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Research Article

Marine endemic species in Tunisia: Biogeography and ecological state in front of anthropogenic activities and climate change
1. Flora

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Abstract: The Mediterranean Sea is a hotspot of biodiversity, and has a relatively high rate of endemism. In Tunisia, around 35% of marine species are threatened, and Tunisian marine waters seem to have a high rate of endemism. Several factors, linked to anthropogenic activities and climate change, have threatened marine biodiversity, mainly endemic species and their habitats. Given the lack of inventory and data on marine endemic species in Tunisia, this work establishes a non-exhaustive list of marine endemic macrophytes (including seagrasses and macroalgae) present in Tunisia. A description of the status of the listed species was given with the biogeographical distribution areas and main threats.

In total, about twenty marine endemic flora species are inventoried in this work, including one Magnoliophyta (*Posidonia oceanica*) and the others are macroalgae.

***Keywords*:** flora; endemic species; Tunisia; marine biodiversity; anthropogenic factors; climate change.

1. Introduction

As a prologue, the notion of endemism must be clearly defined in order to guarantee correct understanding to readers. An endemic species is a native vegetal/animal species that is restricted to a particular geographic area. Thus, the endemism stands for a species that's only found in a defined physical-geographical area and not anywhere else in the world (Morrone, 2008).

Two types of endemism can by distinguished; strict endemism (the species is strictly limited to a geographical area), and broad endemism (the species reaches neighboring areas).

The Mediterranean Basin is recognized as a hotspot for biodiversity: its exceptional flora counts between 15,000 and 25,000 species, 60% of which are unique to the

region (Bernard*et al.*, 1996; Mojetta & Ghisotti, 1996; CSE, 2008).

In Tunisia, there is currently no complete inventory of marine endemic species. Although Tunisian marine ecosystems are characterized by a rich and diverse marine flora (Molinier & Picard, 1953; Zaouali, 1993; Ministère des Affaires Locales et de l'Environnement, 2001; 2014), certain marine habitats (e.g. *Posidonia* meadows, coralligenous, islands, wetlands, insulate banks, etc.) remain poorly studied (Ghrabi-Gammar *et al*., 2009; Chebbi, 2010). The main problems that threaten marine and coastal biodiversity in Tunisia as in the Mediterranean Sea, mainly endemic species, remain the urbanization, the overexploitation of natural resources, the proliferation of alien species, the increasing maritime traffic, and the pollution of the marine ecosystems. All these nuisances imposed on the marine environment have been accentuated in recent decades by climate change (Numa & Troya, 2011).

This work is based on the literature review; it aims to establish the first list of marine endemic flora species in Tunisia (Magnoliophyta and macroalgae) and to assess their biogeography and current ecological status in front of anthropogenic activities and climate change. In this study, endemism is defined in relation to the Mediterranean Sea, but only the species present in Tunisia are listed.

2. Species threats and their impacts on coastal Ecosystems

According to Boudouresque (1997), during the Messinian crises (5 to 6 million years ago), the Mediterranean relatively dried up with the disappearance of most of its communities. Following these crises, the communities of the Mediterranean had to be reconstituted from the Atlantic. Thus, Atlantic species, entering the Mediterranean, evolved to give rise to several species and varieties. The endemic species are therefore the descendants of certain immigrants. This is a recent endemism or neo-endemism manifested at the specific level. The rate of endemism is very high in the Mediterranean compared to other regions of the world (Capapé, 1986; Stehmann & Bürkel, 1986; Fischer *et al.*, 1987; Fredj & Maurin, 1987; Bradaï, 2000).

Endemic marine species have not been the subject of specific inventories in Tunisia, and the few reports made were mostly reported accidentally. As a result, the inventory carried out in this work is mostly based on a review of the available literature. Thus, the list below is not exhaustive and the endemic species in Tunisia would be significantly more numerous. Verification of species names and systematic classification in this work were carried out using the "World Register of Marine Species" website (https://www.marinespecies.org).

2.1. Mognoliophyta

2.1.1. *Posidonia oceanica* (Linnaeus) Delile, 1813

- Plantae (Kingdom);
- Viridiplantae (Subkingdom);
- Streptophyta (Infrakingdom);
- Tracheophyta (Phylum (Division));
- Spermatophytina (Subphylum);
- Magnoliopsida (Class);
- Lilianae (Superorder);
- Alismatales (Order);
- Posidoniaceae (Family);
- *Posidonia* (Genus);
- *Posidonia oceanica* (Species)

Posidonia oceanica is is a Mognoliophyta species, endemic to the Mediterranean. The meadows it forms play an important role in controlling sediment dynamics, storing carbon dioxide, recruiting species of economic interest (spawning grounds/nurseries) and exporting organic matter to deep ecosystems (Pergent-Martini, 2015). In the infralittoral level, it

settles on a hard or soft substrate between 0 and 40m depth (UNEP/IUCN/GIS Posidonie, 1990; Ramos-Esplá *et al.*, 2011) where it forms a climax, i.e. the ultimate evolution of a biocenosis (Pérès & Picard, 1964). In the Gulf of Gabès, Le Danois (1925) reported that *P. oceanica* could be found at a depth of 30m. However, De Gaillande (1970) notes a significant decline in the lower limit, with a loss of the extension of Posidonia meadows due to silting. Ramos-Esplá *et al.* (2011) report that, during marine surveys they carried out in the Golf of Gabes in 2009, a strong vitality of Posidonia was noted in the Kerkennah area, which can colonize degraded bottoms. They add that a few live rhizomes were taken down to 39.6m depth (SE Kerkennah). However, the maximum depth where a living rhizome was found was 44.5m, which means that in the Gulf of Gabès, the lower limit of *P. oceanica* has receded (Ramos-Esplá *et al.*, 2011). Hattour & Ben Mustapha (2013) attributed this decline in part to siltation and turbidity caused in particular by pollution induced by phosphogypsum discharges and by trawling. In addition, these authors estimate that the total area occupied by *P. oceanica* in the Gulf of Gabés is around 1,151,900 ha. Ramos *et al.* (2011) in a study conducted in 2009 carried out diving surveys and experimental fishing and dredging in the Gulf of Gabès. They found that *P. oceanica* is distributed throughout the Gulf at 0-27m depth, with good vitality and living rhizomes up to 40m depth, to the south-east of Kerkennah, to the east of Djerba and at the Kneiss.

Organic pollution, siltation, trawl fishing, coastal managements, sediment deposition and/or the artificial fattening of beaches (Ben Mustapha *et al.*, 1999, 2004; Ben Mustapha & Afli, 2007; Ramos-Esplá *et al.*, 2011) are the main threats. In the Gulf of Gabès, the Posidonia meadow shows significant differences in its spatial distribution. While it is heavily impacted by trawl fishing, especially in the Southwestern sectors of Kerkennah, West and East of Djerba, the meadow appears to be in good condition, in the South-East of Kerkennah and around Kneiss, with some signs of recovery. The monitoring of the network set up by Hattour & Ben Mustapha (2013) should make it possible to assess the dynamics of this meadow over the years, with a view to preservation. In addition, these authors offer relevant recommendations for the conservation of this biocenosis, including the limitation of harmful discharges, the prohibition of illegal fishing, the immersion of artificial repopulation reefs and the establishment of protected marine and coastal areas in the main benthic habitats.

This species is endangered or threatened according to Barcelona Convention (1976) (Appendix II) and Bern Convention (1979) (Appendix I). It forms a Habitat of priority interest according to the Habitat Directive 92/43 of the European Union (Annex I). It is necessary to underline the presence of important “tiger” formations and barrier reefs, in particular in Kerkennah (Blanpied *et al.*, 1979; Burollet & Ellouz, 1986; UNEP/IUCN/GIS Posidonie, 1990; Ramos-Esplá *et al.*, 2011).

2.2. Phaeophyta

2.2.1. *Cystoseira amentacea var. stricta* Montagne, 1846 (including var. stricta and var. spicata)

- Chromista (Kingdom);
- Harosa (Subkingdom);
- Heterokonta (Infrakingdom);
- Ochrophyta (Phylum);
- Phaeista (Subphylum);
- Limnista (Infraphylum);
- Fucistia (Superclass);
- Phaeophyceae (Class);
- Fucophycidae (Subclass);
- Fucales (Order);
- Sargassaceae (Family);
- *Cystoseira* (Genus);
- *Cystoseira amentacea* (Species);

- *Cystoseira amentacea* var. *stricta* (Variety)

This macroalga is endemic to the Mediterranean with three varieties: *amentacea* (Eastern Mediterranean), *spicata* (Adriatic) and *stricta* (Western Mediterranean) (Ramos-Esplá *et al.*, 2011). It lives in the infralittoral stage, on a hard substrate near the surface with strong hydrodynamism. Threats mainly include pollution (it has receded nearly in all major urban areas), grazing by some micro-herbivores, pollution from coastal development (water turbidity), anchoring/mooring of boats and harsh fishing methods for benthic habitats. The inventory and mapping of this alga gives it the status of a strictly protected species (Ramos-Esplá *et al.*, 2011; Bouafif *et al*., 2014).

2.2.2. Ericaria mediterranea (Sauvageau) Molinari & Guiry, 2020

- Chromista (Kingdom);
- Harosa (Subkingdom);
- Heterokonta (Infrakingdom);
- Ochrophyta (Phylum);
- Phaeista (Subphylum);
- Limnista (Infraphylum);
- Fucistia (Superclass)
- Phaeophyceae (Class);
- Fucophycidae (Subclass);
- Fucales (Order);
- Sargassaceae (Family);
- *Cystoseira* (Genus);
- *Cystoseira mediterranea* (Species)

It is a species of macroalgae endemic to the Mediterranean (Ramos-Esplá *et al.*, 2011). It is rarer and more localized than *C. amentacea* but replaces *C. amentacea* in parts of the Western Mediterranean. It lives in the infralittoral stage, on a hard substrate near the surface with a strong dynamism. It is threatened like *C. amentacea* (Ben Maïz et al., 1987; Ramos-Esplá *et al.*, 2011).

2.2.3. *Cystoseira sedoides* (Desfontaines) C. Agardh, 1820

- Chromista (Kingdom);
- Harosa (Subkingdom);
- Heterokonta (Infrakingdom);
- Ochrophyta (Phylum);
- Phaeista (Subphylum);
- Limnista (Infraphylum);
- Fucistia (Superclass);
- Phaeophyceae (Class);
- Fucophycidae (Subclass);
- Fucales (Order);
- Sargassaceae (Family);
- *Cystoseira* (Genus);
- *Cystoseira sedoides* (Species)

This macroalga is endemic to the coasts of Algeria (from the outskirts of Algiers to El Kala), Tunisia and the extreme South of Italy (island of Pantelleria) (Ramos-Esplá *et al.*, 2011). It is a long-lived species, living in a very narrow ecological niche, on hard substrates with moderate wave movements. Its status is comparable to that of *C. amentacea*, but given its narrow ecological niche, it is more threatened (limited distribution area and scarcity of sites) (Ramos-Esplá *et al.*, 2011).

2.2.4. *Cystoseira spinosa* Sauvageau, 1912 (accepted name: Cystoseira montagnei J. Agardh, 1842)

- Chromista (Kingdom);
- Harosa (Subkingdom);
- Heterokonta (Infrakingdom);
- Ochrophyta (Phylum);
- Phaeista (Subphylum);
- Limnista (Infraphylum);
- Fucistia (Superclass);
- Phaeophyceae (Class);
- Fucophycidae (Subclass);
- Fucales (Order);
- Sargassaceae (Family);
- *Cystoseira* (Genus);
- *Cystoseira spinosa* (Species)

It is a macroalga endemic to the Mediterranean. It lives on hard substrates in the infralittoral stage, in particular in

deep water (15–35m), in sciaphilic biotopes (Ramos-Esplá *et al.*, 2011). It formed large beds until the 1960s, and now it is reduced to isolated individuals. Threats include pollution, uprooting by nets and trawlers, and grazing by sea urchins (Ben Maiz et al, 1987, Ramos-Esplá *et al.*, 2011).

2.2.5. *Ericaria zosteroides* (C. Agardh) Molinari & Guiry, 2020

- Chromista (Kingdom);
- Harosa (Subkingdom);
- Heterokonta (Infrakingdom);
- Ochrophyta (Phylum);
- Phaeista (Subphylum);
- Limnista (Infraphylum);
- Fucistia (Superclass);
- Phaeophyceae (Class);
- Fucophycidae (Subclass);
- Fucales (Order);
- Sargassaceae (Family);
- *Cystoseira* (Genus);
- *Ericaria zosteroides* (Species)

This alga is endemic to the Mediterranean. It lives in deep water in the infralittoral stage, but mainly in the circalittoral stage (up to 100m) on hard substrates in sectors with unidirectional currents. It is widely abundant in the Mediterranean and in Tunisian (Bouafif *et al.*, 2014). Threats include increased water turbidity, sedimentation and sea urchin grazing (Ramos-Esplá *et al.*, 2011).

2.2.6. *Laminaria rodriguezii* Bornet, 1888

- Chromista (Kingdom);
- Harosa (Subkingdom);
- Heterokonta (Infrakingdom);
- Ochrophyta (Phylum);
- Phaeista (Subphylum);
- Limnista (Infraphylum);
- Fucistia (Superclass);
- Phaeophyceae (Class);
- Laminariales (Order);
- Laminariaceae (Family);
- *Laminaria* (Genus);
- *Laminaria rodriguezii* (Species)

It is a macroalga endemic to the Western Mediterranean. It lives in much localized sites at great depths (60–150m), where the water is cold and very clear, with fairly strong seabed currents. Threats include eutrophication and/or increased turbidity (Hattour & Ben Mustapha, 2015). This alga generally lives at great depths, on hard bottoms (rocks, coralligenous, detrital concretions), with bottom currents. It avoids troubled waters and loose sediments. In Tunisia, it is found in clear waters from 30m depth (Ben Maïz et al., 1987).

2.2.7. *Cystoseira schiffneri* Hamel, 1939

- Chromista (Kingdom);
- Harosa (Subkingdom);
- Heterokonta (Infrakingdom);
- Ochrophyta (Phylum);
- Phaeista (Subphylum);
- Limnista (Infraphylum);
- Fucistia (Superclass);
- Phaeophyceae (Class);
- Fucophycidae (Subclass);
- Fucales (Order);
- Sargassaceae (Family);
- *Cystoseira* (Genus);
- *Cystoseira schiffneri* (Species)

This Mediterranean endemic species colonizes sandy bottoms and small hard substrates between 1 and 5m depth (UNEP/IUCN/GIS Posidonie, 1990; Ramos-Esplá *et al.*, 2011; Hattour & Ben Mustapha, 2015). It is abundantly found stranded on the beaches of the Kerkennah, Sfax and Djerba islands (UNEP/IUCN/GIS Posidonie, 1990). The species has been found in the *Cymodocea nodosa* meadows between 0 and 3m depth. It is abundant in the infralittoral bottoms of the South-East of Kerkennah and El Bibane lagoon, between 0 and 5m depth. The remarkable abundance of this species should be noted in the El Bibane lagoon, where it forms small beds with *C. compressa*. This

association can be included in threatened *Cystoseira* calm mode stands that need protective measures (Hattour & Ben Mustapha, 2015).The species is threatened mainly by organic pollution, coastal works (e.g. fattening of beaches, marinas, ports), small "kiss" trawl fishing. It is considered endangered or threatened by the Barcelona Convention (1976) (Annex II). Its inclusion in Annex II (endangered or threatened species) is also proposed by the European Union: Annexes to Habitat Directive 92/43 (COM (2009) 585); Proposed by IUCN for its protection (UNEP/IUCN/GIS Posidonie, 1990; Ramos-Esplá *et al.*, 2011).

2.2.8. *Cystoseira corniculata* (Turner) Zanardini, 1841

- Chromista (Kingdom);
- Harosa (Subkingdom);
- Heterokonta (Infrakingdom);
- Ochrophyta (Phylum);
- Phaeista (Subphylum);
- Limnista (Infraphylum);
- Fucistia (Superclass);
- Phaeophyceae (Class);
- Fucophycidae (Subclass);
- Fucales (Order);
- Sargassaceae (Family);
- *Cystoseira* (Genus);
- *Cystoseira corniculata* (Species)

It lives on the rocks of the infralittoral, in light-exposed areas, in beaten and calm mode; up to 70m depth. It is also present in coastal lagoons. In the Gulf of Gabès, the species proliferates on loose substrate (sandy, sandy-muddy, muddy), and is frequent on beaches. The species is endemic to the Mediterranean (Ramos-Esplá *et al.*, 2011; Hattour & Ben Mustapha, 2015), the Adriatic and the Eastern basin. This is a relict species of the tertiary. However, it is recorded North of the Atlantic Ocean in European waters. It is threatened by organic pollution, coastal works (e.g. marinas, ports, fattening of beaches), and trampling of the sediment. It is proposed to be included as a species in danger or threatened (Barcelona Convention 1976, Appendix II).

2.2.9. *Cystoseira crinita* Duby, 1830

- Chromista (Kingdom);
- Harosa (Subkingdom);
- Heterokonta (Infrakingdom);
- Ochrophyta (Phylum);
- Phaeista (Subphylum);
- Limnista (Infraphylum);
- Fucistia (Superclass);
- Phaeophyceae (Class);
- Fucophycidae (Subclass);
- Fucales (Order);
- Sargassaceae (Family);
- *Cystoseira* (Genus);
- *Cystoseira crinita* (Species)

It lives on the rocks of the infralittoral, in light-exposed areas, in beaten and calm mode; between 0–3m depth (Gómez-Garreta *et al.*, 2001). It is an endemic species to the Western and Eastern Mediterranean, Adriatic and Black Seas, also present in the Canaries (Ramos-Esplá *et al.*, 2011; Hattour & Ben Mustapha, 2015). *C. crinita* abounds on the beaches of La Chebba and Zarzis, especially during the hot season (Hattour & Ben Mustapha, 2015). It is affected by organic pollution, coastal works (e.g. marinas, ports, fattening of beaches), and trampling of the sediment. It is a species proposed as endangered or threatened by the Barcelona Convention (1976) (Appendix II).

2.2.10. *Cystoseira dubia* Valiante, 1883

- Chromista (Kingdom);
- Harosa (Subkingdom);
- Heterokonta (Infrakingdom);
- Ochrophyta (Phylum);
- Phaeista (Subphylum);
- Limnista (Infraphylum);
- Fucistia (Superclass);
- Phaeophyceae (Class);
- Fucophycidae (Subclass);

- Fucales (Order);
- Sargassaceae (Family);
- *Cystoseira* (Genus);
- *Cystoseira dubia* (Species)

It lives on the rocks of the lower infralittoral and circalittoral, and deep detrital, between 25 and 170m depth. It is a species endemic to the Mediterranean, Southwestern Italy, Sicily, the Adriatic Sea and the Eastern basin (Greece, Tunisia, and Syria) (Hattour & Ben Mustapha, 2015). It is threatened by organic pollution, excess sediment, and trawling. It is proposed as endangered or threatened species (Barcelona Convention 1976, Annex II).

2.2.11. *Cystoseira sauvageauana* Hamel, 1939

- Chromista (Kingdom);
- Harosa (Subkingdom);
- Heterokonta (Infrakingdom);
- Ochrophyta (Phylum);
- Phaeista (Subphylum);
- Limnista (Infraphylum);
- Fucistia (Superclass);
- Phaeophyceae (Class);
- Fucophycidae (Subclass);
- Fucales (Order);
- Sargassaceae (Family);
- *Cystoseira* (Genus);
- *Cystoseira sauvageauana* (Species)

It lives on the rocks of the infralittoral, in light-exposed and not beaten places (UNEP/IUCN/GIS Posidonia, 1990). It is an endemic species to the Mediterranean, more frequent in the Western basin, but also in the Gulf of Cadiz (Ramos-Esplá *et al.*, 2011; Hattour & Ben Mustapha, 2015). The species seems to be much localized in the Gulf of Gabès: Island of Djerba and Kerkennah. It is threatened by organic pollution, coastal works (e.g. marinas, ports, fattening of beaches), and excess sediment. It is considered vulnerable (UNEP/IUCN/GIS Posidonie, 1990; Boudouresque, 1997).

2.2.12. *Cystoseira brachycarpa* J.Agardh, 1896

- Chromista (Kingdom),
- Harosa (Subkingdom);
- Heterokonta (Infrakingdom);
- Ochrophyta (Phylum);
- Phaeista (Subphylum);
- Limnista (Infraphylum);
- Fucistia (Superclass);
- Phaeophyceae (Class);
- Fucophycidae (Subclass);
- Fucales (Order);
- Sargassaceae (Family);
- *Cystoseira* (Genus);
- *Cystoseira brachycarpa* (Species)

This species exists in Tunisia (Boudouresque, 1997) (=*Cystoseira brachycarpa* var. *Balearica* (Sauvageau) Giaccone, 1992=*Cystoseira caespitosa* Sauvageau, 1912). It is an endangered or threatened species (Annex II of the Barcelona Convention 1976). It lives in the Western and central Mediterranean and in the Atlantic, near the Strait of Gibraltar (Ramos-Esplá *et al.*, 2011).

2.2.13. *Cystoseira elegans* Sauvageau, 1912

- Chromista (Kingdom);
- Harosa (Subkingdom);
- Heterokonta (Infrakingdom);
- Ochrophyta (Phylum);
- Phaeista (Subphylum);
- Limnista (Infraphylum);
- Fucistia (Superclass);
- Phaeophyceae (Class);
- Fucophycidae (Subclass);
- Fucales (Order);
- Sargassaceae (Family);
- *Cystoseira* (Genus);
- *Cystoseira elegans* (Species)

This endemic species exists in Tunisia (Boudouresque, 1997; Ramos-Esplá *et al.*, 2011). *Cystoseira elegans* grew on semi-exposed to exposed rocky shores, in littoral pools, 0-1m depth, frequently associated

with *C. algeriensis* (Ben Maïz *et al.*, 1987 ; Bàez *et al.*, 2005). It has been successively recorded from Algeria, Sicily, South of Italy, Spain and Balearic Islands. In South Mediterranean, it extends its range of distribution to Tunisia where it was found close to the Algerian border (Melloula Bay) and along the Northeastern coast near Sidi Daoud and Kelibia (Bouafif *et al.*, 2014).

2.2.14. Cystoseira foeniculacea (Linnaeus) Greville, 1830

- Chromista (Kingdom);
- Harosa (Subkingdom);
- Heterokonta (Infrakingdom);
- Ochrophyta (Phylum);
- Phaeista (Subphylum);
- Limnista (Infraphylum);
- Fucistia (Superclass);
- Phaeophyceae (Class);
- Fucophycidae (Subclass);
- Fucales (Order);
- Sargassaceae (Family);
- *Cystoseira* (Genus);
- *Cystoseira foeniculacea* (Species)

Originally described from the Adriatic Sea, *C. Foeniculacea* has been successively reported from the Balearic Islands, Corsica, Cyprus, Greece, Italy, Sardinia, Sicily, Spain and Turkey. This endemic species exists in Tunisia (Boudouresque, 1997; Ramos-Esplá *et al.*, 2011). It has been observed in upper subtidal at 0-5m depth of the Tunisian Northern coasts (observed only along the coasts of Cap Bon Peninsula) from March 2012 to February 2013 (Bouafif *et al.*, 2014).

2.3. Rhodophyta

2.3.1. Lithophyllum byssoides (Lamarck) Foslie, 1900

- Plantae (Kingdom);
- Biliphyta (Subkingdom);
- Rhodophyta (Phylum);
- Eurhodophytina (Subphylum);
- Florideophyceae (Class);
- Corallinophycidae (Subclass);
- Corallinales (Order);
- Lithophyllaceae (Family);
- Lithophylloideae (Subfamily);
- Dermatolitheae (Tribe);
- *Goniolithon* (Genus);
- *Goniolithon byssoides* (Species)

It is a macroalga endemic to the Western Mediterranean in much localized sites (Corsica, Sicily, Algeria, Adriatic). It is a calcareous alga with a very narrow ecological niche, in an infracoastal fringe, just below the surface of the water. It is subjected to strong wave movements, on a hard and well-lit substrate. It is vulnerable to trampling (fishermen on foot, swimmers) and to pollution (film of hydrocarbons on the surface of the sea) (Hattour & Ben Mustapha, 2015).

2.3.2. Mesophyllum lichenoides (J.Ellis) Me.Lemoine, 1928 (reported as *Lithophyllum lichenoides* Stoneweed)

- Plantae (Kingdom);
- Biliphyta (Subkingdom);
- Rhodophyta (Phylum);
- Eurhodophytina (Subphylum);
- Florideophyceae (Class);
- Corallinophycidae (Subclass);
- Hapalidiales (Order);
- Mesophyllaceae (Family);
- *Mesophyllum* (Genus);
- *Mesophyllum lichenoides* (Species)

It is a calcareous alga living in the mid-littoral stage, on hard substrates, in biotopes subjected to strong wave movements and slightly in the shade (especially crevices). In a few sites, it has formed small mounds up to 2m wide (sidewalks) over a period of one thousand years. These formations are unique to the Mediterranean (Hattour & Ben Mustapha, 2015). Threats include pollution (mainly hydrocarbons) and trampling, and the destruction of the mounds is irreversible (Hattour & Ben Mustapha, 2015).

2.3.3. Ptilophora mediterranea (H. Huvé) R.E. Norris, 1987 *(=Beckerella mediterranea =Phyllophora aegeae)*

- Plantae (Kingdom);
- Biliphyta (Subkingdom);
- Rhodophyta (Phylum);
- Eurhodophytina (Subphylum);
- Florideophyceae (Class);
- Rhodymeniophycidae (Subclass);
- Gelidiales (Order);
- Gelidiaceae (Family);
- *Ptilophora* (Genus);
- *Ptilophora mediterranea* (Species)

It is a macroalga endemic to a limited area of the Mediterranean (between Greece and Crete): It is mainly localized at depth (25m to more than 120m), on hard substrates, on bioconcretions with calcareous algae (Hattour & Ben Mustapha, 2015).

2.3.4. Schimmelmannia schousboei (J. Agardh) J. Agardh, 1851

- Plantae (Kingdom);
- Biliphyta (Subkingdom);
- Rhodophyta (Phylum);
- Eurhodophytina (Subphylum);
- Florideophyceae (Class);
- Rhodymeniophycidae (Subclass);
- Acrosymphytales (Order);
- Acrosymphytaceae (Family);
- *Schimmelmannia* (Genus);
- *Schimmelmannia schousboei* (Species)

This Mediterranean endemic species is found in much localized sites (Southern Italy, Libya, off the French Atlantic coast). It lives in shallow sciaphilic biotopes (1–2m depth) on hard substrates, usually near cold fresh water. Sites are very rare, and could be destroyed by coastal development (Hattour & Ben Mustapha, 2015).

3. Conclusions

Although marine studies in general are numerous in Tunisia and cover several aspects of biodiversity, studies on endemic marine species in general are rare and fragmentary. To date, there is no complete inventory of marine endemic species in Tunisia, and even less on their status, geographic distribution and nuisance factors. The data reported in this work were collected from scientific articles, PhD theses and scientific reports. They are fragmentary and scattered, and endemic species are generally mentioned incidentally in most scientific works. Therefore, the list of endemic species given in this work is not exhaustive.

Several factors affect biodiversity and endemic species, and most often act concurrently. These include climate change, urban and industrial discharges, excessive fishing, tourism and biological invasions. Invasive species thrive upon the native species, especially endemic species (Ounifi-Ben Amor *et al.*, 2016). They compete with them and even exclude some of them, such the case of the invasive tropical alga *Caulerpa taxifolia* (M. Vahl) C. Agardh, 1817, which competes with *Posidonia* and *Cystoseira* species (Langar *et al*., 2002).

If the impact of nuisance factors on biodiversity in general is obvious and has resulted in the disappearance of certain endemic species and the rarefaction of others, it is very difficult to be able to separate the share of the impact of tourism in relation to all other factors affecting the marine environment, except perhaps in tourist areas where the effect is palpable.

This work is a first study on the status of marine endemic flora species under the impact of tourism and other environmental/anthropogenic factors. The temporal and spatial monitoring of these species will make it possible to complete the list of endemic species and to mark the evolution of their status, mainly in areas under the influence of anthropogenic activities (Krakimel, 2003). This will help decision-makers and managers to adopt strategies and economic development

plans that are more respectful of the environment and that will ensure the conservation of these endemic species.

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