THE LAGOONS OF LESINA AND VARANO

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Riassunto

Questo lavoro sui bacini di Lesina e Varano tratta principalmente dei loro aspetti naturalistici e commerciali. La letteratura riporta pochi dati sulla flora e la vegetazione di Lesina e solo osservazioni occasionali su quella di Varano. Dai pochi dati disponibili, la laguna di Lesina sembra essere un bacino confinato in cui dominano le angiosperme *Nanozostera noltii* e *Ruppia cirrhosa* e un numero limitato di macroalghe quali *Valonia aegagropila*, insieme ad alcune Cladophorales, Gracilariaceae e Corallinaceae. Comunque, la successione delle specie dipende dalle frequenti fluttuazioni di salinità.

Abstract

The present paper on the Lesina and Varano basins mainly focuses on their naturalistic and commercial aspects. The literature contains few data on the flora and the vegetation of Lesina and only occasional observations on the Lake of Varano. From the few data available, the lagoon of Lesina appears to be a confined basin dominated by the angiosperms *Nanozostera noltii*, *Ruppia cirrhosa* and a limited number of macroalgae such as *Valonia aegagropila*, together with some Cladophorales, Gracilariaceae and Corallinaceae. However, the species succession depends on the frequent salinity fluctuations.

Key-words: Adriatic Sea, Angiosperms, Apulia, Lesina lagoon, Lake of Varano, Mediterranean Sea, Seaweeds, Transitional waters

1 Introduction

The lagoon of Lesina and the lake of Varano (Fig. 1) are located on the central-southern Adriatic coast of Italy. Both are connected to the sea by two tidal canals running across their respective dune cordons, which were formed by deposition of sand transported by marine currents. The lagoons are less than 10 km apart and are separated by a rocky promontory known as Monte d'Elio.

The lagoon of Lesina is shallow and is characterised by low shores all around its perimeter, while the lake of Varano is deeper and its shores are higher, indented and rocky, especially on the South-western side.

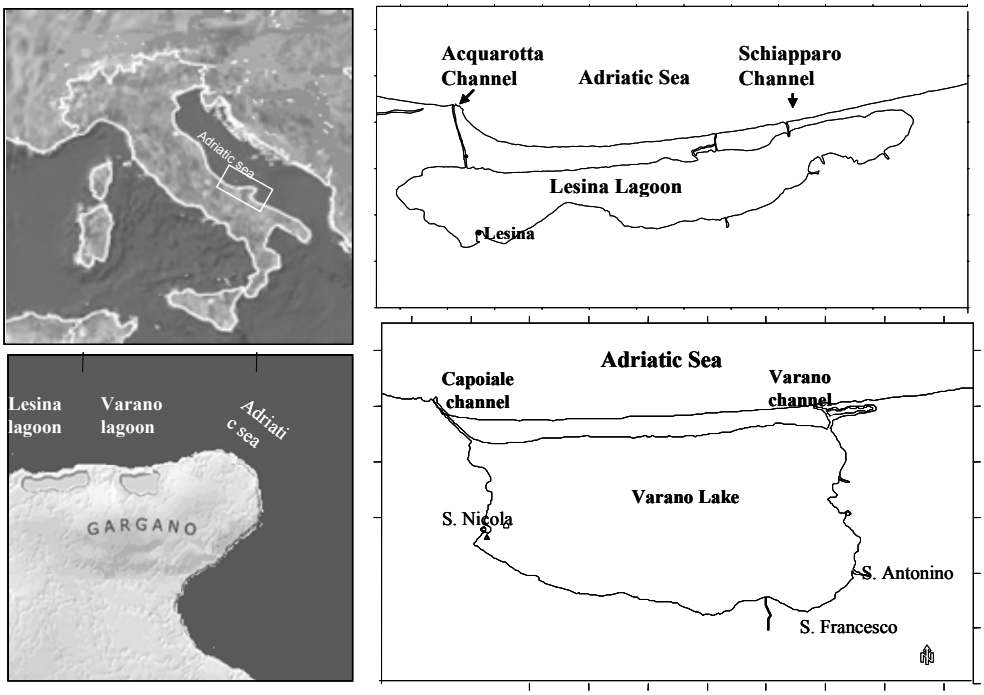

Fig. 1 – Map of the lakes of Lesina and Varano.

The lagoon of Lesina and the lake of Varano, together with the dunes that separate them from the sea, constitute a Special Protection Zone (ZPS), site code IT9110037.

Fishing is the main human activity in both the lagoons. About 120 fishermen operate in the lagoon of Lesina and 70 in Varano. Fishing is mainly traditional, using fyke traps and monofilament nets. Recently aquaculture has been developed in the main part of the basins (*Penaeus japonicus* Bate) and clam-farming (*Tapes philippinarum* Adams *et* Reeve, *Tapes decussatus* Linnaeus and *Crassostrea gigas* Thunberg) is practiced on an experimental basis in the lake of Varano. However, in the last few years, aquaculture has declined in Varano due to continual summer epidemics among the cultivated shellfish.

In Lesina the catchment basin includes livestock farms with cows and buffalos (2000 head) and seed and irrigated crops. There are numerous land-based aquaculture companies that discharge their waters, after treatment, into the western and central-eastern area of the lagoon on the southern shore. The only industries are those associated with primary processing of agricultural products (washing, packaging and storage). The urban waste waters of 3 municipalities, with a combined population of less than 30,000 inhabitants, are discharged into the lagoon after partial treatment.

In Varano the catchment basin is used mainly for tree crops (olives), seed and irrigated crops. There are free-range livestock farms for cattle, sheep and pigs. Land-based aquaculture is modest, with currently only one plant on the dunes. There is little or no industrial activity, and the greatest impact on the lake derives from the processing and shipping of shellfish cultivated in the sea through the Capoiale channel. Leisure activities are practiced on the Varano channel.

2 Description of the site

2.1 The lagoon of Lesina

The lagoon of Lesina (41.88 °N and 15.45 °E) is 22 Km long and a maximum of 3.5 Km wide. The lagoon covers an area of 5,136 ha and its catchment basin 460 km^2 (Bullo 1902). It is linked to the Adriatic Sea by the Acquarotta canal to the West, 2 km long, 6 to 10 metres wide, and 0.8 to 2 metres deep, and by the Schiapparo canal to the East, 1 km long, about 25m wide and from 2 to 4m deep. The depth of the lagoon is about 0.8m on average and does not exceed 1.3 m. Inputs from the land are greatest at the eastern end, where two permanent watercourses (Lauro and Zannella) discharge with an average flow of 600 L s^{-1}, but the lagoon also receives waters from numerous agricultural drainage canals around its shores. Two pumping stations also discharge into the lagoon at its eastern end, drawing waters from drainage canals below the level of the lagoon. The residence time of the water is estimated to be about 70-100 days (Manini et al. 2003a).

From the hydrodynamic point of view the lagoon of Lesina is an extremely thin layer of homogeneous fluid in which both bathymetric variation and stratification are negligible and the movement of the layer is due to tide and wind. The modest tidal range does not cause significant exchange of waters whereas the winds produce longitudinal flows and mixing of the masses of water (Crisciani 1994).

The main ecological characteristics of the Lesina lagoon are shown in Tab. 1.

In Lesina, due to the limited depth, the thermal regime is influenced mostly by weather conditions (Palmegiano et al. 1985, Roselli 2008), and the salinity by lagoon hydrology, with changing spatio-temporal patterns. The highest values (up to 45 psu) occur in the western part of the lagoon and the lowest (ca. 3-6 psu) in the eastern part, where freshwater inputs along the landward shore are the highest (Marolla 1980a, c). Dissolved Oxygen and pH are strongly affected by primary production, reaching a maximum saturation of 214% and a maximum value of 9.93, respectively. Waters are very clear in the central and eastern lagoon where light transmission to the bottom is high, whereas in the western area, especially close to the town of Lesina, light transmission decreases markedly, reaching 0.

Nutrient concentrations in the water column in the lagoon of Lesina follow spatio-temporal patterns that depend on the seasons, primary production, organic matter mineralization and inputs from the catchment basin (Tab. 1) (Lumare and Palmegiano 1980, Marolla 1981, Roselli et al. 2007, Sfriso unpublished data). They are quite high near the canal and river outflows, especially nitrates, ammonium, silicates and total dissolved nitrogen and phosphorus.

The sediments are of a yellow-ochre colour in the first few millimetres on the western side and from dark grey to black in the remaining part of the basin. In summer 2005, pH values ranged from 6.95 to 8.73 whereas E_h was highly

negative. The sediment was 45% sandy-silt, 26% very sandy-silt, 14% clayey-silt, 12% silty-sand and 3% sand (Manini 2008).

Tab 1 - Physico-chemical and biological characteristics of Lesina and Varano lagoons.

	Lesina lagoon		Varano lake	
Area (ha)	5136		6500	
Mean depth (m)	0.8		3.5	
Drainage basin (km^2)	600		300	
Water Column				
	Min	**Max**	**Min**	**Max**
Salinity (psu)	3	45	24	37
Temperature (°C)	7.5	31.2	8.6	31.3
pH (units)	7.49	9.93	7.99	8.28
E_h (mV)	191	281	ns	ns
DO (% saturation)	64	214	96	187
% Light transmission (bottom)	0	50	ns	ns
$NH4^+$ (µM)	3.90	35.7	0.84	3.38
NO_2^- (µM)	0.11	1.06	ns	1.21
NO_3^- (µM)	1.13	41.6	2.43	20.9
DIN (µM)	5.02	65.2	ns	ns
PO_4^{3-} (µM)	0.04	1.11	ns	0.70
SiO_2^- (µM)	1.91	193	0.33	128
N_{tot} (µM)	14.9	152	33.0	88.7
P_{tot} (µM)	0.10	6.27	0.23	7.84
Chl *a* (µg L^{-1})	0.25	56.3	0.49	47.5
Phaeo *a* (µg L^{-1})	0.47	12.1	0.03	71.95
Phytoplankton (cell/L$x10^6$)	0.002	11.2	0.075	4.31
Zooplankton (ind/m^3)	0.38	10591	173	12280
Surface sediments (top 5 cm layer)				
	Min	**Max**	**Min**	**Max**
pH (units)	6.95	8.73	ns	ns
E_h (mV)	-120	-240	ns	ns
% >63 µm	46.8	84.9	ns	ns
Dry density (g dwt cm^3)	0.26	0.64	ns	ns
P_{tot} µg g^{-1} dwt	317	527	ns	ns
P_{ora} µg g^{-1} dwt	120	315	ns	ns
N_{tot} mg g^{-1} dwt	2.09	5.74	ns	ns
C_{tot} mg g^{-1} dwt	32.8	94.0	ns	ns
C_{org} mg g^{-1} dwt	19.9	59.7	ns	ns

Nutrient concentrations vary considerably according to the season and the considered area, with some very high values. In the first 5 cm of sediment, organic carbon, total nitrogen and organic phosphorus reached 59.7 mg g^{-1} dwt, 5.74 mg g^{-1} dwt and 315 µg g^{-1} dwt respectively in summer 2005

Concentrations of pollutants, including metals, pesticides and PCBs, deriving mainly from agriculture or urban waste waters, are very low (Storelli et al. 2007,

D'Adamo et al. 2008).

The phytoplankton community, composed mainly of diatoms (Bacillariophyceae), has changed over the years following different spatial patterns. Phytoplankton as chlorophyll *a* is also characterised by spatio-temporal variability (Marolla et al. 1996, Roselli 2008). There is very little mesozooplankton (mainly Calanoida), the main species being *Calanipeda aquaedulcis* Kritchagin (Brugnano and D'Adamo 2007).

Bivalves make up 93.8% of the benthic macrofauna (19 taxa identified) (Cilenti et al. 2002), *Abra segmentum* Récluz accounting for 83% of their biomass (Breber 1994).

The ichthyic fauna includes migratory marine species (*Mugil cephalus* Linnaeus, *Liza aurata* Risso, *Liza saliens* Risso, *Liza ramada* Risso, *Chelon labrosus* Risso, *Sparus auratus* Linnaeus, *Dicentrarchus labrax* Linnaeus, *Anguilla anguilla* Linnaeus), resident species (*Atherina boyeri* Risso, *Aphanius fasciatus* Nardo, *Knipowitschia panizzae* Verga) and a few occasional species, both marine and freshwater. No resident freshwater species have been found near the river and canal outflows (Lumare and Villani 1989, Priore et al. 1994).

Some "non-indigenous species" have been recorded in this ecosystem, such as the prawn *Penaeus japonicus* Bate (Lumare and Palmegiano 1980) and the clam *Tapes philippinarum* Adams *et* Reeve (Cozzolino and Villani 1993), introduced for aquaculture purposes, the fish *Oreochromis nicotilus* Linnaeus, the crab *Callinectes sapidus* Rathbun, the crayfish *Procambarus clarkia* Girard and the clam *Musculista senhousia* Benson in Cantor, identified recently (Florio et al. 2007).

2.2 Lake Varano

Lake Varano is located on the North-East side of the Gargano promontory (41.88°N; 15.75°E). It covers an area of 65 km^2 with a width of 7 km and a length of 10 km. The average depth is ca. 4 m, with a maximum of ca. 5 m in the centre. It is separated from the sea on its North side by a line of dunes 10 km long and 1 km wide. It is connected to the sea through two canals: Capoiale to the West, 20 to 50 m wide, 1.6 km long and ca. 5 m deep, and Varano to the East, 20 m wide, 1 km long and ca. 2 m deep.

The net outflow is estimated to be about 87 x 10^{-3} m^3 d^{-1}. The hydrology is influenced by exchanges with the sea through the two tidal canals and by the freshwater inputs from the catchment area of ca. 300 km^2. Inputs from the catchment area come from the two storm drains of S. Antonino and S. Francesco, from the Muschiaturo pumping station, and from numerous intermittent water courses (Casa Coccia, Bagno, Irchio, Ospedale, S. Nicola), mainly situated along the South-East edge of the lake, which discharge urban wastewaters from nearby municipalities and the runoff from surrounding farmland (about 50% of which is olive and citrus groves) and grazing land. The residence time of the waters is estimated to be about 3 years due to the limited tidal range (Manini et al. 2003).

The urban waste waters of 3 municipalities with a total of about 18,000 inhabitants are discharged into the lake after partial treatment.

The main ecological characteristics of lake Varano are shown in Tab. 1.

The thermal regime is influenced by weather conditions. Salinity is also influenced by the lake hydrology, with seasonal, temporal changes. It ranges from a maximum of 37 psu near the tidal canals to a minimum of 18 psu on the South-Eastern edge, where the freshwater inputs are most abundant (Marolla 1980b, Specchiulli et al. 2002, Spagnoli et al. 2002).

Dissolved nutrients (nitrogen, phosphorus and silicon) follow spatio-temporal patterns that vary with the seasons, rainfall and freshwater inputs from the land. Chlorophyll *a*, phytoplankton abundance (cells L^{-1}) and zooplankton abundance (ind m^{-3}) also follow different spatio-temporal patterns (Marolla 1980b, Caroppo 2000, 2002, Specchiulli et al. 2002, Roselli 2008).

The surface sediment grain-size of lake Varano is highly heterogenous, due to the abundant detritus of mainly bioclastic origin that constitutes the coarsest fractions of the sediment. The most abundant grain-size fraction is mud (>50%), with the exception of the sediments near the shore, where the sandy component prevails (Scardi et al. 2008). No water stratification has been recorded (Spagnoli et al. 2002).

Pollutants such as metals in the sediments seem to derive mainly from agriculture, but the concentrations are fairly low (Spagnoli et al. 2002).

The benthic macrofauna of this basin has been studied by various authors (Bianchi 1980, Morri 1980, Diviacco 1982, Piscitelli et al. 2001). The most abundant taxa are Polychetae followed by Mollusca, Amphipoda and Crustacea (Scardi et al. 2008).

The ichthyic fauna includes euryhaline and eurythermal species that reproduce in the sea and colonise the lagoon temporarily. Thirty one ichthyic species belonging to 17 families have been recorded. The most frequent are 5 species of Mugilidae and 8 species of Sparidae, as well as *Anguilla anguilla* (Tangioni et al. 2008).

In this lagoon, non-indigenous species have been also recorded. These include *Penaeus japonicus*, *Tapes philippinarum* (Cilenti and Breber 2005) and *Crassostrea gigas* Thunberg (Blundo et al. 1972) introduced for aquaculture purposes, and *Callinectes sapidus*, *Dyspanopeus sayi* Smith, *Rapana venosa* Valenciennes and *Musculista senhousia*, identified only recently (Florio et al. 2007).

3 Macroalgae

Few studies on the macrophyte have been carried out so far, and for lake Varano a review of previous studies has not yet been carried out.

The only studies available for Lesina were performed in June and July 1990 (Cozzolino 1995) and in May and July 2005 (Sfriso et al. 2006, Sfriso unpublished data).

In total, 27 taxa were recorded: 12 Rhodophyta and 15 Chlorophyta. No Ochrophyta were found (Tab. 2). Unfortunately, reproductive phenological data are not available and quantitative data have been reported for only a few species. In 1974, unattached thalli of *Gracilaria gracilis* (as *Gracilaria confervoides*) reached biomass values of up to 20 kg m^{-2} wwt (Trotta 1981, Francavilla and Trotta 2007) in the western area of the lagoon. Cozzolino (1995) reported *Cladophora prolifera* as the most abundant species throughout the lagoon, but this species subsequently declined and in 2005 was not recorded. In the late 1990s, *Valonia aegagropila* reached biomass values of up to 15-20 kg m^{-2} wwt (D'Adamo unpublished data) and in 2005 colonised large parts of the lagoon together with many crustose Corallinaceae (*Hydrolithon farinosum*, *Hydrolithon cruciatum*, *Lithophyllum pustulatum*), especially in the central and eastern lagoon. However, the vegetation is very different in the western part of the lagoon, which is affected by the town of Lesina and a buffalo farm. In that area the dominant species is *Cladophora fracta*; other Cladophoraceae are also present. Surprisingly, no laminar Ulvaceae ("*Ulva rigida*" or *Ulva laetevirens*) have ever been recorded.

The vegetation and ecological characteristics recorded in the central lagoon in 2005 correspond to good environmental conditions for confined transitional environments in the Mediterranean eco-region, as described by the European Water Framework Directive (2000/60/CE) (Sfriso et al. 2009).

Currently (Sfriso et al. 2009), five species (1 Rhodophyta, 1 Ochrophyta and 3 Chlorophyta) recorded by Cozzolino (1995) are no longer present (Tab. 3). Of these, the disappearance of *Valonia aegagropila* is striking. The presence of that species seems to be affected by the significant salinity changes recorded in the last few years.

The only available information on the flora and vegetation of lake Varano is based on occasional observations (Sfriso and Cecere, pers. comm.).

4 Angiosperms

The few data available concern only the lagoon of Lesina. Two species of seagrasses have been recorded: *Nanozostera noltii* (Hornemann) Tomlinson *et* Posluzny [as *Zostera noltii* Hornemann (Cozzolino 1995)] and *Ruppia cirrhosa* (Petagna) Grande (Cozzolino 1995, Sfriso et al. 2006). According to Cozzolino (1995), in 1990 *N. noltii* was present throughout the lagoon, in some areas reaching a density of 300 shoots m^{-2}. In 2005, *N. noltii* colonised the eastern and central lagoon but was almost absent in the western lagoon, which was affected by hypoxic conditions and colonised mainly by strands of *Cladophora fracta*, which overlapped and replaced the remaining seagrass beds. In 2005, *Ruppia cirrhosa* colonised the eastern and less saline part of the lagoon with dense meadows. Shoots were up to 1.10 cm high and many of the plants had long coils with seeds. The plant was also found in the Lauro river but its abundance and height decreased markedly in the central part of the lagoon, and disappeared completely in the eastern basin.

Unfortunately no further quantitative information is available.

Conclusion

The lagoon of Lesina and the lake of Varano are recognized areas of extremely high naturalistic value, despite the relatively high human pressures (fishing and mussel harvesting) and consequent environmental impact. However, knowledge of the flora and vegetation of these basins is poor or non-existent, especially in Varano where no information is available.

The European Water Framework Directive (2000/60/EC) establishes macrophytobenthos as one of the main parameters for quality assessment of transitional waters. The structure of macrophyte beds, the richness of macroalgae and seagrasses and the presence of key species are useful parameters for the final classification of these ecosystems. Lesina lagoon and lake Varano are still relatively unaffected by anthropic impact and the ecological state in large parts of them could be considered as reference conditions for confined transitional environments in the Mediterranean eco-region.

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Tab. 1 - List of seaweeds present in the Lesina lagoon.

Taxa	References
RHODOPHYTA	
Acrochaetium virgatulum (Harvey) Batters	Sfriso unpubl. data
Ceramium siliquosum (Kützing) Maggs & Hommersand	Sfriso unpubl. data
Ceramium virgatum Roth	9 (as *C. rubrum* (Hudson) C. Agardh, Sfriso unpubl. data.
Chondria capillaris (Hudson) M. J. Winne	Sfriso unpubl. data
Chroodactylon ornatum (C. Agardh) Basson	Sfriso unpubl. data
Colaconema daviesii (Dillwyn) Stegenga	Sfriso unpubl. data
Dasya baillouviana (S. G. Gmelin) Montagne	Sfriso unpubl. data
Dasya sp.	Sfriso unpubl. data
Gracilaria gracilis (Stackhouse) Steentoft, Irvine *et* Farnham	Trotta 1981 (as *G. confervoides* Grev.), 9 (as *G. confervoides* Grev.), 14 [as *G. verrucosa* (Greville) Papenfuss], Sfriso unpubl. data
Hydrolithon boreale (Foslie) Y. M. Chamberlain	Sfriso unpubl. data
Hydrolithon farinosum (J. V. Lamouroux) D. Penrose *et* Y. M. Chamberlain	Sfriso unpubl. data
Lithophyllum pustulatum (J. V. Lamouroux) Foslie	Sfriso unpubl. data
Polysiphonia denudata (Dillwyn) Greville *ex* Harvey	Sfriso unpubl. data
Porphyra leucosticta Thuret	Sfriso unpubl. data
TOTAL RHODOPHYTA=14	
CHLOROPHYTA	
Blidingia minima (Nägeli *ex* Kützing) Kylin	Sfriso unpubl. data
Blidingia ramifera (Bliding) Garbary *et* Barkhouse	Sfriso unpubl. data
Chaetomorpha aerea (Dillwyn) Kützing	Sfriso unpubl. data
Chaetomorpha linum (O. F. Müller) Kützing	Sfriso unpubl. data
Cladophora fracta (O. F. Müller *ex* Vahl) Kützing	Sfriso unpubl. data
Cladophora laetevirens (Dillwyn) Kützing	Sfriso unpubl. data
Cladophora rupestris (Linnaeus) Kützing	Sfriso unpubl. data
Cladophora vadorum (Areschoug) Kützing	Sfriso unpubl. data
Derbesia tenuissima (Moris *et* De Notaris) P. *et* H. Crouan	Sfriso unpubl. data
Entocladia viridis Reinke	Sfriso unpubl. data
Rhizoclonium lubricum Setchell *et* N. L. Gardner	Sfriso unpubl. data
Rhizoclonium tortuosum (Dillwyn) Kützing	9 [as *Chaetomorpha capillaris* (Kutzing) Borg.], Sfriso, unpubl. data
Ulotrix flacca (Dilllwyn) Thuret	Sfriso unpubl. data
Ulva intestinalis Linnaeus	9 (as *Enteromorpha intestinalis* (Linnaeus) Link.) Sfriso unpubl. data
Ulvella lens P.& H. Crouan	Sfriso unpubl. data
Valonia aegagropila C. Agardh	9, 23, 14, Sfriso unpubl.data
TOTAL CHLOROPHYTA=16	
TOTAL SPECIES=30	

Tab. 2 - List of seaweeds disappeared from the Lesina lagoon.

Taxa	References
RHODOPHYTA	
Grateloupia filicina (J.V. Lamouroux) C. Agardh	9 [as *G. filicina* (Wulf.) C. Ag.]
TOTAL RHODOPHYTA=1	
OCHROPHYTA	
Ectocarpus siliculosus (Dillwyn) Lyngbye	9 [as *E. confervoides* (Roth) Le Jol.]
TOTAL OCHROPHYTA=1	
CHLOROPHYTA	
Cladophora prolifera (Roth) Kützing	9 [as *Cladophora prolifera* (Roth) Kutz.]
Ulotrix implexa (Kutzing) Kutzing	Sfriso pers.obs.
Valonia aegagropila C. Agardh	9, 23, 14, Sfriso pers.obs.
TOTAL CHLOROPHYTA=3	
TOTAL SPECIES=5	

Tab. 3 – List of species recorded in the Lake of Varano.

Taxa	References
RHODOPHYTA	
Alsidium corallinum C. Agardh	Sfriso and Cecere pers. obs.
Chondria capillaris (Hudson) M.J. Wynne	Sfriso and Cecere pers. obs.
Gracilariopsis longissima (S.G. Gmelin) M. Steentoft, L.M. Irvine *et* W.F. Farnham	Sfriso and Cecere pers. obs.
TOTAL RHODOPHYTA = 3	
CHLOROPHYTA	
Ulva scandinavica Bliding	Sfriso and Cecere pers. obs
TOTAL CHLOROPHYTA = 1	
TOTAL SPECIES = 6	
ANGIOSPERMAE	
Cymodocea nodosa (Ucria) Ascherson	Sfriso and Cecere pers. obs
TOTAL ANGIOSPERMAE = 1	