LIVING ON THE EDGE: UNDERSTANDING THE HABITABILITY OF EUROPA'S ICE-OCEAN INTERFACE WITH HELP FROM EARTH.
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Introduction: The search for life beyond our own planet must ask fundamental questions about the very nature of life itself, and while challenging our notions of what is possible still remaining scientifically grounded. Europa presents us with the unique possibility of extant life closely tied to a likely active ice shell that may provide a stable energy source for life to leverage. However, while microbial life within ice and below it has been studied for decades to understand the strategies that so-called extremophiles may leverage in planetary analog environments, one of the most relevant environments, the ice-ocean interface beneath long lived thick floating ice, has remained largely unexplored…until now.

In the austral summer of 2010, deployment of the SCINI ROV through the Ross Ice Shelf at Coulman High, Antarctica in support of a geophysical drilling project revealed a surprising look at the ice-ocean interface [1]. Employing the ice as a habitat, a previously unknown community of anemones, polychaets and other organisms was thriving in a light-free and nutrient poor environment more than 30 km back from the edge of the ice shelf. This discovery is a potential game-changer for understanding how life could operate in Europa's ocean.

NASA's SIMPLE project, Sub-Ice Marine and PLanetary Analog Ecosystems, will explore and characterize the ice-ocean interface below the McMurdo and Ross ice shelves in order to understand how life persists at the ice-ocean interface. The results from this 4-year program just getting underway are directly relevant to understanding similar light- and nutrient-poor environments as habitats on icy ocean planets beyond the Earth, and especially Europa.

Ice Shelves as Europa Analogs: Antarctic ice shelves are Europan analogs because of the thick ice (>100 m) and long-term presence that allows for a community to evolve over multiple glacial cycles, rather than suffer habitat loss during interglacial retreat (i.e. in Greenland). The McMurdo Ice Shelf is particularly analogous because the ice shelve is home to extensive brine infiltration and basal melt, processes likely to contribute to active cycling of Europa's ice shell, forming features like chaos terrain and delivering exogenic material to its ocean. Such ice may itself be a habitat on Europa.

Ice Shelves as Habitats: Ice processes, like basal melting, may provide physical nooks that shelter the soft-bodied animals and provide nutrients to the microbial life. Sub-ice shelf microbial and macroscopic communities will be oligotrophic relative to other ecosystems due to lack of light, similar to Europa. Accordingly, a food web based on microbial chemosynthesis with lower levels of chemical energy could exist, analogous to cold seep or hydrothermal vent environments. Recent studies have shown that melting icebergs calved from ice shelves raise concentrations of nutrients and particularly iron, a limiting nutrient, in the near field. This enrichment leads to increases in primary producers, the base of the food web. Thus, around icebergs there is an enriched zone of macrofauna in the pelagic system. Inverted benthic communities such as that found at Coulman High could be widespread; there is anecdotal evidence of similar communities discovered under tens of m of ice in the Salmon Bay, Antarctica region in the 1960s. It also likely that sub-shelf macrofaunal communities are indicative of and dependent upon microbial life.

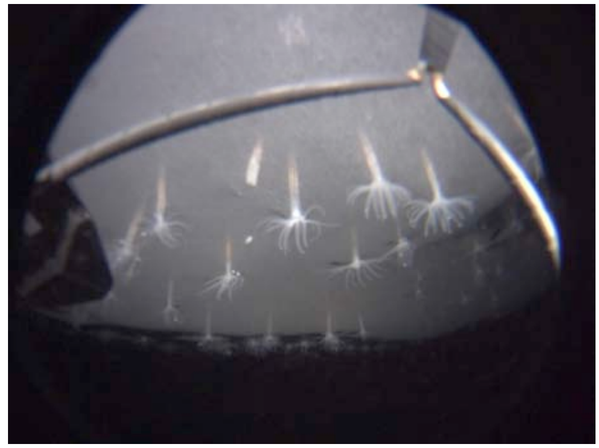

Figure 1: A community of anemones burrowing into the ice at Coulman High, Ross Ice Shelf Antarctica, after [1]. The organisms are using the ice substrate as a habitat.

First Results from SIMPLE: SIMPLE has just completed our first Antarctic field season deploying the ROV SCINI through a bore hole in the McMurdo Ice Shelf. The ice in this region was 56m thick. We deployed SCINI for a four-hour survey through the borehole and returned data showing significant variation in topography, basal roughness and ice type with with distance from the hole. These data will be presented along side airborne radar surveys of the same regions in an effort to both ground-truth radar detection of varying ice properties along the interface as well as to develop a better picture of how the ice and potential habitats may be distributed across the McMurdo and Ross Ice shelves.

We observed several types of animals along the interface, most were mobile and using topographic variations in the ice-ocean interface. These included several polychaetes attached to or within the ice. We also observed a *trematomus hansonii*, a negatively buoyant white fish with a smooth patch between its pectoral fins that allows them to "stick" to smooth surfaces, like the ice, without expending effort to constantly swim.

We did not observe colonies of anemones as were seen at Coulman High, thus work remains to be able to understand what makes the ice-ocean interface habitable to larger animals in this region. There are noticeable differences in the water chemistry and interface topography between the regions despite the fact that in both regions considerable “marine snow” drifts by to potentially provide a source of energy to filter feeding organisms. At Coulman High, the presence of a fresh water melt lense was observed, whereas at the site near Windless Bight on the McMurdo Ice Shelf a mixed layer exited just below the ice. These initial results may suggest that ice-ocean interactions altering the substrate and providing a buffer to changing currents plays as important role in mediating habitability as does potential energy flow from the ocean. In fact, with changing current direction and speed on both tidal and annual cycles, it is unclear that these organisms could be supported by inflow from the open ocean alone. Given their location, both the ice-ocean ecosystem and food web could be reliant on chemosynthesis rather than photosynthesis as the primary energy source. Some organic material may also be supplied from the ice melt as there is likely some incorporation of organic material into the ice shelf. A way to test this is to look for microbe and nutrient-rich ice and to map nutrient inflow from the ocean. In any case, the ability of these animals to burrow into ice as ablation proceeds and in low-nutrient environment is enticing for understanding what niches for life may exist on Europa and other ocean planets.

Future Work: The next few fields seasons will see additional deployments of SCINI through boreholes over a wide range of ice depths and current environments to further test these hypotheses and to characterize the extent of sub-ice communities. In 2015, we will deploy a highly capable AUV to do a full subshelf survey of the ice and any dependent communities, while providing a synergistic data set for comparison with radar surveys.

References: [1] Rack et al, Oceanography 25(3):84–89.

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