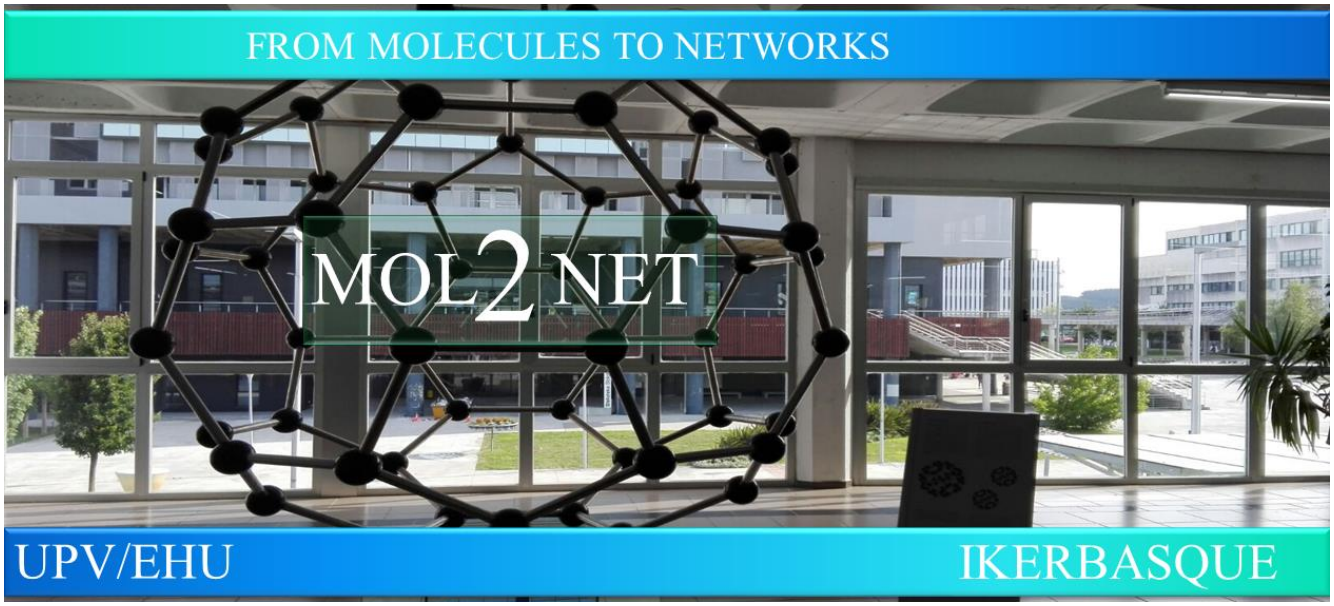

Advances on the conservation status of endemic *Posidonia* K.D. Koenig species from South Australia

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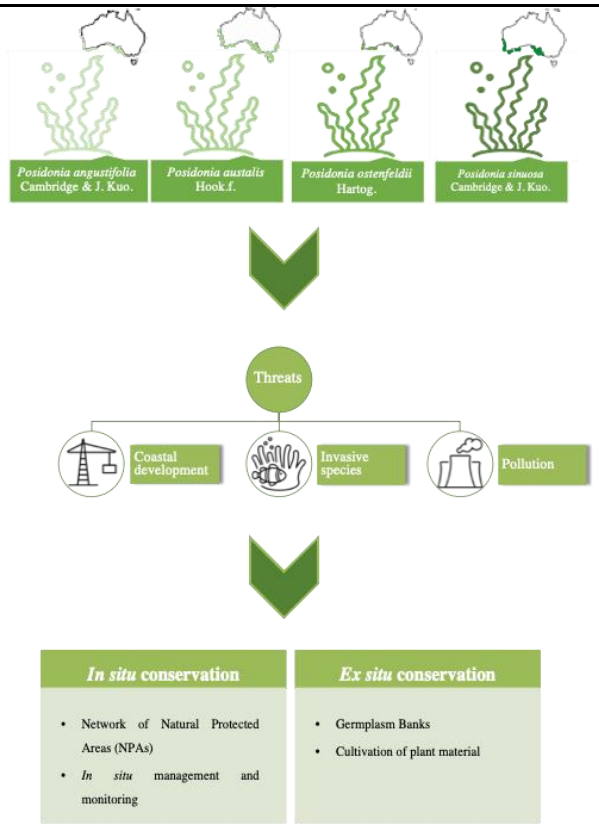
Graphical Abstract	**Abstract.**
	Marine angiosperms are important because they provide stabilization of coastal sediments, water clarity, take part of the breeding habitat for various species, and provide shelter from predators for some marine species, among other benefits. Their conservation is therefore of vital importance for the maintain the homeostasis of the marine environment. However, some threats



to the meadows that they form have been described in South Australia. Among them, coastal development, the presence of invasive species and pollution, are the most important in worsening their conservation status. For this reason, this work is aimed to perform a literature review of the conservation status of the four species of the genus Posidonia endemic to this area: P. angustifolia Cambridge & J.Kuo, *P. australis* Hook.f., *P. ostenfeldii* Hartog *and P. sinuosa* Cambridge & J.Kuo. *To achieve this goal, information was sought on the distribution, population dynamics, threats and conservation strategies for each of the species.*

Both in situ and ex situ conservation strategies are important to slow the decline of marine angiosperms. Posidonia species are slow-growing, and their seeds are sensitive to desiccation, which makes ex situ conservation more difficult to implement than in situ conservation strategies.

Keywords: *Posidonia; Australia; conservation; threat; distribution; population.*

Introduction

Marine angiosperms are flowering plants belonging to the monocotyledons that form marine meadows (Duarte *et al.*, 2017). They constitute a paraphyletic small group, with about 66 species described so far, classified within the order Alismatales R.Br. ex Bercht. & J.Presl. (Den Hartog and Kuo, 2006; Papenbrock, 2012).

Their importance is due to the fact that they provide ecological benefits such as habitat and food for fishes, macroinvertebrates, and megaherbivores. In addition, they act as biological sentinels to different threats, natural or anthropogenic, because they have the ability to respond to various environmental modifications caused in the sediment and water column (Duarte *et al.*, 2017).

Marine angiosperms are cosmopolitan, and are part of tropical (>24°C), temperate (4-24°C) and polar (<4°C) coastal regions (Short *et al.*, 2016). Their growth and distribution depend on physical, chemical and biological properties of their environment among other factors (Greve and Binzer, 2004). To understand the global distribution of marine angiosperms, several biogeographical models have been developed and this work is based in the proposal of Short *et al.* (2007). In this model, six bioregions are presented: four temperate, and two tropical zones. In the present work, Bioregion 6 (Temperate Southern Oceans) has been chosen to review the conservation status of marine angiosperms showing priority needs. In this regard, a total of 18 species are reported to grow in this bioregion, where 4 Australian endemic species belonging to the genus *Posidonia* show the highest interests for conservation: *P. angustifolia* Cambridge & J.Kuo, *P. australis* Hook.f., *P. ostenfeldii* Hartog and *P. sinuosa* Cambridge & J.Kuo.

Biodiversity loss is one of the world's most pressing environmental problems as a large proportion of the world's flora is considered to be endangered (Maunder *et al.*, 2014). Several threats have been

specifically documented for marine angiosperms and, therefore, conservation actions are of great importance to ensure their long-term survival. Basically, conservation actions can be grouped into two main categories: *in situ* and *ex situ* strategies.

In situ measures imply the conservation of biodiversity in its natural habitats such as the establishment of a network of Natural Protected Areas (NPAs) or *in situ* management, and monitoring of wild populations. *Ex situ* conservation strategies complement the previous ones, and are aimed to the preservation of the biodiversity outside the natural habitats, mainly in germplasm banks by storage or cultivation of plant cells, tissues and organs (Heywood, 2015).

Previous works on these four species date back to the assessments published in 2010 by the International Union for Conservation of Nature (www.iucnredlist.org). However, as the concern in marine and coastal biodiversity preservation is currently increasing, new information attaining to the conservation of these species is being published. Therefore, the goal of this work was to review the advances in their distribution, population dynamics, specific threats, as well as the conservation strategies applied to these species in southern Australia in order to update our scientific knowledge on the conservation status of these species.

Materials and Methods

To achieve our objective, a search of literature was done using the scientific databases ISI Web of Science (https://webofknowledge.com/, accessed on 18 June 2021, and Google Scholar (https://scholar.google.com/, accessed on 18 June 2021). In addition, information reported in reputed biodiversity databases such as IUCN Red List of Threatened Species, World Flora online, The Plant List and the Global Biodiversity Information Facility (GBIF) was checked in order to update the state of art on this topic.

Our search was performed considering all works published in the period comprised between 1979 and June 2021. The search strategy was based in the equation: ("Posidonia sinuosa" OR "Posidonia australis" OR "Posidonia angustifolia" OR "Posidonia ostenfeldii") AND (seagrass OR "marine angiosperm") AND (conserv* OR distribution OR "population dynamic" OR "population decline" OR preserv* OR status OR protection OR threat*) AND (Australia). Finally, some inclusion and exclusion criteria were applied, and 38 sources were obtained, and analyzed in the present study.

Results and Discussion

The results obtained in the present review confirmed that the distribution range of the four species considered has not been extended during the last decade, and they remain entirely endemic to southern Australia. *P. australis* and *P. sinuosa* have a wide distribution area, and they also benefit from a remarkable number of studies. However, there is little information on the presence of *P. angustifolia* and *P. ostenfeldii* making it difficult to monitor their current distribution (Carruthers *et al.*, 2007; Bastyan and Cambridge, 2008; Short *et al.*, 2011; Statton *et al.*, 2012).

A large annual population decline has been documented since the beginning of the 21st Century for both *P. australis* (1.8%), and *P. sinuosa* (1.2%) due to the threats described in Short *et al.* (2011). In addition, specific threats to each species have been also documented, such as the increased brine from desalination plants for *P. australis* (Cambridge *et al.*, 2019), and desiccation (Horn *et al.*, 2009), high nutrient concentration (Bryars *et al.*, 2011), and intrusion of sulfide and heavy metals for *P. sinuosa* (Fraser and Kendrick, 2017). As far as *P. angustifolia* and *P. ostenfeldii* concerns, there are very scarce data on population trend, which limits the accurate knowledge about these species' distribution and population viability. The same situation is found for threats, and conservation strategies. Generally, a higher number of reports concerning *in situ* conservation strategies are found when compared to those devoted to *ex*

situ approaches. This fact can be due to the difficulties in establishing germplasm reservoirs out of their natural habitats for these species, as obtained by Irving *et al*. (2010). For instance, it could be very challenging to establish usual seed collections in gene banks, as seeds from these species are reported to be sensitive to desiccation, (Franchi *et al.*, 2011). Alternative methods for *ex situ* conservation (such as seedling culture in aquaculture tanks) have been developed (Ganassin and Gibbs, 2008; Statton *et al.*, 2012). However, further studies are necessary to see whether these approaches could offer a viable alternative for *ex situ* conservations strategies, and long-term preservation of these species.

Conclusions

Based on the results obtained, the following conclusions can be stated:

- The general information obtained on distribution, population, threats and conservation actions is variable depending on the considered species. While *P. australis* is the most studied species (followed by *P. sinuosa*), there is very scarce updated information on *P. angustifolia*, and *P. ostenfeldii* during the last 15 years.
- *P. australis* and *P. sinuosa* are the species with the highest number of implemented conservation strategies. In general, *in situ* conservation actions (such as transplantation and restoration) are the most widely used for the conservation of these two species.
- Seed banking or cultivation of these marine plants in aquaculture tanks (*ex situ* conservation) are very complicated as *Posidonia* seeds are reported to display low desiccation tolerance, and low propagation rates under *in vitro* culture conditions.
- Efforts should be focused on studying in more detail both *P. angustifolia* and *P. ostenfeldii*, as there is still little information available on all items considered.

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