Evaluating seagrass ecosystems as nature-based solutions against ocean acidification

Summary of the project:

Habitat forming species of marine macrophytes, such as seagrasses and macroalgae, play a pivotal role in altering the physical and chemical characteristics of their environment and can increase local mean pH by absorbing CO2 from seawater through net photosynthetic activity. Therefore, seagrass meadows have been hypothesized as potential chemical refugia from ocean acidification (OA). However, cycles of photosynthesis and respiration are highly dynamic on hourly, daily, and seasonal scales, and together with multiple biogeochemical and physical processes can induce pH and carbonate chemistry fluctuations that may diminish seagrass capacity to act as refugia for calcifying organisms, but might favor their adaptability. Previous research's limited spatial and temporal scope combined with the intricating underlying drivers of the acid-base equilibria of seawater impedes a comprehensive understanding of seagrass seawater carbonate system controls, creating uncertainty about their efficacy against OA amidst rising anthropogenic CO2 levels and temperatures. The responses of calcifying marine organisms to OA are anticipated to be diverse and complex, raising the remaining questions about how seagrass ecosystems effectively enhance resilience, whether through stress mitigation or increased organisms' physiological tolerance and adaptation. The overall aim of this proposal is to investigate the role of seagrass ecosystems in conforming the response of calcifying organisms to past, present, and future environmental conditions through a combination of biogeochemical, paleoceanographical, ecological and physiological methods with field and lab approaches.

***Training plan*:**

1) Program of training activities at the Institute of Marine Sciences (ICM)

The ICM has all the infrastructure and services needed to develop this proposal (see www.icm.csic.es/en). ICM also has a long-history of PhD completions in the interuniversity Marine Sciences PhD program in which it participates, as well as undergraduate students' supervision and mentoring. The student will work within the group of Marine Biogeochemistry, Atmosphere and Climate under the main supervision of Dr. Aurora M. Ricart. The student will learn different techniques and will acquire a set of research skills throughout the PhD:

Main research activities in which the student will actively participate (*Learning-by-doing theory*):

A) Study of environmental variability regimes in seagrass meadows: Asses the environmental variability in seagrass meadows by deploying autonomous sensor packages to measure parameters like pH, dissolved oxygen, temperature, photosynthetic irradiance, and water velocity continuously with high-frequency assessment. Perform assessments in two contrasting seasons (i.e., spring, fall) to capture seagrass productivity variations. Use time series analysis in sensors' data to identify areas with higher and lower variability of the seawater carbonate system considering seagrass ecosystem traits, and apply spectral analysis to identify periodic behavior and drivers.

B) Paleoreconstruction of seagrass seawater carbonate system and organisms' response: Foraminifera: *Cibicidoides* spp., are known to accurately record paleo-pH. Foraminifera will be extracted from 5 sediment cores from different *P.oceanica* meadows with coherent chrono-stratigraphy (^{210}Pb + ^{14}C analysis) spanning the last 3,000 years, and will be analyzed for shell thickness and density to assess for potential effects of OA. Boron isotopes analyses (δ^{11}B) will be done in foraminifera samples using advanced spectrometry techniques as a proxy of past seawater pH.

C) Organisms response to present and future environmental variability regimes and transgenerational effects: Transgenerational plasticity in larvae and adult experiments will be done to assess responses to future acidification conditions in a mesocosm experiment.

Main research skills to be acquired by the student:

The project includes multitude of research skills that the student will acquire through the duration of the grant, such as: **Research skill 1** Manipulation, calibration and maintenance of autonomous sensors. **Research skill 2** Conduction of laboratory analyses for the assessment of the seawater carbonate system: pH and total alkalinity analysis. **Research skill 3** Learn methods for paleoecological research: (i) foraminifera species identification and morphometric analysis; (ii) boron isotopes and trace elements analysis of biogenic carbonates and paleoceanographic techniques to reconstruct past pH. **Research skill 4** Skills to work with marine invertebrates in the laboratory: (i) nursing, spawning and fertilization in captivity; (ii) morphometric analysis using image analysis techniques. **Research skill 5** Data visualization, analysis of time series and statistical techniques using R. **Research skill 6** Gain knowledge on marine field work techniques, protocols, and scientific diving.

Additionally, this project will allow the student to gain **complementary and transferable skills** such as:

a) Scientific writing skills
b) Communication skills
c) Public engagement
d) Team management and interpersonal relations
e) Research and time management, and work habits
f) Diversity, Equity and Inclusion (DEI)
g) Scientific networking
h) An authorized international mobility stay

The above-mentioned skills will conform an enrich the educational experience of the student and will also contribute to the student's professional success.