ENVIRONMENTAL CONDITIONS FOR GLASS SPONGE REEF FORMATION IN HOWE SOUND

TUDOR BARBACUTA | EAES 2357

INTRODUCTION

Hexactinellid (glass) sponges are found in cold-water environments around the world. They are characterized by a skeleton constructed from spicules of silicon dioxide (silica) as shown in Figure 1. Presently, only glass sponges found in the Pacific Northwest are known to form biogenic reef habitats (Stevenson, et al., 2020). As a result, glass sponges play a vital role in supporting marine communities in British Columbia's coastal waters. To understand the factors that create the unique habitat conditions for glass sponge reefs in Howe Sound, a comprehensive analysis of water chemistry was undertaken. Existing research determined the importance of examining silica and dissolved oxygen concentration, as well as temperature and pH (see Table 1). The chemical analysis was complemented by an in-depth study of the region's bedrock and surficial geology to gain insight into how geological processes have influenced the formation of glass sponge reefs. In synthesizing these analyses, it is possible to summarize a set of diagnostic criteria that could be used to predict the locations of as-yet undiscovered reefs.

METHODS & MATERIALS

Field work was conducted in Howe Sound by boat at two sites courtesy of Marine Life Sanctuaries Society (MLSS). Water samples were collected at two sites, as show in Figures 2 and 3. The control site was located near Bowyer Island; Halkett Reef near Gambier Island was selected as the second site. An additional sample site was selected at Deep Cove in Indian Arm due to ongoing discussions regarding the notable lack of glass sponge reef formation in the fjord.

At all sites, Niskin and Van Dorn sampling bottles were used to collect water. The Niskin bottle was dropped to a depth of 10 metres while the Van Dorn was dropped to 50 metres. Additionally, MLSS volunteer divers collected water samples (approximately 30 metres and 25 metres at the control and reef sites, respectively). GPS coordinates were recorded upon arrival to each site. Once retrieved, the samples collected with the bottles were immediately transferred to a receptacle and tested for temperature and pH using an Oakton PCTSTestr 50. The diver samples were processed similarly. Due to the depth of the glass sponge reef at Halkett, the 50 metre Van Dorn bottle could not be deployed as there was the concern it could cause damage to the reef. Instead, divers collected two samples at this site, one from the reef surroundings and one from the pinnacle, a geomorphological feature unique to this site.

The water samples were analyzed at the Douglas College Chemistry lab for concentrations of dissolved silica and oxygen. Silicate analysis was performed using the molybdate method (Strickland & Parsons, 1972). Dissolved oxygen was tested after a one-week incubation period using a Vernier LabQuest equipped with an optical DO probe. After using the molybdate method to prepare silicate standards, a calibration curve was constructed using a Vernier SpectroVis Spectrophotometer. The absorbance of each water sample was recorded and plotted onto the calibration curve to obtain the dissolved silica concentration. A Beer's Law plot was constructed (see Figure 4) summarizing the concentrations of each sample.

Several maps were created to examine the hydrology and bedrock geology (see Figure 2), and surficial geology and bathymetric profile (see Figure 3) of Howe Sound. These maps were produced using QGIS and include the locations of sample sites, as well as locations of known and potential glass sponge reefs (DFO, 2018).

DISCUSSION

Chemical analysis demonstrated clear differences in silica concentration between the three sites examined, with interesting variations based on depth. The standards produced using the molybdate method resulted in an R squared value of 0.9989 as shown in Figure 4, and an error of 2%. At the Bowyer Island control site, the 50 metre sample had a concentration of 58 ± 1.16 μM, while the 10 metre surface sample had a concentration of 52 ± 1.04 μM; the diver sample resulted in a concentration of 53 ± 1.06 μM. Silica concentration at this site showed a relationship that increased with depth. A possible explanation for this relationship is the settling of sediment as it falls out of suspension and accumulates on the seafloor (deposition).

At Halkett Reef, the depth profile of silica concentration varied. The 10 metre surface sample had a silica concentration of 50 ± 1.00 μM. For the reef and pinnacle samples, both taken at approximately 25 metres, silica concentration measured 48 ± 0.96 μM and 54 ± 1.08 μM, respectively.

While a flux rate for the glass sponge reef at this location was not established, it is possible that the difference in concentrations reflect the ongoing sequestration of silica by the sponges, resulting in a lower concentration in the immediate vicinity of the reef.

The sample taken from Indian Arm featured a considerably lower silica concentration of 14 ± 0.28 μM. This sample was taken with the 10 metre Niskin bottle from the pier at Deep Cove.

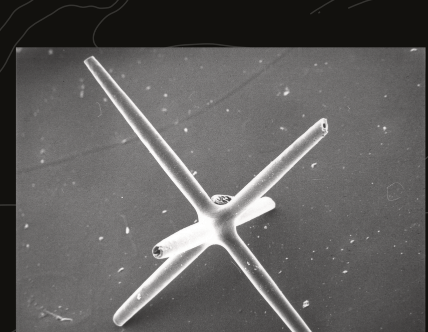
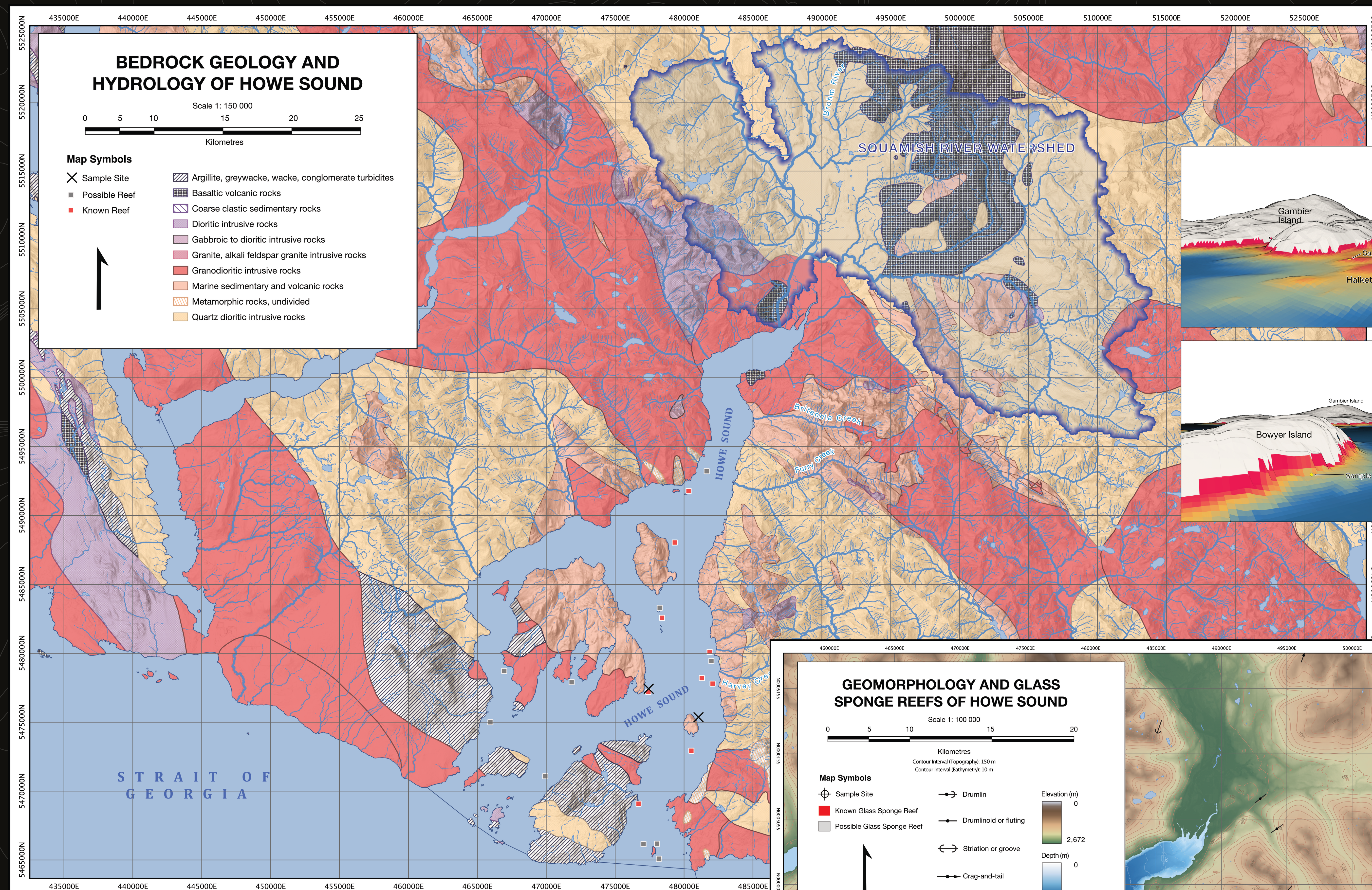


Figure 1. Silicon dioxide sponge spicule. https://en.wikipedia.org/wiki/Sponge_spicule#/media/File:Sponge-spicule_hg.jpg. Copyright 2013 by Hannes Grobe.

Figure 2. Bedrock geology and hydrology of Howe Sound with sample sites and locations of known and suspected glass sponge reefs



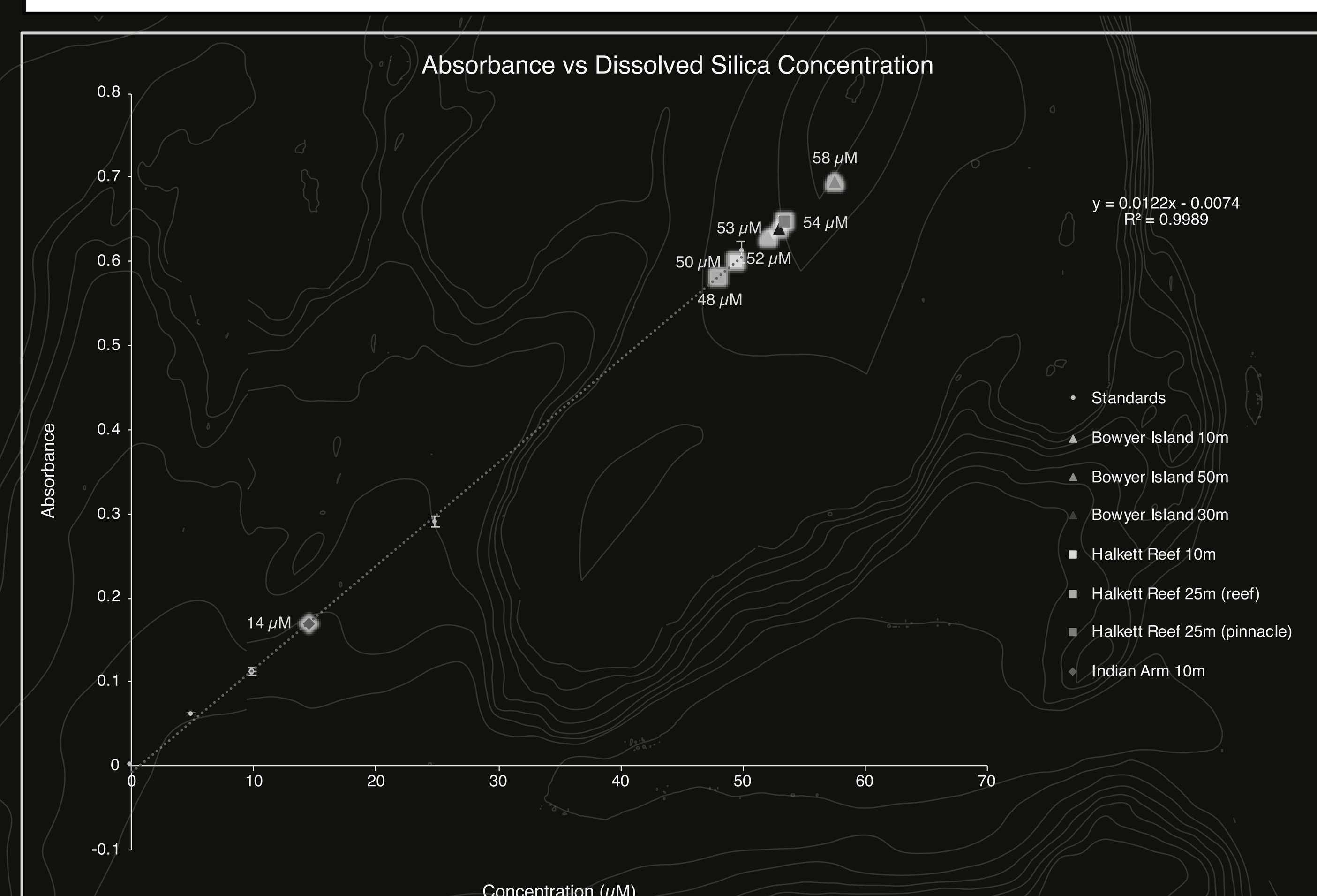


Figure 4. Colorimetric silicate analysis calibration curve and silica concentrations for ocean water samples

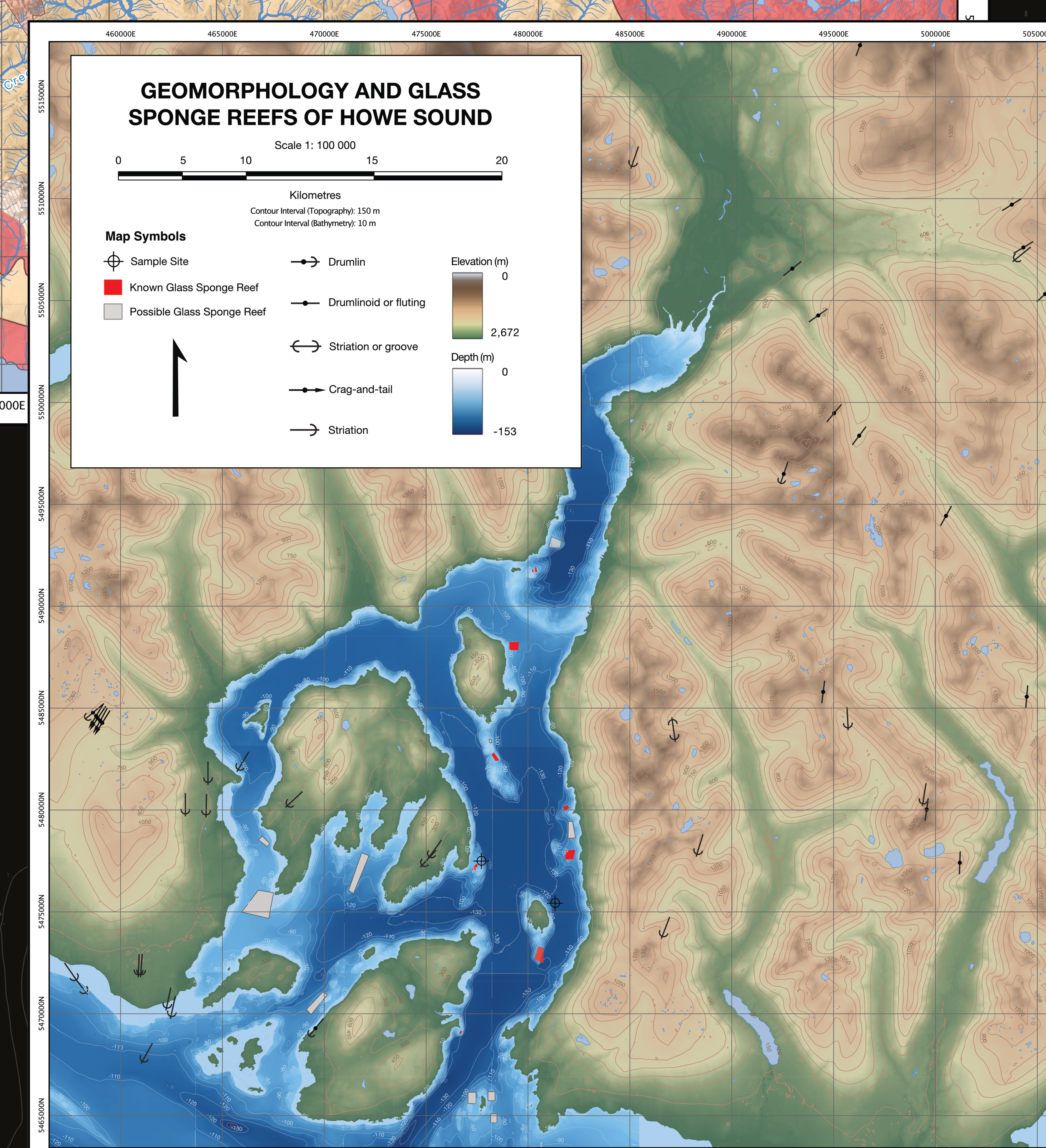


Figure 3. Post-glacial geomorphology of Howe Sound with extents of known and possible sponge reefs

Sample	Dissolved Oxygen Concentration (mg/L)	Temperature (°C)	pH
Bowyer Island 10m	11.31	10.9	7.74
Bowyer Island 50m	12.71	11.1	7.84
Bowyer Island 30m	12.30	10.3	7.63
Halkett Reef 10m	11.93	10.3	7.93
Halkett Reef 25m (reef)	11.51	10.0	7.65
Halkett Reef 25m (pinnacle)	11.59	10.0	7.63
Indian Arm 10m	11.73	12.5	8.17

Table 1. Results for dissolved oxygen concentration, temperature and pH for each ocean water sample

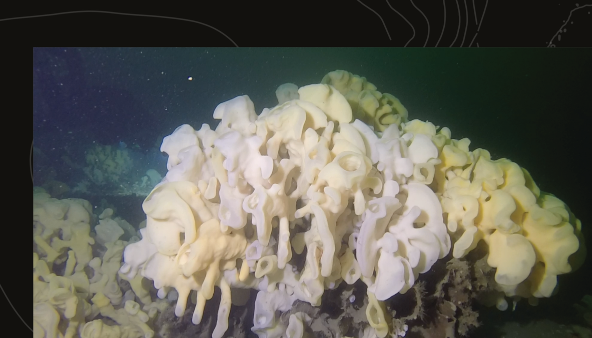


Figure 5. Cluster of Aphrocallistes vastus and Heterochone calyx

Figure 6. Two glass sponge bushes with living (foreground) and dead (background) skeletons

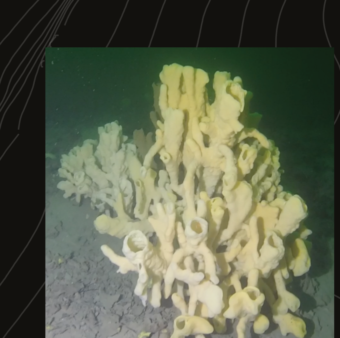


Figure 7. Live sponge skeleton

Figure 8. Glass sponge community dynamics featuring rockfish and plumrose anenome

DISCUSSION CONT.

As freshwater in Indian Arm is supplied by smaller creeks and streams and likely does not feature a comparable level of sediment discharge as Howe Sound (Leys, et al., 2004), it is possible the level of silica supplied to the fjord is also lower. The markedly lower silica concentration could provide a strong explanation for why glass sponges are not found in larger numbers like in Howe Sound.

All locations featured high concentrations of dissolved oxygen, well above the theorized physiological limit of hexactinellids. At 12.5 °C, Indian Arm was noticeably warmer than Howe Sound (see Table 1); warmer water has been demonstrated to impose physiological stress on glass sponges.

Geomorphological processes as a result of Pleistocene glaciation are an important factor for the establishment of hexactinellid reefs. In Howe Sound, reefs have formed on glacial landforms including moraines, drumlins, flutes, and iceberg furrows (Conway, et al., 2017). As shown in Figure 3, known reefs are located on these features as they provide the coarse substrate to which glass sponges need to anchor, as well as elevation off the seafloor.

While a full examination of Howe Sound hydrology and bedrock geology was beyond the scope of this research, the region's active tectonic processes and output of freshwater and sediment from the Squamish River watershed (see Figure 2) likely supplies the high levels of silica required by glass sponges. Howe Sound is part of the Coast Mountain complex, one of the largest plutonic (intrusive igneous rock) systems in the world (Armstrong, 1990). Volcanic rocks like basalt and granodiorite are rich in silicate minerals such as quartz, feldspar, and hornblende. As shown in Figure 2, these types of rocks and minerals can be found in abundance in Howe Sound.

Owing to the region's high precipitation and glacier-fed hydrologic system, much of this silica is likely output into Howe Sound. The Squamish River watershed has an annual mean discharge rate of 300 m³/s, which doubles in the summer due to snowmelt (Leys, et al., 2004). Due to weathering and erosion, the many creeks and streams as shown in Figure 2 likely contribute to the high levels of silica in Howe Sound.

CONCLUSION

Glacial and post-glacial processes have influenced the factors necessary for glass sponge reef formation. Hydrologic processes provide a high input of silica, likely sourced from the region's plutonic bedrock. As a result, silica concentrations were high at the locations sampled. Moreover, results like the sample taken at Halkett Reef may demonstrate the ability of glass sponges to sequester silica.

While it was not determined which factor, if any, is most important in predicting the locations of glass sponge reefs, a set of criteria can be established that considers glacial landforms, bedrock geology, hydrology, and silica and dissolved oxygen concentrations. Together, these criteria can form a set of diagnostic parameters that can be used to assign probabilities of finding glass sponge reefs at candidate locations.

REFERENCES

Armstrong, J. E. (1990). *Vancouver Geology*. Vancouver: Geological Association of Canada.

Conway, K. W., Whitney, F., Leys, S. P., Barrie, J. V., & Krautter, M. (2017). Sponge Reefs of the British Columbia, Canada Coast: Impacts of Climate Change and Ocean Acidification. In J. L. Carballo, & J. J. Bell, *Climate Change, Ocean Acidification and Sponges* (pp. 429-445). Springer International Publishing.

DFO. 2018. Glass sponge aggregations in Howe Sound: locations, reef status, and ecological significance assessment. DFO Can. Sci. Advis. Sec. Sci. Resp. 2018/032

Leys, S. P., Wilson, K., Holeton, C., Reiswig, H. M., Austin, W. C., & Tunnicliffe, V. (2004). Patterns of glass sponge (Porifera, Hexactinellida) distribution in coastal waters of British Columbia, Canada. *Marine Ecology Progress Series*, 133-149.

Stevenson, A., Archer, S. K., Schultz, J. A., Dunham, A., Marliave, J. B., Martone, P., & Harley, C. D. (2020). Warming and acidification threaten glass sponge Aphrocallistes vastus pumping and reef formation. *Scientific Reports*.

Strickland, J. D., & Parsons, T. R. (1972). *A Practical Handbook of Seawater Analysis*. Ottawa: Fisheries Research Board of Canada.

ACKNOWLEDGEMENTS

I would like to thank Adam Taylor with Marine Life Sanctuaries Society, as well as the entire team of volunteer divers who helped collect samples and footage for this project.

Marine Life Sanctuaries Society

Thank you as well to Dr. Brenda Addison-Jones for her guidance on this project. Her insight, supervision, and collaborative nature were immensely valuable.