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SYNTAXONOMIC RELATIONSHIPS OF THE MEDITERRANEAN PHYTOBENTHOS ASSEMBLAGES: PALEOCLIMATIC BASES AND EVOLUTIVE TENDENCIES

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Abstract

This study views the evolution of Mediterranean marine vegetation by examining paleoclimatic events and recently available chorologic and environmental data. The Cenozoic climatic and tectonic history of the Mediterranean itself is largely the history of the origin and distribution of marine biota, that are still now recolonizing the Eastern Mediterranean, after the catastrofic events of Sapropel crises during the prehistoric age.

Introduction

In a recent study (GIACCONE, 1991) we confronted the problem of understanding the evolution of Mediterranean marine vegetation, probing the biogeography of several orders of Brown algae above all on a geodynamic basis (plate tectonics) concerning principally the lower Tertiary (Eocene-Oligocene) and middle (Miocene). Necessarily we had to recall also paleoclimatic and hydrologic elements, which on a planetary level interest the world ocean. Continuing in this research we have widened our window of observation, including, besides the orders Laminariales and Fucales of the Fucophyceae, also some Chlorophyceae belonging principally to the orders Bryopsidales and Dasycladales (GIACCONE & al., 1995).

The geological period, which we want to examine in this paper, covers events that are essentially climatic and hydrologic in nature, which happened in the Pliocene and above all in the Pleistocene and in the Holocene in the area of the present Mediterranean.

Some considerations which we will develop appeared to us, moreover, justified by the phytosociologic synthesis for the Mediterranean, that we have just published (GIACCONE & al., 1993, 1994a, 1994b).

A synthesis on the climatic crises and on the consequent destruction of the biological groupings of the Mediterranean, during the latest geological periods, has been written by DOUMENGE (1993). Interesting information can also be found in BELLAN-SANTINI & al. (1992).

From these and other studies are deduced facts, some well-known others lesser known, that can be put at the base both of the current vegetational characterization of the various basins and sectors of the Mediterranean and of their evolutive tendencies; keeping in mind also the synergy originating from some anthropic actions with both hydrologic (the dam on the Nile at Aswan) and climatic (the greenhouse effect) and edaphic (organic and industrial pollution) effects.

Climatic and hydrologic bases

The marine vegetation of the Mediterranean testifies, in its typology and distribution, to climatic and hydrologic events both preceding and contemporary to and also following the salinity crisis of the Messinian (Higher Miocene).

As is well-known this crisis was caused by geodynamic events (the closure of the communications with the bordering oceans) and climatic events (a dry tropical climate). Before during the Oligocene there had been one of the great crises of coldness in the biosphere, which in the Tethys sea had stimulated intense processes of speciation above all in the inside of the Fucophyceae and of the marine Angiosperms (GIACCONE, 1991; LÜNING, 1990).

The Messinian certainly determined in the old Mediterranean a biological catastrophe above all on a synecologic level. On a floristic level, on the other hand, many species, that we refer as tethyan species, took refuge in the residual basins or "Sea-Lakes" (STANLEY, 1990), and in particular in the areas of contact with the Paratethys, in which marine environmental conditions continued. This is demonstrated among other things by the presence of the *Fucetum virsoidis* from Albania to Venice. Therefore it can be affirmed that the present Mediterranean around 5 million years ago was from the point of view of the vegetational typology at its starting point.

For all of the Pliocene, furthermore, the Atlantic infringement caused long periods of environmental instability and a changeable hydrologic situation. We can date the present vegetational order back to the beginning of the Pleistocene. But also in this period, and then in the Holocene, we have had a series of climatic and hydrologic crises that explain the differences, sometimes profound, in the vegetational typology of the basins and sectors in which the Mediterranean Sea is articulated.

This sea, in fact, is characterized by a considerable dependency on the continental climatic environment both for that which regards the contributions of fresh water and for sediments. The hydrologic basin is supported by both the precipitations and the evaporation which on the oceanic level influence the global eustatic equilibrium. This dependency makes the equilibrium of the Mediterranean basin fragile and unstable in the middle period and it exposes it to recurrent ecological catastrophes. The temporal scale of these events goes from a few millennia to a few centuries; these are not however geological times.

The most evident example of this environmental fragility is given by the Sapropel crises, which, for a dozen times in the Holocene, destroyed in a catastrophic manner the eastern marine biome and some sectors of the western one (STANLEY, 1978). The last of these crises goes back to the era of the first Pharaonic dynasties and there are reports in tales, spread throughout many civilizations, present also in the Bible, of a flood of great dimensions and of long duration. Between 10,000 and 8,000 years B.C. there is the highest point of the last Sapropel crisis, with significant returns up to 5,000 B.C. As a consequence the typology of the vegetation of the Eastern Mediterranean is subsequent to this date and, as we will see below, still in a phase of colonization and structuralization. Similar catastrophic events, but of different origin, have conditioned the immaturity of the marine plant associations along the Ligurian-Provençal and north Adriatic coasts.

The Sapropel crisis takes place every time that a layer of fresh water forms on the surface of the sea which lowers the salinity by 2-3% to a depth of 100 meters. This halothermocline blocks the phenomena of upwelling of the deep waters, which condition their oxygenation. There follow widespread phenomena of dystrophy and anoxia, comparable to those present now in the Black Sea.

The flooding of the Nile, at the origin of the Sapropel, happens under the action of the monsoons of East Africa. The catastrophic phases are regulated by cycles of rainfall provoked by the precession of the equinoxes, that is the cycles of Milankovich (ROSSIGNOL-STRICK, 1985).

Also the Black Sea because of phenomena of rainfall in the basins of the rivers that flow into it (Danube, Dniepr, Dniestr, Don, etc.) and of synergic events of a eustatic nature can cause phenomena of Sapropel in the Aegean Sea with rhythms characterized by a period of 3,000 years (STANLEY & al., 1980). The continental rainfall has caused periodically conditions of eutrophication in the waters of the surface and anoxia in the deeper waters in the sectors around the Ebro, the Rhone and the Po (CALVERT & al., 1992).

The phenomena which cause the Sapropel crises are capable of inverting the currents of entrance and exit in the Straits of Gibraltar and the Sicilian Channel, altering so profoundly the relations of biological and hydrological dispersion between the Eastern Mediterranean and the Western and between the biogeographic sectors in which the two basins are articulated. To worsen this capacity of destabilization of the continental waterways in the last 50 years, a concentration of pollutants (urban and industrial) was added which is causing phenomena of eutrophy and anoxia recurring both in the coastal areas, subject to strong human presence, and in the deep waters (MONACO & al., 1990).

The scenarios in the forecast models for the first century of the third millennium are such as to make one consider the possibility of a return of a Sapropel phase because of the joined action of pollution of continental origin and of weak phenomena tied to the cycles of Milankovich (ROHLING & BRYDEN, 1992; BETHOUX, 1984).

Present state and evolutive tendencies of mediterranean marine vegetation

The climatic and hydrologic phenomena, the coastal pollution, the acceleration in the migration and introduction of species into the Mediterranean are at the foundation of the present distribution of the vegetational typology and of its evolutive tendencies in the medium and short periods.

The marine vegetation in the Mediterranean has been described with the phytosociological method of Braun-Blanquet and there have been found 72 syntaxa: 4 Classes, 8 Orders, 10 Alliances, 43 Associations and 7 Sub-associations (see the Appendix). About 200 species characterize these syntaxa, that is about 1/5 of all the plant species recognized for the Mediterranean, many of these species are also endemic.

The western basin of the Mediterranean is populated by about a thousand species while the eastern one counts about 500 (ATHANASIADIS, 1987), with a relatively scarse endemic contingent. The same proportion is obtained by the animal component (FREDJ & al., 1992).

	Western Mediterranean (salina)	Eastern Mediterranean (Lampedusa)
mean n° species	42,29	28,1
mean R/P	3,41	3,4
mean ID	1,79	1,9

Table 1. *Values and synecologic rates of infralittoral associations in two basins of the Mediterranean.*

	Western Mediterranean (Salina)	Eastern Mediterranean (Lampedusa)
Mediterranean (endemic species)...	25,9 %	23,1 %
Atlantic	47,8 %	45,7 %
Indian-Pacific	01,2 %	1,2 %
Cosmopolite	25,1 %	30,0 %

Table 2. *Chorologic spectrum of the marine plants in two basins of the Mediterranean.*

	Animals	Plants
Mediterranean (endemic species)...	28,6 %	26,7 %
Atlantic	50,1 %	48,3 %
Indian-Pacific	4,4 %	3,5 %
Cosmopolite	16,8 %	21,5 %

Table 3. *Chorologic spectrum of the marine organisms of the Mediterranean.*

	Western Mediterranean	Adriatic Sea	Eastern Mediterranean
Animals sp. n° 4094	87,1 %	48,9 %	43,1 %
Plants sp. n°950	99,5 %	64,4 %	57,6 %

Table 4. *Species living in three basins of the Mediterranean*

The ecological valence and the bionomic distribution of the species in the eastern basin are generally ample; as a consequence the marine associations appear as loosely structured and with characteristics more typical of durable groupings of a edaphic climax than of true associations pointing to a climatic climax. Among the well-described syntaxa only three are reported for the Aegean and ten for the Adriatic. More frequent is the case of the presence of vicariant species in the combination characterizing the floristic composition, which in every case presents a relatively impoverished typology with a prevalence of eurivalent elements (SCAMMACCA & al., 1993).

This impoverishment of species (Table 1), and in particular of stenovalent species, and the structural instability of the vegetable associations of the Eastern Mediterranean and of the Adriatic Sea are the consequence of the repeated natural catastrophes (Sapropel crises) in prehistoric and protohistoric times and of the recent anthropic modifications (Suez Canal, Aswan Dam, anoxia in the Black Sea, coastal pollution).

Paleoclimatic and hydrologic causes explain, therefore, the present state of the destructuralization of the plánt associations in this basin. The evolutive tendencies are put into evidence by their extremely fast dynamism, which in the space of about 20 years (GIACCONE & al., 1972; SCAMMACCA & al., 1993) has caused us to notice in the depths of the Pelagie islands and on the eastern coasts of Sicily (ALONGI & al., 1993) an important change in the typology of the marine vegetation.

The same evolutive tendency is taking place in some sectors and coastlines of the Western Mediterranean subject to strong degradation of anthropic origin.

In the last ten years in these degraded areas both in the Eastern Mediterranean and in the Western Mediterranean several species are spreading with invasive behavior, above all Codiaceae and Caulerpaceae, migrants and/or introduced both from the Atlantic and from the Indian-Pacific (GIACCONE & DI MARTINO, 1995; VERLAQUE, 1994). This phenomenon causes in the degraded areas the initial phase of a new structuring of the plant groupings, but accelerates comtemporaneously the destruction of those present in marginal areas, which often denoted, even before, signs of suffering and imbalance, at least of a quantitive type, in the marine flora.

Concluding considerations

The paleoclimatic data reconstructed through the cycles of Milankovich and the Sapropel crises, of both Nilotic, continental, and Bosphoric origins, explain the profound differences that exist both in the floristic contingent and in the chorologic spectrum of plants (Table 2), and in general of marine organisms (Table 3, 4), present respectively in the western and eastern basins of the Mediterranean.

Both the biocenotic and the phytosociological examinations confirm these differences and make the Eastern Mediterranean characterized as a basin with syntaxa still in an initial stage of rearrangement; the western ones characterized generally by a edaphic climax and by vicariant aspects and with a characterizing contingent that is euriecial and eurichoric respectively. Similar evolutive tendencies are present in the Adriatic and in the Ligurian-Provençal sectors, but they are due to anthropic and/or synergic causes, along with paleoclimatic causes. Because of fluvial contributions and coastal pollution, it is predicted that, if the dumping continues at the same rhythm of the last 30 years, an anoxy crisis in the deep waters of the Mediterranean will occur around the year 2050. This date could bring on, therefore, in both basins (Eastern and Western) a Sapropel crisis of catastrophic consequences for the biotic community and the associations principally of the Circalittoral and of the lower Infralittoral.

The time of renewal of the mediterranean waters, as is well-known, is inferior to a century. As a consequence the rising of the anoxic waters is relatively rapid. The reduction of the contributions of the Nile and that of the river tributaries of the Black Sea is bringing about a 3% deficit in the balance of alimentation/evaporation in the Eastern Mediterranean, with a consequent rise of the water entering the Sicilian Channel. This brings a rise in the values of the density of the intermediate Levantine water as well as a rise of temperature in the waters of Western Mediterranean (DOUMENGE, 1993). This phenomenon is at the base of the present process of tropicalization of the marine environment of the Mediterranean. As a consequence, become unstoppable both the success of the installation and the acceleration of the dispersion of tropical species coming from Indian-Pacific and Atlantic areas , or also introduced by the practices of aquicolture and aquariology.

The case of the Caulerpa with invasive behavior (*C. taxifolia, C.mexicana, C. racemosa* and *C. scalpelliformis*) is the synergic result of this phenomenon of tropicalization and the spread of organic pollution along all the coastlines. the endemic and stenovalent species (*Posidonia oceanica*, Cystoseira sp. pl.) in the degraded areas are absent or present in extremely reduced groupings or show in any case signs of suffering and of reproductive inefficiency. In these conditions their competitivity decreases and the eurivalent species prevale in the characterizing contingent, which is by definition stenovalent.

On mobile substrata organic pollution creates anoxia. The prevalence of reductive processes over those oxidative favors the spread of species, characterized by heterotrofic metabolism such as the Caulerpa (CRAWFORD & al., 1972; GIACCONE & DI MARTINO, 1995; CHISHOLM & al., 1995).

On rocky substratum the sedimentary facies of the Cystoseira beds, with a prevalence of Dictyotales and Sphacelariales, tend to expand both because of the rise in sedimentation and because of the installation of a widespread environmental instability. Even the shade vegetation responds to these sollicitations with the expansion of durable associations independent from the zonation, as do those of the Peyssonnelion squamariae (GIACCONE & al., 1994a, 1994b).

This model of evolution of the vegetation pushed by paleoclimatic conditions, comparable to the present process of tropicalization, is documented in geological times at least for the Caulerpa, which in the old Tethys basin, from the Eocene to the Miocene, had invaded, in favorable paleocologic conditions, extensions comparable to those noteworthy ones occupied today by *C. racemosa, C.mexicana* and by *C. scalpelliformis* in the Eastern Mediterranean and by *C. taxifolia* in the Western Mediterranean (LE RENARD, 1983).

To conclude this necessarily synthetic presentation of the causes of the evolutive phenomena of Mediterranean marine vegetation, it seems we have made an attempt to reconcile the vision in the correct space-time scale, with the significance of the anthropic action, which appears to accelerate to the magnitude of generations, phenomena which until now generally had rhythms of millennia or at least centuries.

Appendix

Check-list of syntaxa described for the marine vegetation in the Mediterranean.

SUPRALITTORAL AND MIDLITTORAL ZONES.

CLASS: ENTOPHYSALIDETEA Giaccone 1993.
Char. class. *Brachytrichia quojii*

ORDER: ENTOPHYSALIDETALIA DEUSTAE Ercegovic 1932.
Char. ord. *Microcoleus lyngbyaceus*

All. Entophysalidion deustae Ercegovic 1932.
Char. all. *Microcoleus lyngbyaceus*

1 Ass. Entophysalidetum deustae Berner 1931.
Char. ass. *Entophysalis deusta*
Mastigocoleum testarum
Calothrix crustacea
Verrucaria symbalana
Verrucaria maura

Order: BANGIETALIA ATROPURPUREAE Giaccone 1993.
Char. ord. *Mesospora macrocarpa*

All. Bangion atropurpureae Giaccone 1993.
Char. all. *Mesospora macrocarpa*

2 Ass. Bangietum atropurpureae Giaccone 1993.
Char. ass. *Bangia atropurpurea*
Ulothrix flacca

3 Ass. Porphyretum leucostictae Boudouresque 1971
Char. ass. *Porphyra leucosticta*
Scytosiphon simplicissimus
Polysiphonia sertularioides

4 Ass. Nemalio-Rissoelletum verruculosae Boudouresque 1971
Char. ass. *Rissoella verruculosa*
Nemalion helminthoides
Audouinella nemalionis

ORDER: RALFSIETALIA VERRUCOSAE Giaccone 1993.
Char. ord. *Ralfsia verrucosa*
Nemoderma tingitanum
Gastroclonium clavatum
Corallina elongata

All. Ralfsion verrucosae Giaccone 1993.
Char. all. *Ralfsia verrucosa*
Nemoderma tingitanum
Gastroclonium clavatum
Corallina elongata

5 Ass. Lithophylletum lichenoidis Giaccone 1993.
Char. ass. *Lithophyllum lichenoides*
Chaetomorpha mediterranea
Laurencia papillosa
Pterocladia melanoidea
Lophosiphonia cristata
Taenioma nanum

6 Ass. Ceramio-Corallinetum elongatae Pignatti 1962
Char. ass. *Ceramium ciliatum*
Ceramium rubrum v. *barbatum*
Gelidium pusillum
Antithamnion cruciatum
Ceramium diaphanum v. *diaphanum* (con ris.)

7 Ass. Fucetum virsoidis Pignatti 1962
Char. ass. *Fucus virsoides*
Enteromorpha flexuosa
Schizothrix calcicola
Gelidium pulvinatum
Gelidium spathulatum

8 Ass. Phymatolithetum lenormandii Giaccone 1993.
Char. ass. *Phymatolithon lenormandii*
Cruoriella armorica
Hildenbrandia rubra
Gymnothamnion elegans

9 Ass. Enteromorphetum compressae (Berner 1931) Giaccone 1993
Char. ass. *Enteromorpha compressa*
Callithamnion granulatum
Cladophora pellucida
Blidingia minima

INFRALITTORAL AND CIRCALITTORAL ZONES. PHOTOPHILIC VEGETATION.

CLASS: Cystoseiretea Giaccone 1965
Char. Class.: *Jania rubens*
Lithophyllum incrustans
Padina pavonica
Dasycladus vermicularis
Dilophus fasciola v. *repens*

Laurencia obtusa
Acetabularia acetabulum
Pseudolithoderma adriaticum
Erythrocystis montagnei
Amphiroa rigida
Liagora viscida

Order: Cystoseiretalia Molinier 1958 *emend.* Giaccone 1994
Char Ord.: *Jania rubens*
Lithophyllum incrustans
Padina pavonica
Dasycladus vermicularis
Dilophus fasciola v. *repens*
Laurencia obtusa
Acetabularia acetabulum
Pseudolithoderma adriaticum
Erythrocystis montagnei
Amphiroa rigida
Liagora viscida

All. Cystoseirion crinitae Molinier 1958
Char All.: *Jania rubens*
Lithophyllum incrustans
Padina pavonica
Dasycladus vermicularis
Dilophus fasciola v. *repens*
Laurencia obtusa
Acetabularia acetabulum
Pseudolithoderma adriaticum
Erythrocystis montagnei
Amphiroa rigida
Liagora viscida

1 Ass. Cystoseiretum strictae Molinier 1958
Char Ass.: *Cystoseira amentacea v. stricta*
Feldmannia paradoxa

Subass. Cystoseiretosum tamariscifoliae Giaccone 1972
Sp. diff.: *Cystoseira tamariscifolia*
Mesophyllum lichenoides
Saccorhiza polyschides
Phyllariopsis brevipes
Asparagopsis armata
Schyzimenia dubyii
Desmarestia ligulata
Halurus equisetifolius

2 Ass. Dasycladetum vermicularis Mayhoub 1976
Char Ass.: *Dasycladus vermicularis*
Polysiphonia ferulacea

3 Ass. Sargassetum vulgaris Mayhoub 1976
Char Ass.: *Sargassum vulgaris*
S. trichocarpum

4 Ass. Cystoseiretum crinitae Molinier 1958
Char Ass.: *Cystoseira crinita*
Sphacelaria cirrosa
Halopteris scoparia
Cladostephus spongiosus f. *verticillatus*
Anadyomene stellata

Subass. Alsidietosum helmintochortonis Molinier 1958
Sp. diff.: *Alsidium helmintochorton*
Subass. Cystoseiretosum compressae Molinier 1958
Sp. diff.: *Cystoseira compressa*
Subass. Halopteretosum scopariae Boudouresque 1971
Sp. diff.: *Halopteris scoparia*
Subass. Halopitetosum incurvi Boudouresque 1971
Sp. diff.: *Halopitys incurvus*
Dipterosiphonia rigens

5 Ass. Cystoseiretum barbatae Pignatti 1962
Char Ass.: *Cystoseira barbata*
Halymenia floresia
Gracilaria bursa-pastoris
Hypnea musciformis
Nemastoma dichotoma
Ceramium diaphanum v. *diaphanum*
C. diaphanum v. *strictum*
C. diaphanum v. *lophophorum*
Bonnemaisonia asparagoides

6 Ass. Trichosoletum myurae Mayhoub 1976
Char Ass: *Liagora farinosa*
Trichosolen myura
Hydroclathrus clathratus

7 Ass. Herposiphonio-Corallinetum elongatae Ballesteros 1988
Char. Ass.: *Herposiphonia secunda* f. *tenella*
Corallina elongata

8 Ass. Cystoseiretum sauvageauanae Giaccone 1994.
Char. Ass.: *Cystoseira sauvageauana*
C. schiffneri f. *tenuiramosa*
Stilophora rhizodes

9 Ass. Chaetomorpho-Valonietum aegagropilae Giaccone 1974.
Char. Ass.: *Valonia aegagropila*
Chaetomorpha linum

10 Ass. Gracilarietum verrucosae Giaccone 1974.
Char. Ass.: *Gracilaria verrucosa*

11 Ass. Cladophoro-Rytiphloeetum tinctoriae Giaccone 1994.
Char. Ass.: *Cladophora echinus*
Rytiphloea tinctoria

12 Ass. Myrionemo-Giraudietum sphacelarioidis Van der Ben 1971
Char. Ass.: *Myrionema orbiculare*
Giraudia sphacelarioides
Cladosiphon cylindricus
C. irregularis
Myractula gracilis
Chondria mairei
Spermothamnion flabellatum f. *bisporum*

All. Sargassion hornschuchii Giaccone 1973
Char. All.: *Sargassum hornschuchii*
Codium bursa
Spatoglossum solieri
Zanardinia prototypus
Zonaria tournefortii

13 Ass. Cystoseiretum spinosae Giaccone 1973
Char. Ass.: *Cystoseira spinosa*
C. schiffneri v. *latiramosa*
Valonia macrophysa
Halopteris filicina
Dictyota dichotoma v. *intricata*

14 Ass. Cystoseiretum zosteroidis Giaccone 1973
Char. Ass.: *Cystoseira zosteroides*
Arthrocladia villosa
Sporochnus pedunculatus
Polysiphonia foeniculacea

Subass. Laminarietosum rodriguezii Giaccone 1973
Sp. diff.: *Laminaria rodriguezii*

15 Ass. Cystoseiretum usneoidis Giaccone 1972
Char. Ass.: *Cystoseira usneoides*
Laminaria ochroleuca
Phyllariopsis purpurascens
Ulva olivascens
Callophyllis laciniata
Phyllophora heredia

Subass. Laminarietosum ochroleucae Giaccone 1994.
Sp. diff.: *Laminaria ochroleuca*
Lithothamnion philippi

16 Ass. Cystoseiretum dubiae Furnari, Cormaci, Scammacca & Battiato 1977
Char. Ass.: *Cystoseira dubia*
Nitophyllum tristromaticum
Kallymenia patens

Order: Ulvetalia Molinier 1958
Char. Ord.: *Ulva rigida*
Spermothamnion irregulare
Gymnogongrus griffithsiae

All. Ulvion rigidae Berner 1931
Char. All.: *Ulva rigida*
Spermothamnion irregulare
Gymnogongrus griffithsiae

17 Ass. Ulvetum rigidae Berner 1931
Char. Ass.: *Enteromorpha linza*
Pterosiphonia parasitica

18 Ass. Pterocladio-Ulvetum rigidae Molinier 1958
Char. Ass.: *Pterocladia capillacea*
Colpomenia sinuosa
Gigartina acicularis
Nitophyllum punctatum

19 Ass. Dictyopteretum polypodiodis Berner 1931
Char. Ass.: *Dictyopteris polypodioides*

20 Ass. Ceramietum rubri Berner 1931
Char. Ass.: *Ceramium rubrum*

21 Ass. Corallinetum officinalis Berner 1931
Char. Ass.: *Corallina officinalis*

CLASS: Zosteretea Pignatti 1953
Char. Class.: *Zostera noltii*

Order: Zosteretalia Bèguinot 1941
Char Ord.: *Zostera noltii*

All. Zosterion Braun-Blanquet & Tüxen 1943
Char. All.: *Zostera noltii*

22 Ass.: Posidonietum oceanicae Molinier 1958
Char Ass.: *Posidonia oceanica*

23 Ass. Cymodoceetum nodosae Giaccone e Pignatti 1967
Char Ass.: *Cymodocea nodosa*

24 Ass. Zosteretum marinae Pignatti 1962
Char Ass.: *Zostera marina*

25 Ass. Zosteretum noltii Pignatti 1953
Char Ass.: *Zostera noltii*

INFRALITTORAL AND CIRCALITTORAL ZONE. SCIAPHILIC VEGETATION.

Class: Lithophylletea Giaccone 1965 *emend.* Giaccone 1994
Char. Classe: *Lithophyllum grandiusculum*
Peyssonnelia rubra
Peyssonnelia inamoena

Order: Rhodymenietalia Boudouresque 1971 *emend.* Giaccone 1994
Char. Ord.: *Botryocladia botryoides*
Cutleria chilosa
Eupogodon planus
Mesophyllum lichenoides
Nereia filiformis
Phyllophora crispa
Valonia macrophysa

All.: Schotterion nicaeensis Boudouresque & Cinelli 1971 *emend.* Giaccone 1994
Car.All.: *Lomentaria clavellosa*
Cruoria cruoriaeformis
Griffithsia flosculosa
Lomentaria articulata

1 Ass.: Schotteretum nicaeensis Berner 1931
Char. Ass.: *Gymnogongrus crenulatus*
Schottera nicaeensis

2 Ass.: Rhodymenietum ardissonei Pignatti 1962
Char. Ass.: *Gigartina acicularis*
Rhodophyllis divaricata

3 Ass.: Pterothamnio-Compsothamnietum thuyoidis Boudouresque, Belsher & Marcot-Coqueugniot 1977
Char. Ass.: *Compsothamnion thuyoides*
Pterothamnion crispum.

All.: Peyssonnelion squamariae Augier & Boudouresque 1975 *emend.* Giaccone 1994
Char. All.: *Botryocladia botryoides*
Cutleria chilosa
Eupogodon planus
Mesophyllum lichenoides
Nereia filiformis
Phyllophora crispa
Valonia macrophysa

4 Ass.: Flabellio-Peyssonnelietum squamariae Molinier 1958
Char. Ass.: *Flabellia petiolata*
Peyssonnelia squamaria
Osmundaria volubilis

Subass.: Osmundarietosum volubilis Serio & Pizzuto 1992
Sp. diff.: *Osmundaria volubilis*

5 Ass.: Halymenietum floresiae Giaccone & Pignatti 1967
Char. Ass.: *Alsidium corallinum*
Boergeseniella fruticulosa
Chrysimenia ventricosa
Cladophora prolifera
Halarachnion ligulatum
Halymenia floresia
Scinaia furcellata
Sphaerococcus coronopifolius
Thuretella schousboei

6 Ass.: Rhodymenio-Codietum vermilarae Ballesteros 1989
Char. Ass.: *Aglaothamnion tripinnatum*
Codium vermilara
Spermothamnion flabellatum

Order: LITHOPHYLLETALIA GIACCONE 1965
Char. Ord.: *Halimeda tuna*
Peyssonnelia polymorpha
Peyssonnelia rosa-marina
Polysiphonia sanguinea
Rhodymenia pseudopalmata

All.: Lithophyllion grandiusculi Giaccone 1965
Char All.: *Halimeda tuna*
Peyssonnelia polymorpha
Peyssonnelia rosa-marina
Polysiphonia sanguinea
Rhodymenia pseudopalmata

7 Ass.: Lithophyllo-Halimedetum tunae Giaccone 1965
Char Ass.: *Halimeda tuna*
Lithophyllum grandiusculum

8 Ass.: Rodriguezelletum strafforellii Augier & Boudouresque 1975
Char Ass.: *Blastophysa rhizopus*
Ceramium bertholdii
Polysiphonia subulifera
Rodriguezella pinnata
Rodriguezella strafforellii
Spermothamnion johannis
Sphacelaria plumula

9 Ass.: Phymatholitho-Lithothamnietum corallioidis Giaccone 1965
Char Ass.: *Lithothamnion corallioides*
Phymatholithon calcareum

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