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PROGRAMA DE INVESTIGACIÓN EN BOTÁNICA MARINA**

**CRITICAL AREAS FOR EELGRASS *Zostera marina* CONSERVATION IN LAGUNA
SAN IGNACIO, BAJA CALIFORNIA SUR**

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Report period: October 2010 to December 2011.

Objective: Identify critical areas for conservation of eelgrass *Zostera marina* in the coastal wetland Laguna San Ignacio, Baja California Sur.

Specific objectives

Determine if four population parameters (seagrass areas, shoot density, seed banks, mesofauna associated).are good indicators of eelgrass conservation.

Compare the change in cover of eelgrass selected meadows for the past 30 years, using Landsat imagery.

Contents of the report:

- a. Compare the change in coverage of selected eelgrass meadows for the last 30 years using Landsat images through overlapping areas in a GIS.
- b. Quantify four parameters indicators of grassland condition selected from. *Zostera marina* (seagrass areas, shoot density, seed banks, mesofauna associated).
- c. Determine the lowest taxonomic level invertebrates in the sediment.
- d. Determining changes in the composition of sediment and invertebrates.

Summary

The seagrass beds are highly productive marine ecosystems that provide a huge amount of ecosystem services. Angiosperms are plants that have developed morphological and physiological strategies to survive submerged in the ocean. Despite its importance, to date, remain one of the least charismatic coastal ecosystems and unknown to mankind, and its rate of disappearance of the world's coastlines is four times greater than that of tropical forests. In Mexico 9 species inhabit seagrass which *Zostera marina* (Zm) is the dominant species in the Pacific and Gulf of California. Information regarding national seagrass is scarce, are devoid of a framework of environmental protection and few protected areas that have seagrass beds. In this report assessed the conservation status of prairie Zm in Laguna San Ignacio (LSI) to identify critical areas for the conservation of this species. To achieve this were sampled in situ (2008-2010), were used Landsat images (1970-2000) and information from previous research in the areas of study. Thanks to this, we obtained a set of indicators of the conservation status of the marine angiosperm. We found that, in descending order, currently there 7320ha in LSI, 218 seeds m⁻² for LSI. The low density of seeds found in LSI indicates that it is a perennial population in this wetland but its density is the lowest in the entire known range of distribution. In LSI seagrass coverage has declined 37% in the last 15 years in LSI overfishing and the use of prohibited fishing gear are one of the main factors that damage to the prairies of Zm. In LSI the critical areas for the conservation of Zm are north and southeast, in North and Pitaya sections, where greater coverage and higher grassland seed banks. Legal rule is needed to protect seagrass in Mexico in addition to long-term annual monitoring of key sites such as the three wetlands analyzed in this thesis in order to determine the effect of local origin disturbances (change of use of soil) and global (ocean warming) on seagrass beds.

Keywords: critical areas for conservation, ecosystem services, seagrasses, *Zostera marina*, *Ruppia maritima*, scallops, San Ignacio.

Introduction

Populations in the Pacific Ocean, San Quintin Bay is one of the most studied regarding seagrass (Ibarra-Obando & Aguilar-Rosas 1985, Ibarra-Obando et al. 1997; Meling-López and Ibarra-Obando 1997, Ward 2003, Ibarra-Obando et al. 2007, Jorgensen et al. 2007) and is one of the first places that you have written record of the presence of *Z. marina* in Mexico (Dawson 1962). There are other locations for which reported the presence of *Zostera marina* in the 1970s (Isla Coronados, Isla Cedros, Isla Guadalupe), but for which there are no subsequent records of its presence. The wetlands where the largest populations of *Z. marina* in the Mexican Pacific Ocean and that they remain under study are six Estero de Punta Banda, San Quintin Bay, Laguna Guerrero Black, Scammon Lagoon, Laguna San Ignacio and Bahía Magdalena Lagoon Complex - Clam Bay (Figure 1, Table 1). These populations are present year-round (perennial), with extensions ranging from tens to hundreds of hectares in each wetland (Santamaria-Gallegos et al. 2001, Lopez-Calderon & Riosmena-Rodriguez 2010; Riosmena-Rodriguez et al. Forthcoming).

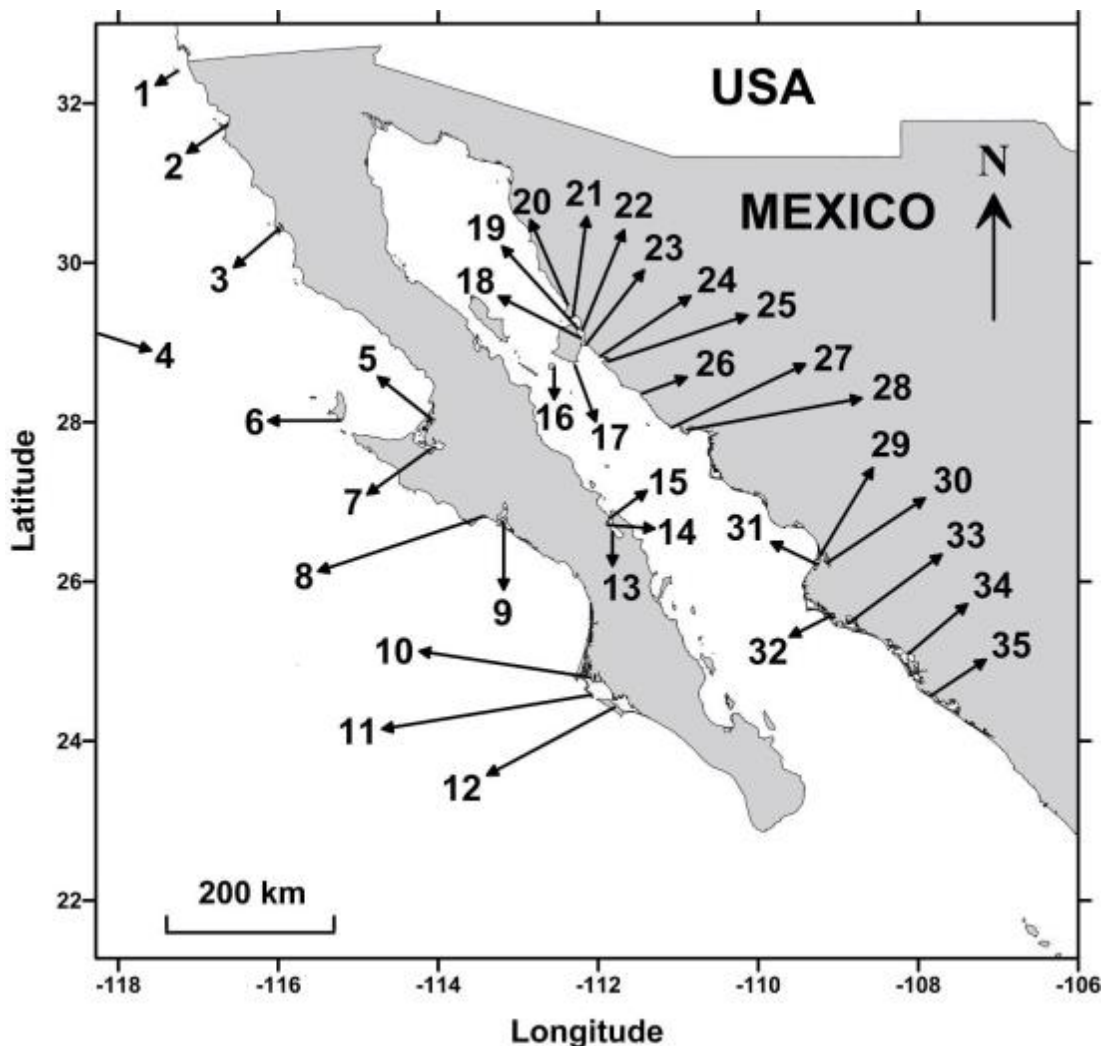


Figure 1. Location historical reports for *Zostera marina* in Mexico. The name of each location along with their references are shown in Table 1.

Table 1. Localities that have reported the presence of *Zostera marina* in Mexico.

Number	Locality	Reference
1	Isla Coronado, B. C.	Den Hartog (1970)
2	Estero de Punta Banda	Ibarra-Obando (1989); Muñiz-Salazar <i>et al.</i> (2005)
3	Bahía San Quintín, B. C.	Dawson (1962); Den Hartog (1970); Ibarra-Obando & Aguilar-Rosas (1985); Ibarra-Obando (1989); Riosmena-Rodríguez & Sánchez-Lizaso (1996); Ibarra-Obando <i>et al.</i> (1997); Poumian-Tapia & Ibarra-Obando (1999); Cabello-Pasini <i>et al.</i> (2003); Carrera-González & de la Fuente-León (2003); Ward <i>et al.</i> (2003, 2004); Muñiz-Salazar <i>et al.</i> (2005); Jorgensen <i>et al.</i> 2007
4	Isla Guadalupe, B. C.	Den Hartog (1970)
5	Laguna Guerrero Negro, B. C. S.	Santamaría-Gallegos <i>et al.</i> (2001); Carrera-González & de la Fuente-León (2003)
6	Isla Cedros, B. C.	Den Hartog (1970)
7	Laguna Ojo de Liebre, B. C. S.	Riosmena-Rodríguez & Sánchez-Lizaso (1996); Santamaría-Gallegos <i>et al.</i> (2001); Cabello-Pasini <i>et al.</i> (2003); Carrera-González & de la Fuente-León (2003); Muñiz-Salazar <i>et al.</i> (2005)
8	Punta Abreojos, B. C. S.	López-Calderón <i>et al.</i> (2010)
9	Laguna San Ignacio, B. C. S.	Santamaría-Gallegos <i>et al.</i> (2001); Cabello-Pasini <i>et al.</i> (2003); Carrera-González & de la Fuente-León (2003); Muñiz-Salazar <i>et al.</i> (2005)
10	Bahía Magdalena, B. C. S.	Santamaría-Gallegos <i>et al.</i> (2007); Riosmena-Rodríguez <i>et al.</i> (2010); Rodríguez-Salinas <i>et al.</i> (2010)
11	Isla Magdalena, B. C. S.	Hernández-Carmona <i>et al.</i> (2007)
12	Isla Margarita B. C. S.	Den Hartog (1970); Riosmena-Rodríguez & Sánchez-Lizaso (1996); Hernández-Carmona <i>et al.</i> (2007)
13	B. Concepción, El Requesón, B. C. S.	Riosmena-Rodríguez & Sánchez-Lizaso (1996)
14	B. Concepción, Isla Bargo, B. C. S.	Den Hartog (1970)
15	B. Concepción, Punta Arenas, B. C. S.	Ramírez-García & Lot (1994); Riosmena-Rodríguez & Sánchez-Lizaso (1996); Sánchez-Lizaso & Riosmena-Rodríguez (1997); Santamaría-Gallegos <i>et al.</i> (2000); Muñiz-Salazar <i>et al.</i> (2005)
16	Isla San Esteban, Son.	Ramírez-García & Lot (1994)
17	Isla Turner, Son.	Ramírez-García & Lot (1994)
18	Canal de Infiernillo, Punta Chueca, Son.	McMillan (1983); Meling-López & Ibarra-Obando (1999)
19	Canal de Infiernillo, Son.	Ramírez-García & Lot (1994); Brusca <i>et al.</i> (2004)
20	El Desemboque, Son.	Felger & Moser (1973)
21	C. de Infiernillo, Bahía Sargento, Son.	Ramírez-García & Lot (1994)
22	C. de Infiernillo, Punta Víboras, Son.	Meling-López & Ibarra-Obando (1999)
23	Canal de Infiernillo, Son.	Muñiz-Salazar <i>et al.</i> (2005)
24	Isla Alcatraz, Son.	Ramírez-García & Lot (1994)
25	Bahía Kino, Son	Ramírez-García & Lot (1994)
26	Estero Tastiota, Son.	Den Hartog (1970)
27	Bahía de San Carlos, Son.	Den Hartog (1970)
28	Guaymas, Son.	Den Hartog (1970)
29	Agiabampo, Son.	Ramírez-García & Lot (1994)
30	Agiabampo, Son.	Ortega <i>et al.</i> (1986)
31	Agiabampo, Son.	Muñiz-Salazar <i>et al.</i> (2005)
32	Topolobampo, Sin.	Aguilar-Rosas & López Ruelas (1985); Ramírez-García & Lot (1994)
33	Bahía Navachiste – Isla El Metate, Sin.	Orduña-Rojas & Riosmena-Rodríguez (2008)
34	Bahía Santamaría, Sin.	Muñiz-Salazar <i>et al.</i> (2005)
35	Altata, Sin.	Den Hartog (1970)

Unfortunately, in most of the reports about Mexico seagrass prior to 2000, information on the geographical coordinates that define the meadows of *Z. marina* and density of seagrass is scarce (Riosmena-Rodriguez et al. 2013). This information is useful as an indicator of the stability of the grasslands in the medium and long term. We need to increase the effort in monitoring the coastal ecosystem for two main reasons, the first one due to the importance of the ecosystem services provided (Wyllie-Echeverria & Cox 1999, Costanza et al. 1997, Duarte 2000, Worm et al. 2006) and the second is because seagrasses are sensitive environmental indicators on the quality of coastal habitat. Regular monitoring provides quantitative elements to determine the time in which natural and anthropogenic disturbances (Short & Wyllie-Echeverria 1996) begin to have a deleterious effect on seagrass. The fail in this task will involve an increase in the deterioration of this valuable coastal ecosystem and the concomitant loss of ecosystem services in the medium term. There are examples which recognizes the positive impact the seagrass beds in local fisheries and the need to prioritize their management as a conservation (Unsworth et al. 2010). Also exist that define different work requirements for carrying out the monitoring of such habitats (Fonseca et al. 1998 Finkbeiner et al. 2001, Short et al. 2006 Rigby et al. 2007; van Katwijk et al. 2009). In order to carry this out in Mexico is not only necessary to include seagrass conservation targets in the management plans and marine protected areas as a fishery resource by the state and federal fisheries agencies, but also is necessary to sensitize the general public about the nature and importance of the coastal ecosystem unknown, which is as important as mangrove forests and coral reefs (Duarte et al. 2008). Currently, only six marine protected areas that exist in Mexico are located in areas with seagrass beds (Green & Short 2003), of which, the Biosphere Reserve El Vizcaino is the only one located on the west coast of Mexico.

Background

Laguna San Ignacio stands out as one of the most pristine wetlands nationally and internationally, due to the low human development has been subjected. This wetland provides various ecosystem services, which can be divided into direct services:

- Sources of employment for the local community through fishing or aquaculture. Baja California Sur ranks sixth nationally in fish production (INAPESCA 2005) and Laguna San Ignacio is one of the main fishing sites for the state.
- Sources of food for humans and for countless species, including migratory birds are ducks and geese (*Branta bernicla*) (Carrera-Gonzalez & de-la-Source-León 2003; Sedinger et al. 2004; Ward et al. 2005) Marine mammals such as the gray whale (*Eschrichtius robustus*) (Urban et al. 2003; Caraveo-Patiño & Soto 2005; Urban & Swartz 2007) endangered species such as the black turtle (*Chelonia mydas*) (Gardner & Nichols 2001, Koch et al. 2006) and commercially important species such as scallops (*Pinna rugosa*, *Atrina maura*), grouper (*Paralabrax* spp.), puffer fish (*Sphoeroides* spp.), elasmobranchs (rays, sharks) , cephalopods (octopus), crustaceans (shrimp, crab), among others (Danemann & de-la-Cruz-Agüero 1993, Villavicencio & Abitia-Cardenas 1994 Zarzosa Segura et al. 1997; De-la-Cruz-Argüero & Cota-Gomez 1998).
- Ecotourism for bird watching and marine mammals.
- Scientific Research.

Indirect Services:

- Climate regulation because their coastal ecosystems (marsh flats, seagrass beds, mangrove forests) remove greenhouse gases from the atmosphere and ocean (CO₂) and stored in the sediment, which helps to slow the global warming and ocean acidification (Nellemann et al. 2009).

- Biogeochemical Cycles.
- Export of organic matter, nutrients and organisms (plankton blooms) to adjacent ocean areas.

And intrinsic services:

- Conservation of biodiversity to be home to hundreds of species of fish, invertebrates, birds, marine mammals and plants.
- Resources for future generations.

Objective

Identify critical areas for conservation of eelgrass *Zostera marina* in the coastal wetland Laguna San Ignacio, Baja California Sur.

Specific Objectives

Determine if four population parameters (seagrass areas, shoot density, seed banks, mesofauna associated).are good indicators of eelgrass conservation.

Compare the change in cover of eelgrass selected meadows for the past 30 years, using Landsat imagery.

Methodology

Five samplings were conducted in Laguna San Ignacio. During each sampling, information was obtained on four parameters indicators of conservation of eelgrass meadows, and other environmental data (temperature, salinity, substrate type). The samples were made using a 7m boat with outboard and using scuba equipment, only for the case of grassland located in the subtidal zone. Grasslands were sampled at different depths ranging from the intertidal zone to 10 m depth. The monitoring consisted of conducting tours on board the vessel, visually identifying seagrass areas, using traditional knowledge of local fishermen to turn to seagrass areas. We used a global positioning unit (GPS Trimble Juno ST ®) to record the coordinates of seagrass areas and also followed the outer contour of the seagrass areas with this information later to calculate the area of each of these areas. During these tours also carried out a search about the different seafloor types (sandy, rocky, muddy, conchal).

For monitoring underwater eelgrass meadows different points were selected each wetland, ensuring that these would cover all the Laguna, which was divided into four sections or areas for spatial analysis, following the scheme of Urban and Swartz (2007) : Northern Sections, Medium, Low and Pitaya or Gilmore. The methodology used in each monitoring was next. We worked along a transect of 40m away from the edges of the meadow, choosing four random sites along this transect where stood a quadrant of 25x25cm PVC constructed to estimate the density or number of bundles of *Z. marina* per quadrant. Subsequently chose three random locations from which sediment cores were extracted from approximately 10 cm thick, using a PVC nucleator 15cm diameter (Figure 2) (Lopez-Rodriguez Calderon Riosmena 2011). Additionally recorded canopy height, and macroflora macrofauna associated with the prairie, from the boat measured surface temperature and salinity using a bucket thermometer and conventional refractometer (model A366ATC VISTA, accuracy 0.5ups). We obtained time series of irradiance and temperature (atmospheric and underwater) using HOBO ® sensors (UA-002-64 And U22-001) for April 2009.

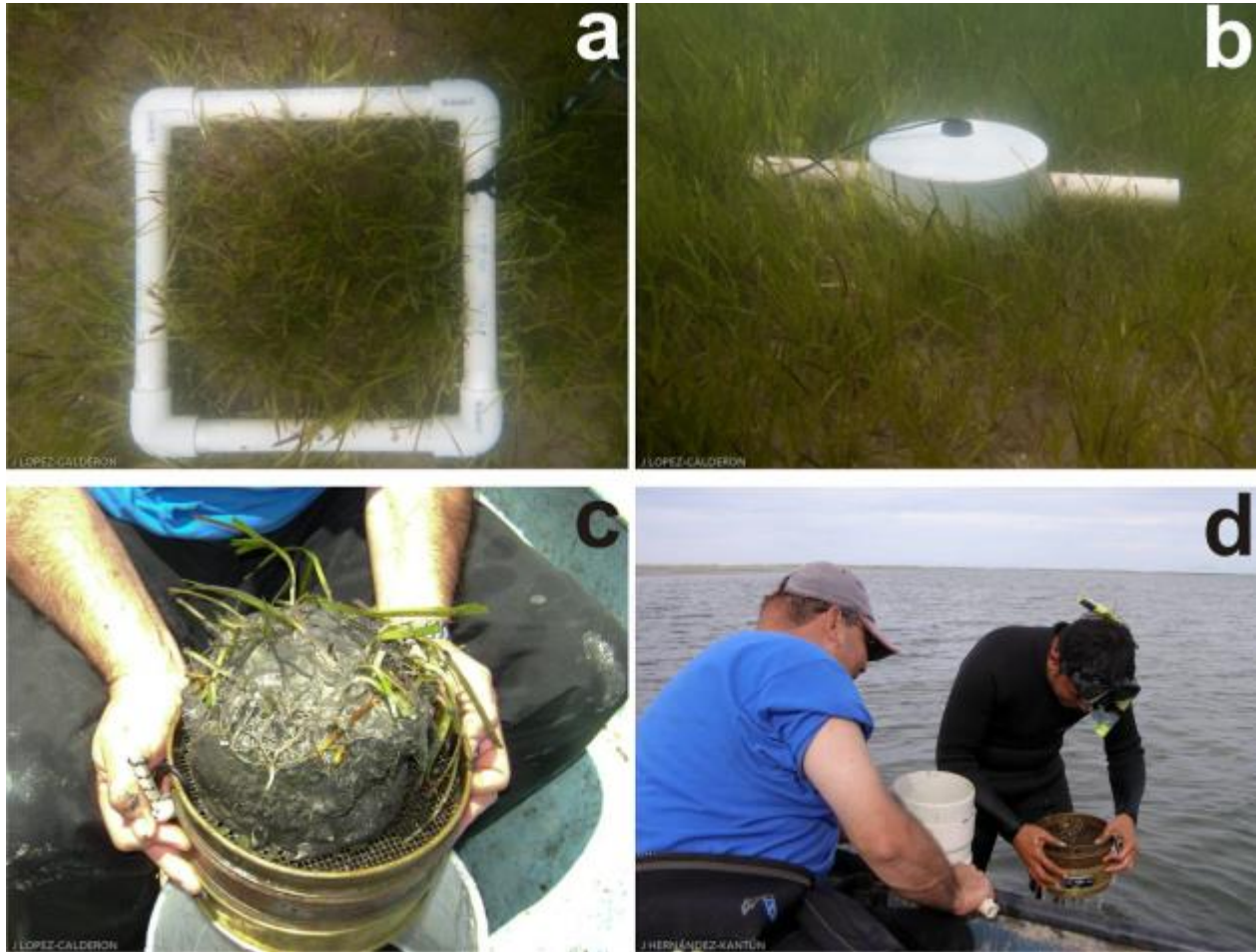


Figure 2. Procedure followed during sampling seagrass: (a) estimate the number and height of beams in one quadrant of 25x25cm, (b) sediment coring 10x15cm, (cd) sediment core fractionation using sieves with three lights mesh.

In each sediment core vessel was placed on a set of three screens (# 6, # 20, # 40, U.S. Standard Sieve Series ®) having the following mesh sizes and that were used to obtain the following fractions:

- 3360 microns - To remove rocks and calcareous fragments and collect seagrass beams
- 840 microns - To collect invertebrates and seeds of *Z. Navey*, whose dimensions are ~ 1x3mm
- 420 microns - To collect smaller invertebrates

Seawater was passed through sieves to ensure that all finer material has been removed, then the fraction of each of the three sieves were separately placed in plastic vials or pre-labeled Ziploc ® bags and ethanol 70% for preservation and subsequent laboratory analysis. Once in the laboratory, seagrass beams were used to confirm the identification of the species, following keys Phillips & Menez (1988) and den Hartog & Kuo (2001). Measured the number of seeds in each

replica to estimate the density per square meter of seed banks. Invertebrates were also quantified and identified to the lowest possible taxonomic level using keys to amphipods (Barnard 1965), polychaetes (Salazar-Vallejo et al. 1989) and molluscs (Keen 1980). The information gathered during this monitoring focused on databases that are part of the Geographic Information System (GIS) for seagrass software created using ArcPad and ArcGIS 7.1 ® 9.3 ®.

Landsat Images

Historical comparisons in the coverage of eelgrass meadows in Laguna San Ignacio multispectral images were obtained from the Landsat. Landsat series comprises a total of six satellites which provide images of the earth's surface since 1972. During this time the Landsat remote sensing have evolved and can be classified into three groups: MSS (Multi-Spectral Scanner), TM (Thematic Mapper) and ETM + (Enhanced Thematic Mapper Plus). The detection range of these sensors covering the visible spectrum (0.4 - 0.7 μ m), infrared (0.7 - 10.4 μ m) and thermal infrared (10.4 - 12.5 μ m). We obtained a total of 5 images for the 1970, 1990 and 2000. These images were downloaded from the site Earth Science Data Interface (<http://glcfapp.glc.f.umd.edu:8080/esdi/index.jsp>). To make the calculation of areas on satellite images and to identify areas with seagrass were used ArcGIS 9.3 ® software and Multispec2.7 ®. To identify areas of sea grass and other bottom types, we used the supervised classification analysis (Song et al. 2001), to perform this analysis we have the validations that were performed during surveys in 2008-2010 where GPS marked, among other things, the location of eelgrass meadows.

Results and discussion

The conservation status indicators allowed us to determine that the prairies of *Z. marine* extend throughout Laguna San Ignacio (~ 7000 ha), however they are mainly concentrated in the North sections (~ 3000 ha) and Pitaya (~ 2800 ha), as could be estimated using Landsat image October 2005. Although there was high spatial variability in shoot density of prairie *Z. marine* maximum observed density (688 ± 158 shoots m⁻²) was low, according to annual averages reported by Cabello-Pasini et al. (2003) to Bahia San Quintin (695 ± 54 shoots m⁻²), Scammon Lagoon (992 ± 50 shoots m⁻²) and for the same Laguna San Ignacio (1089 ± 52 shoots m⁻²) showed higher densities for the period January 1999 to April 2000 the maximum recorded for June 1998 (638 ± 73 shoots m⁻², Salt Flats San Ignacio project). This can be partially explained if one takes into account that in June the highest summer temperatures cause a decrease in the presence of this species characteristic of temperate waters. However, what is a fact is that autumn 2008 to winter 2010 beam densities throughout Laguna San Ignacio did not show values greater than 700 shoots m⁻² while a decade ago Cabello-Pasini et al. (2003) found densities of up to 1500 shoots m⁻² for the same months of the year. The length of the beams or canopy height follows the same pattern of decline since its peak occurred in the summer of 1998 with an average length of 142 ± 4 cm and 175 ± 8 cm for North and Media sections, respectively. Cabello-Pasini et al. (2003) reported for Laguna San Ignacio lengths not exceeding 20 cm and currently the average for the entire Laguna observed was 37 ± 21 cm. What we see today are possibly less dense grasslands with lower canopy height, although it is noteworthy seasonal and interannual variability inherent in perennial and annual grasslands of Laguna San Ignacio which according to environmental fluctuations such as El Niño show morphologic response (leaf size, density beam) and physiological (respiration, photosynthesis) differently. Therefore it is necessary to have more robust time series for weighting plasticity in response *Z. Navy* to changes in the availability of light, nutrients, temperature, salinity, freshwater inputs, storms, etc.. We also have to take into

account biological factors such as predation by herbivores, not only but also seed leaves (Fishman & Orth 1996) and anthropogenic disturbances such as fishing, boat traffic (Sargent et al. 1995), anchor drag (Creed et al. 1999), dumping of waste in or near meadows, etc..

The third indicator of the conservation status of prairie *Z. marina* is perhaps the most important, the low density of seed banks in Laguna San Ignacio. The main seed banks were found in the northern section and section Pitaya and match most extensive areas of seagrass. Found the highest densities ranged between 300 and 850 seeds m⁻². These low densities may not be considered a problem if you take into account that eelgrass populations along the east coast of the Pacific Ocean are mainly perennial and it is through asexual reproduction that these grasslands are preserved. But according to Olesen (1999) *Z. marina* perennial grassland marina that lie between 29 ° N and 56 ° N have a density of seeds whose median is 6176 seeds m⁻², well above that found in Laguna San Ignacio. Although there are reports for populations like in the Bay of Aomori, Japan where annual grasslands are mixed (in the innermost part of the Bay) and perennial grasslands (near the mouth of the Bay) to *Z. marina* densities reported 1157 ± 360 seeds m⁻² and 21 ± 19 seeds m⁻², respectively. Present as low seed banks may involve sexual reproduction plays a limited role for these populations and thus low genetic diversity, which results in an increased vulnerability before or natural type perturbations antropogénico (Ehlers et al. 2008). There are other examples of prairie *Z. marina* highly eutrophic marine zones (van Katwijk et al. 2010) presenting very low densities (<100 seeds m⁻²) and continued for over a decade that present in the area through the germination of seeds and asexual reproduction until it reached a point that grasslands collapsed and disappeared. The time of its collapse could not be predicted, but the factors that caused it were the high level of eutrophication present at the site for years, low winter temperatures do not allow enough survive to perpetuate grasslands, low densities seed and the presence of macroalgae competing for nutrients and light beams *Z. marina* (Short et al. 1995). All this led to a chronic problem that eventually led to the extinction of a population of *Z. marina* on the shores of the Netherlands (van Katwijk et al. 2010). At Laguna San Ignacio found in most tropical latitude (26 ° N) is facing higher temperatures assume that populations north of 29 ° N and therefore must rely on a greater proportion of sexual reproduction (and their banks seed) to survive the summer temperature increases (Jarvis & Moore 2010). This is even more relevant for populations found in the intertidal zone, where desiccation stress is a factor that increases mortality beam (Boese et al. 2005). The low seed densities represent a potential threat to the permanence of the meadows of *Z. marina* at Laguna San Ignacio to the occurrence of climate-type disturbances (Johnson et al. 2003) or anthropogenic. In the end you have a more detrimental effect on seagrass is not the scale of the riots but their daily lives to exhaust, in this case, seed banks that do not have sufficient density to repopulate the prairies disturbed for two or three consecutive years (Jarvis & Moore 2010).

In Laguna San Ignacio *Z. marina* meadows were identified Navy throughout the study area, density beam (Figure 3a) and seed density (Figure 3b), including section Pitaya, for which there is no knowledge of previous research in this area. It is observed that the highest densities of you are in North and Pitaya sections, but more importantly, we see that the seeds of *Z. marina* are distributed throughout the lagoon, although at very low densities (<80 seeds m⁻²), because as mentioned Olesen (1999) *Z. marina* perennial grasslands marina located between 29 ° N and 56 ° N mostly have densities greater than 6000 seeds m⁻². Van Katwijk et al. (2010) reported densities between 5 seeds m⁻² to 11,000 seeds m⁻² for perennial grasslands (1800 seeds m⁻² on average) from Denmark, the Netherlands, Japan and the United States. So that the prairies of *Z. marina* Laguna San

Ignacio marine part of a small group of perennial populations with densities below 1000 seeds m^{-2} or their low densities are an indicator of environmental stress. High mortalities beam, due to higher temperatures in summer, eutrophication, decreased availability or fishing light depend largely on the germination of seed banks to replenish lost beams. The occurrence of these high mortalities in consecutive years does not allow replenishment of seed banks and gradually reduces the resilience of the prairie to environmental disturbances and causes long-term losses of seagrass beds (Jarvis & Moore 2010).

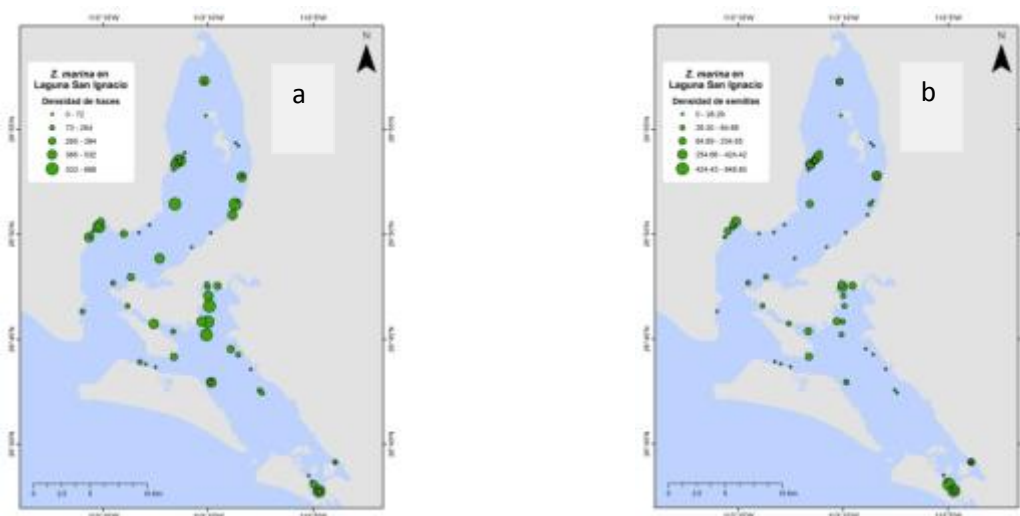


Figure 3. Distribución beam density m^{-2} (a) and density of seeds m^{-2} (b) of *Zostera marina* in selected prairies of Laguna San Ignacio (2008-2010).

For cases of Laguna San Ignacio is urgent actions in favor of the preservation of the coastal ecosystem. According to the information obtained in this thesis recommends the creation of critical areas for conservation of *Z. three* marine wetlands. The conservation status of populations in Laguna San Ignacio is half as the Laguna now has more than 7000 ha of seagrass which more than 4000 have remained stable over the past 15 years (Figure 4). The density of the seed banks (169 seeds m^{-2}), however, is below what is reported in the literature to perennial pasture (1000-6000 seeds m^{-2}), which may be an indicator of a deterioration of the health status of this population. It recommends the creation of critical areas for the conservation of this species in North and Pitaya sections because this is where the greatest concentration extension of seagrass beds, the highest densities of seed and its location are sections with lower traffic marine. The conservation status of these populations is determined based on the current extent of its meadows, its density seed banks and the rate of change experienced by its coverage in the last ~ 20 years.



Figure 4. Distribution of seagrasses present in the image of April 1990 (polygons cream) and those areas of seagrass remained until October 2005 image (green polygons). They include meadows mapped in December 2008 (red polygons) and April 2009 (yellow polygons).

Draw out a permanent monitored not only these three but the remaining wetland sites with seagrass populations, because it is a coastal ecosystem as valuable as mangrove forests (Nellemann et al. 2009) and actually these ecosystems are ecological connections to each other, to exchange not only organic but also organisms (Heck et al. 2008), functioning as habitat for fish and invertebrates at different stages of development (Perkins-Visser et al. 1996; Nagelkerken et al. 2002, Heck et al. 2003). For this we recommend a minimum monitoring includes estimating the coverage of seagrass beds, density and height of the beams and density of seed banks grasslands. The estimate of seagrass coverage can be done from a boat, aerial photography or satellite imagery. In the case of aerial photography is recommended that monitoring of this type every five years, trying to choose the period in which the prairies are in their peak (between winter and spring). For satellite images periodicity depend on the specifications of the sensor to be used (IKONOS, Landsat, SPOT) multispectral images should be used. Satellites provide information seabed to a depth of 15 m, depending on the characteristics of the sensor and the attenuation coefficient of light of the water column (Mumby et al. 1999 Mumby & Edwards 2002). The hedges from the boat have a smaller spatial extent and form part of the monitoring site and therefore should be focused on specific grassland, of which a record is kept as constant as possible. The frequency of field surveys is recommended annually. The mechanics of the monitoring should be based on the level of knowledge of the seagrass population of each wetland, ie, populations with higher levels of prior knowledge require less monitoring effort and vice versa. It is recommended to maintain a continuous monitoring of at least five representative of each wetland meadows, with a detailed database of environmental conditions associated with these grasslands. CARICOMP NaGISA guides and provide useful information and standardized methods for performing the monitoring (CARICOMP 2001, Rigby et al. 2007).

Mesofauna associated with eelgrass meadows

Through sediment cores obtained in the monitoring in Laguna San Ignacio in 2008-2010 was possible to determine that the diversity of micro-invertebrates in seagrass beds is high, it was possible to identify a total of 74 species. In terms of their abundance, most of the identified species can be considered rare because of the 74 species, only 35 accounted for 95% of the variability observed average. In autumn 2008 the 99% of the variability was concentrated on 16 species, in winter 2008 this number increased to 25 species concentrating 96% of the observed variability and spring 2009 to 90% of the variability corresponded to a total of 26 species.

The 5 most abundant taxa in seagrass beds of Laguna San Ignacio are shown in Figures 5 and 6: annelids, bivalves, gastropods, ostracods and peracarids. Bivalves appeared mainly in autumn 2008, with densities reached 300,000 ind m⁻², while in winter their total abundance was less than 300 ind m⁻². A major reason for the overestimation of fall was that these samples showed a degree of poor care, which did not allow us to differentiate between gastropods and bivalves were alive remains of organisms, whose bodies were already part calcareous sediment. The gastropods were the second most abundant group in the four sections of the lagoon (North, Pitaya, Medium and Low) with abundances which reached 12,000 ind m⁻². In third place are the peracarids abundance, with high abundances in sections Pitaya, and Baja, the maximum abundance occurred in Pitahayas with 8000 ind m⁻² in spring 2009. Fourth ostracods, which reached higher abundances of 3500 ind m⁻² in Baja and Pitaya sections in winter and spring, respectively. The next group was that of the annelids that were more abundant in Media and Pitaya sections, with more than 3000 ind m⁻² in winter 2008.

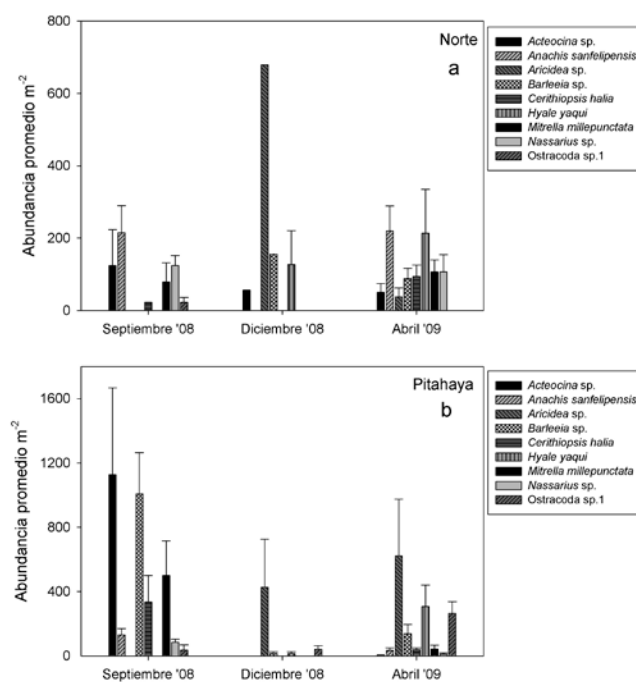


Figure 5. Average density of the nine species of microinvertebrates recurring in at least two sampling periods, with abundances > 100 ind m⁻² in sediments of seagrass beds; North sections (a) and Pitaya (b).

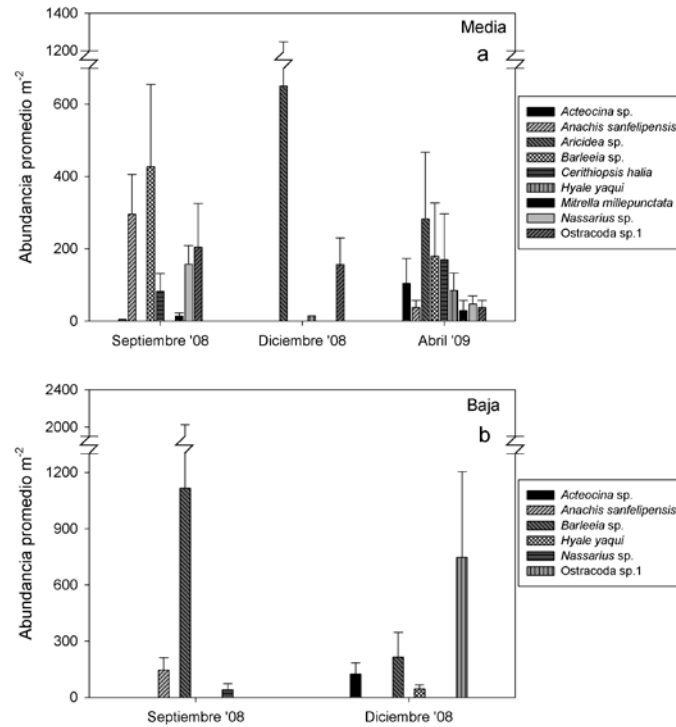


Figure 6. Average density of the nine species of microinvertebrates recurring in at least two sampling periods, with abundances > 100 ind m⁻² in sediments of seagrass beds; North sections (a) and Pitaya (b).

To determine the relationship between the mesofauna associated with eelgrass meadows in Laguna San Ignacio and density of beams that form the canopy, was performed using the Spearman correlation total available data for Laguna (Figure 7). We found a significant correlation ($p = 0.003$) with a coefficient of 0.5 indicating an increase in the total abundance of micro-invertebrates per square meter to increase the number of shoots per unit area. This relationship was even stronger for the section Pitaya (Gilmore) where the correlation coefficient was 0.82 (Figure 8).

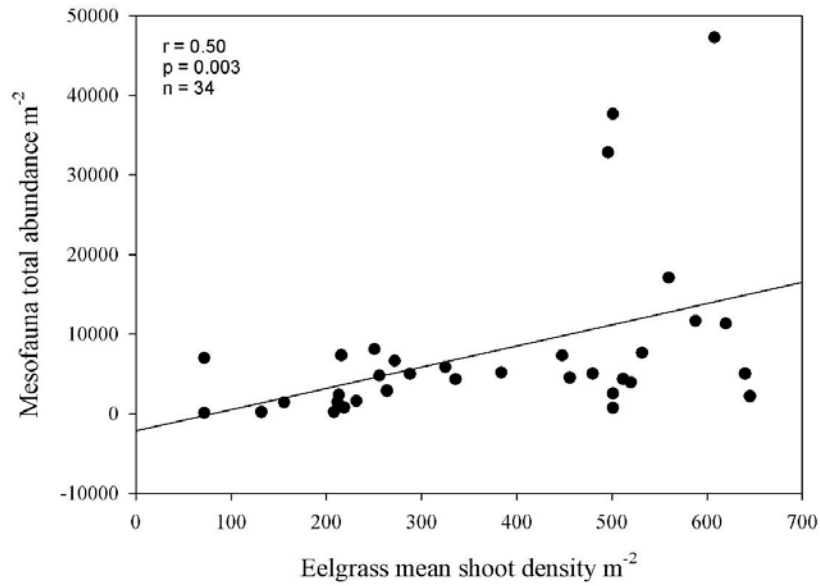


Figure 7. Spearman correlation between the average shoot density and abundance *Zostera marina* microinvertebrates total for stations sampled in the four sections of Laguna San Ignacio.

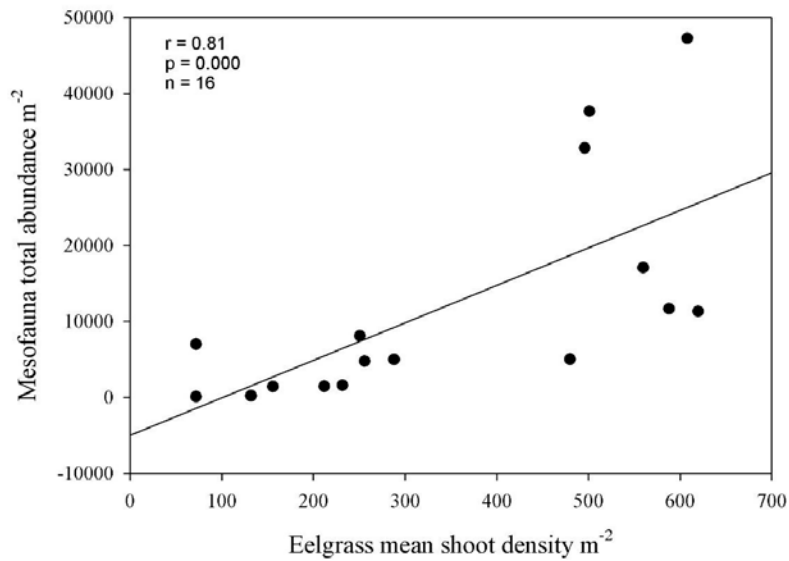


Figure 8. Spearman correlation between the average shoot density and abundance *Zostera marina* microinvertebrates total stations sampled for pitahaya section Laguna San Ignacio.

Conclusions

- The maximum beam density to Laguna San Ignacio is found in North and Pitaya sections (500-688 shoots m⁻²). No significant differences in shoot density of grassland monitored between September 2008 and December 2010 with those monitored in June 1998.
- The maximum height of the canopy to Laguna San Ignacio is found in North and Pitaya sections (50-96 cm). There was a 78% decrease in canopy height of grassland monitored between September 2008 and December 2010 with those monitored in June 1998.
- The maximum power densities of eelgrass seeds in the sediment were found in North and Pitaya sections (311-849 seeds m⁻²). Compared with other density perennial grassland seed banks in Laguna San Ignacio is very low.
- We identified a total of 74 species of micro invertebrates associated with *Zostera marina* meadows during autumn 2008, winter 2008 and spring 2009, which were grouped into five taxonomic groups: annelids, bivalves, gastropods, ostracods and peracarids.
- The highest densities of scallops found in the northern section which also contains the largest expanses of *Zostera marina*. The scallop catch (147 tonnes live weight), the number of permits issued for its fishing and its economic value annually (1.8 million dollars) have increased significantly in the last 12 years (1996-2008) as the pressure on their habitat: eelgrass meadows.
- There was a 37% decrease in seagrass coverage in Laguna San Ignacio in a period of 15 years, Landsat images April 1990 to October 2005.
- Sections were identified as North and Pitaya as critical areas for conservation of seagrass *Zostera marina* in Laguna San Ignacio, due to its higher coverage grassland increased shoot density, the highest number of seed banks and their remoteness from the local major urban centers: El Cardon and Luis Echeverria.

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