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Biological data extraction from imagery – How far can we go? A case study from the Mid-Atlantic Ridge

Daphne Cuvelier [a,b,*], Fanny de Busserolles [a], Romain Lavaud [a], Estelle Floc'h [a], Marie-Claire Fabri [a,c], Pierre-Marie Sarradin [a], Jozée Sarrazin [a]

[a] Ifremer, Centre de Brest, Département Ressources physiques et Ecosystèmes de fond de Mer, Institut Carnot-EDROME, Unité de recherche EEP, Laboratoire Environnement Profond, 29280 Plouzané, France

[b] Instituto do Mar (IMAR) & Department of Oceanography and Fisheries, University of the Azores, 9901-862 Horta, Portugal

[c] Ifremer, Centre de Méditerranée, Département Océanographie et Dynamique des Ecosystèmes, Laboratoire Environnement Ressources, 83500 La Seyne sur Mer, France

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ABSTRACT

In the past few decades, hydrothermal vent research has progressed immensely, resulting in higher-quality samples and long-term studies. With time, scientists are becoming more aware of the impacts of sampling on the faunal communities and are looking for less invasive ways to investigate the vent ecosystems. In this perspective, imagery analysis plays a very important role. With this study, we test which factors can be quantitatively and accurately assessed based on imagery, through comparison with faunal sampling. Twelve instrumented chains were deployed on the Atlantic Eiffel Tower hydrothermal edifice and the corresponding study sites were subsequently sampled. Discrete, quantitative samples were compared to the imagery recorded during the experiment. An observer-effect was tested, by comparing imagery data gathered by different scientists. Most factors based on image analyses concerning *Bathymodiolus azoricus* mussels were shown to be valid representations of the corresponding samples. Additional ecological assets, based exclusively on imagery, were included.

1. Introduction

For the past few decades, deep-sea environments such as hydrothermal vents have been intensively studied by researchers worldwide. These extreme ecosystems are traditionally characterized by their remoteness (both from shore as in depth), and hostile environment (e.g. elevated temperatures, high hydrogen sulphide concentrations, steep chemical gradients). The chemosynthetic micro-organisms present at hydrothermal vents support very specific faunal assemblages. In order to increase our knowledge about the functioning and dynamics of vent ecosystems and their associated communities, faunal sampling is considered fundamental. Information collected through sampling on species composition, densities and biomass is, as such, essential to understand community ecology and biological productivity (Juniper et al., 1998). In this perspective, collecting animals is also crucial to study organism's physiology. With time, new techniques have been developed, allowing more precise analyses, higher quality samples and long-term studies.

Behind this progress, however, the question of the potential effects of unregulated sampling on these isolated ecosystems arises (Tyler et al., 2005). At hydrothermal vents, sampling is carried out with manned submersibles and Remotely Operated Vehicles (ROV's) which use their robust manipulator arms to sample the uneven and mostly hard substrata inhabited by vent organisms. The irregularity of these sampling surfaces makes quantitative sampling complicated and can result in local perturbations, lastingly changing fluid flow patterns and faunal communities. Such fluid flow modifications were shown to have a profound influence on local assemblages (Hessler et al., 1985, 1988; Fustec et al., 1987; Tunnicliffe, 1991; Sarrazin et al., 1997, 2002; Shank et al., 1998). Despite the precautions taken in choosing more easily accessible sites and relatively flat surfaces, sampling at vents remains intricate and can still be disturbing for faunal communities. This threat was recognized by vent researchers early on (Tyler et al., 2005) but only a few studies have been carried out on sampling impacts. Tunnicliffe (1990) is one of those few studies that assessed sampling effects on deep-sea hydrothermal vents and its fauna and demonstrated that the local vent community, in this case siboglinid polychaetes, had major difficulties to maintain itself after such an

* Corresponding author. Ifremer, Centre de Brest, Département Ressources physiques et Ecosystèmes de fond de Mer, Unité de recherche EEP, Laboratoire Environnement Profond, BP 70, 29280 Plouzané, France. Tel.: +33 (0) 2 98 22 43 29; fax: +33 (0) 2 98 22 47 57.
E-mail addresses: daphne.cuvelier@ifremer.fr, daphne.cuvelier@gmail.com (D. Cuvelier).

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anthropogenic disturbance, resulting in a lack of subsequent colonization of the sampling area. Overall, while certain geological structures appear to recover quickly from sampling effects, the faunal community, depending on the scale of sampling, may take up to several years to regain its original state (i.e. prior to sampling).

All submersibles and ROV's are equipped with piloting cameras that record imagery footage while diving and carrying out experiments. Contrastingly to sampling, image analysis is a non-invasive technique, which is also one of its greatest advantages. Moreover, imagery analysis permits investigating a larger surface (larger spatial coverage) than discrete sampling and therefore gives a more extended overview of the habitat and faunal communities. It is also more random than sampling, especially in the type of irregular terrain encountered at vents. Imagery analysis has been used to estimate surface areas, faunal coverage and the presence of associated fauna in a variety of ecosystems, such as coral reefs and coastal habitats (Norris et al., 1997; Magorrian and Service, 1998; Ninio et al., 2000). At hydrothermal vents, imagery analysis already proved its value as it is an indispensable, and often the only, tool available in analysing community distribution and temporal variations (Desbruyères, 1998; Sarrazin et al., 1997; Shank et al., 1998; Tunnicliffe et al., 1997; Desbruyères et al., 2001; Tsurumi and Tunnicliffe, 2001; Shank et al., 2003; Copley et al., 2007a,b; Nees et al., 2008; Marcus et al., 2009; Cuvelier et al., 2009, 2011a,b; Podowski et al., 2009; Fabri et al., 2011). Nevertheless, not all parameters are easy to assess based on imagery, and even while video studies are not invasive, they often require ground-truthing with collection of discrete samples at some stage in the investigation (Godet et al., 2010). However, once the connection between what we see and what we sample is established, visual recognition can be used to assess faunal distributions and physico-chemical environmental changes over time and on larger scales (Cuvelier et al., 2011a,b). With all that said, the question remains: how far can we go with imagery analyses without compromising on accurateness?

Currently, hydrothermal vents are somewhat "protected" in the sense that an international code of conduct was drawn up by the international scientific community (Tyler et al., 2005; Devey et al., 2007). The world's first deep-sea Marine Protected Area (MPA) was established in 2003 on the Endeavour segment on the Juan de Fuca Ridge (Canada, Devey et al., 2007). In the Atlantic, the Lucky Strike vent field was proposed as an important conservation area (Azores, Santos et al., 2003) and was included in the Oslo and Paris Conventions network of MPA's in 2007. It was also accepted in 2009 by the European Community as a Site of Community Importance under the Natura 2000 network (O.J. L 344, 2009). The goal of these MPA's is to preserve the integrity of hydrothermal ecosystems including the species and habitats to allow a better understanding of their natural diversity, productivity and dynamics. These protective measures do not allow sampling at certain sites and therefore emphasize the increasing importance of imagery and the accurateness of its interpretations in monitoring natural dynamics.

This paper concurrently investigates the potential and limitations of imagery analyses. In addition, we highlight complementary features that can only be extracted from imagery and are thus an asset to discrete sampling. As part of an in-depth ecological study, twelve instrumented chains equipped with temperature probes were deployed on visibly different faunal assemblages on the Eiffel Tower edifice (Lucky Strike vent field, Mid-Atlantic Ridge – MAR). These twelve sites were thoroughly investigated, comparing imagery analyses with the corresponding ground-truth samples. In order to evaluate possible subjectivity in analysing imagery, we also compared the imagery analyses carried out by two different scientists to evaluate the observer's effect. The major objective of this study is to compare the results obtained by video imagery with those obtained through quantitative sampling.

2. Material & methods

2.1. Study site

Data gathering for this study was carried out during the MoMARETO cruise (2006) which took place in the MAR region, situated south-west of the Azores Triple Junction (ATJ). Data were collected on the hydrothermal Eiffel Tower edifice, a sulphide structure located south-east of the central lava lake of the Lucky Strike vent field. This 11 m high edifice, situated at a depth of 1690 m, is colonized by *Bathymodiolus azoricus* mussels as well as by *Mirocaris fortunata* shrimp assemblages (Comtet and Desbruyères, 1998; Desbruyères et al., 2000, 2001; Cuvelier et al., 2009). After several monitoring/screening dives, 12 locations were chosen at various places on and around Eiffel Tower (Fig. 1), featuring various assemblages and possibly different physico-chemical conditions. A temporary "chain", equipped with autonomous temperature probes, was placed on each sampling location (Fig. 2).

2.2. Faunal sampling

The ROV Victor6000 was used to sample the fauna at each sampling site. First the temporary chain was removed, after which the mobile fauna on the area previously covered by the chain was sampled with the ROV suction sampler. Subsequently, the underlying faunal assemblages (on the same area as previously sampled with the suction sampler) were sampled with Victor's arm grab and put into separate sampling boxes. Finally, a second suction sample was taken on the bare surface in order to recover the remaining fauna. Surfaces sampled have been delineated on the faunal assemblages and sampling locations as presented in Fig. 2.

2.3. Image analysis

2.3.1. Imagery collection and characteristics

During all the dives, video imagery data was recorded by a 3-CCD camera (HYTEC, VSPN 3000) and a digital high-definition still camera (Sony, Cybershot), mounted above the principal camera of the ROV. Pan, tilt and zoom were kept constant to the extent possible (i.e. not compromising manoeuvres from the ROV). All imagery data was digitally recorded on DVDs. Lighting was provided by 8 flood lights on a fixed bar at the front of the ROV, totalling 5 kW.

For the image analysis, all imagery available (from the approach of the sampling site and the sampling itself) was used, comprising high-resolution photographs, video imagery and screen-stills. Still-images were used as templates to map the surface sampled and analyse the fauna within. Preference was given to the use of high-resolution images, which were mostly available for all sites, however when these were unavailable or unusable, screen-stills were used as a template for analyses. High-definition images had a resolution of 2048×1536 pixels while screen-stills were 696×576 pixels. Additional high-resolution photographs, featuring zoom-ins, different angles, alongside video imagery from different angles were used to study these sampling sites to reduce the visual distortion of the irregular hydrothermal surfaces, the differences in lighting and shadows cast by the ROV.

2.3.2. Evaluation of sampled surfaces

In order to allow comparisons between the different sampling sites, the surfaces sampled were measured with pixel-based image analysis software IPLAB Spectrum© as described in Sarrazin et al. (1997) (Fig. 2). For this study, the twelve instrumented chains with links of 9 cm were used to set the calibration. Because the chains were removed before sampling the fauna, the length of a remarkable