FINAL REPORT

SHORT TITLE

ACIDVEG – Effects of ocean acidification on marine vegetation using Baja California upwelling as natural laboratories

PROJECT TITLE

A novel approach to study the effects of ocean acidification on marine vegetation (seagrass and seaweeds): Using upwelling-exposed coastal lagoons in Baja California as natural laboratories.

ACRONYM:

ACIDVEG

PROJECT TEAM

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INTRODUCTION

As a consequence of human actions, CO_2 in the atmosphere is increasing. Oceans are taking up to 25%[1] of this CO_2, which results in increasing dissolved inorganic carbon (DIC) and decreasing pH in seawater, i.e. ocean acidification. While several dramatic negative effects have been described for marine organisms, submerged marine vegetation may benefit from a high-CO_2 scenario by increasing its productivity[2].

Submerged marine vegetation, like seagrasses and seaweeds, are among the world's most valuable marine ecosystems. Despite they are constrained to the land-sea interface of coastal areas, occupying the shallow subtidal and intertidal zones, these vegetation hold a very high ecological and economical importance providing a number of essential ecosystem services such as oxygenation, nutrient recycling, carbon sequestration and fisheries support[3,4].

Most of our current knowledge about the effects of ocean acidification on marine vegetation derives from laboratory-controlled experimentation[5]. However, these experimental approaches are unable to recreate the time scale, environmental variability and biological interactions organisms are exposed under natural conditions[6]. This information is key to reduce uncertainty in predicting the ecological consequences of climate change. Field (*in situ)* studies to explore the responses of marine vegetation to ocean acidification are thus imperative.

Studies conducted *in situ* in submarine CO_2 vents suggest that seagrasses and fleshy seaweeds have adapted to live under high CO_2 levels[7]. However, results are still inconclusive since the variability in the physico-chemical composition of vent seeps and the presence of deleterious compounds may confound the effects of high-CO_2[8]. Oceanic upwelling events surfaces CO_2-enriched deep seawater in coastal areas. Thus, upwelling zones are a promising, still unexplored, alternative as natural laboratories for study of ocean acidification effects on coastal communities.

Along the Pacific coast of California, including Baja California, seasonal upwelling influenced by the California Current occurs[9]. Associated to these upwelling events, cold deep seawater enriched with CO_2 and nutrients shallows and a DIC gradient develops along coastal lagoons[10]. Such is the case of Bahía San Quintín (BSQ), a coastal lagoon where vegetation growing at the mouth of the bay is naturally more exposed to upwelling CO_2 than vegetation developing at innermost parts of the bay, creating an ideal natural location for ocean acidification experimentation.

Along BSQ, extensive intertidal and shallow subtidal flats dominated by the seagrass *Zostera marina* and the seaweed of the genus *Ulva* occur[11]. These meadows play a major ecological role by improving the water quality through carbon and nitrogen recycling[12,13] and supporting local clam and oyster farming, one of the main economic activities in the area[14].

ACIDVEG aims at evaluating ocean acidification effects on the functioning of ocean-land interface ecosystems builders in Baja California.

OBJECTIVES

- To evaluate *in situ* the effects of ocean acidification on seagrasses and seaweeds.

- To validate the use of upwelling gradients along coastal lagoons as natural laboratories for ocean acidification experimentation.

WORK PLAN AND METHODOLOGY

To achieve these objectives an interdisciplinary approach was applied following the natural DIC pattern associated to the upwelling at BSQ using the seagrass *Z. marina* as model species. Although initially planned to include seaweed species, the lack of presence of the seaweed *Ulva spp*. during the field work season determined that only the seagrass *Z. marina* was considered for this study.

Experimental field work was carried out at Bahía San Quintín, a coastal lagoon located in the north-western Pacific coast of the Peninsula of Baja California, Mexico (30° 30′ N, 116°W). The system is under the influence of the California Current with a typical wind-driven upwelling occurring from April to August[15]. The characteristic Y-shape of BSQ, with a single mouth connecting with the ocean and two arms (eastern and western) opening northwards, in combination to the upwelling' advection towards the bay mouth originates a consistent natural gradient of DIC and pH along the BSQ[16] (*further details on BSQ reported in*[12,17,18]).

A series of *in situ* incubations of *Z. marina* plants were performed along the BSQ following a within-site Nested-design. Two sampling sites were stablished at BSQ, one at the mouth of the bay (Boca) exposed to the upwelling influence, and another in the inner part of the bay (Molino) away from the upwelling influence (Fig. 1). At each site, plants from both locations (Boca and Molino) were incubated following a cross-site design.

Figure 1. Map of Bahía San Quintín (BSQ) form GoogleMaps). Stars indicate the sampling locations at the mouth of the BSQ (BOCA) and in the inner part of the Bay (MOLINO).

Physico-chemical descriptors of the water mass were monitored using a combination of autonomous submersible sensors from IIO-UABC and analytical techniques. A CTD, ADCP and a SeapHOx sensor (SeaBird Scientific) recording depth, water current, velocity, pH, temperature, salinity, and oxygen were mounted in a submersible platform and deployed at the mouth of the bay (Boca) (Fig. 2). Another SeapHOx sensor recording depth, pH, temperature, salinity, and oxygen was deployed at the inner part of the bay (Molino). The data recorded allowed the monitoring of the water mass at BSQ and the evolution of eventual up-welling coming into the BSQ.

Figure 2. Deployment autonomous sensor structure at the mount of the BSQ.

Plants were collected at the same sampling sites were incubations were performed. Discrete samples of DIC and nutrients were also taken during the sampling at each station in order to fully describe the water mass at each sampling location. Samples were collected kept in cold and dark and transported to IIO-UABC until analysis [12,17] (Fig. 3).

Autonomous physico-chemical sensors (Hobo irradiance and temperature sensors) were deployed within the seagrass meadow at each sampling site during the incubations to describe the physico-chemistry of the water mass surrounding the seagrass meadows (Fig. 4).

The net metabolic balance of individuals (i.e. balance between photosynthesis and respiration) was used as an indicator of organisms' fitness since it gives information about the energy and carbon available for growth[19] and ultimately determines whether organisms act as a source or a sink of CO_2[20]. Metabolic incubations were performed *in situ* in both light and dark conditions (Fig. 4). The net metabolic balance of individuals was evaluated measuring oxygen evolution with optodes in light (balance between photosynthesis and respiration) and dark (only respiration) conditions using transparent and dark incubations chamber, respectively according to team' protocols[8,13]. Plants from both sites were also collected for organisms' structural descriptors (weight, length, biomass ration) and complementary physiological descriptors of energy input (i.e. photochemistry, bio-optical properties, pigments, carbohydrates), samples kept for analysis at the Instituto de Investigaciones Oceanológicas (IIO-UABC).

Figure 3. Field work at BSQ. Details of *Zostera marina* collection and sorting, plant transplant deployment and samples collections.

Figure 4. Deployment of autonomous light and T sensors (left). Detail of transparent incubation chamber (right).

RESULTS

Please note these are preliminary results that have not been published yet. We kindly ask for a 12 months embargo on the dissemination of the results and graphs showed in this report.

Autonomous physico-chemical sensors were deployed at the mouth of Bahía San Quintín (BSQ) to detect and track the up-welling occurrence and water mass dynamics at BSQ (Fig. 5).

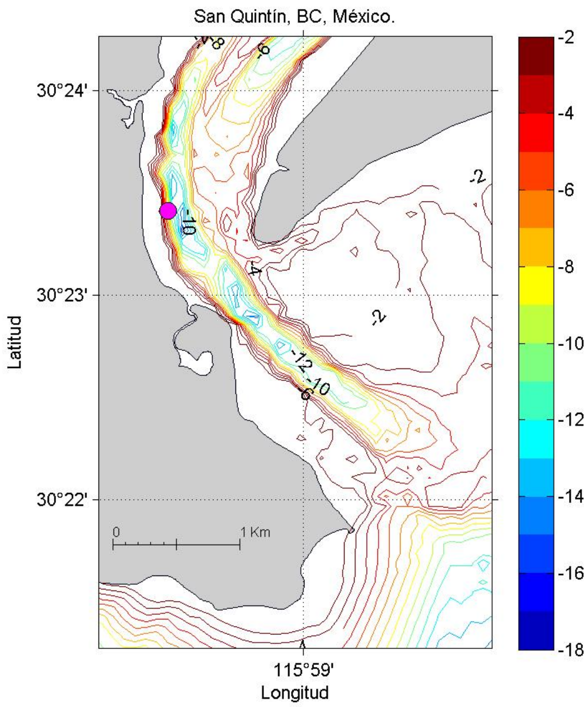

Figure 5. Bathymetric map of BSQ mouth. Pink point indicates the location where the structure with the autonomous physico-chemical sensor was deployed. Coordinates: Lat: 30.39024 ºN, Long: 115.99439 ºW, depth 13m NMM.

Plants were collected and incubated at two sites within the BSQ (Boca and Molino). At each site coordinates, physico-chemistry and nutrients were measured (Table 1 and 2).

Table 1. Coordinates and mean temperature of seawater recorded at the incubation sites. Values are mean ± Standard deviation.

Location	Coordinates	Temperature (ºC)
MOLINO (01 May 19)	N 30º28'57.3", W 115º58'35.7"	21.6 ± 0.7
BOCA (02 May 19)	N 30º23'23.0", W 115º59'46.0"	18.0 ± 1.9

Table 2. Nutrient concentration recorded at the sampling stations in BSQ. Values are mean ± Standard deviation.

Location	NO3+NO2	PO4	H4SiO4
MOLINO (01 May 19)	0.37±0.26	1.06±0.01	26.45±6.08
BOCA (30 Apr 19)	7.29±2.29	1.02±0.10	13.47±0.96
BOCA (02 May 19)	1.23±0.50	0.68±0.10	12.13±1.86

Preliminary results showed that *Z. marina* plants growing at both the mount and the inner part of BSQ are under a good physiological condition.

Plants collected at the mount of the BSQ (Boca) and inner part of the BSQ (Molino) present a good photochemical status (Fig. 6) with fluorescence Yield values (Fv/Fm) higher than 0.75. Slightly higher values were recorded in plants from Boca site, periodically exposed to the upwelling influence. No significant differences were detected between Boca and Molino plants in their capacity to transport electrons (ETR) at different irradiances (Fig. 6).

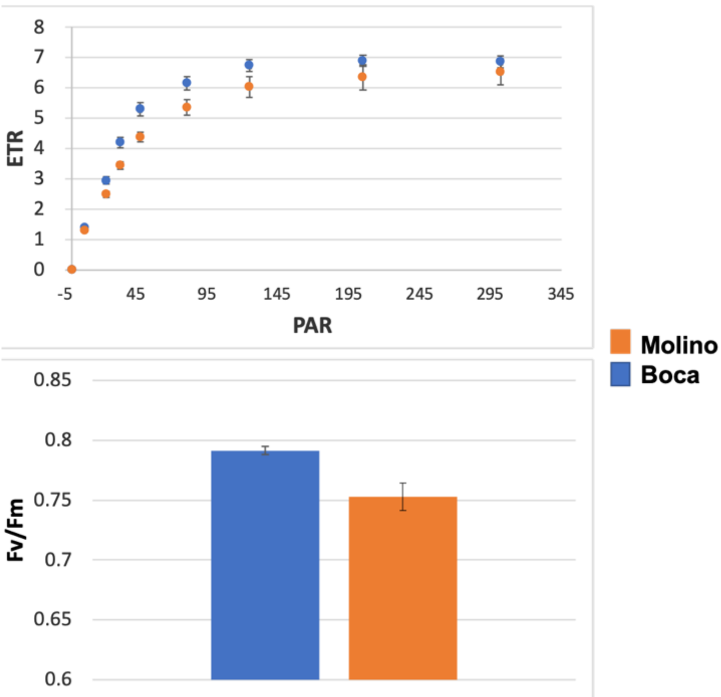

Figure 6. Fluorescence data. ETR vs Irradiance curve (above) and Maximum fluorescence Yield (Fv/Fm) (below) of plants collected at Molino (orange) and Boca (blue) sites. Error bars are Standard error.

Similarly, plants from both locations showed a good photosynthetic response at increasing irradiances (Fig. 7) with no significant differences detected between sites.

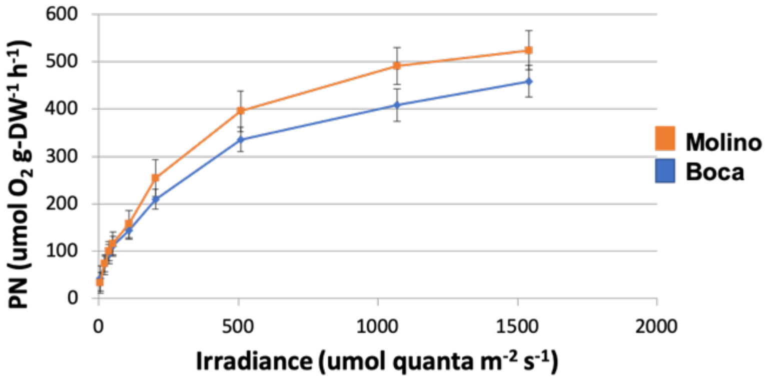

Figure 7. Photosynthesis vs Irradiance (PE) curves of plants collected at Molino (orange) and Boca (blue) sites. Error bars are Standard error.

Following a within-site nested design, plant carbon metabolism was measured at both sites in plants from both locations (Fig. 8). All the incubations performed confirmed that *Z. marina* is a net autotrophic organism with productivity rates exceeding respiration, i.e. acting as a carbon sink. Globally, plants growing under the influence of upwelling events (Boca site) showed slight, although not significant, higher productivity than plants growing at the inner bay not subjected to upwelling influence (Molino site). Productivity rates of plants from both sites were higher when plants were incubated in water from the Boca site, i.e. up-welling influenced, compared to water from Molino site.

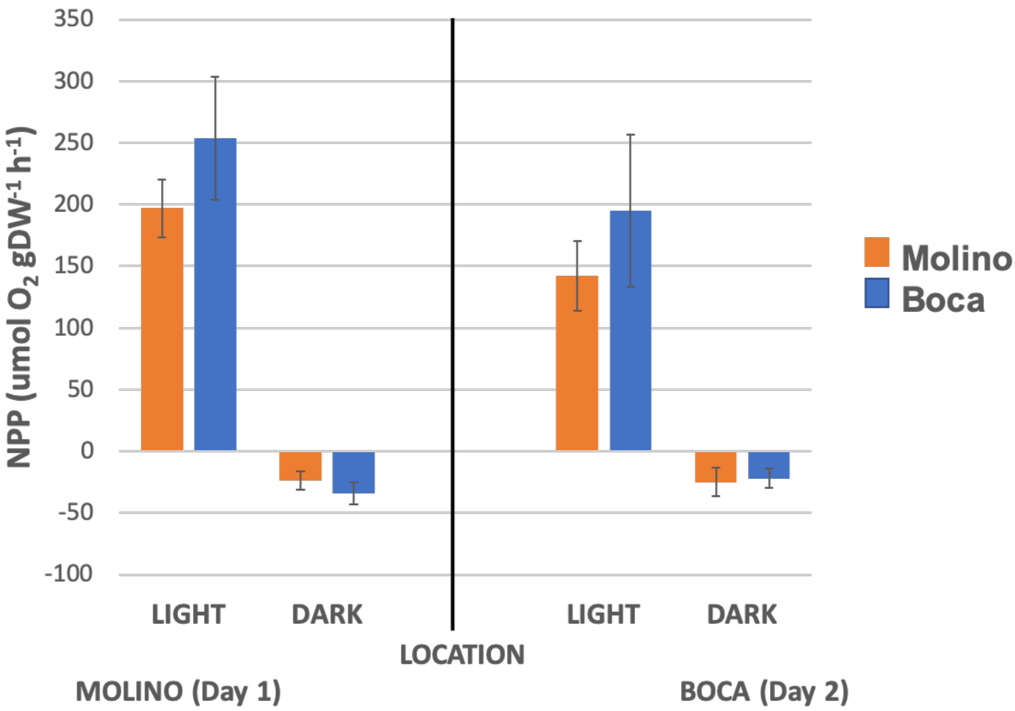

Figure 8. Net plant productivity (NPP). Light refers to incubations performed in transparent chambers. Dark refers to incubations performed in dark chambers. Molino (Day 1) refers to incubations performed on the first day at the Molino site, Boca (Day 2) refers to incubations performed on the second day at the Boca site. Orange bars refer to plants collected at Molino site, blue bars refer to plants collected at Boca site. Error bars are Standard error.

OUTPUTS AND NEXT STEPS

N-Gen research Grant and Next-Generation Sonoran Desert Researchers has been acknowledged in all outputs and dissemination activities associated to ACIDVEG project.

Research dimension

- Samples and data derived from ACIDVEG project are still under processing.

- A scientific publication on open-access in a peer-reviewed international ISI-Journal (e.g. Estuaries and Coasts) is expected by 2020-21.

- A communication in international scientific congress (e.g. ASLO meeting, ISBW-14) is expected by 2020-21.

- Application to international collaborative multidisciplinary project calls (e.g. PADI grants, Mexico-EU bilateral collaborations, CONACYT grant) are expected by 2020-21.

Academic dimension

- Students internships.
  The pregraduate student Jesica Paola Ortiz Arias (BSc in Biology, Mexico DF) performed a week internship in Dr. Sandoval and Dr. Hernández-Ayón research groups. She followed the project development and received training on plant physiology and inorganic carbon analysis of samples from ACIDVEG project.

- Academic seminars
  The academic seminar "Acidificación oceánica y productividad en los océanos: El papel de los pastos marinos" organized by IIO within the seminar series "Seminarios de Posgrado y Oceanografía" was delivered by Irene Olivé on 17th May 2019.

- University publications.
  Two press notes were issued on the project ACIDVEG at the IIO Bulletin on 13 May 2019. One press note was issue on the project ACIDVEG at the GES Bulletin from University of Glasgow on 13th May 2019. (Fig. 9)

Social dimension

- Journal press notes
  One press note was issue about the project ACIDVEG on the journal El Vijia on 27th May 2019. Link: https://www.elvigia.net/el-valle/2019/5/27/estudian-pastos-marinos-de-sq-328972.html

- Collaboration with local communities and companies.
  Access and facilities (e.g. dock access, boats) required for field work were rented to local companies (i.e. Ostrícola Nautilus).
  Workers from local companies belonging to the local community of San Quintín were invited to collaborate and participate in the field work. The responsible of the company Ostricola Nautilus, Mr. Carlos Alberto Guerrero, and the local workers, Mr. Jose Partida and Ms. Eulalia Heredia, provided very valuable knowledge on the field work area. Their help and participation on the field work was greatly appreciated.

- Social network dissemination
  ACIDVEG project and its associated activities has been shared on Twitter under the hashtags #ACIDVEG, #ACIDVEGproject
  ACIDVEG project is disseminated under the research network “ResearchGate”.


INFORMA

EL IIO

Realiza campaña de investigación en la bahía de San Quintín

INFORMA

INVESTIGADORA DE GLASGOW

Colabora en estudio de la bahía de San Quintín


University of Glasgow | School of Geographical & Earth Sciences

GES News May 2019

Figure 9. Press notes form IIO bulletin (above) and GES - University of Glasgow bulletin (below)

CONCLUSIONS

The ACIDVEG project was successfully accomplished.

Globally results confirm a good status of *Z. marina* meadows growing along BSQ. The tendency to increase productivity (NPP) observed in plants from both sites when incubated in water from the Boca site seems to confirm the hypothesis that carbon-enriched up-welling water increases productivity in seagrasses. Further analysis of the seawater physico-chemistry (*sample and data analysis are in progress*) will shed more light on the effect of ocean acidification in seagrass productivity and the adequacy of up-welling areas as natural locations to test future climate change scenarios in the ocean.

ACIDVEG contributed to understand the ecological functioning of and important natural area in Baja California peninsula (Mexico), as is Bahía San Quintín, with an important economic interest associated with oyster farming, an activity which is largely depending on environmental conditions of seawater.

Besides the scientific scope and results of the project, the challenging multidisciplinary approach presented by the ACIDVEG has been successfully implemented among researchers from different disciplines (i.e. ecology, oceanography, physics, chemistry) (Fig. 10). ACIDVEG project has demonstrate the potential for multidisciplinary studies in climate change and seagrass ecology. Further interdisciplinary collaborations from the network of researchers and collaborators generated in ACIDVEGS project is really envisaged.

On the social dimension of the project, complementing the scientific nature of the project, ACIDVEG contributed to social and academic formation, dissemination and engagement. Short internships were offered to students for training scientific and research skills in field and laboratory. Cooperation and participation in field work was stablish with local communities in San Quintín and oyster farming.

Figure 10. ACIDVEG wrapping-up meeting among researchers and collaborators.

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