S. Calvo, A. Tomasello, M. Pirrotta, P. Calì, F. Cascino, G. Di Maida & C. Orestano

Posidonia oceanica as biological indicator of climate changes in a coastal mediterranean lagoon

Abstract

Calvo, S., Tomasello, A., Pirrotta, M., Calì, P., Cascino, F., Di Maida, G. & Orestano, C.: *Posidonia oceanica* as biological indicator of climate changes in a coastal mediterranean lagoon. — Bocconea 16(2): 889-895. 2003. — ISSN 1120-4060.

The study of cyclic variations of sheaths thickness (lepidochronological analysis) of the marine phanerogam *Posidonia oceanica* was carried out on orthotropic rhizomes in a coastal lagoon (Stagnone) to investigate the effects of climate changes. This study has allowed to learn information on the evolution of meadows since 1981 to 1995. *P. oceanica* meadow, in the study area, shows evident regression signals. Rhizomes annual mean growth, in the latest five years, shows a significative decrement, stimated around 28%. In addition, a gradual decrease of rhizomes primary production has been observed during historical series explored. The extrapolation for the whole meadow gives an estimated total rhizome production of 26,05 tons dw y^{-1} in 1981 and 15,32 tons dw y^{-1} in 1995, recording a loss of 41%. Thus, rapid decline of *P. oceanica* meadow indicates that coastal lagoons may be considered a highly vulnerable habitat where short-term climatic effects on seagrass ecosystem are possible and where the lepidochronological parameters employed constitute a useful tool in the definition of *P. oceanica* as a "biological indicator" of the environmental changes.

Introduction

Palaeoceanographic and palaeoclimatic evolution of Mediterranean basin has been characterised, in the latest millenniums, by a climatic instability which has played an important role in the marine communities dynamic (Trincardi 2000). *Posidonia oceanica* ecosystem is a climax of successional process on mobile substrates in the Mediterranean Sea, forming dense meadows which covered around 4% of infralittoral bottom, between the sea surface and the lower limit of 40 m (Molinier & Picard 1952; Den Hartog 1977; Meinesz & Laurent 1978).

In such an ecosystem, the crucial element is the plant itself; with its phenological features, growth dynamics and biomass partitioning, it plays multiple roles in maintaining the order equilibrium among animal and plant associations and chemical-physical characteristics of water and sediments (Colantoni 1995). A significative change has been seen in the biocoenotic structure because of increase of sea temperature and in particular of the effects of global warming (Trincardi 2000).

In fact changes in sea level, salinity, temperature, atmospheric CO_2, and UV radiation can modify seagrass distribution, productivity, and community composition. In turn, potential changes in distribution and structure of seagrass communities may have ecological implications for local regional biota, nearshore geomorphology and biogeochemical cycles (Short & Neckles 1999).

Posidonia oceanica (L.) Delile is an endemic marine phanerogam of the Mediterranean Sea belonging to the subphylum *Angiospermae*, class *Monocotyledoneae*, order *Potamogetonales*, family *Posidoniaceae*. The rhizomes of this seagrass show cyclical changes in sheath thickness according to insertion rank along the rhizome (Crouzet 1981; Pergent & al. 1983). The cycle period, delimited by two thickness minima, is called "lepidochronological year", by analogy with dendrochronology (Pergent 1990). Therefore, the reconstruction over years of the history of a significant number of rhizomes (lepidochronological analysis) allows to study the variations that characterise the ecological system of *P. oceanica* by the analysis of synthetic parameter (primary production, growth rate of the meadow, flowering rate etc.) (Chessa & al. 1995). In particular, among these parameters, the growth rate and the leaf formation rate show a significant relationship with the temperature and rainfall variations (Marbà & Duarte 1997).

The aim of this research is to estimate environmental quality of *P. oceanica* ecosystem, and in particular of the coastal area, through means of remote sensing techniques and lepidochronological analysis.

Material and methods

The Stagnone lagoon (Trapani, Italy) is natural reserve wide about 20 km^2, located in the western coast of Sicily (Fig. 1).

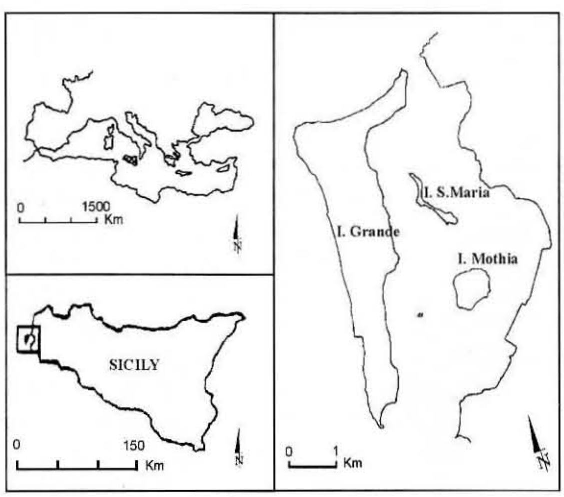

Fig. 1. Northern sub-basin of Stagnone lagoon (Trapani, Italy).

It is geomorphologically composed by two sub-basins: the northern sub-basin, that extends on 14 km^2 and its depth is around 1m, and the southern one, that extends on 6 km^2 and its depth is around 2m. The former, that is the study area, shows high lagoon characteristics, high annual variability of temperature (6-35 °C) and salinity (37-46 ‰) (Genchi & al. 1985); the latter represents the hydraulic connection with the open sea.

Water exchange with the sea occurs through two openings: the northern opening is narrower and shallower than the southern one that it is moreover biologically delimited by *P. oceanica* barrier reef. The main biotic component is represented by *P. oceanica* meadow which shows a patch distribution with reef formations 2-3 m wide.

The study area is affected by low and different hydrodynamic conditions and *P. oceanica* lives near environmental death point in the more internal sectors (Balzano & al. 2000).

Currently, *P. oceanica* meadow shows evident signals of regression in the lagoon and it is partially replaced by *Cymodocea nodosa* and *Caulerpa prolifera* prairies (Calvo & al. 1982).

The analysis of submerged vegetation was carried out using a DAEDALUS AADS 1268 CZCS airborne imaging multispectral scanner, while global solar irradiance was measured in the same area using a portable spectroradiometer (Calvo & al. 1995a, 1996).

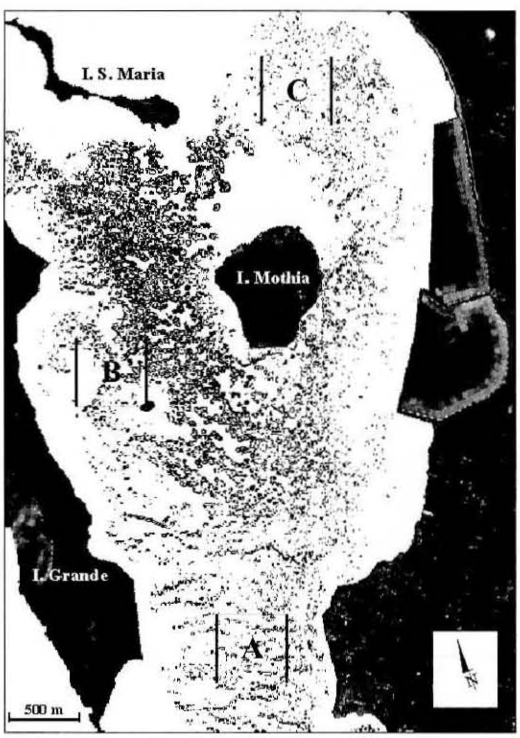

Fig. 2. Map of *P. oceanica* meadow inside the study area and sample sites.

A non-directional filter (Sobel) was applied on the first principal component to enhance the peculiar linear and circular *P. oceanica* features.

Orthotropic rhizomes were collected in three different sites of northern sub-basin lagoon (Fig. 2), located along hydrodynamic decreasing gradient (A—>B-C).

The lepidochronological analysis was carried on 82 orthotropic rhizomes. From each rhizomes the sheaths were detached, according to the insertion rank, by a blade razor and they were numbered from the older sheaths to the more recent ones and each rhizome segments (lepidochronological years) were dated (Pergent 1990; Pergent-Martini & Pergent 1994).

In addition, the length and dry weight (105 °C x 24h) of rhizomes fragments, between the sheaths of minimum thickness, are measured and the primary production was expressed as mass per dry weight (gr dw shoot^{-1}).

Results and discussion

The total area examined was 1178 ha and *P. oceanica* meadow, that occupies the central and southern sectors of the lagoon, covers 148,5 ha (12,6%). In the central-western sector seagrass meadow covers 21% of the benthic habitat, compared to 11,7% in southern area and 5,9% in central-eastern side where a greater regression was observed (Calvo & al. 1996).

In the sample area located near the southern opening (A), where hydrodynamic conditions are more favourable, rhizomes annual mean growth shows the highest values among sample sites, ranging from 6,45±2,95 mm to 10,39±1,14 mm.

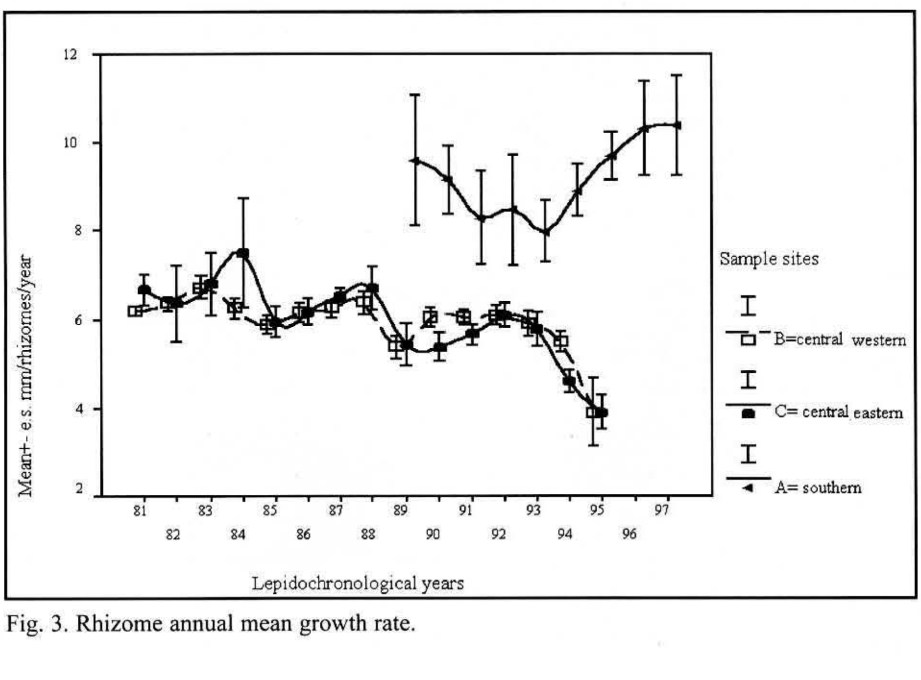

Fig. 3. Rhizome annual mean growth rate.

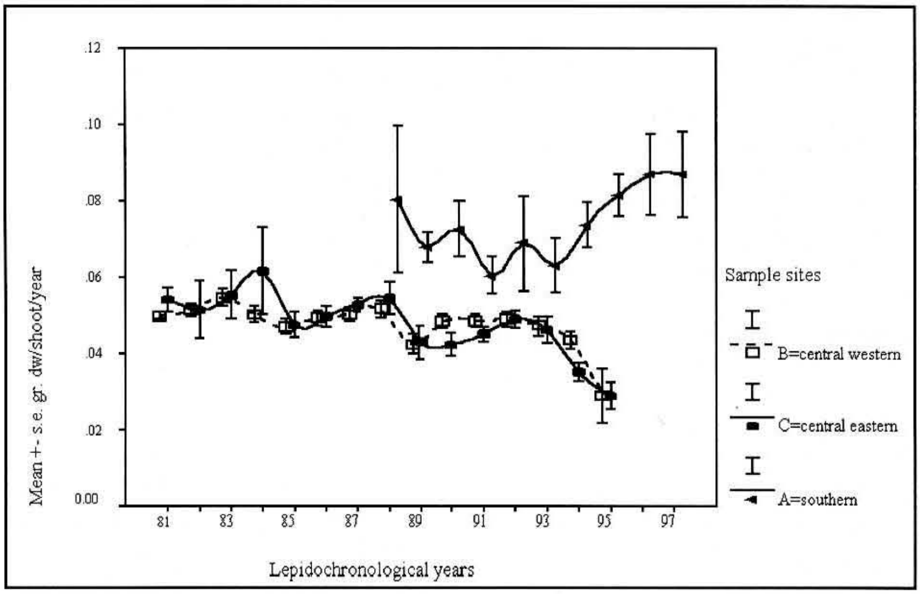

Fig. 4. Rhizome primary production trend.

In fact, in the more internal sample sites of the lagoon (B and C), rhizomes growth rate decreases from 6,34±0,41 mm to 3,9±1,22 mm in the explored temporal range. These values show a significative decrement in the latest five years, stimated around 28% (Fig. 3). According to Pergent & al. (1995) the rhizomes growth rate, independent on bathimetric gradient, shows "normal" and "subnormal" values in A site and in B-C sites respectively (Pergent & al. 1995). In particular, in the latest years, in the more internal sites the trend to "abnormal" values is recorded.

Consequently, the primary production shows the highest values (0,08±0,04 gr dw shoot^{-1}) and stability in the sample site (A) while, in the more internal sample sites, rhizomes primary production ranges from 0,035±0,01 gr dw shoot^{-1} to 0,061±0,02 gr dw shoot^{-1},

Table 1. Mean annual orthotropic rhizomes primary production in different simple sites of north western Sicily.

Sites	**Depth (m)**	**Rhizomes growth (mm)**	**Primary Production (g. dw /rhizome)**
S.Nicola L'Arena	3	11,5	0,120
S.Nicola L'Arena	6	14,0	0,150
P.ta S. Giuliano	11	15,3	0,130
Scoglio Formica	11	15,2	0,170
P.ta Scario	12	17,2	0,180
Stagnone	**1**	**7,1**	**0,058**

gradually decreasing during historical series explored (Fig. 4). The extrapolation for the whole meadow gives an estimated total rhizome production of 26,05 tons dw y^{-1} in 1981 and 15,32 tons dw y^{-1} in 1995, recording a loss of 41%.

Recorded data turned out to be among the lowest ones observed in north western Sicily (Table 1, Calvo & al. 1995b). It is interesting to remark the great difference with values observed off Punta Scario, because it is located in front of the lagoon. In fact, this area shows the highest values of primary production recorded in the Mediterranean Sea (Pergent-Martini & Pergent 1994).

Conclusion

P. oceanica meadow in the Stagnone lagoon shows some evident signals of regression, as shown by the marked decrease in the primary production of the plant within the observed temporal range. The rapid decline of the meadow could be caused by two conditions: 1) a decrease in water exchange and a increase of confinement of the lagoon respect to marine environment; 2) the rapid increase in temperatures of the last decades, caused by the climate's global changes.

Indeed, *Posidonia oceanica* lies near the environmental death point in the more internal sectors, where decreasing hydrodynamic characteristics and the high temperature values are recurrent.

Thus, the coastal lagoons such as the Stagnone may be considered a highly vulnerable habitat where short-term climatic effects are possible and where the lepidochronological parameters employed constitute a useful tool in the definition of *P. oceanica* as a "biological indicator" of the environmental changes.

References

Balzano, A., Calvo, S., Ciraolo, G. & La Loggia, G. 2000: Remote sensing as a tool to calibrate hydrodynamic model-transport numerical models. Proceedings of an International Conference "New Trends in Water and Environmental Engineering for Safety and Life. Eco-compatible Solutions for Aquatic Enviroments". — Capri, Italy, 3-7 July 2000. Maione, Majone Lehto, Monti (eds), A. A. Balkema, Rotterdam: 1-10.

Calvo, S., Ciraolo, G., Di Stefano, C. & La Loggia, G. 1995a: Remote sensing techniques for mapping submerged vegetation in coastal areas of Mediterranean Sea. — La *Posidonia oceanica*, Supplemento alla Rivista Marittima **12**: 150-157.

— , —, La Loggia G., Malthus, T. J., Savona, E. & Tomasello, A. 1996: Monitoring *Posidonia oceanica* meadows in Mediterranean Sea by means of airborne and satellite remote sensing. — Atti Second International Airborne Remote Sensing Conference and Exhibition, San Francisco, California, 24-27 June 1996, **3**: 659-668.

— , Fradà Orestano, C. & Tomasello, A. 1995b: Distribution, structure and phenology of *Posidonia oceanica* meadows along sicilian coasts. — Giornale Botanico Italiano **129(1)**: 351-356.

— , Giaccone, G. & Ragonese, S. 1982: Tipologia della vegetazione sommersa dello Stagnone di Marsala (TP). — Naturalista siciliano **6**: 187-196.

Chessa, L. A., Fresi, E. & Lorenzi, C. 1995: Stato di salute di una prateria di *Posidonia oceanica* - Metodi di studio. — La *Posidonia oceanica* Supplemento alla Rivista Marittima **12**: 72-77.

Colantoni, P. 1995: I sedimenti delle praterie a *Posidonia oceanica*. — La *Posidonia oceanica*, Supplemento alla Rivista Marittima **12**: 48-51.

Crouzet, A. 1981: Mise en èvidence des variations cycliques dans les ècailles des rhizomes de *Posidonia oceanica* (*Potamogetonaceae*). — Trav. Sci. Parc Nat. Port-Cros **7**: 129-135.

Den Hartog, C. 1977: Structure, function and classification in seagrass communities. Seagrass ecosystems. — A Scientific perspective: 89-121.

Genchi, G., Calvo, S., Lugaro, A. & Ragonese, S. 1985: Idrologia di una laguna costiera e caratterizzazione chimico-fisica dei sedimenti recenti in relazione alla distribuzione dei popolamenti vegetali sommersi (Lo Stagnone, Marsala). — Quaderni Ist. Pesca Marittima **4**: 149-161.

Marbà, N. & Duarte, C. M. 1997: Interannual changes in seagrass (*Posidonia oceanica*) growth and environmental change in the Spanish Mediterranean littoral zone. — Limnol. Oceanogr. **42(5)**: 800-810.

Meinesz, A. & Laurent, R. 1978: Cartographie et état de la limite inferieure de l'herbier de *Posidonia oceanica* dans les Alpes Maritimes (France). — Botanica Marina **21**: 513-526.

Molinier, R. & Picard, J. 1952: Recherches sur les herbiers de Phanérogames marines du littoral méditerranéen français. — Annales de l'Institut Océanographique **27**: 157-234.

Pergent, G. 1990: Lepidochronological analysis of the seagrass *Posidonia oceanica* (L.) Delile: a standardize approach. — Aquatic Botany **37**: 39-54.

—, Boudouresque, C. F., Crouzet, A. & Meinesz, A. 1989: Cyclic changes along *Posidonia oceanica* rhizomes (Lepidochronology): Present state and perspectives. — Marine Ecology P.Z.N.I. **10(3)**: 221-230.

—, Pergent-Martini, C. & Boudouresque, C. F. 1995: Utilisation de l'herbier a *Posidonia oceanica* comme indicateur biologique de la qualitè du milieu littoralen Méditerranée: état des connaissances. — Mésogée **54**: 3-27.

Pergent-Martini, C. & Pergent, G. 1994: Lepidochronological analysis in the Mediterranean seagrass *Posidonia oceanica*: state of the art and future developments. — Oceanologica acta **17(6)**: 673-681.

Short, F. T. & Neckles, H. A. 1999: The effects of global climate change on seagrasses. — Acquatic Botany **63**: 169-196.

Trincardi, F. 2000: Variabilità climatica dei regimi passati: raccolta, validazione e razionalizzazione dei dati recenti. — P. 267 in: Global change IGBP-Censimento delle ricerche italiane. — CNR Roma.

Addresses of the authors:
S. Calvo*, A. Tomasello, M. Pirrotta, P. Calì, F. Cascino, G. Di Maida & C. Orestano, Università degli Studi di Palermo, Dipartimento di Scienze Botaniche, via Archirafi, 38 - 90123 Palermo, Italy.
(*)Email: calvo@unipa.it