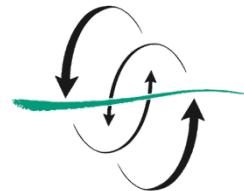




FACULTAD
DE CIENCIAS
DEL MAR



UNIVERSIDAD DE LAS PALMAS
DE GRAN CANARIA

**Spatial and temporal variability
of *Cymodocea nodosa* meadows in
Gran Canaria island**

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Curso 2018/2019**

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Trabajo Fin de Título para la obtención del
título de Grado en Ciencias del Mar



Spatial and temporal variability of *Cymodocea nodosa* meadows in Gran Canaria island

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Abstract

Seagrasses worldwide constitute a key habitat on shallow soft bottoms, but they are experiencing a rapid decline. In order to describe the anatomical, morphological and demographic variations of *Cymodocea nodosa* over time, samples were taken during two years at three meadows on the island of Gran Canaria; one meadow is affected by the action of humans (Arinaga) and two outside the influences of relevant human actions (Gando and Castillo del Romeral). The anatomical changes were evaluated through the above ground biomass and below ground biomass, the morphometric study through the measurement of the leaf length, leaf width and number of leaves per shoot and, finally, the number of shoots were counted as a demographic descriptor. The three morphometric descriptors (leaf length, leaf width and number of leaves per shoot), the density of shoots and above ground biomass showed a seasonal pattern at the three meadows, with maximum in summer and minimum in winter. In contrast, below ground biomass showed a seasonality with maximums in winter and minimums in summer. The study showed that decreased genotype and genetic diversity of the seagrass meadow at Arinaga was directly related with a greater interannual variability of the demographic-anatomical descriptors of seagrass, relative to the other two meadows. On the other hand, this relationship was insignificant for the morphometric descriptors, which are more influenced by other ecological processes at the local scale.

1. Introduction

Seagrass meadows constitute a very important marine ecosystem because they have a high primary and secondary productivity (Hemminga and Duarte, 2000), acting as carbon sinks (Fourqurean et al., 2012; Deyanova et al., 2017), stabilizing sediments and providing O₂ (Peduzzi and Vukovic, 1990). They provide habitat and food for many species, concentrating a rich biodiversity (Duffy, 2006; Unsworth and Cullen, 2010) of organisms, turning the seabed into breeding, nursery and resting areas (Heck et al., 1997), providing protection against predators (Main, 1987) and food to the associated fauna (Tuya et al., 2006; Espino et al., 2011; Tuya et al., 2014a). They regulate the quality and turbidity of coastal waters and decrease the probability of sediment loss, since they reduce coastal hydrodynamics, stabilize sediments and protect the coastline from coastal turbulence events (Hemminga and Nieuwenhuizen, 1990; Gacia et al., 2003; Cabaço et al., 2010).

However, in the last years, there has been a generalized loss of seagrass around the world (Orth et al., 2006) due to direct and indirect human damage: habitat alterations, coastal constructions, dredging, fishing, anchoring, eutrophication by discharges, aquaculture and variation of sedimentation. In addition, the effects of climate change and natural causes, such as cyclones and floods, have also contributed to seagrass meadow deterioration (Duarte, 2002). The loss of the meadow leads to a decrease in productivity and marine biodiversity, which could produce changes in coastal dynamics, decrease in water quality and increase the instability of the substrate with the consequent loss of sand on the beaches and reduction of the fishing resources. Waycott et al., (2009) observed that seagrass meadows worldwide have suffered a regression at a speed of 110 km² year⁻¹ since the 1980s, also estimated a loss since the first record of seagrass meadows in 1879 with a loss of 29 % in extension. From 1990, an acceleration in the loss of seagrass of 7% year⁻¹ was noted. A more specific case, like the Mediterranean case of *Posidonia oceanica*, a loss was recorded between 13% and 38% of the area occupied since 1960 (Marbà et al., 2014). With a remarkable worldwide regression, the notable need to conserve these ecosystems is evident (Hemminga and Duarte, 2000; Duarte, 2002; Unsworth and Cullen, 2010).

1.1. *Cymodocea nodosa*

Cymodocea nodosa (Ucria) Ascherson is a perennial herbaceous marine plant; it has a main stem of creeping type called rhizome, which every few centimetres (1 - 6 cm) contain knots; from these knots, in the direction of the substrate split the roots and in the opposite direction upwards small stems from which arise the shoot of leaves and flowers.

The rhizome, cylindrical, with a diameter of 2 to 4 millimetres has a pink colour. We can find two types of rhizomes: the rhizomes of horizontal growth (plagiotropic), buried in the substrate, and those of vertical growth (orthotropic) (Figure 1) (Espino et al., 2008; Reyes, 2011). The plagiotropic present a larger size than the others and, furthermore, are the main cause of the extension of the meadow. The rhizome can grow parallel or perpendicular to the substrate. In case of parallel growth (plagiotropic rhizome), it is used to spread across the seabed, covering large areas. The vertical or orthotropic growth is the one used to correct the variations in the height of the sediment, such as after an episode of weather. By means of orthotropic growth, plants are able to sustain their shoots of leaves above the substrate.

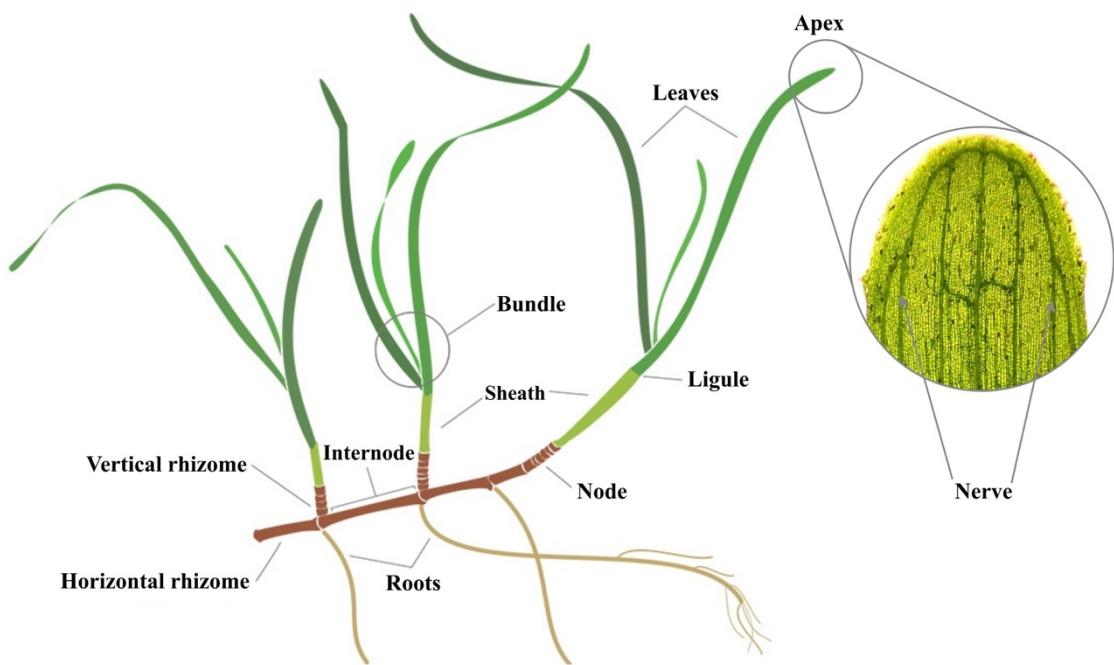


Figure 1. Anatomical parts of *Cymodocea nodosa*. Modified from V. González Ortiz.

The seagrass, like the algae, carry out photosynthesis (autotrophs), for which, they use sunlight, carbon dioxide and water, thus in this way to produce its own organic matter. With these reactions, the biological functions are made while oxygen and vegetal biomass are generated. The organs responsible for this function are leaves.

Leaves are associated at the ends of the rhizomes. In each shoot, there is a variable number of leaves that oscillate between 2 to 4, being able to reach until 10. The leaves are elongated, narrow and ribbon-shaped. In the Canary Islands, seagrass leaves can reach up to 70 cm, although the average values range between 14 and 35 cm and reach a width of 4 mm, during the spring and summer period have the maximum values of length and width are obtained because of the most favorable conditions. In the basal zone, the leaves

are surrounded by a sheath between 2.5 and 7 cm length (ligule), are light green with 7 to 9 longitudinal nerve, the edges are slightly dentate, and the apex has a rounded shape (figure 1). When the leaves die leave a mark on the rhizome, called a leaf scar that gives rise to a knot, these scars can be used to date the age, considering that there is an average of 13 new leaves per shoot per year (Reyes, 1993). In the Canary Islands, *Cymodocea nodosa* can reach up to 5000 shoots per m⁻² in a meadow from Fuerteventura (Espino *et al.*, 2003a, b).

The roots are born from both, the horizontal and vertical rhizomes. In each of the knots, the roots branch as they enter the sediment, reaching to penetrate more than 35 cm deep. In some populations of the Mediterranean, we can get to find in a square meter of meadow an average of 600 meters of roots considering their ramifications that can reach 97 cm in length (Terrados and Marbá, 2004).

Meadow patches are composed of ramets that are physiologically autonomous and genetically identical shoots that propagate under the substrate, and on the other hand, the genets are genetically equal individuals derived from a single zygote, these can be composed of one or more ramets.

1.2. World distribution of *Cymodocea nodosa*

Cymodocea nodosa is distributed throughout the Mediterranean without reaching the Black Sea. In the Atlantic, it is found on the southern coasts of the Iberian Peninsula (southern Portugal and Andalucia) and on the northwestern coast of Africa to Mauritania, reaching its limit in Senegal (den Hartog, 1970). In addition, there is a notable presence in the archipelagos of Macaronesia in Madeira (Wirtz, 1995) and Canarias (Figure 2).



Figure 2. World distribution of *Cymodocea nodosa* meadows. Recovered from
<https://www.gbif.org/species/5328492>

1.3. Distribution in the Canary Islands

In the waters of the Canarian archipelago, there are three species of seagrass (Haroun et al., 2003): *Cymodocea nodosa*, *Halophila decipiens* (Gil-Rodríguez and Cruz-Simó, 1981) and *Zostera noltii* (Gil-Rodríguez et al., 1987). The most important of all is *Cymodocea nodosa*, which forms meadows known in the Canary Islands with the name of "sebadales" (Afonso-Carrillo and Gil-Rodríguez, 1980; Espino, 2004) or "manchones" (Pizarro, 1985), *H. decipiens* and *Z. noltii* go unnoticed due to their minority populations (Guadalupe et al., 1996; Pavón-Salas et al., 2000; Rumeu et al., 2007).

In the Canary Islands, meadows of *Cymodocea nodosa* are distributed in areas protected from energetic swells, mostly in the east, southeast, south and southwest of all the islands (Figure 3). These meadows are more abundant in the Eastern Islands (Fuerteventura and Lanzarote) and central (Tenerife and Gran Canaria), as these are the oldest and eroded, with a submerged insular platform of greater dimensions and greater quantity of sediments (Brito, 1984; Haroun et al., 2003). On the other hand, in the most western islands, the bottoms are more rocky and abrupt, with lower insular platform and lower amount of sediments. For this reason, the number and extension of meadows decreases in the island of La Gomera, being its punctual presence in El Hierro (Blanch et al., 2006) and La Palma (Pavón-Salas et al., 2000). In Gran Canaria, the species has a presence in the east, southeast and southwest and the Confital Bay (Espino et al., 2003a; Pavón-Salas et al., 2000).

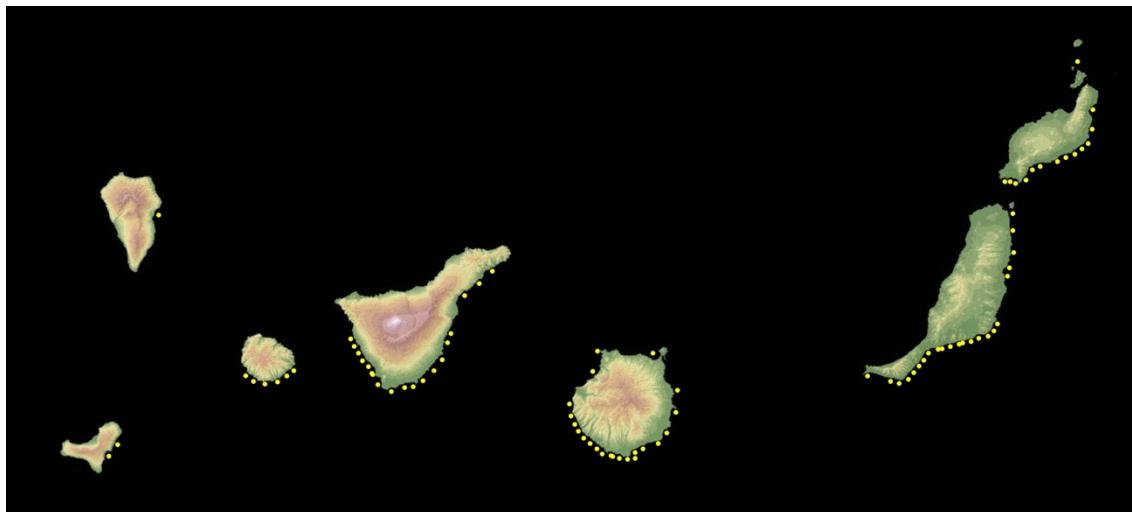


Figure 3. Distribution of *Cymodocea nodosa* meadows in Canary Islands. Modified from Pavón-Salas et al., 2000; Espino et al., 2008.

1.4. Ecological requirements

The seagrass *Cymodocea nodosa* is distributed considering the different environmental factors of the coast, such as: bathymetry, type of coastal hydrodynamics, currents, dominant swell, type of substrate, turbidity, salinity and water temperature (Fernandez and Sanchez, 2006).

Cymodocea nodosa is able to live in a wide range of environments. It is a species that is usually found in the infralittoral, a strip of coastline where you begin to find sand or mud bottoms and there are low hydrodynamics. It forms more or less density meadows in the littoral strip between 6 and 20 meters of depth (Duarte, 1991); it is common to find it forming mixed meadows together with the green alga *Caulerpa prolifera*.

Considering the depth, *Cymodocea nodosa* can appear in the puddles of the intertidal zone, arriving exceptionally to be partially exposed during low tide. In the shallow infralittorals funds, the seagrass can appear in a range of between 2 and 35 meters deep (Pavon-Salas et al., 2000), being the most frequent bathymetric distribution between 10 and 20 meters deep (Brito, 1984; Reyes et al., 1995a; Pavon-Salas et al., 2000). Barquin et al. (2005) found a distribution bathymetric from 2 to 25 meters in the seagrass of Tenerife, being the maximum distribution between 10 and 15 meters deep.

The seagrass grows in coastal areas with soft soil, sandy or sandy-muddy substrates, and rarely on rocky substrates and backgrounds of Märl (rodoliths beds) (Reyes et al., 2000). It can develop in sediments poor and rich in organic matter, tolerating certain conditions of anoxia in the sediment.

Good lighting is considered as another essential ecological requirement, because if there is an excess of turbidity, this may negatively affect the photosynthetic activity (Marbá and Terrados, 2004), the minimum irradiation you need is at least 11% of the surface (Pérez et al, 1994). It can grow in hypersaline lagoons reaching to withstand salinity levels of up to 45‰ (Luque and Templado, 2004), as happens in some shallow coastal lagoons in the Mediterranean. However, recent studies in the Mediterranean showed that both *Cymodocea nodosa* and *Zostera noltii* are sensitive to increases in salinity above 41 ‰ (Fernández and Sánchez, 2006), as occurs in areas close to brine discharges from the activity of desalination plants. The optimum development range is between 30 ‰ and 37 ‰ (Luque and Templado, 2004).

Human actions, which can be direct and indirect, produce alterations in the habitat of seagrass meadows (Tuya et al., 2014b). Because of this, the meadows are altered in their proper functioning, leading to a loss in coverage and shoot density. This degradation that occurs in the meadows, from a landscape and demographic point of view, is

associated with the regression of the genotypic and genetic diversity of a meadow (Manent et al., 2019, in review).

1.5. Background and rationale of the study

The construction of coastal infrastructures, such as ports, has severely affected seagrass meadows (Tuya, et al., 2002; Ruiz and Romero, 2003; Roca et al., 2014). In the case of the bay of Arinaga, located on the east coast of Gran Canaria, it was found that after the construction of an industrial port, it began to progressively reduce the extension to the current critical state. In the study of Manent et al., (in review), after the construction of the port, a coverage loss of 21 to 1.5 ha and a decrease in shoot density of approximately 1800 to 400 m⁻² shoots was registered. Also, there was a loss of genetic and genotypic diversity, for example a decrease in allelic richness of 22%. In summary, the degradation of meadow was associated from a demographic and landscape point of view with genotypic and genetic variation. On the other hand, meadows outside the influence of human impacts, e.g. those located in Gando and Castillo, are stable through time, including a high genetic and genotypic diversity.

In another study carried out by Tuya et al., (2019), genetic diversity (alleles per sample, \hat{A}_{38}) and genotypic (genotypes per sample, R) were obtained from the meadows of *Cymodocea nodosa* from Gando, Arinaga and Castillo. In that study, it was confirmed that the meadow of Arinaga has a lower genetic and genotypic diversity than the other two control meadows (Table 1), so it is concluded that the construction of an infrastructure, such as the Arinaga port affected genetic and genotypic diversity.

Table 1. Summary of genotypic and genetic diversity attributes from *Cymodocea nodosa* meadows, including the clonal richness (R) and standardized allelic richness (\hat{A}_{38}). Modified from Tuya et al. (2019).

Meadow	R	\hat{A}_{38}
Gando	0.647	2.84
Arinaga	0.545	2
Castillo	0.625	2.73

1.6. Study objectives

The objective of this work was to study the spatial and temporal (interannual) variability in the structure, from an anatomical, morphometric and demographic point of view, of three *Cymodocea nodosa* meadows from the island of Gran Canaria through two years. In particular, we compared the degree of interannual variation of a meadow

(Arinaga's bay) impacted by the construction of an industrial port, what resulted in low genetic and genotypic diversity, with variation of two controls (Gando and Castillo del Romeral). I hypothesised that decreased genotypic and genetic diversity at Arinaga would be connected with a lower interannual variation, in contrasts with the two control meadows, where a higher genetic diversity is expected to increase interannual variation of anatomical, morphometric and demographic descriptors.

2. Material and methods

2.1. Study area

In this study, Arinaga, on the southeast of the island, where the meadow extends between 3 and 20 m deep, was used as an impacted meadow. Moreover, two control meadows were selected out of the influence of relevant direct human actions. The first control, Gando, is situated on the southeast of the island near the coast, where the meadow extends between 2 and 15 m deep. The second control, Castillo del Romeral, is also located in the southeast of the island of Gran Canaria, between 2 and 10 meters deep (table 2) (Figure 4).

Table 2. Location and ecological/environmental context of each meadow within each region. Modified from Tuya et al., (2019).

	Castillo	Gando	Arinaga
Latitude	27°47'16.02"	27°55'29.33"	27°51'6.59"
Longitude	15°29'28.82"	15°22'50.17"	15°23'43.11"
Light (Lux)	26,701.8	20,397.3	10,268.3
Temperature (Cº)	22.58	21.33	21.16
Depth (m)	5	9	10
Meadow area (Ha)	25	5	1.5
Shoot density (m²)	787	654	424
Grain type	Medium sands	Medium sands	Coarse sands

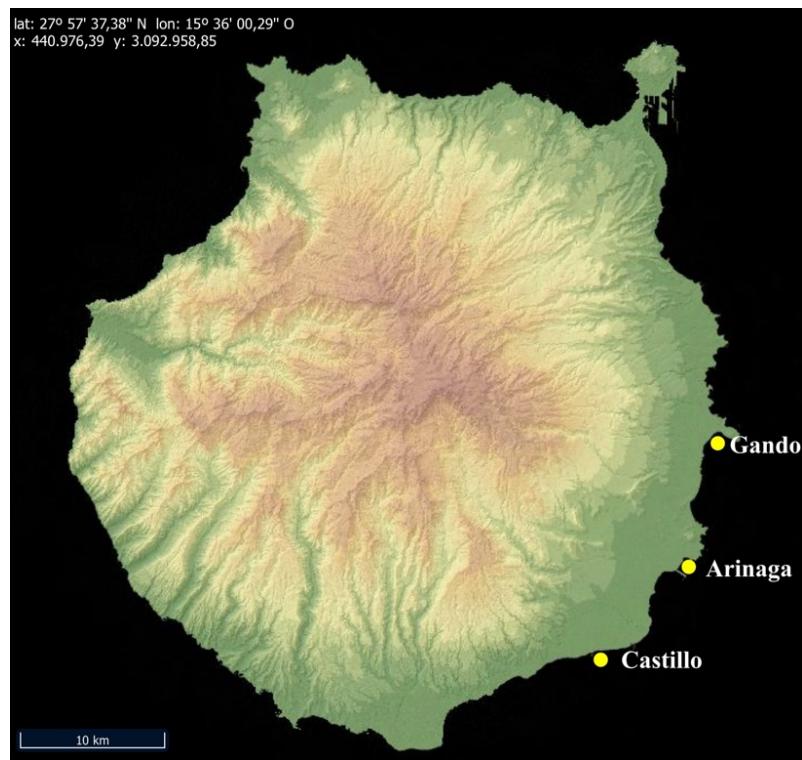


Figure 4. Map of the study area on the island of Gran Canaria, including location of the three meadows.

2.2. Sampling and laboratory work

This work included collection of samples by scuba diving and subsequent laboratory work for each meadow at 9 times, between November 2016 and November 2018. In brief, the shoot density, biomass, number of leaves per shoot, leaf length and leaf width were estimated four times a year to include the minimum (February) and maximum (August) values, as well as an additional sampling between seasons (November and May) over two successive years. Overall, 9 times were then included in this work.

To estimate the shoot density of *Cymodocea nodosa*, we counted seagrass shoots (set of leaves surrounded by the ligule located at the end of the rhizomes) by means of a square of 20 x 20 cm in each of the three meadows ($n = 10$) while by scuba diving (Duarte and Kirkman, 2001) (Figure 5). This a paramount demographic descriptor of seagrasses.

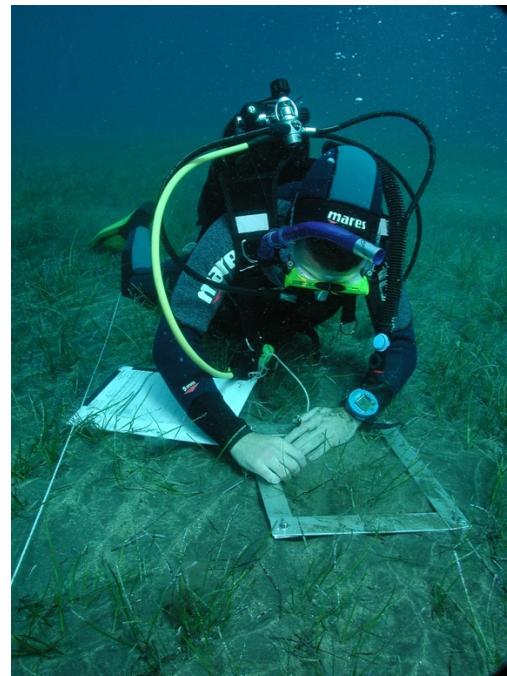
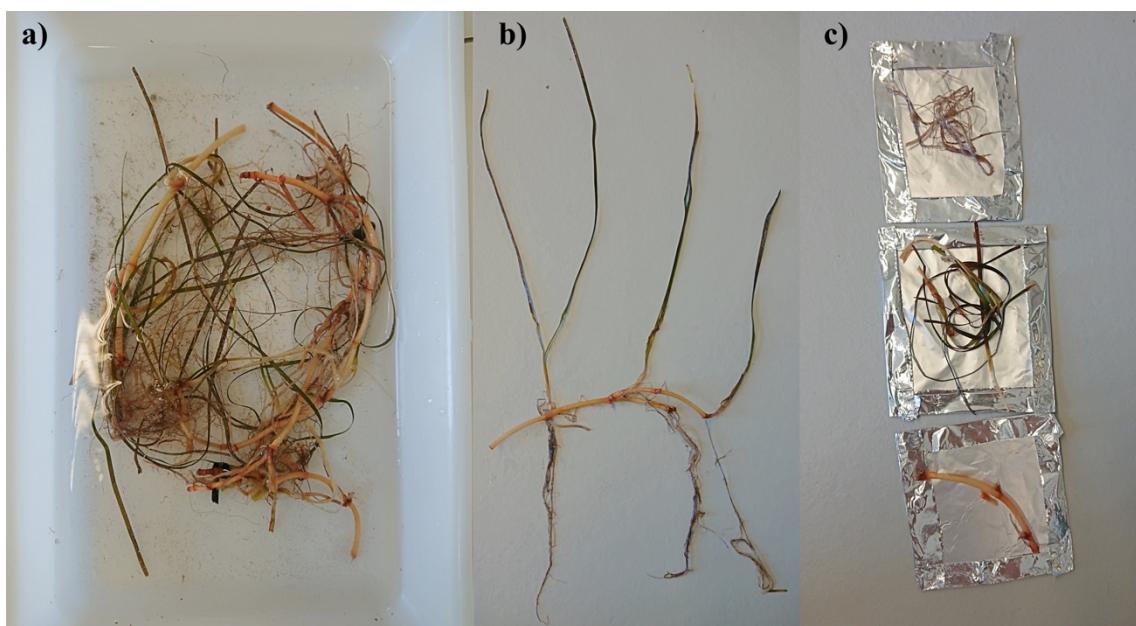


Figure 5. Counting the number of shoots from F.Espino

To estimate anatomical descriptors, above and below-ground biomasses were obtained. The samples ($n = 10$) of the three meadows were collected with a corer with an internal section of 20 cm. The corer is pushed into the sediment and all the biomass of seagrass is extracted, this is cleaned of sediment for the later treated. Each sample is divided into leaves, rhizomes and roots, then dried in an oven at 60°C until constant weight (Duarte and Kirkman, 2001) and the dry weights are then recorded, measured with a precision balance (Figure 6), for further processing of data.



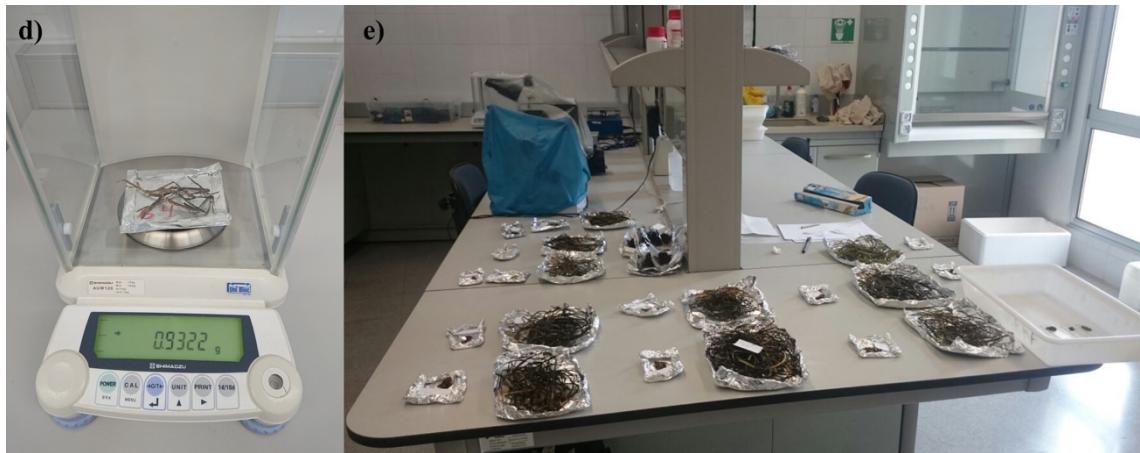


Figure 6. a) Sample of *Cymodocea nodosa*. b) Ramet of *Cymodocea nodosa*. c) Leaves, roots and rhizomes separated to put them in the oven. d) Weighing leaves of *Cymodocea nodosa*. e) Set of samples of a meadow.

For the morphometric study of *Cymodocea nodosa* leaves, 20 shoots were collected per meadow and time. The following procedure was performed on each of the shoots: the number of leaves per shoot was counted; the width and length of each leaf was measured from the point of birth (ligula) to the apex (Figure 7).

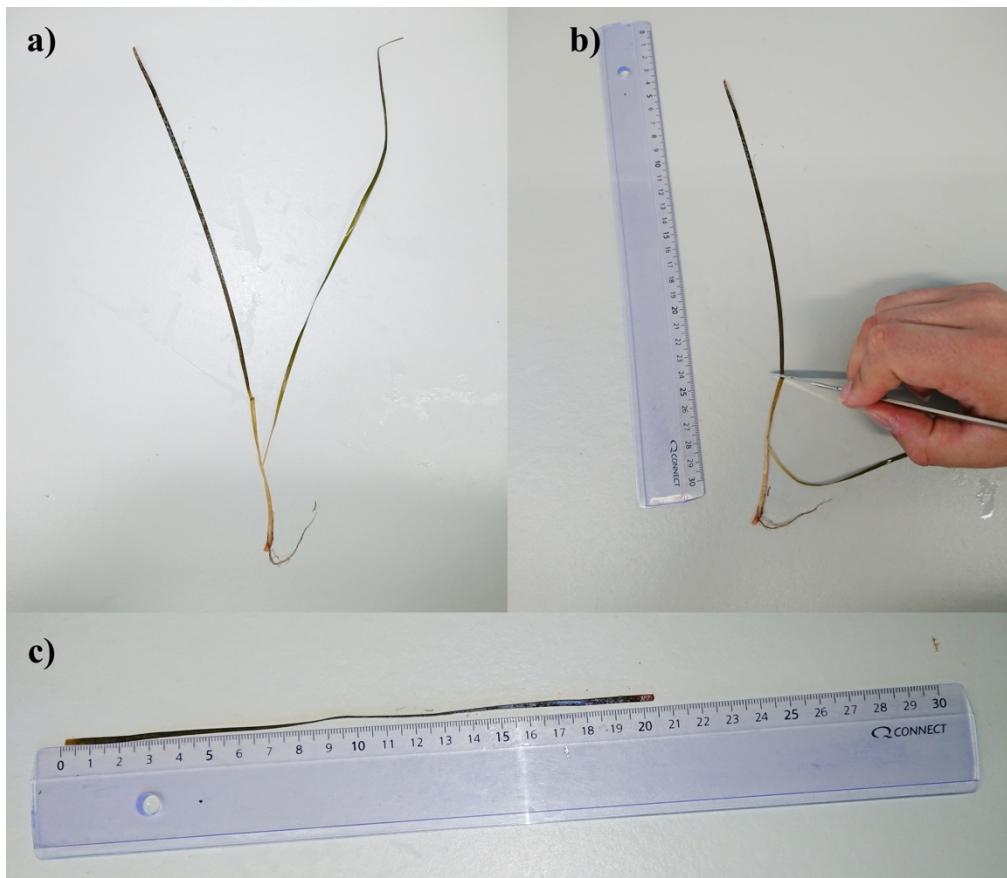


Figure 7. a) Counting the number of leaves per shoot. b) Separating the leaf by the ligule. c) Measure of the length of the leaf.

2.3. Statistical analyses

The data obtained in the study were separate in two main blocks: demographic-anatomical and morphometric descriptors. The demographic-anatomical descriptors included: shoot density, and above and below-ground biomasses. Morphometric descriptors included: the number of leaves per shoot, the leaf length and the leaf width. For each descriptor, their average and standard deviation were obtained, for each meadows and sampling time and subsequently graphically. The coefficient of variation, an adimensional statistic of variation relative to the mean (expressed in percentage), was calculated for each meadow, time and descriptor. As a result, we managed to obtain the mean coefficient of interannual variation for each meadow, which was graphically represented. The coefficient of interannual variation obtained in the present study and the genetic and genotypic diversity data of each meadow (data from Tuya et al., 2019) were then connected through linear regressions. All the graphs were represented using the SigmaPlot 12.0.1 package and the statistical (regression) analyses were performed with the R statistical package.

3. Results

3.1. Demographic-anatomical changes

During the study period, the shoot density (Figure 8a) was larger in Castillo, between a maximum of 1365 shoots per m⁻² in summer and a minimum of 545 shoots per m⁻² in winter. The lowest shoot density was found in Arinaga during the second year of study (2018), with the lowest shoot density in winter of 2018 with 357 shoots per m⁻² (Figure 8a).

With regard to the below ground biomass (Figure 8b), a great difference was obtained between meadows; in Arinaga, we found minimum values, oscillating between 48.75 (g DW m⁻²) in the first sampling and 7.25 (g DW m⁻²) in summer of 2017. However, in the winter of 2018, the maximum is at Castillo with 404 (g DW m⁻²) (Figure 8b). In general, the values are maximum in winter and minimum in summer. For the above ground (leaves) biomass, Arinaga is also the meadow that has the lowest amount of biomass throughout the study, except for the samples taken in 2016 and February 2017. The above ground biomass changed throughout the study, between 118.5 (g DW m⁻²) in Castillo and 18.5 (g DW m⁻²) in Gando, with typically higher values in summer and lower values in winter (Figure 8c).

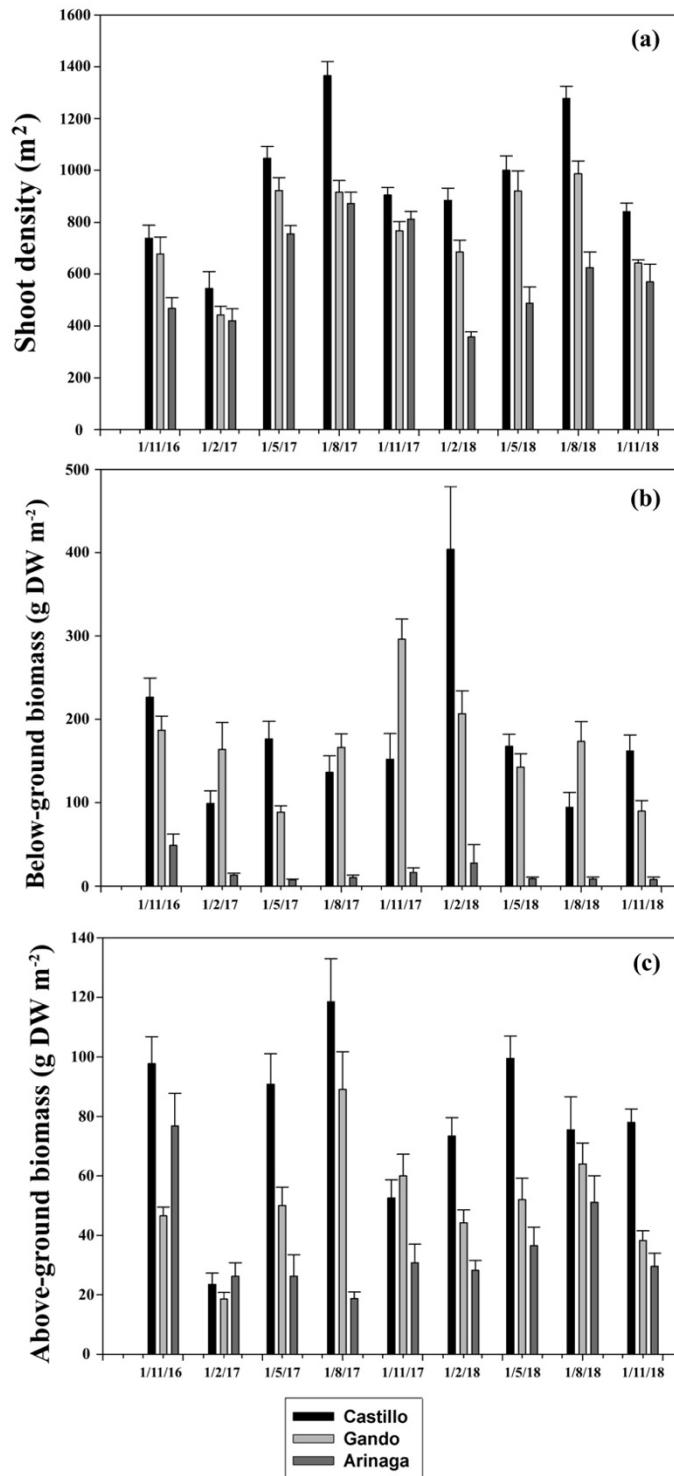


Figure 8. Demographic-anatomical descriptors, including a) shoot density at each time for each meadow, b) below-ground biomass at each time for each meadow and c) above-ground biomass at each time for each meadow. Data are mean + SE.

3.2. Morphometric changes

Throughout the study, there was a temporal variability in the three morphometric descriptors, with minimums during the month of February and maximums in the month of August.

The number of leaves per shoot was very similar among the three meadows, ranging from 2.25 to 3.05 in Gando, with maxima in summer and minimum in winter (Figure 9a).

In the first sampling time of 2017, the leaf length (Figure 9b) in Gando was 4.58 cm, being the lowest of the whole study. The highest leaf lengths were found in August 2017, being 24.2 cm and 23.9 cm for Castillo and Arinaga, respectively. On the other hand, the maximum leaf width (Figure 9c) is found in Castillo with 3.4 cm in summer and the minimum 1.5 cm in November 2018 in Castillo as well.

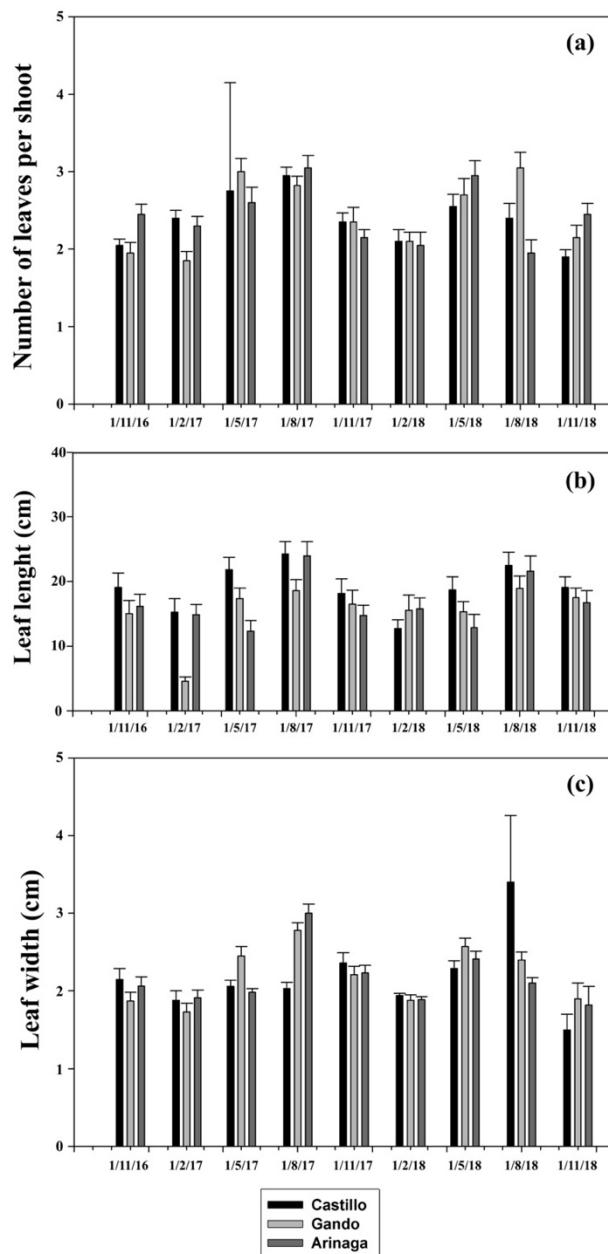


Figure 9. Morphometric descriptors. a) number of leaves per shoot at each time for each meadow, b) leaf length at each time for each meadow and c) leaf width at each time for each meadow. Data are mean + SE.

3.3. Coefficient of interannual variation

The coefficients of interannual variation ranged from a minimum of 4.98% for the leaf width of Arinaga to a maximum of 31.61% for the below-ground biomass of Arinaga.

With regard to the morphometric descriptors (Figure 10a), their coefficients of variation do not present relevant patterns among the three meadows, the greater variability in Castillo being appreciable for the width and number of leaves per shoot. On the other hand, relative to the anatomical-demographic descriptors (Figure 10b), the greater variability was found for the three descriptors from Arinaga.

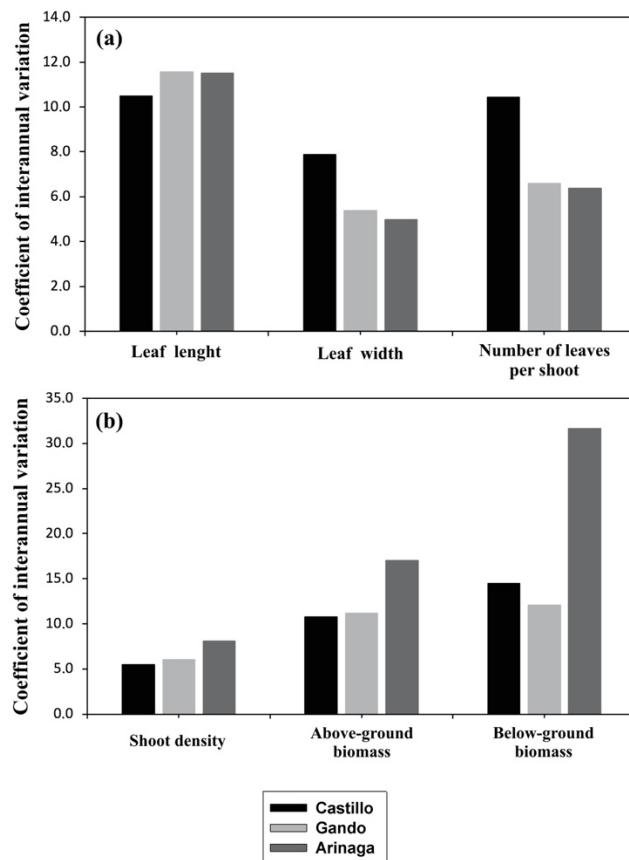


Figure 10. Coefficients of interannual variation for a) morphometric descriptors and b) demographic-anatomical descriptors.

Figure 11a shows the relationship between the coefficient of interannual variation of the morphometric descriptors for each meadow and its genetic diversity (\hat{A}_{38}) (table 1). The linear regression is included, with an equation of the line $y = 8.2306x + 3.4095$,

$R^2 = 0.0126$ and a p-value 0.6574. Figure 11b shows the same coefficients of annual variation with the genotypic diversity (R) of each meadow with an equation of the linear regression line $y = 1.1883x + 5.396$, $R^2 = 0.0189$ and its p-value of 0.5855.

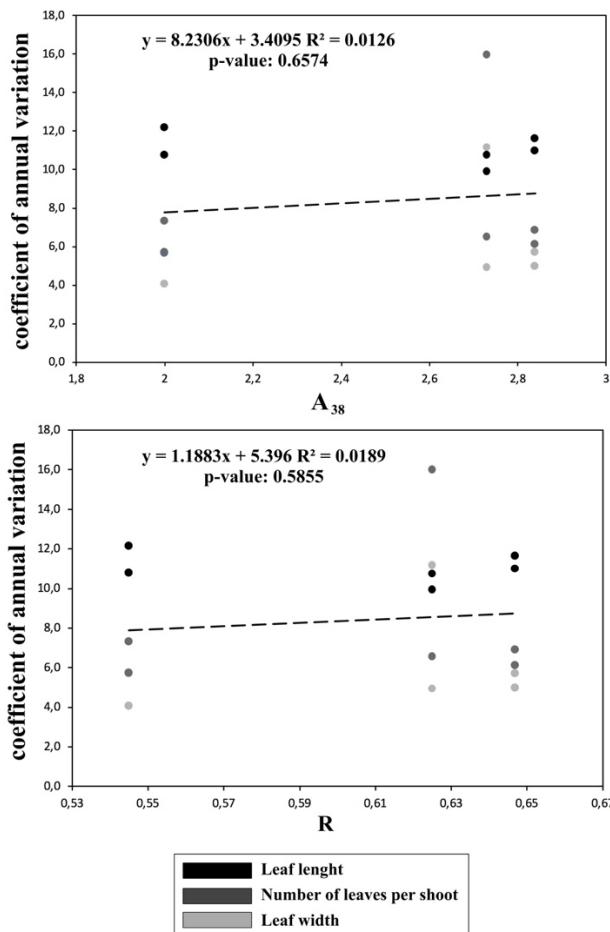


Figure 11. Relationship between the coefficient of interannual variation of the morphometric descriptors and (a) the genetic diversity and (b) genotypic diversity of each meadow.

Figure 12 shows the relationship between the demographic-anatomical descriptors of each meadow and their genetic diversity (\hat{A}_{38}) (Figure 12a) and genotypic diversity of (R) (Figure 12b). The equation of the regression line for \hat{A}_{38} is $y = -11.336x + 41.759$, $R^2 = 0.2546$ and its p-value 0.03275; the regression line for R is $y = -95.462x + 70.973$, $R^2 = 0.2496$ and the p-value is 0.03481.

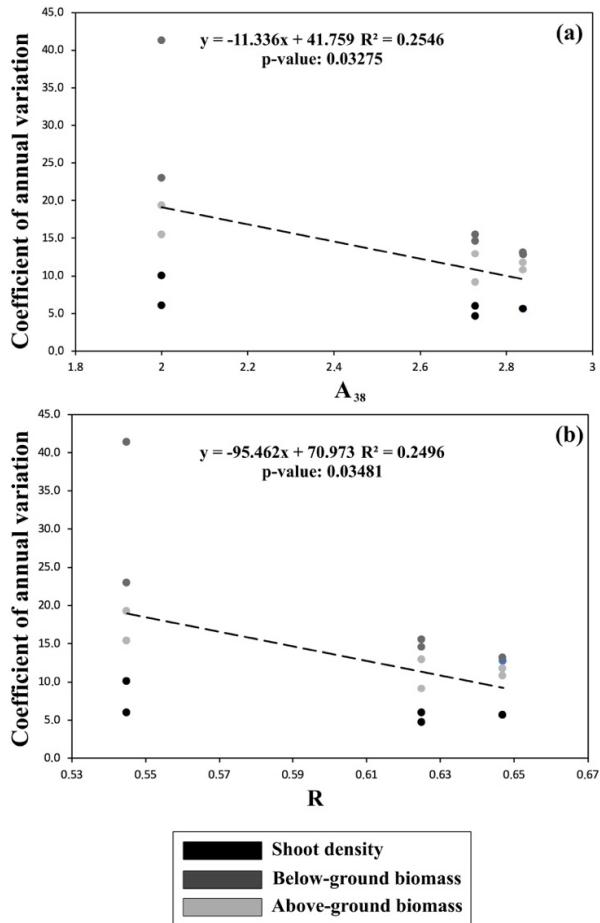


Figure 12. Relationship between the coefficient of interannual variation of the demographic-anatomical descriptors and (a) the genetic diversity and (b) genotypic diversity of each meadow.

4. Discussion and conclusions

This study has demonstrated that decreased seagrass genotypic and genetic diversity of a seagrass meadow (i.e. Arinaga), as a result of a human-induced disturbance, was directly connected with increased temporal variation, i.e. interannual variability of seagrass ecological descriptors. This outcome, however, was only observed for demographic-anatomical seagrass descriptors, but not for morphometric responses. Here, the process of reducing the area and shoot density of the Arinaga meadow, which occurred after the construction of the port (2002) (Manent et al., in review), is therefore linked with a larger interannual variation in demographic-anatomical seagrass descriptors.

The two control meadows, however, which harbor a greater clonal richness (R) and genetic diversity, showed a lower interannual variability in their demographic-anatomical descriptors, and therefore displayed a larger ecological stability.

Typically, erosion in seagrass meadows, as a result of human-induced disturbances, produce a subsequent erosion in genotypic/genetic diversity. For example, in populations of *Zostera marina*, Reusch (2003) found that the fragmentation of populations limited their reproductive capacity. Something very similar could be happening for the *Cymodocea nodosa* meadow in Arinaga. The values of genetic diversity and genotypic, which were lower in Arinaga than the controls, could be attributed to a decrease sexual recruitment according (Manent et al., in review). A decrease in genotypic diversity was here linked with a larger variation in demographic-anatomical descriptors. If the genotypic diversity of the meadow is low, i.e. the number of seagrass clones is low, the functioning of the meadow is considerably determined by the way this low number of clones behaves. On the contrary, when the number of clones of the meadow is high, i.e. what I here observed in Gando and Castillo, ecological complementary of a large number of clones seem to buffer the relevance of a few clones determining the functioning of the meadow. As a consequence, the presence of a large number of clones ensures ecological stability, here measured in terms of interannual variation in seagrass descriptors.

Strong seasonality was found by this study for the demographic-anatomic descriptors. Importantly, above ground biomass and below ground biomass followed contrasting patterns. On the one hand, during winter, the roots and rhizome (below ground) presented their maximum biomass (i.e. production), while the leaves did so in summer (Cunha and Duarte, 2007). This study revealed that periods of biomass growth vary throughout the year, with a period of growth of aerial biomass at the beginning of spring and summer. The seasonal behaviour of *Cymodocea nodosa* in the Canary Islands is somehow similar to the Mediterranean (Peduzzi and Vukovic, 1990, Pérez and Romero, 1994, Cancemi et al., 2002, Agostini et al. 2003). Caye and Meinesz (1985), on the French Mediterranean coast, found also a marked seasonality in the width and length leaves and the number of leaves per shoot, with quicker growth in May and April, and a slower growth between October and March. This is despite the seasonal variations are less marked in the Canary Islands, due to the lower thermal fluctuations of seawater in the Canary Islands.

The maximum values of below ground biomass found in winter by this study are explained by the need of the plant to develop strong rhizomes and roots to set well in the background and cope with winter storms. Meadows of *Cymodocea nodosa* in Gran Canaria Island are very exposed to energetic oceanic swells from any direction, which rip off rhizome fragment (Portillo, 2014). On the contrary, the growth, in spring-summer, of the leaves is due to the temperature and irradiation, the main controlling factors of the annual variability of the above ground biomass of *Cymodocea nodosa* (Peduzzi and Vukovic, 1990; Cancemi et al., 2002; Zharova et al., 2008). The seasonal growth pattern

of *Cymodocea nodosa* is mainly associated with changes in temperature and irradiation. During the summer, under the highest solar radiation and temperature, the leaves of *Cymodocea nodosa* develop larger dimensions, while during the winter, low temperatures and low irradiation result in a slowing down of the metabolism to save energy (Reyes et al., 1995b).

The battery of morphometric responses here analysed did not have the same behaviour as the demographic-anatomic responses. Effectively, the interannual variability of these descriptors was independent of the meadow genotypic and genetic diversity. It can be said that morphometric descriptors do not react in the same way to possible environmental disturbances and, therefore, do not benefit from diversity. Most likely, the amount of interannual variation of these morphometric responses seem to be affected by other ecological processes, most likely acting at local scales. For example, the intense of seasonal herbivory associated with the annual *Cymodocea nodosa* life cycle induced by herbivorous fishes is a relevant process, with a greater influence than previously considered (Tomas et al., 2005; Heck and Valentine, 2006; Doropoulos et al., 2009; Vergés et al., 2011), which governs the way in which the morphometry of the leaves behaves in the meadows constituted by *Cymodocea nodosa* in the Canary Islands. The herbivore intensity has a seasonal pattern, with maximum values in the late summer and minimum in the spring, coinciding with the annual cycle of *Cymodocea nodosa* (Tuya et al., 2006; Espino et al., 2011). In particular, the abundance of *S. cretense*, the main herbivorous fish in the study regions reaches its maximum abundance in September-October (Espino et al., 2014).

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Memoria final del Trabajo Fin de Grado (TFG)

Año Académico: 2018/2019. Alumno: David García Gutiérrez

1. Descripción detallada de las actividades desarrolladas durante la realización del TFT.

Las prácticas externas que se llevaron a cabo para la realización del TFG se realizaron en el laboratorio de biología del instituto de investigación IU- ECOAQUA. Las instalaciones usadas comprenden dos laboratorios situados en el Parque Científico y Tecnológico Marino de Taliarte en Gran Canaria. Estas fueron supervisadas por Fernando Tuya Cortés, profesor de la ULPGC e investigador dentro del grupo ECOAQUA.

Se realizaron diferentes actividades para la realización del TFG, que comprenden desde una reunión previa hasta la redacción del TFG.

1.1 Reunión

Se llevó a cabo una reunión inicial para determinar las actividades necesarias para llevar a cabo la correcta realización del TFG. En la reunión se determinó de qué apartados constaría el trabajo y las horas que se iban a emplear en cada una de las partes.

1.2 Estudio previo de *Cymodocea nodosa*

La primera actividad que se llevó a cabo fue la recopilación de información a cerca de *Cymodocea nodosa*, nuestra fanerógama de estudio. Se dedicó tiempo a la búsqueda de bibliografía diversa. Se emplearon artículos científicos, libros y trabajos varios relacionados con nuestra fanerógama.

Se recopiló información sobre la distribución mundial y local de la especie, su estructura y morfología, la importancia como ecosistema y sus requerimientos ecológicos. Esta información se empleó para la posterior redacción del TFG.

1.3 Muestreo de *Cymodocea nodosa*

Se llevó a cabo el muestreo en tres puntos distintos en la isla de Gran Canaria, se muestearon tras praderas de *Cymodocea nodosa*, en Arinaga, Gando y Castillo del Romeral.

Se realizó el conteo de haces por metro cuadrado de cada una de las praderas para la obtención de la densidad de haces. Se llevó a cabo por medio de buceo autónomo.

Se llevo acabo un muestreo para un posterior calculo de biomasa, las muestras ($n=10$) de las tres praderas se recolectaron con un corer y se limpiaron la de sedimentos, además, se realizo un tercer muestreo en el que se recolectaron 20 haces por pradera para realizar el posterior estudio morfométricos.

1.4 Procesado de muestras

Para el calculo de biomasa se separaron de cada muestra hojas, rizomas y raíces, posteriormente se procedió al secado en estufa a 60°C hasta peso constante.

Para el estudio morfométricos se contaron el numero de hojas por haz; se midió anchura y longitud de cada hoja desde el punto de nacimiento hasta el ápice; además, las hojas se limpiaron de epifitos (separación mecánica). Se procedió al secado de la biomasa foliar en estufa a 60°C hasta peso constante.

Todos los pesajes se realizaron con una balanza de precisión.

Todas las muestras se procesaron en el laboratorio ubicado en Taliarte. Tras los periodos de muestreo, las que fueron posibles y el resto, que fueron muestreadas con anterioridad, fueron congeladas. Se descongelaron y se procedió a su procesado.

1.5 Procesado de datos

Los datos obtenidos, se procesaron por medio del software libre [R] por medio del entorno de trabajo de RStudio. En primer lugar, se importaron los datos necesarios.

Se realizaron las medias de los tiempos de muestreo y se obtuvieron las desviaciones típicas. Una vez obtenidos se realizaron las representaciones graficas pertinentes por medio del software SigmaPlot 12.0.1.

Con [R] se realizaron las rectas de regresión y su error, necesarias para comparar los datos.

2. Formación recibida

Se me proporcionaron papers en los cuales se explicaban los usos de los programas empleados para el tratado de los datos. Por otro lado, el tutor me formo en el uso del programa SigmaPlot, programa informático usado para análisis estadísticos, con el cual se pueden obtener graficas de muy buena calidad y muy útiles para comparar los datos de los diferentes meses, desconocido por mi hasta ese momento.

Para el procesado de las muestras se me explico como debía realizarlas y además se me enseño a utilizar la estufa.

Previo a la practica, yo tenia experiencia previa con el uso de [R] y su entorno de trabajo RStudio, además, fue mi tutor quien me dio a elegir este entorno de trabajo, lo cual facilito en gran medida el proceso de aprendizaje.

Mi tutor me ha proporcionado todo el material y conocimientos necesarios para la correcta realización de las practicas, además de dejarme experimentar por mi mismo lo que es resolver imprevistos con la mayor brevedad posible.

3. Nivel de integración e implicación dentro del departamento y relaciones con el personal

Me sentí integrado en todo momento en el laboratorio, desde el principio fui presentado a la gente del grupo y durante todo el proceso me proporcionaron la ayuda necesaria. Siempre podía pedir ayuda y no tenia ningún impedimento para contactar con nadie.

Con esta practica no solo he aprendido de temas relacionados con *Cymodocea nodosa*, sino que he aprendido de diversos temas científicos y técnicos. Además, mi tutor me ha enseñado todo lo que ha podido sobre el mundo de la investigación científica.

4. Aspectos positivos y negativos más significativos relacionados con el desarrollo del TFG

Como aspecto positivo, hay que recalcar la oportunidad de poder trabajar con grandes investigadores en un proyecto real, ayudándome a comprender como funciona el mundo de la investigación y las dificultades que podemos encontrarnos en el camino.

En el entorno de trabajo me sentí muy cómodo desde el principio y agradezco mucho la ayuda recibida y espero haber sido de utilidad cuando me han necesitado.

También es positivo la adquisición de nuevos conocimientos, sobre el funcionamiento de las comunidades en el intermareal y como se ven afectadas por la acción del ser humano.

Gracias a la libertad que me ha dado mi tutor me he visto en una situación en la que al tener mas independencia sobre el trabajo ha amentado la responsabilidad a la hora de realizar tareas.

Como aspecto negativo es el hecho de encontrarme un poco perdido al inicio del proyecto, sin embargo, conforme ha ido avanzado el trabajo he ido observando como tomaba forma y he ido esclareciendo las ideas principales.

5. Valoración personal del aprendizaje conseguido a lo largo del TFG

He aprendido a usar diferentes softwares de análisis estadísticos, muy útiles para futuros estudios e investigaciones. Además, de aprender a utilizar diversos programas he ampliado mi conocimiento sobre fanerógamas, mas concretamente sobre *Cymodocea nodosa*.

El TFG también me ha servido para usar parte de los conocimientos recibidos durante la carrera. Sobre todo, aquellos relacionados con la biología y la ecología y, además, darme cuenta de todo lo que queda por aprender.

Considero que lo aprendido en el TFG me será de gran utilidad a la hora de la incorporación al mundo laboral. Aunque me planteo en el futuro dedicarme a la investigación, este proyecto me ha hecho ver lo duro que es dedicarse a esta.