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The use of video imagery to gather biological information at deep-sea hydrothermal vents

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Hydrothermal vent environments are still difficult to visit and the collection of quantitative biological samples is often constrained by both technology and time. Video imagery is the most reliable method for obtaining data that we have while exploring the deep-sea hydrothermal vent environment. Beside the fact that it is continuously recorded, video imagery rapidly covers large surfaces, replication is easy to obtain and it is non-destructive for the ecosystem. Some studies have shown that submersible intervention and sampling can have a significant impact on faunal dynamics and fluid flow at vents (Tunnicliffe, 1990; Sarrazin et al.; 1997) modifying naturally occurring patterns.

This paper presents three different approaches developed to extract biological data from systematically collected video imagery at different scales at deep-sea hydrothermal vents. At the scale of a high-temperature hydrothermal edifice, video imagery was used to map community distributions as well as environmental changes occurring during a time period of years (Sarrazin et al., 1997). At a smaller spatial scale, digitized video frames were used to determine the composition of mega/macrofaunal assemblages (Sarrazin et al., submitted) and also, to estimate sampled surfaces (Sarrazin and Juniper, submitted). We also review the limitations associated with the use of video imagery. If systematically gathered, this method has a lot of potential to provide ecological information to be tested by limited in situ sampling.

I. Structure-scale mapping

We developed the structure-scale mapping approach during a time-series study of a sulphide edifice and its associated communities (Sarrazin et al. 1997). The study examined community distribution in relation to environmental changes. A 10 x 5 x 10 m high temperature edifice on Endeavour Segment (Juan de Fuca Ridge) named S&M (for Smoke and Mirrors) was visited by different submersibles (*Jason, ROPOS* and *Alvin*) during several cruises in 1991, 1994 and 1995. During each mapping dive, we first acquired overall views of the edifice using low-light black and white SIT cameras. This imagery was used to determine the general morphology of the structure, including the distribution of smoker vents as well as to develop a base map. Base maps were drawn from several perspectives by on-screen tracing of captured video frames from the SIT cameras. The west face of the edifice was selected for detailed study because of its less complex morphology. The face was carefully imaged by conducting several overlapping vertical and horizontal imaging transects with the submersibles' colour cameras at approximately one meter from the edifice walls. Maintaining a constant distance was important as was having identifiable geological features or edifice edges in images. Depths were also recorded at the summit of different parts of the edifice, at different base levels and around important features.

The spatial distribution of the six identified communities on the western face of S&M was mapped for each year of the study (1991, 1994 and 1995) from a SIT image base map drawn by Dr. Mark Hannington (Geological Survey of Canada) from a 1991 Jason image. This base map was copied to a large (60 cm x 100 cm) sheet. Our first step was to refine the general profile of the structure with SIT imagery and to map major geological features. Once these features were carefully placed on the edifice, close-up colour video images were repeatedly viewed and, with the help of wall edges and recognizable features, we started to map the different communities. After completing a draft faunal map, we reviewed all video imagery to verify the relationship and size of faunal patches, and used frozen frames to add more details. These steps were repeated for each year of the study, beginning from the 1991 base map. The same method was used to map the location of visible shimmering flow and black smokers (Fig. 1). Maps were then digitized and analysed by two different techniques. To

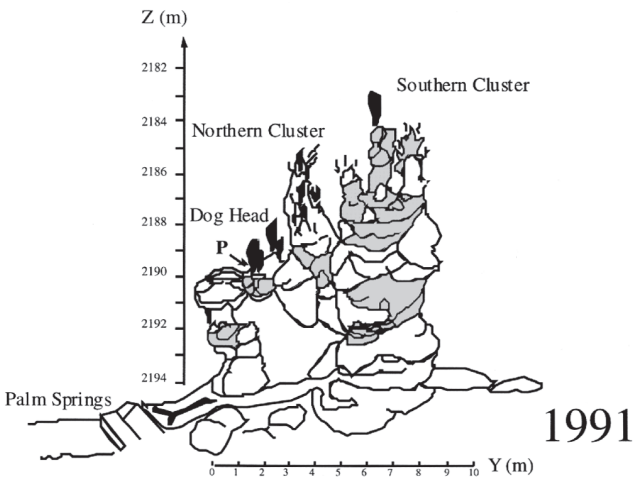

Figure 1. Example of faunal distribution map on the western face of the S&M edifice with electronically-generated analytical grid (adapted from Sarrazin et al., 1997).

determine total surface area occupied by identifiable faunal communities, faunal patches were traced on-screen and surface area was determined in pixels using the image analysis program IPLab Spectrum (Grehan and Juniper, 1996). Each patch was digitized and analyzed 3 times to reduce error from on-screen tracing. To analyse temporal evolution of the edifice surface, an electronically-generated grid was overlain on the digitized maps in order to quantitatively determine changes in faunal composition, edifice morphology, bare surfaces, flow patterns (etc.), at the scale of individual grid squares (0.0625 m2). The grids were registered to a visible common reference point that was fixed to GPS coordinates during the 1995 *Alvin* dive series. From this reference origin, every grid square was assigned individual Y/Z coordinates. Each of the approximately 1600 grid squares was assigned a surface attribute (S) according to the dominant faunal community type. The resulting Y/Z/S data base was then analysed to determine the frequency of change at the scale of individual grid squares and the relationship of change to position on the structure. The data base was also used to construct a transition probability matrix to examine successional patterns.

II. Cm-scale faunal composition

To determine links between faunal distribution and in situ measured environmental factors (Sarrazin et al., submitted), two high-temperature edifices of the Juan de Fuca Ridge were sampled using the SUAVE chemical analyser. The remote-operated vehicle *ROPOS* was deployed in 1993 to acquire 32 data series on Fountain (North-Cleft Segment) and in 1995, to gather 46 data series on S&M (Endeavour Segment). While sampling with the chemical analyser, video images of the faunal assemblages surrounding the probe tip were recorded. To avoid scaling problems, markers (1993) or lasers (1995) had to be present in the pictures. For each data series, video images were captured to disk using a Raster-Ops video board on a Macintosh computer. Relation of faunal composition to conditions measured at the probe tip had to take into account the observation that considerable variability in environmental factors could be observed between 10 cm spaced points. Faunal composition was determined in two arbitrarily-chosen intermediate scale circles (2 and 5 cm) centred on the probe tip. A high correlation (R = 0.86) between faunal data at these two scales allowed us to use the larger scale (5 cm) for our analyses. For each data series, the image analysis software IP-Lab Spectrum was used to scale the 5 cm-circle around the chemical analyser tip in digitized video images. Faunal abundance, richness and density were then estimated (Fig. 2) and used to establish links between species distribution and in situ measured environmental factors. Faunal sampling following in situ measurements would provide more information, but these operations are very time-consuming and destructive. Video imagery provides an alternative means of determining faunal distribution and at the same time reveals global ecological patterns. The complexity of the resulting data base, containing information on the presence-absence and density of different species in relation to 3 chemical variables and temperature, as well as substratum type and fluid flow characteristics, required a sophisticated statistical treatment. We used canonical correspondence analyses to identify environmental controls on organism distribution and weigh the importance of different environmental factors.

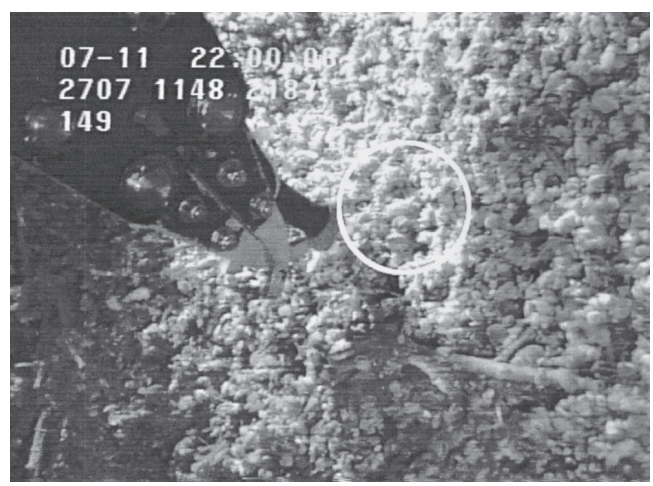

Figure 2. Determination of cm-scale faunal composition from a digitized video frame. A 5 cm circle (white) is drawn to estimate faunal abundance around the SUAVE chemical analyser probe tip.

III. Surface determinations for quantitative sampling

The lack of good quantitative sampling tools is a fundamental problem for vent ecologists. Quantitative samples are essential to determine basic ecological descriptors such as density and biomass. In a recent paper (Sarrazin & Juniper, in press), we used video imagery to estimate the size of surfaces sampled using different tools on the remotely-operated vehicle *ROPOS*. Video imagery was taken before and after community collections and lasers were placed in the middle of the sampling scars. Three selected video images of each sampled surface were digitized and imported in IP-Lab Spectrum image analysis software (Grehan & Juniper 1996; Sarrazin et al., 1997). The scale was set on each picture using visible 10 cm spaced laser points. The sampled area was then contoured by on-screen tracing (Fig. 3) and the surface was directly calculated with the Spectrum segment measurement function. Areal determinations were performed in triplicate for each image, to reduce error resulting from manual tracing. Total sampled area was calculated in square meters as the mean of nine (3 separate images x 3 replicates measurements). Faunal data were used to define the composition and biomass characteristics of previously described communities (see Juniper et al., this issue). Resulting quantitative information was also used to refine our community succession model (Sarrazin et al., 1997).

IV. Conclusions and limitations

Recent ecological studies at vents have demonstrated that video imagery is a valuable tool for the evaluation of mega/macrofaunal distribution and composition (Chevaldonné & Jollivet 1993; Grehan & Juniper 1996; Sarrazin et al., 1997; Sarrazin et al., submitted, Sarrazin & Juniper, in press). Faunal dynamics can also be monitored in video imagery, even on large sulphide edifices where imaging transects and reconstructive mapping can reveal overall and fine-scale patterns. Nevertheless, video imagery has limitations. It does not take thickness of faunal cover into account, leading to underestimation of faunal abundance and consequently density. Smaller organisms are often hard to see and therefore are either not included or underestimated. A particular effort should be made to optimize submersible lighting systems in order to facilitate species identification. Relief is another problem. Estimating surface area from 2-D images results in errors in estimation of surface-dependent ecological descriptors such as density and biomass. A multi-beam laser or acoustic device could permit more accurate determination of surface area, as may the eventual use of 3-D video imaging systems and 3-D mapping. In the near-term, further development of quantitative sampling tools for submersible use is becoming essential to study the ecology of vent communities (Sarrazin & Juniper, in press). Sampling remains essential to complete the information gathered by submersible-collected imagery.

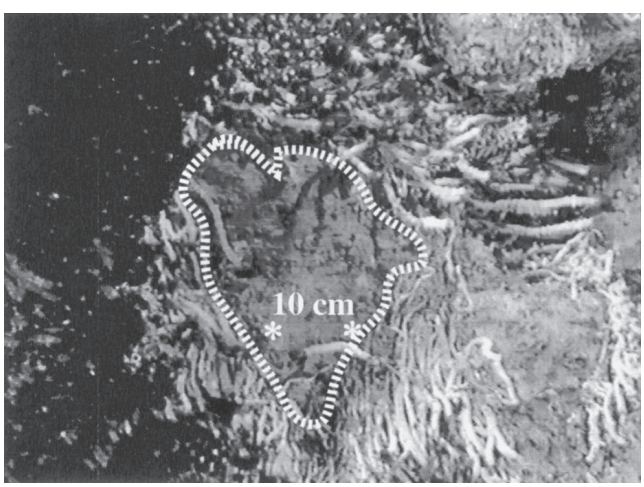

Figure 3. Areal surface determination by on-screen tracing of sampling scars on digitized video frame. The IP-Lab Spectrum segment measurement is used to estimate surface area from 3 images of the same sampling area and 3 manual tracing replicates per image. The 2 star symbols (*) overlay the 10 cm spaced laser points visible on images. These points are used to scale the sampled area.

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