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Environmental gradients and macroalgae in Mediterranean marshes: the case of Pego-Oliva marsh (East Iberian Peninsula)

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HIGHLIGHTS

- Mediterranean marshes are highly diverse in macroalgae despite high nitrogen levels
- Macroalgal assemblages can be used to evaluate ecological quality of Mediterranean marshes
- These systems are severely threatened by human activities and climate change
- Mediterranean marshes deserve to be protected and better studied as sentinels of climate change

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ABSTRACT

Although Mediterranean marshes have historically suffered high anthropogenic pressure, they have maintained their remarkable biodiversity. They are severely threatened but remain comparatively unexplored systems from the algological point of view. For example, most of the indexes proposed for monitoring ecological quality are based on diatoms and very few have explored the use of macroalgae. The Pego-Oliva marsh is located in the east of the Iberian Peninsula close to the Mediterranean coast with warm annual temperature and fairly high precipitation. The aims of this study were to ascertain the ecological variables that explained macroalgal distribution in the Pego-Oliva marsh and to assess their indicator value. Macroalgal biodiversity was seen to be high (50 taxa) despite the high nitrogen concentration of the marsh. All the environmental variables studied had a broad range of variation throughout the marsh, especially conductivity (500–12290 μS/cm), temperature (14.3–31.7 °C), nitrate (9.493–64.113 mg/L) and ammonium (0.004–0.814 mg/L). A clear gradient of conductivity and dissolved oxygen was observed from fresh to saltwater. *Batrachospermum arcuatum*, *Calothrix parietina*, *Chaetophora tuberculosa*, *Draparnaldia mutabilis*, *Hildenbrandia angolensis* and *Leptolyngbya angustissima* were seen to act as indicators of low conductivity and dissolved inorganic nitrogen, and high dissolved oxygen, while *Calothrix pulvinata*, *Ulva intestinalis*, *Homoeothrix violacea*, *Phormidium tergestinum* and *Thorea violacea* were indicators of high conductivity and low dissolved nitrogen habitats. *Cladophora glomerata*, *Compsopogon coeruleus*, *Polysiphonia subtilissima* and *Ulva flexuosa* are the most widespread species and have a broad ecological range. Irrigation ditches have high ammonium and low dissolved oxygen concentrations and host infrequently reported species like *Kumanoa mahlacensis*. The data presented confirm the usefulness of macroalgae for the ecological monitoring of marshes, while increasing our knowledge of the distribution and ecological range of some species. However, more experimental work is needed to know the tolerance range of species living in dynamic systems like Mediterranean marshes.

1. Introduction

Marshes are transitional waters (TW) located between terrestrial and aquatic systems and may be frequently or continually inundated (Espinar et al., 2002; McLusky and Elliott, 2007). Several international agreements and laws (the Water Framework Directive, the Ramsar Convention on Wetlands, the Habitats Directive 92/43EC, and the Directive 79/409/EEC on the Conservation of Wild Birds) have addressed the protection and conservation of transitional waters because they are cradles of biological diversity, providing the water and primary productivity upon which large numbers of plant and animal species depend for survival. They also play an important role as carbon sinks (Laffoley and Grimsditch, 2009) and are also important locations of plant and animal genetic diversity, supporting a large numbers of vertebrate and invertebrate species (Espinar et al., 2002; Ferreira et al., 2007).

Although our knowledge of vascular flora (Espinar et al., 2002) and vertebrate fauna (Galewski et al., 2011) in Mediterranean marshes is

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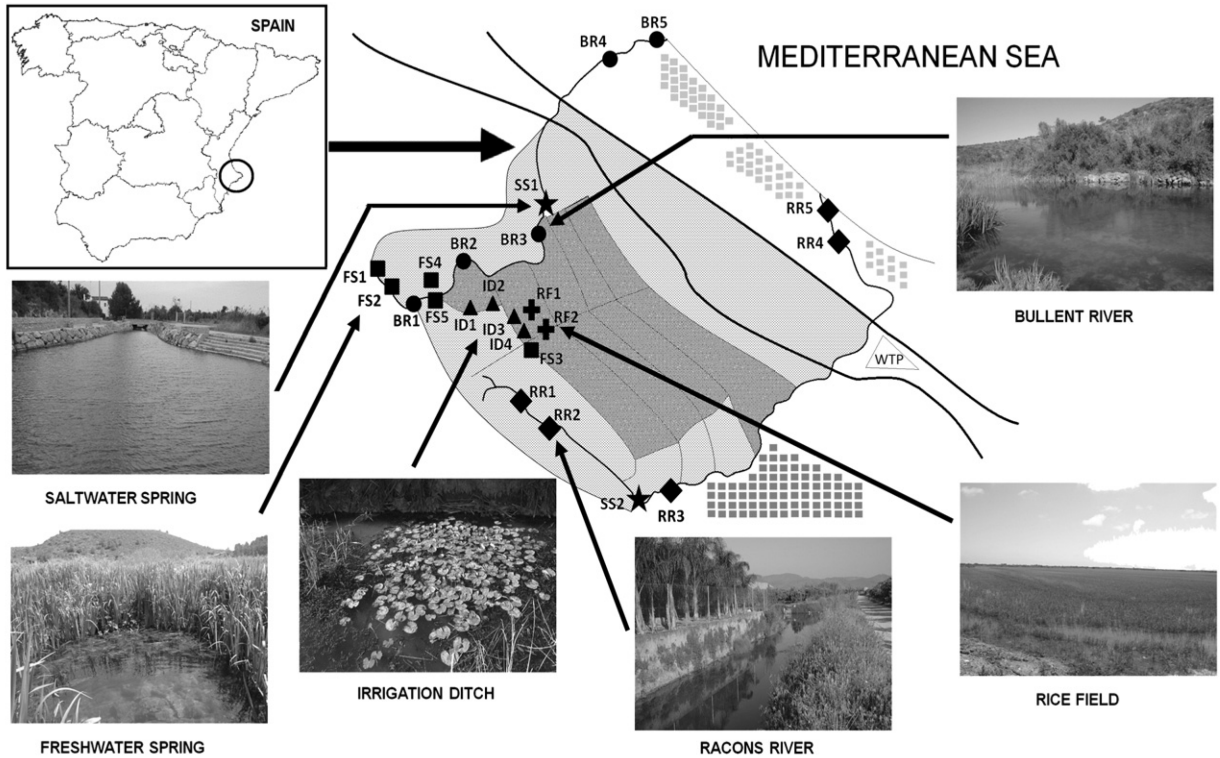

Fig. 1. Sampling points in Pego-Oliva marsh and different habitats sampled (■ FS: Freshwater Spring, ★ SS: Saltwater Spring, ● BR: Bullent River, ◆ RR: Racons River, ▲ ID: Irrigation Ditch, ✚ RF: rice field, dark grey shaded area: rice field, grey shaded area: citric fruits, ■ (grey square): Tourist Resorts, WTP: water treatment plant).

fairly detailed, very few data exist on macro or microalgal assemblages. At the same time, continued anthropogenic pressure has led to their degradation and they will almost certainly be severely affected by climate change (Álvarez-Rogel et al., 2007; Elsdon et al., 2009). Some opportunist macroalgal species are implicated in nuisance blooms worldwide (Nedwell et al., 2002; Scanlan et al., 2007) and others may become invasive, but there is scant information on the ecological requirements of such species.

Algae are valuable bioindicators of ecosystem ecological conditions because they respond quickly both as regards species composition and density to environmental changes (Whitton, 1991). Microalgae, especially diatoms, are commonly used in monitoring programmes (Coste M in Cemagref, 1982; Kelly et al., 2008) but the use of macroalgae has increased in recent years, especially in rivers (Schneider et al., 2013; Schneider and Lindstrøm, 2011). The more important advantages of using macroalgae are that can be determined on macroscopic and

Table 1
Annual variation (minimum and maximum) of main physical and chemical variables in the different sampling points and habitats of Pego-Oliva marsh.

Habitats	Sampling points	Conductivity (μS/cm)	Temperature (°C)	DIN[a](mg/l)	SRP[b](mg/l)	O_2 (mg/l)	P.A.R.[c](μE/cm^2/s)	Chlor b/a	Chlor c/a
Bullent river	BR1	1066–2380	18.1–18.3	16.559–21.161	0.015–0.028	8.62–10.17	124.65–450.00	0.348–0.670	0.284–0.670
	BR2	941–1280	17.2–19.8	14.474–18.844	0.013–0.019	7.6–10.64	246.00–944.32	0.273–0.865	0.122–0.685
	BR3	1910–2700	17.8–20.6	15.907–27.407	0.016–0.036	8.60–9.58	1390.00	0.527–3.099	0.124–0.222
	BR4	2970–6300	18.3–22.7	15.767–18.248	0.016–0.023	7.53–9.90	211.20–2508.80	0.173–0.273	0.100–0.290
	BR5	6490–8630	18.5–22.9	17.617–22.753	0.015–0.055	6.63–11.40	217.92–837.10	0.254–0.506	0.084–0.142
Racons river	RR1	1507–2290	14.3–20.2	17.737–28.247	0.019–0.035	5.68–9.56	147.70–1757.20	0.192–0.836	0.081–0.520
	RR2	1749–3350	15.7–29.1	10.602–14.299	0.010–0.021	5.78–15.41	182.30–1528.63	0.389–0.734	0.252–0.431
	RR3	2630–3600	15.8–21.8	16.717–38.021	0.012–0.021	5.83–13.12	202.90–798.05	0.169–0.375	0.068–0.155
	RR4	3100–4260	15.4–22.8	16.161–149.28	0.022–0.062	6.55–13.31	269.57–598.35	0.227–0.551	0.152–0.330
	RR5	3100–4260	14.8–28.0	13.277–21.816	0.012–0.082	4.60–9.11	204.30–1585.80	0.403–0.881	0.056–0.550
Saltwater springs	SS1	2200–12290	22.9–24.4	22.756–64.154	0.031–0.104	5.89–7.33	111.12–349.10	0.074–0.130	0.082–0.219
	SS2	4410–8760	15.9–27.7	17.329–40.169	0.022-0.043	5.57–8.17	493.79–1042.35	0.237–0.407	0.246–0.409
Freshwater springs	FS1	740–983	17.4–18.6	9.601–19.322	0.012–0.023	7.93–12.81	34.41–2071.17	0.307–0.410	0.129–0.315
	FS2	810–1494	16.9–18.9	9.715–16.850	0.014–0.024	7.41–13.58	87.09–2070.86	0.060–0.207	0.080–0.200
	FS3	913–1705	17.8–18.9	33.532–36.708	0.022–0.039	6.93–8.20	–	0.570–0.613	0.115–0.122
	FS4	500–900	18.7–19.1	21.500–25.400	–	11.0–13.4	–	0.092–1.000	0.348–1.000
	FS5	700–800	18.5	18.000	0.01	8.9	–	–	–
Irrigation ditches	ID1	569–628	14.4–24.7	11.246–18.532	0.016–0.031	2.57–8.30	–	0.374–0.508	0.039–0.158
	ID2	1190–1850	16.7–26.7	17.907–29.238	0.017–0.087	6.25–10.54	–	0.139–0.722	0.102–0.687
	ID3	1028–1773	15.9–24.2	12.072–34.770	0.011–0.014	3.26–8.43	21.20–1303.60	0.150–0.941	0.151–1.032
	ID4	1045–1220	14.5–23.4	35.272–55.950	0.017–0.032	3.42–8.98	83.90–1724.36	0.176–0.303	0.101–0.133
Rice fields	RF1	6530–2190	18.5–31.70	23.830	0.011	4.00–9.65	1519.89	–	–
	RF2	2130	29.60	125.219	0.015	15.57	125.17	–	–

[a] Dissolved Inorganic Nitrogen.
[b] Soluble Reactive Phosphate.
[c] Photosynthetic Active Radiation.