

Hydrothermal vent crabs feast on sea 'snow'

The riddle is solved of how vast crab populations can thrive in an extreme, toxic habitat.

The crab *Xenograpsus testudinatus* lives at enormously high densities around the sulphur-rich hydrothermal vents found in shallow waters off Taiwan, even though this acidic environment is low in nutrients. Here we show that these crabs swarm out of their crevices at slack water and feed on the vast numbers of zooplankton that are killed by the vents' sulphurous plumes, and that rain down like marine 'snow'. This opportunistic feeding behaviour explains how the crabs are able to survive in the adverse toxic environment of these shallow hydrothermal vents.

Investigation into the ecology of animals living in deep-water hydrothermal vents has been extensive^{1,2}, but much less is known about those living in shallow-water systems (at depths of less than 200 m)²⁻⁵. Compared with the species-rich communities associated with deep-water vents^{1,2}, shallow-water vents are low in animal diversity and their ecosystems are simple — only two species of brachyuran crab, *X. novaeinsularis* and *X. testudinatus*, have been identified so far⁵⁻⁸.

The shallow-water vents off Kueishan Island (121° 57' E, 24° 50' N; Fig. 1, and see supplementary information) in northeastern Taiwan are part of the Okinawa Arc⁹. In this unusual system, the vent discharges are highly acidic (pH 1.75–4.60) and sulphur-rich¹⁰ — with up to nine large smokers (2–6 m in height) at any one time spewing sulphurous plumes and bubbles of gas (mainly carbon dioxide, nitrogen, oxygen, sulphur dioxide and hydrogen sulphide), which emerge at temperatures of 65–116 °C.

High sulphide concentrations are normally important for the establishment of a chemolithotrophic food-web^{1,2} and the growth of sulphur-dependent bacterial mats¹¹. However, these food sources are not present in Kueishan, where the shallow-water vent discharges contain high concentrations of elemental sulphur (99.5% purity)¹⁰ and toxic volcanic gases (see supplementary information), so it is not surprising that the habitat is species-poor.

Almost nothing is known about the ecology of *Xenograpsus* crabs. The species *X. novaeinsularis* has been observed feeding on the ocean floor using its setae-tipped pincers⁷ but its diet is not known. At Kueishan, *X. testudinatus* congregates in large numbers in vent crevices^{6,8} (at an average density of 364 crabs per square metre; Fig. 2a, and see supplementary information), and the question arises as to how this ecosystem can



Figure 1 Kueishan Island. Sulphur particles are seen on the sea surface as a whitish area; the density of these particles varies with the number of chimneys under the sea and the prevailing wave and current conditions.

support such a substantial crab population. What are the crabs feeding on?

Our observations of the crabs at Kueishan show that *X. testudinatus* is feeding on zooplankton. During slack water, thousands of *Xenograpsus* crabs swarm out of the sulphur-rich crevices (Fig. 2b, and see movie in supplementary information) and begin to feed frantically on the sea floor over an area of a few square metres. This previously undescribed swarming behaviour is seen only during such slack-water periods. Dissection of *Xenograpsus* specimens revealed that their guts were full of zooplankton (mainly pelagic copepods). Studies of the mouthparts and

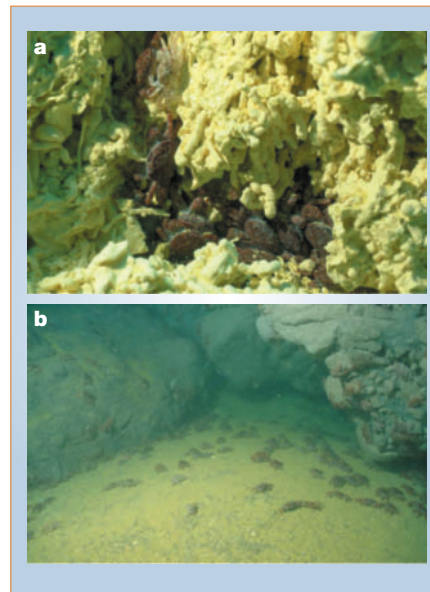


Figure 2 Crab feeding behaviour at shallow hydrothermal vents on the eastern side of Kueishan Island. **a**, Dense groups of *Xenograpsus* crabs in the crevices of sulphur-rich rubble at the base of a chimney. **b**, During a slack tide, the crabs swarm out to feed on the 'snowfall' of dead zooplankton that have been killed by toxic gases and sulphur particles, which billow from the vent.

gastric mill of *Xenograpsus* confirm that it is a scavenger¹².

During optimal conditions, we witnessed a gradual precipitation of fine particulate matter and dead fish during slack water around the vents. Analysis of water samples collected at this time revealed a high concentration of inorganic particles and dead or narcotized zooplankton. During slack water, when currents are weak or absent, the vent plumes are directed vertically, instantly killing any organism in their path¹³ and causing it to drop straight down the water column. The mass of descending zooplankton has the appearance of falling snow.

As soon as the currents increase again and the deadly plume veers away, the bombardment by dead zooplankton ceases and the crabs return to their crevices. As tides in Taiwan are semidiurnal, crab feeding runs probably take place twice daily (although we have not confirmed this because diving at night is too dangerous).

The crabs time their foraging to coincide with these marine snowfalls in order to maximize their efficiency in harvesting the plankton kill. This opportunistic feeding behaviour by *Xenograpsus* crabs, which to our knowledge has not been seen in any other hydrothermal organism, represents a remarkable adaptation to their nutrient-poor environment.

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