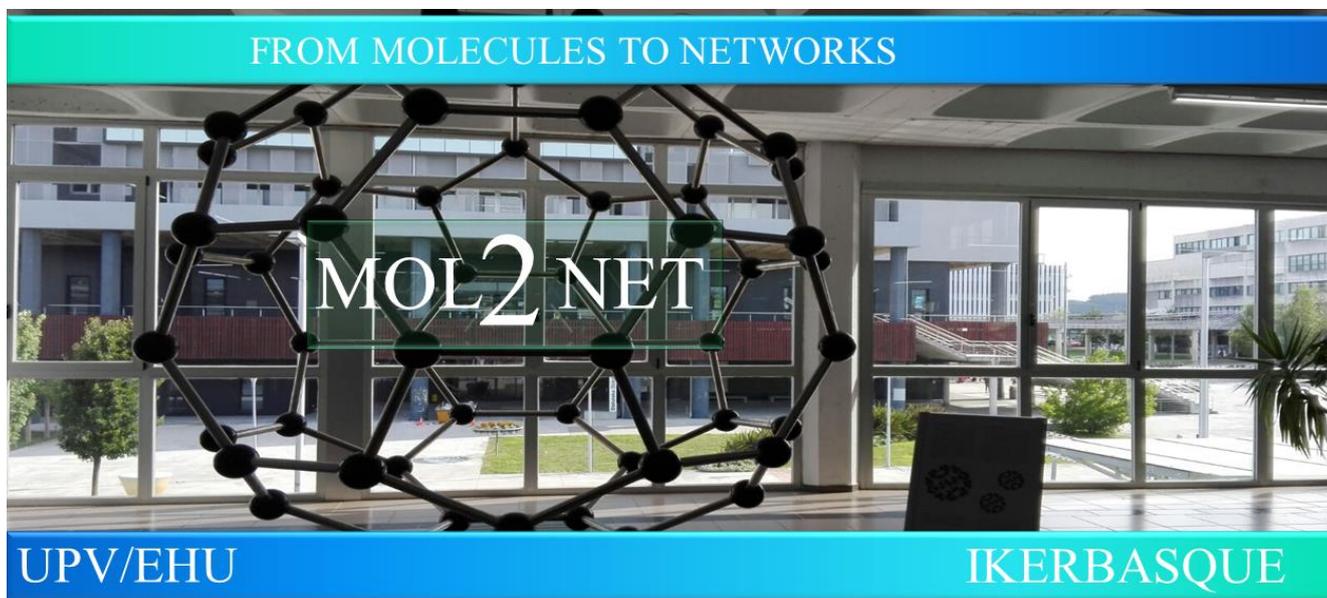




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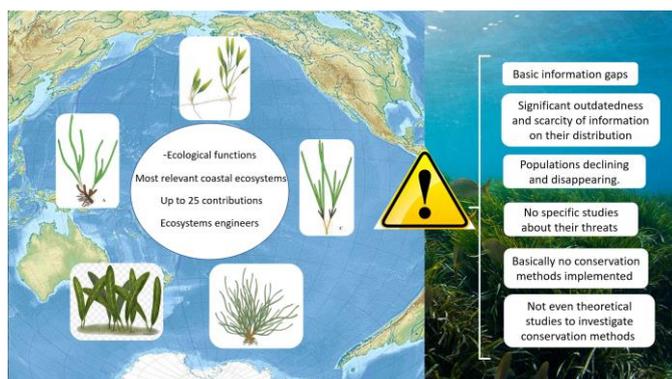


A critical review on the conservation of Pacific marine angiosperms.

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Graphical Abstract



Abstract

Marine angiosperm meadows are considered one of the most valuable ecosystems in the world along with estuaries due to their role as primary producers, and as shelter for the biodiversity. The activity of the human being is greatly affecting these meadows. For this reason, a comprehensive bibliographic review on the conservation actions applied to marine angiosperms from the Pacific Ocean has been carried out. The main objective was to study its current state of conservation and compare it to previous assessments on this topic. The review was made taking into consideration

Sources (Li et al., 2020; <i>Halophila beccarii</i> Flora - Seagrass, SAV, 2022; Hawaiian Flower, 2022; <i>Zostera noltii</i> Flora - Seagrass, SAV, 2022)	articles published between 2006 and 2021 based on distribution, population trend, threats, and <i>ex situ</i> and <i>in situ</i> conservation measures applied to the target species. The results obtained showed that scarce information was found for all species in the previously mentioned areas. For example, for the species <i>Halophila hawaiiiana</i> Doty & B.C. Stone 1966 no information was found. More information was found on <i>H. beccarii</i> Ascherson. 1871 and <i>Phyllospadix japonicus</i> Makino 1897. However, all this information does not have a direct applicability in the state of conservation of these species. In conclusion, much more research is needed in relation to all aspects of interest, especially those focused on conservation measures both <i>in situ</i> and <i>ex situ</i> in order to prevent these species from severe population decline.
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Introduction

Seagrasses are the only angiosperms that inhabit the coastal benthos and have developed unique physiological, morphological, and ecological adaptations to thrive in the marine environments (Singh, 2019). Seagrasses can be grouped into 4 different botanical families: Cymodoceaceae, Hydrocharitaceae, Posidoniaceae, and Zosteraceae, with 13 genera, and 72 accepted species, 14% of which are considered to be endangered (Soong et al., 2013; Laffoley and Baxter, 2016; Singh, 2019). These meadows are also one of the most relevant ecosystems in coastal areas (Short et al., 2011) due to their ecological functions, and numerous contributions for the human society (Singh, 2019).

The defined as tropical Indo-Pacific bioregion by Short et al. (2007) is considered the area where seagrasses originated, and currently the oceanic region with the highest diversity of seagrasses. In spite of this, the area covered by seagrass meadows is estimated to be decreasing by approximately 1.5% per year, in addition to the already reported loss of about 29% during the first decade of the 20th Century (Singh, 2019). Therefore, conservation of these species and the ecosystems that they develop are of primary concern for the global sustainability on coastal areas. In this regard, there are basically four types of measures for plants, and vegetation conservation: technical, scientific, social, and legal measures (Aguilella *et al.*, 2010). In this work, we have focused in the technical measures for *in situ* and *ex situ* conservation of endemic species to the Pacific Ocean through a bibliographic review. Specifically, we have studied the most threatened species according to the IUCN *Halophila beccarii* Ascherson 1871 (Short et al., 2010a), *Phyllospadix japonicus* Makino 1897 (Short and Waycott, 2010a), *Phyllospadix iwatensis* Makino 1931 (Short and Waycott, 2010b), *Zostera caespitosa* Miki 1932 (Short and Waycott, 2010c), and *Halophila hawaiiiana* Doty and B.C. Stone 1966 (Short et al., 2010b).

Materials and Methods

To achieve the previously mentioned goal, a database was generated through a search of literature using the academic databases ISI Web of Science (<https://webofknowledge.com/>, accessed on 23 February 2021), and Google Scholar (<https://scholar.google.com/>, accessed on 20 April 2021). Also scientific information published in official biodiversity databases such as IUCN Red List of Threatened Species, World Flora online, The Plant List, and the Global Biodiversity Information Facility (GBIF) were consulted.

This search was done considering works published between 2006 and 2021. The search strategy was based in the search equation Pacific AND (seagrass OR angiosperms OR phanerogam) AND (distribution OR Patchiness OR ecology OR biology OR habitat OR threats OR diversity OR “bioregional model” OR conservation OR “population dynamic” OR status OR “In situ” OR Transplantation OR Restoration OR “Ex situ” OR “In vitro” OR “Gene bank” OR “Cryopreservation” OR “seed storage” OR “pollen storage” OR “DNA storage”) AND (“*Halophila beccarii*” OR “*Phyllospadix japonicus*” OR “*Phyllospadix iwatensis*” OR “*Phyllospadix scouleri*” OR “*Zostera caespitosa*” OR “*Halophila hawaiiiana*” OR “*Halophila ovalis* subsp. *Hawaiiiana*”). Inclusion and exclusion criteria were applied, and a total of 11 sources was taken into account to develop the present study.

Results and Discussion

The results obtained in the present work show that there is a significant outdatedness and a great scarcity of information in terms of distribution, population dynamics, and threats for each species considered, as discussed below.

The species for which more information has been found is *H. beccarii*, probably due to its wide range of distribution (Short *et al.*, 2010a), while the least reported is *H. hawaiiiana*, probably due to its restricted location within its limited area of distribution (Short *et al.*, 2010b). As far as *H. beccarii* meadows concern, a remarkable decline in its extension has been documented, and some of its populations have even disappeared in the last decade in southern China (Jiang *et al.*, 2020). For this reason, more research would be desirable to achieve a better understanding on its current distribution.

Regarding population trends, and threats, more research about the causes behind the documented decrease should be also taken into account as there are no works focused on monitoring the population dynamics, and factors affecting them specifically.

Regarding conservation measures, information was rather limited as well. We found gaps in scientific knowledge for almost all aspects. This scarcity does not only occur concerning information on the design of *in situ* and *ex situ* conservation measures, but also basic information on distribution, population trend, and threats of these angiosperms, as commented above.

Ex situ conservation measures such as the application of tissue culture techniques, the *in vitro* conservation (or other type of preservation approach developed in gene banks) have been remarkable scarce since only one article was found that dealt with short-term seed storage (Park *et al.*, 2014). This strongly contrasts with the higher development of these studies, and strategies applied to the conservation of endemic, rare, and threatened plants from coastal environments (Juan-Vicedo *et al.*, 2019; 2022).

Conclusions

Based on the results presented, a series of conclusions can be drawn:

- In general, there are not big differences (in terms of number of available studies, depth of the scientific research, and strategies directed to the conservation) among all species here studied. However, it can be emphasized that *H. beccarii* (firstly), and *P. japonicas* (secondly) are the ones that more information has been obtained.
- In line to the previous conclusion, it is remarkable the lack of information on *H. hawaiiiana* since no information has been found for this species.
- As the number of articles found was extremely low, it was not possible to interpret any kind of research trend beyond the lack of research attention to these angiosperm species, and the most urgent needs for their conservation.
- Considering the conservation measures implemented, no article has been found that directly and actively addresses *in situ* or *ex situ* conservation strategies for the species considered in this work, beyond preliminary articles on the design of conservation measures with no conclusions on their efficacy.

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