THE MACROFAUNA OF THE SHALLOW HYDROTHERMAL VENTS AT PALEOHORI BAY, MILOS.

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ABSTRACT

Ακουμιανάκη, Ι. & Hughes, J. A.: Μελέτη της βενθικής μακροπανίδας στις παράκτιες υδροθερμικές πηγές στον Κόλπο Παλαιοχωρίου (Μήλος).

Στα πλαίσια του κοινοτικού προγράμματος MAST II το οποίο εστιάστηκε στη μελέτη της παραγωγικότητας κατά μήκος βιογεωχημικών διαβαθμίσεων που σχετίζονται με οξικές-ανοξικές διεπιφάνειες, διερευνήθηκε η επίδραση των παράκτιων υδροθερμικών πηγών στον Κόλπο Παλαιοχωρίου, στη σύνθεση και κατανομή της βενθικής μακροπανίδας. Οι εργασίες πεδίου πραγματοποιήθηκαν σε τρεις χρονικές περιόδους (Ιούλιος 1993, Οκτώβριος 1993 και Απρίλιος 1994). Οι δειγματοληψίες διενεργήθηκαν κατά μήκος δύο διατομών 5 μέτρων καθε μία από τις οποίες περιελάμβανε 5 σταθμούς σε αποστάσεις ενός μέτρου μεταξύ τους. Η Διατομή Α (TrA, 10 μέτρα βάθος) τοποθετήθηκε κατά μήκος της θερμοκρασιακής διαβάθμισης που δημιουργήθηκε από τις διαρροές υδροθερμικής προέλευσης και εκτεινόταν από την περιφέρεια ενός εκτεταμένου αλγοβακτηριακού τάπητα (2000 τετρ. μέτρα) προς τις παρυφές ενός λειμώνα του είδους *Cymodocea nodosa*. Η Διατομή C (TrC, 14 μέτρα βάθος) τοποθετήθηκε σε μια περιοχή χωρίς καμία ένδειξη υδροθερμικής δραστηριότητας. Ελήφθησαν δείγματα για τον προσδιορισμό του σωματιδιακού οργανικού άνθρακα, χλωροφύλλης α και φαιοχρωστικών, ATP του ιζήματος καθώς και της ποικιλότητας, αφθονίας και υγρής βιομάζας της βενθικής μακροπανίδας. Επίσης μετρήθηκαν *in situ* οι κάθετες θερμοκρασιακές διαβαθμίσεις μέσα στο ιζημα. Από τα αποτέλεσματα της μελέτης αυτής προκύπτουν τα εξής συμπεράσματα: 1. Το γαστερόποδο μαλάκιο *Cyclope neritea* αποτελεί το μοναδικό μακροπανιδικό οργανισμό που παρουσιάζει ανοχή στις υψηλές θερμοκρασίες και την τοξικότητα των υδροθερμικών αναβλύσεων στην περιοχή του αλγοβακτηριακού τάπητα. 2. Διακρίνεται μία συγκεκριμένη διαδοχή ειδών, με παρόμοιους οικολογικούς θώκους όμως, κατά μήκος της Διατομής Α, με επικράτηση θερμοανεκτικών και οπορτουνιστικών ειδών (*Microphthalmus aberrans*, *Capitella* sp. complex *Microspio mecznikowianus*), των οποίων η αφθονία μειώνεται προς τον αλγοβακτηριακό τάπητα. Τα είδη αυτά απουσίαζαν από τα δέγματα της Διατομής C. 3. Η θερμοκρασία αποτελεί τον κύριο περιοριστικό παράγοντα στην κατανομή και σύνθεση της βενθικής μακροπανίδας. 4. Ο οργανικός άνθρακας στις εντοπισμένες υδροθεμικές πηγές στον Κόλπο Παλαιοχωρίου φαίνεται πως προκύπτει από τη θερμική αποσύνθεση των φανερογάμων και από το πλέγμα των σχέσεων ανάμεσα σε χημειοσυνθετικά και φωτοσυνθετικά βακτήρια που εκμεταλλεύονται το σχηματισμό οξικών-ανοξικών διεπιφανειών κατά την εκροή των υδροθερμικών αναβλύσεων προς το περιβάλλον θαλασσινό νερό. 5. Η θερμοτοξική επίδραση του υδροθερμικού πεδίου στον Κόλπο Παλαιοχωρίου επί της βενθικής μακροπανίδας, είναι περιορισμένη και εντοπισμένη στις περιοχές των υγρών και αέριων εκροών.

INTRODUCTION

The only quantitative studies focused on the species composition and the structure of benthic macrofaunal communities around shallow hydrothermal vents have been carried out in the Kraternaya Bight in the Kurile Islands (Tarasov *et al.* 1990) and in the Bay of Plenty, New Zealand (Kamenev *et al.* 1993). In the Aegean Sea, descriptions of the biological communities associated with the hydrothermal fields around the Hellenic Volcanic Arc derived from preliminary surveys in Santorini and various sites around Milos (Dando *et. al*., 1994, Thiermann *et al,*. 1994) and in a volcanic sea area around the island of Nisyros (Diapoulis *et al.* 1994). Here are presented the effects of shallow gaseohydrothermal vents on the composition and distribution of benthic macrofauna in Paleohori Bay, Milos. This study was founded by EC in the frames of the MAST II program "Oxic-anoxic interfaces as productive sites".

MATERIAL AND METHODS

Paleohori Bay (24o31.00'E, 36o40.00'N) is a sandy bay approximately 1.4 km wide, at the south coast of Milos island. Hydrothermal brine fluids and gas seepages have been detected throughout the bay. These sites were identified during preliminary underwater surveys by the white algobacterial mats formed on the sediment surface in association with high sediment temperatures and elevated interstitial salt and sulphide concentrations hereafter called brine seep areas. In close proximity with the "white patches" occurred patches of the seagrass *Cymodocea nodosa* (UCRIA).

Sampling surveys were conducted in July and October, 1993 and in April, 1994 and focused at the periphery of an extensive "white patch" (2000m2) at 10 m depth, along a five meters long transect (Transect A or TrA). Within the bay, at 14 m depth and 150 m SEt of TrA, in an area without evident hydrothermal activity, Transect C or TrC (5 meters long),

was evaluated simultaneously. Samples were taken by SCUBA divers at 1 m intervals along Transects A and C. Permanent markers were deployed at the sites to enable the exact relocation of the sampling stations. Considering TrA, Stations 0 to 1 were located on the seagrass bed. Stations 2 to 3 were located on bare sand and Stations 4 to 5 were located in the " white patch". Along Transect C, Stations 0 to 1 were placed in the *Cymodocea* bed and the rest of the stations on light brown bare sand. Permanet markers were deployed to enable the exact relocation of the stations during the three sampling periods.

50 cm long probes were used for in situ measurements of vertical sediment temperature profiles at 5 cm intervals at all stations along both transects. Microscopic observations were made to selected sediment cores, immediately after sampling. Undisturbed 50 ml cut off syringe sediment cores were sampled to a depth of 6 cm for the estimation of the particulate content (POC, ATP, Chl a and Phaeopigments) of the sediment. The samples were sectioned at 2 cm intervals and stored frozen at -22^{o}C. Detailed description of the methods followed in the laboratory is given by Thiermann *et al*. (1996).

Five replicate macrofauna cores (9.4 cm internal diameter) were obtained from each station along Transects A and C. The samples were sieved through a 0.5 mm mesh, immediately fixed in 4% buffered formalin and stained with 1% rose Bengal. The animals retained were sorted into the major taxonomic groups (Polychaeta, Mollusca, Crustacea, Echinodermata and Miscellaneous) and transferred to 70% ethanol. The wet weight biomass of the major taxa was measured to the nearest 0.0001 g, after blotting the animals dry on filter paper. All the individuals were subsequently enumerated and identified to species level.

RESULTS-DISCUSSION

Along TrA a sediment temperature gradient was observed with increasing temperatures from the seagrass bed (Stration 0) towards the brine seep area (Station 5) and from the surface of the sediment towards deeper layers (30 cm sediment depth). Temperatures at the sediment surface ranged from 15.1 ^{0}C (Station 0, April) to 22.8 ^{0}C (Station 0, July) with ambient seawater values 14.5 and 23 ^{0}C, rerespectively. Temperatures at 30 cm sediment depth always exceeded 80 ^{0}C. Along TrC, the temperature recordings were always lower than any of those measured at TrA.

The estimation of the particulate material of the sediment provides indirect information about the availability of food resources. Organic carbon is recognised as becoming available to macrofauna after microbial activity (Fenchel, 1977). At the seagrass stations (Stations 0 and 1) along TrA, the *Cymodocea* leaves and roots may die and disintegrate quickly due to the elevated sediment temperatures. Heterotrophic bacteria respond at first as well as microalgae benefited from the release of nutrients. The seagrass decomposition process is reflected to the percentages of the chlorophyll degradation products (phaeopigments) which always exhibited more than 50 % of the total chloroplastic pigments level along TrA. In a distance of few meters from the seagrass bed, the majority of particulate matter is derived from the photosynthetic and chemolithotrophic organisms that comprise the algobacterial mat formed in the brine seep area. Thus, heterotrohic, photosynthetic and chemolithotrophic bacteria as well as decaying seagrass contribute to the organic stock along TrA. Particulate organic carbon values along TrA showed an enhancement towards Station 5 and did not exceed the level of 4648.235 μg/g (Station 5, section 0-2 cm, July). The POC content along TrA was approximately twice as high as along TrC during all sampling occasions while there was not monitored a temporal variation indicating a higher trophic input along TrA.

Mean ATP values, a measure of the microbial activity within the sediment, ranged from 6.61±3.67 ng/g (TrA, Station 5, section 4-6 cm, October) to a maximum of 3915 ng/g (g (TrA, Station 2, section 4-6 cm, July). Along TrA, ATP displayed a peak in the vicinity of the Stations 2 and 3 due to the enhanced microalgal and ciliate populations in the vicinity of these stations (van Gemerden, pers. com.) while there was not exhibited an ATP concentration gradient along TrC. Meyer-Reil (1987) also reported a strong decrease of proteolytic activity in anoxic sediments suggesting that the stored protein food may become available when the anoxic situation terminates. Thus, bacterial activity is expected to be more pronounced in oxic conditions -in surface sediment layers at the seagrass stations at TrA and along TrC- as well as along oxic - anoxic interfaces as those formed at the contact of the hydrothermal brine fluids with the ambient seawater.

The numbers of taxa observed along TrA ranged from 0 (Station 5, October) to 17 (Station 1, July). The numbers of individuals along TrA ranged from 0/100 cm^2 (Station 5, October) to a maximum of 90.5/100 cm^2 (Station 0, July) due to the large number of the hessionid polychaete *Microphthalmus aberrans* (66.3/100 cm^2) which dominated the infauna of the seagrass stations during all sampling periods. This species is considered as herbivore and it was found in association with the seagrass roots at around 10 cm depth within the sediment. Oligochaetes occurred in relatively large numbers at Station 1 in July and October (11.8 and 19.3 individuals per 100 cm2, respectively) while there were not present in April.

In general, there was a reduced inafunal abundance at the Stations 0 and 1 in April due to an extension of the hydrothermal brine seep towards Station 0. *Capitella* species complex together with the spionid polychaete *Microspio mecznikowianus* were the most dominant species at the Stations 2 and 3 during all sampling periods although occurring in no more than 5 individuals per 100 cm2 while they were present at almost all stations. They are both opportunistic species and they may share the niche related to trophic guild and thermotolerance. Small amphipods and tanaid species (*Perioculodes,Apseudes*) were also observed in extremely low abundances in the vicinity of the Stations 2 and 3. The nassariid gastropod *Cyclope neritea* was the only species found in the samples from the Stations 4 and 5. Cyclope neritea, a relatively large, highly mobile, thermotolerant and omnivorous animal, was the only macrofaunal species inhabiting the "white patch". Although *C.neritea.* did not have symbiotic gill bacteria neither any biochemical adaptation to hydrogen sulphide, it was quite tolerant to concentrations up to 1 mM (Southward *et. al.*, unpublished data). The only defence *C. neritea* possesses is its shell, which was commonly observed to be pitted and eroded, and a thick periostracum. No other peripheral systems of hydrogen sulphide exclusion, such as mucus formation or iron precipitation and other physiological defences as listed by Vismann (1991) have been observed. It may benefit from the meiofauna killed by the high temperatures and interstitial sulphide concentrations. 0.25 cm^2 quadrats were used for the quantitative measurement of its density in the "white patch" and revealed an average of 144 individuals per square meter. High numbers of this species occurred in Station 0 during April due to their movement towards the seagrass bed for spawning. In general the macrofauna along TrA consisted mainly of thermophilous opportunistic species. With the exception of Stations 4 and 5, the majority of the species belonged to Phylum Anellida. No specialised hydrothermal macrofauna was found around the hydrothermal vents in Paleohori Bay.

The numbers of taxa along TrC ranged from 49 (Stations 2 and 5, October) to 77 (Station 4, July). Abundance ranged from 30.6/100 cm^2 (Station 0 m, October) to 67.5/ 100 cm^2 (Station 4, July), where large numbers of the maldanid polychaete *Clymenura* sp. were observed (55.1/100 cm^2). There was not any evidence of succession in the composition of the fauna between the stations along this transect.. In July the most common species were the polychaetes *Aricidea cerrutii*, *Clymenura* sp., *Polycirrus* sp. and the tanaid *Apseudes latreilli mediterranea*. In October the most common species were the polychaetes *Peresiella sp.* and *Hyalinoecia bilineata*, together with the tanaid *Apseudes latreilli mediterranea*. In April polychaetes accounted for a smaller percentage of the fauna than during the previous two sampling periods due to the presence of enteropneusts that were found only during this occasion. In general much higher numbers of taxa and individuals were observed along TrC compared to TrA.

Wet weight biomass results did not indicate any clear trends along Transects A and C during any of the sampling periods due to the dissimilar animal sizes found at different stations. The biomass values at TrA ranged from 0/100 cm^2 (Station 5, October) to 0.1565 g/100 cm^2 (Station 3, October). At TrC it ranged from 0.0084 g/100 cm2 (Station 0, April) to 0.9643 g/100 cm2 (Station 4, October). The values from TrA were in general lower than those obtained at TrC. During April the wet weight biomass at several stations along Transect C was dominated by enteropneusts.

Although reduced numbers of taxa and individuals as well as wet biomass were observed in both transects in October samples in relation to the July and April ones, a paucity of information concerning the life histories of the species does not encourage any assumption for seasonality involved in these results. Besides, the extreme environmental conditions along Transect A induced by hydrothermalism and the generally high hydrodynamic regime of this shallow bay, appeared to contribute significantly to the spatial and temporal fluctuations of the fauna. However, given that macrofauna is not food limited at Transect A, high sediment temperatures and interstitial sulphide concentrations are the master ecological factors that limit the spatial distribution of macrofauna..

REFERENCES

Dando, P.R., Hughes, J.A. & Thiermann, F., 1994. Preliminary observations on biological communities at shallow hydrothermal vents in the Aegean Sea. In "*Hydrothermal Vents and Processes*" (ed. Dixon, J.R. & Parsons, L.M.), Special Publication, *The Journal of the Geological Society*.

Diapoulis, A., Koutssouris, T., Bogdanos, C., Fotis, G. & Bertahas, I., 1994. Distribution of benthic organisms in a volcanic sea area, Aegean Sea, Greece. *Fresenius Envir. Bull.*, **3**, 18-23.

Meyer-Reil. L. A. (1983). Benthic response to sedimentation events during autumn to spring at a shallow-water station in the Western Kiel Bight: II. Analyses of benthic bacterial populations. *Marine Biology*, 77: 247-256

Kamenev, G.M., Fadeev, V.I., Selin, N.I., Tarasov, V.G. & Malakhov, V.V., 1993. Composition and distribution of macro- and meiobenthos around sublittoral hydrothermal vents in the Bay of Plenty, New Zealand. *New Zealand Journal of Marine and Freshwater Research*, **27**, 407-418.

Tarasov, V.G., Propp, M.V., Propp, L.N., Zhirmunsky, A.V., Namsaraev, B.B., Gorlenko, V.M. & Starynin, D.A., 1990. Shallow-

water gaso-hydrothermal vents of Ushishir volcano and the ecosystems of Kraternaya Bight (The Kurile Islands). *P.S.Z.N.I.: Marine Ecology*, **11**, 1-27.
Thiermann, F., Windhoffer, R. & Giere, O., 1994. Selected meiofauna around shallow hydrothermal vents around Milos (Greece): ecological and structural aspects. *Vie et Mileu*, **44**, (**3-4**), 215-226.
Thiermann, F., Akoumianaki, I., Hughes, J.A. & Giere, O., 1996. The benthic fauna of the shallow gaseohydrothermal vents at Paleohori Bay, Milos (South Aegean). *Marine Biology, in press.*
Vismann, B., 1991. Sulfide tolerance: physiological mechanisms and ecological implications. *Ophelia*, **34**, 1-27.
Fenchel, T. 1977. Aspects of the decomposition of seagrasses. In C.P. McRoy, and C. HELFFERICH, (eds), Seagrass Ecosystems: A Scientific Perspective. Marcel Dekker, Inc. New York, p. 123-143.