Response to Review 2; Kas' glaciar paper

General comments. The effects of ice-marginal lakes are a topical and emerging area of research. Due to the scarcity of glacial lake observations, the authors make a strong case for investigating physical lake properties and their impacts on ice mass loss. This is a nicely designed and detailed study which reports a holistic analysis of lake temperature, calving events, lake bathymetry and calving front geometry from an ice-marginal lake in Arctic Sweden from several time periods within the last decade. This work provides an interesting and valuable dataset but perhaps the novelty could be teased out a little more (see specific comments). Overall, the manuscript is well-written. I suggest mostly minor corrections which I expect can be addressed very easily. These suggestions are merely intended to help tighten up the precision of the text, but otherwise I support it's publication.

Authors response; Thank you for the detailed and carefully considered review of the manuscript. The synthesis and composition of several field seasons at an unstudied remote field site has been somewhat challenging and all comments are greatly appreciated. We will carefully revise the manuscript in light of these and greatly appreciate the suggested improvements.

Specific comments. I understand the value of the study, so I focus my review on the data and the methods. A small concern is how lake temperature is reported. The authors state that temperatures of >4 $_{\circ}$C are 'warmer than expected'. But what constitutes as 'warm'? Where has this assumption come from, given that given that the same authors in Dye et al. (2021) also find 'warm' lake temperatures (albeit from satellite analysis), and similar temperatures have been reported elsewhere (as is stated in the introduction (line 33). Perhaps the authors could frame their objectives more explicitly to test a hypothesis between what they 'expect' from their own previous analyses vs uniform temperatures of 1 $_{\circ}$C reported in the literature?

Authors response; We greatly appreciate the support of the value of the study. The uniform 1^{o}C assumption comes from Truffer and Motyka (2016) – we shall review this statement in the Introduction and put it more clearly in context with other studies;

"Whilst previous studies have assumed small proglacial lakes to be a uniform 1^{o}C (Truffer and Motyka, 2016), proglacial lake temperatures of >4 ^{o}C have been reported in Nepal, New Zealand, Patagonia and Arctic Sweden (Kirkbride and Warren 2003; Sugiyama et al., 2016; Watson et al., 2020; Dye et al., 2021)."

I think it needs to be acknowledged more clearly that these 'warm' temperatures have been measured at just one single point in the lake and over a short time period (~6 weeks). Given this limitation, it is a shame that stratification/mixing can't be considered. It seems a relatively shallow lake, so some inferences could be made between both the *depths and* temperatures of other lakes that have been recorded before making direct comparisons.

Authors response; A very prescient point. We chose to just present data from the ice front for 2019 for simplicity, as we felt this highly likely to be the coldest point across the lake at the time and also the most pertinent with regard to ice melt. We have also presented temperature readings of 3.5^{o}C from ~20m depth 8th August 2019 in the supplementary (S3) – so we believe the lake to have been well mixed at this time.

We also have in situ lake temperature data for 2017 and 2022 – but felt this would potentially overcomplicate the manuscript (possibly best published in a more limnology focused paper?). Summaries of this are;

- 2017 – temperature gradient across lake in July (3 C at front, 8 C at distal end) – rainfall event mixed the lake to uniform 3.5 C.
- 2022 – lake had already mixed to uniform 3 C by 10th July. Max temperature reading ~4 C.

Some other thoughts are that the stage of lake evolution is important and could be commented on. When did the lake form? As the glacier begins to retreat out of its basin it could be that lake temperature has less of an effect on calving and ice dynamics.

Authors response; Yes another very pertinent point (I have a lot of thoughts on this but need several glaciers to demonstrate it on). We shall add/expand comments to '2. Study Area' section line 67 – with reference to the mapping from 1959 in Dye et al. (2022).

Technical corrections.

Line 19. 'Scandinavian proglacial lake'/ 'Arctic Sweden'. Ensure consistency with terminology throughout if you can.

Authors comments; Thanks we shall review this.

L21-24. Last sentence of abstract reads more as rationale rather as wider implications, I would make it more specific to the study or move higher up in the abstract.

Authors comments; Excellent point – we shall move this to the second sentence of the abstract.

L30. Can these citations be placed next to each location rather than grouped at the end of the sentence?

Authors comments; Yes I think this would be more useful.

L31. There are 6 instances of Roehl et al. (2006), I think it should be Röhl (2006).

Authors comments; Thanks we shall review this.

L35. Could you explain more explicitly how thermal notches promote ice berg calving

Authors comments; Thanks we shall amend this to;

" High subaqueous melt rates remove mass from the glacier terminus and cause thermal undercutting (producing thermal notches) that promotes iceberg calving *through failure of overhanging subaerial ice cliffs* (Iken, 1977; Warren and Kirkbride, 2003; Roehl et al., 2006).

L38 – 'Such high subaqueous melt rates remove ice from the terminus' – this is repeated from line 34 so I would move this explanation higher up and rephrase

Authors comments; Thanks we shall amend this to;

"Proglacial lake temperatures have been found to control seasonal ice front position in Patagonia and terminus morphology in New Zealand, where rapid (0.65 cm d^{-1}) thermal notch development has led to substantial undercutting of glacier termini (Minowa et al., 2017; Roehl et al, 2006). *Such thermal undercutting* alters the stress balance at the ice front, as support is removed from the subaerial ice front so stresses increase within the ice, which may either fracture above the overhang (calving icebergs) or develop crevasses parallel to the ice front (Iken, 1977)."

L45. Do you mean downstream temperatures?

Authors comments; Yes

L48. I would argue there has been quite a bit of attention recently

Authors comments; We feel that in proportion to the size and number of glacial lakes across the Arctic there has been relatively little attention focusing on case study scale glacial-lake interlinkages – Mallalieu's work in Greenland, Carrivick's work in W Greenland, some small studies in Norway. Beyond that are mostly regional based (mostly remote sensing?) studies in Greenland and Novaya Zemlya. I've had a quick search, but couldn't find anything further but may have missed something – please let us know if we have missed some studies!

We could amend line 48 to;

'To date *there have been few processed based field studies at* proglacial lakes *in the Arctic*, despite being associated with enhanced glacier retreat rates around the Greenland Ice sheet and Novaya Zemlya (MacIntyre et al., 2009; Carr et al., 2017; Carrivick and Quincey 2014; Carrivick et al., 2017; Mallalieu et al., 2021; Carrivick et al., 2022).'

L65. ~2,000 m – add a.s.l.

Authors comments; Thanks we shall amend this.

L68. ~1916 – add CE

Authors comments; Thanks we shall amend this.

L70. Could you add a few more specifics about the study site, e.g. does the lake free over in winter? Is there a lake outlet?

Authors comments; Thanks we shall amend line 66;

"KGL is situated at 1,100 m a.s.l. and was 670 m long, with a surface area of 0.13 km^2 in August 2014 *with an outlet at the northernmost point and freezes over during winter* (Dye et al., 2022)."

L102. Was any post-processing software used for the sonar data, and did you post-process this data yourselves?

Authors comments; Thanks for identifying this oversight, we shall add to line 102;

'The side view sonar images were viewed and trimmed in SonarTRX software before being exported to QGIS.'

L146. I think this is the first time an englacial conduit is mentioned so it came a little surprised. Perhaps you could introduce it in the study site section?

Authors comments; Thanks we shall amend this and add the following sentence at the end of the study area section;

'At the start of fieldwork in 2017 the glacier termini was observed to have two englacial conduits at lake level, that became active most afternoons as demonstrated by export of icebergs.'

L151. A more extensive survey grid next to the glacier revealed the shallow (margins of the lake to be relatively limited, extending out <10 m from the eastern shore… - what do you mean by this?

Authors comments; Thanks for the clarification we shall amend this to;

'A more extensive survey grid next to the glacier revealed *the western margin of the lake has a shallower (<5m) shelf extending ~50m from shore, whereas the eastern margin deepens (>5m) steeply within 10m of the shore (Supplementary S1).'*

L170. Is 'cave' a commonly used term to describe ice geometry in this way?

Authors comments; Interesting point. We weren't sure of the best terminology here, but 'cave' seemed fitting where; depth>height (for large undercut features). Where depth<height we refer to arches. We are open to suggestions on this and will revisit How et al. (2019). We shall also consider defining these features in the Methodology.

L187. 'Removal of the glacier ice surface (down to lake level) was between 0 to 23 m from removal of ice from the 2015 terminus extent (Fig. 4a).' – I'm not sure I follow this? Would suggest rephrasing.

Authors comments; Apologies for that. This section has been very tricky to get right and we will delete the sentence on line 187 and amend it some more to;

"The area of ice removed from the terminus since 2015 is represented by the pink polygon (Fig.4), some of this ice was relatively close to the lake water level (0 m; Fig.4) whilst sections near the central part of the 2019 terminus were ~23m above lake level."

L217. 'metres across' - I would rephrase to 'meters wide' instead

Authors comments; Thanks. Shall do.

L377. You could also add the following citation in here: Carrivick, J. L., Smith, M. W., Sutherland, J. L., & Grimes, M. (2023). Cooling glaciers in a warming climate since the Little Ice Age at Qaanaaq, northwest Kalaallit Nunaat (Greenland). *Earth Surface Processes and Landforms*, *48*(13), 2446-2462.

Authors comments; Thanks! I hadn't seen that paper, which looks to be a very interesting and pertinent read! Reference added.

L392. I'm not sure how you can constrain melt rates from side scan sonar data?

Authors comments; Excellent point. One that I am hopefully going to continue to develop – I would rather not expand on it here though if possible? We can remove the statement if needed.

L402. I would reiterate again that several studies of 'warm' lake temperatures have been reported elsewhere and cite these studies (Himalaya, New Zealand etc).

Authors comments; We agree and will add the following sentence;

"Further adding to studies documenting warm (>4 C) proglacial lakes in other regions of the world (Kirkbride and Warren 2003; Röhl, 2006; Sugiyama et al., 2016; Watson et al., 2020)."

Figures.

Figure 1. an inset map to panel (a) might be useful

Authors comments; Thank you for the suggestion, but we feel the extent of inset (a) and the grid lines are sufficient to give the location.

Figure 2. It is obvious but could you add an x-axis label (time/years)

Authors comments; Yes we can.

Figure 5. could directional arrows be placed on the photograph e.g. orientation photograph was taken from or is looking towards.

Authors comments; Thanks for the excellent suggestion. We can amend the caption to link in more with Fig. 1;

“Figure 5. Images *(looking southwest) from eastern timelapse camera location (Fig. 1)* of calving activity at the glacier terminus in summer 2017.”

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References

Truffer, M. and Motyka, R.J., 2016. Where glaciers meet water: Subaqueous melt and its relevance to glaciers in various settings. *Reviews of Geophysics*, *54*(1), pp.220-239.