Sci. Rep. Port-Cros natl. Park, 33: 179-214 (2019)

Mediterranean seaweeds listed as threatened under the Barcelona Convention: A critical analysis

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Abstract. The modern biodiversity crisis, the seventh extinction, is different from the six former crises in that one species, Man, is alone responsible, rather than volcanic and astronomic events. In addition to species that have become extinct due to human activity, an increasing number of species are threatened (critically endangered, endangered, vulnerable and rare species). The IUCN Red List of threatened species, together with the European Union (EU) Habitats Directive and international conventions, largely ignore marine species. The reason could be that these organisations are dominated by terrestrial taxonomic lobbies. Here, the authors focus on macroalgae, a customary ensemble of multicellular photosynthetic organisms, which is actually polyphyletic and encompasses three classes: Ulvophyceae ('green algae') and Florideophyceae ('red algae') (kingdom Archaeplastida) and Phaeophyceae ('brown algae') (kingdom Stramenopiles). In order to offset the huge imbalance between the treatment of threatened species in the terrestrial and marine realms, by the 1980s Mediterranean marine biologists had proposed a number of marine species for inclusion on red lists and for legal protection. Highly conservative lists of 11 species, then of 47 species, were included within Annex II ('endangered and threatened species') of the Barcelona Convention (Mediterranean Action Plan of the United Nations): the Ulvophyceae *Caulerpa prolifera* (as *C. ollivieri*), the Florideophyceae *Beckerella dentata, Felicinia spathulata, Gymnogongrus crenulatus, Lithophyllum byssoides, Schimmelmannia schousboei, Sphaerococcus rhizophylloides, Tenarea tortuosa, Titanoderma ramosissimum* and *T. trochanter,* and the Phaeophyceae *Cystoseira abies-marina, C. algeriensis, C. amentacea, C. barbata, C. barbatula, C. brachycarpa, C. corniculata, C. crinita, C. crinitophylla, C. dubia, C. elegans, C. foeniculacea, C. funkii, C. humilis, C. hyblaea, C. jabukae, C. mauritanica, C. mediterranea, C. micheleae, C. montagnei, C. nodicaulis, C. pelagosae, C. rayssiae, C. sauvageauana, C. schiffneri, C. sedoides, C. squarrosa, C. susanensis,, C. tamariscifolia, C. usneoides, C. zosteroides, Fucus virsoides, Laminaria rodriguezii, Sargassum acinarium, S. flavifolium, S. hornschuchii* and *S. trichocarpum*. Unfortunately, this list is a mix on one hand of species that are far from threatened (e.g. *Cystoseira amentacea*) and in some cases could even take benefit from human impact and global warming (e.g. *Caulerpa prolifera*), and on the other of species that are on the brink of extinction (e.g. *Sargassum acinarium* and *S. hornschuchii*). In any case, this question is beside the point since, unlike terrestrial species, which benefit from legal protection, these marine species do not benefit from legal protection, in France as in most Mediterranean countries. It is quite astonishing that some marine species, 1 000 to 10 000 times rarer than terrestrial protected species, which have disappeared from a number of regions and are on the brink of extinction elsewhere, like a marine equivalent of the giant panda, do not benefit from any legal protection status, in France or in most of the 21 Mediterranean countries that have signed the Barcelona Convention. The cases of *Sargassum acinarium* and *S. hornschuchii* exemplify this situation, almost to the point of caricature; this is what Thibaut *et al.* (2016a) referred to as 'the *Sargassum* conundrum'.

Keywords: Barcelona Convention, Bern Convention, habitats Directive, macroalgae, Mediterranean, protected species, threatened species.

Résumé. **Les macroalgues méditerranéennes menacées de la Convention de Barcelone : une analyse critique**. La crise moderne de la biodiversité constitue la septième extinction majeure dans l'histoire de la vie sur Terre ; elle diffère des six crises qui l'ont précédée par le fait que c'est une espèce, l'Homme, qui en est le seul responsable, et non (en particulier) des épisodes de volcanisme ou la collision avec des astéroïdes. En plus des espèces éteintes du fait de l'Homme, un nombre croissant d'espèces sont menacées (en danger critique, en danger, vulnérables et rares). Il est important de noter que, sans être éteintes, un certain nombre d'espèces sont éteintes localement (dans une région, par exemple la Provence) ou éteintes fonctionnellement (elles sont devenues trop rares pour jouer le rôle qui était le leur dans le fonctionnement des écosystèmes).

La liste rouge des espèces menacées de l'IUCN (Union internationale pour la conservation de la nature), de même que la Directive habitats de l'Union Européenne (UE), et les conventions internationales telles que la Convention de Berne (Convention relative à la conservation de la vie sauvage et du milieu naturel de l'Europe) et la Convention de Barcelone (Convention pour la protection du milieu marin et du littoral de la Méditerranée), ignorent largement ou totalement les espèces marines autres que les oiseaux marins, les mammifères marins et les tortues marines. La raison pourrait être que ces organismes internationaux sont dominés par des représentants des lobbies taxonomiques terrestres. Dans le cadre du présent travail, les auteurs ont focalisé leur attention sur les macroalgues, un ensemble coutumier d'organismes photosynthétiques pluricellulaires qui est en fait polyphylétique ; cet ensemble correspond à trois classes : Ulvophyceae ('algues vertes') et Florideophyceae ('algues rouges'), ces deux dernières dans le règne des Archaeplastida, et Phaeophyceae ('algues brunes'), appartenant au règne des Stramenopiles.

De façon à tenter de corriger l'énorme déséquilibre qui existait dans le traitement des espèces menacées, entre le milieu terrestre et le milieu marin, dans les années 1980s, des biologistes marins méditerranéens ont établi une première liste d'espèces menacées, afin qu'elles soient incluses dans les listes rouges et reçoivent un statut de protection légale. Dans les années 1990s, cette démarche s'est poursuivie, dans le cadre des conventions de Berne et de Barcelone. Finalement, une liste très restreinte de macroalgues a été incluse dans l'annexe II ('espèces en danger et menacées') de la Convention de Barcelone ; elle comportait au départ 11 espèces, nombre porté ensuite à 47 du fait de l'inclusion de toutes les espèces du genre *Cystoseira*: l'Ulvophyceae *Caulerpa prolifera* (sous le nom de *C. ollivieri*), les Florideophyceae *Beckerella dentata, Felicinia spathulata, Gymnogongrus crenulatus, Lithophyllum byssoides, Schimmelmannia schousboei, Sphaerococcus rhizophylloides, Tenarea tortuosa, Titanoderma ramosissimum* et *T. trochanter,* et les Phaeophyceae *Cystoseira abies-marina, C. algeriensis, C. amentacea, C. barbata, C. barbatula, C. brachycarpa, C. corniculata, C. crinita, C. crinitophylla, C. dubia, C. elegans, C. foeniculacea, C. funkii, C. humilis, C. hyblaea, C. jabukae, C. mauritanica, C. mediterranea, C. micheleae, C. montagnei, C. nodicaulis, C. pelagosae, C. rayssiae, C. sauvageauana, C. schiffneri, C. sedoides, C. squarrosa, C. susanensis,, C. tamariscifolia, C. usneoides, C. zosteroides, Fucus virsoides, Laminaria rodriguezii, Sargassum acinarium, S. flavifolium, S. hornschuchii* et *S. trichocarpum*. Malheureusement, cette liste est un mélange d'espèces qui sont loin d'être menacées (e.g. *Cystoseira amentacea*), et même qui pourraient tirer profit de l'impact de l'Homme et du réchauffement climatique (e.g. *Caulerpa prolifera*) et d'espèces qui sont réellement menacées, et même au bord de l'extinction (e.g. *Sargassum acinarium* et *S. hornschuchii*).

Quoi qu'il en soit des considérations qui précèdent, la question de la pertinence de cette liste d'espèces n'a pas de réelle importance puisque, contrairement aux espèces terrestres, dont des milliers bénéficient d'un statut de protection légale, aucune de ces espèces marines n'est effectivement protégée, en France et dans la plupart des pays méditerranéens signataires de la Convention de Barcelone. En effet, L'Annexe II établit une liste d'espèces menacées, mais il appartient aux États de leur accorder un statut de protection légale. Il est surprenant de constater que certaines espèces marines, qui sont 1 000 à 10 000 fois plus rares que certaines espèces terrestres effectivement protégées, qui ont disparu dans un grand nombre de régions et qui sont au bord de l'extinction ailleurs, équivalents marins du grand panda, ne bénéficient d'aucun statut de protection légale en France et dans la plupart des 21 pays qui

ont signé la Convention de Barcelone. Les cas de *Sargassum acinarium* et de *S. hornschuchii* sont exemplaires, presque caricaturaux, de cette situation ; c'est ce que Thibaut *et al.* (2016a) ont appelé 'l'énigme des sargasses'.

Mots-clés : Convention de Barcelone, Convention de Berne, Directive habitats, espèces menacées, espèces protégées, macroalgues, Méditerranée.

Introduction

For millennia, 'modern' Man was not aware of his ability to eliminate species. However, the Neanderthal *Homo neanderthalensis*, who occupied Europe when modern humans *Homo sapiens* first arrived there, was perhaps his first victim (Noonan *et al*., 2006; Pennisi, 2007). Many other species followed: the mammoth *Mammuthus primigenius*, the dwarf elephant of Sicily *Elephas falconeri*, the horse of Przewalski *Equus caballus przewalskii* in Western Europe, the deer *Megaloceros cazioti* in Corsica, etc. Certain authors have naively attributed these extinctions to the warming that followed the LGM (Last Glacial Maximum, 21 000 years BP), forgetting that 30 glaciation-deglaciation episodes had followed one another over a period of 2.5 Ma (millions of years); if this were indeed the cause, it would be hard to explain why it was only the last deglaciation, the one where modern Man was present, which caused massive extinctions.

More than 200 years ago, Jean-Baptiste de Lamarck, one of the precursors of the theory of evolution, which was to be developed later by Charles Darwin (1859), wrote: *'Animals living in the water, especially the sea waters are protected against the destruction of their species by man. Their multiplication is so rapid and their means of evading pursuit or traps are so great that there is no likelihood of his being able to destroy the entire species of any of these animals'* (Lamarck, 1809; translated from French; Gould, 1991). His confidence seems naively optimistic today (DeMaster *et al.*, 2001).

Man is now aware of his ability to cause the extinction of the species with which he coexists. Extinctions of species have marked the history of life on Earth. The oldest known crisis is that of 'Snowball Earth': 750-590 Ma ago (the crisis experienced several peak episodes), the Earth was covered by an ice cap, from the poles to the equator; this crisis was also the most severe that the Earth has ever known: life almost became extinct, and its survival (around volcanoes?) is an enigma (Kerr, 2000; Kirschvink, 2002; Kennedy *et al*., 2008). Five other crises occurred, due to asteroid impacts and/or to major volcanic episodes: the Late Ordovician crisis (438 Ma), the late Devonian crisis (370 Ma), the PT crisis (Permian-Triassic: 252 Ma), the crisis of the Triassic-Jurassic junction (215 Ma), and finally the KT crisis, between the Cretaceous and the Tertiary, 66 Ma ago; this latter crisis owes its celebrity to the extinction of the dinosaurs (Benton, 1995; De Wever, 2002; Boudouresque *et al.,*

2003; Rohde and Muller, 2005). Man is now responsible for a new crisis, the seventh extinction[1] (Lawton and May, 1995; Pimm *et al.,* 1995).

The IUCN Red List of threatened species

The International Union for the Conservation of Nature (IUCN) classifies species into a number of categories, depending on the degree of threat to them (IUCN, 2018):

- **(i)** Extinct species (**EX**). E.g. the great auk *Pinguinus impennis* that lived in the Mediterranean and in the North Atlantic.
- **(ii)** Species extinct in the wild (**EW**), only present in zoos or botanical gardens.
- **(iii)** Critically endangered species (**CR**), for which extinction may have become unavoidable, despite protection and management measures. This may be the case with the Mediterranean monk seal *Monachus monachus*.
- **(iv)** Endangered species (**EN**), which are in severe decline, but which can be saved from extinction through protection and management measures.
- **(v)** Vulnerable species (**VU**), for which decline is significant, but which are not threatened with extinction. This is the case of the magnoliophyte *Posidonia oceanica* (Boudouresque *et al.,* 2009).
- **(vi)** Rare species (**RA**), the decline of which is not proven, but which are vulnerable because of their scarcity. This category has been removed in the latest versions of the IUCN Red List, which is probably an error.
- **(vii)** Near threatened species (**NT**). This category makes it possible to satisfy the members of the 'taxonomic lobbies' (birds, bats, marine mammals, etc.) who have difficulty accepting that the species they like do not appear on the lists of threatened species.
- **(viii)** Low concern species (**LC**), i.e. species for which the risks are low.
- **(ix)** Insufficiently documented species – data deficient (**DD**).
- **(x)** Non-evaluated species (**NE**).

Without being extinct, species can be extinct locally or functionally. For example, the monk seal *Monachus monachus* is locally extinct in the western Mediterranean; although it survives in Turkey and Greece (eastern Mediterranean), it is functionally extinct, as the few individuals surviving there no longer play the role (top-predator) that the species once played in

[1] For many students and some scientists, who are unaware of the advances of Science over the last three decades, especially the discovery of the Snowball Earth crisis (the most severe crisis that the Earth has ever experienced), the current crisis is still named 'sixth extinction', as it was in the early 1990s.

the functioning of coastal ecosystems. Several species of *Cystoseira* (brown algae; Phaeophyceae) are extinct locally and/or functionally (see below).

The categories EW, CR, EN, VU and RA are grouped under the name of threatened species. It should be noted that the distinction between 'threatened species', a broad category, and 'endangered species', a more restricted sub-category of 'threatened species', was not made in earlier documents and publications. In addition, it should be emphasized that IUCN is dominated by terrestrial experts, so that most of the approximately 97 000 species assessed, out of the 1 750 000 currently described and accepted species, are terrestrial species (Guitton and Combes, 2006; IUCN, 2018). Marine species (apart from turtles, birds and marine mammals) are in the NE category (not evaluated), even when scientific data do exist. This is the case for all the species of seaweeds (macroalgae) mentioned below (NE for the IUCN); using the IUCN criteria, when possible, or 'expert judgement', we propose below, for each species, a category, specifying 'IUCN-like category'.

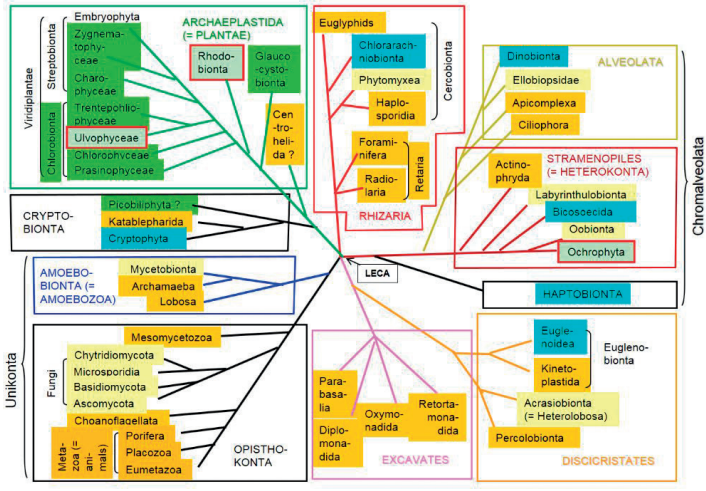


Figure 1. The phylogenetic tree of eukaryotes, much simplified. In the center, the last common ancestor (Last Eukaryotic Common Ancestor - LECA). The ten kingdoms (Archaeplastida, Alveolata, Opisthokonta, etc.) are enshrined in a rectangle. In green highlighting, taxa claimed by botanists; in ochre highlighting, the taxa claimed by zoologists; in yellow highlighting, the taxa claimed by the mushroom specialists; finally, in blue highlighting the taxa claimed by both botanists and zoologists (after Boudouresque *et al.,* 2015a). The macroalgae mentioned in the Barcelona Convention belong to three groups, framed in red: Ulvophyceae and Rhodobionta (kingdom Archaeplastida) and Ochrophyta (kingdom Stramenopiles).

Seaweeds (macroalgae) under the Barcelona Convention

The customary notion of macroalgae actually constitutes a polyphyletic complex within eukaryotes (Boudouresque, 2015; Boudouresque *et al.,* 2015a). The species that will be discussed here,

which are multicellular photosynthetic organisms, belong to three classes, very far apart in the phylogenetic tree of eukaryotes. **(i)** The **Ulvophyceae** (phylum Chlorobionta, subkingdom Viridiplantae) are part of what are commonly known as 'green algae'. **(ii)** The **Florideophyceae** (subkingdom Rhodobionta) are part of what are popularly called 'red algae'. Ulvophyceae and Florideophyceae belong to the kingdom Archaeplastida. **(iii)** Finally, the **Phaeophyceae** belong to the phylum Ochrophyta (= Chromobionta), within the kingdom Stramenopiles (= Heterokonta); they are popularly known as 'brown algae' (Fig. 1).

The Barcelona Convention (Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean; Mediterranean Action Plan of the United Nations), was signed in 1976 in Barcelona (Spain) and revised in 2009 in Marrakech (Morocco) (UNEP, 2000; United Nations, 2002; UNEP, 2009). The protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (with annexes of 24 November 1996) was signed in Barcelona on 10 June 1995 and entered into force on 12 December 1999. Annex II establishes a list of endangered or threatened (*sic*) species in the Mediterranean. Of the approximately 1 200 to 1 300 species of macroalgae present in the Mediterranean (Boudouresque, 2004; Coll *et al.,* 2010), this list includes 16 species, in addition to all representatives of the genus *Cystoseira*, with the exception of *Cystoseira compressa* (Esper) Gerloff & Nizamuddin, which is common and quite tolerant towards the quality of the environment. This Convention was transcribed into French law by Decree No. 2002-1454 of 9 December 2002, amended by Decree No. 2014-1195 of 16 October 2014, issuing the Protocol concerning Specially Protected Areas and Biological Diversity of Mediterranean Importance (SPAMI), which specifies: **(i)** '*The parties shall manage species of flora and fauna with the aim of maintaining them in a favourable state of conservation'*. **(ii)** '*The parties shall (…) identify and compile lists of the endangered or threatened species of flora and fauna and accord protected status to such species (…)*' (France, Ministère des Affaires Étrangères, 2002; France, Ministère des Affaires Étrangères et du Développement International, 2014).

As is the rule in international law, the ratification and transcribing of an international agreement at national level does not authorize any modification of the original text: neither amendment of the lists of species nor updating of the names of species (according to taxonomic nomenclature updates). Therefore, the list of endangered or threatened macroalgae of the Barcelona Convention has been transcribed *in extenso* in the national laws, without nomenclatural correction, nor adaptation to the specific national littoral situation (e.g. removal of absent species).

The list of threatened species of macroalgae in the Mediterranean is the result of a long process, the stages of which are described in Table

I. One of the lists (Boudouresque *et al.,* 1990; Jeudy de Grissac, 1991) comes from an international working group convened by UNEP (United Nations Environment Programme). Curiously, a species introduced from Japan, *Undaria pinnatifida* (Boudouresque *et al.,* 1985), was included in Belsher *et al.* (1987), as a result of the automatic, and of course irrelevant, application of the scarcity criterion. Similarly, species introduced from the Red Sea, *via* the Suez Canal (Ribera and Boudouresque 1995, Boudouresque and Verlaque 2002), or aquaculture (Verlaque 2001), were included in Boudouresque *et al.* (1990) (Table I). These introduced species were subsequently excluded by Boudouresque *et al.* (1996). Among the criteria used to place a species in these endangered species lists were a number of proven or potential threats (Table I): trawling, uprooting by fishing nets, overgrazing (usually a consequence of overfishing), hyper-sedimentation, trampling, pollution, turbidity, coastal urbanization and variation of salinity; observing a pronounced decline was also a criterion. Boudouresque *et al.* (1996) added the existence of protection measures at the level of a region or a country; although these protection measures could seem unjustified for specialists, the urgency of the moment meant that they were not disputed. Boudouresque *et al.* (1996) specified the degree of threat, on an empirical scale from 0 to 5.

A critical review of the 16 species of macroalgae other than *Cystoseira* (Phaeophyceae), as well as the 31 Mediterranean species of *Cystoseira*, other than *C. compressa*, of the Barcelona Convention, led us to make the following comments.

Ulvophyceae

Caulerpa ollivieri Dostál. This species was described from Villefranche-sur-Mer (French Riviera) by Dostál (1929), at a very inextensive site, and has been reported from a few other French Riviera localities (Ollivier, 1929; Meinesz, 1980). It has been observed subsequently at a few localities of the Balearic Islands, the Canary Islands, Libya and Turkey (Meinesz, 1980; González Henriquez and Santos-Guerra, 1983; Nizamuddin, 1991; Gallardo *et al.,* 1993). In the American tropical Atlantic, the species is considered as introduced from the Mediterranean (Lapointe *et al.,* 2005). However, according to González Henriquez and Santos-Guerra (1983), *C. ollivieri* is only a dwarf ecomorphosis of *C. prolifera* (Forsskål) J.V. Lamouroux. The species should therefore be excluded from the list because *C. prolifera* is a species that is neither threatened nor protected; it has even benefitted from the regression of the *Posidonia oceanica* seagrass meadows (e.g. in Liguria, Italy) and from global warming to increase its dominance and geographical extension (Bianchi and Morri, 1993, 1994; Boudouresque *et al.,* 2009). IUCN-like category: LC.

Table I. Threatened species of macroalgae in the Mediterranean Sea proposed for protection and mentioned in red lists, international documents or scientific articles (usually designated 'endangered or threatened'). +: cited. Putative threats: D: concerning decline. Tra: trawling. Net: uprooting by fishing nets. Trp: trampling. Pol: pollution. R: rare. Sal: variations of salinity. Sed: over-sedimentation. Ovg: overgrazing. Tur: turbidity. CD: coastal development. War: global warming.

	Belsher *et al.* (1987)	**Boudouresque *et al.* (1990)**	**Boudouresque (1995)**	**Boudouresque *et al.* (1996)**	**UNEP (2000)**	**Boudouresque (2003)**	**UNEP (2009)**
Concerned area	France	Mediterranean	Mediterranean	Mediterranean	Mediterranean	Mediterranean	Mediterranean
Ulvophyceae							
Acetabularia calyculus	-	Pol, R, Sal	-	-	-	-	-
Caulerpa mexicana	-	R (1)	-	-	-	-	-
Caulerpa ollivieri	CD, D, R	CD, D, R	CD	R, CD	+	-	+
Caulerpa chemnitzia	-	CD, R (1, 2)	-	-	-	-	-
Caulerpa scalpelliformis	-	Pol (1)	-	-	-	-	-
Parvocaulis parvulus	-	R (3)	-	-	-	-	-
Penicillus capitatus	R, Pol	CD, D, Pol, R	CD	-	-	R	-
Florideophyceae							
Beckerella dentata	-	Pol, R (4)	Tur (4)	R, Tur (4)	+ (4)	-	+ (4)
Chondrymenia lobata	-	R	-	-	-	-	-
Felicinia spathulata	-	-	-	-	-	-	+ (5, 21)
Grateloupia turuturu	-	R (1, 6)	-	-	-	-	-
Gymnogongrus crenulatus	-	R	-	-	-	-	+ (21)
Halarachnion ligulatum	-	Pol	-	-	-	-	-
Halymenia elongata	-	Pol, Tra, Tur (7)	-	-	-	-	-
Hypnea cervicornis	-	R (1)	-	-	-	-	-

	Belsher *et al.* (1987)	Boudouresque *et al.* (1990)	Boudouresque (1995)	Boudouresque *et al.* (1996)	UNEP (2000)	Boudouresque (2003)	UNEP (2009)
Lithophyllum byssoides	Pol, Trp (8,9)	Pol (8)	Pol, Trp (8)	Pol, Trp, Tur (8)	+ (8)	-	+
Naccaria wiggii	-	Tur	-	-	-	-	-
Nemastoma dichotomum	-	R	-	-	-	-	-
Platoma cyclocolpum	-	Pol (10)	-	-	-	-	-
Sarconema filiforme	-	CD, Pol (1)	-	-	-	-	-
Schimmelmannia schousboei	-	Pol, R (11)	CD (11)	CD, R (11)	+	R (11)	+
Sphaerococcus rhizophylloides	-	-	-	-	-	-	+ (21)
Schizymenia dubyi	-	R	-	-	-	-	-
Spyridia hypnoides	-	CD, Pol, R	-	-	-	-	-
Tenarea tortuosa	-	Pol, R	-	-	-	-	+
Titanoderma ramosissimum	-	R, Trp (12)	Pol, Trp (12)	Pol, R, Trp (12)	+ (12)	-	+
Titanoderma trochanter	-	-	-	-	-	-	+
Phaeophyceae							
Cystoseira abies-marina	-	-	-	-	-	-	+ (20)
Cystoseira algeriensis	-	-	-	-	-	-	+
Cystoseira amentacea	Pol (13)	D, Pol (14)	-	D, Pol	+	D	+
Cystoseira barbata	-	-	-	-	-		+
Cystoseira barbatula	-	-	-	-	-	-	+

	Belsher *et al.* (1987)	Boudouresque *et al.* (1990)	Boudouresque (1995)	Boudouresque *et al.* (1996)	UNEP (2000)	Boudouresque (2003)	UNEP (2009)
Cystoseira brachycarpa	-	CD, Ovg, Pol (15)	-	-	-	-	+
Cystoseira corniculata	-	-	-	-	-	-	+
Cystoseira crinita	-	-	-	-	-	-	+
Cystoseira crinitophylla	-	-	-	-	-	-	+
Cystoseira dubia	-	-	-	-	-	-	+
Cystoseira elegans	-	CD, Ovg	-	-	-	-	+
Cystoseira foeniculacea	-	D (16)	-	-	-	-	+
Cystoseira funkii	-	-	-	-	-	-	+
Cystoseira humilis	-	-	-	-	-	-	+
Cystoseira hyblaea	-	-	-	-	-	-	+
Cystoseira jabukae	-	-	-	-	-	-	+
Cystoseira mauritanica	-	-	-	-	-	-	+
Cystoseira mediterranea	-	Pol	-	D, Pol	+	D	+
Cystoseira micheleae	-	-	-	-	-	-	+
Cystoseira montagnei	Ovg, Pol (17)	(17)	-	D, , Ovg, Pol, Tra (17)	+ (17)	D (17)	+
Cystoseira nodicaulis	-	-	-	-	-	-	+
Cystoseira pelagosae	-	-	-	-	-	-	+
Cystoseira rayssiae	-	-	-	-	-	-	+

	Belsher *et al.* (1987)	Boudouresque *et al.* (1990)	Boudouresque (1995)	Boudouresque *et al.* (1996)	UNEP (2000)	Boudouresque (2003)	UNEP (2009)
Cystoseira sauvageauana	-	R	-	-	-	-	+
Cystoseira schiffneri	-	Net, Pol, R	-	-	-	-	+
Cystoseira sedoides	-	R	Pol	Ovg, Pol, R	+	D	+
Cystoseira squarrosa	-	-	-	-	-	-	+
Cystoseira susanensis	-	-	-	-	-	-	+
Cystoseira tamariscifolia	-	-	-	-	-	-	+
Cystoseira usneoides	-	-	-	-	-	-	+
Cystoseira zosteroides	-	Ovg, Sed, Tur	-	D, Ovg, Tur	+	D	+
Desmarestia dudresnayi	-	R (18)	-	-	-	-	-
Desmarestia ligulata	-	R	-	-	-	-	-
Desmarestia viridis	-	R (22)	-	-	-	-	-
Dictyota mediterranea	-	Pol, R, Tur (19)	-	-	-	-	-
Fucus virsoides	-	Pol	-	-	-	-	+
Laminaria ochroleuca	-	Pol, R, Tra	Tur	CD, Pol, R	-	R	-
Laminaria rodriguezii	Pol, R, Tur	Net, Pol, R, Tur	Tur	R, Tur	+	R, Tur, War	+
Padina boergesenii	-	R (1)	-	-	-	-	-
Phyllariopsis purpurascens	-	R	-	-	-	-	-
Sacchorhiza polyschides	-	Pol, R	-	-	-	-	-

	Belsher *et al.* (1987)	Boudouresque *et al.* (1990)	Boudouresque (1995)	Boudouresque *et al.* (1996)	UNEP (2000)	Boudouresque (2003)	UNEP (2009)
Sargassum acinarium	-	-	-	-	-	-	+
Sargassum flavifolium	-	-	-	-	-	-	+
Sargassum hornshuchii	-	-	-	-	-	-	+
Sargassum trichocarpum	-	-	-	-	-	-	+
Undaria pinnatifida	R (1)	-	-	-	-	-	-

(1) Introduced species! (2) As *Caulerpa racemosa*. (3) As *Acetabularia parvula*. (4) As *Ptilophora mediterranea*. (5) As *Kallymenia spathulata*. (6) Erroneously attributed to *G. doryphora*. (7) The type specimen of *Halymenia trigona* belongs to *Scinaia furcellata*; in fact, Boudouresque *et al.* (1990) were dealing with *H. trigona* as interpreted by Codomier (1974), now named *H. elongata*. (8) As *L. lichenoides*. (9) The threats concern the rims, not the species itself. (10) As *P. cyclocolpa.* (11) As *Schimmelmannia ornata.* (12) As *Goniolithon byssoides* or *G. byssoideum.* (13) As *Cystoseira stricta*. (14) As *Cystoseira amentacea, C. spicata* and *C. stricta,* regarded as synonyms of *Cystoseira amentacea* (or of one of its varieties) by Cormaci *et al*. (2012). (15) As *Cystoseira caespitosa*. (16) As *Cystoseira ercegovicii*. (17) As *Cystoseira spinosa* (Sellam *et al.,* 2017). (18) As *Desmarestia dresnayi*. (19) As *Dilophus mediterraneus*. (20) It is indicated: 'genus *Cystoseira* (exept *Cystoseira compressa*)'; the list of the Mediterranean species is not specified; the list of the 31 species of *Cystoseira* present in the Mediterranean, which is specified here, is from Guiry (2019). (21): It should be noted that Annex II erroneously places three species of Florideophyceae (Rhodophyta), *Gymnogongrus crenulatus*, *Felicinia spathulata* et *Sphaerococcus rhizophylloides*, within the Phaeophyceae (Heterokontophyta); here, the error has been corrected. (22) The Mediterranean populations described as *Desmarestia adriatica* could belong to a distinct taxon, rare and endemic to the Adriatic Sea.

Florideophyceae

Beckerella dentata (Kützing) Athanasiadis. In the Barcelona Convention, this species has retained its former name of *Ptilophora mediterranea* (H. Huvé) R.E. Norris (Fig. 2). It is a Mediterranean endemic dwelling in deep water (-20 to -100 m) ('deep' means here 'for photosynthetic organisms'), only known from Greece (Eastern Mediterranean: Huvé, 1962; Akatsuka, 1987; Boudouresque *et al.,* 1990). Like the other deep-sea species, it is strongly threatened by any alteration of the transparency of the water (turbidity, hyper-sedimentation). IUCN-like category: RA.

Felicinia spathulata (J. Agardh) L. Le Gall & A. Vergés. In the Barcelona Convention, this species has retained its former name of *Kallymenia spathulata* (J. Agardh) P.G. Parkinson. It is a species with a very fragile vegetative apparatus, dwelling in deep water (between -30 and -50 m), which has been described from Provence (Fig. 2) and observed especially in Andalusia, Balearic Islands, Croatia, Sicily and Venetia, (Furnari *et al.,* 1999; Gallardo *et al.,* 2016; Le Gall *et al.,* 2018). *Felicinia spathulata* has been observed in the Coastal Detritic ecosystem of Port-Cros Island (Augier and Boudouresque, 1978). Once very abundant, to the point of characterizing a community of the Coastal Detritic ecosystem (Costa, 1960; Pérès and Picard, 1964), it has become extremely rare since the middle of the 20th century (Huvé and Passelaigue, 1970). The causes of its decline are probably the degradation of the environment (hyper-sedimentation, turbidity) and fishing (trawling). IUCN-like category: VU.

Gymnogongrus crenulatus (Turner) J. Agardh. This temperate species of cold affinities, described from the Atlantic, is at the very limit of its range area in the Mediterranean Sea (Fig. 2) (Boudouresque *et al.,* 1990). In France, it is mainly present in the Gulf of Lion, where it grows near the sea surface in shaded cavities ('blow holes'). Mediterranean populations possibly belong to an endemic species distinct from the Atlantic species (Marc Verlaque, unpublished observations). The species is strongly threatened by the degradation of the environment, the destruction of its habitat and by global warming, as the Gulf of Lion constitutes a kind of trap where it cannot shift northwards. IUCN-like category: VU.

Lithophyllum byssoides (Lamarck) Foslie. This calcified species thrives in the midlittoral zone (a few decimetres above mean sea level). It is neither rare nor threatened in the western Mediterranean. However, *L. byssoides* shows high cryptic genetic diversity and encompasses several distinct clades, maybe species (Pezzolesi *et al.,* 2017), the much more restricted geographical range of which could constitute a threat. Its placement on the list of threatened species of the Barcelona Convention

was justified by its capacity to build conspicuous bio-constructed formations above the sea level: the *'Lithophyllum byssoides* algal rims', also known as *'Lithophyllum byssoides* trottoirs' (Fig. 3). These limestone formations are remarkable in many ways. They are a marker of the mean sea level and, when conditions are very favourable, they can reach more than 1 m width, testifying to a stability of the sea level over several centuries (Pérès and Picard, 1964; Laborel *et al.,* 1983 Laborel, 1987; Faivre *et al.,* 2013). Unfortunately, their growth is too slow to offset the current more rapid increase in the rise of the sea-level due to global warming. Many of these 'natural monuments' are already submerged and dead and all of them are threatened with extinction in the medium term (Verlaque, 2010; Blanfuné *et al.,* 2016a). *Lithophyllum byssoides*, as well as the rims it builds, are found throughout the Adjacent Marine Area (AMA, *Aire Maritime Adjacente*; see Astruch *et al.,* 2018) and the core area of Port-Cros National Park (Belsher *et al.,* 1976). IUCN-like category: LC (species), CR (rims).

Schimmelmannia schousboei (J. Agardh) J. Agardh. This red alga (Fig. 2), one of the most beautiful in the world according to eminent phycologists, is part of the small group of rare species of the north-eastern Atlantic that have penetrated into the Mediterranean due to Pleistocene glaciations and which occur only in the south-western basin (Boudouresque, 2004). It lives in shallow (-1 to -2 m) shady habitats, near inputs of cold fresh water. Only four localities are known in the Mediterranean: Catania and Palermo (Sicily), Porto-Cesareo (Apulia, Italy) and Tripoli (Libya), (Nizamuddin *et al.,* 1979; Giaccone *et al.,* 1985; Boudouresque *et al.*, 1990). The species does not occur in France. The extreme scarcity of its populations makes it a species highly threatened by the degradation of the environment, the destruction of its habitat and global warming. IUCN-like category: RA.

Sphaerococcus rhizophylloides J.J. Rodríguez. This species has been described from the Balearic Islands (Fig. 2). It thrives in deep habitats (-50 to -130 m) and is very rare, only reported in the western Mediterranean and the nearby areas of the eastern Atlantic (Huvé, 1970). It had been observed only once in France, between the islands of Port-Cros and Le Levant (Port-Cros National Park) (Belsher *et al.,* 1976). It was further recorded from La Gabinière Islet (Port-Cros Archipelago) at 50 m depth in October 2008 (Line Le Gall, pers. comm.). The species, dependent on clear waters, is strongly threatened by any alteration of the transparency of water (turbidity) and by hyper-sedimentation. IUCN-like category: RA.

Tenarea tortuosa (Esper) Me. Lemoine. This calcified species is very fragile: it breaks or detaches itself from the substrate at the slightest touch (Fig. 3) (Huvé, 1963). It is a Mediterranean endemic only present in

the Adriatic and the eastern Mediterranean (Boudouresque et al., 1990). It lives preferentially between the sea surface and - 1.5 m, in exposed and well-lit hard substrate habitats (Huvé, 1963; Pérès and Picard, 1964). The species is rare, with the possible exception of Greek coasts; it does not occur in France. The scarcity of *T. tortuosa* populations, their proximity to the sea surface and the fragility of their vegetative apparatus make them very vulnerable to habitat destruction (coastal development), surface pollution and trampling. IUCN-like category: VU.

Titanoderma ramosissimum (Heydrich) Bressan & Cabioch. This species forms small, very fragile calcareous ridges near the sea surface, in the infralittoral fringe, in well-lit and exposed hard substrate habitats; it often thrives in the understorey of *Cystoseira amentacea* forests (Fig. 3) (Huvé, 1963; Boudouresque *et al.,* 1990, 1996). It has been reported from Corsica, Sardinia, Sicily and Algeria (Boudouresque and Perret-Boudouresque, 1987; Perret-Boudouresque and Seridi, 1989; Boudouresque *et al.,* 1996; Babbini and Bressan, 1997); the records from the eastern Mediterranean and the Adriatic correspond to a confusion with *T. trochanter*, or to a synonymy with this latter species (Babbini and Bressan, 1997) which is no longer accepted (see below). In France, *T. ramosissimum* is present only in Corsica. The scarcity of its populations, its localization near the sea surface and its weak adherence to the rock make it a species very vulnerable to the destruction of its habitat (coastal development), to mechanical damage (shocks, trampling) and to the sea surface pollution. IUCN-like category: VU.

Titanoderma trochanter (Bory) Benhissoune, Boudouresque, Perret-Boudouresque & Verlaque. It is a calcified species endemic to the eastern Mediterranean and the Adriatic, where it is the vicariant species of *T. ramosissimum*; it occupies the same habitat, namely hard substrates of the infralittoral fringe, exposed and well-lit (Fig. 3) (Huvé, 1963; Babbini and Bressan, 1997; Bressan and Babbini, 2003). *Titanoderma trochanter* does not occur in France. The threats are the same as for *T. ramosissimum*. IUCN-like category: VU.

Phaeophyceae

The genus Cystoseira. Most of the *Cystoseira* species are large macroalgae constituting a tree stratum (rarely exceeding 30 to 40 cm in height) with stands referred to as 'marine forests'. They are perennial with erect axes and more or less deciduous branches, except *C. corniculata*, of which the axes are creeping (Ercegović, 1952). The *Cystoseira* forests are distributed from the surf zone (midlittoral zone and infralittoral fringe) down to 70 to 90 m deep (in the clearest waters of the Mediterranean). These forests are home to a very rich flora and fauna and have an important functional role, especially for juveniles of many species

(nurseries) (Cheminée *et al.,* 2013). All Mediterranean species (except *C. compressa*), i.e. 31 species, were included in Annex II of the Barcelona Convention: *Cystoseira abies-marina* (S.G. Gmelin) Setchell & N.L. Gardner*, C. algeriensis* Feldmann*, C. amentacea* (C. Agardh) Bory (Fig. 4), *C. barbata* (Stackhouse) C. Agardh*, C. barbatula* Kützing*, C. brachycarpa* J. Agardh*, C. corniculata* (Turner) Zanardini*, C. crinita* Duby (Fig. 4)*, C. crinitophylla* Ercegović*, C. dubia* Valiante*, C. elegans* Sauvageau*, C. foeniculacea* (Linnaeus) Greville (Fig. 4)*, C. funkii* Schiffner ex Gerloff & Nizamuddin*, C. humilis* Schousboe ex Kützing*, C. hyblaea* Giaccone*, C. jabukae* Ercegović*, C. mauritanica* Sauvageau*, C. mediterranea* Sauvageau*, C. micheleae* Verlaque, Blanfuné, Boudouresque, Thibaut & Sellam*, C. montagnei* J. Agardh*, C. nodicaulis* (Withering) M. Roberts*, C. pelagosae* Ercegović*, C. rayssiae* Ramon*, C. sauvageauana* Hamel*, C. schiffneri* Hamel*, C. sedoides* (Desfontaines) *C.* Agardh*, C. squarrosa* De Notaris*, C. susanensis* Nizamuddin*,, C. tamariscifolia* (Hudson) Papenfuss*, C. usneoides* (Linnaeus) M. Roberts and *C. zosteroides* (Turner) C*.* Agardh (Fig. 4). Their geographical distribution varies according to the species: *C. rayssiae* is restricted to the Levantine coast (Israel and Lebanon) (Ramon, 2000; Badreddine, 2018; Mulas *et al.,* 2019) and *C. sedoides* to Algeria, Tunisia and Panteleria Island (Italy) (Boudouresque *et al.*, 1996; Bouafif *et al.,* 2014), while *C. amentacea* is present in most of the Mediterranean, except Catalonia (Ribera *et al.*, 1992). As far as the vertical range is concerned, *Cystoseira amentacea* (Fig. 4) and *C. mediterranea* are restricted to very shallow and exposed habitats of the infralittoral fringe (Barceló Martí *et al.,* 2000); *C. cornicalata* thrives in shallow habitats down to 5-6 m depth (Huvé, 1972); *C. crinita* (Fig. 4) thrives in shallow and relatively sheltered habitats (Blanfuné *et al.,* 2016c); *C. brachycarpa* and *C. foeniculacea* are common in the infralittoral zone of the western Mediterranean basin, from sea level down to 10 m and 20-30 m depth, respectively (Huvé and Pellegrini, 1970; Barceló Martí *et al.,* 2000); finally, *C. zosteroides* (Fig. 4) is a deep species, restricted to the lower part of the infralittoral zone and to the circalittoral zone, dwelling in particular in the coralligenous ecosystem (Bonhomme et al., 2014; Boudouresque *et al.,* 2017a). In many areas of the Mediterranean, the *Cystoseira* forests are conspicuously declining and even disappearing (e.g. Boudouresque, 2003; Boudouresque *et al.,* 2003; Thibaut *et al.,* 2005; Mangialajo *et al.,* 2008; Perkol-Finkel and Airoldi, 2010; Fraschetti *et al.*, 2011; Thibaut *et al.,* 2015; Blanfuné *et al.,* 2016c; Kletou *et al.,* 2018). There are many causes for this decline: habitat destruction and pollution for shallow species, overgrazing by herbivores (sea urchins and fish) for medium-depth species, uprooting by fishing gear and anchors, and alteration of water transparency for deep-sea species (e.g. Boudouresque *et al.,* 1996; Thibaut *et al.,* 2015; Blanfuné *et al.,* 2016c; Thibaut *et al.,* 2016b; Melis *et al.,* 2019). Once destroyed over large areas, the natural restoration of the *Cystoseira* forests is very difficult,

due to the short distance dissemination of *Cystoseira* eggs and regime shift (e.g. Soltan *et al.,* 2001; Boudouresque *et al.,* 2005; Ballesteros *et al.,* 2009; Capdevila *et al.,* 2018; Melis *et al.,* 2019). While *C. amentacea* is still very common, despite local loss (Thibaut *et al.,* 2014), several species have become locally or functionally extinct; for example, *C. crinita* is extinct in French Catalonia and functionally extinct in French Riviera (Thibaut *et al.,* 2005; Blanfuné *et al.,* 2016c); *C. elegans* is extinct in French Riviera and functionally extinct in French Catalonia (Thibaut *et al.,* 2005, 2015); *C. crinita, C. foeniculacea, C. humilis* and *C. montagnei* are extinct at Tremiti Islands (Italy) (Cormaci and Furnari, 1999). Along the Levantine coast, *C. rayssiae* is threatened by the sea water warming and by Lessepsian herbivores (Mulas *et al.,* 2019). IUCN-like category: LC to RA and CR, according to the species.

Fucus virsoides J. Agardh. The species is endemic to the northern Adriatic: Italy, Slovenia, Croatia, Montenegro and Albania (where its southern limit is located). *Fucus virsoides* is close to the north Atlantic species *F. spiralis* Linnaeus; it probably derives from the latter, which entered the Mediterranean Sea during the Pleistocene glacial episodes. The species lives above mean sea level, in the mid-littoral zone, on sheltered or semi-exposed hard substrates (Fig. 5) (Forti, 1931; Linardić, 1949; Giaccone 1978; Boudouresque *et al.,* 1990; Turk and Vuković 2000; Mačić, 2006; Cormaci *et al.,* 2012). The species is threatened by environmental degradation and the destruction of its habitat. It is also threatened by global warming: its cold water affinities make the Adriatic a trap for it. Its regression is observed everywhere (Turk and Vuković, 2000; Blanfuné *et al*., 2016b). IUCN-like category: VU.

Laminaria rodriguezii Bornet. This species, the leaves of which can measure more than 1 m in length and more than 20 cm wide, is a rarely observed Mediterranean endemic, as it thrives on deep rock and detritic substrates (between -60 and -120 m), swept by strong bottom currents (Pérès and Picard, 1964; Fredj, 1972); Ercegović (1960), in the Adriatic, indicates depths of down to 260 m. It differs from all other species of the genus *Laminaria* in Europe in that, instead of having a single leaf attached to the substrate by a holdfast, it has creeping rhizomes on which leaves form. The first year, the leaf consists of a single blade; the following year, this leaf is pushed upwards by a new blade, so that the leaf has two blades (Fig. 5) (Bornet, 1988; Huvé, 1955; Boudouresque *et al.,* 1990; Cormaci *et al.,* 2012). It is the second largest seaweed in the Mediterranean, after the other species of *Laminaria*, namely *Laminaria ochroleuca* Bachelot de la Pylaie. *Laminaria rodriguezii* has been reported from Catalonia, Balearic Islands, the Valencia region, Ustica, Pianosa, Stromboli, Sicily (Italy), Algeria, Tunisia and Morocco in the western Mediterranean, Croatia in the Adriatic, and Turkey in the eastern Mediterranean; in France, it is present at the Magaud Bank,

which is part of the AMA of the Port-Cros National Park, and around Corsica (Bornet, 1988; Huvé, 1955; Giaccone, 1969; Boudouresque and Perret-Boudouresque, 1987; Perret-Boudouresque and Seridi, 1989; Boudouresque *et al.,* 1990; Ribera *et al*., 1992; Taşkin and Öztürk, 2013). The species is sensitive to environmental degradation, including increased turbidity and hyper-sedimentation (coastal development, waste water outfalls, dredging, dumping of dredged materials), and mechanical destruction (trawling, anchoring, uprooting by fishing nets). In the Adriatic, it has regressed in an extensive and long-lasting way; its status is unknown in the western Mediterranean (Araújo *et al.,* 2016; Žuljević *et al.,* 2016). IUCN-like category: RA (western Mediterranean), EN (Adriatic Sea).

Sargassum acinarium (Linnaeus) Setchell. The species has been reported from most Mediterranean countries; it may also be present in the American, African and Canary Islands tropical Atlantic Ocean (Fig. 5) (Ribera *et al.,* 1992; Aouissi *et al.,* 2018). It is a deep-sea species which thrives on hard substrates, down to -30 to -40 m (Barceló Martí *et al.,* 2000). Wherever old and recent data are available, it appears that *S. acinarium* abundance has dropped conspicuously or that the species can no longer be found. In the Strait of Sicily (Linosa Island), the last record dates back to 1973 (Serio *et al.,* 2006). In France, the species is extinct locally in Catalonia, Languedoc and Western Provence; it is in strong decline (functionally extinct) in Eastern Provence and the French Riviera (Thibaut *et al.,* 2005, 2015, 2016a). With regard to the AMA and the core area of Port-Cros National Park, *S. acinarium* is still present at only one of the five localities where it was previously observed: the island of Port-Cros (Thibaut *et al.,* 2016a). The threats are turbidity, hyper-sedimentation, trawling, uprooting by fishing nets and anchoring. IUCN-like category: EN.

Sargassum hornschuchii C. Agardh. The species is endemic to the Mediterranean and has been reported from most bordering countries, with the exception of Spain and Egypt, but it was always very rare (Fig. 5) (Ribera *et al.* 1992; Barceló Martí *et al.,* 2000; Aouissi *et al.,* 2018). It is a deep-sea species that thrives on hard substrates, down to -30 m. In the Adriatic, Ercegović (1960) reported it down to 250 m depth; such a depth is doubtful, and probably concerns a drift specimen. In France, *S. hornschuchii* is considered locally extinct in Catalonia, Languedoc, Western Provence and Eastern Provence; it has not been observed either on the French Riviera or in Corsica but, having always been rare there, extinction is only a hypothesis (Thibaut *et al.,* 2005, 2015, 2016a). Overall, for the French coasts, the last observation goes back to 1958 (Marseille) for the continental coasts and 1988 for Corsica. The threats are the same as for *S. acinarium*: turbidity, hyper-sedimentation, trawling, uprooting

by fishing nets and anchoring. IUCN-like category: EN (Mediterranean), CR (continental France and Corsica).

Sargassum flavifolium Kützing. This species seems to be restricted to a range from the Bay of Biscay to the Canary Islands (Aouissi *et al.,* 2018). It is the native species of *Sargassum* reported furthest northwards in Europe (Gruet, 1983). Mediterranean records (Verlaque and Boudouresque, 1981) could result from a misidentification (Aouissi *et al.,* 2018). This species should therefore be excluded from Annex II of the Barcelona Convention.

Sargassum trichocarpum J. Agardh. This species is assumed to be endemic to the Mediterranean Sea (Fig. 5). It has been described from North Africa and is regarded as a species of warm water affinities. In France, the sighting of *S. trichocarpum* (in Western Provence) is probably linked to artificial inputs of warm water by a power plant (Verlaque *et al.,* 1979). For decades, this power plant worked episodically and *S. trichocarpum* has never been observed again in Provence. Category IUCN-like: VU.

A critical analysis

In the marine realm, where the artificial (and today devoid of any phylogenetic significance - Fig. 1) fauna-flora separation has long been abandoned, lists of threatened species have always been unitary lists, combining taxa considered traditionally as belonging to the former plant and animal kingdoms. For the purposes of the present analysis, we have extracted taxa belonging to 'macroalgae' (Table I, Ulvophyceae, Florideophyceae and Phaeophyceae).

The list of threatened Mediterranean seaweeds (improperly named 'endangered or threatened' in international documents) stemmed from the observation of the flagrant imbalance between the terrestrial and marine environment, both in the red lists and in legal protection measures (Boudouresque and Bianchi, 2013). In the early 1980s, no marine species, with the exception of seabirds, marine mammals and marine turtles, were taken into consideration. For these last three groups, it is possible to think that their 'luck' was to belong to taxa supported by powerful 'terrestrial' lobbies (see e.g. Tempier, 2018; Mammides, 2019). The Red List of Belsher *et al.* (1987) is therefore seminal, although the choice of the seven species of macroalgae is highly questionable: it includes an introduced species, two very abundant species and a species with doubtful taxonomic status (Table I). It is within the framework of the Bern Convention (Bern Convention on the conservation of European wildlife and natural habitats) that a more elaborate list has been established (Conseil de l'Europe, 1979; Boudouresque *et al.,* 1996), a list that has

been validated in Appendix I of this Convention. This list served as a basis for the Barcelona Convention, for the drawing up of its own list (UNEP, 2000), which has been subsequently improved (UNEP, 2009). Curiously, *Laminaria ochroleuca*, present among the earlier propositions (Boudouresque *et al.,* 1990, Boudouresque, 1995, Boudouresque *et al.,* 1996) and in the Bern Convention, was withdrawn, perhaps owing to an oversight, because the species obviously has its place within the Barcelona Convention.

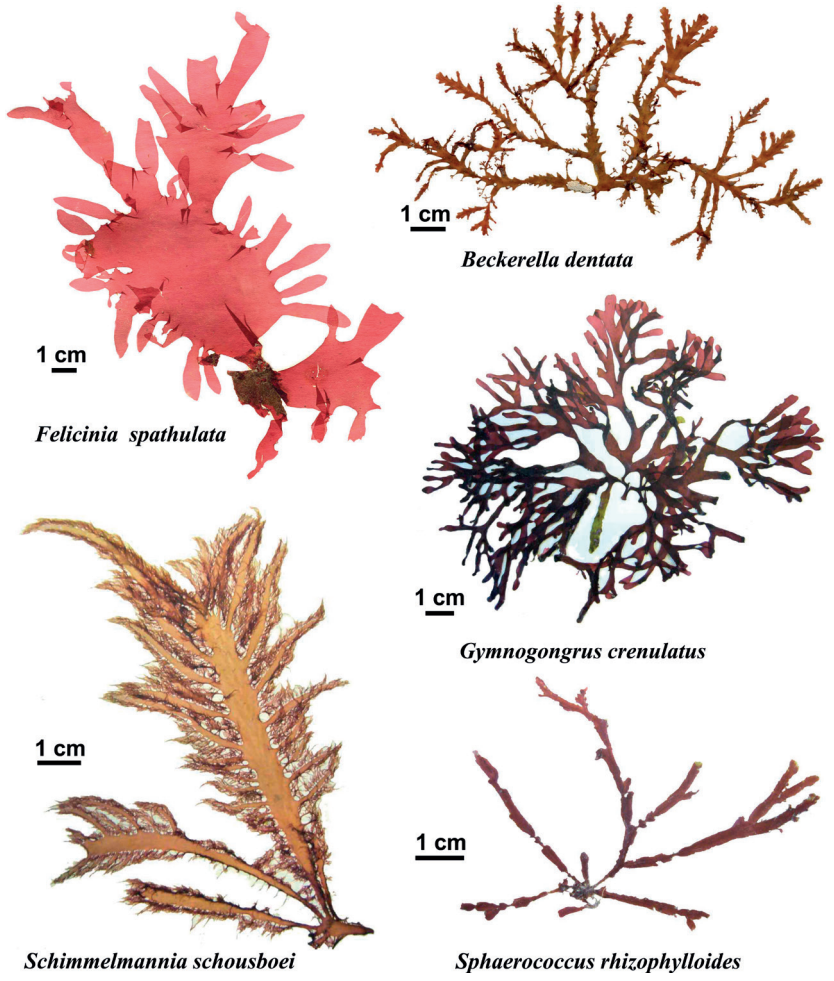
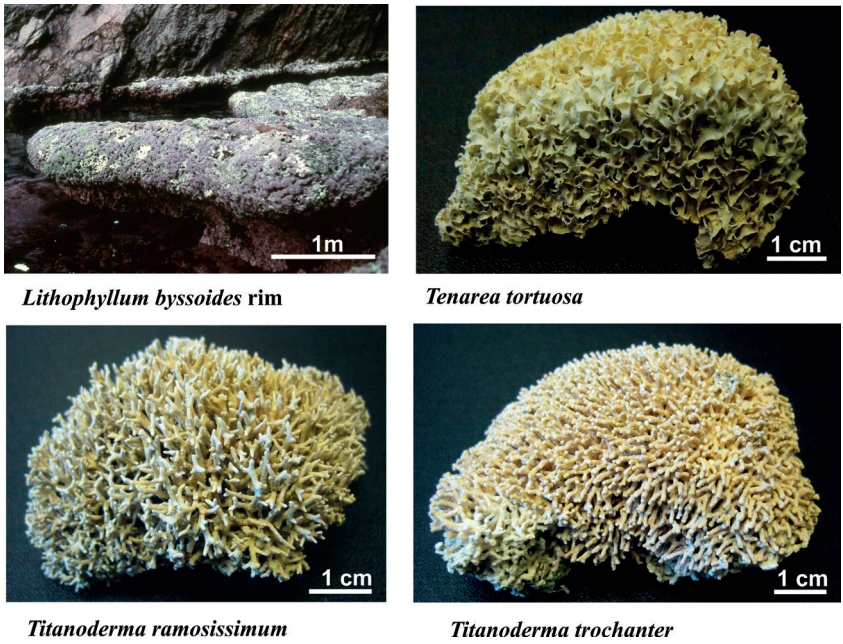


Figure 2. 'Endangered or threatened' macroalgae under the Barcelona Convention (Annex II): *Beckerella dentata, Felicinia spathulata, Gymnogongrus crenulatus, Schimmelmannia schousboei* and *Sphaerococcus rhizophylloides*. Photos © Marc Verlaque.



Lithophyllum byssoides rim | *Tenarea tortuosa*

Titanoderma ramosissimum | *Titanoderma trochanter*

Figure 3. 'Endangered or threatened' macroalgae under the Barcelona Convention (Annex II): *Lithophyllum byssoides* (rim), *Tenarea tortuosa, Titanoderma ramosissimum* and *T. trochanter*. Photos © Marc Verlaque.

The list of threatened species of the Barcelona Convention has the immense merit of existing. Nevertheless, it is open to a number of criticisms. **(i)** It includes species that progress in taxonomy has invalidated; *Caulerpa ollivieri* is a dwarf form of a common species in the Mediterranean, *C. prolifera*, which is favoured by man and by global warming; *Sargassum flavifolium* is an Atlantic species that possibly has never existed in the Mediterranean. **(ii)** In accordance with the tradition of international conventions and the law, species appear under names that no longer conform to the rules of nomenclature and/or the advancement of taxonomy; this is the case of *Kallymenia spathulata* (now *Felicinia spathulata*) and *Ptilophora mediterranea* (now *Beckerella dentata*). **(iii)** Some species are not really threatened, such as *Caulerpa prolifera* (see above) and *Cystoseira amentacea*, the decline of which has been widely overestimated and which is one of the most common species of macroalga in the Mediterranean (Thibaut *et al.,* 2014). **(iv)** Most of the species listed are actually under threat, but many other species that are not listed are equally at risk. The list proposed by Boudouresque *et al.* (1990) included many other species, which Boudouresque (1995) and Boudouresque *et al.* (1996) withdrew; Why? Realism and prudence:

proposing too long a list might scare the representatives of the Parties, who generally do not have a real oceanographic culture, and experts specialized in terrestrial taxa, who sometimes seem to consider the protection of the environment as their private preserve. The idea was to 'open a breach', hoping that this very restricted first list would pave the way for further additions. Unfortunately, more than 20 years later, the initial list has not really been completed, except for the inclusion of all *Cystoseira* species; this inclusion, replacing the four species that it previously contained, was a result of practical considerations: very few specialists are able to identify the different species of the genus *Cystoseira*.

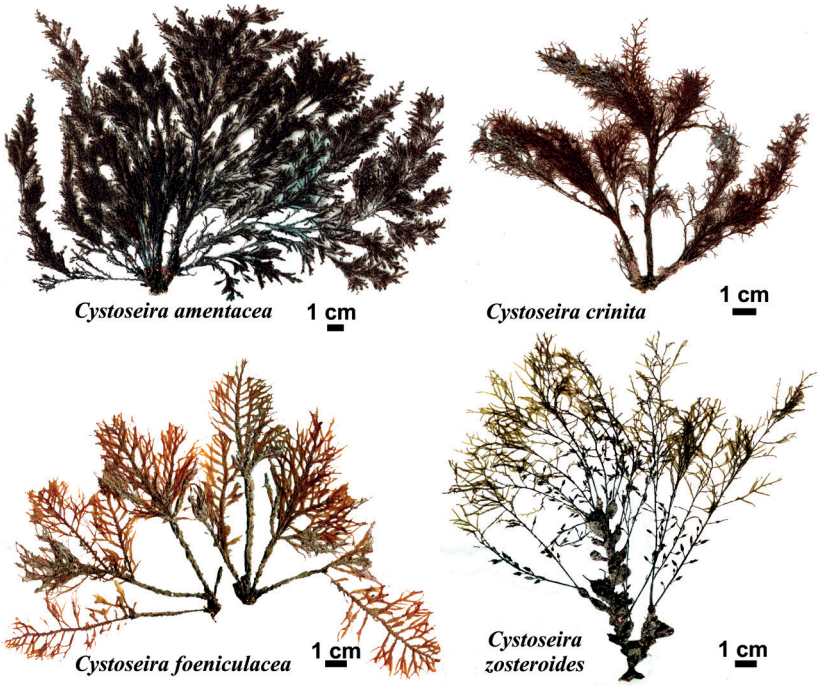


Figure 4. 'Endangered or threatened' macroalgae under the Barcelona Convention (Annex II): *Cystoseira amentacea, C. crinita, C. foeniculacea* and *C. zosteroides*. Photos © Marc Verlaque.

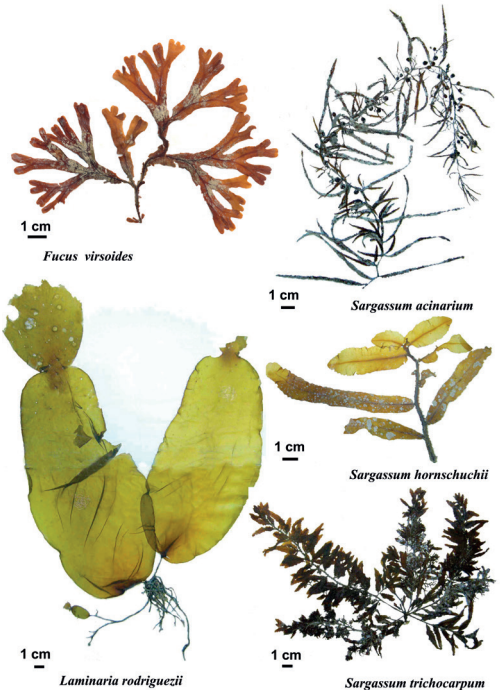


Figure 5. 'Endangered or threatened' macroalgae under the Barcelona Convention (Annex II): *Fucus virsoides*. *Laminaria rodriguezii*, *Sargassum acinarium, S. hornschuchii* and *S. trichocarpum*. Photos © Marc Verlaque.

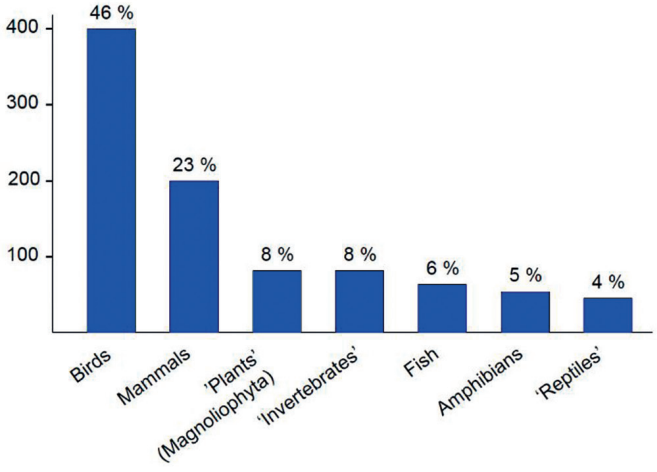


Figure 6. Number (and percentage) of European Union's LIFE projects per taxonomic group since the beginning of the programme, in 1992. From Mammides (2019), modified and redrawn.

It is important to note that neither the Habitats Directive nor the Bern and Barcelona Conventions formally constitute legal protection tools. Annex IV of the Habitats Directive (which does not contain any species of macroalgae) indicates, for the species listed therein, 'in need of strict protection'. The Bern Convention entitled its Annex I 'strictly protected plant species', a name which has been preserved in its transcription in French law (Decree No. 99-615 of 7 July 1999; France, Ministère des Affaires Étrangères, 1999): the 12 species of macroalgae that appear in it (see Boudouresque *et al*., 1996; Table I) are therefore theoretically protected in France, as in all countries that are Parties to the Convention and have transcribed this text into national law. As far as the Barcelona Convention is concerned, Annex II, which includes the genus *Cystoseira* (except *C. compressa*) and 16 other species of macroalgae, is just entitled 'List of endangered or threatened species' (UNEP, 2009); the Convention says that '*the parties shall (…) accord protected status to such species (…)*', which they usually do not do. Concerning the Bern Convention, the annexes of which are entitled 'strictly protected species' and which have been transcribed into French law, officials of the French Ministry of the Environment consider that the 12 species of macroalgae they include are not protected *(in:* answer to a question by Marc Verlaque). This strange interpretation of the law ('the law is what civil servants think, and not the texts adopted by Parliament and published in the *Journal Officiel de la République Française*') is not unusual; it has already been pinpointed, with reference to a text of Law adopted by the French Parliament (the Barnier Law of 1995), when civil servants of the French Ministry of Environment had refused to publish the decrees of application of a number of articles, which made them inapplicable (Boudouresque, 2002).

The issue of the absence of macroalgae (as of almost all true marine species) in the lists of threatened and/or protected species is not an ancillary issue. Natura 2000 sites, which are at the core of the EU diversity conservation strategy, and which are established to protect habitats and species, are based upon the species listed in the annexes. Unfortunately, these annexes, which include hundreds of terrestrial species, contain virtually no truly marine species. Under these conditions, it is not surprising that the Natura 2000 marine sites show no difference from the adjacent areas (Thibaut *et al.,* 2017; Mazaris *et al.,* 2018; Guidetti *et al.,* 2019), and are considered by Meinesz and Blanfuné (2015) as legal scams.

Of the 47 species listed in the Barcelona Convention, directly or indirectly (in the latter case, the 31 Mediterranean species of the genus *Cystoseira*), 24 have been reported in France (French Catalonia, Languedoc, Provence, French Riviera and Corsica): *Caulerpa prolifera* (as *C. ollivieri*), *Cystoseira amentacea, C. barbata, C. brachycarpa, C. crinita,*

C. crinitophylla, C. elegans, C. foeniculacea, C. funkii, C. jabukae, C. mediterranea, *C. montagnei, C. pelagosae, C. sauvageauana, C. squarrosa, C. usneoides, C. zosteroides, Felicinia spathulata, Gymnogongrus crenulatus, Laminaria rodriguezii, Lithophyllum byssoides, Sargassum acinarium, Sargassum hornschuchii* and *Titanoderma ramosissima*. Of these species, 16 have been recorded in the AMA and the core area of the Port-Cros National Park: *Cystoseira amentacea, C. barbata, C. brachycarpa, C. crinita, C. elegans, C. foeniculacea, C. funkii, C. jabukae*, *C. montagnei, C. sauvageauana, C. zosteroides, Felicinia spathulata, Laminaria rodriguezii, Lithophyllum byssoides, Sargassum acinarium* and *Sphaerococcus rhizophylloides*.

The protection of species leads to the species-by-species system of management of the environment, which characterized the 20th century and which is still favoured, openly or implicitly, by the agencies in charge of the environment. It satisfies taxonomic lobbies, but it is neither satisfactory nor effective. Clearly, only the ecosystem-based approach, the new frontier of 21st century ecology, can guarantee the real protection of species, as part of their ecosystem (Laffoley *et al.,* 2004; Cheminée *et al.,* 2013; Personnic *et al.,* 2014; Ruitton *et al*., 2014; Boudouresque *et al.,* 2015b; Rastorgueff *et al.,* 2015; Boudouresque *et al.,* 2017b; Ruitton *et al.,* 2017; Thibaut *et al.,* 2017). Of course, the ecosystem-based approach does not reject the protection of species, a tool for the ecosystem-based approach. As stressed by Enserink and Vogel (2006), photogenic species, umbrella species and charismatic species can act as flagship species: '*the decision to protect their habitat often results in a whole series of measures (…) that will help protect many other, less charismatic species*' (see also Branton and Richardson, 2010).

Conclusions

The huge imbalance in the treatment of species between the terrestrial and marine realms is not only not being redressed, but is continuing to widen, as illustrated by the case of the marine macroalgae. Most of the thousands of terrestrial organisms on the red lists of threatened species that are legally protected deserve this treatment, even though relatively abundant, and even proliferating, species are part of it. The problem is that marine species, a thousand to 10 000 times rarer, which have disappeared from a number of regions and are on the brink of extinction elsewhere, like a marine equivalent of giant panda, do not enjoy any legal protection status, in France as in the 21 Mediterranean countries, all of which have signed the Barcelona Convention. The cases of *Sargassum acinarium* and *S. hornschuchii* exemplify this situation, almost to the point of caricature; this paradox was referred to by Thibaut *et al.* (2016a) as 'the *Sargassum* conundrum'.

At the beginning of the 21st century, beautiful (or less so) flowers receive more attention and have much more luck than the macroalgae that live below the surface of the water, some of them being of indisputable beauty, in addition to having become almost extinct. Is it a case of 'out of sight, out of mind'?

Acknowledgements. The authors are indebted to two reviewers (Line Le Gall and Jean-Georges Harmelin) for valuable suggestions, to Philippe Ponel for sharing information and to Michael Paul, an English native speaker, for proofreading. The origin of this article lies in a request from Alexandre Meinesz, professor emeritus at the University of Nice, to update the 2019 edition of the remarkable book of which he is the editor, '*Méditerranée vivante*'. It seemed useful to present, in a more detailed and scientifically reasoned way than for the general public, our thinking and the data set.

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