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Remote sensing of organism density and biomass at hydrothermal vents

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Information on organism density and biomass is fundamental to understanding of community ecology and biological productivity at deep-sea hydrothermal vents. The traditional approach in benthic ecology has been to obtain this information through quantitative sampling. The generally small area and restricted distribution of vent communities and their location in deep water require that ecological studies use manned or unmanned submersibles for primary data gathering. Since most vent communities occur on hard substrata, sampling requires the use of tools mated to submersible manipulators to remove organisms from basalt or sulphide surfaces. Surfaces are inevitably irregular and quantitative collection is difficult. As well, sampling is destructive and can have a significant impact on processes that are under investigation such as faunal community and habitat changes (Tunnicliffe, 1990; Sarrazin et al., 1997). This paper presents examples of how submersible-gathered video imagery can be used in combination with other methods to determine organism density at hydrothermal sites in contrasting geological settings. Use of video imagery minimizes habitat perturbation and, because it is non-destructive, permits time-series studies of individual vents and groups of organisms.

While most submersibles are equipped to acquire both still photos and video imagery, we emphasize the use of video. Film does provide much higher resolution information, but the continuous coverage and feedback control offered by video imagery make it a much more attractive tool for survey work. It has also been our experience that obtaining good quality photos of vent communities is still an uncertain process, since most still cameras regularly used by scientific submersibles do not permit remote adjustment of lighting and focal length to compensate for changing situations on the seafloor. In the following section, we present examples of three studies in different geological settings that have used video imagery for the determination of organism density or biomass. All three examples used imagery acquired by the remotely-operated vehicle ROPOS.

Middle Valley

At this sedimented hydrothermal site on the Juan de Fuca Ridge, SIT video imagery was used to reconstruct a vesicomyid clam bed to determine overall dimensions, the relationship of clam density to bathymetry and to estimate clam abundance. The study emphasized the development of mosaicking techniques, from image acquisition by the ROV through to assembly of the mosaic and its orientation and scaling in GPS space (Grehan & Juniper, 1996). The clam bed was located on relatively flat seafloor at the base of a hydrothermal mound. Spot counts in high resolution imagery permitted development of clam density contours and estimation of total numbers of living and dead clams within the field. We were also able to relate clam density to bathymetry and indications of flow intensity (temperature profiles in sediments). Limited sampling provided information on average size. Finally, a quantitative 2-D flow model was developed from temperature and pore water hydrogen sulphide gradients in the sediments within the clam bed, from which we were able to estimate the energy available for biological productivity based on chemoautotrophic oxidation of H_2S.

CoAxial

Following a post-eruption bloom of bacteria at this segment of the Juan de Fuca Ridge a substantial part of a new lava flow was covered by microbial floc. In order to obtain a biomass estimate of the floc, and therefore quantify the amount of material produced in the few days following the eruption, we used image analyses at two scales (Juniper et al., 1995). First, the ROPOS suction sampler was used to collect microbial material from the surface of a pillow lava. The cleared surface was quantified from digitized video imagery, allowing the analytical data on total sample carbon, protein, etc. to be reported on an areal basis. In parallel, video images from zigzag transects across the lava flow were sampled at one minute intervals to estimate percent coverage of the seafloor by microbial floc. These data were then extrapolated to the entire 64 Ha area of the lava flow by kriging, and a contour map of microbial floc coverage was developed. The single biomass estimate for the sampled floc was then used to estimate the total amount of microbial material present on the surface of the lava flow; on the order of 10-40 kgC. While very approximate, these data permitted the first quantitative estimate of the production of microbial biomass in the short-lived blooms that have been observed to follow seafloor eruptions (Juniper et al., 1995).

Endeavour Main Field

This study followed up on previous work that had identified 6 recurring faunal assemblages on sulphide edifices of the Main Endeavour Field on the Juan de Fuca Ridge (Sarrazin et al, 1997). We used several ROV tools and collection techniques to sample five of the six faunal communities. The main instrument for sampling tube worm assemblages was a grab sampler that deposited the sample in a hydraulically-closing collection box on the front of the vehicle. A suction sampler was used for alvinellid polychaete communities. Following removal of the sample, laser scaling in captured video frames was used to determine the area cleared by the sampling operation, and allow reporting of abundance and biomass on an areal basis. Community biomass can be compared in this way, although precise comparison of species diversity is not possible since area sampled was not equal between samples, and diversity does not vary proportionally with area sampled. We were then able combine these biomass data with annual 2-D maps of the distribution of these communities on one edifice to consider how total biomass at the scale of a large structure was affected by geological changes. In a parallel study we found that many visible (in video imagery) morphological features of dominant vent organisms were significantly correlated with wet and dry weight on sampled species. These latter relationships may permit time series observations of biomass changes without the perturbative effects of sampling.

The introduction of image analyses into benthic ecology has been slow, and imagery has more frequently been used as a last resort source of information on organism abundance and biomass than as a tool of choice. Image analyses, when properly calibrated by ground truthing, is particularly adapted to the quantitative study of spatially-limited deep-sea habitats such as hydrothermal vents and cold seeps where sampling procedures are likely to have a significant impact on organism abundance and habitat change. Table 1 compares wet weight biomass data for vent community from several studies in the eastern Pacific that

Table 1. Published biomass estimates for hydrothermal vent communities from the Eastern Pacific.

Reference	Wet Weight Biomass
	Low Temperature Diffuse Flow Habitat
Somero et al., (1983)[1]	10-15 kg m^{-2} for Galapagos *Riftia pachyptila*
Hessler & Smithey (1983)[2]	10 kg m^{-2} for Galapagos *Bathymodiolus thermophilus*
Fustec et al., (1988)[3]	8.5 kg m^{-2} for EPR 13°N tube-worm/bivalve assemblage
Desbruyères & Laubier (1991)[4]	44.5 kg m^{-2} for EPR *Riftia*/mussel assemblage
Brault et al., (1985)[5]	0.08 kg m^{-2} for serpulid polychaetes on vent periphery
Sarrazin & Juniper (1998)[6]	20 kg m^{-2} for Juan de Fuca *Ridgeia* tube-worm assemblage
	High Temperature Alvinellid Habitat
Brault et al., (1985)[5]	16 kg m^{-2} for EPR 13°N alvinellids
Fustec et al., (1988)[3]	2.4 kg m^{-2} for EPR 13°N alvinellid community
Desbruyères & Laubier (1991)[4]	2.2 kg m^{-2} for EPR 13°N alvinellid community
Chevaldonné & Jollivet (1993)[7]	0.14-0.52 kg m^{-2} for EPR 13°N *Alvinella* colony
Sarrazin & Juniper (1998)[6]	0.05-0.80 kg m^{-2} for Juan de Fuca alvinellid polychaete community

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[3] Oceanol. Acta 8, 15-21
[4] Ophelia. Suppl. 5, 31-45
[5] C.R. Hebd. Séanc. Acad. Sci., Paris 301, 1-8
[6] Mar. Ecol. Prog. Ser. (in press)
[7] Mar. Ecol. Prog. Ser. 95, 251-262

have combined limiting sampling with videoscopic analysis. One point that emerges from this comparison is the general agreement between results, despite the imprecision of some of the earlier studies. The near order of magnitude difference in faunal biomass between low temperature and high temperature biotopes has been attributed to the different capacities of faunal assemblages in these to environments to exploit available energy. This trend is consistent with results of a recent geochemical modelling study by McCollom & Shock (1997) who show that according to thermodynamic considerations, the greatest energy potential for chemolithoautrophic metabolism (and faunal growth) is through the oxidation of hydrogen sulphide in fluids <38°C.

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