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VisSed Software as a tool in monitoring programs for benthic data interpretation

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Resumo

Caracterização do material dragado e monitoramento de áreas de disposição geraram uma grande quantidade de dados difíceis de interpretar devido a necessidade de compilação e comparação de um extenso número de amostras de diferentes locais ao longo do tempo sob a influência de vários parâmetros ambientais. Nosso objetivo é testar a viabilidade de VisSed como uma ferramenta para ajudar a interpretação de dados bentônicos, consistindo de índices bióticos usuais na avaliação da estrutura das Comunidades Bentônicas e variabilidade temporal. As características exibidas pelo software VisSed, juntamente com a metodologia escolhida para a avaliação da estrutura da comunidade bêntica, fornecem uma representação visual das alterações que sofreu ao longo do tempo e do espaço pelos índices (diversidade, regularidade, riqueza e abundância total dos indivíduos). Os exemplos aqui considerados apoiam a utilidade desta ferramenta em programas de monitoramento, realçando os padrões e tendências de dados visuais, e direcionando o pesquisador para potenciais fatores determinantes. Também fornece bases para o processo de decisão por fazer tornar o processo de análise compreensível tanto para profissionais especialistas como não especialistas.

Palavras-chaves: monitoramento; material dragado; fauna bêntica; interpretação visual.

Abstract

Characterization of dredged material and monitoring of disposal areas generate a large amount of data hard to interpret due to the necessity of compilation and comparison of an extensive number of samples from different locations over long period under the influence of multiple environmental parameters. Our goal is to test the feasibility of VisSed as a tool to assist benthic data interpretation consisting of biotic indexes usual in assessment of benthic communities' structure and temporal variability. The characteristics displayed by the software VisSed, along with the chosen benthic structural methodology, provide a visual representation of changes sustained over time and space by the indexes (diversity, evenness, richness and individuals' total abundance). The examples considered here support the usefulness of this tool in monitoring programs by enhancing visual data trends and patterns, and directing the researcher to potential determinant factors. It also provides grounds for the

decision making process understandable by specialists and non-specialists professionals.

Keywords: monitoring; dredged material; benthic fauna; Visual interpretation.

Introduction

The assessment and monitoring of disposal areas for dredged material is a prominent part of port activity management worldwide. Each country has its own norms regulating dredging activities and sediment quality criteria based on reference values that support decision-making process regarding management of disposal areas. Different approaches have been used for the establishment of sediment quality criteria (ALVAREZ-GUERRA et al., 2007; MOZETO et al., 2006), which are, by the way, not yet established in Brazilian legislation.

Characterization of dredged material and monitoring of disposal areas generate a large amount of data hard to interpret due to the necessity of compilation and comparison of an extensive number of samples from different locations over long period under the influence of multiple environmental parameters. The interpretation of such data requires appropriate techniques such as quotients derivation (LONG et al., 2006) that briefly characterizes data subsets behavior. As an alternative to the numerical worksheets analysis and complementary use of statistical techniques, it has been argued that monitoring data interpretation can benefit from the appropriate use of graphic and data interaction techniques.

Graphic and data interaction techniques are derived from “Information Visualization” expertise area. Its goal is to facilitate information deriving processes and its interpretation through datasets visual analysis (CARD et al., 1999; CHEN, 2002). Based on the VisSed software, which proved useful in previous studies (UMBUZEIRO et al., 2009; SILVA & UMBUZEIRO, 2010), an information visualization prototype was developed providing visual and interactive analysis for a set of biological monitoring data through heat map matrix representation. The persistence of sediment contamination is the reason why several benthic groups have been used as indicators of stress or pollution. The analysis of changes in benthic communities, using various univariate and multivariate methods, have become an important tool in this assessment, however, the results obtained are generally difficult to be interpreted by non-scientists. The process can be clearer by the use of a biocriteria that permits the assessment of ecological status addressing only: the level of diversity, evenness, richness and abundance of invertebrate taxa.

The software enables data analysis from a specific sampling point, campaign, or parameter. Using dynamic query filters (SHNEIDERMAN, 1994), the software can reduce or enlarge the amount of data being displayed on the screen according to the user's need without requiring programming language knowledge.

Our goal is to test the feasibility of VisSed as a tool to assist benthic data interpretation consisting of biotic indexes usual in assessment of benthic communities' structure and temporal variability. Datasets used to attain this goal were from a monitoring program of a new spot for oceanic disposal of dredged material in Santos, São Paulo region. We hope to contribute for the decision-making process through the proper analysis of benthic data.

Material and methods

The application of ecological indexes to assess benthic communities' structural changes is usual in impact monitoring programs. The indexes used in the monitoring program of a new spot for oceanic disposal of dredged material were total abundance of individuals (N) (individuals/m²), species richness (S) (number of species/m²), Shannon-Wiener diversity (H') and Pielou evenness (J'). Usually, values for these indexes are presented in graphs and tables that do not provide an easy and comparative visualization.

For a clear interpretation of each indexes variations' significance we opted for not using absolute values, but rather, the expression of a relation between initial and final values, such as difference or ratio, for instance, between what was found in the campaign 0 and any subsequent campaigns (2 or 5), as detailed below. Comparisons are visually facilitated through a color scheme, indicating whether variations over time were larger or smaller.

As temporal variation is a major and intrinsic component of benthos, knowledge of benthic community annual cycle is strongly recommended as an initial step. But even in the absence of a prior full annual cycle appraisal, comparison among communities from stations receiving material disposal and those regarded as "control" (not in use and out of impacted areas) allows us to distinguish different intensities of structural changes suffered by a particular benthic community.

The methodology used for data presentation is based on the information visualization reference model proposed by Card et al (1999) followed four steps.

a. Selection of raw data

It was considered as raw data the spreadsheets provided by the benthic community monitoring program. From these data, the relevant characteristics to be graphically represented by VisSed were selected. The descriptors N, S, J' and H' were selected and inserted in a new worksheet where the new descriptors, described below, were derived and used for visual representations thereafter.

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- ΔJ' = | J '− J0 ' |: variation of Pielou species evenness values, according to set value J0' taken as reference.

- ΔH' = | H'− H0' |: variation of Shannon-Wiener diversity values, according to set value H0' taken as reference.

- S/S0: ratio between species richness value for a given campaign sampling site and S0 taken as reference.

- N/N0: ratio between the individual total abundance values for a given campaign sampling site and N0 taken as reference.

The purpose of a clear display of descriptors' variations and relationships is to assist in the monitoring of benthic communities structural changes in relation to the initial state, i.e. the community structure immediately prior to deposition process. The revealed structural changes assessed but the use of such descriptors may be derived from the sediment deposition process but also from benthic populations' natural seasonal cycles.

For VisSed feasibility study, J0' H0', N0 and S0 values were, respectively, the calculated values J ', H ', N and S for campaign 0 benthic data, sampled in January 2010, and then related to data from the following campaigns sampled respectively in April and July 2010. Datasets were generated as spreadsheets by different laboratories and are from a monitoring program conducted in the area.

b. Data Processing (creating data tables)

Data were organized in tables composed of tuples {N, S, J, H, N/N0, S/S0, ΔJ', ΔH'} related to each sampling year, point and replica obtained. Tables are processed by a particular program, which generates a database for later VisSed use. Database contains values of the descriptors N/N0, S/S0, ΔJ' and ΔH', and information about campaigns and sampling sites. Each pair {sampling site, replica} was adopted as a particular sampling site, rather than the average values between replicas, but replica average values can be considered also, if convenient.

c. Visual structural definition and variables mapping

VisSed supports data representation in heat map graphics among others not relevant here. The matrix style representation allows representing three (3) variables: two in X and Y-axis, and a third as color gradation. For color scheme, captions displayed next to graphics are used. Additional controls such as selection lists can be combined to the chart through programming, making it more interactive and admitting the possibility of handling more variables.

VisSed is prepared to deal with four variables from the environmental scenarios (sampling sites, campaigns, parameters and measured values). Considering that the benthic community proposed scenario, in terms of variables, applies the same number of variables, it can be concluded that the same visual mappings can be used when VisSed is dealing with benthic data, with the exception of those dealing with sediment particle size analysis. These should be hidden by VisSed when dealing with a database whose parameters do not involve particle sizes. Thus, the set of visual VisSed maps for benthic community data can be described as follows:

− Campaigns × Sampling sites: interactive chart representing the value measured for each campaign and sampling site (represented by axes) for a given parameter selected from a list.

− Campaigns × Parameters: interactive chart representing the measured value for each campaign and parameter (represented by axes) for a given sampling site selected from a list.

− Parameters × Sampling sites: interactive chart representing the measured value for each parameter and sampling site (represented by axes) for a given campaign selected from a list.

Captions definition and color scheme for visual mappings deserve further consideration. VisSed uses three distinct types of captions for sediment data: (1) a gradation of pastel shades for particle size; (2) green, yellow and red representing, respectively, below the action level 1, between level 1 and level 2, level 2 and above; and (3) gradient transition from green to red representing sum of metal quotient. Recently, bluish tones have been added to represent the toxicity criteria (absence of toxicity, chronic and acute toxicity). Diversity data representation should have subtitles that would allow the visual distinction of descriptors values' change in magnitude, whether they increase or decrease. It is also important to define a single set of colors to represent all possible ranges avoiding caption size overload, and, consequently, cognitive overload in the interpretation of data. This color scheme set should be different from those already in use by VisSed, featuring exclusively diversity data (as already done for particle size). Therefore, shades of green, ranging from dark green to light green, were adopted indicating descriptor variation degree.

By default, dark green was adopted to represent situations where there was no or little descriptor variation when compared to values set as reference; in opposition, light green indicates major variations.

Tables 1 and 2 present colors and shades for each descriptor. Within the current VisSed limitations, i.e. the admittance of only discrete interval colors as caption (and not color gradients defined by minimum and maximum values), it was necessary to define different colors for each range set of values relating to a specific index.

Table 1. Caption color scheme for richness and individuals' total abundance descriptors.

Color / Descriptor	N/N_0	S/S_0
Light green	0 – 0.3	0 – 0.3
...	0.3 – 0.7	0.3 – 0.7
...	0.7 – 0.9	0.7 – 0.9
Dark green	0.9 – 1.1	0.9 – 1.1
...	1.1 – 1.3	1.1 – 1.3
...	1.3 – 1.7	1.3 – 1.7
Light green	> 1.7	> 1.7

Table 2. Caption color scheme for diversity and evenness descriptors.

Color / Descriptor	∆J'	∆H'
Dark green	0 – 0.25	0 – 0.5
...	0.25 – 0.5	0.5 – 1.0
...	0.5 – 0.75	1.0 – 1.5
Light green	0.75 – 1.0	> 1.5

Different indexes have its characteristic variation range, so that caption ranges vary accordingly, but at least four range sets were maintained for all descriptors. It is worth mentioning that species evenness (J') value ranges from 0 to 1, and so the legend ∆J' maintains four 0.25 intervals. Diversity (H') value ranges from 0 to infinity, in theory, presenting for benthic natural communities values between 0 and not greater than 5; four 0.5 intervals were used for ∆H'. For individual abundance (N/N0) and number of species (S/S0) ratios, depending on variations suffered by descriptors' absolute values (S and N), there may be species and/or individuals loss or gain, therefore, values of 1 (100%) or greater were divided into 3 intervals sets each.

d. Interactive features

Interactive features already provided by VisSed were used. Some of them inherited from JInfoVis heat map visual representation tool (SILVA, 2006), such as: capacity to select and hide on the screen part of the data set, by interaction with axes or with matrix cells; ability to manually reorder matrix rows and columns in order to identify data patterns; possibility to alter visual mapping to one of the available ones; possibility to show or hide values displayed in cells. Thus, VisSed follows the successful heuristic expressed by Visual Information

Seeking Mantra: "Overview first, zoom and filter, then details-on-demand" (SHNEIDERMAN, 1996).

Results

Some VisSed visual representations are presented, based on assessed benthic communities' data provided by CPEA. Examples are organized according to VisSed three (3) visual maps groups:

a) Campaigns × Sampling sites:
- ΔH' values for all sampling sites and campaigns (Figure 1);
- ΔH' values from all campaigns, for sampling sites P25, P02 and P05 (Figure 2);
- ΔJ' values for all sampling sites and campaigns (Figure 3);
- ΔJ' values from all campaigns, for sampling sites P25, P02 and P05 (Figure 4);
- N/N0 values for all sampling sites and campaigns (Figure 5);
- N/N0 values from all campaigns, for sampling sites P25, P02 and P05 (Figure 6);
- S/S0 values for all sampling sites and campaigns (Figure 7);
- S/S0 values from all campaigns, for sampling sites P25, P02 and P05 (Figure 8);

b) Campaigns X Parameters:
- Values measured for replica P02A from all campaigns and parameters (Figure 9);

c) Parameters X sampling sites:
- Values measured for all sampling sites and parameters from campaign 05 (Figure 10);
- Values measured for all parameters in sampling sites P01 to P10 from campaign 05 (Figure 11)

It is particularly noteworthy the increase in ΔH' and S/S0 values (Figures 2 and 7) with time (April/02 and July/05 campaigns). Diversity index values variations for campaigns 2 and 5 were compared to 0 for each of the stations considered (Figure 1). As the number of stations is high, stations in use P02 and P05 and control station P25 were presented separately (Figure 2). Notice that diversity values alteration from campaign 0 was higher for stations in use.

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Fig. 1: ΔH' values for all sampling sites and campaigns.

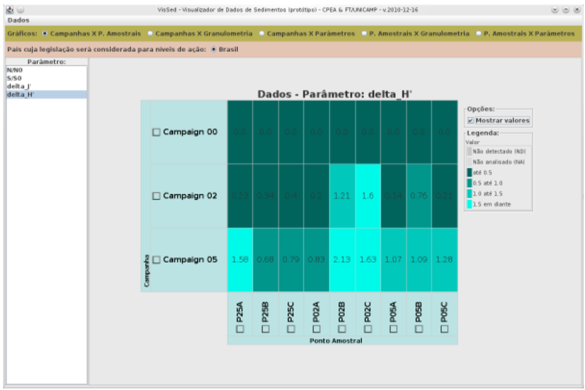

Fig. 2: ΔH' values from all campaigns, for sampling sites C, P02 and P05.

The same procedure described above for diversity index was adopted for species evenness index. Descriptor species evenness values for all grid stations are represented in Figure 3, while in Figure 4 only for those in use, P02 and P05, and control P25. There are no significant differences in this index values when compared, showing that individuals' distribution in species categories over space and time period is constant.

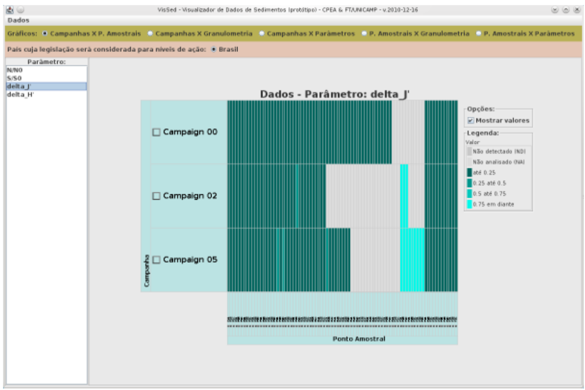

Fig. 3: ΔJ' values for all sampling sites and campaigns.

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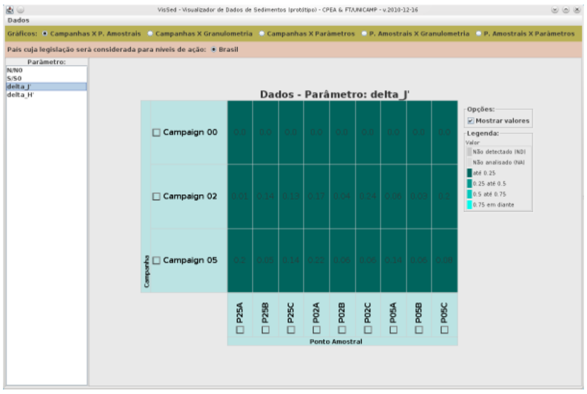

Fig. 4: ΔJ' values from all campaigns, for sampling sites P25, P02 and P05

Changes in number of individuals of later campaigns in relation to campaign 0, were considered graphically both in terms of numbers decrease and increase (Figure 5). A clear decrease in individual numbers over time is perceived in all stations, and can be regarded as a natural seasonal cycle. Given the high numbers of stations, only stations in use in (P02 and P05) and control (P25) are represented in Figure 6.

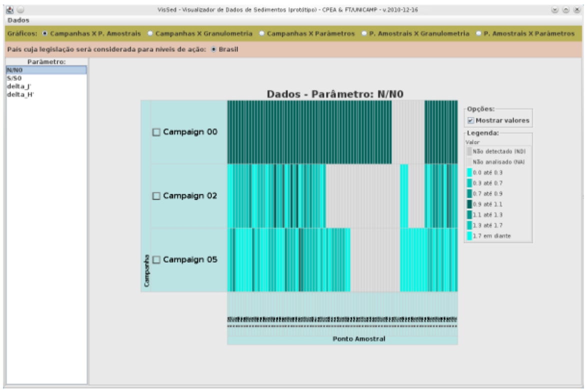

Fig. 5: N/N_0 values for all sampling sites and campaigns.

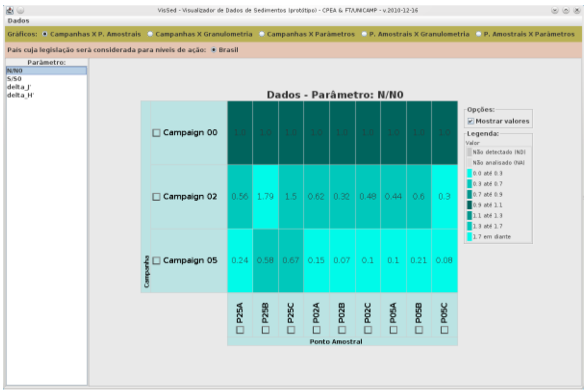

Fig. 6: N/N_0 values from all campaigns, for sampling sites P25, P02 and P05.

FLYNN, Maurea Nicoletti; DA SILVA, Celmar Guimarães; SUMIDA, Paulo Yukio Gomes; GÜTH, Arthur Ziggiatti; ALVES, Betina Galerani Rodrigues; UMBUZEIRO, Gisela de Aragão. VisSed Software as a tool in monitoring programs for benthic data interpretation. Revista Intertox-EcoAdvisor de Toxicologia Risco Ambiental e Sociedade, v. 8, n. 3, p. 22-35, out. 2015.

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In Figure 7 the changes suffered by species richness index, considered here as the ratio between the number of species in a specific later campaign and campaign 0, were represented for each station. A gradual decrease in number of species occurred from February to April and July (respectively campaigns 0, 2 and 5). Stations in use (P02 and P05), and control (P25) were presented separately (Figure 8). There is a probable seasonal cycle, which is more pronounced for stations in use.

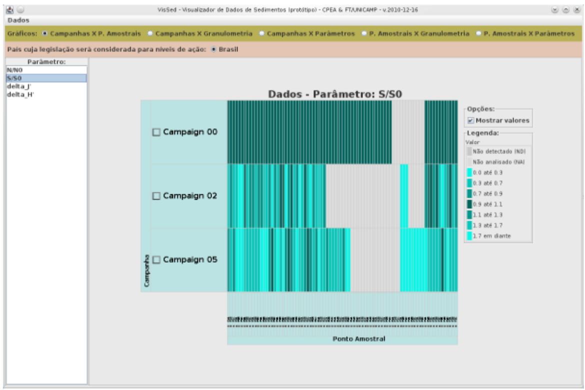

Fig. 7: S/S_0 values for all sampling sites and campaigns

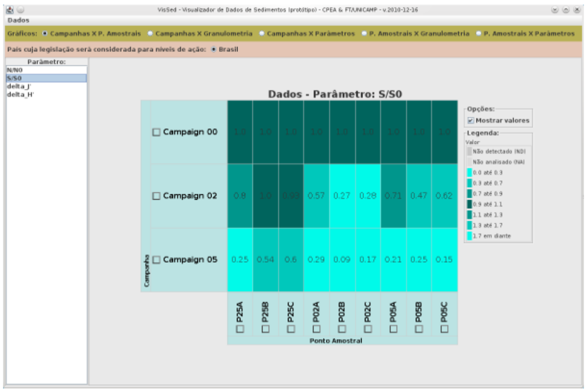

Fig. 8: S/S_0 values from all campaigns, for sampling sites P25, P02 and P05

As an option for data presentation, as shown in Figure 9, indexes calculated for a single replica (A) of a given station (for example, P02) can be presented for all campaigns over the time period considered. In this manner, it can be perceived major variations in individuals' total abundance and richness indexes for P02A, and also that evenness values do not vary significantly. Another option for data graphical presentation could be the joint appearance of all structural indexes, similar to what was done for a single replica, but considering all stations (Figure 10), or a set of stations (Figure 11). These graphs underscore the general trend of major changes in richness and individuals' abundance values in contrast to diversity and evenness more stable values.

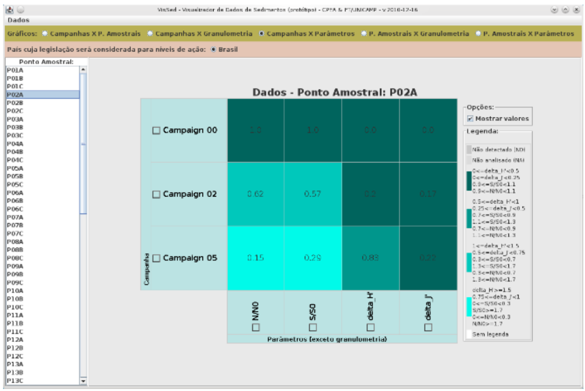

Fig. 9 Values measured for replica P02A from all campaigns and parameters

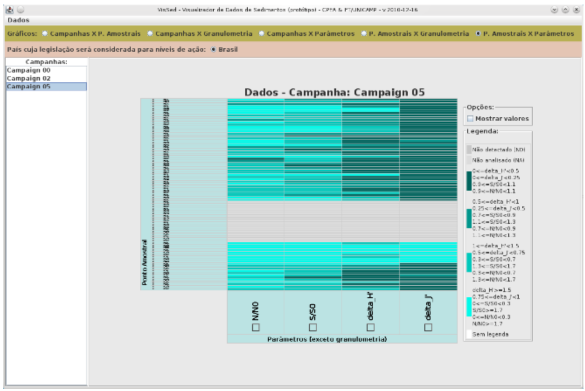

Fig. 10: Values measured for all sampling sites and parameters from campaign 05.

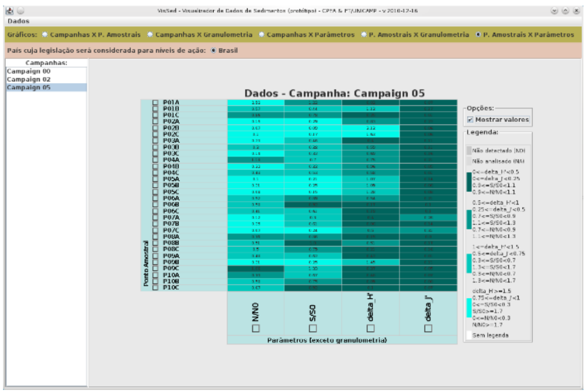

Fig. 11: Values measured for all parameters in sampling sites P01 to P10 from campaign 05.

Conclusions

The characteristics displayed by the software VisSed, along with the chosen benthic structural indexes methodology, provide a visual representation of changes sustained over time and space by the indexes (diversity, evenness, richness and individuals' total abundance). The examples considered here support the usefulness of this tool in monitoring programs by enhancing visual data trends and patterns, and directing the researcher to potential determinant factors. It also provides grounds for the decision making process understandable by specialists and non-specialists professionals.

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