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QUALITATIVE MINIMAL AREA OF PHYTOBENTHIC COMMUNITIES IN THE INLETS OF THE LAGOON OF VENICE (ITALY, MEDITERRANEAN SEA)

Riassunto. *Area minima qualitativa del fitobentos nelle bocche diporto della laguna di Venezia.*
Uno studio dell'area minima qualitativa del fitobentos è stato condotto nella primavera-estate dei 1995 nelle tre bocche di porto della laguna di Venezia utilizzando il metodo dei quadrati imbricati con incremento d'area lungo la diagonale. I campionamenti sono stati condotti tra il mesolitorale e l'infralitorale sino alla profondità di 7 m. L'area minima qualitativa della comunità algale portuale risulta compresa tra 900 e 1600 cm². La comparazione con i dati riportati in letteratura per il Mediterraneo evidenziano valori di area minima superiori.

Summary. A study on the qualitative minima) area of phytobenthic communities was carried out at the inlets of the lagoon of Venice. Starting from an initial quadrat in the centre of the total sampling area, and using the method of imbricate quadrats of increasing area along the diagonal, the qualitative minima) area for the alga) community in the lagoon was estimated to be between 900 and 1600 cm². Comparing our data with those of the Mediterranean, differences in minimal area were evident.

Key words: Qualitative minima) area, phytobenthos, lagoon of Venice, Mediterranean.

INTRODUCTION

Sampling is the essential basis of ali ecological researches and should include all species occurring in the community. In practice, a compromise between a larger sampling area, including all species, and a smaller one, with the risk of obtaining incomplete collection of species, must be reached, thus allowing truly representative data about the studied communities to be used for later comparisons with other areas.

Several researches using different methods have been carried out on the minima) sampling area (BALLESTEROS, 1986, 1990; BOUDOURESQUE, 1974; BOUDOURESQUE & BELSHER, 1979; CINELLI et al., 1977a, 1977b; DHONDT & COPPEJANS, 1977; PIZZUTO & SERIO, 1994). These studies demonstrate how a minimal area cannot be generalized for all environments, but must be determined every time, due to its strict dependance on edaphic and geographic characteristics (BOUDOURESQUE, 1974; CORMACI, 1995; PIZZUTO & SERIO, 1994). Different minimal areas for the saure communities have been estimated in different geographical areas (CINELLI et al., 1977b; BALLESTEROS, 1988).

The most common sampling methods (imbricated subsamples of increasing area, not imbricated subsamples of increasing area, reticulate samples), due to difficulties in operating during dives and on sometimes hard substrata (limestone), which do not allow complete removal ofphytobenthos, are often approximate when compared to sophisticated statistical analysis. This means that the minimal area is generally larger than the estimated one (CORMACI, 1995). BOUDOURE-

SQUE (1974) and DHONDT & COPPEJANS (1977) considered sampling problems in diving and concluded that it is only possible to obtain limit values, inside which the minimal area is placed.

We decided to follow the method by PIZZUTO & SERIO (1994) for its simplicity, starting from an initial quadrat and then expanding it along alternately opposite directions.

STUDY AREA, MATERIALS AND METHODS

Samples were collected by scuba divings in spring and summer of 1995 at the three inlets of the lagoon of Venice (Lido, Malamocco and Chioggia) (Fig. 1). In each inlet, four stations were chosen, one in the midlittoral and three in the sublittoral, to a maximum depth of 7 m (Table 1).

The tidal range in the area is about 1 m and salinity is between 23‰ and 37‰. The mean value of transparency (Secchi disk) varied between 2.2 m at ebb tide and 4.5 m during flood tide. The substratum is composed of limestone blocks.

Sampling was carried out using the method of imbricate quadrats of increasing area, starting from a 10 x 10 cm area. The initial quadrat was then increased by increments of 10 cm on each side, alternately in two directions, to give a final surface area of 2500 cm^2 (Fig. 2). The total sampled surface area could not be extended over 50 x 50 cm, due to the lack of larger adequate homogenous and uniform surfaces. At each station, the whole area was scraped off with a chisel collecting five separated subsamples (A, B, C, D, E) and then assembled following the scheme of Table 1, after species identification in the laboratory.

RESULTS AND DISCUSSION

All over the 12 samplings, although showing different numbers of species and structure also due to the influente of abiotic factors (depth, exposure, inclination, transparency, water dynamics and type of substratum) indicate similar trends in the species-area curves (Fig. 3, Table 1). The curves rise quickly in each station until they reach an area of 900 cm^2. In the following increment to 1600 cm^2 a small increase in species numbers is already present in the stations 1, 4, 7 and 8; in the next increment to 2500 cm^2 a slight or no increase is found for all the stations.

On the basis of data the qualitative minimal arca for the algal community in the lagoon of Venice can be estimated between 900 cm^2, where the algal community is more crowded, and 1600 cm^2, where it is more sparsely distributed.

The species percentage averaged across all the stations for the 900 cm' area is 92.3, from 74.1 (station 3) to 97.7 (station 8). In the 1600 cm^2 area, the mean species percentage is 98.9, ranging from 94.4 (station 11) to 100 (station 2 and 10) (Tab. I).

The application of one of the most used method, Molinier's point 20/2 and 20/1 (BOUDOURESQUE & BELSHER, 1979), have noticed that the 1600 cm^2 area satisfies the 20/1 point (higher limit) for eight stations and the 20/2 point (lower limit) for eleven. Station 8 already satisfies both Molinier's points at 900 cm^2, while they are both higher than 1600 cm^2 for station 11.

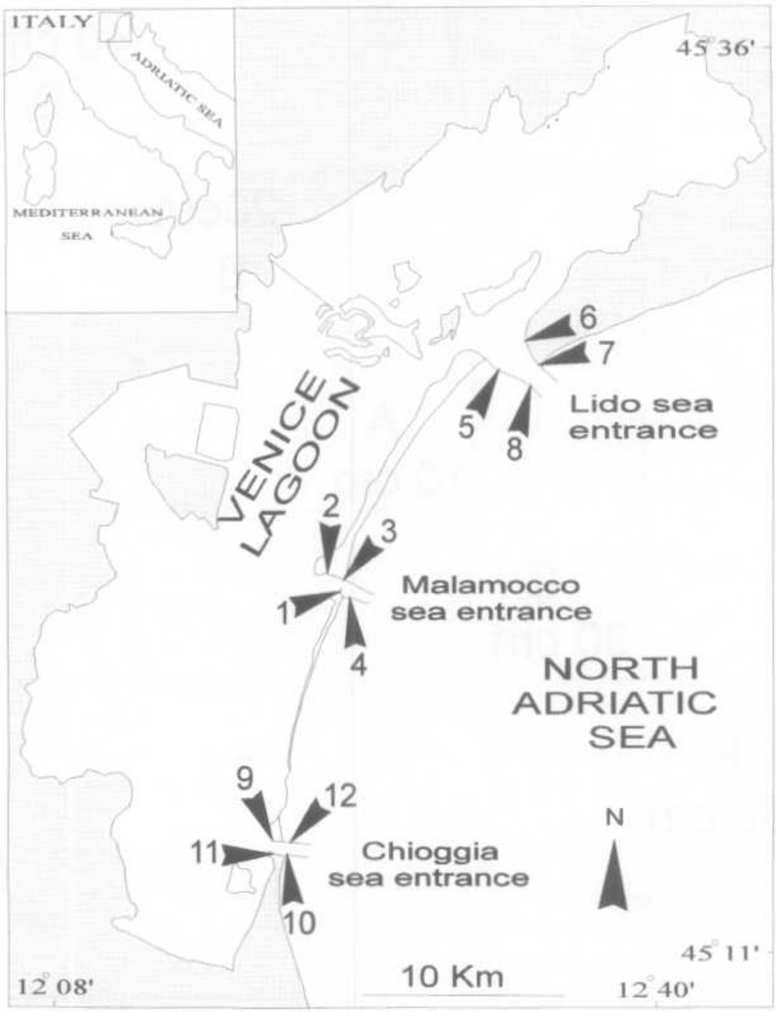

Fig. 1. Map of study area and location of sampling stations.

Differentiated data analysis for midlittoral (1, 6 and 11 stations) and lower sublittoral (3, 4, 8, 10, 11 stations), does not highlight great differences over the minimal area but the curve of lower sublittoral stations shows lower values (Fig. 4). This further confirms what was found in CURIEL et al., (1997; 1999) where in comparison to the surface, the deep stations showed a sharp fall in species number, total coverage of species, biomass and coverage of photophilous taxa. Such a clearcut differente over such a slight bathymetric range (5-7 m) is probably due to water turbidity.

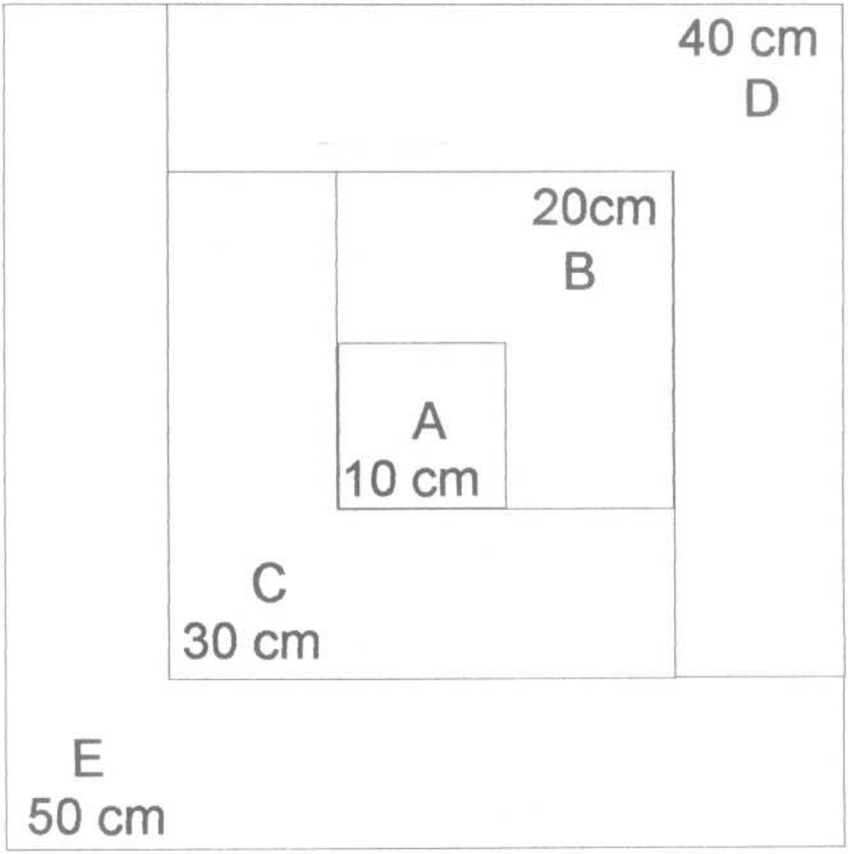

Fig. 2. Subsampling diagram.

	Inlet	Malamocco				Lido				Chioggia			
	Station	1	2	3	4	5	6	7	8	9	10	11	12
	Zone	(M)	(S)	(S)	(S)	(S)	(M)	(S)	(S)	(S)	(S)	(M)	(S)
	Depth (m)	(0.5)	(1.5)	(7.0)	(3.0)	(1.0)	(0.6)	(2.2)	(5.0)	(1.5)	(3.5)	(0.2)	(5.0)
	Surface (cm^2)	Species				species				species			
A	100	32	28	9	20	20	24	13	29	12	7	18	13
A+B	400	43	36	15	31	27	31	21	35	33	19	26	22
A+B+C	900	51	41	20	41	35	34	27	43	36	26	29	26
A+B+C+D	1600	53	47	26	43	40	39	29	44	39	32	34	30
A+B+C+D+E	2500	54	47	27	44	41	40	30	44	40	32	36	31

Table 1. Number of species by sampling at three inlets of the lagoon of Venice (M-Midlittoral, S= Sublittoral).

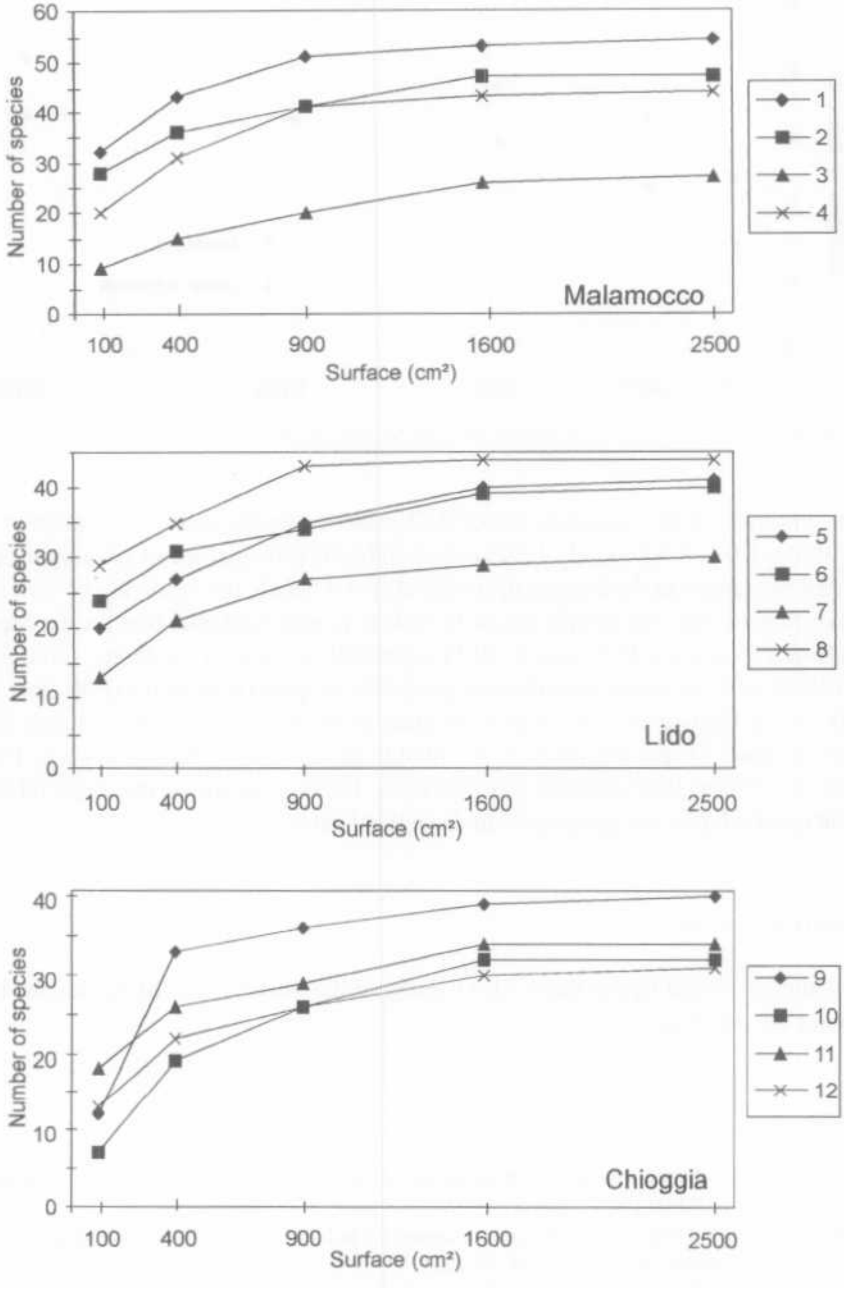

Fig. 3. Species-area curves of phytobenthos at three inlets.

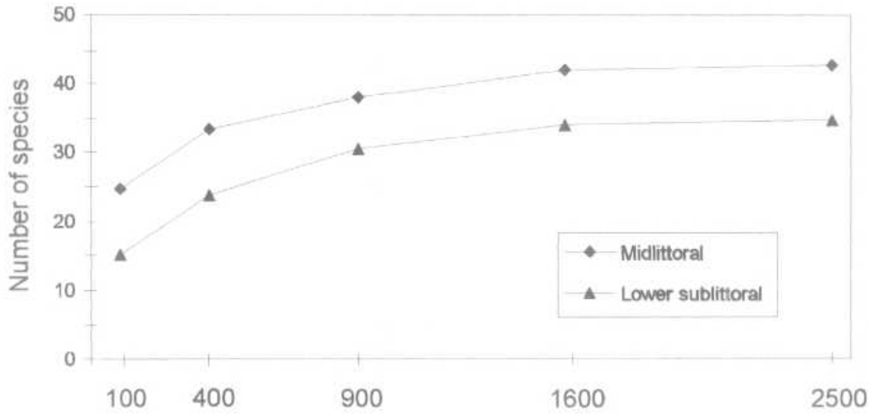

Fig. 4. Mean species-area curves for midlittoral and lower sublittoral stations.

The eutrophic water characteristics of the Northern Adriatic and of the lagoon of Venice (MARCHETTI, 1983; SFRISO et al., 1992) appear to be the principal factor limiting the number of species per sample and enlargering the minimal area. Overall, the mean number of identified taxa (see floristic list) per sample is low (27-54) in comparison with that for the Mediterranean (40-80) (CORMACI & FURNARI, 1991), especially in view of the larger surface area of study (2500 cm2) compared with the area generally adopted (from 400 to 900 cm^2). Consequently, the qualitative minimal area in the inlets of the lagoon of Venice is larger than that normally studied for phytobenthos in the Mediterranean ports (BOUDOURESQUE, 1974; CINELLI et al., 1977a; BOUDOURESQUE & BELSHER, 1979), confirming the close relationship between minimal area and geographic and edaphic factors.

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FLORISTIC LIST

RHODOPHYCEAE

Aglaothamnion sp.
Antithamnion cruciatum (C. Agardh) Naegeli
Antithamnion pectinalum (Montagne) Brauner *ex* Athanasiadis et Tittley
Antithamnionella spirographidis (Schiffner) E. M. Wollaston
Audouinella daviesii (Dillwyn) Woelkerling
Audouinella sp.
Bangia atropurprurea (Roth) C. Agardh
Bonnemaisonia hamifera Hariot
Callithamnion corymbosum (J. E. Smith) Lyngbye

Ceramium ciliatum (J. Ellis) Ducluzeau
Ceramium diaphanum (Lightfoot) Roth
Chondracanthus acicularis (Roth) Fredericq
Ceramium rubrum auctorum
Chondria capillaris (Hudson) M. J. Wynne
Chondria coerulescens (J. Agardh) Falkenberg
Chondria dasyphylla (Woodward) C. Agardh
Compsothamnion thuyoides (J. E. Smith) Naegeli
Corallina officinalis Linnaeus
Cryptonemia lomation (A. Bertolini) J. Agardh
Dasya corymbifera J. Agardh
Dasya hutchinsiae Harvey
Erythrocladia irregularis Rosenvinge
Erythrothrichia carnea (Dillwyn) J. Agardh
Gastroclonium clavatum (Roth) Ardissone
Gastroclonium reflexum (Chauvin) Kuetzing
Gelidium pusillum (Stackhouse) Le Jolis
Gracilaria bursa-pastoris (S.G. Gmelin) P. C. Silva
Gracilariopsis longissima (S.G. Gmelin) Stuntoft, L.M. Irvine *et* Farnham
(=Gracilaria verrucosa (Hudson) C. Agardh
Grateloupia dichotoma J. Agardh
Grateloupia doryphora (Montagne) M. Howe
Grateloupia filicina (J. V. Lamouroux) C. Agardh
Gymnogongrus griffithsiae (Turner) Martius
Halymenia floresia (Clemente) C. Agardh
Hvdrolithon farinosum (J. V. Lamouroux) Penrose *et J.* M. Chamberlain
Lithophyllum pustulatum (J. V. Lamouroux) Foslie
Lomentaria chylocladiella Funk
Lomentaria clavaeformis Ercegovic
Lomentaria clavellosa (Turner) Gaillon
Monosporus pedicellatus (J. E. Smith) Solier
Nitophyllum punctatum (Stackhouse) Greville
Peyssonnelia sp.
Pleonosporium borreri (J. E. Smith) Naegeli
Polysiphonia breviarticulata (C. Agardh) Zanardini
Polysiphonia denudata (Dillwyn) Greville
Polysiphonia elongata (Hudson) Sprengel
Polysiphonia elongella Harvey
Porphyra leucosticta Thuret
Pterothamnion crispum (Dueluzeau) Naegeli
Pterothamnion plumula (J. EIIis) Naegeli

Radicilingua reptans (Kylin) Papenfuss
Radicilingua thysanorhizans (Holmes) Papenfuss
Rhodophyllis divaricata (Stackhouse) Papenfuss
Rhodymenia ardissonei J. Feldmann
Spermothamnion flabellatum Bornet
Spermothamnion repens (Dillwyn) Rosenvinge
Stylonema alsidii (Zanardini) Drew

PHAEOPHYCEAE
Asperococcus compressus Griffiths ex Hooker
Asperococcus fistulosus (Hudson) Hooker
Dictyopteris polypodioides (A. P. De Candolle) J. V. Lamouroux
Dictyota dichotoma (Hudson) J.V. Lamouroux var. *intricata* (C. Agardh) Greville
Dictyota linearis (C. Agardh) Greville
Ectocarpus siliculosus (Dillwyn) Lyngbye var. *siliculosus*
Ectocarpus siliculosus var. *arctus* (Kuetzing) Gallardo
Ectocarpus siliculosus var. *dasycarpus* (Kuckuck) Gallardo
Ectocarpus siliculosus var. *pygmaeus* (Areschoug) Gallardo
Hincksia granulosa (J. E. Smith) P. C. Silva
Hincksia ovata (Kjellman) P. C. Silva
Hincksia sandriana (Zanardini) P. C. Silva
Kuckuckia spinosa (Kuetzing) Kuckuck
Petalonia fascia (O. F. Mueller) Kuntze
Pilayella littoralis (Linnaeus) Kjellman
Pseudolithoderma adriaticum (Hauck) Verlaque
Punctaria latifolia Greville
Sargassum muticum (Yendo) Fensholt
Scytosiphon dotyi M. J. Wynne
Scytosiphon simplicissimus (Clemente) Cremades
Sphacelaria cirrosa (Roth) C. Agardh
Stictyosiphon adriaticus Kuetzing

CHLOROPHYCEAE
Blidingia marginata (J. Agardh) P. J. L. Dangeard *ex* Bliding
Blidingia minima (Naegeli *ex* Kuetzing) Kylin
Bryopsis adriatica (J. Agardh) Meneghini
Bryopsis duplex De Notaris
Bryopsis plumosa (Hudson) C. Agardh
Bryopsis sp.

Chaetomorpha linum (O.F. Mueller) Kuetzing
Cladophora albida (Nees) Kuetzing
Cladophora coelothrix Kuetzing
Cladophora dalmatica Kuetzing
Cladophora hutchinsiae (Dillwyn) Kuetzing
Cladophora laetevirens (Dillwyn) Kuetzing
Cladophora lehmanniana (Lindenberg) Kuetzing
Cladophora rupestris (Linnaeus) Kuetzing
Cladophora sericea (Hudson) Kuetzing
Cladophora vagabunda (Linnaeus) C. Hoek
Codium fragile (Suringar) Hariot subsp. *tomentosoides* (Goor) P.C. Silva
Derbesia tenuissima (Moris *ci* De Notaris) P. L. *et H.* M. Crouan
Enteromorpha compressa (Linnaeus) Nees
Enteromorpha intestinalis (Linnaeus) Nees
Enteromorpha lima (Linnaeus) J. Agardh
Enteromorpha prolifera (O. F. Mueller) J. Agardh
Entocladia viridis V. Reinke
Gayralia oxysperma (Kuetzing) K. L. Vinogradova *ex* Scagel *et al.*
Pedobesia lamourouxii (J .Agardh) J. Feldmann *et al.*
Rhizoclonium tortuosum (Dillwyn) Kuetzing
Ulva rigida C. Agardh
Ulvella lens P.L. et H.M. Crouan