

Sponges in cavities of tropical coral reefs form major sink of dissolved organic carbon

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Large amounts of dissolved organic carbon (DOC) disappear in coral cavities, at rates equalling the primary production of tropical reefs. The dominant consumers are encrusting sponges, which cover 25% of the total surface in cavities but account for 75% of the organic matter removal. Three sponge species were studied in detail that live in association with microbes. Speculations about the role of these microbes in DOC uptake have been going on for decades. By tracing ^{13}C -enriched algal derived DOC in specific fatty acids it was shown that the microbes as well as the cells of the sponge *Halisarca caerulea* assimilate DOC. The high DOC consumption by sponges concurred with a surprisingly fast sponge cell turnover. This emphasizes the important role of cavity sponges in the processing and transformation of organic matter on coral reefs.

The research focussed on organic matter cycling in cavities in coral reefs of Curaçao (Netherlands Antilles). Flux studies revealed that coral cavities are quantitatively important net sinks of dissolved organic carbon (DOC). More than 90% of total organic carbon disappearing in coral cavities and cryptic habitats comprise of DOC. The total organic carbon removed daily in coral cavities amounted to $342 \text{ mmol C}\cdot\text{m}^{-2}$ cryptic surface in Curaçao. The areal surface of the cavities usually exceeds the open reef surface. The cryptic surface in a coral reef may comprise up to 8 m^2 per square metre planar reef and is often the largest habitat in reefs. This implicates that the organic matter fluxes into cavities may even be up to 8 times higher than $342 \text{ mmol C}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$, equalling the primary production on coral reefs which amount up to $2250 \text{ mmol}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$ (Hatcher 1997). Therefore coral cavities play a key role in processing organic matter on reefs. Considerable parts of the inner walls of coral cavities are covered with a thin veneer of sponges. The DOC and bacterioplankton removal by these sponges within the cavities was compared with the removal by organisms living in or on other dominant surface components as 'bare rock' and the sandy sediments on the bottom of the caves. We selected 3 species of coral cavity sponges notably the 2.5 mm thick encrusting sponges *Halisarca caerulea*, *Mycalce microsigmata* and *Merlia normani* for experiments. The sponges, considered representatives for the sponge commu-



A typical coral cavity with a sandy bottom under live coral overhangs (volume of ca 80 L)

nity in cavities, removed $840\text{--}1080 \text{ mmol carbon}\cdot\text{m}^{-2}$ sponge surface $\cdot\text{d}^{-1}$ in incubation chambers. After closure of incubation chambers with sponge the DOC concentration in the water (average $125 \mu\text{M}$) dropped by 13-20% within 10 minutes (Fig. 1). Cavity sponges are apparently important consumers of DOC comprising 95% of their diet. Up to 75% of the organic carbon removed in coral cavities in Curaçao is estimated to be removed by sponges, despite the fact that encrusting sponges cover only 25% on average of the total surface area in coral cavities (walls and sandy bottom). The organic matter consumption by the

sediments amounted to only 18% of the total removal of organic carbon by cavities. It is obvious that in coral cavities, the encrusting sponges consume the largest amounts of organic matter, with DOC as their bulk food.

The different sponge species taken from coral cavities harbored high concentrations of microbial cells, with densities in excess of 109 per ml of sponge tissue. The role of these sponge associated microbes is still unclear. It has been speculated for decades that they play a role in DOC con-

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DOC removal by sponges

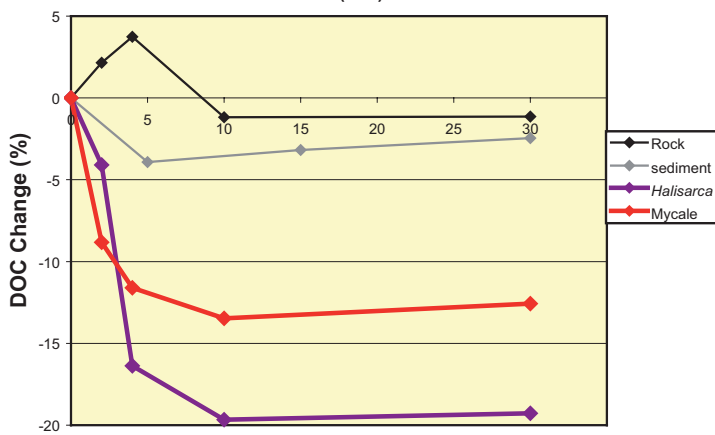


Fig. 1. The encrusting sponge *Halisarca caerulea* under a coral overhang. Note the star-like outflow openings of the sponge (oscula). Size of the sponge ca 10cm diameter.

sumption by the sponge holobiont, but proof failed as yet. In incubation experiments with ^{13}C -enriched organic matter substrates we investigated whether the sponge or its associated microorganisms are responsible for the DOC removal. ^{13}C -enriched glucose, diatom derived DOC, diatom derived particulate organic carbon (POC) and bacterioplankton respectively were added to the sponge *H. caerulea* and the fate of this material was traced in specific bacterial and sponge biomarkers. The ^{13}C enriched-glucose was marginally incorporated in sponge associated bacteria and mainly respired. The ^{13}C -DOC was rapidly (within 1h) incorporated in the sponge associated microbes as well as in the sponge evidencing for the first time that also sponge cells directly assimilate DOC. As biomarker for the sponge phytanic acid was used, a fatty acid, which cannot be synthesized by bacteria nor occurred in the diatom derived food. Certain sponges can synthesize phytanic acid from degradation products of chloro-

phyll. Particulate diatom derived food and bacterioplankton were, as expected, mainly processed by the sponge host. *H. caerulea* consistently respired ca 40% and assimilated ca 60% of the consumed organic matter. The high assimilation rate was surprising considering the relatively low biomass increase and reproductive effort.



Relative changes in dissolved organic matter concentrations in closed incubation chambers of 1.7 L with encrusting cavity sponges *Halisarca caerulea*, *Mycale microsigmatosa*, sediment on the bottom of the cavity and microbiota on bare rock in the cavity respectively.

To investigate the fate of assimilated carbon, the sponge *H. caerulea* was incubated with bromodeoxyuridine (BrdU). BrdU is incorporated in newly synthesized DNA strands during the cell division, so BrdU positive cells are actually dividing cells. Their numerical increase in time allows assessment of the proliferation of sponge cells and the duration of the cell cycle. Results showed that choanocyte cells that line the chambers of the sponge where the food is taken up, turn over rapidly, i.e. every 5-6 hour. Histological preparations of sections through the sponge revealed that "old" choanocyte cells may be shed and are removed via the aquiferous canal system of the sponge. This study on the ecophysiology of the cavity dwelling sponge *H. caerulea* contributed to our insight of the processes of organic matter cycling in sponges and to our understanding of the carbon mass balance in coral cavities.

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