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Long-term decline of the populations of Fucales (*Cystoseira* spp. and *Sargassum* spp.) in the Albères coast (France, North-western Mediterranean)

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Abstract

Only five of fourteen species of Fucales reported at the end of the XIXth century are currently present in the Albères Coast (France, NW Mediterranean). According to historical data there has been a steady decrease of all the populations since the 1940s. Seven taxa now extinct (*Cystoseira crinita*, *Cystoseira barbata*, *Cystoseira foeniculacea* f. *tenuiramosa*, *Cystoseira spinosa*, *Cystoseira spinosa* var. *compressa*, *Sargassum hornschuchii* and *Sargassum vulgare*) were considered frequent and some of them were the dominant and engineering species in several phytobenthic assemblages. Moreover, only one of the five species left, shows no signs of regression (*Cystoseira compressa*), two are considered as rare (*Cystoseira caespitosa*, *Cystoseira zosteroides*), and one is very rare (*Cystoseira elegans*). *Cystoseira mediterranea*, a species that was reported to make a continuous belt along the shores of the Albères coast, has almost disappeared from some areas. Overgrazing by sea urchins, outcompetition by mussels, habitat destruction, scientific research sampling and, probably, human trampling and chemical pollution are to be blamed for the decline of populations thriving in shallow waters. Deep-water species have been affected by an increase in water turbidity and, probably, chemical pollution and direct plant destruction attributed to net fishing. If degradation of the environmental conditions continues, the remaining *Cystoseira* species will face a most unwelcome prospect. Even after the removal of the causes that led to its die-off, natural restoration of extinct species seems not to be possible because the decline has also affected populations from nearby areas and zygotes are unable to disperse over long distances. Urgent management actions have to be designed in order to improve the current situation of the populations of Fucales in the Albères coast.

Keywords: Fucales; Biodiversity erosion; Mediterranean; Pollution; Overgrazing; Outcompetition

1. Introduction

The genus *Cystoseira* C. Agardh and *Sargassum* C. Agardh are the main representatives of the order Fucales Kylin in the Mediterranean Sea (Ribera et al., 1992). Most of the species of *Cystoseira* and *Sargassum* inhabiting the Mediterranean are endemic, and they are distributed along the entire infralittoral as well as the upper circalittoral zone (Giaccone and Bruni, 1973). They are relatively large seaweeds in relation to the average size of Mediterranean algae and their canopies provide suitable habitats for a large amount of other algal and animal species (Sauvageau, 1912; Funk, 1927; Rull and Gómez-Garreta, 1989; Ballesteros, 1992; Ballesteros et al., 1998). Moreover, some *Cystoseira* species are the dominant seaweeds in several communities and they have been widely used to

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describe Mediterranean phytobenthic assemblages (Feldmann, 1937a,b; Molinier, 1958; Pignatti, 1962; Giaccone, 1973; Giaccone and Bruni, 1973; Verlaque, 1987; Ballesteros, 1990a,b).

Some studies have detected the modification, regression, and even disappearance of *Cystoseira* populations when subjected to increased pollution levels (Bellan-Santini, 1966, 1968; Belsher, 1977; Munda, 1974, 1982; Hoffman et al., 1988; Rodríguez-Prieto and Polo, 1996; Soltan, 2001). Other authors have related the disappearance of *Cystoseira* species and other canopy-forming algae to blooms in the populations of sea urchins (Gros, 1978; Vukovic, 1982; Verlaque, 1987; Arrighi, 1995; Sala et al., 1998; Hereu, 2004). Mussels can also outcompete *Cystoseira* species in exposed habitats with a great amount of suspended particulate organic matter (Gros, 1978). Finally, Cormaci and Furnari (1999) blamed increased water turbidity to explain the decline of *Cystoseira* populations in the Tremiti islands, an isolated Archipelago in the Adriatic Sea. All these evidences have prompted Mediterranean phycologists to propose species of the genus *Cystoseira* as biological indicators of water and ecosystem quality (Gros, 1978; Panayotidis et al., 1999), and they are already being used in the assessment of the environmental quality of some Mediterranean regions according to the Water Framework Directive (2000/60/EC) (Pinedo et al., 2004; Torras et al., in press).

Jackson et al. (2001) pointed out the importance of using historical data to detect and understand recent changes that may occur in marine ecosystems due to human activities. This approach has seldom been used in benthic marine vegetation, as availability of suitable data is unusual. Nevertheless, if applicable, it would tell us the long term evolution of the benthic vegetation and we could be able to relate these changes to changes in anthropogenic pressures. In this way, the Albères coast (France, North-western Mediterranean) is a unique place because it has been selected for sampling by numerous phycologists since the end of the XIXth century. The published results and observations as well as the preserved specimens in public and personal herbaria was used to track the evolution of the Fucales populations in the Albères coast during the last century. We also made an exhaustive survey along the Albères coast in spring and summer 2003 to know what were the remaining species and their abundance.

The aim of this study is (1) to assess the current state of the populations of species belonging to the genera *Cystoseira* and *Sargassum* in the Albères coast, (2) to compare it with historical records, (3) to try to relate the evolution of these algal populations to environmental changes, and (4) to provide clues for environmental managers in order to improve or at least not to deteriorate the present situation.

2. Materials and methods

2.1. Study site

The Albères coast (France, Department of Pyrénées-Orientales) is located in the westernmost part of the Gulf of Lions including four municipalities: Collioure, Port-Vendres, Banyuls and Cerbère (Fig. 1). The Albères mountains dive into the sea and form, along 42 km, an irregular coast alternating high cliffs, flat rocky pools and small sandy bays (Feldmann, 1937a,b). The coast has remained almost unchanged during the last century: only the harbour of Banyuls was built in the 1970s.

The Albères coast receives the water from the Liguro-Provençal current, directed to the South along this coast, transporting waters and material from the Rhône river but also from other numerous rivers, lagoons and cities (Grémare et al., 1998). Water transparency seems to have decreased since the last third of the XXth century. Both Sauvageau (1912) and Feldmann (1937b) described relatively clear and limpid waters. In the years 1965–1966, Bhaud et al. (1967) gave a mean value of water transparency (Secchi disk) of 12.5 m, with values ranging from 16 to 28 m in summer and from 1.5 m to less than 15 m in the rest of the year. However, Guille (1970) observed a strong turbidity in the waters of the region of Banyuls and Gros (1978) noted the water as frequently turbid. Ballesta et al. (2000) also noted a high level of turbidity at Banyuls. During all our dives, performed in spring–summer 2003, we never encountered clear water and the visibility was always reduced to few meters.

A marine protected area (MPA) (Réserve Naturelle de Cerbère-Banyuls) was established in 1974 between Banyuls and Cerbère and, in 1978, part of the MPA was given full protection as "integral marine reserve" (65 ha), prohibiting all human take-off activities. Nevertheless, net fishing, angling, scuba-diving and anchoring are permitted in the rest of the MPA (650 ha). Only spear-fishing and plant and invertebrate collection are prohibited in all the reserve.

Along the Albères coast the permanent population has been estimated to be around 20,000 inhabitants, but it increases three fold in summer (Réseau Satese, unpublished). Sewage outfalls are located in different points of the coast. The sewage outfall of Collioure, located before the Presqu'île St Vincent, was used as permanent wastewater outfall receiving untreated water until 1994; since then it is used only in case of overflowing. The wastewater plant collecting the wastewaters of Collioure and Port-Vendres (maximum capacity 29,000 inhabitants, debit 1700 $m^3\,day^{-1}$ in winter and 3500 $m^3\,day^{-1}$ in summer) was set up in 1994 and the outfall was located at 24 m depth in front of the entrance of the port until 1998; now it is much longer and the outfall

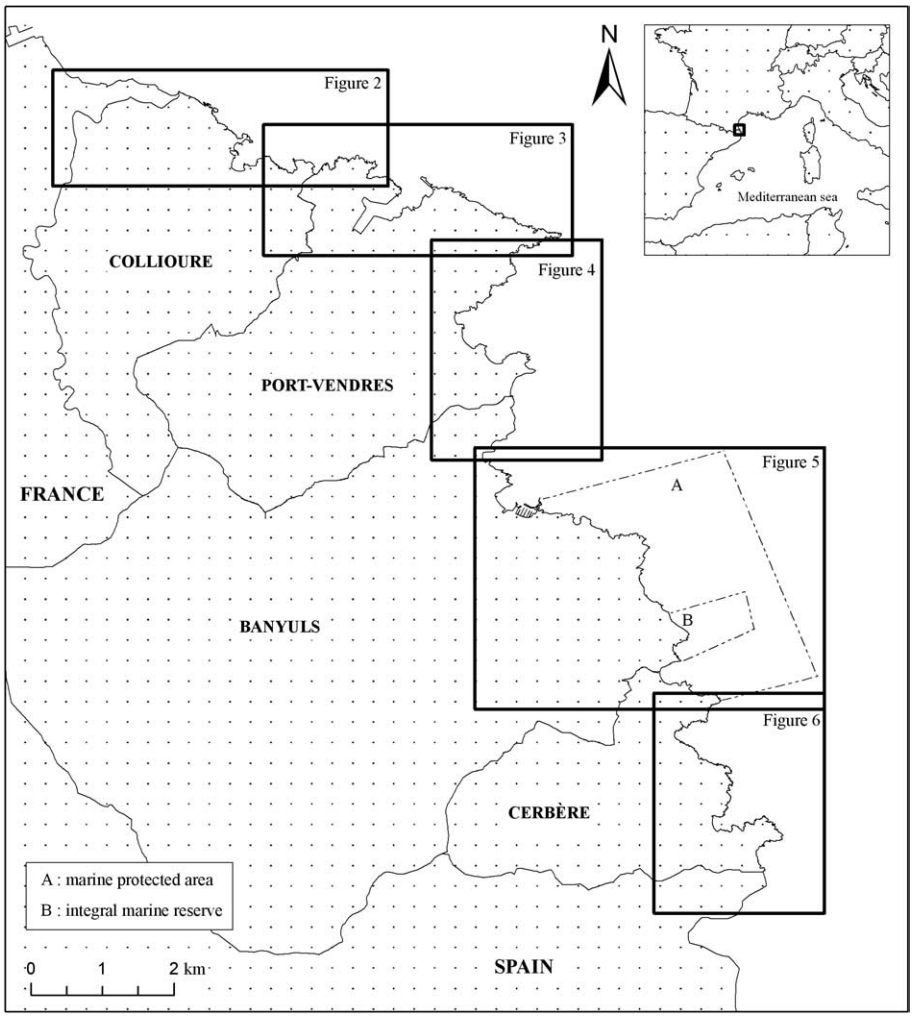

Fig. 1. The Albères coast.

is situated at 100 m depth. The outfall of the rainwater is located inside the port of Port-Vendres. The wastewater plant of Banyuls was set up in 1988 (maximum capacity 15,000 inhabitants, debit 10,000 m^3 day^{-1} in winter and 16,000 m^3 day^{-1} in summer); the outfall is located in front of the anse du Troc at 24 m depth. This outfall was built in the 1930s (Feldmann, 1937a,b). Another outfall located in the anse du Sana mentioned by Feldmann (1937b) does not exist anymore. The wastewater plant of Cerbère was set up in 1993 (maximum capacity 7500 inhabitants, debit 3000 m^3 day^{-1} in winter and 7000 m^3 day^{-1} in summer) and the outfall is located in a ravine arriving at the beach of Peyrefite.

2.2. Data collection

2.2.1. Published data

Four monographs have focused on the vegetation of the Albères coast with descriptions on the abundance, locations, and associated species of the *Cystoseira* populations. Although the first data available dates back to the 1880s, the first complete work was published by Sauvageau (1912), who described the morphology, life cycle, and the ecology of 10 species and 3 varieties of *Cystoseira* (with the description of four new species: *Cystoseira caespitosa*, *Cystoseira elegans*, *Cystoseira mediterranea* and *Cystoseira spinosa*). Feldmann (1937a,b) made a reference work in the marine vegetation of the Albères coast and described several communities dominated by species of *Cystoseira*. Gros (1978) studied the evolution in the abundance and distribution of the Fucales in this region in relation with the data provided by Sauvageau (1912) and Feldmann (1937a,b).

Our revision of the sites once occupied by *Cystoseira* and *Sargassum* and all data concerning their abundances is mainly based on the above-mentioned monographs. We have also used other published works such as those of Feldmann and Davy de Virville (1933), Guern (1962), Boudouresque (1969), and Knoepffler-Péguy (1973).

2.2.2. Herbaria

We also checked the following herbaria:

- Sauvageau Herbarium, Feldmann Herbarium, Thuret Herbarium, Montagne Herbarium, France Herbarium, Général Herbarium, and Hamel Exsiccatas held in the Laboratoire de Cryptogamie of the Museum National d'Histoires Naturelles de Paris,
- the University of Girona Herbarium (UdG Herbarium),
- the University of Barcelona Herbarium (UB Herbarium),
- Meinesz Herbarium held in the Laboratoire d'Environnement Marin Littoral of the University of Nice-Sophia Antipolis,
- Huvé and Verlaque Herbaria held in the Centre d'Océanologie de Marseille,
- Feldmann Herbarium held in the Laboratoire Arago (Banyuls, University Pierre and Marie Curie).

2.2.3. Unpublished data (''carnets de récoltes'')

Further information on specimens collected by Sauvageau and Feldmann was obtained from their field diaries (''carnets de récolte''), held in the Laboratoire de Cryptogamie of the Museum National d'Histoires Naturelles de Paris.

2.2.4. Field work

The field work was carried out from April to August 2003. We surveyed all the littoral, with special attention to the sites sampled by previous phycologists (Figs. 2–6). The locality named ''Les Roches Toreilles'' is further north than the Albères coast and is not represented on the maps. Snorkeling was used to survey the upper-infralittoral zone and SCUBA-diving was used in the lower infralittoral and circalittoral zones, down to 35 m depth. Vouchers of all the species found are conserved in 4% formaline:seawater (E. Ballesteros Herbarium, Blanes). Cartography of the present distribution of *C. mediterranea* populations was performed by visual census (Torras et al., in press).

3. Results

The historical and current distribution of the populations of *Cystoseira* spp. and *Sargassum* spp. along the Albères coast is summarized in Table 1 (Panel A) and (Panel B). Following we present the current distribution and an extended commentary of each species.

3.1. Cystoseira barbata C. Agardh

First observations were done by Sauvageau (1912) between 1906 and 1911 (specimens held in Sauvageau Herbarium, Thuret Herbarium, France Herbarium). He observed the species in very sheltered and shallow locations such as the ''Anse du Sanatorium'' (actual name ''Anse du Sana'') and ''cale de Radoub''. *C. barbata* was specially abundant in front of the Laboratoire Arago (now occupied by the harbor), growing on pebbles among a sandy substrate. To be aware of its abundance, he noted that in spring, the tips of the branches reached the surface when the waters were high, but when the waters were low, the plants formed a canopy spreading at the surface and filling all the space in front of the laboratory.

Feldmann collected *C. barbata* in 1927 in Cerbère (Feldmann Herbarium). He noted the species as

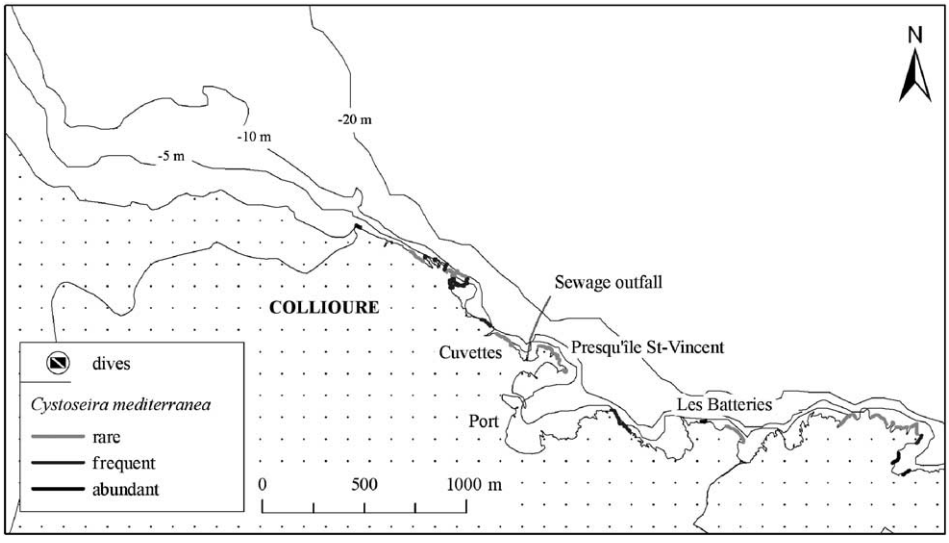

Fig. 2. Localities explored by former phycologists and during this present work (2003). Actual distribution of *C. mediterranea* along the coast of Collioure.

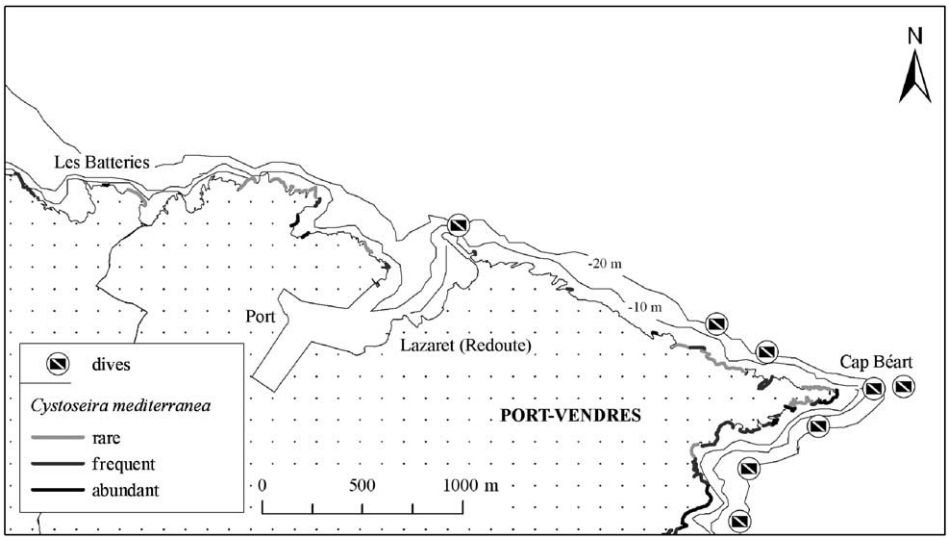

Fig. 3. Localities explored by former phycologists and during this present work (2003). Actual distribution of *C. mediterranea* along the coast of Port-Vendres.

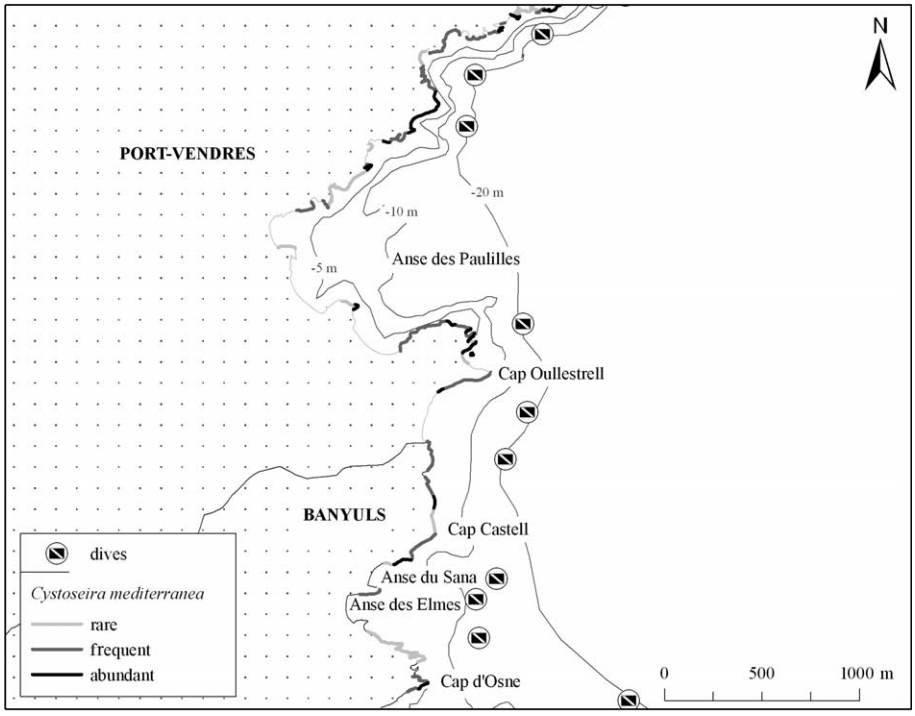

Fig. 4. Localities explored by former phycologists and during this present work (2003). Actual distribution of *C. mediterranea* along the coast of Port-Vendres—Banyuls.

abundant along the Albères coast and located the species in Collioure, Port-Vendres, Cerbère and Banyuls and very abundant in front of the Laboratoire Arago (Feldmann, 1937a). He considered *C. barbata* a characteristic of the "Association à *Cystoseira foeniculacea* et *C. barbata*" (Feldmann, 1937b), thriving in rocky bottoms with high sedimentation in sheltered, shallow-water environments and rock pools, down to 5 m depth.

Between the 1960s and the 1990s *C. barbata* was collected inside the rock pools of Collioure (Meinesz Herbarium, France Herbarium, UB Herbarium, UdG Herbarium). Gros (1978) stated that the species was restricted to the northern part of the rock pools.

We did not find *Cystoseira barbata* f. *barbata* during our surveys. However, we collected two drifting specimens of *Cystoseira barbata* f. *repens* Zinova and Kalu-

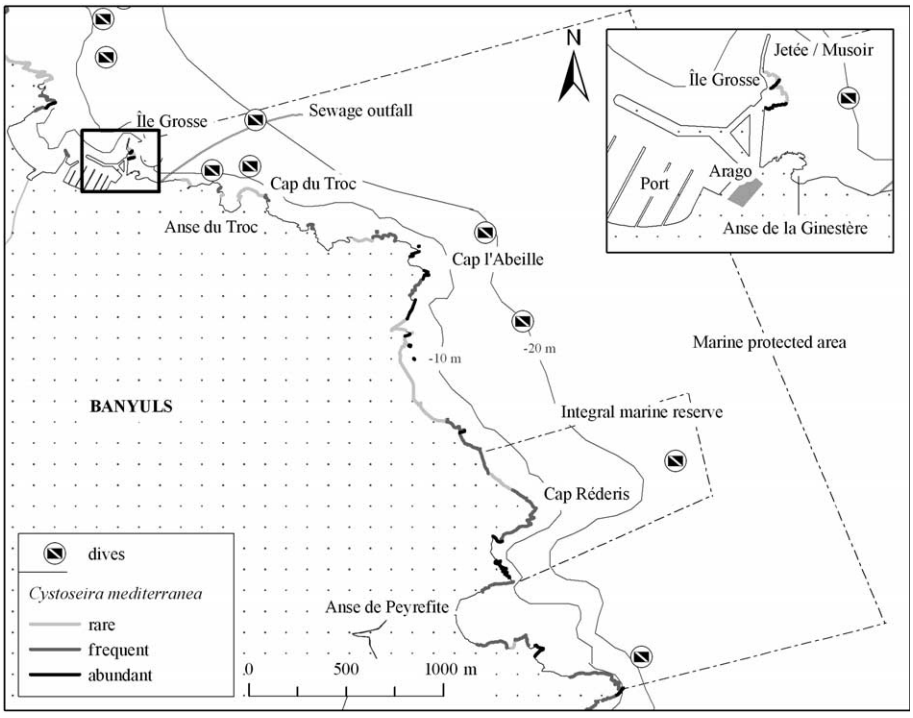

Fig. 5. Localities explored by former phycologists and during this present work (2003). Actual distribution of *C. mediterranea* along the coast of Banyuls.

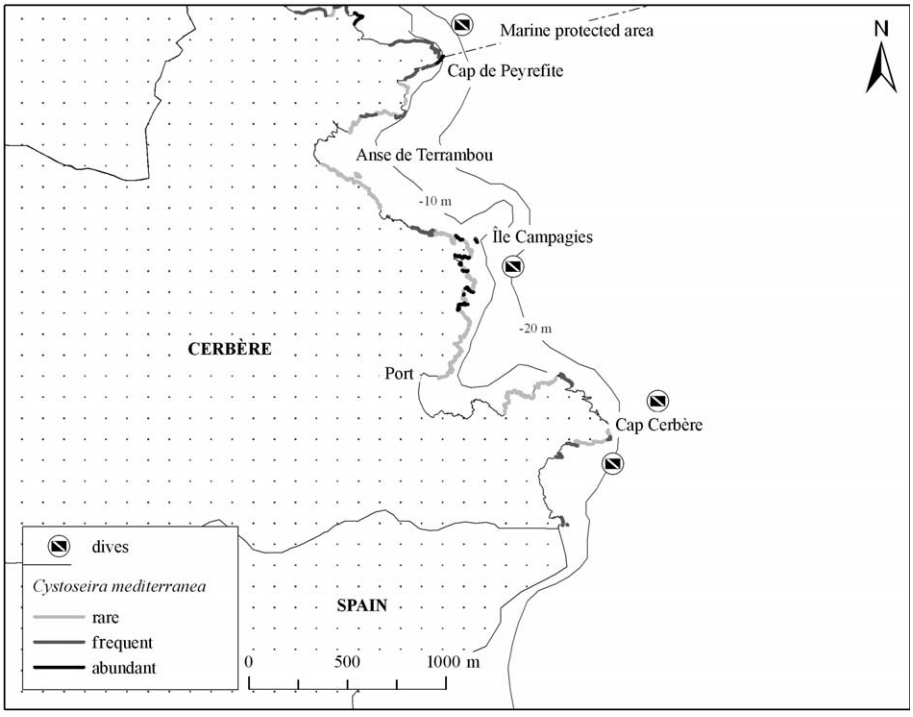

Fig. 6. Localities explored by former phycologists and during this present work (2003). Actual distribution of *C. mediterranea* along the coast of Cerbère.

gina in Collioure and Banyuls. This free living, floating form seems to be common in the lagoons located north to the Albères coast (Knoepffler-Péguy, personal communication; Baghdadli et al., 1990).

Table 1
Years of collection of *Cystoseira* spp. and *Sargassum* spp. in the localities of the Albères coast

	C. barbata	*C. caespitosa*	*C. compressa*	*C. crinita*	*C. elegans*	*C. foeniculacea* f. *latiramosa*	*C. foeniculacea* f. *tenuiramosa*	*C. funkii*
Panel A								
Cuvettes	1937, 1967, 1971, 1978, 1988, 1994	1989,1992, **2003**	1933, **2003**	1933,1937, 1962, 1965, 1971, 1976, 1981	1989		1933, 1962, 1967, 1971, 1978, 1980, 1981, 1988, 1989	
Presqu'île St-Vincent			**2003**	1933				
Les Batteries			**2003**				1883	
Le Lazaret	1937		**2003**					
Cap Béar								1932
Cap Oullestrell								
Cap Castel								
Roches de Paula								
Anse du Sana	1906, 1907, 1911	1926, 1989, **2003**	**2003**	1905–1911, 1978	1906–1910		1906–1911	
Anse des Elmes		1907, 1937, **2003**	1929, 1937, 1958, **2003**	1927, 1929	1907, 1927, 1934, 1937, **2003**		1937	
Cap d'Osne		1907			1907			
In front of Arago	1906, 1907, 1937		1912	1905–1911	1909, 1929			
Vivier and Radoub	1907		1905–1912		1978		1907	
Jetée/musoir/ phare		1907			1906–1910			
Ile Grosse		1907, 1908, 1927, 1962, 1972, 1975, **2003**	1927, 1950, 1937	1931, 1978	1931, 1950, 1962, 1981, 1978, **2003**		1950	
Anse de la Ginestère			1907				1907	
Anse du Troc	1906–1911, 1927, 1937	1907, 1962, **2003**	1907, 1908 1927, 1929, 1937, 1958, **2003**	1905–1911, 1927 1937, 1978	1907, 1929	1886	1927	
Cap du Troc		1937, 1977	1929, 1933, 1958, 1965		1906–1910, 1929, 1937, 1964, 1978		1929, 1931	1908
Between Cap du Troc and Cap l'Abeille								
Cap l'Abeille		1933, 1963	1933, **2003**		1933, 1937		1933, 1939	
Cap Rédéris								
Anse de Peyrefite		1907, 1937, **2003**	**2003**					
Cap Peyrefite								
Anse de Terrambou		**2003**	**2003**					
Îles Campagies								
Cap Cerbère	1937					1886		
Cerbère	1927		**2003**		1891			

	C. mediterranea	*C. sauvageauana*	*C. spinosa* var. *compressa*	*C. spinosa* var. *spinosa*	*C. zosteroides*	*S. acinarium*	*S. hornschuchii*	*S. vulgare*
Panel B								
Cuvettes	1965, 1981, **2003**							
Presqu'île St-Vincent								
Les Batteries		1883, 1937						
Le Lazaret	1906–1907	1906–1907						
Cap Béar	1937		1931, 1932, 1937		1932, 1934		1931, 1937	1932
Cap Oullestrell	1937		1932				1937	1937
Cap Castel			1932, 1978		1932, 1978, **2003**			
Roches de Paula								
Anse du Sana	1921, 1929, 1937			1906–1908, 1921				
Anse des Elmes	1927, 1929, 1937							
Cap d'Osne	1907		1927				1927	
In front of Arago								
Vivier and Radoub								
Jetée/musoir/ phare	1907, 1910, 1967							
Ile Grosse	1927, 1934, 1975, 1978, 1981,			1907, 1908, 1950, 1975	1978	1931		1932
Anse de la Ginestère								
Anse du Troc	1904, 1906, 1907, 1929, 1937			1907				1907
Cap du Troc	1929, 1932, 1933, 1965, 1969		1907, 1929, 1932		1932, 1978		1932, 1955	1955, 1931
Between Cap du Troc and Cap l'Abeille			1932		1932		1932	
Cap l'Abeille	1931, 1933		1886, 1907, 1932, 1937, 1963, 1964	1964	1931, 1937, 1969, 1978, 1992, **2003**	1932	1931, 1932, 1937	1933
Cap Rédéris							1931	
Anse de Peyrefite								
Cap Peyrefite			1886		**2003**		1932	
Anse de Terrambou								
Îles Campagies					**2003**			
Cap Cerbère			1886, 1937, 1939		1932, 1939, 1962, 1972		1933	
Cerbère	1891				**2003**			

The years of collections correspond to specimens held in different herbaria or mentioned in published or unpublished works.

3.2. Cystoseira caespitosa Sauvageau

We maintain *C. caespitosa* as a valid species, different from *Cystoseira brachycarpa* J. Agardh var. *balearica* (Sauvageau) Giaccone until genetic and more accurate morphological data confirm the synonymy proposed by Cormaci et al. (1992). *C. caespitosa* was described by Sauvageau (1912) from Banyuls: he collected numerous specimens between 1907 and 1908, on sheltered rocks (''Ile Grosse'', ''Anse du Troc'', ''Anse Peyrefite'', ''Cap d'Osne'') from the surface to 3–4 m depth (Sauvageau Herbarium, Thuret Herbarium, France Herbarium). The species was mixed with *C. elegans*.

Feldmann collected the species in 1926 in the ''Anse du Sana'' and observed the species from the surface to 2–4 m depth in Banyuls at the same sites of Sauvageau (Feldmann, 1937a) and also inside the rock pools in ''Cap l'Abeille'' (Feldmann: carnet de récolte). He considered *C. caespitosa* as a characteristic species of the ''Association à *C. elegans*'', which throve in photophilic shallow environments with low to medium water movement. *C. caespitosa* was the dominant species between 2 and 3 m depth (Feldmann, 1937a,b).

According to Guern (1962), *C. caespitosa* was frequent in Banyuls, in sheltered environments (''Anse du Troc'', ''Ile Grosse''). Feldmann (1963: carnet de récolte) collected the species in Banyuls. Gros (1978) observed the species living in the same location as *C. elegans* in Banyuls. Different specimens were collected in 1977, 1989 and 1992 in Banyuls (''Anse du Sana''), in Cap du Troc and inside the rock pools of Collioure (Verlaque Herbarium, UdG Herbarium).

We always observed *C. caespitosa* in rather sheltered, photophilic environments, very close to the surface (0–1 m depth), together with the far more abundant *C. compressa*. It was very scarce in the rock pools of Collioure, the ''Anse du Sana'' (Banyuls), the less exposed part of the crevices of the ''Cap d'Osne'' (Banyuls), the left end corner of the ''jetée'' of the ''Ile Grosse'' (Banyuls) close to a very small population of *C. elegans*, ''Anse du Troc'' (Banyuls), ''Anse de Peyrefite'' (Banyuls), and the rock pools at the ''Anse de Terrambou'' (Cerbère). *C. caespitosa* was only common in the most sheltered areas of the ''Ile Grosse'' and the southern part of the ''Cap d'Osne''.

3.3. Cystoseira compressa (Esper) Gerloff and Nizamudin [= Cystoseira abrotanifolia auct., Cystoseira fimbriata (Desfontaines) Bory]

Sauvageau (1912) collected numerous specimens of *C. compressa* in shallow, both sheltered and exposed sites of Banyuls (''Anse de la Ginestière'', in front of the Laboratoire Arago, ''Anse du Troc'', ''Cale de Radoub'', ''Anse du Sana'', the light house of Banyuls—Cap d'Osne) and Port-Vendres, between 1905 and 1912 (Sauvageau Herbarium, Thuret Herbarium).

Feldmann and Davy de Virville (1933) observed *C. compressa* in rock pools of ''Cap Oullestrell'', between ''Anse du Troc'' and ''Cap l'Abeille'', and also in Collioure.

Feldmann (1937a) cited the species as very abundant in the Albères coast. He collected specimens in ''Ile Grosse'', ''Cap d'Osne'', ''Anse du Troc'', and ''Anse des Elmes'' (Feldmann Herbarium). From the 1950s until now, *C. compressa* has been observed and collected in the Albères coast (Guern, 1962; Gros, 1978. Meinesz Herbarium, France Herbarium, UB Herbarium, UdG Herbarium, Huvé Herbarium, Verlaque Herbarium). Gros (1978) noted that *C. compressa* is the only species of its genus which has colonized the artificial rocks of the port of Banyuls.

Currently *C. compressa* is extremely common along the Albères coast. The species was found in all its suitable habitats (shallow waters between 0 and 1 m depth and, occasionally, in the lower mediolittoral zone) in Collioure, Port-Vendres, Banyuls and Cerbère.

3.4. Cystoseira crinita (Desfontaines) Bory

Between 1905 and 1911, Sauvageau (1912) observed and collected numerous specimens of *C. crinita* in sheltered areas of Banyuls (''La Ginestière'', ''Anse du Troc'', ''Anse du Sana'') and he particularly noted its abundance in front of the Laboratoire Arago, mixed with *C. barbata* (Sauvageau Herbarium, Thuret Herbarium, France Herbarium). In 1926 a specimen was collected in Banyuls by Sauvageau (France Herbarium).

Feldmann and Davy de Virville (1933) observed *C. crinita* mixed with *C. foeniculacea* in some rock pools in Collioure. Feldmann (1937a) observed and collected specimens in Collioure, ''Anse des Elmes'', ''Anse du Troc'', ''Ile Grosse'' (Feldmann Herbarium, carnet de récolte) where the species was rather common in sheltered environments of the upper infralittoral zone, growing in rocky substrates or even over the rhizomes of *Cymodocea nodosa* (Ucria) Ascherson. It was usually associated to *C. barbata*, *C. foeniculacea* and *C. compressa*, but it was also found in the association of *C. elegans* (Feldmann, 1937b). Feldmann also collected *C. crinita* in 1950, 1962 and 1971 (Huvé Herbarium, France Herbarium, Feldmann: carnet de récolte).

Guern (1962) noted the species as abundant in the Albères coast. Meinesz and Verlaque collected specimens in the rock pools of Collioure in 1965, 1976 and 1981 (Meinesz Herbarium, Verlaque Herbarium). Boudouresque collected the species in 1975 in Banyuls (Verlaque Herbarium). Gros (1978) observed *C. crinita* in the east part of the ''Anse du Sana'' and in the south–west corner of the ''jetée'' of the ''Ile Grosse''. Knoepffler-Péguy et al. (1987) collected the species at ''Ile Grosse''.

C. crinita was still present in Banyuls in 1988 and 1989 (UdG Herbarium).

We did not find *C. crinita* in our surveys.

3.5. Cystoseira elegans Sauvageau

The first specimen of *C. elegans* was collected in 1891 in Cerbère (France Herbarium). Sauvageau (1912) observed and collected the species between 1906 and 1910, in sheltered areas of Banyuls (''Anse du Troc'', ''Ile Grosse'', ''Anse du Sana''), where *C. elegans* dominated *C. mediterranea*, and it was scarce in more exposed sites like ''Cap d'Osne'' or the exposed entrance of ''Anse du Troc'' (Sauvageau Herbarium, Thuret Herbarium, France Herbarium). Gontran Hamel collected a specimen in Banyuls in 1921 (Feldmann Herbarium).

Feldmann and Davy de Virville (1933) observed *C. elegans* in rock pools mixed with *C. compressa* and *C. foeniculacea* between ''Cap l'Abeille'' and the ''Anse du Troc''. Several specimens were collected by Feldmann in ''Anse des Elmes'', ''Anse du Troc'', ''Cap du Troc'' (Feldmann Herbarium, France Herbarium). He also observed the species in Collioure, ''Cap l'Abeille'' and Cerbère (''Anse de Terrambou'') (Feldmann, 1937a), and he collected one specimen at ''Ile Grosse'' in 1950 (Huvé Herbarium). According to Feldmann (1937a,b) *C. elegans* made extensive meadows at the innermost areas of the coves and other sites with medium to low water movement, down to 2–3 m depth; it was usually associated to *C. caespitosa* and *C. crinita*.

Guern (1962) only observed a small population in a sheltered area of the ''Ile Grosse'' and concluded that *C. elegans* was becoming rare in Banyuls since the observations of Sauvageau and Feldmann, although Boudouresque collected some specimens in 1975 and 1981 (Verlaque Herbarium). Gros (1978) noted the species again abundant in two populations around the ''Ile Grosse''; however he did not find the species in the ''Anse des Elmes'' nor in the ''Anse du Troc''. Coudret and Jupin (1985) collected *C. elegans* in Banyuls. The species was still present in Collioure in 1989 (UdG Herbarium).

We found only one specimen of *C. elegans* in the ''Anse des Elmes'' inside a population of *C. mediterranea*, *C. compressa* and *C. caespitosa.* A rather small population (less than 20 plants) was present in the left corner of the ''jetée'' of the ''Ile Grosse'', mixed with *C. caespitosa*.

3.6. Cystoseira foeniculacea (L.) Greville f. tenuiramosa (Ercegovic) Gómez Garreta et al. [= Cystoseira discors (L.) C. Agardh, Cystoseira ercegovicii Giaccone]

C. foeniculacea was first collected in 1883 by Sauvageau in Collioure (Thuret Herbarium). Sauvageau (1912) collected the species between 1906 and 1911 in shallow, sheltered environments near Banyuls (''Cale de Radoub'', ''La Ginestère'', ''Anse du Sana'') (Sauvageau Herbarium, Thuret Herbarium, France Herbarium). All these specimens correspond to the form *tenuiramosa* (Ercegovic) Gómez-Garreta et al., which occurs in shallow waters.

Feldmann collected the species in shallow sheltered deep rock pools and different shallow water sites near Banyuls (''Anse du Troc'', ''Cap du Troc'', ''Cap de l'Abeille'', ''South of Troc'', ''Anse des Elmes'', ''La Ginestière'') (Feldmann and Davy de Virville, 1933; Feldmann, 1937a; Feldmann: carnet de récolte). According to Feldmann (1937a) *C. foeniculacea* was often associated with *C. barbata*, *C. compressa* and *C. crinita*. He collected a specimen in 1950 at ''Ile Grosse'' (Huvé Herbarium). In 1962 and 1971 he collected the species in the rock pools of Collioure (France Herbarium; Feldmann: carnet de récolte). The species is also present in Meinesz Herbarium (1967) and Verlaque Herbarium (1981).

Gros (1978) noted a regression of *C. foeniculacea* as he only found the species in some rock pools of Collioure. Gómez-Garreta collected the species in the same place (UB Herbarium). The species was still present in this locality in 1988 and 1989 (UdG Herbarium).

We did not find this taxon during our surveys.

3.7. Cystoseira foeniculacea (L.) Greville f. latiramosa (Ercegovic) Gómez Garreta et al

Sauvageau (1912) found in June 1908 in the net of a fisherman two specimens looking like *Cystoseira foeniculacea* f. *latiramosa* (Sauvageau Herbarium: SA5388, SA5392) Sauvageau (1912) also cited that C. Flahaut collected similar specimens in the ''Anse du Troc'' at 6–10 m depth , and in ''Cap Cerbère'' at 30 m depth in October 1886.

We did not find this taxon during our surveys.

3.8. Cystoseira funkii Schiffner ex Gerloff et Nizamuddin (= Cystoseira mediterranea var. valiantei Sauvageau, pro parte)

Sauvageau (1912) collected in 1908–1909, some plants from deep waters that he attributed to *C. mediterranea* var. *valiantei* (Sauvageau Herbarium: SA4441-4442, SA4444-4447; Thuret Herbarium: TA7617). He collected specimens from nets or trawls at 15–20 m depth (''Anse du Troc'', ''Cap de l'Abeille'').

Feldmann also dredged some plants from Cap Béar and Cap l'Abeille in 1932, 1933 and 1937 that were attributed to *C. mediterranea* var. *valiantei* (Feldmann Herbarium: classeur 38–34). They were collected by 12–30 m depth, together with *C. spinosa* and *Cystoseira zosteroides* (Feldmann, 1937a).

After a careful revision of these specimens held in Sauvageau, Thuret and Feldmann Herbaria, we concluded that some of them correspond to *Cystoseira funkii* as described by Gerloff and Nizamuddin (1976) and suggested by Verlaque et al. (1999). The specimens that unequivocally correspond to *C. funkii* are TA7617 (Thuret Herbarium), FAB4464-4465 and FAB4468-4472 (Feldmann Herbarium, classeur 38).

We did not find this species.

3.9. Cystoseira mediterranea Sauvageau

Gomont collected specimens of *C. mediterranea* in Cerbère already in 1891 (France Herbarium). Between 1904 and 1911, Sauvageau (1912) described and collected, at different months, the very abundant *C. mediterranea* in Banyuls, near the lighthouse (''Cap d'Osne''), all around the ''Ile Grosse'', at the entrance of the ''Anse du Troc, ''le musoir de la jetée'', on the cliffs between the ''Ile Grosse'' and the ''Anse du Troc'', and also in Port-Vendres above the ''Lazaret'' (Sauvageau Herbarium, Thuret Herbarium, France Herbarium). In 1921, Hamel collected specimens in the ''Anse du Sana'' (Feldmann Herbarium).

According to Feldmann (1937a,b) the species was very abundant all along the Albères coast, and described the association of *C. mediterranea*, being characteristic of the exposed rocky areas, between 0 and 1 m depth. He observed and collected specimens on the ''Cap Oullestrell'', ''Anse du Sana'', ''Anse des Elmes'', ''Cap d'Osne'', ''Ile Grosse'', ''Le Troc'', ''Anse du Troc'', Collioure, ''Cap Cerbère'', ''Cap Béar'', ''Cap l'Abeille'', during different field trips (Feldmann, 1937a,b; Feldmann and Davy de Virville, 1933; Feldmann Herbarium, Feldmann: carnet de récolte). Hamel collected specimens in 1932, 1934 and 1937 (Exsicattas Hamel).

Several studies concerning *C. mediterranea* (Guern, 1962; Péguy, 1965) or its community (Boudouresque, 1969) were performed during the 1960s, when the species was still qualified as abundant in the Albères coast. Several specimens were collected between the 1960s and the 1980s (Huvé Herbarium, Verlaque Herbarium, UB Herbarium). However, Knoepffler-Péguy (1973) noted that *C. mediterranea* populations were regressing. Gros (1978) also observed *C. mediterranea* populations at the ''Ile Grosse'' but noted that they were less abundant than reports by Sauvageau and Feldmann. Gros (1978) stated that mussel belts had almost completely replaced*C. mediterranea*, particularly on the exposed sites between the ''Ile Grosse'' and ''Cap de l'Abeille''.

During our survey we found *C. mediterranea* in the coasts of Collioure, Port-Vendres, Banyuls and Cerbère (Figs. 2–6). The species is very common but regular dense populations are rare. Considering that the total length of the rocky coast between Collioure and Cerbère measures 38 km, *C. mediterranea* is present in only 19 km. Mussels (*Mytilus galloprovincialis* Lamarck, 1819) are extremely abundant and form dense belts from 1 m depth to 1 m above the sea level, sometimes mixed with *C. mediterranea* and *Corallina elongata* Ellis and Solander (Corallinales, Rhodophyceae).

3.10. Cystoseira mediterranea var. valiantei Sauvageau

Sauvageau (1912) described the variety *valiantei* of *C. mediterranea* from specimens collected both in shallow and deep waters in Banyuls. The re-examination of a specimen collected in shallow waters at the ''Ile Grosse'' (Sauvageau Herbarium: SA4443) showed that it unequivocally corresponds to *C. mediterranea*, as it is the case for the specimen collected in July 1981 by Boudouresque, near the sea level in Banyuls and kept in Verlaque Herbarium (H2765) (Verlaque et al., 1999). Whether these specimens merit the rank of variety requires further investigation. Sauvageau's deep water specimens belong to *C. funkii* (cf. *C. funkii*).

3.11. Cystoseira sauvageauana Hamel (= Cystoseira selaginoides auct., non C. selaginoides Nacc.)

P. Oliver collected the first specimen of *Cystoseira sauvageauana* in 1883 in Collioure, ''Les Batteries'' (Thuret Herbarium). Sauvageau (1912) collected the species mixed with *C. mediterranea* and *C. compressa*, only in Port-Vendres, in 1906–1907; according to his observations the population was restricted to few m^2 in the Lazaret. Feldmann collected one specimen in Collioure in 1937 (Feldmann Herbarium). Since then, *C. sauvageauana* has not been observed again in the Albères coast.

3.12. Cystoseira spinosa Sauvageau v. spinosa

The first specimens of *C. spinosa* of the Albères coast were collected in 1883–1884 in Collioure by P. Oliver (Thuret Herbarium). Sauvageau (1912) studied specimens collected by Charles Flahaut in Banyuls and Cerbère and he collected by hand from 1906 to 1908 and 1910 *C. spinosa* in Banyuls near the surface at 1–1.5 m depth (''Ile Grosse'', ''Cap d'Osne'', ''Anse du Sana'', ''Anse du Troc'') (Sauvageau Herbarium, Thuret Herbarium). According to Sauvageau (1912) and Feldmann (1937a) the shallow water form of *C. spinosa* (which corresponds to var. *spinosa*) is found as isolated specimens in sheltered, shadow sites close to the surface (crevices, deep rock pools).

Feldmann collected *C. spinosa* in 1921 (''Anse du Sana'') (carnet de récolte) and in 1950 (''Ile Grosse'') (Huvé Herbarium). Gros (1978) noted that Knoepffler-Péguy collected a specimen near the surface in the 1964 in ''Cap l'Abeille'' but he did not find again *C. spinosa*

in this area. Boudouresque also collected one specimen at "Ile Grosse" in 1975 (Verlaque Herbarium).

We did not find the species in our surveys.

3.13. *Cystoseira spinosa var. compressa (Ercegovic) Cormaci, Furnari, Giaccone, Scammacca and Serio*

Sauvageau (1912) already noticed some morphological differences between deep-water and shallow-water plants of *C. spinosa*, but he did not describe any new taxon for them. Cormaci et al. (1992) described these deep water plants as a new variety of *C. spinosa* (*compressa*). Sauvageau (1912) observed specimens, held in Montpellier Herbarium, collected by Charles Flahaut in 1886 around 30 m depth at "Cap l'Abeille", "Cap Cerbère" and "Cap Peyrefite". He also collected deep-water specimens of *C. spinosa* from "Cap l'Abeille" between 10 and 20–30 m depth and "Cap du Troc" between 6 and 15 m depth in 1907 (Sauvageau, 1912; Sauvageau Herbarium).

Feldmann collected *C. spinosa* in several places ("Cap d'Osne", "Le Troc", "Cap l'Abeille", "Cap Rédéris", "Cap Béar", "Cap Cerbère") (Feldmann Herbarium; Feldmann: carnet de récolte). According to Feldmann (1937b) *C. spinosa* formed extensive populations over rocky bottoms between 10 and 35 m depth, mixed with *C. zosteroides* and *Sargassum hornschuchii* along the Albères coast. In fact, he described an "Association à *C. spinosa* et *C. zosteroides*", very rich in algal species (he reports more than 150 species), which was present everywhere where there was rocky substrata below 10 m depth (Feldmann, 1937b).

During the end of 1960s and 1970s different specimens were dredged in "Les Roches Toreilles", below 30 m depth (Combault et al., 1976, Meinesz Herbarium; France Herbarium; Verlaque Herbarium). Guern (1962) noted that *C. spinosa* was rare in deep waters, but Vidal (1967) collected *C. spinosa* in the "Roches Toreilles", "Roches St. Laurent" and "Plateau St. Nazaire", being more abundant than *C. zosteroides*. Some years later, Gros (1978) reported that *C. spinosa* was extremely rare in deep waters, and he noticed that *C. zosteroides* was far more abundant, at least in "Roches Toreilles".

We did not observe *C. spinosa* var. *compressa* in our dives, although we have search it in almost all sites where *C. spinosa* was previously reported from deep waters ("Cap Oullestrell", "Cap Castell", "Cap l'Abeille", "Cap du Troc", "Cap Peyrefite", "Cap Rédéris", "Iles Campagies", "Cap Cerbère", "Roches Toreilles").

3.14. *Cystoseira zosteroides (Turner) C. Agardh (= Cystoseira opuntioides Bory in Montagne)*

Between 1907 and 1908, Sauvageau collected specimens of *C. zosteroides* coming from nets, dredges or wrecked on the beach in Banyuls (Sauvageau Herbarium, Thuret Herbarium).

Feldmann (1937a,b) reports *C. zosteroides* from different localities in Banyuls, always associated to *C. spinosa*, between 10 and 40 m depth. He collected specimens by dredging in "Cap Béar" 15–28 m (1932, 1934), "Cap Cerbère" 30–35 m (1932, 1939, 1962, 1972), "Cap du Troc" (1932), between the "Cap du Troc" and "Cap l'Abeille", 20 m (1932), "Cap l'Abeille" (1931, 1937), between "Cap Oullestrell" and "Cap Castell" (1932), "Cap Oullestrell" 10–12 m (1932) (Feldmann Herbarium; Feldmann: carnet de récolte).

Also from Banyuls are the specimens kept in Meinesz Herbarium (year 1962), Verlaque Herbarium ("Les Roches Toreilles", year 1965) and Feldmann Herbarium held in Laboratoire Arago ("Les Roches Toreilles", year 1963; "Cap l'Abeille", year 1969; carnet de récolte). Vidal (1967) collected *C. zosteroides* in "Les Roches Toreilles", "Roches St. Laurent" and "Plateau St. Nazaire", mixed with the abundant *C. spinosa*.

Gros (1978) qualified *C. zosteroides* as abundant in Banyuls and in "Les Roches Toreilles" (5–15 thallus m^{-2}), living in very turbid conditions (few meters of visibility). He observed a dozen specimens of *C. zosteroides* at the "Ile Grosse" (15 m), on pebbles in the "Cap du Troc" (20 m), "Cap l'Abeille" (19 m), and between "Cap Castell" and "Cap Oullestrell" (between 15 and 20 m). The UB Herbarium and the UdG Herbarium held specimens collected in Banyuls between 1988 and 1992.

We dived in all the locations known as previously hosting *C. zosteroides*. The only site where we found a dense population of *C. zosteroides* is at the South of "Cap Oullestrell" (Port Vendres), in the place known by divers as "Les roches de Paula"; a forest of *C. zosteroides* covers the flat rocks emerging from sand between 20 and 22 m depth. The plants, around 20 cm high, are highly branched with numerous tophules. We also observed abundant specimens of *C. zosteroides* between "Cap Castell" and "Cap Oullestrell", growing on flat rocks (arising at 2–3 m high from the sand). In other places ("Cap Peyrefite" at 20 m, "Cap l'Abeille" at 20–22 m, "Iles Campagies" at 18–22 m, "Cap Cerbère", between 12 and 22 m), *C. zosteroides* can be considered rare or very rare since only few (2–20), small, individuals were found after 30 diving for each location by two expert divers.

3.15. *Sargassum acinarium (Linnaeus) C. Agardh (= Sargassum linifolium C. Agardh)*

Feldmann (1937a) identified as *Sargassum linifolium* a specimen wrecked at "Ile Grosse" in 1931 and another specimen dredged at "Cap l'Abeille" in 1932 (Feldmann Herbarium, classeur 104: FAB6816-6817). Among specimens identified as *Sargassum salicifolium* J. Agardh f.

diversifolia (Bory) Grunow in Feldmann Herbarium (classeur 104) at least a fertile specimen FAB6845, dredged from "Banyuls", belongs to *S. acinarium*. There are other fertile specimens of an unidentified *Sargassum* in Feldmann Herbarium (classeur 104), dredged in June–July 1937 from "Cap Béar", "Cap l'Abeille" and "Cap Oullestrell" (FAB6835-6838), which probably also correspond to *S. acinarium*.

We did not find the species in our surveys.

3.16. Sargassum hornschuchii C. Agardh

Specimens of *S. hornschuchii* in Feldmann Herbarium need taxonomical re-examination. According to Feldmann, the first specimens of *S. hornschuchii* observed along the Albères coast were collected in 1927 at the "Cap d'Osne". Then he collected dredged specimens in "Cap Béar" and between "Cap l'Abeille" and "Cap Rédéris" in 1931, "Cap Peyrefite", "Cap l'Abeille" (20–25 m), "Cap du Troc", between "Cap l'Abeille" and "Cap du Troc" (20 m) in 1932, "Cap Cerbère" (1933), "Cap Oullestrell", "Cap l'Abeille" (20–30 m) and "Cap Béar" in 1937, "Cap du Troc" in 1955 (Feldmann Herbarium; Feldmann: carnet de récolte). According to Feldmann (1937a) *S. hornschuchii* was rather frequent between 15 and 30 m depth, amongst *C. spinosa*.

Nobody else observed this species in the Albères coast. We did not find it in our surveys.

3.17. Sargassum vulgare C. Agardh [= Sargassum vulgare var. megalophyllum (Mont.) Vickers]

Sauvageau collected *Sargassum vulgare* in 1906 in Banyuls (Thuret Herbarium) and he observed a specimen collected on the beach by M. Joubin in the "Anse du Troc" in 1907 (France Herbarium).

According to Feldmann (1937a,b) *S. vulgare* (as var. *megalophyllum*) was frequent in summer near the sea level, on moderately exposed rocks and in rock pools opened to the sea. He collected the species in "Cap du Troc", "Le Troc", "Ile Grosse", "Cap Béar" and Collioure (Feldmann Herbarium).

We did not find *S. vulgare* during our surveys.

4. Discussion

According to our surveys, in the Albères coast there are only five species of Fucales left of fourteen that were reported in the first thirty years of the XXth century by Sauvageau (1912) and Feldmann (1937a,b), or the nine species reported twenty-five years ago by Gros (1978) (Table 2). Therefore, we confirm the steady decrease of the Fucales populations along the Albères coast and the total collapse of the genus *Sargassum* already pointed out by Gros (1978). The setting is even worst when we consider that seven taxa now extinct (*C. crinita*, *C. barbata*, *C. foeniculacea* f. *tenuiramosa*, *C. spinosa*, *C. spinosa* v. *compressa*, *S. hornschuchii* and *S. vulgare*) were considered frequent or abundant by Feldmann (1937a,b) and some of these species were the dominant and engineering species in several phytobenthic associations described at this time. Moreover, only one of the five species left shows no signs of regression (*C. compressa*), two are considered as rare (*C. caespitosa*, *C. zosteroides*), and one is very rare (*C. elegans*). *C. mediterranea*, a species that was reported to make a continuous belt along the shores of the Albères coast (Feldmann, 1937a,b) and to be very abundant in, for

Table 2
Status of the Fucales species on the Albères coast

Species	Abundance				Trend
	Sauvageau (1912)	Feldmann (1937a,b)	Gros (1978)	This study	
C. barbata	F	F	R	–	Extinct
C. caespitosa	F	F	R	R	Decrease
C. compressa f. *compressa*	VA	VA	VA	VA	=
C. crinita	F	F	R	–	Extinct
C. elegans	F	F	R	VR	Nearly extinct
C. foeniculacea f. *latiramosa*	R	–	–	–	Extinct
C. foeniculacea f. *tenuiramosa*	F	F	R	–	Extinct
C. funkii	R	R	–	–	Extinct
C. mediterranea	VA	VA	A	A	Decrease
C. sauvageauana	R	VR	–	–	Extinct
C. spinosa var. *compressa*	A	A	VR	–	Extinct
C. spinosa var. *spinosa*	R	?	VR	–	Extinct
C. zosteroides	F	F	F	R	Decrease
S. acinarium	?	R	–	–	Extinct
S. hornschuchii	?	F	–	–	Extinct
S. vulgare	R	F	–	–	Extinct

A: abundant, F: frequent, R: rare, VA: very abundant, VR: very rare, ?: unknown; –: not reported.

example, the "Ile Grosse" and at the entrance of the "Baie du Troc" (Sauvageau, 1912), is now far less abundant and has almost disappeared from some areas as "Ile Grosse".

There are probably several reasons for the observed decrease in the populations of *Cystoseira* and *Sargassum*. Eutrophication could be one of them. However, Lefèvre et al. (1997) concluded that there is no systematic eutrophication in the Gulf of Lions due to the considerable increase (50% over the last two decades) of the nitrate concentration in the Rhône river outflows. Also, the amount of urban waste-waters being released in the Albères coast is reduced in comparison with other Mediterranean areas and they are mostly released in deep waters far from the shoreline. Grémare et al. (1998) concluded that eutrophication was probably not driving the observed changes in macrobenthic soft bottom communities in the Albères coast.

Grémare et al. (1998) considered that the only significant source of contaminants were associated to agricultural pest controls. Gros (1978) suggested that chemical pollution coming from the products used to treat the main agricultural crop of the region (vineyards) could be responsible for disturbing *Cystoseira* populations. Freshwater analyses have revealed the presence of numerous herbicides and pesticides (Réseau Satese, unpublished data). Also Marcot-Coqueugniot (1983) reported a dramatic increase of chemical pollution in Port-Vendres by the end of the 1970s. Unfortunately, there are no experimental evidences on the effects of all these chemicals in *Cystoseira* or *Sargassum*. Both shallow and deep-water species of these genus can be equally affected by chemical pollution.

The increase of water turbidity in the last thirty-five years (Guille, 1970; Gros, 1978) can be the result of an increase in suspended sediment in the water, an increase in suspended particulate organic matter (POM), or both. In fact, the increase in the extension of mussel beds already noticed by Gros (1978) seems to point to an increase of POM (Bellan-Santini, 1965). Feldmann (1937b) already reported the development of a dense mussel bed on exposed rocks close to a waste-water outfall. Gros (1978) reported the replacement of the belt of *C. mediterranea* by a mussel bed of *Mytilus galloprovincialis* Lamarck 1819. Mussels seem to decrease the settlement probability and survival of *C. mediterranea* juveniles because of the instability of the mussel support or to the lack of light for plantules which have reached the rock (Gros, 1978).

Water turbidity can also be enhanced by an increase in suspended inorganic particles. However, Grémare et al. (1998) concluded that there is not any evidence of an increase in particle input of biogenic, atmospheric, or river origin in the Albères coast during the last fifty years, but they found that the increase of easterly winds during the period 1965–1990 could result in strongest resuspension events that could lead to increased water turbidity. Grémare et al. (1998) also reported an increased trawling activity since the 1960s that, even if performed offshore, it can be an important source of resuspended particles (Palanques et al., 2001). Any increase in turbidity can easily affect *Cystoseira* and *Sargassum* species living in deep waters. The higher photosynthetic efficiency and lower saturation and compensation irradiances of *C. zosteroides* in relation to *C. spinosa* var. *compressa* (Sant, 2003) could explain the progressive replacement of *C. spinosa* var. *compressa* by *C. zosteroides* that took place between the 1940s and the 1970s (Guern, 1962; Vidal, 1967; Gros, 1978). The total collapse of *C. spinosa* var. *compressa* at the end of the 1970s (Gros, 1978) and the maintenance of at least some populations of *C. zosteroides* strongly support the hypothesis of a progressive change in water turbidity.

Overgrazing by sea urchins is another, frequent, cause of demise of *Cystoseira* forests, mainly in sheltered or deep-water environments (Verlaque, 1987; Arrighi, 1995; Sala et al., 1998). It is well known that *Paracentrotus lividus* Lamarck 1816, feeds preferentially on erect algae and particularly on *Cystoseira* and *Sargassum* species (Verlaque and Nédelec, 1983; Verlaque, 1984; Knoepffler-Péguy et al., 1987; Frantzis et al., 1988). Gros (1978) already noted the overgrazing of communities of *Cystoseira* from sheltered habitats by sea urchins in places where Feldmann (1937a,b) reported *Cystoseira* forests. Overfishing of predators of sea urchins (mainly Labridae and Sparidae; Sala, 1997) has been blamed as the most important factor affecting density of *Paracentrotus lividus* populations (Sala et al., 1998). Sparidae (*Diplodus* spp.) are the main capture of professional fishermen and *Coris julis* Linnaeus 1758 (Labridae) is the main target fish for anglers inside and around the MPA (artisanal fishing and angling are allowed everywhere except in the integral MPA) (Bell, 1983; Dufour et al., 1995). Also, the uptake of *Paracentrotus lividus* for consumption is prohibited since 1974 inside the MPA and since 1996 outside it. Moreover, increase in domestic pollution (POM) increases sea urchin population (Harmelin et al., 1981). Probably the concurrence of these three reasons (overfishing of sea-urchin predators, prohibition of sea-urchin collection, POM increase) has lead to an overcrowding of sea urchins all along the Albères coast. We measured a mean (±s.e) *Paracentrotus lividus* density of 84.1 ± 12.8 ind m^{-2} ($n = 18$) of a mean size of 3.1 ± 0.1 cm ($n = 27$) in shallow waters of the "Ile Grosse" and "Cap du Troc", a figure that can be extrapolated to most of the Albères coast. The MPA has also increased the densities and individual size of the herbivorous fish *Sarpa salpa* (Ferrari, personal communication), which has *Cystoseira* spp. as a preferential food (Verlaque, 1990). Therefore, it seems reasonable that overgrazing has also contributed to the

regression or total collapse of most of the species inhabiting sheltered environments (*C. barbata*, *C. caespitosa*, *C. crinita*, *C. elegans*, *C. foeniculacea* var. *tenuiramosa*, *C. spinosa*, *S. vulgare*).

Although very impressive in some European Mediterranean shores (Meinesz and Lefèvre, 1978), habitat destruction is limited in the Albères coast. However, the construction of the port of Banyuls (1970s), in front of the Laboratoire Arago, caused the elimination of some stands of *C. barbata* and *C. crinita* and has also caused changes in the *Cystoseira* populations in the Bay of Banyuls (Gros, 1978). The construction of a parking adjacent to the harbour in the 1980s completely modified some rock pools with *Cystoseira* stands and the immediate "Anse de la Ginestère", sampled by Sauvageau and Feldmann was completely filled with rocks causing the elimination of *C. barbata*, *C. crinita* and *C. elegans*. The "Cale de Radoub" was destroyed during the second World War.

Scientific research can also be blamed for the decrease in some *Cystoseira* populations. This is the case of *C. elegans*in the "Ile Grosse" which was almost eradicated for chemical studies (Knoepffler-Péguy, personal communication). Intensive sampling by students of marine training course during 50 years in the rock pools of Collioure has also reduced the populations of *Cystoseira* spp. (Rodríguez-Prieto, personal communication). *C. sauvageauana* was described as abundant in the entrance of Port-Vendres but its distribution was reduced to few m^2 (Sauvageau, 1912). Sauvageau collected between 1906 and 1907 at least 60 specimens that are now held in different herbaria, probably wiping out the entire population.

Experimental studies performed in the MPA of Ustica Island (Italy) have demonstrated that human trampling can strongly affect canopy algae of the genus *Cystoseira* in shallow environments (Milazzo et al., 2002). Therefore, human trampling could be an important disturbance in some areas of the Albères coast, as it also hosts a MPA which attracts a lot of tourists. The large amounts of nets that are being thrown every day all along the coast can also have an effect on deep-water *Cystoseira* species, since it is known that these plants are easily pulled up from the bottom by fishing nets in stormy weather (Sauvageau, 1912; Feldmann, 1937a). Even very low extraction rates can be crucial for the maintenance of deep-water *Cystoseira* populations, due to the long life spans, low recruitment levels, and low growth rates of these species (Ballesteros et al., 2002).

A question arising from our findings is if the observed decline of *Cystoseira* and *Sargassum* populations in the Albères coast is a local problem or if it is also happening in adjacent coasts. Extensive rocky bottoms do not exist north of the Albères coast, at least for more than 180 km, and therefore there are no Fucales. The Albères coast extends to the south in the huge rocky coast of Cap de Creus (Spain), where the available historical data is very scarce. However, Sauvageau (1912) reported shallow-water populations of *C. barbata*, *C. caespitosa*, *C. compressa*, *C. foeniculacea*, *C. sauvageauana* and *C. spinosa* from Port-Lligat, and *C. barbata*, *C. crinita*, *C. compressa C. foeniculacea*, *C. sauvageauana* and *C. elegans* from Roses, with vouchers conserved in Sauvageau and Thuret Herbaria (Seoane-Camba, 1975). Regular monitoring of these sites from 1992 (Water Catalan Agency, unpublished data) has shown that only *C. compressa* is present now and there are no traces of the other species. Cormaci and Furnari (1999) also found the local extinction of shallow-water (*C. crinita*, *C. foeniculacea*, *Cystoseira humilis*) and deep-water (*C. spinosa*, *S. acinarium*, *S. hornschuchii*) species of Fucales in the Tremiti islands. Therefore, available data suggests that the current decline of Fucales in the Albères coast is a widespread problem, at least in several Mediterranean areas. Ecological consequences are huge since the disappearance of these structural and engineering species involves the loss of entire communities, the regression of other species, and the homogenization of the underwater landscape.

Degradation of the environmental conditions does not seem to stop, and conditions for the remaining *Cystoseira* species will be worst in the future years. Natural restoration of communities dominated by Fucales will probably be very long, even after the removal of the causes that led to its regression or its complete collapse. Mats of algal turfs or mussel beds that colonize the substratum after the demise of Fucales drastically inhibit its recruitment and prevent the reinstallation of *Cystoseira* (Huvé, 1960; Gros, 1978; Benedetti-Cecchi and Cinelli, 1996). Colonization by zygotes coming from other populations seems not possible, since the decline has also affected populations from nearby areas and zygotes are very large (Guern, 1962), being probably unable to disperse over long distances (Soltan et al., 2001). Thus, unless strong environmental amelioration and human-mediated restoration, most of the Fucales populations remaining in the Albères coast face a most unwelcome prospect and there are no chances at all for restoration of extinct populations.

More environmental data is needed to state precisely which are the causes leading to the decline of *Cystoseira* spp. and *Sargassum* spp. populations in the Albères coast. We urge local administrations and managers of the MPA to begin an exhaustive monitoring of year-round physico-chemical characteristics of coastal waters as well as of all the chemicals and urban waste-waters that are being thrown to the sea. Experimental data is also needed on the effects of organic and chemical pollution to different species of Fucales. The importance of sea urchins, mussels, and turf algae as organisms that can kill out or outcompete species of *Cystoseira* or

Sargassum thriving in shallow-waters has been highlighted in this and other studies (e.g. Gros, 1978; Verlaque, 1987; Benedetti-Cecchi and Cinelli, 1996) but need further attention; management measures designed to decrease densities and strength of these organisms will probably improve the state of the remaining populations of Fucales.

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