—報告—
Report

Breaching of a perennial snow dam below Lake Hyoga Ike in the Langhovde region of the Sôya Coast, East Antarctica: Probable effect of disturbance events on the distribution and colonization of flora within/around the lake

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東南極宗谷海岸ラングホブデ域にある「氷河池（仮称）」の多年性雪堤防決壊：決壊に伴った撹乱による湖沼内とその周辺植生への影響に関する考察

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要旨：南極の陸域環境の植物の分布と定着は，洪水をも含む環境の物理的撹乱による制限を強く受けていると考えられる．近年（第47次観測隊以降），日本南極地域観測隊の活動を通じ，東南極宗谷海岸のラングホブデ域にある氷河池（仮称）の多年性雪の堤防に大きな穴が開き決壊したことを確認した．同様の現象は約25年前にも報告されている．以前の穴はその後閉塞し，今回の決壊直前まで氷河融解水が涵養した湖沼となっていたが，現在ではその湖水のほとんどが失われ，湖の面積は著しく縮小している．ラングホブデ南部にある隣接したいくつかの渓谷及び湖沼は，土壌藻類・地衣類・蘚類や湖底藻類蘚類群落が発達した地域として知られている．これらの中で，氷河池内やこの雪の堤防の下流側の渓谷（やつで沢）にはごく乏しい植生しか見出すことはできない．この対照的に貧弱な植生の分布と定着状態は，繰り返し発生する堤防の決壊による物理的撹乱が湖沼内及びその下流側での植物の分布･定着を制限した結果であると考えられる．この報告を通じ，著者らはこの地域の氷床の融解量の変化の評価とともに，露岩域での生態学的研究及びこのエリアで今後とも行われる観測活動に際しての安全確保という観点から，この多年性雪堤防と氷河池の長期監視の重要性を訴えるものである．

Abstract: The distribution and colonization of flora in Antarctica may be limited by disturbance events, including flooding. Recently, we observed a large hole in the perennial snow dam below Lake Hyoga Ike (temporary name), located in the Langhovde region on the Sôya Coast in East Antarctica. This phenomenon was also reported by a previous Japanese Antarctic Research Expedition, almost 25 years earlier. The earlier breakage was subsequently closed and the lake was refilled. At present, the surface area of the lake has

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decreased significantly due to the loss of water. Many of the neighboring valleys and lakes in the southern part of the Langhovde area contain well-developed colonies of algae, mosses, and lichens. By contrast, both Lake Hyoga Ike and the river below the snow dam contain very little flora. Such a contrast in the distribution and colonization of flora suggests that the repeated occurrence of physical disturbances, induced by breaching of the dam, may be a critical factor limiting flora in this ice-free region of Antarctica. We recommend long term observation of the fate of the ice cave and changes in the lake level for the purpose of evaluating climatic change and ecology. The observations also contribute to the maintenance of safety in the field works in this area.

1. Introduction

Physical disturbance is one of primary factors limiting the colonization and distribution of flora (algae, lichens, and mosses) on the Antarctic continent. For example, strong winds, freeze-thaw, and erosion occur commonly in Antarctica, and can lead to instability and slow the development of soil layers. Similarly, the movement of lake ice is known to disrupt the benthic assemblages that inhabit shallow lake beds. Sheltered areas, where physical disturbances are rare and the conditions for growth (*e.g*. light, water, and nutrients) are suitable, are scarce in Antarctica. Given this, the Antarctic terrestrial ecosystem is often regarded as one of the harshest on earth.

The Yukidori Valley (Antarctic Specially Protected Area No. 141) in the southern region of Langhovde on the Sôya Coast of East Antarctica contains a rich abundance and diversity of flora. In this area, colonies of mosses, lichens, and soil algae grow along a small stream and around Yukidori Ike, a kettle lake (Kanda, 1982). The water bodies in this valley are fed by melt water from a perennial snow patch located at the terminus of the Langhovde Glacier (Fig. 1). This area, and the adjacent ice-free region, is sometimes referred to as the 'Syowa Oasis'. A number of small valleys run parallel with the Yukidori Valley. Many of these valleys, with the exception of Yatude Zawa Valley, contain abundant plant colonies.

The Yatude Zawa Valley, a typical U-shaped valley, begins at the terminal of the Heitô Glacier (a branch of Langhovde Glacier), and runs north-west to the sea (*ca.* 4 km). The valley was likely created following glacial retreat after the last glacial maximum (Miura *et al.,* 1998). Historically a glacial lake (annually ice covered lake), Hyoga Ike (temporary name) was formed behind a snow dam in the upper section of the valley. The lake was long and narrow (approximately 1 km in length and 100 m in width), and was deep enough to hold liquid water in winter. The lake was fed *via* a small stream (approximately 200 m in length) originating at the terminal of Heitô Glacier. A large hole or a cave in the perennial snow dam was noted by the 47th Japanese Antarctic Research Expedition (JARE) in 2006. In 2007, the 48th JARE members reported that the lake's surface area had shrunk considerably. These observations suggest that the snow dam has been breached and that the lake is emptying. Prior to this event, Lake Hyoga Ike was part of a limnological survey evaluating the distribution of submerged algae and mosses (Imura *et al.,* 1999, 2003). During the 40th and the 45th JARE seasons (1999–2000, 2004–2005), JARE members surveyed the lake, but failed to collect samples of benthic flora or lithogenic sediments, instead, only small rocks were collected.

We surveyed the flora of the Yatude Zawa Valley in the summer season of the 49th JARE (Feb. 2008). We discuss the probable effect of disturbance events on the local flora.

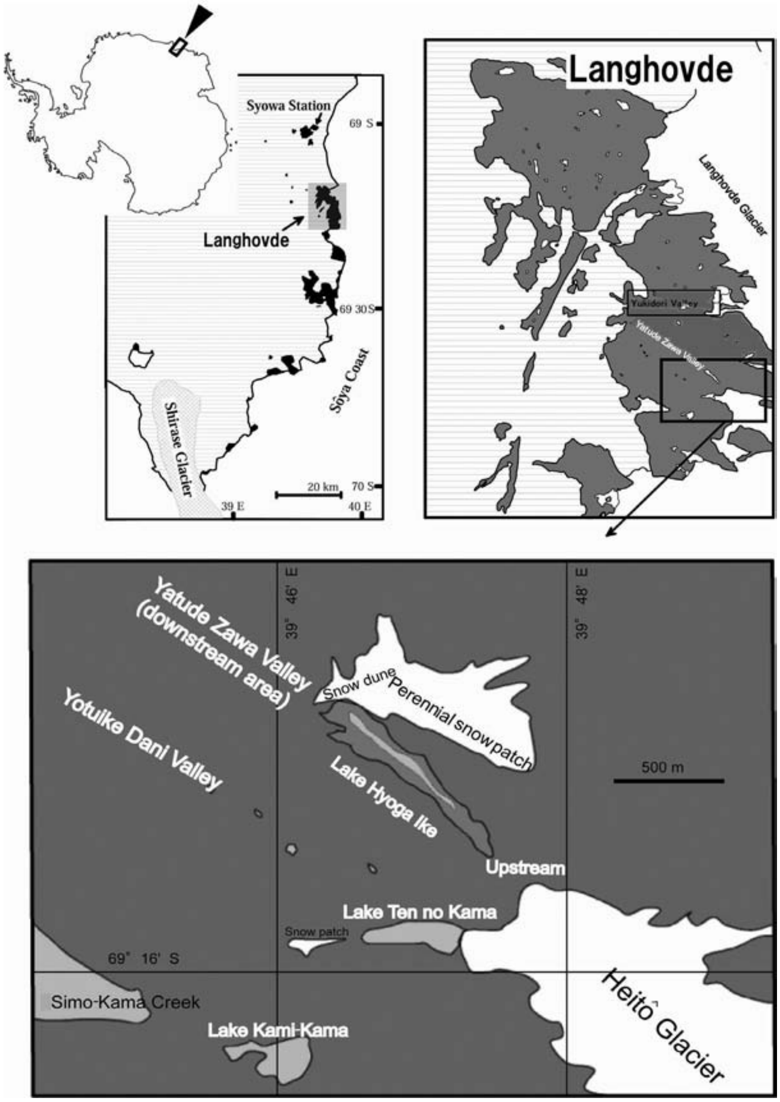


Fig. 1. Map of the study area. The past and present extent of Lake Hyoga Ike (temporary name) is indicated in the lower map by the solid line and light gray color, respectively.

2. Landscape description

2.1. Downstream, flat area

The majority of the river flows below the surface in this region, although the river is occasionally visible in areas with rough rocks. Where visible, the water surface was covered by thin ice during our visit on 2 February, 2008 (Fig. 2). However, the river still contained running water, which flowed into the sea from the river mouth. We did not find any large colonies of mosses or lichens in this region.

However, snow petrels, nesting in the surrounding hills, may supply nutrients for plant growth.

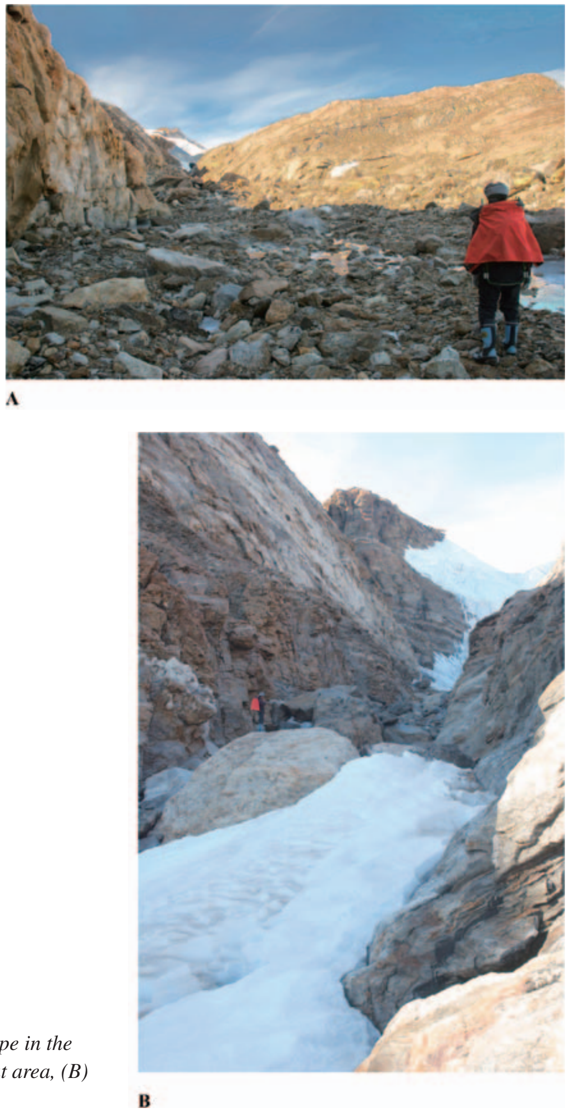


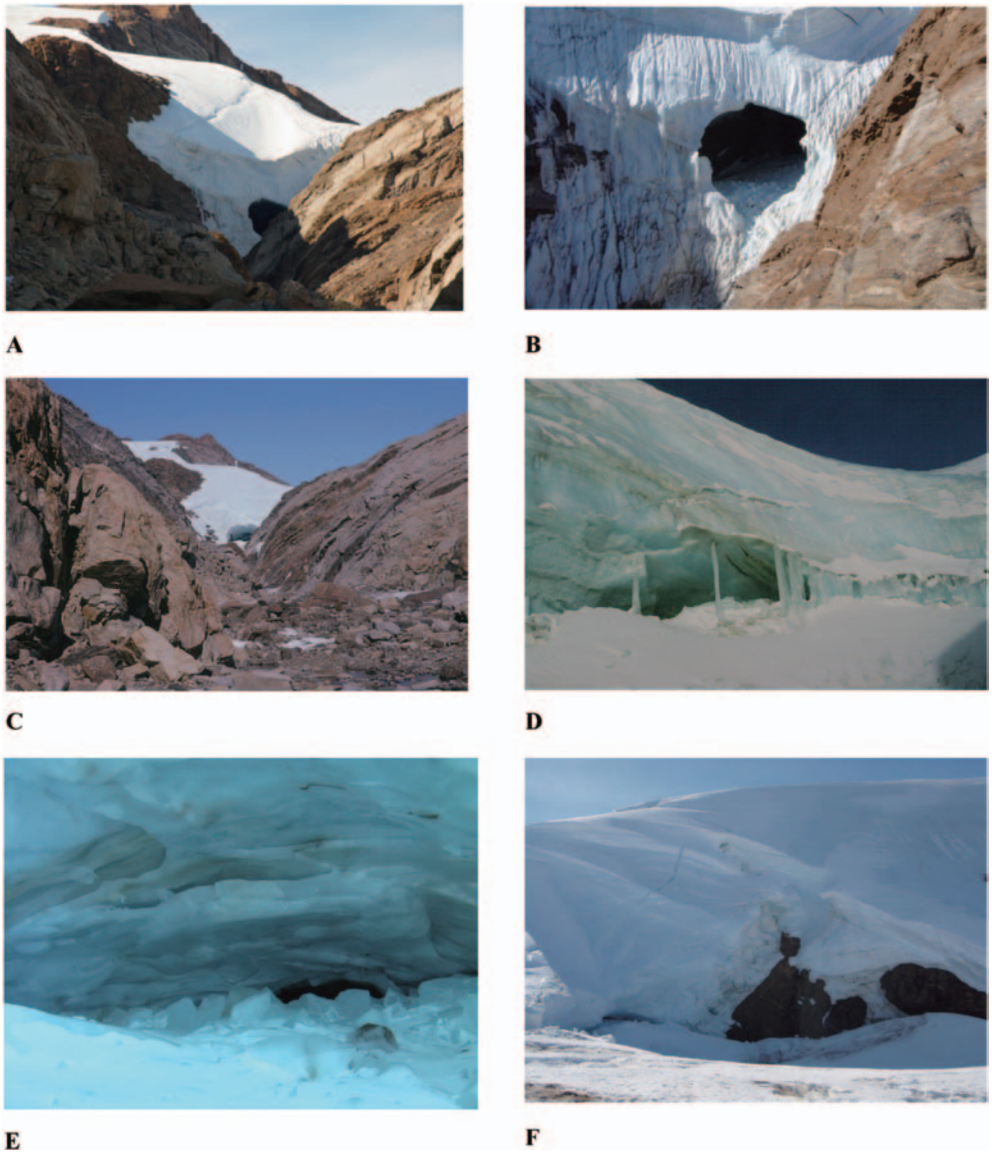
Fig. 2. Photograph of the landscape in the downstream areas. (A) Flat area, (B) V-shaped valley

2.2. The perennial snow dam

The initial break in the dam occurred almost 3 years prior to the current expedition. Despite this, a large circular mouth at the entrance to an ice cave remained visible approximately 1 km below the peak of the perennial snow dam (Fig. 3A). We did not find any water in the cave. However, many large ice lumps were observed, suggesting that the cave was beginning to collapse. The size of the cave mouth was estimated from the photographs to be approximately 15 m in diameter (Fig. 3B).

A similarly sized break in the snow dune was mentioned briefly by the 24th JARE summer party (Ohyama and Sano, 1984). This observation suggests that the snow dam has experienced breaks of a similar magnitude historically (Fig. 3C). Following the earlier break, more than the half of the cave mouth was buried by broken ice and snowdrift within five years (Fig. 3D). However, the exact timing of complete closure is unknown. Following closure, water passage was again blocked by the snow dune, and the lake was subsequently refilled.

A hemi-round shaped entrance was visible on the lake side of the cave. Inside the mouth, there was a chamber with approximately 50 m^2 of flat ice floor and approximately 3 m between the floor and



A B C D E F

Fig. 3. The hole in the face of the perennial snow dam, seen from approximately 1 km downstream (A) and from a cliff facing the snow dam (B) in 2008. Photographs of the previous ice cave, taken during the 24th (1984) (C) and 29th (1989) JARE (D). The ice cave entrance during the 48th (2007) (E) and 49th (2008) JARE (F).

ceiling. A vertical hole connected the cave entrance and exit (Fig. 3E). We observed cracks in the lid and ribs of the entrance. Furthermore, the presence of snowdrifts in front of the cave indicated that the cave was beginning to close (Fig. 3F).

2.3. Lake Hyoga Ike basin

Clear traces of the historic lake water level were observed on the surrounding wall of the northern hills (Fig. 4A). Based on photographic evidence, we estimate the difference in lake level between historic and current levels is approximately 3–5 m. During previous expeditions (the 40th and 45th JARE) the lake stored a significant quantity of water (Fig. 4B). Currently, Lake Hyoga Ike is little more than a river. Reddish or pink-colored rocks, which appeared to be compressed, were observed around the present lakeshore. Dried fragments of thin laminar bio-films were found among the rocks (Fig. 4C). The bio-film samples occasionally consisted of nearly ten layers of laminar (Fig. 4D). However, the exact number of layers could not be counted due to fragmentation of the films. The films contained microscopic traces of algae and bacteria.

2.4. Between the lake and Heitô Glacier

Very little vegetation was found in the downstream area and around the current lake shore.

Fig. 4. Photographs of the present extent of Lake Hyoga Ike (A), the historic lake area, taken from an aircraft in 2004 (B), the present lake shore (C), and biofilms taken from the former shallow lake bed site (present lake shore) (D).

Fig. 5. Well-developed colonies of lichens and mosses in the upstream area. (A) Thalli of Umbilicaria aprina and crustose lichen, Buellia frigida, on stones near the bank of the small stream. (B) Moss colonies and lichen encrusted Bryum sp. and Ceratodon sp.

However, soil algae and well developed colonies of mosses and lichens were distributed along the short stream in the upstream area (Fig. 5A, B). *Bryum pseudotriquetrum* and *Ceratodon purpureus* were the dominant mosses, while *Buellia frigida* and *Umbilicaria aprina* were the dominant lichens. The thalli of *U*. *aprina* were especially large, sometimes exceeding 10 cm in width, and were distributed along the river between the lake and the terminal of Heitô Glacier. Although lichens require water for growth they generally live in rather dry habitats, such as on rocks, soils, and mossy surfaces in the terrestrial environment of Antarctica. Lichens have never been observed growing fully submerged in an environment such as a lake. Given this, the areas where we observed well-developed lichens are unlikely to have been covered by water for some time. This suggests that the water in Hyoga Ike was drained before the lake inundated the lichen colonies due to the breaching of the snow dam noted during this expedition.

2.5. *Probable effects of disturbance due to frequent breaching of the snow dam*

We did not directly observe the flood event induced by breaching of the perennial snow dam. However, we believe that the force and magnitude of the event would be sufficient to prevent the distribution and colonization of slow-growing terrestrial flora in the downstream area. Furthermore, such events appear to be relatively frequent. The repeated and frequent loss of water from Lake Hyoga Ike is also likely to prevent colonization of laucustrine organisms, including the algal mats which are ubiquitous in many of the shallow lakes in Antarctica (Goldman *et al.,* 1963; Vincent *et al.,* 1993). Our hypothesis is supported by the lack of vegetation in the downstream area of Yatude Zawa Valley, and the failure to find benthic organisms in Lake Hyoga Ike during previous JARE expeditions.

Global warming is often associated with glacial retreat and acceleration of ice-sheet melting, etc (*e.g.* Sone *et al.,* 2007; Nghiem *et al.,* 2007). However, the event we describe is unlikely to be related to global warming. The lake is most likely repeatedly flushed when the mechanical tolerance limit of the snow dam is exceeded by overfilling of the lake. The exact frequency of this occurrence is unknown. Our observations suggest that it occurs with sufficient frequency to prevent the colonization of terrestrial and laucustrine vegetation around/within the lake and its downstream area. Sawagaki *et al.* (2008) also discuss the possibility of repeated flushing of lake water in the Yatude Zawa valley based on geomorphological evidence. Although such repeated catastrophic flooding may be a regular event, climatic warming may accelerate the frequency of these events.

We recommend long-term monitoring of the water level in the lake and the integrity of the snow dam. Such data will provide information regarding the effects of recent climatic change, and ensure the safety of researchers working in the Yatude Zawa Valley. The contrast in terrestrial vegetation along the stream in this valley provides an ideal model site for evaluating the effects of physical disturbances on the distribution and colonization of flora on the Antarctic continent. Furthermore, monitoring the re-establishment of laucustrine organisms in the lake bed would yield valuable information regarding the recolonization process of organisms in newly-created lake habitats.

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References

Goldman, C.R., Mason, D.T. and Wood, B.J.B. (1963): Light injury and inhibition in Antarctic freshwater phytoplankton. Limnol. Oceanogr., **8**, 313–322.

Imura, S., Bando, T., Saito, S., Seto, K. and Kanda, H. (1999): Benthic moss pillars in Antarctic lakes. Polar Biol., **22**, 137-140.

Imura, S., Bando, T., Seto, K., Ohtani, S., Kudoh, S. and Kanda, H. (2003): Distribution of aquatic mosses in the Sôya Coast region, East Antarctica. Polar Biosci., **16**, 1–10.

Kanda, H. (1982): 3.4. Sentai-rui. Nankyoku no Kagaku, 7. Seibutsu, Natl Inst. Polar Res., Tokyo, Kokonshoin, 219-246 (in Japanese).

Miura, H., Maemoku, H., Igarashi, A. and Moriwaki, K. (1998): Late quaternary raised beach deposits and radiocarbon dates of marine fossils around Lützow-Holm Bay, with explanatory text. Spec. Map Ser. Natl Inst. Polar Res. No. 6, Tokyo, 46 p.

Nghiem, S.V., Steffen, K., Neumann, G. and Huff, R. (2007): Snow accumulation and snowmelt monitoring in Greenland and Antarctica. Dynamic Planet: Monitoring and Understanding a Dynamic Planet with Geodetic and Oceanographic Tools: IAG Symposium, Australia, August, 2005, ed. by C. Rizos and P. Tregoning. Berlin, Springer, 31–38 (International Association of Geodesy Symposia, 130).

Ohyama, Y. and Sano, M. (1984): Dai24ji Nankyoku kansoku natsutai hôkoku. Kyokuchi (Polar News), **19** (2), 24–34 (in Japanease).

Sawagaki, T., Miura, H. and Iwasaki, S. (2008): Discovery of an ice cave in the Yatude Valley, Langhovde, Dronning Maud Land, East Antarctica. Polar Sci., **2**, 287–294.

Sone, T., Fukui, K., Strelin, J.A., Torielli, C.A. and Mori, J. (2007): Glacier lake outburst flood on James Ross Island, Antarctic Peninsula region. Polish Polar Research, **28**, 3–12.

Vincent, W.F., Downes, M.T., Castenholz, R.W. and Howard-Williams, C. (1993): Community structure and pigment organization of cyanobacteria-dominated microbial mats in Antarctica. Eur. J. Phycol., **28**, 213–221.