

MORTALITY IN THE OCEAN - WITH LESSONS FROM HYDROTHERMAL VENTS OFF KUEISHAN TAO, NE-TAIWAN

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Key words: Plankton, mass mortality, hydrothermal vents.

ABSTRACT

There is evidence of plankton mortality and extinction at various temporal and spatial scales induced by man-made pollution, or by natural causes (ageing, competition, predation, diseases, natural pollution). If mortalities take place at large scale they might become of environmental concern and may impact other biotic compartments including fisheries substantially. Such mortalities are a consistent phenomenon at time scales from geological mass extinctions to regularly occurring HABs, that appear to be increasing on a global basis. Several mass mortalities might have escaped our notice for their patchy and erratic occurrences. This also holds for mortalities caused by hydrothermal vents (HVs) that cover possibly more than 1.5% of the ocean floor. We studied zooplankton diversity, abundance and distribution patterns above shallow water hydrothermal vents at Kueishan Tao (Turtle Island), off the northeast coast of Taiwan (West Pacific). The HVs at this site provide an opportunity for the study of mortality, community and population effects of HV effluents with ecophysiological investigations that are otherwise difficult to perform at the more common HV environment, the deep sea. We found evidence for a bottle-neck situation for plankton above vent sites since holoplankton was generally deadly affected when immersed directly in vent plumes. Here we used copepods from HV sites for ecotoxicological testing in mesocosm field experiments.

I. INTRODUCTION

The causes of episodic mortality events such as mass mortalities in the oceans remain poorly understood [5]. Predation, starvation, and diseases are traditionally assumed to be the most important biological causes of death. However, little attention

has been given to the identification of other sources of natural mortality [25]. Here we report on effluents of a shallow hydrothermal vent site that cause mass mortality of plankton. Hydrothermal vent (HV) sites provide a habitat for a number of organisms [20, 28, 51, 52] that show particular physiological and biochemical adaptations [12, 42]. Whereas those of benthic organisms at HV sites are better studied [27, 53], is plankton widely neglected as yet [22, 41].

Kueishan Tao (or Turtle Island) is a holocene volcanic island close at the NE Taiwan coast, with HVs that are located 60 miles from those of the Okinawa Trough [31]. The HVs of Kueishan Tao are located at a tectonic junction of the fault system extension of Taiwan and the southern rifting end of the Okinawa Trough [31, 54]. A cluster of more than 50 HVs, detectable by side scan sonar and echo sounder sensors, at water depths between 10 m and 80 m off the southeastern tip of Kueishan Tao, emits hydrothermal fluids and volcanic gases. The gases of a mantle source region without significant crust contamination show a similar composition of low temperature fumaroles worldwide, with high CO₂ and H₂S but low SO₂ and HCl contents [11, 55]. We know that plankton is deadly affected by the HV site [35]. How and to what extent HV effluents and gases affect the pelagic biota above HV sites, particularly the plankton [32, 33], has never been investigated.

In this study, we exposed planktonic copepods collected from the field in cages that were exposed to the effluents of HVs in the field and were compared with those exposed to unaffected waters off-shore as a control. This study aimed to estimate the extend of mortality events caused by toxic effluents from HVs in shallow waters.

II. MATERIAL AND METHODS

Planktonic assemblages used in field mesocosms were collected on the 13th August 2008 from surface waters about 1 km away to the south from the main vent area of Kueishan Tao (Fig. 1). The plankton comprised predominantly of copepods and was transferred into 5 L polyacryl bottles that had 20 cm² meshed (meshsize 100 µm) openings on opposite lateral sides (Fig. 2). Always 3 bottles were grouped and tied to ropes that were anchored at 1, 6, and 11m depth and exposed for 3 hours to the following situations: 1). off-shore outside the HV site and

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2). in the area of HV site A (see Fig. 1). Lethally affected copepods belonging to different taxa were recognized by their upwardly flexed abdomina.

Statistical analysis

Data of survivorship were assessed for normality with the Shapiro & Wilk Test [56]. Since none of the data met the normality assumption for parametric analysis, they were analyzed using non-parametric statistics [56]. Data are presented as the means \pm standard deviation (S.D.). All statistical analyses were conducted using SPSS version 12.0 (SPSS Inc., Michigan Avenue, Chicago, Illinois, USA).

III. RESULTS AND DISCUSSION

In the present study we explored the sensitivity of a given plankton assemblage taken from the field outside but adjacent to an area of HV activities and exposed to different depths outside the HV site and to HV effluents in cages in the field for 3 hours. The survivorship was significantly reduced next to the hydrothermal vent site compared to unaffected waters offshore within the short period of 3 hours tested (Fig. 3). At the vent site we found highest survivorship at midwaters (6m depth) of 4.5%, whereas it was lower at the bottom with 3.1% (11m depth) and lowest at the surface (1m depth) with 1.2%. Although the mortality endpoint was easy to measure (indicated by upwardly flexed abdomina) it might not be sufficient for a thorough ecological evaluation. The same holds for a systematic account that would have provided information about species-specific sensitivity and to what extent HV stress would have affected the biodiversity of plankton assemblages differentially. Entire plankton assemblages in field mesocosms have not been employed as yet for ecotoxicological testing, but several copepod species were used in marine ecotoxicity testing and biomonitoring since the 1960s [13, 44, 47]. A standardized, full life cycle bioassay with the estuarine copepod *A. tenuiremis* [2] has been used in several studies [1, 14, 50]. Sensitivity to pollutants also depends on the type of organisms and the stage of development used [10]. His et al. [29] conducted a comprehensive review of the assessment of marine pollution using bivalve embryos and larvae as testing organisms. Copepods have many attributes [8, 16, 17, 18] that make them an attractive group of organisms for toxicity testing of marine as well as freshwater chemical pollutants [3, 26, 47]. These include their small size, rapid reproduction, and cultivability as well as their remarkable biodiversity in benthic as well as pelagic environments. There is a need to develop and standardize toxicity tests for meeting the regional environmental and regulatory requirements. Four species of marine copepods, namely, the planktonic calanoid *Acartia tonsa* (the genus *Acartia* was also present at our experimental HV site at Kueishan Tao) and the three harpacticoids, *Nitocra spinipes*, *Tisbe battagliai*, and *Amphiascus tenuiremis* have been identified as potential model species for EDCs [37]. DiPinto and co workers [21] studied lethal and sublethal effects of sediment associated PCB Aroclor 1254 on a meiobenthic copepod. In a recent overview, the

OECD has highlighted *Tigriopus japonicus* as another species for toxicity testing risk assessment of EDCs [44].

Toxicity results of chemicals are significantly affected by environmental variables [40, 45, 46]. Toxicities of certain chemicals have been reported to be affected by these variables [39]. For instance, Kwok and Leung [38] observed that toxicities of Cu and TBT are significantly increased in *T. japonicus* when culture temperature was increased by 10°C. At higher temperatures, animals can also undergo dormancy [19]. Therefore, environmental variables and confounding factors have to be considered in the laboratory as well as in field-based bioassays.

Naturally occurring chemical stressors such as HV effluents have not been a research object for testing as yet. This is likely so since their impact on human and environmental health has not been questioned. There is a need, however, in basic and applied ecology to develop new methods and test new model species for such purpose [36]. Concerted efforts should be made to develop and standardize for both, acute and chronic tests for the evaluation of the impacts of environmental pollutants, also if they are naturally occurring and not fostered by man [7].

- Mass mortalities in geological times

Mass mortalities occurred throughout the history of the earth. Hsü et al. [30] postulate catastrophic geologically instantaneous mass mortalities near the end of the Cretaceous, and much reduced productivity to cause immediate changes of the pH of oceanic surface waters. The more acidic surface waters caused a catastrophic rise of CCD, which led to a widespread deposition of clays at the C-T boundary. A reduction of productivity in the oceans led to an increase of CO₂ in the atmosphere, and a greenhouse effect resulted in a temperature increase in ocean waters. Hsü et al. [30] postulate that such catastrophic environmental changes at the beginning of the Tertiary were the consequences of mass mortalities in the oceans, not their causes. The assumed cause was the impact of a large meteorite.

Berner [4] assumed that mass mortality at the Permian-Triassic boundary would also have affected marine plankton. The killing of marine plankton would stop the “biological pump” whereby photosynthetically fixed and isotopically light carbon was transferred to the deep ocean by settling of dead plankton and its oxidation back to CO₂ in deep waters. This situation has been referred to as a “strangelove” ocean. The drop in $\delta^{13}\text{C}$ of dissolved inorganic carbon in oceanic surface waters as a result of oceanic overturn following cessation of the biological pump has been shown to be about 1–1.5‰ by D'Hondt et al. [15] for the Cretaceous–Tertiary mass extinction. Also, cessation of the present-day biological pump has been shown by Sarmiento and Orr [48] to result, after exchange with the atmosphere, in a rise in atmospheric CO₂ from 280 ppm to about 500 ppm.

- Diseases

There are various causes of diseases that in turn are responsible for mass mortalities. Viruses are evidently the most

abundant entities in the sea and the question may arise whether they are widespread regulators of oceanic populations. However, there is very little known about marine viruses and their role in aquatic ecosystems and the species that they infect (for a review, see [23]). There is some evidence that viral infection might accelerate the termination of phytoplankton blooms [24, 34]. Viruses are held responsible for the collapse of *Emiliania huxleyi* blooms in mesocosms [6] and in the North Sea [9] and are shown to induce lysis of *Chrysochromulina* [49]. Because most viruses are strain-specific, they can increase the genetic diversity of their hosts [43].

Dense aggregations of plankton organisms may increase the transmission of disease causing agents. Gómez-Gutiérrez et al. [25] postulated that dense euphausiid aggregations may increase the transmission of parasitoids after an infected animal bursts and sinks through the aggregation, distributing infective stages. This phenomenon may lead to large-scale euphausiid mortalities as have been observed by these authors at the base of Astoria Canyon, Oregon, where they discovered high densities of dead *Euphausia pacifica* on the ocean floor between 550 and 220 m depth. Parasitoids may also modify the behaviour of the infected members of the prey population.

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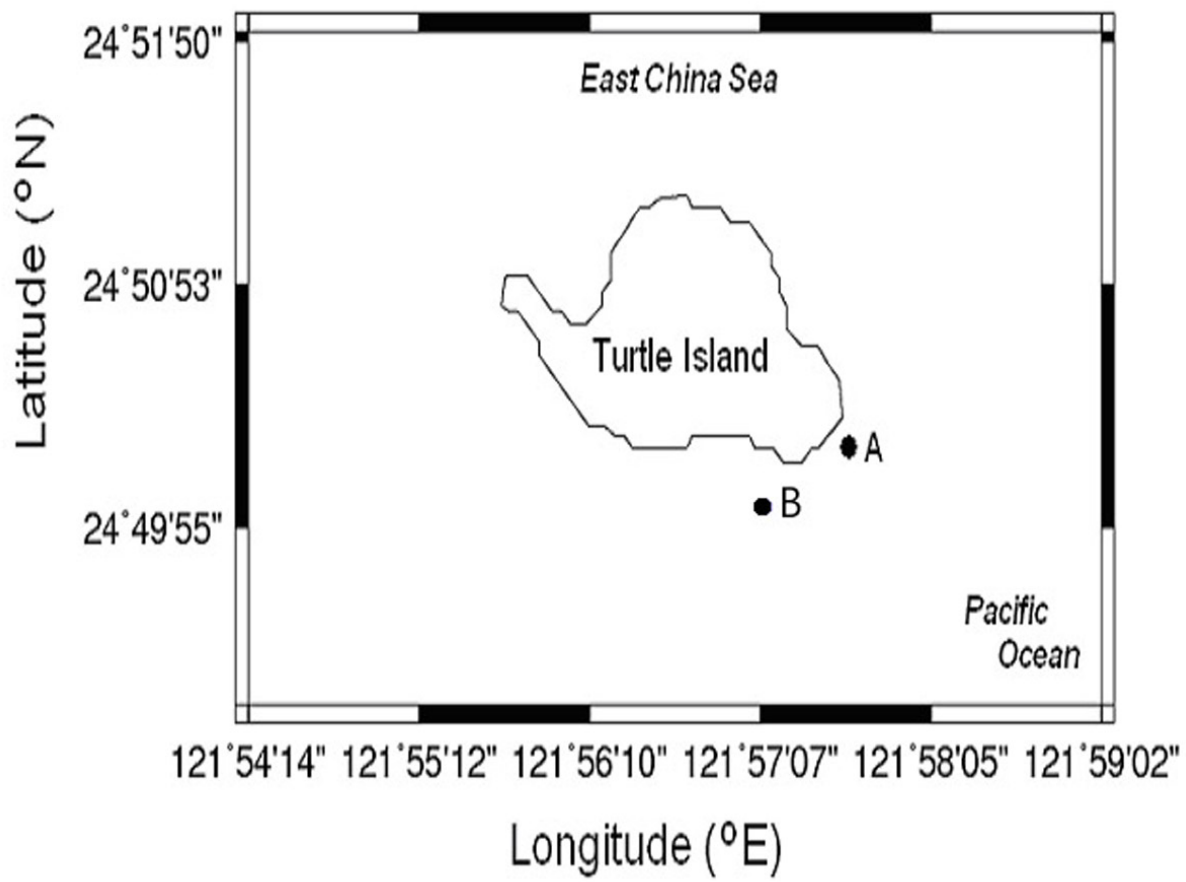


Fig. 1. Experimental hydrothermal vent side "A" at Kueishan Tao.

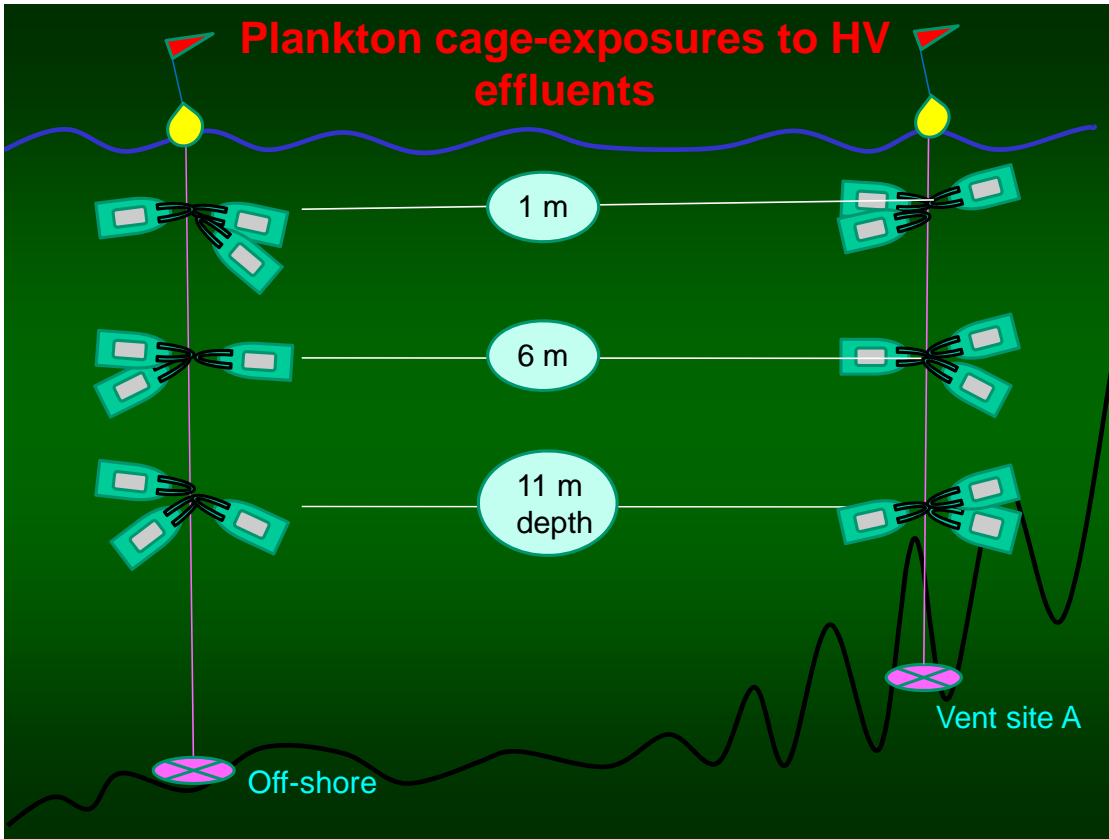


Fig. 2. Experimental set-up of exposure-cages in the field.

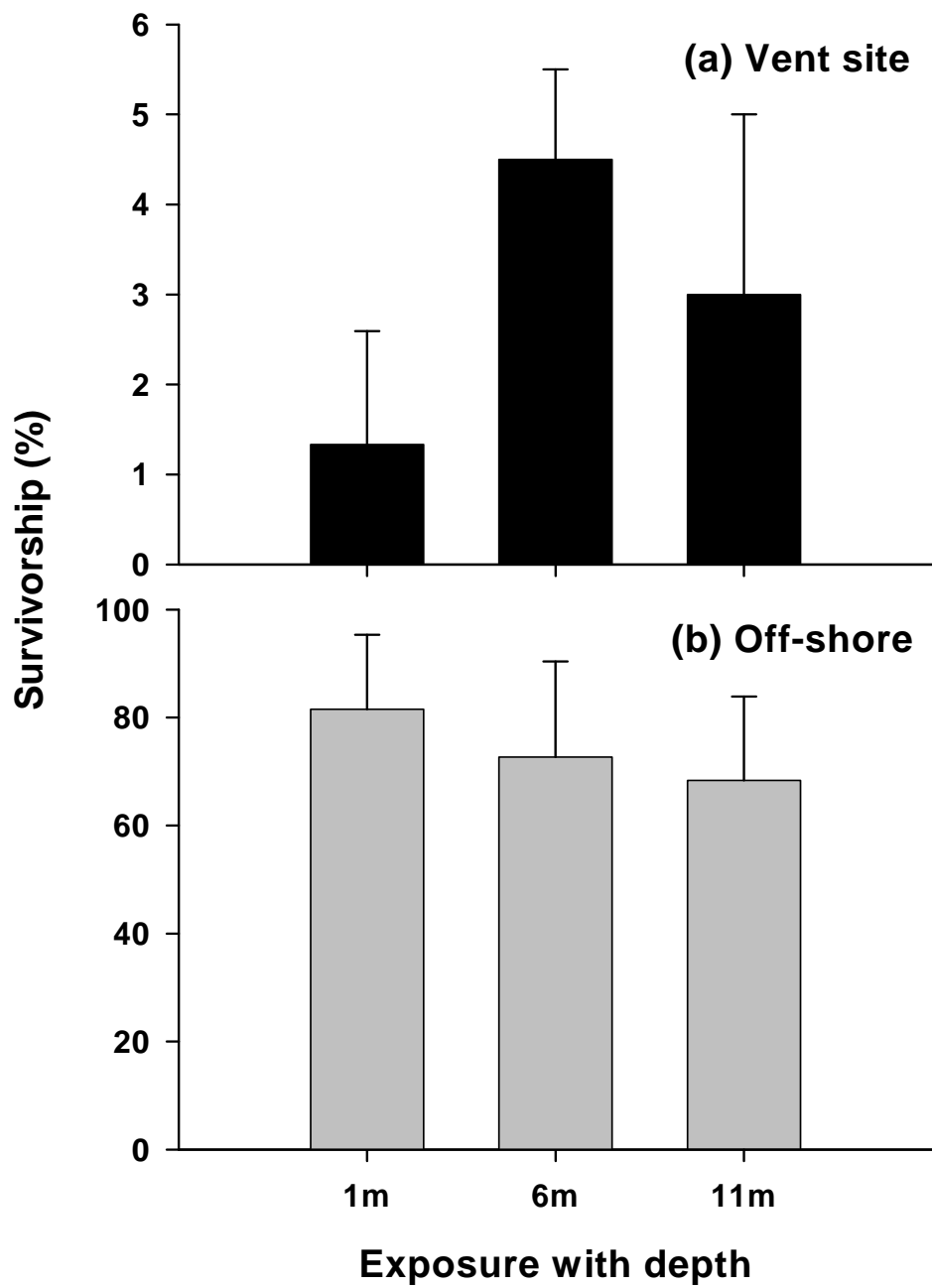


Fig. 3. Survivorship percentage of planktonic copepods caged at different depths above a hydrothermal vent site and in unaffected waters offshore.