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Rapid de novo assembly of animal-microbe biofilter following seabed methane leakage

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Globally, vast amounts of methane are trapped within subseafloor gas hydrates. Recent evidence suggests that climate- and human-induced perturbations can destabilize gas hydrates and trigger methane release, yet the response of deep-sea ecosystems to these changes remains poorly understood. Here, through multi-year, high-resolution *in situ* monitoring of a hydrate-bearing seabed, we show rapid *de novo* establishment of a seep ecosystem following anthropogenic methane leakage. Within just two years, benthic microbial and eukaryotic diversity in the affected areas declined by >50%, alongside the swift assembly of an efficient “methane biofilter” community. Integrated geochemical and biological analyses reveal an unexpectedly parallel proliferation of aerobic methanotrophs (*Methyloprofundus*), anaerobic methanotrophs (ANME-2e, ANME-3), and opportunistic polychaetes that extensively bioturbated the seabed to >50 cm depths. Active animal-microbe interactions in this intensely mixed zone, together with the microbial sulfate reduction zone underneath, jointly sustained exceptionally high rates of methane oxidation (30-60 $mmol/m^2/day$) through coupled carbon, nitrogen, and sulfur cycling. We demonstrate that gas hydrate destabilization can trigger rapid collapse of seabed biodiversity while driving the formation of an intricate animal-microbe biofilter consuming the potent greenhouse gas methane much faster than previously estimated. These findings provide critical insights for predicting benthic ecosystem response and feedback under ongoing global change and for developing sustainable strategies for methane hydrate resource management.