CURRENT KNOWLEDGE STATUS OF THE ECOLOGY OF HARD BOTTOM BENTHIC COMMUNITIES IN BRAZIL AND THE NEED FOR NEW APPROACHES

Natalia Pirani Ghilardi[1,*], *Guilherme Henrique Pereira Filho*[1] *& Flávio Berchez*[1]
[1] Instituto de Biociências, Universidade de São Paulo, Dep. de Botânica – Rua do Matão, 277 travessa 14, CEP 05508-900, São Paulo - SP- Brazil.
*E-mail: natalinoel@gmail.com

ABSTRACT

Since most environments on the planet are being threatened by anthropogenic activities, the ecological characterization and monitoring of extensive areas becomes urgent. In Brazil, 33 papers dealing with descriptive ecology of hard bottom communities were published, characterizing a total area of about 3,550m^2. Most of these studies focused on the midlittoral zone, employed transect sampling methods and considered species as the operational units. Data obtained this way is finely detailed, but cannot be extrapolated to the whole area being studied. This happens not only in Brazil, but all over the world, and the amount of sampled area is way below desirable levels. Some studies proposed the employement of functional-form groups, higher taxonomic ranks or considered dominant species to increase the sampling velocity. Time-saving approaches in association with random sampling, photographic and remote sensing techniques are a feasible alternative to increase the size of the sampled area and consequently our knowledge about the environment being studied. The "Physiognomic Assessment" method is one of these alternatives and it made possible the characterization of 29,605m^2 of rocky shores over a five-year period.
Keywords: Sampling methods, community ecology, rocky shore, physiognomic assessment.

RESUMO

ESTADO ATUAL DO CONHECIMENTO SOBRE A ECOLOGIA DE COMUNIDADES BENTÔNICAS DE SUBSTRATO CONSOLIDADO NO BRASIL E A NECESSIDADE DE NOVAS ABORDAGENS. A caracterização e o monitoramento de áreas costeiras extensas são urgentes, já que a maior parte dos ecossistemas está ameaçada pelas atividades humanas. No Brasil, 33 trabalhos de ecologia descritiva de comunidades bentônicas de substrato consolidado foram publicados, caracterizando uma área de 3.550m^2. A maior parte enfocou o mediolitoral, utilizou elementos dispostos em transecções em suas amostragens e considerou as espécies como unidades operacionais. Os dados obtidos nestes estudos, embora detalhados, não podem ser extrapolados para toda a área de estudo. Isso ocorre não só no Brasil, mas em todo o mundo, e a área caracterizada é muito menor do que a desejada. Alguns trabalhos propuseram o uso de grupos morfo-funcionais, grandes grupos taxonômicos e espécies dominantes para aumentar a velocidade das amostragens. Abordagens rápidas associadas com amostragem aleatória, técnicas fotográficas e de sensoriamento remoto são alternativas para aumentar a área amostrada e consequentemente o conhecimento sobre este ambiente. O método "Levantamento Fisionômico" é uma destas alternativas e o seu uso já possibilitou a caracterização de 29.605m^2 de costão rochoso em um período de cinco (5) anos.
Palavras-chave: Métodos de amostragem, ecologia de comunidades, costões rochosos, levantamento fisionômico.

THE PROBLEM

The lack of ecological knowledge about rocky shore benthic communities and even about terrestrial communities is serious, since these environments have been very much impacted by man's activities, apart from being susceptible to global climate changes, which can lead to a decrease in the diversity of organisms and to an irreversible loss of biological information (Field *et al.* 2007).

The absence of preterit data prevents the detection of impacts, the evaluation of their extent and a possible forecast of their consequences, and in last resort, the implementation of effective actions aiming at their mitigation or compensation.

In Brazil, from the first ecological descriptive studies of hard bottom marine benthic communities back in the 1930's, only small areas have been characterized. In this study we present a brief overview about the articles published so far, correlating the area described in these studies with the methodological approach employe d. Moreover, we comment on the recent alternatives to increase the efficiency of characterization programs.

THE CURRENT KNOWLEDGE STATUS AND ITS RELATION TO METHODOLOGICAL APPROACHES EMPLOYED

Table I presents a list of the main papers published with ecological descriptions in the Brazilian coast. A total area of about 3,550m^2 was characterized over 33 published papers. Although no data from thesis or technical reports were included, this total area surveyed is certainly minimal in face of the complete extent of the Brazilian coastline.

The total sampled areas were not specified in the papers published between the 1940's and the 1960's, since they employed a type of approach that was a superficial description of extensive areas, frequently in association with taxonomic studies. Nonetheless, these papers were important to build a baseline body of knowledge regarding the hard bottom benthic communities of Brazil, summarizing the most common organisms and their spatial organization, mainly in the midlittoral zone.

Later on, Oliveira Filho & Mayal (1976), Maggs *et al.* (1979), Oliveira Filho & Paula (1983), Eston *et al.* (1986), Teixeira *et al.* (1987), Guerrazzi (1987), Muricy (1989), and Castro *et al.* (1995) introduced qualitative, semi-quantitative, and/or quantitative approaches that were based on the punctual data of transects.

This transect method prevailed in the 90's and up to the present decade (*e.g.* Johnscher-Fornasaro *et al.* 1990, Corrêa *et al.* 1998, Gherardi & Bosence 2001, Kelmo & Attrill 2001, Costa Jr *et al.* 2002, Amado Filho *et al.* 2003, Figueiredo *et al.* 2004, Oigman-Pszczol *et al.* 2004, Marins-Rosa *et al.* 2005). Yet in this period the papers incorporated concepts of sampling sufficiency, precision of the obtained data, and validation by statistical analysis.

Oigman-Pszczol *et al.* (2004) worked with the greatest sampled area of all the previous papers. This was made possible because the authors used 1m^2 sample units randomly positioned along fourteen 56m-long transects, in ten different locations. In contrast, Yoneshigue-Valentin & Valentin (1992) used the smallest sampled area, wherein few unit areas were intensively and minutely sampled, in a phytosociological approach.

Most researches (70%) focused mainly on the midlittoral region, and the infralittoral region was given more attention by the beginning of the present decade, during which all published studies presented results related to this zone.

Table II presents the total area sampled in these studies per year. It can be noticed that the greatest areas were sampled in the 1980`s (139.68m^2.year^{-1}) and in the present decade (209.97m^2.year^{-1}). Even minding that a significative amount of the data produced during the 90's was only published in the form of dissertations, thesis, and technical reports, the total area sampled is not sufficient to extensively represent the Brazilian diversity of coastline environments.

Expressive improvement in efficiency of the descriptions was accomplished with the use of alternative methodological approaches.

ALTERNATIVE SAMPLING METHODOLOGIES

An efficient sampling method should generate samples that represent the population being studied (Ballesteros 1986, Krebs 1999) with the minimum possible sampling effort.

Communities can be sampled through several approaches. An important decision when designing a sampling procedure is where to position the sampling units, which can be distributed in a continuous manner, systematic manner or at random. Nevertheless, statistical procedures usually assume that the sampling was done in a random manner, *i.e.* that each member of that (statistical) population should have an equal and independent chance of being sampled (Zar 1999).

It is not always possible to sample at random in the field. Therefore, ecologists sometimes have no other alternative but to use non-probabilistic sampling designs if they want to obtain any information at all.

Table I. Research articles on ecology of hard bottom marine benthic communities published in Brazil, with the zone studied, and sampled area (m^2) in each one of them. A"?" is placed where the authors did not specify the actual sampled area.

Article	**Zone**	**Sampled area (m^2)**
Rawistcher 1944	supralittoral, midlittoral	?
Oliveira 1947	supralittoral, midlittoral, infralittoral	?
Oliveira 1951	supralittoral, midlittoral, infralittoral	?
Joly 1957	supralittoral, midlittoral,	?
Nonato & Pérèz 1961	supralittoral, midlittoral, infralittoral	?
Costa 1962	midlittoral	?
Oliveira Filho & Mayal 1976	midlittoral	3.9
Oliveira Filho & Berchez 1978	supralittoral, midlittoral,	?
Maggs *et al.* 1979	infralittoral	40
Coelho & Ramos-Porto 1980	supralittoral, midlittoral, infralittoral	?
SUDENE 1981	supralittoral, midlittoral, infralittoral	207
Oliveira Filho & Paula 1983	midlittoral	3.5
Edwards & Lubbock 1983	infralittoral	?
Eston *et al.* 1986	supralittoral, midlittoral, infralittoral	150
Guerrazzi 1987	midlittoral	4.4
Teixeira *et al*. 1987	infralittoral	5
Muricy 1989	infralittoral	1.030
Johnscher-Fornasaro *et al.* 1990	midlittoral	0.95
Silva & Fernandes 1990	midlittoral	?
Berchez & Oliveira Filho 1992	supralittoral, midlittoral,	?
Yoneshigue-Valentin & Valentin 1992	supralittoral, midlittoral, infralittoral	0.6
Castro *et al.* 1995	infralittoral	3.5
Villaça & Pitombo 1997	midlittoral, infralittoral	1.6
Corrêa *et al.* 1998	midlittoral	3.6
Muñoz & Pereira 1998	midlittoral	1
Muricy & Moraes 1998	midlittoral, infralittoral	?
Gherardi & Bosence 2001	supralittoral, midlittoral, infralittoral	84.2
Kelmo & Attrill 2001	midlittoral, infralittoral	140
Costa Jr. e*t al.* 2002	midlittoral, infralittoral	62.5
Amado-Filho *et al.* 2003	infralittoral	20
Figueiredo *et al.* 2004	infralittoral	15
Oigman-Pszczol *et al.* 2004	infralittoral	1,750
Marins-Rosa *et al.* 2005	infralittoral	28
Total		**3,554.75**

Table II. Total area sampled (m^2) per year considering only published journal articles on ecology of hard bottom marine benthic communities in Brazil.

Decade	**Sampled area ($m^2.year^{-1}$)**
40's	?
50's	?
60's	?
70's	4.39
80's	139.68
90's	1.12
00's	209.97

In general, in order to make statistical procedures possible, a random component is inserted in the sampling, such as random transects, random sampling units over a transect or random sampling points inside the sampling units in the case of the point-quadrat method (Gounot 1969).

It is a worldwide common practice to use transects to describe terrestrial and coastal communities. The transect method consists of positioning sampling units along a line (called line transect) or a strip of area (called belt transect). In the case of rocky shores, the first authors to employ transect methodology were Doty (1946) and Stephenson & Stephenson (1949), and it has been used ever since (*e.g*. Díez *et al.* 2003, Oigman-Pszczol *et al.* 2004, Ingólfsson 2005, Schembri *et al.* 2005 and many others).

Transects have the advantage of showing possible gradients clearly and thoroughly (Green 1979), and if the same transect is sampled more than once, subtle differences in the distribution and composition of organisms over time can be perceived, which is important to monitoring purposes.

However, sampling units positioned along lines or strips have neither equal nor independent chances of being chosen if all the potential sampling units of the area are regarded, thus data obtained this way cannot be extrapolated to the rest of the study area, even if a random component is inserted in the sampling. Therefore, studies with this kind of approach usually describe only a part of the community. This means that if an area of 1,000m^2 is being studied and the sampling units were positioned over a 10m^2 strip, any conclusions can only be drawn regarding that sampled 10m^2 area, but if the sampling units had been placed all over the area at random, given that sufficient sampling was made, the obtained samples could be considered representative of the community being studied, and data could be extrapolated to an area that were hundreds of times larger.

What is a matter of concern and occurs in some ecological studies is the employment of few sampling transects and the extrapolation of the obtained data to the whole conservation unit, island or coastal region. This can be misleading when defining the preservation strategy, assessing the conservation status of that area, evaluating the effects of environmental impacts, etc, based on such conclusions.

On the other hand, random sampling has the main disadvantage of being very time-consuming. However, this happens mainly when traditional methodologies, such as point-quadrat or destructive methods, are employed, since numerous specimens must be identified in the field (in the case of point-quadrat), or all specimens must be adequately collected and conserved (in the case of destructive methods) (Littler & Littler 1985).

In fact, the biological unit most usually considered in studies characterizing rocky shore communities is species (Murray *et al.* 2006), and this presents several disadvantages. Small-sized and entangled specimens are difficult to identify in the field, and specimens whose identification depends on the presence of reproductive structures (*e.g.* some seaweeds) can be hard to identify even in the laboratory. In addition, rare and ephemeral species show high spatial variability, leading to low precision and accuracy in their sampling (Berchez *et al.* 2005b).

When the species-level identification in the field is not the objective of the study, some alternatives have been proposed to minimize the sampling time, mainly through using functional-form groups (Littler & Littler 1980, 1984, Steneck & Dethier 1994), life-form groups (Rioja 1929, Raunkjaer 1934, Cain 1950) and guilds (Root 1967). Researchers, though, frequently try to identify as many species as possible and try to place them in some of the proposed groups, thus the problem persists.

In Brazil, some attempts to reduce sampling time have been made after the 90's: *e.g*. Villaça & Pitombo (1997) and Figueiredo *et al.* (2004) used functional-form groups; Corrêa *et al.* (1998) and Gherardi & Bosence (2001) summarised their data by using great taxonomic groups; Costa Jr. *et al.*(2002) used both of the previous approaches; and Oigman-Pszczol *et al.* (2004) considered only the dominant species found. Such approaches facilitate increasing the sampling area by reducing sampling time in the field and, consequently, more sampling units can be obtained.

In a study aiming at comparing the use of different sampling methodologies with rocky shore communities, Meese & Tomich (1992) encouraged the use of photography to save time in the field, while also remarking the precision and easy replicability of the method.

Landscape ecology studies which use remote sensing methods are also an alternative solution to the problem of the extension of the sampled area. Remote sensing has been employed worldwide with a variety of marine areas (Guichard *et al.* 2000, Cuevas-Jiménez & Ardisson 2002, Mumby & Edwards 2002, Hochberg & Atkinson 2003, Zharikov *et al.* 2005) with geographical and ecological aims (Metzger 2001). However, obtaining information depends on the image scale and resolution (Bissonette 1997, Mumby *et al.* 1997) and thus modifications in marine environments can be noticed too late for their recuperation, as they are naturally dynamic and susceptible to modifications in a much smaller scale than are terrestrial areas (Murray *et al.* 2006).

Recently, Berchez *et al.* (2005b) presented the method entitled "Physiognomic Assessment of Hard Bottom Benthic Communities" as an alternative to increase the sampled area of rocky shores in Brazil. This method uses photographs as sampling units – following Meese & Tomich (1992) – taken at random. The method is grounded in landscape ecology concepts and it should be stressed that although landscape ecology is generally thought as a scientific approach intended only for large-scale use, it is also perfectly suited to map rocky shore environments because it considers spatial heterogeneity regardless of scale or biological levels. In fact, rocky shores generally present elevated spatial heterogeneity in a much smaller scale than do terrestrial ecosystems, generating a mosaic of several facets determined by the presence of one or some structural species in association, each one of them related to a characteristic habitat. Each homogeneous facets is a component of the landscape heterogeneity termed 'settlement' (Berchez *et al*. 2005b) that is the operational unit of the method proposed.

The Physionomic Assessment is divided in four approaches that are supplementary and return increasingly detailed results. Depending on the objectives of the study, all or some of them can be used. Approach n. 1 includes the characterization and description of the settlements of a community or area; approach n. 2 includes the determination of the georeferenced spatial distribution of each settlement; approach n. 3 includes the quantification of the percent coverage of each settlement based on digital photographs of the study area; approach n. 4 includes the evaluation of the specific composition and spatial variation of each settlement.

The application of this methodology made possible the characterization of hard bottom communities rapidly and on a large scale. Approaches 1 and 2 were employed at 10 rocky shore stations in São Paulo State: three stations at Anchieta Island (Palmas Bay), one at Toninhas Beach (Ubatuba), one station at Baleeiro Head (São Sebastião), two at Moela Island and one at Munduba Head (both in Guarujá), one station at Guará Island and another one at Monte Pascoal Island (both in Bertioga). The method was also employed in one station at Francês Island in Espírito Santo State. Theses studies (Table III) totalized 5,195m of rocky shores mapped with a precision of 5m or more, corresponding to a total described area of approximately 29,605m^2, at

Table III. Stations in which the Physiognomic Assessment Method was employed, with the approximate extension and area sampled, and the number of settlements found in the midlittoral and infralittoral zone of each station.

Station	extension (m)	approx. area (m^2)	midlittoral settlements	infralittoral settlements
Munduba Head	530	1,200	10	19
Moela Island (SW)	155	1,550	12	26
Moela Island (NE)	200	2,000	9	22
Guará Island	200	2,000	12	12
Monte Pascoal Island	100	1,000	-	27
Palmas Bay (E – Presídio/Engenho)	260	1,380	24	31
Palmas Bay (E – Engenho/Pta Norte)	1,000	3,000	33	-
Palmas Bay (W)	750	5,500	23	66
Baleeiro Head	270	1,350	44	25
Francês Island	1,400	9,800	38	-
Toninhas	330	825	33	24
Total sampled	**5,195**	**29,605**		

a rate of about 5,921m^2 sampled per year^{-1}, which is far greater than any study of the sort in Brazil (Tables I and II). The sampling rate proved quick for experienced observers: up to 200m per hour in some areas with low diversity.

Regarding approach n. 3, the acquisition of images at random and annotations in the field is very quick (5min.sample^{-1}), but posterior analysis in the computer needs more time (1h.sample^{-1}). Yet, the method is more efficient than the traditional ecological techniques for studying communities, which usually include analysis of sampling units in the field that depends on the low tide period (midlittoral studies) or on the air supply of the divers (infralittoral studies). Through physiognomic sampling, more sampling units can be taken in the same amount of time, consequently increasing the sampled area. Most images taken so far had suitable resolution for sorting all settlements (Foster *et al.* 1991, Meese & Tomich 1992, Ducrotoy & Simpson 2001, Kollmann & Stachowitsch 2001, Pech *et al.* 2004, Tkachenko 2005), what is not possible working in species-level identification, especially in turfs and most beds (Foster *et al.* 1991, Meese & Tomich 1992, Dethier *et al.* 1993). Furthermore, the images used as evidence can be stored in databases for later reevaluation or new analyses (Foster *et al.* 1991).

The sampling of settlements with environmental monitoring purposes at the stations of Guarujá and Bertioga in the Santos Bay, São Paulo State (Berchez *et al.* 2004, Berchez *et al.* 2005a, Ghilardi *et al.* 2007), was made in a less complicated and more precise manner than would have been monitoring procedures based on species, which commonly present non-seasonal variation resulting from sporadic or cyclic causes (Holme & Mcintyre 1984).

CONCLUSION

The current challenge in benthic descriptive ecology is to propose methodologies for data collection and analysis that will establish a suitable balance between the size of the described area and the level of detail in the description, as to improve the efficiency of studies of natural and anthropogenic disturbances in these environments. The use of traditional techniques limits the size of the sampled area not only in Brazil but over the rest of the world, rendering the regions surveyed far below desirable dimensions (Murray 2006).

The use of random sampling in association with time-saving techniques, like avoiding the use of species as operational units or making use of images as sampling units, makes it possible the characterization of larger areas. Several protocols pointing to this direction were presented recently (Mumby & Edwards 2002, Malthus & Karpouzli 2003, Karpouzli *et al.* 2004, Preskitt *et al.* 2004, Martins *et al.* 2005), showing a growing concern of researchers with this problem.

One of these protocols is the "Physiognomic Assessment of Hard Bottom Benthic Communities", which couples these basic ideas with principles of landscape science. However, landscape science itself is new, and many of its concepts and methods are still developing (Farina 2006). Furthermore, this line of study is mainly applied to larger terrestrial areas, and its use in smaller scales is still recent and more limited (Metzger 2001). On the other hand, rocky shores are a good model to test this method in a small scale, as they present great spatial heterogeneity, thus being a mosaic with several facets related to characteristic habitats, thus in perfect agreement with the definition of a landscape.

As further steps in this method, we are now testing its applicability in different perspective scales with the aid of remote sensing techniques, such as high spatial resolution satellite images and field spectroscopy.

Adding to the amount of knowledge about benthic communities is a priority, since these communities are very much threatened by human activities, both on a local and global scale. In spite of it and of the vast amount of benthic area in Brazil, they certainly are the least known ecosystems, and structural alterations in these ecosystems cannot be detected with the present state of knowledge. Several response actions can be proposed, like increasing the formations of researchers in this field, or increasing the resources destined to the area. We herein also suggest changing the present methodological paradigms and turning to more efficient methodologies and approaches.

ACKNOWLEDGEMENTS: We thank FAPESP (process 02/07412-8) and CNPq (process 140787/2004-6) for the financial support. We also thank A.S.Ferreira for polishing the English, and P.L. Lopes, G.H. Filho, L. Hayashi, M. Mosca and L.B. Ferreira for the useful comments on the text.

REFERENCES

AMADO FILHO, G.M.; BARRETO, M.B.B.B.; MARINS, B.V.; FELIX, C. & REIS, R.P. 2003. Estrutura das comunidades fitobentônicas do infralitoral da Baía de Sepetiba, RJ, Brasil. *Revista Brasileira de Botânica*, 26: 329-342.

BALLESTEROS, E. 1986. Métodos de análisis estructural en comunidades naturales, en particular del fitobentos. *Oecologia Aquática*, 8: 117-131.

BERCHEZ, F.; GHILARDI, N.P.; FLUCKIGER, G. & LIMA, S.N.P. 2004. Levantamento fisionômico de comunidades bentônicas de substrato consolidado da Ilha da Moela, Ponta do Munduba e Ilha do Guará (SP). 96p. CETESB, São Paulo.

BERCHEZ, F.; GHILARDI, N.P.; FLUCKIGER, G.; PEREIRA FILHO, G.H.; SIMÕES, M.C. & MOSCA, M.M. 2005a. Levantamento de povoamentos de Comunidades Marinhas Bentônicas de Substrato Consolidado das Áreas Ecologicamente Sensíveis sob influência direta do Lançamento de Material Dragado da Companhia Docas de São Paulo- CODESP. 109p. CETESB, São Paulo.

BERCHEZ, F.A.S. & OLIVEIRA FILHO, E.C. 1992. Temporal changes in the benthic marine flora of the Baía de Santos, SP, Brazil, over the last four decades. Pp 120-131. *In:* C. Cordeiro-Marino, M.T.P. Azevedo, C.L. Sant'anna, N.Y. Tomita & E.M. Plastino,(eds.), Algae and environment: a general approach. Sociedade Brasileira de Ficologia, São Paulo.

BERCHEZ, F.A.S.; ROSSO, S.; GHILARDI, N.P.; FUJII, M.T. & HADEL, V.F. 2005b. Characterization of hard bottom benthic communities: the physiognomic approach as an alternative to traditional methodologies. Pp 207-220. *In:* Sociedade Brasileira de Ficologia, (ed.), Formação de Ficólogos: um compromisso com a sustentabilidade dos recursos aquáticos. Museu Nacional, Série Livros, Rio de Janeiro.

BISSONETTE, J.A. 1997. Scale-sensitive ecological properties: historical context, current meaning. Pp 3-31. *In:* J.A. Bissonette, (ed.), Wildlife and landscape ecology : effects of pattern and scale Springer-Verlag, New York.

CAIN, S.A. 1950. Life forms and phytoclimate. *Botanical Review*, 16: 1-32.

CASTRO, C.B.; ECHEVERRÍA, C.A.; PIRES, D.O.; MASCARENHAS, B.J.A. & FREITAS, S.G. 1995. Distribuição de Cnidaria e Echinodermata no infralitoral de costões rochosos de Arraial do Cabo, Rio de Janeiro, Brasil. *Revista Brasileira de Biologia*, 55: 471-480.

COELHO, P.A. & RAMOS-PORTO, M. 1980. Bentos litorâneos do nordeste oriental do Brasil II. Povoamentos de substratos duros. *Boletim do Instituto Oceanográfico, Universidade de São Paulo*, 29: 133-134.

CORRÊA, M.S.D.; RIBEIRO, R.S.; BRITO, L.V.R.; CARLONI, G.G. & CARVALHEIRA, L.V. 1998. Estrutura de comunidades bênticas de mesolitoral de costões rochosos adjacentes ao terminal petrolífero da Baía da Ilha Grande, RJ. Pp 212-214 XI Semana Nacional de Oceanografia – Oceanografia e suas interfaces. UFPel, Rio Grande do Sul (Pelotas).

COSTA, H.R. 1962. Note preliminaire sur les peuplements intercotidaux de substrat dur du littoral de Rio de Janeiro. *Recueil des Travaux de la Station Marine d'Endoume*, 27: 197-207.

COSTA JR, O.S.; ATTRILL, M.J.; PEDRINI, A.G. & DE-PAULA, J.C. 2002. Spatial and seasonal distribution of seaweeds on coral reefs from southern Bahia, Brazil. *Botanica Marina*, 45: 346-355.

CUEVAS-JIMÉNEZ, A. & ARDISSON, P.L. 2002. Mapping of shallow coral reefs by colour aerial photography. *International Journal of Remote Sensing*, 23: 3697–3712.

DETHIER, M.N.; GRAHAM, E.S.; COHEN, S. & TEAR, L.M. 1993. Visual versus random-point percent cover estimations: 'objective' is not always better. *Marine Ecology Progress Series*, 96: 93-100.

DÍEZ, I.; SANTOLARIA, A. & GOROSTIAGA, J.M. 2003. The relationship of environmental factors to the structure and distribution of subtidal seaweed vegetation of the western Basque coast (N Spain). *Estuarine, Coastal and Shelf Science*, 56: 1041-1054.

DOTY, M.S. 1946. Critical tide factors that are correlated with the vertical distribution of marine algae and other organisms along the Pacific Coast. *Ecology*, 27: 315-328.

DUCROTOY, J. & SIMPSON, S.D. 2001. Developments in the application of photography toecological monitoring, with reference to algal beds. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 11: 123-135.

EDWARDS, A. & LUBBOCK, R. 1983. The ecology of Saint Paul's Rocks (Equatorial Atlantic). *Journal of Zoology*, 200: 51-69.

ESTON, V.R.; MIGOTTO, A.E.; OLIVEIRA FILHO, E.C.; RODRIGUES, S.A. & FREITAS, J.C. 1986. Vertical distribution of benthic marine organisms on rocky coasts of the Fernando de Noronha archipelago (Brazil). *Boletim do Instituto Oceanográfico, Universidade de São Paulo*, 34: 37-54.

FARINA, A. 2006. *Principles and methods in landscape ecology: towards a science of landscape* (Second edition). Springer, New York.

FIELD, C.B.; MORTSCH, L.D.; BRKLACICH, M.; FORBES, D.L.; KOVACS, P.; PATZ, J.A.; RUNNING, S.W. & SCOTT, M.J. 2007. North America. Climate Change 2007: Impacts, Adaptation and Vulnerability. Pp 617-652. *In:* M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden & C.E. Hanson, (eds.), Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

FIGUEIREDO, M.A.O.; BARRETO, M.B.B. & REIS, R.P. 2004. Caracterização das macroalgas nas comunidades marinhas da Área de Proteção Ambiental de Cairuçú, Parati, RJ - subsídios para futuros monitoramentos. *Revista Brasileira de Botânica*, 27: 11-17.

FOSTER, M.S.; HARROLD, C. & HARDIN, D.D. 1991. Point vs. Photo quadrat estimates of the cover of sessile marine organisms. *Journal of Experimental Marine Biology and Ecology*, 146: 193-203.

GHERARDI, D.F.M. & BOSENCE, D.W.J. 2001. Composition and community structure of the coralline algal reefs from Atol das Rocas, South Atlantic, Brazil. *Coral reefs,* 19: 205-219.

GHILARDI, N.P.; PEREIRA FILHO, G.H.; FLUCKIGER, G.; SIMÕES, M.C.; MOSCA, M.M. & RIBEIRO, H.L. 2007. Levantamento de povoamentos de Comunidades Marinhas Bentônicas de Substrato Consolidado das Áreas Ecologicamente Sensíveis sob influência direta do Lançamento de Material Dragado da Companhia Docas de São Paulo- CODESP. 41p. CETESB, São Paulo.

GOUNOT, M. 1969. *Méthodes d'étude quantitative de la végétation*). Masson, Paris.

GREEN, R.H. 1979. *Sampling design and statistical methods for environmental biologists*. Wiley-Interscience, New York.

GUERRAZZI, M.C. 1987. Estudos preliminares sobre a estrutura de uma comunidade de costão rochoso, em mesolitoral, num gradiente de salinidade. Pp 221-232, SIMPÓSIO DOS ECOSSISTEMAS DA COSTA SUL E SUDESTE BRASILEIRA: SÍNTESE DOS CONHECIMENTOS, 1. Academia de Ciências do Estado de São Paulo, São Paulo.

GUICHARD, F.; BOURGET, E. & AGNARD, J.P. 2000. High-resolution remote sensing of intertidal ecosystems: A low-cost technique to link scale-dependent patterns and processes. *Limnology and Oceanography*, 45: 328-338.

HOCHBERG, E.J. & ATKINSON, M.J. 2003. Capabilities of remote sensors to classify coral, algae, and sand as pure and mixed spectra. *Remote Sensing of Environment*, 85: 174-189.

HOLME, N.A. & MCINTYRE, A.D. 1984. *Methods for the study of Marine Benthos* (Second edition). Blackwell, Oxford.

INGÓLFSSON, A. 2005. Community structure and zonation patterns of rocky shores at high latitudes: an interocean comparison. *Journal of Biogeography*, 32: 169-182.

JOHNSCHER-FORNASARO, G.; LOPES, C.F. & MILANELLI, J.C.C. 1990. Similaridade faunística entre comunidades da zona entre-marés de costões rochosos do litoral norte do Estado de São Paulo. Pp 75-88, SIMPÓSIO DOS ECOSSISTEMAS DA COSTA SUL E SUDESTE BRASILEIRA: ESTRUTUTA, FUNÇÃO E MANEJO, 2. Águas de Lindóia.

JOLY, A.B. 1957. Contribuição ao conhecimento da flora ficológica marinha da Baía de Santos e arredores. *Boletim da Associação dos geógrafos brasileiros*, 217: 07-27.

KARPOUZLI, E.; MALTHUS, T.J. & PLACE, C.J. 2004. Hyperspectral discrimination of coral reef benthic communities in the western Caribbean. *Coral Reefs*, 23: 141-151.

KELMO, F. & ATTRILL, M.J. 2001. Cnidarian community structure of coastal reefs from northern Bahia. *Bulletin of Marine Science*, 69: 547-557.

KOLLMANN, H. & STACHOWITSCH, M. 2001. Long-Term Changes in the Benthos of the Northern Adriatic Sea: A Phototransect Approach. *Marine Ecology*, 22: 135-154.

KREBS, J.C. 1999. *Ecological methodology*. Harper & Row Publ., New York.

LITTLER, M.M. & LITTLER, D.S. 1980. The evolution of thallus form and survival strategies in benthic marine macroalgae: field and laboratory tests of a functional form model. *The American Naturalist*, 116: 25-44.

LITTLER, M.M. & LITTLER, D.S. 1984. Relationships between macroalgal functional form groups and substrata stability in a subtropical rocky-intertidal system. *Journal of Experimental Marine Biology and Ecology*, 74: 13-34.

LITTLER, M.M. & LITTLER, D.S. 1985. *Handbook of phycological methods. Ecological field methods: macroalgae*). Cambridge University Press, Cambridge.

MAGGS, C.A.; MILNER, A.A.; WATTS, W. & WHITTLE, M.R. 1979. The Oxford diving expedition to Cabo Frio, Brazil. *Bulletin of the Oxford University Exploration Club*, 4: 13-40.

MALTHUS, T. & KARPOUZLI, E. 2003. Integrating field and high spatial resolution satellite-based methods for monitoring shallow submersed aquatic habitats in the Sound of Eriskay, Scotland, UK. *International Journal of Remote Sensing*, 24: 2585-2593.

MARINS-ROSA, B.; AMADO-FILHO, G.; MANSO, C. & YONESHIGUE-VALENTIN, Y. 2005. Estrutura do fitobentos do sub-litoral das formações recifais da Baía de Todos os Santos (Bahia, Brasil). Pp 255-274. *In:* SociedadeBrasileira de Ficologia, (ed.), Formação de Ficólogos: um compromisso com a sustentabilidade dos recursos aquáticos. Museu Nacional, Série Livros, Rio de Janeiro.

MARTINS, G.M.; WALLENSTEIN, F.F.M.; ÁLVARO, N.V.; NETO, A.I. & COSTA, A.C. 2005. Sampling strategies for biotope definition: minimal sampling area for selected groups of macroinvertebrates in the rocky subtidal of São Miguel, Azores. *Helgoland Marine Research*, 59: 219-223.

MEESE, R.J. & TOMICH, P.A. 1992. Dots on the rocks: a comparison of percent cover estimation methods. *Journal of Experimental Marine Biology and Ecology*, 165: 59-73.

METZGER, J.P. 2001. O que é ecologia da paisagem? *Biota Neotropica*, 1.

MUMBY, P.J. & EDWARDS, A.J. 2002. Mapping marine environments with IKONOS imagery: enhanced spatial resolution can deliver greater thematic accuracy. *Remote Sensing of Environment*, 82: 248–257.

MUMBY, P.J.; GREEN, E.P.; EDWARDS, A.J. & CLARK, C.D. 1997. Coral reef habitat mapping: how much detail can remote sensing provide? *Marine Biology*, 130: 193-202.

MUÑOZ, A.O.M. & PEREIRA, S.M.B. 1998. Estrutura de comunidades de macroalgas em formações recifais do Estado de Pernambuco, Brasil. Pp 287-297, CONGRESSO LATINO-AMERICANO DE FICOLOGIA, 4, Caxambú.

MURICY, G. 1989. Sponges as pollution biomonitors at Arraial do Cabo, southeastern Brazil. *Revista Brasileira de Biologia*, 49: 347-354.

MURICY, G. & MORAES, F.C. 1998. Marine sponges of Pernambuco State, NE Brazil. *Revista Brasileira de Oceanografia*, 46: 213-217.

MURRAY, S.N.; AMBROSE, R.F. & DETHIER, M.N. 2006. *Monitoring rocky shores*. University of California Press, Berkeley.

NONATO, E.F. & PÉRÈZ, J.M. 1961. Observation sur quelques peuplements interdidaux de substrat dur dans la region d'Ubatuba. *Cahiers de Biologie Marine*, 2: 263- 270.

OIGMAN-PSZCZOL, S.S.; FIGUEIREDO, M.A.O. & CREED, J.C. 2004. Distribution of benthic communities on the tropical rocky subtidal of Armação dos Búzios, Southeastern Brazil. *Marine Ecology*, 25: 173-190.

OLIVEIRA FILHO, E.C. & BERCHEZ, F.A.S. 1978. Algas bentônicas da Baía de Santos - alterações da flora no período de 1957-1978. *Boletim de Botânica da Universidade de São Paulo*, 6: 49-59.

OLIVEIRA FILHO, E.C. & MAYAL, E.M. 1976. Seasonal distribution of intertidal organisms at Ubatuba, São Paulo (Brazil). *Revista Brasileira de Biologia*, 36: 305-316.

OLIVEIRA FILHO, E.C. & PAULA, E.J. 1983. Aspectos da distribuição vertical e variação sazonal de comunidades da zona das marés em costões rochosos do litoral norte do Estado de São Paulo. Pp 44-61, Encontro de Macrófitas Marinhas, 1. Instituto de Pesquisas da Marinha. Projeto Cabo Frio (147), Arraial do Cabo.

OLIVEIRA, L. 1947. Distribuição geográfica da fauna e flora da Baía da Guanabara. *Memórias do Instituto Oswaldo Cruz*, 45: 709-735.

OLIVEIRA, L. 1951. Nota prévia sobre a fauna e flora marinha bentônica da Ilha da Trindade. *Memórias do Instituto Oswaldo Cruz*, 49: 443-456.

PECH, D.; CONDAL, A.R.; BOURGET, E. & ARDISSON, P.L. 2004. Abundance estimation of rocky shore invertebrates at small spatial scale by high-resolution digital photography and digital image analysis. *Journal of Experimental Marine Biology and Ecology*, 299: 185-199.

PRESKITT, L.B.; VROOM, P.S. & SMITH, C.M. 2004. A Rapid Ecological Assessment (REA) Quantitative Survey Method for Benthic Algae Using Photoquadrats with Scuba. *Pacific Science*, 58: 201-209.

RAUNKJAER, C. 1934. *The life forms of plants and statistical plant geography*. Oxford University Press, Oxford.

RAWITSCHER, F.K. 1944. Algumas noções sobre a vegetação do litoral brasileiro. *Boletim da Associação dos geógrafos brasileiros*, 4: 13-28.

RIOJA, E. 1929. *Los animales marinos*. Labor, Barcelona.

ROOT, R.B. 1967. The niche exploitation pattern of the Blue-gray Gnatcatchger. *Ecological Monographs*, 37: 317-350.

SCHEMBRI, P.J.; DEIDUN, A.; MALLIA, A. & MERCIECA, L. 2005. Rocky shore biotic assemblages of the Maltese Islands (Central Mediterranean): A conservation perspective. *Journal of Coastal Research*, 21: 157-166.

SILVA, E.P. & FERNANDES, F.C. 1990. O bentos de substrato duro das margens da Lagoa de Araruama. Pp 231-240, SIMPÓSIO DOS ECOSSISTEMAS DA COSTA SUL E SUDESTE BRASILEIRA: ESTRUTUTA, FUNÇÃO E MANEJO, 2. Academia de Ciências do Estado de São Paulo, Águas de Lindóia.

STENECK, R.S. & DETHIER, M.N. 1994. A functional group approach to the structure of algal-dominated communities. *Oikos*, 69: 476-498.

STEPHENSON, T.A. & STEPHENSON, A. 1949. The universal features of zonation between tide-marks on rocky coasts. *The Journal of Ecology*, 37: 289-305.

SUDENE. 1981. Projeto Algas - Estado do Rio Grande do Norte. *Estudos de Pesca*, 9: 1-120.

TEIXEIRA, V.L.; PEREIRA, R.C.; MARQUES JÚNIOR, A.N.; LEITÃO FILHO, C.M. & SILVA, C.A.R. 1987. Seasonal variations in infralittoral seaweed communities under a pollution gradient in Baía de Guanabara, Rio de Janeiro (Brazil). *Ciência e Cultura*, 39: 423-428.

TKACHENKO, K.S. 2005. An evaluation of the analysis system of video transects used to sample subtidal epibiota. *Journal of Experimental Marine Biology and Ecology*, 318: 1-9.

VILLAÇA, R.C. & PITOMBO, F.B. 1997. Benthic Communities of Shalow-Water Reefs of Abrolhos, Brazil. *Revista Brasileira de Oceanografia*, 45: 35-43.

YONESHIGUE-VALENTIN, Y. & VALENTIN, J.L. 1992. Macroalgae of the Cabo Frio upwelling region, Brazil: ordination of communities. Pp 31-50. *In:* U. Seeliger, (ed.), Coastal plant communities of Latin America. Academic Press, San Diego.

ZAR, J.H. 1999. *Biostatistical Analysis* (Fourth edition). Prentice-Hall, New Jersey.

ZHARIKOV, Y.; SKILLETER, G.A.; LONERAGAN, N.R.; TARANTO, T. & CAMERON, B.E. 2005. Mapping and characterising subtropical estuarine landscapes using aerial photography and GIS for potential application in wildlife conservation and management. *Biological Conservation*, 125: 87-100.

Submetido em 15/01/2008.
Aceito em 28/03/2008.