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Editorial: Tropicalization in seagrasses: Shifts in ecosystem function

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Editorial on the Research Topic
Tropicalization in seagrasses: Shifts in ecosystem function

Seagrass meadows form highly productive and diverse ecosystems that provide a range of ecosystem services along coasts of most continents (Barbier et al., 2011; Nordlund et al., 2016), yet they continue to experience large losses through direct and indirect human disturbances (Waycott et al., 2009; Duarte et al., 2018). Like other coastal ecosystems, including coral reefs and kelp forests, seagrasses are showing strong negative responses to elevated ocean temperatures and heatwaves, in which rising temperatures exceed their thresholds for survival. These negative temperature effects are enhanced by poleward shifts in the distributions of tropical herbivores that bring novel consumers to established habitats and can result in large changes in the abundance and composition of foundational plant species, as has been repeatedly documented in kelp forests (Vergés et al., 2014). To date, far less is known about these effects on seagrass ecosystems, although it has been predicted that tropicalization will profoundly affect the functioning of temperate seagrass meadows, shifting them from detrital-based to grazing-based ecosystems and impacting the valuable services they provide, such as carbon sequestration, nursery habitat provision and the export of nutrients to other ecosystems (Hyndes et al., 2016). In this Research topic, we highlight recent advances in our knowledge of the direct and indirect effects of increasing ocean temperatures, including marine heat waves and tropicalization. The seven papers presented can be broadly grouped into three themes: (1) range shifts of seagrasses; (2) effects of range shifts on ecosystem processes; and (3) impacts of tropical consumers on seagrass food webs.

Our knowledge on range shifts of seagrasses is still greatly limited, primarily due to the paucity of long-term monitoring programs that could allow us to detect such shifts. In the absence of such programs, the best short-term option is to utilize past studies that have some common locations across time. Bartenfelder et al. used this approach to examine the persistence of *Zostera marina* (eelgrass) at the edge of its southern distribution in North Carolina, where the tropically associated *Halodule wrightii* is shifting poleward. This study indicated that predicting range shifts is not simple, as factors other than water temperature, such as water clarity, along with the traits of *H. wrightii* influence eelgrass persistence. Indeed, *H. wrightii* appears to facilitate the persistence of *Z. marina* through maintaining increased water clarity during periods of seasonal eelgrass decline.

Despite the type of complexities noted by Bartenfelder et al., the lack of adequate information means that we often rely on predicting the extent of range shifts through modelling. For example, Wesselman et al. modelled the expansion of the tropical *Halophila stipulata* globally and predicted greater expansion of the seagrass species in the Mediterranean Sea by 2100. While they suggested that this species is unlikely to outcompete the dominant *Posidonia oceanica*, it is likely to replace it as water temperatures exceed its thermal threshold. However, the impacts to ecosystem functioning by this potential species replacement is, unfortunately, not yet understood.

In terms of impacts of tropicalization on ecosystem processes, Marx et al. showed that the main impact of the replacement of temperate *P. oceanica* in the Mediterranean Sea by the tropical seagrass *Cymodocea nodosa* and the green calcareous alga *Halimeda incrassata* would be a decrease in primary production, and possibly impacts on nutrient dynamics. Mateo-Ramirez et al. showed that increases in Mediterranean *H. incrassata* would likely enhance epifaunal communities, particularly those with opportunistic life history traits. The opinion paper by Lepoint and Hyndes recognised the value of detrital seagrass exported from *P. oceanica* meadows to other ecosystems, and suggested that shifts to other seagrass species will likely impact other Mediterranean subtidal ecosystems that rely on seagrass macrophytodetritus as food and habitat. The magnitude of this impact will depend on the extent of other forms of macrophytodetritus in those other systems and the impact of ocean warming on donor systems such as algal-covered rocky reefs.

Lastly, seagrass food web structure can be impacted by range shifts of consumers from grazers to mesopredators and higher order predators. Rodriguez et al. showed that native urchins can graze heavily on the seagrass *Thalassia testudinum* in the northern warm-temperate Gulf of Mexico, but when coupled with influxes of tropically-associated green turtles, a significant compounding effect on the reduction of above-ground biomass results in denuded areas within the meadows. Such seagrass loss will have a detrimental effect on a range of seagrass associated animals that rely on seagrass for protection and food resources. In their opinion paper, Martin and Valentine argued that influxes of predators of tropical origin will impact seagrass food webs, and that the establishment of mesopredators in temperate seagrass meadows will be analogous to that of invasive species. Higher-order predators, however, are likely to have the greatest effect on the seagrass-associated fauna.

Seagrasses impacted by acute thermal stress will lead to seagrass loss where water temperatures exceed thresholds for survival (Nguyen et al., 2021). In temperate regions, these "losers" will almost certainly be replaced by "winners" from the tropics. Based on the papers in this Research Topic, there can be both positive and negative effects of tropicalization on seagrass ecosystem functions. However, research to understand and predict the direct and indirect effects of increasing ocean temperatures on seagrass ecosystems is still very much in its infancy and requires far more attention. Interestingly, a large focus of current seagrass research is on the ability of seagrasses to sequester and store carbon (blue carbon). While a worthy research topic, it is possibly diverting attention away from other equally or more important functions, such as the provision of critical habitat for a range of species at different stages of their life cycles, improving water quality, stabilizing sediments, and exporting seagrass detritus to other ecosystems. For example, a search of key words "seagrass" and either "carbon sequestration" or "nursery" for the period 2018-2021 in Scopus yielded 312 versus 159 published papers, respectively, even though seagrasses in many regions play vital roles as nursery habitats for a range of fish and invertebrates, including those of economic importance. We recommend a far greater focus on examining the full suite of functions in seagrass meadows so that we can more accurately predict the effects of ocean warming and tropicalization on them.

Author contributions

GH, JJ and KH conceived the article. GH wrote and JJ and KH edited the article. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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