

2016 Heard Island Expedition Project Description

Definition

TITLE

FIRST COLONIZERS OF VERY RECENT GLACIOMARINE LAGOONS ON HEARD ISLAND

Abstract

Due to the extraordinarily rapid melting of the Stephenson Glacier on the eastern flank of Heard Island, a large (ca. 1 mi) lagoon was created within the last decade. The lagoon communicates with the ocean through a large vent on its southern extreme; mixing with oceanic water undoubtedly is enabling invasive colonization of the lake by marine organisms. We will investigate these first colonizers by two means: (1) Documenting and sampling the intertidal zone and shallow water biota on the lake edge; and (2) Sampling the benthic sedimentary deposits in the deeper parts of the lake using a clamshell grab equipped with an underwater camera. In addition to the biota, water samples will be taken for physical and chemical analysis. Other lagoons on Heard Island also show opening and closing of oceanic channels during the past 20 years, and these will be studied in the context of first colonizers.

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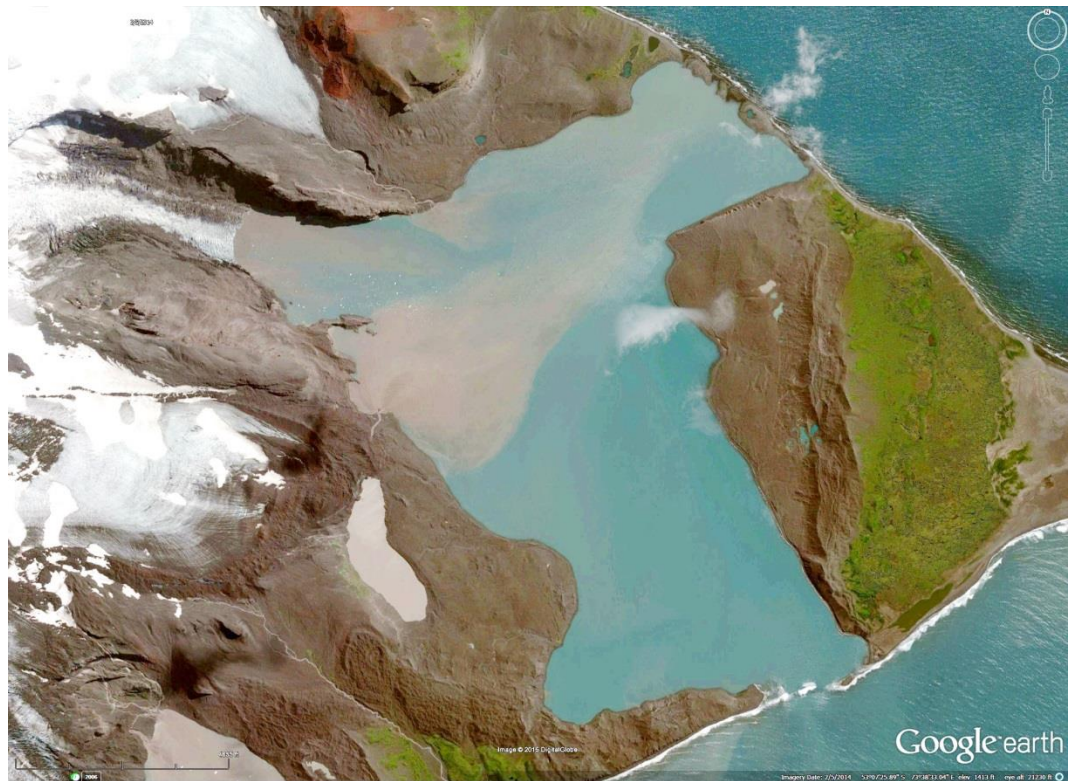
Context

Background

Satellite images show that the Stephenson Glacier, formerly dominating the area at Spit Bay, retreated by more than a mile in the short interval 2003-2008. The removal of the glacier and the increased flow of meltwater into the glacial basin have enabled the filling of a large (ca. 1 mile) lake, which we will call the Stephenson-Doppler (S-D) Lagoon. The images clearly show a major inlet of sediment-laden water from an elevated tarn. The lake has spread to the northern and southern edges of the main island landmass, opening channels to the outlying ocean. The southern opening is about 550 m wide, providing a clear path for mixing between oceanic and glacial lagoon water. As of 2014, the northern opening appears to be closed, although it is possible that by 2016 there will be openings there as well. The eventual outcome will be the complete cutoff of the Spit from the rest of Big Ben

Currently the lagoon is filled by the freshwater runoff from the tarn to its west which changes slowly with the annual seasonal cycle, and rapidly flushed with oceanic water with the (presumed) semidiurnal tidal cycle. Clearly, the salinity, temperature, and other physio-chemical characteristics of the lake change in response to two forcing functions, one of which (the tidal) supplies marine biota to the lake, the other of which (tarn drainage) tends to flush the lagoon with fresh water and prevent colonization by sedimentation.

Given this relatively complex dynamics, it is not possible to accurately predict which of the marine organisms would be able to establish colonies in the lagoon. However, it does seem reasonable that subtidal organisms, seeking protection from violent storms and the annual rise and fall of the shoreline, would be the first colonizers, taking up residence in the sediment that accumulates from glacial runoff. The meiofauna in this sediment could give a clear indication of whether the lagoon is hospitable for colonization.

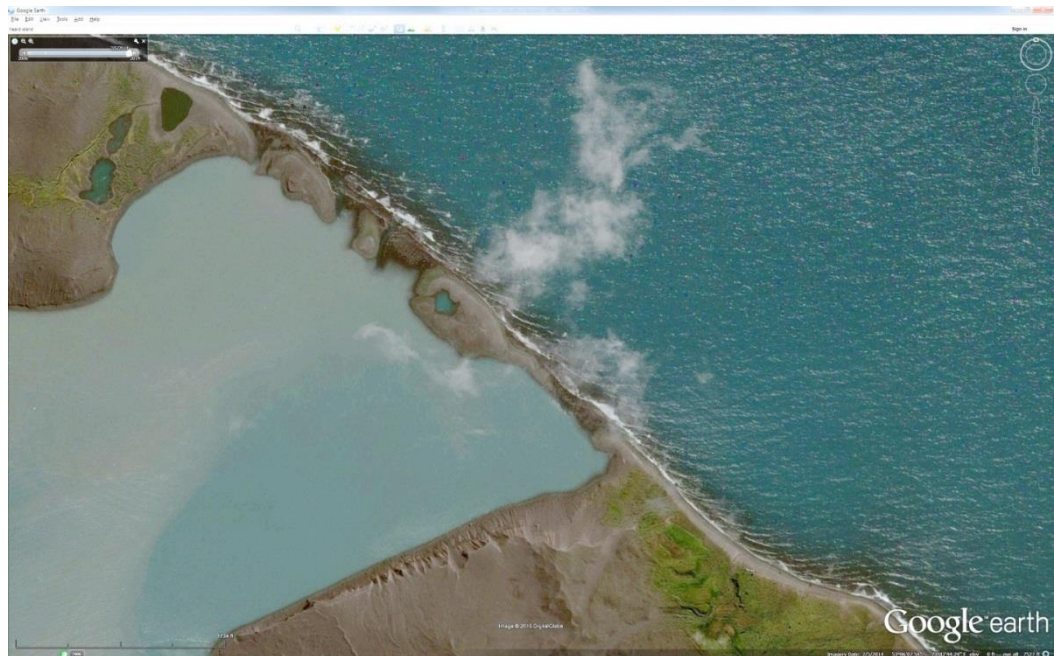


The Stephenson-Doppler Lagoon. Note the tarn to the left of the lagoon, which provides the main inlet (and a major source of sediment) from the glaciers into the lagoon.



The opening in the seawall on the south side of the lagoon. It provides access to the ocean (and diurnal flooding), enabling the invasion of the lake by marine organisms.

The difference between the northern and southern limits of the S-D Lagoon may be important for the nearshore and shallow-water first colonizers. If the northern boundary is not open, this area might have very calm water, enabling colonization similar to the deeper benthic areas, and allowing intertidal colonies on the soil at the water's edge. In contrast, the shoreline nearer the southern boundary will be subjected to more violent stress due to the tidal flow, hence might be unable to support colonial communities.



The seawall on the north side of the lagoon is still closed, as of this 2014 satellite image. It is likely that eventually it will be breached in the same manner as the southern seawall.



The photograph above shows the lagoon in 2012. [Photo: Doug Thost]

Motivation and goals

The S-D Lagoon at Spit Bay is the only large body of water recently created on Heard Island, so it presents a unique opportunity to understand how Heard Island interacts with its marine environment. The central goal is to document pioneer species in and around the Lagoon. Which of the available species from the oceanic reservoir are succeeding in establishing colonies is the central question to be answered.

So far as we know, there is no survey of the marine life in and around the S-D Lagoon. Because the S-D Lagoon is so new, colonization is very likely incipient, making this survey critical to support future investigations with baseline data. Speciation within the lagoon will not be significant; all species should be well-known marine species.

The central goal is to make a reasonably comprehensive survey of the S-D Lagoon, documenting the marine biota with photographs and voucher specimens. Voucher specimens are needed to confirm identifications.

Description

Onsite

Equipment



Along the waterline, only cameras, GPS, a basic trowel, and sterile containers (e.g., Ziploc bags) will be needed to make documented collections of the marine biota and lake water.

To obtain the benthic sediment samples we will use a combination clamshell grab and underwater camera, deployed from the inflatable landing boat. The camera will be tethered on the dropline, pointing down at the grab. This arrangement ensures that images are obtained of the bottom samples as they are collected.



The grab, called a Ponar Petite (Model 1728-G30). The grab has a bite depth of 7 cm, screen mesh of 500 microns. It weighs 11 kg, and can collect a 2.4 liter sample.

Location(s)

The Stephenson-Doppler Lagoon at Spit Bay. However, as noted in Appendix 4, the other lagoons (Winston, Brown, and Compton) also have experienced recent (last 20 years) openings and closings of oceanic channels, and therefore it would be of great value to investigate these lagoons in the context of colonizers, and within time and resources available we will investigate these other sites.

In addition to the samples from the lagoons, it is of value to obtain samples of the subtidal offshore marine life to provide correspondence with the lagoonal samples, and to the extent that time and resources permit, we will use the grab to obtain such samples. If conditions permit, we will seek samples from the area around Spit Bay (rather than Atlas Cove), in order to establish correspondences with the lagoonal biota.

Procedure

The intertidal and shallow-water biota will be documented with photographs, GPS locations, and verbal descriptions. Representative specimens will be collected by hand into sterile containers (jars, Ziploc bags, etc.).

Benthic samples of the bottom sediment will be obtained using the clamshell photo-grab illustrated above. Samples will be preserved in Ziploc bags; a fraction will be fixed and will be examined onsite using the microscope. Another fraction will be kept as collected for possible culturing in laboratories upon return and distribution.

We plan to carry out preliminary examination of the samples onsite at Heard Island, using the digital microscope. The microscope generates high-resolution

images of the sample on the computer screen, and we will be able to upload these to our internet site, where collaborating scientists will be able to download them. We are encouraging our collaborators to provide real-time feedback on the samples, possibly providing guidance for further sampling. We will have a relatively large number of marine specialists examine the images.

Records

Photo-documentation

Shoreline individual organisms will be documented with GPS-photographs, whether collected or not. Underwater photography may be used for the shallow water near the shoreline, but no subtidal photography by diving is planned.

Logging

A verbal/written record will be kept of all tracks by the investigators, eventually summarized in maps of the observations. GPS-equipped cameras will provide locations of the images. Some of the images can be uploaded from the island, enabling collaborators, including the AAD, to interact with the field team.

Nonliving specimens

Some of the benthic sediment will be fixed and processed to eliminate organic constituents. The digital microscope will provide images of the grains of sediment, and other organic objects such as mollusk shells, tests, and scales.

Live specimens

A fraction of the benthic samples will be kept as collected, and kept cold until delivered to selected collaborators for culturing. The digital microscope will provide images of living organisms for color reference.

Post-expedition procedure

Destination(s) of records

University of California, Berkeley, Davis; Los Angeles Museum of Natural History; U. S. National Museum of Natural History.

Processing of records

Samples brought live to collaborators will be put into culture. Follow-on processing and analysis will depend on the results of the culture. Nonliving samples will be examined principally by microscopic identification.

Publication(s) expected

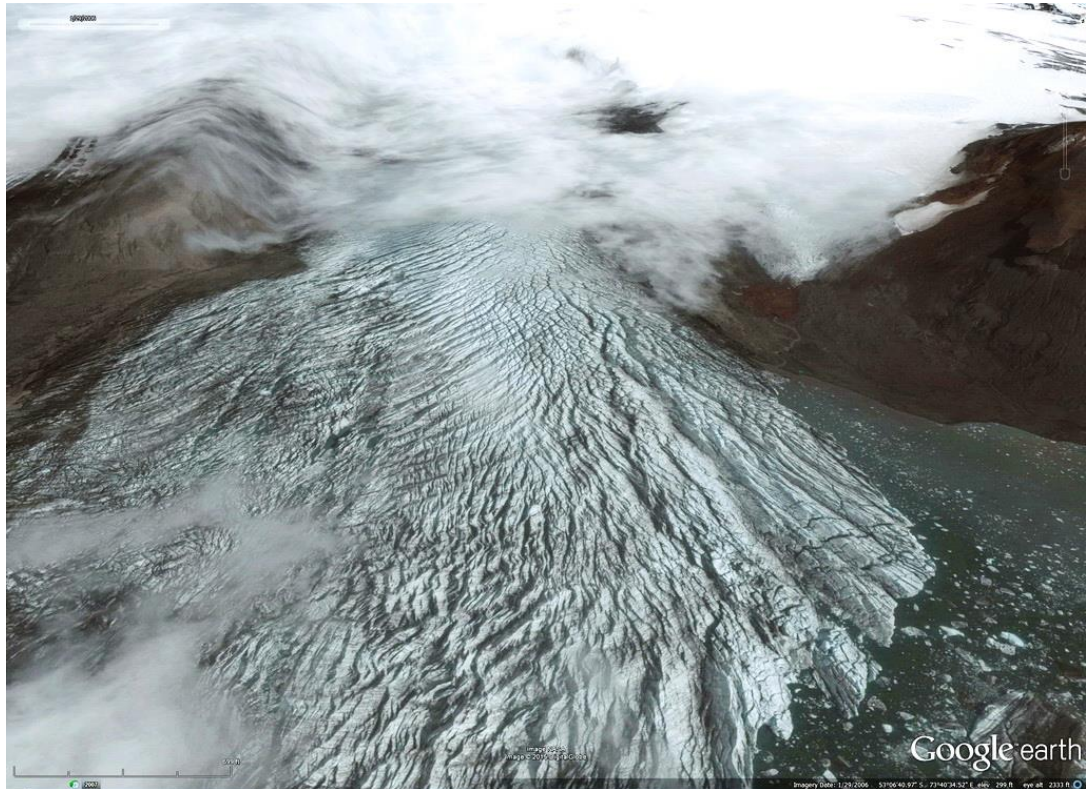
Paper in the Heard Island monograph, and possible additional journal articles.

Definition of success

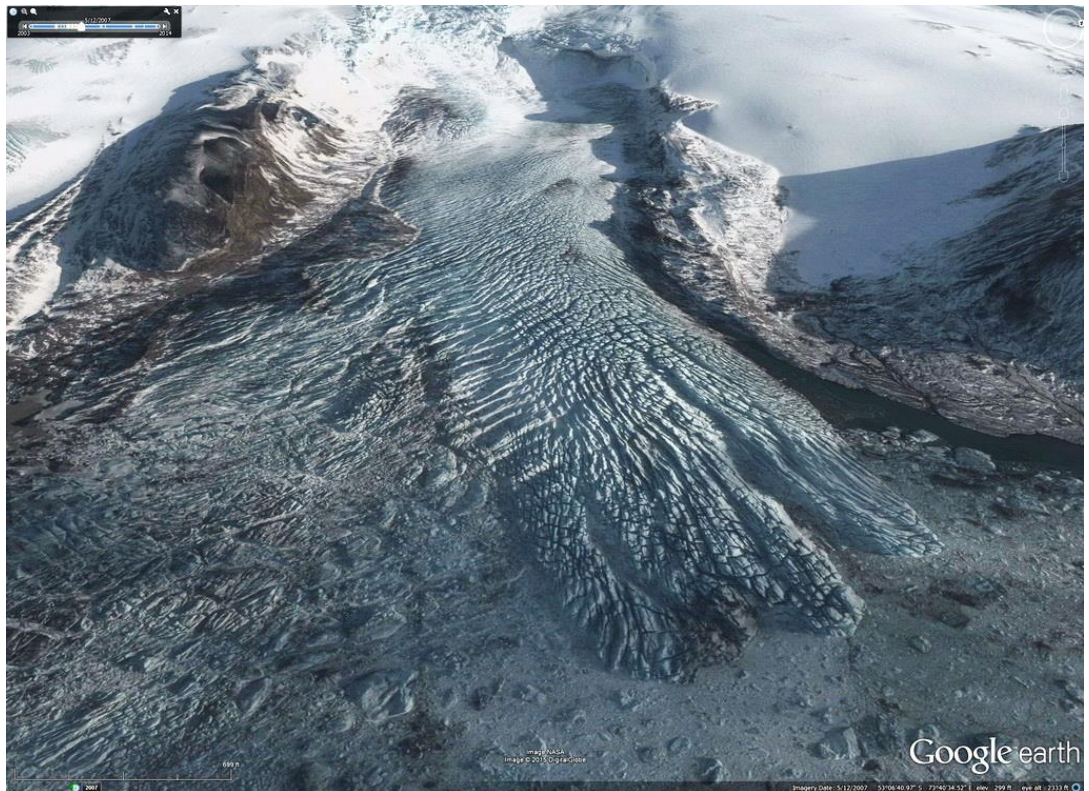
Relatively complete inventory of biota associated with the S-D Lagoon, including shoreline species and the contents of benthic sediments.

Appendices

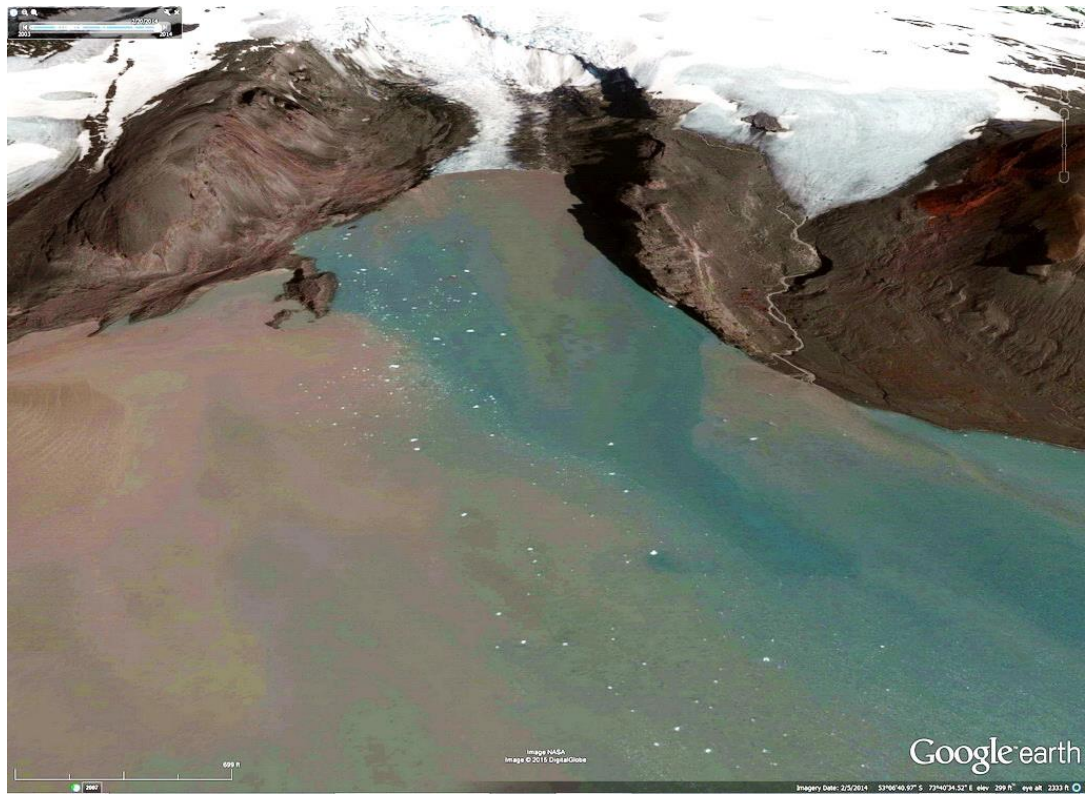
Appx. 1 Retreat of the Stephenson Glacier – images [Source: Google Earth]



2006



2007



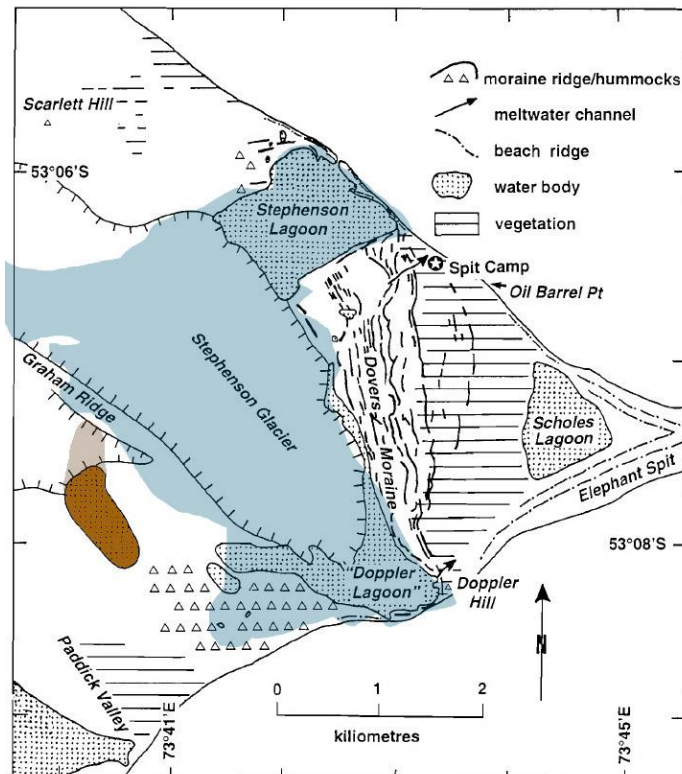
2014

Appx. 2

Map of the S-D Lagoon

The drawing below was made as an overlay to the map published by Kiernan and McConnell of observations made in 2000. The dark brown tarn, its northern third covered by the glacier, has now been exposed. The waterline is confined at the northern end of the tarn by the Graham Ridge. Since this map was made, the lower Stephenson Glacier has essentially disappeared, leaving the

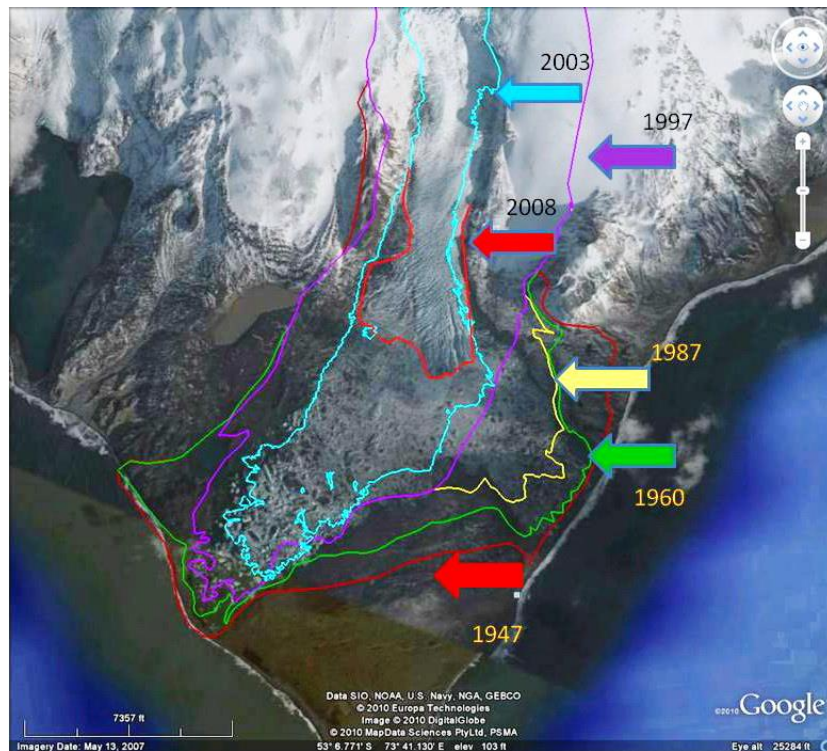
area (colored bluish) between the Stephenson and Doppler Lagoons as a large lagoon.



Because of the opening of the seawall at the southern end, the sea can flush the entire area, which means that the entire lagoon is brackish, and it probably supports an extensive marine community. Because this area is protected from storm seas and is tidally flushed, the lagoon community probably differs substantially from the nearshore (outer) marine community.

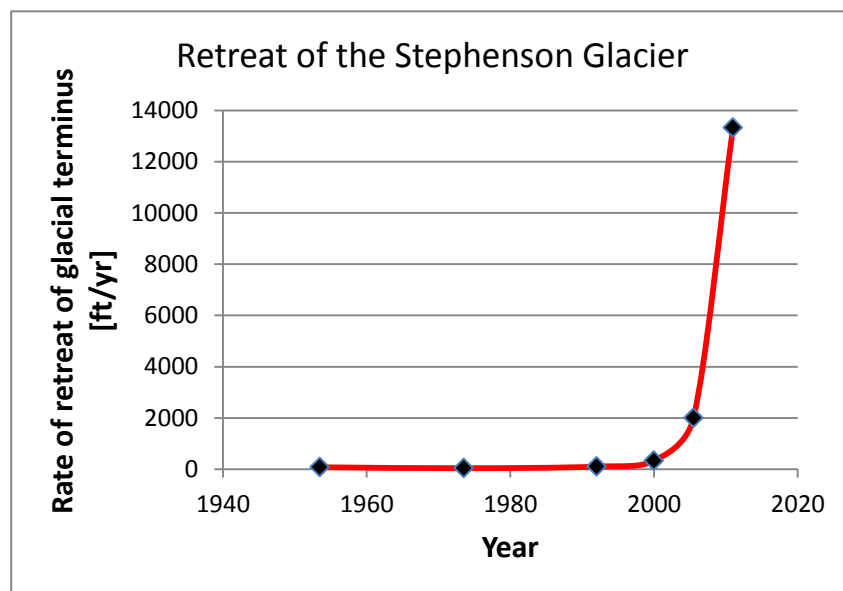
Appx. 3 Rate of Retreat of the Strepenson Glacier

The following diagram shows the retreat of the Stephenson Glacier since 1947. Note that the retreat between 2003 and 2008 was almost 2 miles, and by 2014 it was almost 3 miles. Continuing at the average rate (about 1/3 mile/year), in 2016 it will have retreated another 2/3 mile.



[Source:]

From this chart we can roughly determine the rate of retreat, shown in the following plot.

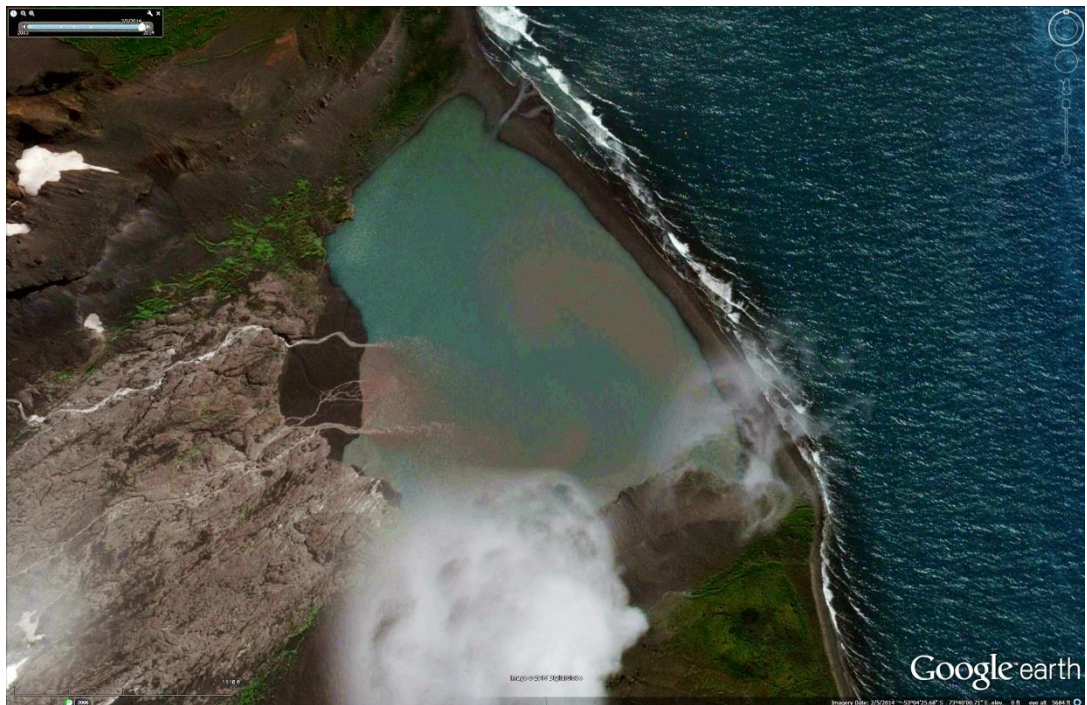


Appx. 4 Comparison with the other lagoons on Heard Island

We note that there are four major lagoons on Heard Island, each with a different connection to the ocean. Images of these are shown here (not at the same scale).



Winston Lagoon. No connection to the ocean.



Brown Lagoon. Very weak connection at the northern corner.

It is of considerable interest that the algal content of these four lakes corresponds with their access to flushing with oceanic water: The color of Winston Lagoon (no oceanic exchange) is considerably greener than the ocean outside the seawall, while the water in Compton Lagoon (open exchange) is indistinguishable from the ocean. Examination of the algal content will therefore be worthwhile.



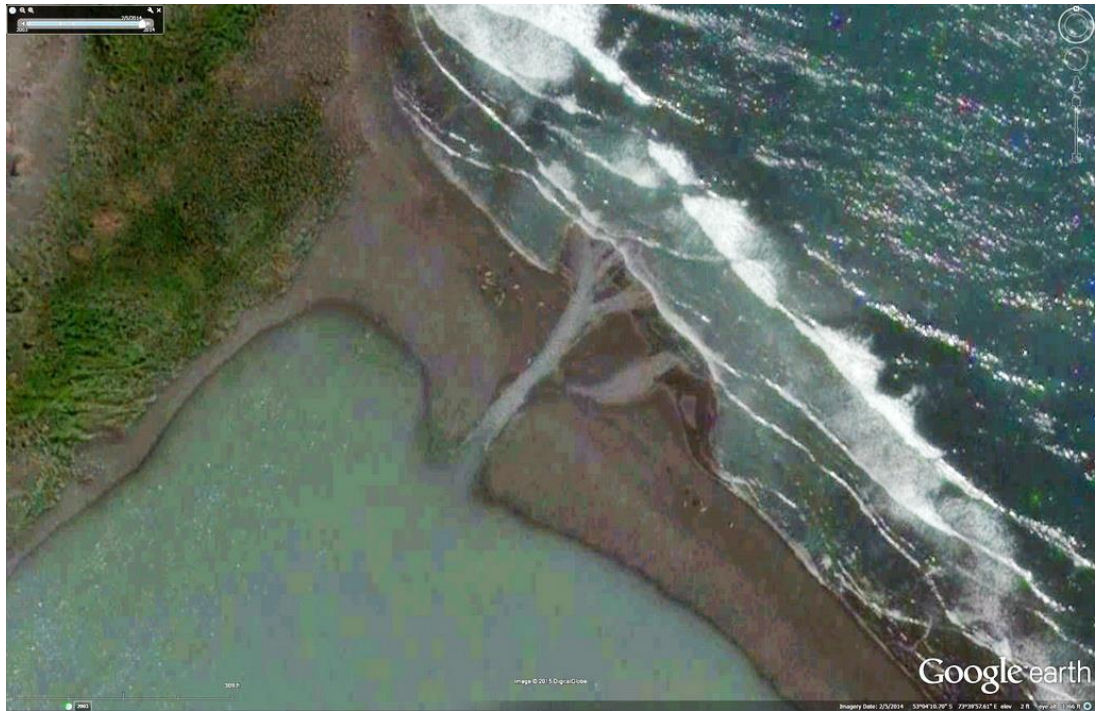
Stephenson-Doppler Lagoon. Recent strong connection to the ocean (southern limit).



Compton Lagoon. Nearly complete opening to the ocean.

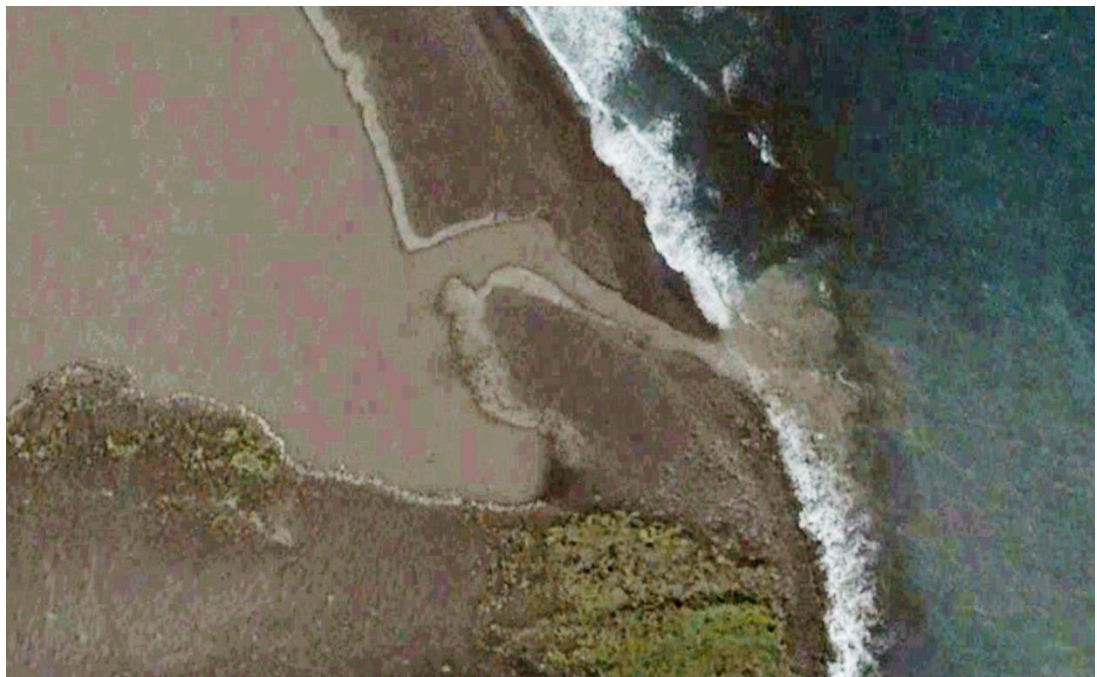
All Lagoons have major inflows of sediment-laden meltwater. While not obvious in the satellite images, these sediments will have different compositions and structures. Sampling these flows at their inputs to the lagoons therefore should provide another means for comparing these lagoons. Such sampling of these streams is described in a separate document (Biogeochemical Composition of the Subglacial Regime on Heard Island using Glacial Streams as Remote Sampling Probes). The oceanic connection in the Brown Lagoon (shown in the next photograph) is particularly interesting. Based on the braided delta as the stream enters the ocean, it is predominantly a drain, although a shallow one (the elevation data indicates the entire seawall is only 1-3 ft. high). Thus, it is virtually certain that high surf will flood into the lagoon, contributing marine organisms. This link

is certainly much weaker than that in the Stephenson-Doppler Lagoon, hence might be a more valuable target for study of the first colonizers. We will attempt to carry out the same kind of investigation along the shoreline as for the S-D Lagoon, including *in situ* measurements of pH, dissolved solids, etc., although of course we will not be able to use the bottom grab there.



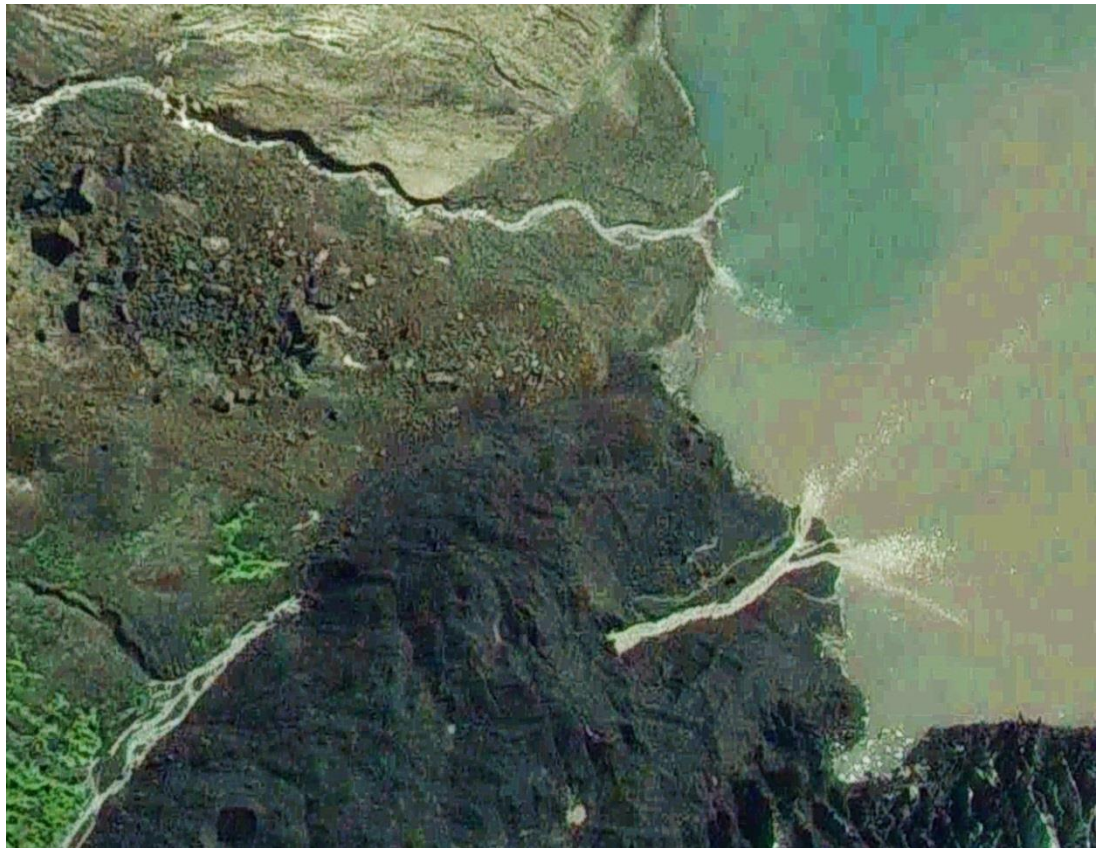
The shallow drain at the northern corner of the Brown Lagoon in 2014

Historically the lagoons have opened and closed channels to the ocean. As shown in the next images, in 2006 the Brown Lagoon had an open channel on its south corner and no channel at the north corner. It was almost totally clouded with sediment.



The Brown Lagoon in 2006, showing the opening at the south corner.

Like the Stephenson-Doppler Lagoon, Compton Lagoon has an inlet that travels underground (about 128 m) before emerging and forming the delta.



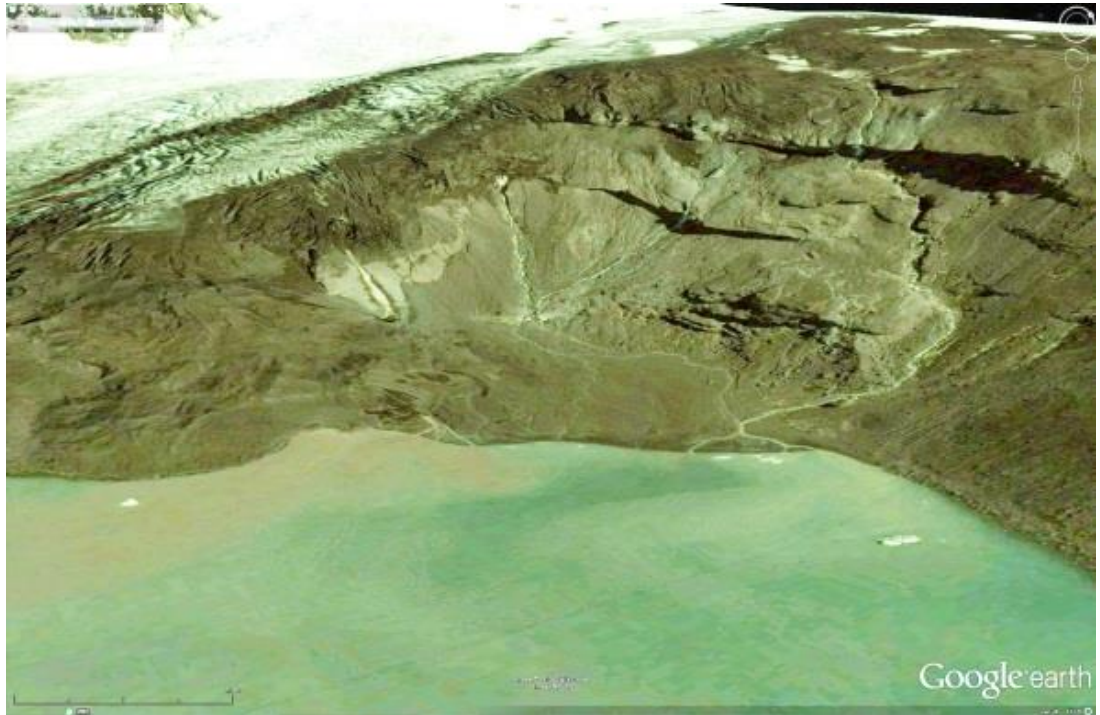
Subsurface stream inlet to Compton Lagoon 2014

The Winston Lagoon also had an opening in 2006, shown in the following 2007 image.



Winston Lagoon in 2007

The following two images give insight into the ephemeral nature of the drainage channels.



Winston Lagoon drainage basin in 2007



Winston Lagoon drainage basin in 2014

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Suppl. 1 Excerpt from the paper by Kiernan and McConnell, 2002

Glacier retreat and melt-lake expansion at Stephenson Glacier

Conclusions

Rates of both glacier retreat and melt-lake enlargement have increased by about one order of magnitude during the last two decades. Precise ice-volume loss cannot presently be calculated, but about 30% of the cross-sectional area of the terminal zone of Stephenson Glacier above sea level has vanished in the past three decades. That accelerated melting of older ice-cored moraines is contributing so significantly to melt-lake expansion rather than it being the product solely of glacier recession perhaps emphasizes the significance of temperature increases in causing environmental change on Heard Island. The resulting transformation of the landscape implies there have been some fundamental alterations to the nature, rates, and relative contributions of the various geomorphological processes that are shaping eastern Heard Island.

Fluvial and other non-glacial processes are likely to play an increasingly significant role. Because atmospheric warming should also be accompanied by atmospheric moistening (Sun and Held 1996; Simmonds and Keay 2000), there may also be significant changes in glacial processes that could trigger further changes in glacial, glaciofluvial, and glaciolacustrine sedimentation and its interaction with coastal processes.

These changes in geomorphological processes and ongoing landscape evolution are having a pronounced impact on the character of this World Heritage Area, which is now a vastly different place to that experienced by the sealers and earliest ANARE expeditioners. In addition to

impacts upon geodiversity, these changes also have implications for biodiversity, such as shoreline and other habitats, and by facilitating expansion of terrestrial vegetation. There are also implications for cultural heritage, notably archaeological sites dating from the nineteenth-century sealing days that are now subject to accelerated erosion due to changed interactions between glacial and coastal processes. Hence, this transformation has important implications for management of the Heard Island Wilderness Reserve.

Heard Island is uninhabited, infrequently visited, and about as remote from centres of direct human disturbance as any place on Earth, but there is increasing evidence of the pervasiveness of human impacts in southern polar latitudes (Liguang and Zhongqing 2001). If the climate changes responsible for glacier recession are of anthropogenic origin (Jones and others 1999; IPCC 2001), then the wilderness values and natural-process values upon which listing of this World Heritage property was partly based have in one sense been compromised. Heard Island remains about as wild and untouched as any place can be. But the changes that are occurring raise the philosophical question of whether any place on an artificially warming planet can be regarded with any validity as an untouched wilderness. These changes present the managing authority with difficult philosophical and practical issues regarding the desirability and level of any on-ground intervention for management purposes.

HIMI Management Plan

The present project is sanctioned by Items **A3, A5, A6, A11**, and **B1** of **Table 2, Section 5.5** of the Heard Island and McDonald Islands Marine Reserve Management Plan 2014-2024, viz.:

A3) Surveys to determine the presence and extent of possible non-native species

A5) Long-term monitoring of climate, glaciers and fauna and flora colonisation of newly deglaciated areas.

A6) Surveys to improve understanding of the Reserve's biodiversity and its response to climate change.

A11) Quantitative baseline biological studies of near shore marine ecosystems.

B1) Stratified random sampling of the benthos, particularly habitat-forming benthos (such as sponges and corals) in and around the Reserve.

Section 5.5 of the HIMI Management Plan provides the following:

“Research within the Reserve is required [emphasis added] for the integrated and ecologically sustainable management of the broader HIMI region. ... Scientifically robust evidence is needed to make effective conservation management decisions. ... Research and monitoring activities must be undertaken in accordance with the research and monitoring priorities identified in Table 2 and the Australian Antarctic Science Strategic Plan.”

Further, the AAD controls access to the biological resources [in the Territory] according to the requirement that “the resources not be used for any commercial purpose.” We affirm that this project has no commercial interest or activity.

Priority

This project has extremely high priority within the 2016 Heard Island expedition, based on the nature of the opportunity to obtain unique information about a major ecosystem process involving redistribution of species and the effects of deglaciation on the ecosystem, and the high likelihood of achieving its goals.

Specimens

The collection of specimens is essential to this project. While the onshore biota could be photo-documented, that is a poor and inadequate response to this opportunity. In the case of the benthic biota, collection of minimal amounts of bottom sediment is absolutely essential—no information can be obtained without it.

Risks

There is a risk in the operation of the boat for deploying the photograb, e.g., due to poor weather, but this is considered a reasonable risk and controllable by planning and conservative decision-making.