

Author's response to Reviewer 1

We would like to thank Reviewer 1 for the constructive and insightful comments, which have significantly helped us refine the manuscript. We have addressed all suggestions, particularly regarding the formal definition of PMLs, the framing of our ecological hypotheses, and the comparison of glacier retreat data.

1. Definition and Placement of PML Concept

We fully agree that an earlier definition is essential. We have moved the structural definition and geomorphological criteria of Paraglacial Moraine Lagoons (PMLs) from the Discussion to the Introduction. We now explicitly define PMLs as coastal water bodies separated from the open sea by barriers primarily composed of former push or terminal moraines, often ice-cored, deposited during recent glacier retreat. This distinguishes them from deltaic or wave-built systems. We have also clarified that while these features originate in proglacial zones, their classification depends on the moraine barrier's presence, regardless of the current proximity of the glacier terminus.

We appreciate critique in 5.3 on Geoecology. We have removed the speculative biological claims from the Discussion to maintain the manuscript's geomorphological focus. As suggested, we have created a new section (5.5 Perspectives and Future Research) where we frame the potential of PMLs as ecological refugia as a central hypothesis for future interdisciplinary study. Section "5.3 Potential for Geoecological Shifts" now focuses strictly on the physical shifts in habitat—specifically the transition from high-energy open coasts to sheltered, low-energy basins—that occur as a direct result of barrier formation.

Updated Section 5.3 Potential for Geoecological Shifts

The following section has been changed to address the Reviewer's geoecological suggestion.

"The formation of PMLs introduces a fundamental shift in the physical energy of the nearshore environment. By establishing a moraine barrier, these systems transform high-energy, wave-dominated open coasts into sheltered, low-energy basins. This transition significantly alters the physical template available for colonization. In Svalbard, such sheltered conditions are typically associated with increased retention of fine-grained sediments and organic matter, which are otherwise flushed into the deeper fjord (Kavan and Strzelecki, 2023). While the temporal window of PMLs is transient, the immediate transition from a glacial terminus to a sheltered lagoon creates a unique brackish-water habitat. These geomorphological changes suggest that PMLs may function as temporary biodiversity centres, though empirical evidence regarding the specific rate of benthic species establishment or the role of these lagoons as stopover sites for migrating fauna remains to be gathered."

Updated Section 5.5: Perspectives and Future Research

The following section has been added to the end of the Discussion to address the Reviewer's suggestion for a future-oriented framing of the ecological and physical uncertainties:

"The identification of Paraglacial Moraine Lagoons (PMLs) as a distinct landform category opens several new avenues for Arctic coastal research. Because these features represent a transient state in the paraglacial landscape cycle, their future evolution will likely serve as a high-resolution indicator of the pace of Arctic coastal

reorganization. However, fully decoding the role of PMLs in the changing Arctic requires a shift toward integrated, interdisciplinary studies that bridge the gap between geomorphology, cryospheric science, and marine ecology:

A critical uncertainty remains regarding the internal structure of PML barriers, necessitating collaboration between geomorphologists and geophysicists. Since many terminal moraines in Svalbard are known to be ice-cored, rising Arctic temperatures may trigger internal degradation through thermo-erosion and settlement. This could lead to catastrophic barrier failure and breaching, independent of surface wave action. Future research utilizing Ground Penetrating Radar (GPR) or electrical resistivity tomography is needed to quantify the volume of ground ice within these barriers and predict their vulnerability to sudden structural collapse.

The function of these basins as low-energy traps suggests a major opportunity for paleoenvironmental reconstruction. PMLs likely contain undisturbed, high-resolution sedimentary records of post-Little Ice Age environmental change that are often erased on high-energy open coasts. Extracting these site-specific insights into past glacier retreat and meltwater fluctuations requires an interdisciplinary approach combining sedimentology with biogeochemical investigations to quantify the potential for these lagoons to sequester terrestrial organic carbon before it reaches the deep ocean.

The physical transition from high-energy open coasts to sheltered, brackish-water basins create a unique template for colonization, raising a fundamental question for marine biologists regarding the successional window of these systems. It remains unknown if the transient lifespan of a PML—often only decades to a few centuries—is sufficient for the establishment of stable benthic communities and mature food webs. Interdisciplinary efforts are required to investigate whether these lagoons provide critical refugia for species moving northward due to "atlantification," or if their rapid geomorphological evolution makes them too ephemeral for successful biological succession.

Finally, large-scale climate and oceanographic models must account for the geomorphological "pause" created by PML formation. By trapping coarse glaciogenic material that would otherwise be lost to the shelf or deep sea, PMLs fundamentally alter the sediment budget of glaciated coasts. Integrating these landforms into regional sediment transport models is essential for coastal managers and oceanographers to avoid miscalculating the volume of material delivered from land to sea in a warming Arctic.”

Reviewer Specific comments

RC1: Figures 2–7:

While I understand the authors' intention to show detailed landscape and lagoon-size changes, these figures are somewhat repetitive. It may be more effective to combine them into a single multi-panel figure (a, b, c, etc.). This would also benefit the reader by allowing easier comparison across sites.

Response: Thank you for this comment. The convention we have adopted for this section is to present a fragment of text followed with a corresponding illustration. We would like it to stay that way.

RC1: Figure 8:

Please include the orthophoto date from NPI (presumably 2010?).

Response: Thank you for this comment. We added information about the dates. A, B, E – 2010; C, D – 2011; F, G, H - 2009 .

RC1: Figure 12:

It is not immediately clear from the figure what distinguishes panels E and F. Including the explanation from line 398 in the caption would improve clarity.

Response: Thank you for your comment. To clarify the differences between the stages, we have added descriptions for each stage directly onto the graph.

RC1: Table 4:

Revise the caption to define EPR and NSM. I had to refer back in the text for clarification; including this information in the caption would improve readability.

Response: Thank you for pointing that out. We added the information about EPR (End Point Rate) and NSM (Net Shoreline Movement) in the caption of the figure.

RC1: Table 5:

Consider merging this dataset with another table (e.g., Table 1) to reduce the total number of tables. Additionally, the terms “leaky” and “choked” should be explicitly defined. While their meaning can be inferred, a clear explanation is preferable. Since “leaky” is also used in line 272, a definition is necessary.

Response: Thank you for your suggestion. However, we decided that presenting this data in a separate table would be better. Please note that each table presents different data; therefore, combining data on the lagoon’s openness with, for example, its surface area would break with established convention. We have added an explanation regarding the morphological types of lagoons, “Temporal changes in lagoon openness. Closed – a closed lagoon, with only a temporary connection to the sea; choked – single-inlet lagoons; restricted – two-inlet lagoons; leaky – lagoon with three or more inlets (Kjervfe, 1994)”.

Line-specific comments

RC1: Lines 32–33: Include a quantitative estimate of Arctic warming, rather than stating “four times” alone.

Response: Thank you for your feedback. However, we have determined that this term better captures the nature of Arctic amplification. For more information, readers are referred to the relevant literature.

RC1: Line 49: Add a date for the end of the LIA in Svalbard for clarity.

Response: Thank you for noticing this. We have added the information that the end of the Little Ice Age in Svalbard is dated to the early 20th century.

RC1: Lines 50–55: This section is unclear—does it refer to one surge event or multiple (e.g., one earlier and another in 2019–2020)? Please clarify.

Response: Thank you for pointing out this ambiguity. We have revised this paragraph to clearly distinguish between two separate historical episodes of glacier advance and their contrasting impacts on the lagoon's morphology. The first event refers to the historical glacier surge (early 20th century) that originally formed the lagoon by creating a natural barrier, as documented by Zagórski et al. (2012). The second event refers to the recent

2019–2020 surge/readvance of Recherchebreen, which led to rapid delta growth and a subsequent reduction in the lagoon's surface area, as documented by Kavan et al. (2024).

Now, in the text, it states “The initial development of the paraglacial lagoon – Recherche Laguna – was documented by Zagórski et al. (2012) and was associated with a rapid glacier surge that created a natural dam from emerging deltas, enabling the rapid establishment of a water body at the glacier front. Decades later, following a new surge and the readvance of the marine-terminating Recherchebreen between 2019 and 2020, the formation of a massive delta was observed once again in front of the glacier meltwater outlet, this time significantly reducing the lagoon’s surface area (Kavan et al., 2024)“.

RC1: Line 65: Define GLOF and LGM in full before using abbreviations. (Agreed: PML is a better abbreviation than MCPALS.)

Response: Thank you for pointing that out. However, we have revised the text, and the abbreviations no longer appear in this section. The new text is as follows: “Although the preliminary concept of these landforms was introduced previously under different terminology (Owczarek, 2025 – MCPALS from moraine-controlled paraglacial lagoon systems), we now advocate adopting PML as the standard geomorphological nomenclature”.

RC1: Line 89: See general comment regarding the definition of PMLs.

Response: Thank you for this comment. We have refined the definition of PML. The exact change is described above.

RC1: Line 116: Why were both ArcGIS and QGIS used? Could the workflow be completed within a single GIS platform?

Response: The two GIS software programmes were used solely because the team members prefer different programmes. However, all the analyses can be carried out using a single programme.

RC1: Line 118: A note: manual vectorization can sometimes yield higher accuracy, as the operator is more aware of precision requirements.

Response: Thank you for this note, we appreciate it. We also believe that manual vectorisation has its advantages, although it is, unfortunately, time-consuming.

RC1: Lines 185–188: The stated average recession rates – can these be compared with values from other studies or empirical datasets for the same sites?

Response: Thank you for this valuable suggestion. While a single, unified database tracking long-term coastal glacier recession specifically for all fourteen of our studied lagoon sites does not exist, we have cross-referenced our calculated retreat rates with broader regional glacier inventories (Li et al., 2025) and published site-specific studies to validate our findings.

Our calculations show good agreement with available literature. For instance, our data for Eidembreen (a calculated total retreat of over 3.1 km since 1936) closely aligns with the independent findings of Šiaulys et al. (2026), who noted a landward retreat of approximately 3 km between 1936 and 2023. On a regional scale, the high retreat rates we quantified for major systems like Deltabreen (75.5 m per year) and Eidembreen (36.1 m per year)

are entirely consistent with the accelerated multi-decadal frontal recession rates and mass loss trends documented across the Svalbard archipelago by Geyman et al. (2022) and the historical datasets maintained by the Norwegian Polar Institute (NPI).

The following section has been changed to address the Reviewer's suggestion "The glaciers' retreat associated with PMLs exhibits notable spatial and temporal variability across Svalbard (Tables 2 and 3). Overall, every studied system is linked to a retreating glacier, with average recession rates ranging from $7.6 \text{ m}\cdot\text{yr}^{-1}$ to over $75 \text{ m}\cdot\text{yr}^{-1}$ (Table 2). Changes in PMLs are primarily a consequence of melting glaciers. In this case, the greatest change was observed in Deltabreen – the glacier connected to Tjuvfjordlaguna. Over the course of 88 years, the glacier retreated inland by more than 6.6 km (at a rate of approx. $75 \text{ m}\cdot\text{yr}^{-1}$). During the most recent interval (2010–2024), Deltabreen also exhibited the greatest recession, retreating by approximately 1.7 km, followed by Eidembreen at 0.85 km. Both glaciers demonstrated relatively consistent retreat rates throughout the entire study period. In contrast, Makarobreen, Makarovlaguna's (Fig. 7) "parent" glacier, showed a notable deceleration. Despite previous retreat magnitudes ranging from 0.282 km to 0.589 km per period (0.484 km between 1936 and 1960, 0.589 km between 1960 and 1990, and 0.282 km between 1990 and 2010), its margin remained nearly stationary between 2010 and 2024, with a negligible shift of only 0.002 km.

These rates are broadly consistent with previously published values for comparable glaciers, although glacier-specific retreat estimates for the individual systems studied here are largely absent from the literature, so comparisons are necessarily drawn at the scale of regionally and morphologically analogous glaciers. The closest analogue is the work of (Kavan et al., 2022), who examined 11 tidewater glaciers along the south-east coast of Spitsbergen using a 1970 DEM combined with recent ArcticDEM and Landsat/Sentinel-2 imagery, and reported an average frontal retreat rate of $48 \text{ m}\cdot\text{yr}^{-1}$ (range $10\text{--}150 \text{ m}\cdot\text{yr}^{-1}$), with four of the eleven glaciers becoming land-based as their termini retreated. Our values fall squarely within this published range: the lower end of our dataset ($7.6 \text{ m}\cdot\text{yr}^{-1}$) corresponds to typical land-terminating behaviour, while Deltabreen's $\sim 75 \text{ m}\cdot\text{yr}^{-1}$ lies within the upper-middle of the tidewater range. This is also in line with the glacier-type typology of Rachlewicz et al. (2007), who distinguished land-terminating glaciers receding at roughly $5\text{--}15 \text{ m}\cdot\text{yr}^{-1}$, non-surging tidewater glaciers at about $15\text{--}70 \text{ m}\cdot\text{yr}^{-1}$, and surging tidewater glaciers reaching $100\text{--}220 \text{ m}\cdot\text{yr}^{-1}$. More broadly, our findings support the regional picture in which eastern Svalbard has experienced some of the most pronounced ice loss in the archipelago: the Edgeøya ice field has shown the largest retreat rates of all Svalbard glaciers over recent decades (Nuth et al., 2013), and since the Little Ice Age, glaciers on Barentsøya and Edgeøya have lost 16.7% of their area – the highest proportional loss among the main islands of the archipelago (Martín-Moreno et al., 2017).

Differences between our rates and previously published values can be attributed to several factors. First, methodological and temporal differences are important: our long-term rates are centreline recession distances averaged over an 88-year, multi-epoch baseline (1936–2024), whereas satellite-era studies such as Li et al. (2025), who resolved calving-front change across the Barentsøya – Edgeøya sector, derive shorter-interval, calving-front rates that are more sensitive to seasonal and interannual variability; averaging over different epochs and reference baselines inevitably yields divergent values. Second, glacier dynamics play a role, as eastern Svalbard is one of the principal clusters of surge-type glaciers, and terminus advances during surges have historically punctuated the general post-LIA retreat in this region; the near-stationary margin of Makarobreen between 2010 and 2024 is consistent with a post-surge quiescent phase rather than a simple climatic deceleration. Third, and most likely for the decelerating systems, the transition from a marine- to a land-terminating configuration removes the calving

and submarine-melt component that drives rapid tidewater retreat; once a terminus grounds in shallower water or on land, retreat tends to slow, a mechanism invoked to explain the eventual stabilisation of retreating Svalbard tidewater glaciers (Li et al., 2025), and this paraglacial transition is itself the process generating the new coastal lagoons examined here (Kavan and Strzelecki, 2023). Finally, local controls – bed slope and overdeepening, water depth at the grounding line, aspect, and hypsometry – produce substantial inter-glacier variability superimposed on the regional climatic signal (Małecki, 2013; Rachlewicz et al., 2007).”

RC1: Lines 346–347: The point about the absence of PMLs in models is valid. However, given their transient nature, it would be useful to assess how significant their omission is. This section would benefit from a more rigorous discussion.

Response: Thank you for this suggestion. However, we consider the analysis we have presented to be sufficient. In that section, we highlighted the role of the PML in the paraglacial sedimentary cascade as a sedimentary reservoir. We also pointed out that this mechanism disrupts the standard transport of water and sediments from land directly to the sea, which stands in opposition to the generally accepted model of Arctic coast functioning, which assumes direct transport of water and sediments to the sea.

RC1: Line 371: Why focus specifically on the LIA? The conceptual diagram could represent any time slice during which glacier advance occurs.

Response: Thank you for this comment. Our framework is based on specific data and forms from the LIA; therefore, the LIA is a natural point of reference for us in creating a conceptual model for PML development.

RC1: Line 367: The framework relies heavily on a single citation (Ballantyne, 2002). Additional relevant references should be incorporated throughout.

Response: Thank you for this suggestion. We updated the text with the appropriate references “Their buffering role aligns with paraglacial slope readjustment and sediment redistribution after glacier retreat (Ballantyne, 2002; Zagórski et al., 2012; Strzelecki et al., 2020; Kavan et al., 2024)”.

RC1: Line 400: The authors correctly note that glacier re-advances (e.g., during the LIA) can destroy lagoons. However, glacier surges—common in Svalbard—can have similar effects. This process should be included and considered throughout the paper.

Response: Thank you for pointing that out. We consider glacier surge to be just one example of the glacier re-advance, which is shown in the diagram as point G. We have added information about the surge to the text to make it clearer. “However, glacier re-advances (also glacial surge) can destroy lagoons, as likely occurred during LIA glacier expansions (Fig. 12G).”

Author's response to Reviewer 2

We would like to thank Reviewer 2 for their positive evaluation of the manuscript and for recognizing the value of our multi-decadal dataset and the proposed evolutionary pathways for PMLs. We are particularly encouraged that the reviewer finds the study timely and scientifically sound. In response to the reviewer's overarching concerns, we have undertaken a comprehensive revision of the manuscript:

We have revised the Introduction and Discussion to more clearly define the structural and genetic criteria that distinguish Paraglacial Moraine Lagoons (PMLs) from standard Arctic lagoons (e.g., those sheltered by deltaic or wave-built sandy barriers). We have emphasized that the novelty lies in the moraine-core foundation, which dictates a unique set of morphodynamics and a distinct paraglacial lifespan.

We have refined our analysis in Section 4 to ensure that our interpretations of shoreline change (DSAS) and glacier retreat are more explicitly linked to the underlying data, avoiding over-generalization where local factors (e.g., bathymetry) play a dominant role.

Following the reviewer's guidance, we have expanded the Discussion to include a more nuanced look at the role of these lagoons as sedimentary buffers. We have also added a new section (5.5 Perspectives and Future Research) to address the interdisciplinary implications of our findings, which we believe adds the depth and "broader impact" requested.

We believe these refinements have significantly strengthened the manuscript's scientific narrative.

Reviewer Specific Comments

Conceptual clarity. The introduction of PMLs is a key contribution, but the definition remains somewhat broad.

The manuscript would benefit from:

- a clearer diagnostic definition (criteria for classification),
- a stronger distinction from other lagoon types (e.g. deltaic or moraine-dammed systems),
- a more cautious framing of PMLs as a "formalized" rather than entirely "new" landform type.

Response: We appreciate the Reviewer's guidance on the conceptual framing of the PML term. We agree that "formalizing" the nomenclature of an existing but under-described phenomenon is a more scientifically accurate approach than claiming the discovery of an entirely "new" landform.

To address these points, we have revised the manuscript as follows:

We have added a specific set of classification criteria in Section 1 (Introduction) and Section 3 (Methods). To be classified as a PML in this study, a system must meet three criteria: (1) its seaward barrier must be primarily composed of landforms of glacial origin (terminal or lateral moraines); (2) the basin must have been formed as a direct result of post-LIA glacier retreat; and (3) the moraine must remain the dominant control on the lagoon's hydrodynamics.

We have strengthened the distinction between PMLs and other common systems. Unlike deltaic lagoons (governed by fluvial sediment flux) or spit-governed lagoons (governed by longshore drift), the stability of a PML is dictated by the mechanical and thermal properties of the moraine itself (e.g., ice-core presence). We also clarify the difference from moraine-dammed proglacial lakes, which lack marine connectivity and tidal exchange.

Throughout the text, we have shifted the language from a "new" landform to a "formalized landform category." This acknowledges that while these features have long been observed, they have lacked a standardized geomorphological definition and a systematic analysis of their unique evolutionary trajectories.

RC2: Interpretation of ecological and sedimentary roles

Statements regarding PMLs as biodiversity hubs and sediment/carbon sinks are interesting but appear somewhat speculative based on the data presented. These claims should be either softened or more clearly framed as hypotheses for future research, and, where possible, supported by relevant recent studies on Svalbard lagoons.

Response: Thank you for the suggestion which was also expressed by the Reviewer 1. We agree that our discussion of geoecology was speculative in the absence of direct biological sampling. We have followed the suggestion to move the more exploratory and speculative aspects of this discussion to the new "5.5 Perspectives and Future Research" section at the end of the paper. There, we frame the potential of PMLs as ecological refugia as a key hypothesis for future interdisciplinary studies. We have significantly shortened Section 5.3 now entitled "Potential for Geoecological Shifts" in the Discussion, focusing strictly on the physical shifts in habitat—such as the creation of low-energy, brackish environments—that occur as a direct geomorphological consequence of moraine-barrier formation.

RC2: Results

The Results section is strong and represents one of the main strengths of the paper. The quantified expansion of lagoon area and the clear documentation of morphodynamic variability are particularly convincing. Some descriptive parts could be slightly shortened.

Response: Thank you for the comment. We have shortened the descriptions in this section in a few places.

RC2: The Discussion would benefit from:

- stronger synthesis (clear hierarchy of controlling processes),
- reduced repetition of Results,
- broader contextualisation (e.g. relevance to other Arctic regions),
- tighter integration of the conceptual model.

Response: Thank you for these constructive suggestions to improve the depth and structure of our Discussion. We have revised the text to ensure a more robust synthesis and broader scientific impact. We appreciate this point and have revised Section 5.1 to clarify the primary geomorphological thresholds. We explicitly state that the overarching control is the structural transition of the "parent" glacier from marine-terminating to land-terminating. This transition triggers a fundamental shift from marine-dominated forcing (scouring, calving waves) to terrestrial-dominated forcing (fluvial sediment delivery via proglacial rivers). While secondary factors—such as local bathymetry, fetch, and storm frequency—introduce localized variability, we have now structured the discussion to clearly reflect this primary glacio-marine vs. terrestrial hierarchy.

We appreciate the reviewer's diligence regarding text economy. Our intention in including specific metrics in the Discussion was not to repeat the Results section, but to provide immediate empirical support for the geomorphological mechanisms being discussed. However, to address your concern, we have thoroughly audited the Discussion and removed redundant numerical values, keeping only the essential benchmarks necessary to substantiate our comparative arguments. We believe this has significantly streamlined the narrative flow.

While systematic, multi-site studies focusing explicitly on moraine-controlled lagoon systems (PMLs) are currently lacking in other Arctic sectors, we agree that the manuscript benefits from a broader circum-Arctic

context. We have expanded the text to discuss how these paraglacial mechanisms apply to other rapidly deglaciating, ice-cored coastal landscapes, such as parts of Greenland, the Canadian Arctic Archipelago, and Alaska. We have also expanded our comparisons of shoreline erosion rates to position Svalbard's PML dynamics within the wider spectrum of Arctic coastal change (e.g., contrasting them with thermo-abrasional permafrost coasts).

To ensure a tighter integration of our conceptual model within the broader narrative, we have restructured the final part of the Discussion. Rather than presenting the model as an isolated component, we have woven its core stages directly into the synthesis of the two divergent evolutionary trajectories (the erosional-fragmenting pathway vs. the stabilizing-isolating pathway). This allows the conceptual figure to serve as a direct visual summary of the processes discussed throughout Section 5.

Minor points

RC2:

- Simplify long sentences for clarity.
- Avoid repetitive phrasing (e.g. “it is worth noting that”).
- Ensure consistent terminology throughout.

Response: Thank you for your suggestions. We have made the necessary corrections in this regard.

RC2: Conclusion.

This is a strong and original contribution to Arctic coastal geomorphology. With clearer conceptual framing and slightly more cautious interpretation, the manuscript will be suitable for publication and likely to have a significant impact.

Response: Thank you for this valuable suggestion. In line with the Reviewer's recommendation, we have thoroughly revised and expanded the Conclusions section to enhance the depth and clarity of our final synthesis. Specifically, the text was modified to provide a concise summary outlining the evolutionary development of PMLs and to explicitly highlight their unique diagnostic features, which will facilitate future comparative studies. Furthermore, we contextualized the precise significance and role of PMLs within the broader paraglacial sediment cascade, while also expanding on the ecological dimension by identifying specific areas within these landforms that offer potential microhabitats. We believe that these additions substantially strengthen the conclusions, providing a more robust and comprehensive summary of our study's contribution to the field. The completely revised section has been provided below:

“The rapid retreat of Svalbard's glaciers has transitioned the archipelago into a new paraglacial stage, characterised by the widespread emergence of Paraglacial Moraine Lagoons (PMLs). This study provides the first archipelago-wide identification and quantitative analysis of this landform, formalising the PML as a distinct, moraine-controlled category of Arctic lagoon – one whose stability and evolution are governed by the mechanical properties, ice content, and geometry of former Little Ice Age moraines rather than by the fluvial or sandy-barrier dynamics that define previously described paraglacial lagoons.

Drawing on a near-90-year, multi-source record (1936–2024) and standardised DSAS shoreline analysis across the complete set of 14 systems, we demonstrate that PMLs are not merely passive features of deglaciation but active,

transient "sinks" in the Arctic coastal system. Their surface area has nearly tripled since the 1930s, now covering approximately 83 km² and accounting for more than half (56%) of Svalbard's total lagoon area – a clear signal of how quickly moraine-controlled coasts are expanding under Arctic amplification. Crucially, we show that the fate of each PML is inextricably linked to the status of its "parent" glacier. While glaciers remain marine-terminating, lagoons undergo massive expansion and intense marine reworking; once a glacier retreats onto land, the sedimentary regime shifts and the lagoon begins to act as a terminal sink for glacio-fluvial material, leading to rapid infilling and eventual terrestrialisation. From this glacier–coast coupling, we derive two divergent evolutionary trajectories – an erosional–fragmenting pathway dominated by marine forcing (e.g., Tjuvfjordlaguna) and a stabilising–isolating pathway driven by terrestrial sediment supply (e.g., Scheilaguna, Femtelaguna) – which we synthesise into a four-stage conceptual model of PML genesis, maturation, terrestrial transition, and destruction.

The significance of these findings extends well beyond landform taxonomy. First, by sequestering coarse glaciogenic material in the nearshore zone rather than delivering it directly to the shelf or deep sea, PMLs introduce a previously unrecognised "pause" in the paraglacial sediment cascade; neglecting them risks a systematic miscalculation of the land-to-sea sediment budgets of glaciated Arctic margins. Second, by converting high-energy, wave-dominated open coasts into sheltered, low-energy brackish basins, PMLs create distinctive habitat templates that may serve as transient biodiversity refugia – potentially important for species advancing northward under ongoing atlantification. Third, because PMLs are short-lived features confined to a narrow paraglacial time window, their formation and eventual destruction constitute a high-resolution proxy for the pace of polar coastal reorganisation, and their low-energy basins are likely to preserve undisturbed sedimentary archives of post-Little Ice Age environmental change that are typically erased on exposed coasts.

Taken together, our results establish PMLs as a key, climate-sensitive component of the feedback system linking glacier activity to the evolving Arctic coast. As warming continues and more glaciers detach from their marine margins, both the proliferation of new PMLs and the terrestrialisation or fragmentation of existing ones are expected to accelerate. Quantifying the internal (ice-cored) structure of moraine barriers, the carbon-sequestration potential of these sediment traps, and the ecological viability of their transient habitats now emerges as a priority for integrated geomorphological, cryospheric, and marine-ecological research in a rapidly changing Svalbard.”