Ocean and Climate Change Institute
2009 ARI Project Final Report

"Identification of riverine and indigenous permafrost microbiota (eukarya, archaea, bacteria) involved in the (an)aerobic degradation of ancient organic matter stored in thawing permafrost"

Marco Coolen, Marine Chemistry and Geochemistry

What were the primary questions you were trying to address with this research? (Or, if more appropriate, was there a hypothesis or theory that you were trying to prove or disprove?)

(1) To what extent does ancient permafrost (which is prone to thaw as a result of global warming) provide degradable organic matter (OM) to promote growth of the indigenous soil microbiatau?

(2) Are Arctic river microbes able to degrade the ancient OM stored in permafrost when thawing permafrost is released to the Arctic rivers by leaching or erosion as a result of global warming?

What have you discovered or learned that you didn't know before you started this work?

The combined exoenzyme assays (EEA) and molecular survey suggest that Holocene Alaskan permafrost underlying moist acidic tundra contains labile as well as recalcitrant soil OM that can be readily decomposed by the indigenous microbial communities in the event of future permafrost thaw. The quality of the soil OM seemed to play a significant role in shaping microbial communities since the viable bacterial and eukaryotic community structure and the EEA greatly differed between the active layer, the organic-rich upper permafrost table, and deeper, up to 4100-year-old permafrost soils with lower carbon content.

What is the significance of your findings for others working in this field of inquiry and for the broader scientific community?

SOM decomposition and mineralization rates will most likely vary among permafrost collected from various Arctic locations since many factors including vegetation cover and origin of permafrost material could influence soil chemistry, physiology and biology. Therefore, more time-series thaw incubation experiments under both aerobic and anaerobic conditions combined with detailed physical, geochemical and biological characterization of Arctic soils are required to ultimately reach a global picture on the extent to which global warming will contribute to permafrost SOM decomposition and the release of greenhouse gasses through microbial respiration.

What is the significance of this research for society?

Permafrost soils harbor twice as much carbon in the form of peat than is currently present in the form of atmospheric carbon dioxide (CO_2). This carbon is currently fixed under frozen conditions, but the results of this study imply that in the event of global warming-induced

permafrost thaw, permafrost microbes are quickly reactivated and they immediately start to decompose the millennia-old OM. Further microbial respiration of the soil OM could release gigantic amounts of the greenhouse gas CO_2 to the atmosphere. These processes will then accelerate global warming, which affects all mankind.

What were the most unusual or unexpected results and opportunities in this investigation?

Most unusual is that I noticed a response in microbial activities within hours upon thaw and it was a wonderful experience of doing research in the Arctic.

What were the greatest challenges and difficulties?

I was unable to shed new light on the second research question outlined above since field incubations of riverine water with freshly thawed permafrost soil were unsuccessful. The riverine microbes appeared to be inhibited as a result of "overexposure" to the OM stemming from the permafrost soils.

When and where was this investigation conducted? (For instance, did you conduct new field research, or was this a new analysis of existing data?)

The research was conducted at the LTER Toolik Field Station, Northern Alaska. I conducted a relatively new research field with limited pre existing data.

What were the key tools or instruments you used to conduct this research?

Microbial exoezyme assays using fluorescent substrate analogs to determine the rate in which permafrost microbes were capable to decompose plant-derived soil litter (cellulose), proteins, and organic-bound phosphates. Microbes that were activated upon permafrost thaw during the two week time series incubation experiment at 4 °C were identified using molecular phylogenetic tools.

What are your next steps?

We (Spivak, Coolen, Galy, and Wang) recently submitted a proposal to NSF OPP to sample surface sediment and water samples along environmental gradients of the Mackenzie Delta. The main goal of the proposal is to predict how future changes in organic carbon export from terrestrial landscapes may affect aquatic carbon pools and processes, using a space-for-time substitution design by comparing river systems situated in watersheds with different permafrost extents.

Have you published findings or web pages related to this research? Please provide a citation, reprint, and web link (when available).

Coolen, M. J. L., van de Giessen, J., Zhu, E. Y., and Wuchter, C., 2011. Bioavailability of soil organic matter and microbial community dynamics upon permafrost thaw. *Environmental Microbiology* **13**, 2299-2314.