Impact of multiple stressors on sea pen meadows

Two subjects:

- Impact of temperature changes on the sea pen *Pennatula phosphorea*
- Impact of acidification on the sea pen *Pennatula phosphorea*.

Complementary information:
The proposed subjects are part of a joint research project between UCLouvain and the Goteborg University.

We have entered the United Nations Decade of Ocean Science for Sustainable Development (2021-2030) aimed at developing "the science we need for the **ocean we want**"[1]. Accordingly, a cry has been raised "to reverse the cycle of decline in ocean health"[2], a universal need emphasized by international policy instruments such as Sustainable Development Goals (in particular, SDG 13 and 14). Sustainable, resilient, and healthy ocean ecosystems depend on the management of marine stressors at all scales[3,4].
Among the greatest current threats to ocean health are **global changes**, in particular ocean warming (OW) and ocean acidification (OA)[3-5]. These are happening on top of **local changes** such as pollution, habitat destruction, and over-exploitation of resources[3-4]. In-depth understanding of ongoing and emerging impacts of local and global changes on marine species and ecosystems, and their causes and mechanisms, is required to protect and manage our marine ecosystems. Resolving **multiple stressor's** impacts is a key challenge of the UN Decade[4] as the identification of the main stressors (exposure and local sensitivity) is the pre-requirement to the identification and implantation of adaptation and mitigation solutions[6].
The project, in which master student will be included, proposes the **development and implementation of a scientific strategy**, combining single and multiple stressors experiments and allowing to resolve the mechanisms behind the combined effects of multiple stressors and provide the basis for the identification of priorities at a local scale. This strategy will be applied to a poorly understood but key ecosystem, Sea Pen Meadows (SPMs).
I selected the keystone species *Pennatula phosphorea* as **model**. Under specific conditions, they form sea pen meadows (SPMs) in plains of fine muds bioturbated by burrowing megafauna. SPMs act as **biodiversity hotspots** and are classified as "**Vulnerable**" by the IUCN red list and sea pen-dominated communities are considered as **Vulnerable Marine Ecosystems** (VME) and **Essential Fish Habitats** (EFH)[7]. Usually associated with burrowing megafauna, the fine muddy sediments plains are covered with conspicuous populations of sea pen[8,9]. They create a complex habitat with key ecosystem functions and services[9]. They modulate the physical and geochemical sediment properties through burrowing activities, allowing oxygen to deeply penetrate the mud. As suspensive feeders, they capture and recycle the suspended organic matter. They provide a suitable environment for species, serving as feeding platform, ground

nursery, shelter, or food supply[8-14]. They also provide human resources by hosting key species target by fisheries[8].
Few information is available on the stressors faced by SPMs. Trawling fisheries are singled out without studies on other factors (OA, OW, etc.). Studies suggested that sea pen presence or density could serve as **indicators of good condition** in mud habitats, making them **umbrella species** for this biotope[15-17]. So, it is urgent to understand the multiple stressors facing SPMs.

Resolving single stressors impacts. For any single stressor, the relationship between an environmental variable and organismal performance (*i.e.* a performance curve), needs to be determined to quantify species vulnerability and thresholds. Each stressor has a different non-linear performance curve and mode of action. This knowledge is required to understand and model interactions and the effect of combined stressors[4]. For key stressors, we will characterize **single stressor performance curves** and resolve their mode of action. Stressors will include temperature (OW; **<u>one master thesis</u>**), pH/*p*CO2 (OA; **<u>one master thesis</u>**), extreme events, pollution, habitat alteration and density (trawling). We will use a regression approach[18], covering present and future range of variability, to identify thresholds and tipping points, and characterize the curve shape. For temperature, we will use a range between 4 and 25°C covering today's variability and +4.8°C above the present variability range using heaters and temperature controllers. For pH, we will directly inject gas with *p*CO2 values ranging from 400 ppm (present/control *p*CO2) to 1000 ppm into the experimental system, preserving the natural seawater fluctuations. These parameters ranges will cover the present and the projected natural variability values for year 2100 (IPCC 2022)[19].

Data collected through these two master theses will be used for **multiple stressors** assessments.

[1] UNESCO, The Science we need for the Ocean we want; [2] UNESCO, The Decade; [3] IPCC Fifth Assessment Report (Cambridge Univ. Press 2014); [4] Boyd et al. 2018. *Glob. Chang. Biol.* 24, 2239; [5] Przeslawski et al. 2015. *Glob. Chang. Biol.* 21, 2122; [6] IOC-UNESCO 2022. In Multiple Ocean Stressors: A scientific summary for policy makers; [7] Rogers and Gianni. 2010. The implementation of UNGA resolutions 61/105 and 64/72 in the Management of Deep-sea Fisheries on the High Seas; [8] Hughes. 1998. *Scottish Assoc. Mar. Sci.* 105; [9] De Clippele et al. 2015. *Cont. Shelf Res.* 105, 67-78; [10] Buhl-Mortensen et al. 2017. In Marine Animal Forests; [11] Baillon et al. 2012. *Front. Ecol. Environ.* 10, 351-356; [12] Masuda and Stone. 2003. *Alsk. Fish. Res. Bull.* 10, 104-118; [13] Malecha et al. 2005. *Am. Fish. Soc. Symp.* 41, 289; [14] Boulard et al. 2024 *Deep sea Res. II* 218, 105417; [15] Greathead et al. 2007. *J. Mar. Biol. Ass. U.K.* 87, 1095-1103; [16] Downie et al. 2021. *MEPS* 670, 75-91; [17] Murray et al. 2015. Joint Nature Conservation Committee/Cefas Partnership Report Series N°9; [18] Kreyling et al. 2018. *Ecol. Lett.* 21, 1629-1638; [19] IPCC 2022.

<u>Conditions:</u>

- Laboratory and field work at the Kristineberg Marine Research Station, Sweden (minimum 3-4 months). The master's student will take steps to find funding to enable him/her to meet his/her needs in terms of travel, food, and accommodation (available at the station).
- Work: organism collections, organism maintenance, data acquisition (morphologic, ethologic, physiologic), microscopy, respirometry, luminometry, data analyses, statistics.
- Highly motivated student, rigorous, fluent in English, able to work independently (part of the thesis will be performed with regular online meetings).