Microbial Survival in The McMurdo Dry Valleys of Antarctica: Ecological Strategies and Biodiversity in Extreme Environments

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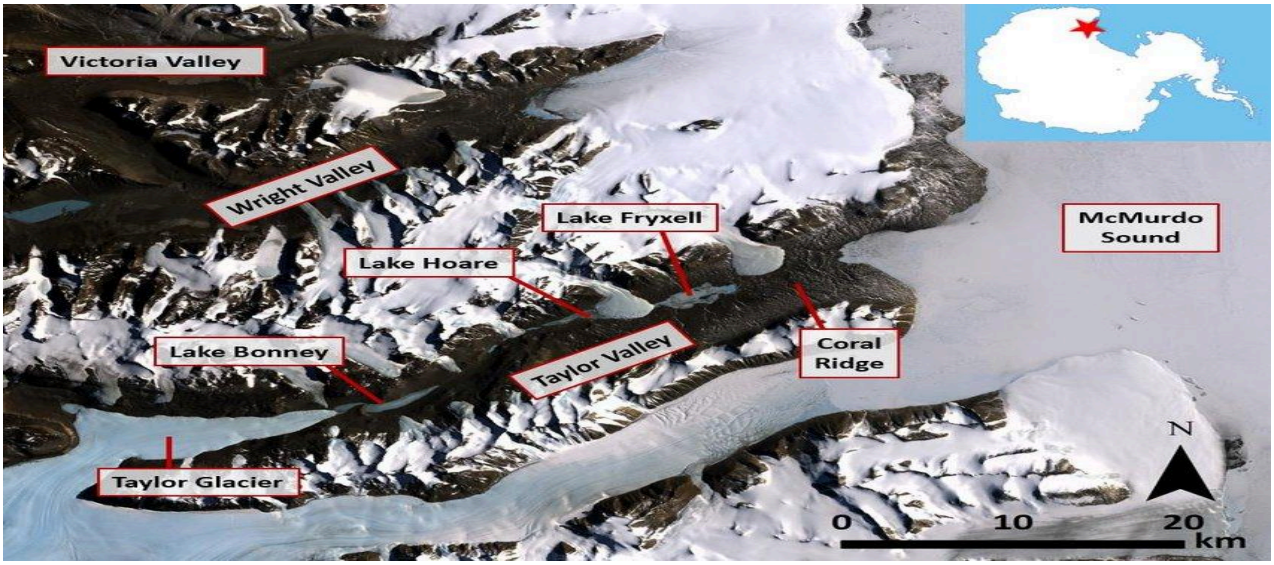
The Dry Valleys of Antarctica are one of the most extreme but unique environments on Earth. The Dry Valleys are located within the Transantarctic Mountains and are called the Dry Valleys because they are largely free of snow and ice, unlike the rest of Antarctica. Which is why these valleys are so unique because only about “0.3% of Antarctica is perpetually ice free”, and primarily “the largest single area being the McMurdo Dry Valleys”(S.C. Cary et al.,2010). The Dry Valleys are also known for being considered as a polar desert because of the extremely low humidity, frigid temperatures, and for the very little precipitation they receive. The extreme weather conditions in the Dry Valley also include harsh winds, rocky terrain, and frozen lakes. These harsh weather conditions are why the Dry Valleys are characterized as a barren landscape. However, even with these harsh weather conditions, the Dry Valleys are still the home to specially adapted microbial life. Some of the microbial life that can be found in the McMurdo Dry Valleys includes Bacteria like Phyla, which are most commonly found, and Actinobacteria, which are found in dry or cold soils. There are also Bacteroidetes that are normally found in wetter soils and Proteobacteria that are found near glacial melt areas. The bacteria Chloroflexi are found in low-nutrient soil, and Cyanobacteria are found mainly under rocks. Another type of microbe found in the Dry Valleys is Archaea, which is less common than bacteria. However, Archaea are still present, especially Euryarchaeota and Crenarchaeota, which are found in extremely low-nutrient soils. Fungi are another microbial community that is found in the Dry Valley. Mainly, only Ascomycota and Basidiomycota are found, and these play a role in organic matter and decomposition. In the Dry Valley, algae are able to be found in microbial mats and endolithic communities. Lastly, viruses, which are typically found infecting bacteria and archaea, can be found in this environment. Also, specialized Microbial communities like hypoliths, usually found under translucent rocks, endoliths found inside rock pores, and soil crust communities, which are a thin surface layer with a mixed microbial population, can all be found in the McMurdo Dry Valleys. Since there is a large and diverse group of microbial life, it has become the reason why the Dry Valleys are a very important site for scientific research on the limits of life and are often compared to possible life in extraterrestrial environments, like Mars.

For this reason, there is a station called McMurdo Station that is located on the tip of McMurdo Sound, which is a frozen body of water in Antarctica that is located at the south end of the Ross Sea. This Station lies close to a few major research sites like McMurdo Dry Valleys, Mount Erebus, and the Transantarctic Mountains. This station was originally a military base when it was established in 1956 during Operation Deep Freeze by the U.S Navy. However, becuase of its location, it now supports a wide range of Antarctic research, like Glaciology, Astrobiology, Geophysics, and Biology, like the Microbial life in extreme environments like the Dry Valleys. For example, in the past, there have been studies like “On the Rocks: The Microbiology of Antarctic Dry Valley Soils” in 2010 by Craig Cary. This study shows the resilience and ecological significance of microbial communities in the McMurdo Dry Valleys.

The Dry Valleys spanned approximately 4,800 square kilometers. The Dry Valleys get less than 100 mm of precipitation per year, which is most of the time being snow. Also, these valleys receive katabatic winds that exceed speeds of 100 km/h, which causes these valleys to remain constantly dry. The Dry Valleys experience heat waves that reach temperatures of more than 70°F. Which is the hottest area compared to the other parts in Antarctica, which are typically extremely cold. However, not only do the Dry Valleys get the hottest temperatures in Antarctica, but they also reach the coldest temperatures, getting to about -4°F. Also, the McMurdo Dry Valleys experience intense ultraviolet radiation, especially during their summer months. Which is because of the combination of the thin ozone layer in Antarctica and because of the high albedo effect from the ice and the snow surfaces in the Dry Valleys. Due to the drastic weather changes in the Dry Valley it has affected the soil tremendously. The heat waves are caused by an intense atmospheric storm system that transports moisture and warm air over long distances to the polar region. During the heatwaves, this sudden influx of heat causes the glaciers and snow to melt. Which then causes the valley’s soils to become wetter than the soil would be for most typical summer thaws. Where the land and soil would be mostly dry and have no moisture. However, after the heatwave, temperatures will plummet rapidly, which will then cause the soil to refreeze. This quick transition disrupts the life cycles of many organisms and leads to a significant mortality among plants, insects, and animals. The Dry Valley is very poor in nutrients, causing there to be little to no life. While there are no plants, insects, or animals in the Dry Valleys, there are microbes that have adapted and can survive in these harsh conditions. The Dry Valleys’ harsh weather conditions, poor nutrients, and exposure to intense UV radiation are

the main reasons why microbes are studied there. Microbes' survival in the Dry Valleys helps scientists monitor climate change impacts, understand the limits of life, and explore how life might exist on other planets like Mars.

Additionally, there has been a plethora of research that has been done in the Dry Valleys on microbial ecology. One example is the research done by S.C. Cary, I.R. McDonald, J.E. Barrett, and D.A. Cowan. Craig Cary and Ian R. McDonald both worked at the University of Waikato in the Department of Biological Sciences. The other researcher in this study, John E. Barrett, worked at Virginia Polytechnic Institute and State University for the Department of Biological Sciences. As well as Don A. Cowan worked at the University of the Western Cape, South Africa, for the Institute for Microbial Biotechnology. This study was published in 2010 by *Nature Reviews Microbiology* and was titled " On the Rocks: The Microbiology of Antarctic Dry Valley Soils". This research conducted a comprehensive examination of the microbial life that is in the McMurdo Dry Valleys. This study focused on various valleys within the McMurdo Dry Valleys, including Taylor Valley, Wright Valley, Victoria Valley, and among some others.



This picture shows an overview map of the McMurdo Dry Valleys. Highlighting some of the main areas where research is primarily conducted. As well as where McMurdo Sound is located and where the McMurdo Station is located in the Dry Valleys.

In this research, with Carig Cary and his co-authors, they used a few different research methods. The first one is that they used modern molecular techniques that have not been utilized

in any other research before. They used a 16S rRNA gene sequencing to identify and classify the different bacteria and archaea that were present in the soil. They also used a Denaturing Gradient Gel Electrophoresis, which was used to analyze microbial community structures based on the DNA sequence variation. They also utilized Metagenomics, which showed as a future direction, and sometimes to examine the entire genetic content of the environment. The last molecular and genomic technique they used was Polymerase Chain Reaction, which was used to amplify microbial DNA from the sample soil to study the genes related to phylogeny and function. This research also utilized culture-based methods. They specifically used culturing on low-nutrient media to isolate psychrophilic microorganisms under lab conditions. In this research, they also did a lot of analysis on the soil at the McMurdo Dry Valleys. They did a nutrient and pH analysis, as well as moisture content measurement, and did temperature logging. To observe the microbial cells, structures, and biofilms in situ, they used light and electron microscopy. Ecological sampling was also utilized in this research, including microhabitat comparisons like soil depth, endolithic, and hypolithic, to be able to compare microbial diversity across these environments. While this research's primary focus was on the McMurdo Dry Valleys of Antarctica soil, they did have other sites where they were testing the soil so that they would be able to compare the data from the different environments. The other soils that they tested were Antarctic Peninsula soils, hot desert soils, and temperate surface soils. Lastly, they used statistical and ecological modeling, more specifically multivariate statistics like ordination and clustering, to correlate the environmental factors with microbial diversity. This research utilized these different tools and methods to find valuable insight into Microbial ecology and biodiversity.

This study had some crucial findings that help advance our knowledge of microbial ecology and biodiversity. The finding that Craig Cary and his co-author had pioneered and transformed our understanding of microbial life in Antarctica's McMurdo Dry Valleys. Some of their key findings were that before this research, there was an assumption that the McMurdo Dry Valleys' soil had minimal microbial life. However, in this research, it highlights that because of modern molecular techniques like the 16S rRNA gene sequencing and metagenomics that we have now was able to revealed a rich diversity of microbial groups. That in which many are uncultured and unique to the Dry Valley environment.

Another key contribution this research made to microbial ecology and biodiversity was that it found and emphasized that abiotic factors are the main forces structuring microbial communities. They found that the microbial diversity and activity heavily correlated with the water availability and the soil moisture. Therefore, in the areas near the glacial melt or snow patches, the communities are much more active and even sometimes more diverse. They also found that in the drier soil, there were fewer microbes and they were more dormant, and the community structures shifted to a desiccation-tolerant state. They also found that the soil salinity plays a role in that if there are high salt concentrations, which were common in the older or evaporated soils. They found that it would reduce microbial diversity and select for halotolerant or halophilic organisms. Salinity was shown to be a crucial variable in explaining which microbes dominate in certain McMurdo soils. This study also brought to light some entail into how the temperature, freeze, and thaw cycles have an effect on microbial communities. They found that when in the extreme cold and frequent freeze and thaw cycles actually limit metabolism and favor psychrophilic (like the cold) and resistant organisms. This shows that the physical stress from the temperature variation acts like an environmental filter. In this study, they also found that the soil chemistry, like the pH and nutrient levels, plays a role in the microbial communities. They found that limited organic carbon and nitrogen lead to oligotrophic (low in nutrients) adaptations. Also, this study shows that the pH level of the soil influences presence, though to a lesser extent than moisture. In this study, the researcher argued that biotic interactions like competition and predation are minimal in these extreme conditions in the Dry Valley. Due to the fact that there is little to no water, and the harsh environment filters out microbes based on what it can tolerate, not competition.

Since the Dry Valleys are considered to be one of the harshest environments, it is fascinating how microbial life persists in these environments through remarkable physiological and ecological adaptations. Without the microbial communities' ability to adapt to extreme environmental factors then they would not be able to survive. For example, in this study, they found microbial communities' desiccation tolerance. In the study, they highlight how dry soil is very common in the Dry Valley, and because of this, the microbes adapt and enter a dormant state or will form spores to survive the prolonged dryness of the soil. Also, microbes have adapted to the intense amount of UV radiation by producing protective pigments such as carotenoids and melanins that absorb UV rays. Also, microbes protect themselves by DNA repair

enzymes like photolyases, which then reverse the UV damage. They also found that even some organisms live under translucent rocks or within rocks, using them as a natural UV filter. Since the temperatures in the Dry Valleys are extremely cold and drop below zero at times, some microbes have become psychrophiles or psychrotolerant. This means that they have enzymes adapted to function at low temperatures and are able to maintain membrane fluidity by using unsaturated fatty acids. Also, some microbes can remain metabolically active at below-zero temperatures by using thin films of brine in soil or even ice to allow for a small amount of reaction even when frozen. Due to the fact that there are low nutrients in the soil to utilize in the McMurdo Dry Valleys, microbial communities have become efficient at scavenging for traces of nutrients from mineral-rich but nutrient-poor soils. Even some microorganisms can fix atmospheric nitrogen or use inorganic compounds like sulfur or iron for energy. Craig Cary's research on the microbiology of Antarctic Dry Valley soil brought some new knowledge on how microbes were able to adapt so well to this extreme environment in order to survive in the Dry Valleys.

In conclusion, the McMurdo Dry Valleys of Antarctica are a fascinating and unique place. Due to the extreme and harsh environment in the Dry Valley, it was once thought to be mostly lifeless. However, because of the large amount of research done, like that of Craig Cary and his colleagues, it has become clear that this extreme environment is actually very diverse and uniquely adapted with microbial communities. Microbes in the Dry Valleys show extraordinary ecological and physiological adaptation, like desiccation tolerance, UV resistance, and below-zero metabolic function, which then allows them to be able to survive and even thrive in what is considered Earth’s harshest environment. While these discoveries not only expand our knowledge and understanding of microbial ecology and biodiversity but also can give very important implications for climate change studies and the search for life in extraterrestrial environments, the McMurdo Dry Valleys are and continue to be a crucial natural laboratory for discovering possibilities and limits of life on our planet.

References

Cary, S. C., McDonald, I. R., Barrett, J. E., & Cowan, D. A. (2010). *On the rocks: The Microbiology of Antarctic Dry Valley soils. Nature Reviews Microbiology,* 41028897_Cary_SC_McDonald_IR_Barrett_JE_Cowan_DA_On_the_rocks_the_microbiology_of_Antarctic_dry_valley_soils_Nat_Rev_Microbiol_8_129-138

Goordial, J., Davila, A., Greer, C.W., DiRuggiero, J., & McKay, C. (2020). *Antarctica Dry Valley Soil microbial communities are structured by moisture availability and salinity. Frontiers in Microbiology,* https://pmc.ncbi.nlm.nih.gov/articles/PMC7654227/

Mashamaite, L., Lebre, P. H., Varliero, G., Maphosa, S., Ortiz, M., Hogg, I. D., & Cowan, D. A. (2023, July 24). *Microbial diversity in Antarctic Dry Valley soils across an altitudinal gradient*. Frontiers in microbiology. https://pmc.ncbi.nlm.nih.gov/articles/PMC10406297/

National Aeronautics and Space Administration(NASA). (n.d.). *Dry Valleys, Antarctica* https://www.nasa.gov/image-article/dry-valleys-antarctica/#:~:text=The%20McMurdo%20Dry%20Valleys%20are,relatively%20moist%20interior%20of%20rocks.

National Science Foundation(NSF). (n.d.). *McMurdo Station* https://www.nsf.gov/geo/opp/ail/mcmurdo-station

Schahter, E. (2010, January). On the rocks. *Small Things Considered*

https://schaechter.asmblog.org/schaechter/2010/01/cr.html

M. Krista & D. Peter et. al. (2020). *Thermal legacy of a large paleolake in Taylor Valley, East Antarctica as evidenced by an airborne electromagnetic survey.*

https://www.researchgate.net/figure/Overview-map-of-the-McMurdo-Dry-Valleys-Lake-Fryxell-is-located-in-the-eastern-portion_fig1_345494895

Ye, Y. (2024, September 4). *How Earth's most intense heat wave ever impacted life in Antarctica*.

CU Boulder

https://www.colorado.edu/today/2024/09/04/how-earths-most-intense-heat-wave-ever-impacted-life-antarctica