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Vegetation patterns in a South American coastal wetland using high-resolution imagery

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ABSTRACT
The aim of this study was to identify and characterize the main plant communities in a temperate coastal wetland using high-resolution imagery. We produced a map of Samborombón Bay at 1:25,000 scale using a WorldView-2 image. An Object-based Image Analysis approach was chosen, and an unsupervised classification algorithm was applied. Overall classification accuracy was 81%, and the Kappa index was 78.1%. Six land cover types were mapped including four main natural monospecific plant communities. The lower intertidal area was dominated by mudflats without vegetation and stands of *Bolboschoenus maritimus*. The middle intertidal area was dominated by *Sarcocornia ambigua*, while, in the higher intertidal area, *Sporobolus densiflorus* and grasslands with *Cortaderia selloana* prevailed. We found four spatial patterns at a landscape scale, based on the presence and spatial distribution of the natural plant communities. This map represents a valuable tool for future studies on wetland environmental indicators.

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Coastal marshes; plant communities; Worldview-2; Samborombón Bay; object-based image analysis; tidal plain

1. Introduction

Coastal wetlands provide a wide range of essential environmental services such as coastline protection, sustainment of food webs through organic matter exchange, wildlife habitat, and improvement of estuary water quality (Adam, Bertness, Davy, & Zedler, 2008; Bertness, 1998; Isacch, Escapa, Fanjul, & Iribarne, 2011). In South America, towards the southern portion of the Atlantic Ocean, coastal wetlands are characterized by marshes, which are subjected to extreme environmental conditions of low temperature, salinity, regular tidal flooding, and the mechanical impact of waves and storms (Cagnoni & Faggi, 1993; Chabreck, 1988; González Trilla, De Marco, Marcovecchio, Vicari, & Kandus, 2010). As a consequence of this limiting environment, plant communities are composed of a few species that are distributed as patches or narrow fragmented fringes almost parallel to the shoreline (Adam, 1990; Day, Kemp, Yañez Arancibia, & Crump, 2012). These zones move up and down along topographic gradients in response to changes in the sea level and associated stressors (Belluco et al., 2006; Chapman, 1964; Silvestri & Marani, 2004). Thus, changes in the environmental conditions, such as sea level rise, increase in freshwater runoff from terrestrial areas and storm waves, or changes in evapotranspiration due to an increase in temperature range are expected to affect the spatial pattern of these marsh plant communities (Canziani et al., 2013). In this framework, mapping vegetation distribution seems crucial for a better management of wetlands and coastal monitoring.

Remote sensing provides the best tool to map and monitor large-scale patterns of coastal ecological systems and offers a practical and economical means to discriminate plant communities (Carle, Wang, & Sasser, 2014). The most common source of remote sensing data for coastal wetland classification and monitoring has been optical-based multispectral sensors of medium spatial resolution, such as Landsat TM and SPOT (Cardoso, Souza, & Souza-Filho, 2014). Many researchers have used this type of sensors to map land cover (Berberoglu, Yilmaz, & Özkan, 2004; Cardoso et al., 2014), identify vegetation classes and/or discriminate broad vegetation communities (Harvey & Hill, 2001; Li, Ustin, & Lay, 2005; McCarthy, Gumbricht, & McCarthy, 2005).

Medium-resolution satellites can be more cost-effective in terms of the spatial coverage captured in each satellite scene, the availability of multi-temporal series, and the free access to many data banks. Nonetheless, oftentimes, they are too coarse to discriminate highly fragmented landscapes and types of plants at small spatial scales (Mumby & Edwards, 2002). High-spatial resolution satellite images, in turn, allow for a

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simultaneous collection over a relatively large geographical area for mapping wetlands at a much smaller spatial scale (Adam, Mutanga, & Rugege, 2010). Moreover, they have succeeded in providing detailed discrimination of wetland vegetation species (Andréfouët et al., 2003; May, Pinder, & Kroh, 1997; Mumby & Edwards, 2002). The natural fragmentation and location in narrow vegetation fringes of the coastal marshes suggest that higher spatial resolution remote sensing, such as IKONOS, Quick Bird and World View 2, is the most appropriate tool for an accurate classification at a fine scale, and that it supports a better and more detailed discrimination of marsh vegetation species (Carle et al., 2014; Sawaya, Olmanson, Heinert, Brezonik, & Bauer, 2003).

Samborombón Bay is one of the largest and most important wetlands on the temperate South Atlantic coast. With more than 2400 km^2 of productive marshlands, it serves as a habitat for numerous migratory birds and wildlife, and sustains livestock development as well (Tosi et al., 2013).

Despite the importance of this coastal wetland, only two mapping studies have been conducted in this area so far. Cagnoni and Faggi (1993) mapped plant communities at a landscape level using a visual interpretation approach to black–white aerial photography and field work. Isacch et al. (2006) produced a coarse regional map of the South-West Atlantic saltmarshes between Lagoa dos Patos, southern Brazil (31° 5'S, 51°14'W) and Chubut River, South of Argentina (43°20'S, 65° 3'W) using Landsat images (spatial resolution: 30 m).

The aim of this study was to identify and characterize the main plant communities in the coastal marshes of Samborombón Bay using WorldView-2 high spatial resolution imagery.

2. Methods

2.1. Study site

The study area covers 160 km^2 of the southern portion of Samborombón Bay, along the main tidal channel named Ría de Ajó (56° 56' W, 36° 24'S). Most of the study area is occupied by several protected areas including Campos del Tuyú National Park, designed to protect one of the remaining populations of the endangered Pampa deer (*Ozotoceros bezoarticus celer*) (Vila, Beade, & Barrios Lamunière, 2008).

The climate of the area is sub-humid to humid, mesothermal, with scarce to null water deficit (Carol, Kruse, & Pousa, 2008). Annual precipitation reaches 1078 mm and mean temperature is around 14.6 °C (Carol, Kruse, & Mas-Pla, 2009; Vervoorst, 1967).

The area displays an estuarine environment characterized by a microtidal regime where marine water penetrates below the fresh water of the Río de la Plata river (Acha et al., 2008; Tosi et al., 2013).

The tidal regime is semidiurnal with a mean amplitude of 0.8 meters. The coastal plain of the Samborombón Bay is composed of Pleistocene-Holocene deposits with signs of the sea level fluctuations that occurred after the last glaciation (Cavallotto, Violante, & Parker, 2004; Violante & Parker, 2004; Violante, Parker, & Cavallotto, 2001). The main landscape patterns are reflected in the extensive marshes furrowed by active tidal channels, tidal plains with mudflats or crab lands, and sequences of shell ridges colonized by tala forests (*Celtis ehrenenbergiana* synonym of *Celtis tala*) and grasslands (Cavallotto et al., 2004; Gonzalez & Weiler, 1983). The general relief is sub-horizontal with a slope of 0.1% and an altitude of less than 5 masl (meters above sea level). Soils are alluvial and saline with poor drainage (Carol et al., 2008; Fidalgo, Colado, & De Francesco, 1973).

Four plant communities in the Samborombón Bay form almost monospecific stands which are named after by their dominant species: ***Sarcocornia ambigua*** *(Michx., M.A. Alonso & M.B. Crespo,* previously cited in the literature as *Sarcocornia perennis);* ***Sporobolus densiflorus*** (Brongn., P.M. Peterson & Saarela, synonym of *Spartina densiflora*); ***Bolboschoenus maritimus*** (synonym of *Scirpus maritimus),* and ***Cortaderia selloana***. Companion species are *Juncus acutus, Distichlis spicata* and *Apium sellowianum,* among others (Cagnoni & Faggi, 1993; Isacch et al., 2006; Vervoorst, 1967).

These plant communities are related to particular environmental conditions and have different structural features that facilitate their spectral differentiation (Table 1). *Sa. ambigua* is a perennial succulent subshrub that grows gregariously on saline soils (Davy et al., 2006) with plant coverage below 30% (personal observation). *Sp. densiflorus* is a perennial cordgrass with clonal growth (Doust, 1981), an average height of 1.3 m and coverage between 50%–100% (González Trilla et al., 2016). *B. maritimus* is a rhizomatous bulrush found in shallow marshes with a cryptophytic life cycle. This means that only rhizomes, seeds and deadsteams are present during the winter months. This plant can reach 1.5 m during the summer (Lieffers & Shay, 1982; Lillebø, Pardal, Neto, & Marques, 2003). Finally, *C. selloana* is a long-lived perennial grass native to South America that has invaded many parts of the world (Domènech, Vilà, Pino, & Gesti, 2005). It grows up to 3 m high and is frequently found in mid slopes near wetlands and disturbed areas.

2.2. Study area mask

The study area included active marshes, defined as surface areas under tidal influence. To discard the areas without such influence, the inland terrestrial limit of the active marshes was delineated using an unsupervised classification on the acquired Landsat 5 TM image (Path/Row = 224/85, date: 16 December 2004)

Table 1. Main features of the plant communities present at the study site.

Plant community	*Sarcocornia ambigua*	*Sporobolus densiflorus*	*Cortaderia selloana*	*Bolboschoenus maritimus*
Features				
Main height (cm)	13	80	150	130
Life form	Sub scrub	Graminoid	Graminoid	Graminoid
Cover in m^2 (%)	5%–60%	50%–100%	90%	10%–50%

with the highest tidal level historically registered (2.5 m). Despite the fact that Landsat images have less spatial resolution, the extensive historical archive of the series allows to acquire scenes with extreme environmental situations, in this case, tidal height condition.

Precipitation data of the 3 days preceding the image acquisition was also checked to dismiss its influence.

The Landsat TM image was acquired in surface reflectance units at the USGS website (https://earthexplorer.usgs.gov/). Near-infrared band (band 4, NIR), short-wavelength infrared band (band 5, SWIR), and Normalized Difference Water Index (NDWI) (Ji, Zhang, & Wylie, 2009; McFeeters, 1996) were used to maximize the differences between land and water covers.

NDWI was calculated as the normalized difference between the visible green and near-infrared bands. These bands were selected because they: (1) maximize the typical reflectance of water features by using green light wavelengths; (2) minimize the low reflectance of NIR by water features, and (3) take advantage of the high reflectance of NIR by terrestrial vegetation and soil features (McFeeters, 1996).

The three-band image was classified by means of an unsupervised classification based on ISODATA algorithm (Tou & Gonzalez, 1977). Fifty classes were obtained using 1000 iterations. Classes were regrouped into two main classes (active and non-active marshes) using a hierarchical cluster analysis based on Euclidean distance as dissimilarity metrics and average criteria as the grouping method (McCune & Grace, 2002). The limit between both classes was inspected based on field knowledge and visual interpretation with high-resolution imagery.

2.3. Mapping strategy

A WorldView-2 image (WV-2) was used to map land covers of active marshes. The WV-2 image was acquired on November 17, 2010, courtesy of the Digital Globe Foundation. The tidal level at the acquisition time was 1.8 m. The image features a high spatial resolution (2 m) and eight multispectral bands: coastal (400–450 nm), blue (450–510 nm), green (510–580 nm), yellow (585–625 nm), red (630–690 nm), red edge (705–745 nm), near-infrared 1 (770–895 nm), and near-infrared 2 (860–1040 nm). The WV-2 satellite data were calibrated to top of atmosphere reflectance.

The Jeffries–Matusita (JM) distance was calculated as a separability criterion for optimal band selection. The JM distance method ranges from 0 to 2. JM value ≥1.9 indicates good spectral separation between classes (Thomas et al., 2003). WV-2 green, red and near-infrared 1 bands were selected based on JM distance, because they maximized the separability between the covers of interest (*Sa. ambigua, Sp. densiflorus, C. selloana, B. maritimus,* and water) and prevented correlation between bands (Figure 1).

An Object-based Image Analysis (OBIA) approach was adopted to map vegetation types. OBIA has gained much attention as an alternative to traditional pixel-based methods. The packaging of pixels into discrete objects, so-called segments, minimizes the variance (noise) experienced by high-spatial resolution images, allowing the classification of objects rather than individual pixels (Mui, He, & Weng, 2015). These segments are spatially continuous, disjoint and homogeneous regions (Blaschke et al., 2014). Segmentation was performed using the Large-Scale Mean-Shift (LSMS) algorithm using Monteverdi 2 software (Grizonet & Inglada, 2010). This algorithm requires three parameters: Spatial Radius, Range Radius, and Minimum Region Size. The first two parameters determine whether two pixels are either spatially or spectrally 'near', and the last one is the minimum size for the resulting segments. A grid of operational parameters for LSMS was tested, and the ones leading to a segmentation best representing the actual objects in the scene were selected (Spatial Radius: 10 pixels, Range Radius: 0.05%, Minimum Region Size: 5 pixels). We obtained 1,700,120 segments.

Segments were classified into 100 clusters using an expectation maximization algorithm applied to a

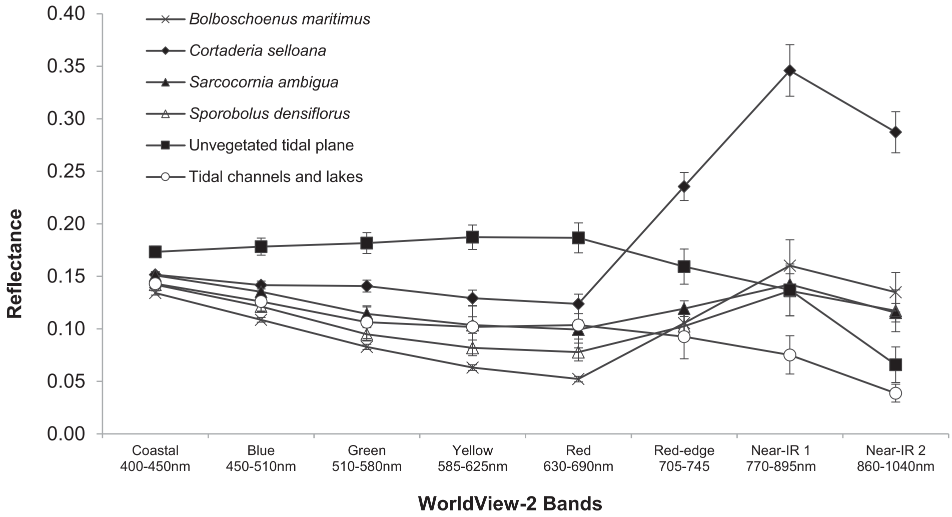

Figure 1. Spectral signatures of the main covers found in the study site for WorldView-2 bands. IR: Infrared. Error bars means standard deviation.

multivariate Gaussian mixture model implemented in the Python scikit-learn library (Murphy, 2012; Pedregosa et al., 2011). Then, each of the 100 clusters was characterized by its mean and standard deviation. These attributes were used to group the clusters into six classes using the hierarchical h-clust classification algorithm (Maechler, Rousseeuw, Struyf, Hubert, & Hornik, 2013) based on the Euclidean distances. These six classes were labeled according to six information classes, including the four vegetation classes described before: *Sa. ambigua, Sp. densiflorus, C. selloana, B. maritimus,* and two water classes.

One hundred and sixty accuracy assessment points were determined in the field between March 2015 and May 2017. Eighty-six additional points were selected from high-resolution imagery. Homogeneous regions were generated around these points and compared to the classes obtained. Results were summarized in an error matrix and produceŕs accuracy, useŕs accuracy, overall accuracy, and Kappa index were calculated.

2.4. Identification and delimitation of Landscape Units

To analyze the spatial distribution and plant community patterns, the study area was gridded into 946 cells of 500 m^2 each. Landscape 'metrics' provide simple measures of landscape structure that can be easily calculated with readily available data and software. Class metrics was calculated for each cell based on WV2-map coverage using FRAGSTATv4 software (Mcgarigal, 2015). The calculated metrics were: aggregation (number and patch density, Euclidean nearest neighbor distance), area (class area), and shape (fractal dimension index). Cells were regrouped using the Euclidean distance on a transformed matrix to normalize and compare the variables with different units. The grouping method chosen was averaged, because it presented the best correlation with the cophenetic distance. A 50% similarity was used as a cut-off criterion.

3. Results and discussion

The main plant communities and open water areas of the active marshes were successfully mapped in the study area (see Main Map) (160 km^2). Most of the total area was covered by *Sa. ambigua* (24.5%) and *Sp. densiflorus* (21.9%), while *C. selloana* accounted for 14.9% and *B. maritimus* for 4.42%.

Overall classification accuracy was 81% and Kappa value was 78.1% (Table 2). Most of the confusion arose from the similar physiognomies that plant communities presented. Even though *B. maritimus* showed the highest useŕs accuracy (97%), a substantial number of segments identified as *B. maritimus* (bulrush) in the field were misclassified as *Sp. densiflorus* (cordgrass). Thus, the produceŕs accuracy of *B. maritimus* was 60% and the useŕs accuracy of *Sp. densiflorus,* 69%. The useŕs accuracy of *Sa. ambigua* also amounted to 69%, mostly due to the inclusion of several segments of unvegetated tidal plain and small and narrow *B. maritimus* stands. *C. selloana* plant community showed the highest useŕs and produceŕs accuracy (95% both).

Based on Landsat 5 TM image classification, Isacch et al. (2006) found that *Sp. alterniflorus*, *Sp. densiflorus,* and *Sa. ambigua* (named *Sa. perennis*) were the main plant species that dominated the middle and intertidal saltmarshes. Our study showed that the main plant communities were *Sp. densiflorus* and *Sa. ambigua* in Samborombón Bay area. In spite of the fact that Isacch et al. (2006) reported the presence of *Sp.alterniflorus* in high tide flooded areas, in our study, only a few plants were observed near the coastline and in mixture patches with *Sa. ambigua*. *B. maritimus* was reported

Table 2. Confusion matrix resulting in object-based image analysis.

	Reference data						
Classification	*Sa. ambigua*	*Sp. densiflorus*	*B maritimus*	*C selloana*	Tidal channels and shalow lakes	Unvegetated tidal plain	Row total
Sa. ambigua	33	2	6	0	2	5	48
Sp densiflorus	2	40	15	1	0	0	58
B maritimus	0	1	31	0	0	0	32
C selloana	0	2	0	40	0	0	42
Tidal channels and shallow lakes	0	0	0	0	32	6	38
Unvegetated tidal plain	4	0	0	0	1	29	34
Column total	39	45	52	41	35	40	252
Overall Accuracy	205/253 = 81%						
	Producer's accuracy (%)		User`s accuracy (%)				
Sa. ambigua	80	*Sa. ambigua*	69				
Sp densiflorus	87	*Sp densiflorus*	69				
B maritimus	60	*B maritimus*	97				
C selloana	98	*C selloana*	95				
Unvegetated tidal plain	73	Unvegetated tidal plain	85				
Tidal channel and shallow lakes	91	Tidal channel and shallow lakes	85				

by Isacch et al. (2006) as part of brackish marshes along with other species such as *J. acutus L*, *Scirpus americanus* and *Phragmites australis*. We found that *B. maritimus* covered the margins at the end of the tidal channels, and ranked third in importance in terms of spatial extension. Cagnoni and Faggi (1993) mapped the vegetation of Campos del Tuyú National Park and found that *Sa. ambigua* and *Sp. densiflorus* were the prevailing plant communities, in line with our results. Albeit using aerial photographs with high spatial resolution and intensive field work, they obtained a low detail map.

Researchers have demonstrated the use of high-resolution satellite data for mapping and studying coastal wetlands. Belluco et al. (2006) achieved overall accuracies greater than 95% when classifying salt marsh species using QuickBird and IKONOS imagery. Carle et al. (2014), on their part, carried out species distribution maps within freshwater delta systems and compared them to hyperspectral imagery. The authors found that high-spatial resolution sensors were successful at a much lower cost and with greater ease of processing. Wei and Chow-Fraser (2007) indicated that IKONOS imagery can be used in inventory wetlands with the advantages of wide spatial coverage and the accuracy of supervised classification. In this work, we obtained the first high-resolution vegetation map of Samborombón Bay, which suggests that higher resolution imagery can be effectively used to delineate coastal wetlands with very high accuracy and spatial detail (Lane et al., 2014).

Four different Landscape Units of active marshes were identified at Samborombón Bay based on the presence and spatial distribution of the main plant communities. Each landscape unit presented a characteristic pattern. Landscape Unit 1 stretches next to the estuary and corresponds to the most recent sediment deposits with the greatest tidal influence and exposure to storm effects. This area has been mostly classified as *Sa. ambigua,* and is subjected to daily tidal flooding with short periods of immersion, and located in middle intertidal zones (Cagnoni & Faggi, 1993; Davy et al., 2006; Isacch et al., 2006). In the marshes at Scolt Head Island, Norfolk, *S. perennis* has an elevation range within the tidal frame of + 1.98 m to + 2.42 m ODN (Ordnance Datun Newlyn) representing a number of 570–575 tidal submergences per year (Davy et al., 2006). In Argentina, *Sa. ambigua* is found in wide areas of the Atlantic coast from Buenos Aires to Tierra del Fuego provinces (Bortolus, Schwindt, Bouza, & Idaszkin, 2009; Isacch et al., 2006). Thus as an halophyte confined to tidal salt marshes, *Sa. ambigua* is not found above the level of the highest astronomical tides (Davy et al., 2006). In this unit, individuals of *Sp. alterniflorus* were recorded in lower topographic positions in the field, but could not be classified due to their reduced spatial distribution. Even though *Sp. alterniflorus* has traditionally been considered as a native species of South America, it has been recently proposed that this species was introduced in the 18th or early nineteenth century by human activity (Bortolus, Carlton, & Schwindt, 2015). These authors postulated that this species is particularly concentrated in areas near harbors and ports, which is well in agreement with the hypothesis that seeds and vegetative fragments were long transported by ships. The incipient presence of *Sp. alterniflorus* near the port of San Clemente del Tuyú (southeastern Samborombón Bay) supports this notion.

In this Landscape Unit, there were 13,778 patches of *Sp. densiflorus,* 3628 patches of *Sa. ambigua,* and 8563 patches of *C. selloana.* Also, the class area was 2701 hectares (ha) for *Sa. ambigua,* 898 ha for *Sp. densiflorus* and 460 ha for *C. selloana.* Finally, the patch size was 1.1 ha for *Sa. ambigua* compared with only 0.01 ha for *Sp. densiflorus.*

The Landscape Unit 2 is located on both margins of the Ría de Ajó channel, under tidal influence, though protected from the direct effect of the storms and limited by thin shell ridges with tala forests. The pattern showed a *Sa. ambigua* matrix with isolated stands of *C. selloana* in the highest topographic position, which are surrounded by narrow belts of *Sp. densiflorus* at intermediate topography. The lower intertidal areas (low marshes) were not occupied by *Sp. Alteniflorus,* as reported in many coastal marshes occupying this position. Instead, they were characterized by mudflats without vegetation. *C. selloana*, a native species of South America was present in this pattern as low height formations. *C. selloana* can live in brackish habitats, and Bacchetta, Dettori, Mascia, Meloni, and Podda (2010) reported that this species has a remarkable salt tolerance at the germination and seedling stages.

In this Landscape Unit, there were 15,658 patches of *Sp. densiflorus,* 4,282 patches of *Sa. ambigua,* 4282 patches of *C. selloana,* and 880 patches of *B.maritimus.* Also, the class area was of 1808 ha for *Sa. ambigua,* 621 ha for *Sp. densiflorus,* 644 ha for *C. selloana,* and 21 ha for *B.maritimus*. Patch size was of 0.5 ha for *Sp. Densiflorus,* and of less than 0.01 ha for other communities.

The Landscape Unit 3 was found inland of the Ría de Ajó channel in inner positions but under tidal influence. This area was dominated by *B. maritimus* along the margins of the channels in low intertidal areas, while *Sa. ambigua* and *Sp. densiflorus* stands were found in higher topographic positions. *Scirpus maritimus* mature populations grow under 90 cm deep water (Costa, 1998; Dykyjová, 1986). This species can be found in fresh and brackish tidal areas as well as in inland waters (Charpentier & Stuefer, 1999; Clevering & Hundscheid, 1998). Even though plants were able to tolerate high salinity only for short time periods, exposure to different salinities significantly affected plant survival (Lillebø et al., 2003). The elevation of *B.maritimus* is similar to that where *Sp. alterniflorus* is commonly found. The less tolerance to high levels of salinity could indicate brackish conditions in the area where *B. maritimus* was found.

In this Landscape Unit, there were 5541 patches of *Sp. densiflorus,* 8718 patches of *Sa. ambigua,* 1632 patches of *C. selloana,* and 2725 patches of *B.maritimus*. Also, the class area was of 340 ha for *Sa. ambigua,* 477 ha for *Sp. densiflorus,* 417 ha for *C. selloana,* and 720 ha for *B.maritimus*. Patch size was of 0.24 ha for *B. maritimus,* and of less than 0.1 ha for other communities.

Finally, Landscape Unit 4 was found inland at a higher elevation with a slight tidal influence. This sector was mostly dominated by *Sp. densiflorus,* and, in a higher topographic position, by *C. selloana,* which forms a mosaic with pampa grassland (*Bromus unioloides, Lolium* sp., *Paspalum dilatatum*, *Melilotus albinus, Melilotus oficinalis*, *Trifolium* sp., and *Sternotaphylum secundatum*). As in the USA (Kittelson & Boyd, 1997) and Spain (Castillo et al., 2005), *Sp. densiflorus* was restricted to the middle and high elevations of the coastal marshes, and it was rarely found in the low intertidal areas (Bortolus, 2001; Kandus et al., 2010; Nieva, Dı´az-Espejo, Castellanos, & Figueroa, 2001). These plant communities are flooded between 9.4% and 22.3% in Mar Chiquita coastal marshes (Buenos Aires province) (González Trilla et al., 2010). The location of this species is equivalent to that of *Spartina patens* (Aiton) Muhl in the North Hemisphere (Mitsch & Gosselink, 2007).

In this Landscape Unit, there were 8124 patches of *Sp. densiflorus,* 4238 patches of *Sa. ambigua,* and 938 patches of *B.maritimus.* Also, the class area was of 2000 ha for *Sp. densiflorus* and *C. selloana,* 50 ha for *Sa.ambigua,* and 10 ha for *B.maritimus*. Patch size was of 1.5 ha for *C.sellona,* and of less than 0.01 ha for other communities.

The pattern found in Samborombón Bay marshes was characterized by the low intertidal areas dominated by mudflats without vegetation and few isolated individuals of *S. alterniflorus* in the outer estuary (Landscape Unit 1), only mudflats without vegetation in the middle estuary (Landscape Unit 2), and *B.maritimus* in the inner estuary (Landscape Unit 4). The middle intertidal area was dominated by *Sa. ambigua* in the four Landscape Units, while the high intertidal area was dominated by *Sp. densiflorus* and grassland with *Co. sellona* (Landscape Unit 3). The middle intertidal areas showed the same features in all the landscape units, because *Sa.ambigua* has a wide spectrum related to salinity. In contrast, species replacement in the low zone could indicate a change in salinity conditions in the different units. In the higher areas, the presence of *C. selloana* in Landscape Unit 1 and of grasslands in Landscape Unit 4 could indicate more salinity in the former.

4. Conclusions

The distribution pattern of the main plant communities in active marshes of Samborombón Bay were mapped and described using WV2 imagery, which allowed to differentiate in high detail plant communities at a landscape scale. The relevance of this work resides in the fact that it is the first research effort conducted in this area, representing a valuable tool for wetland management.

Software

Monteverdi 2 was used to segment the image. QGIS was used to produce and design the map. Fragstat was used to delineate landscape units.

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Disclosure statement

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