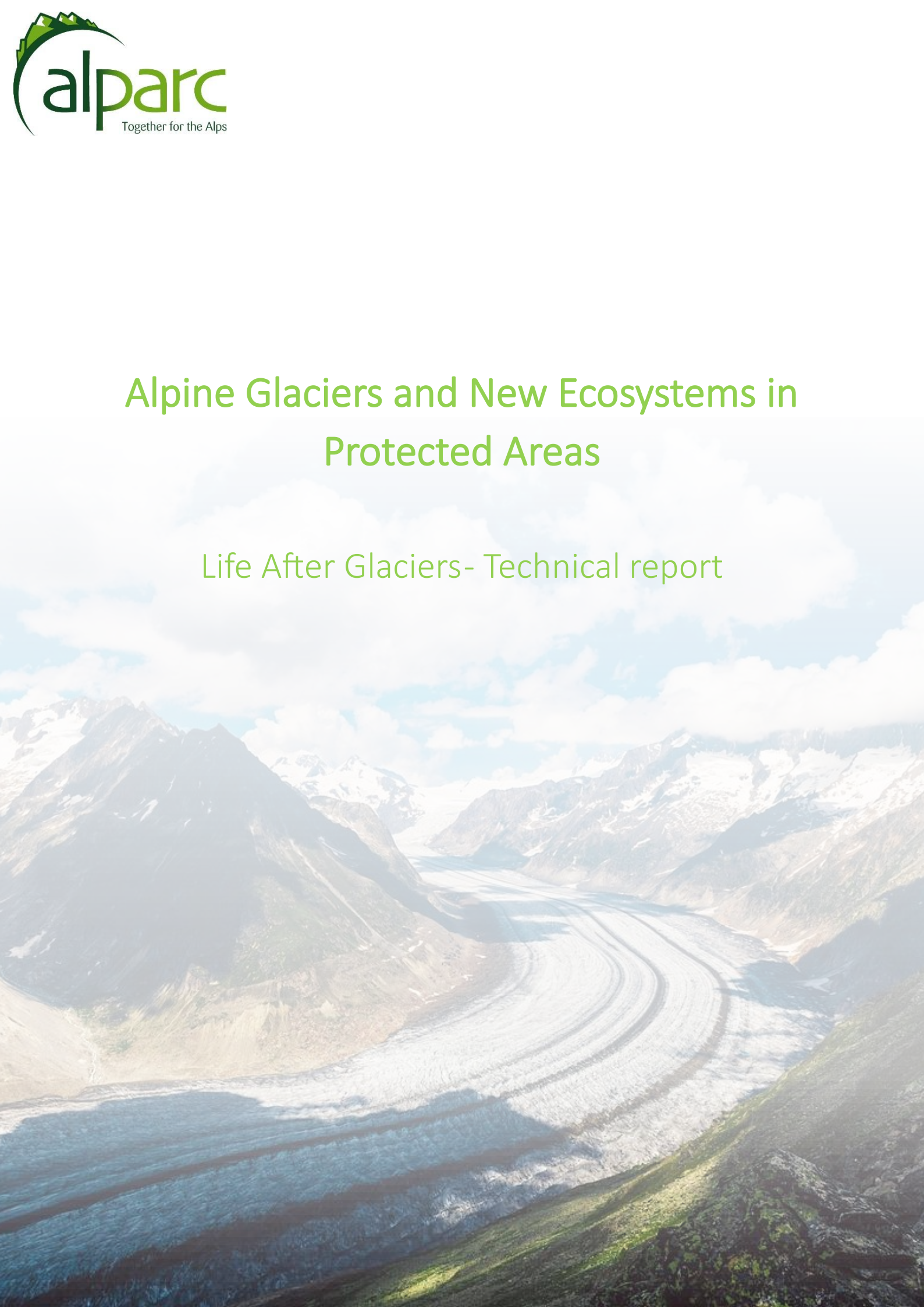
Alpine Glaciers and New Ecosystems in Protected Areas

Life After Glaciers- Technical report



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ABBREVIATIONS

APAs: Alpine Protected Areas

GLOF: Glacial Lake Outburst Flood

GPR: Ground Penetrating Radar

LIA: Little Ice Age

m. w.e.: Meters Water Equivalent

ÖAV Austrian Alpine Club

SCC: Swiss Commission for Cryosphere observation

SWE: Snow Water Equivalent

WGMS: World Glacier Monitoring Service

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1. INTRODUCTION

1.1 Context, objective and approach

Among the many and pressing consequences of ongoing climate change, glacier retreat stands out as both a powerful indicator and a catalyst for wider environmental change. According to the latest findings from the WGMS, 2024 has been the 37th consecutive year in which the global glacier mass balance has been negative. Alarmingly, eight of the ten most negative mass balance years on record have occurred since 2010. This persistent and accelerating trend underscores a very clear reality: glaciers are melting at an unprecedented rate, driven not only by rising global temperatures, but also by intensifying positive feedback mechanisms that amplify their loss.

In this context, the idea of a world without glaciers is no longer a distant, hypothetical scenario. Scientific models warn that a global average temperature increase of just three to four degrees Celsius above current levels could result in the near total disappearance of glaciers worldwide. What is troubling is that such a trajectory closely matches current climate trends, suggesting that this level of warming is not only plausible, but increasingly likely within this century. The disappearance of glaciers would trigger a cascade of effects far beyond the immediate mountain landscapes they occupy. One of the most widely recognised global consequences is the potential for sea levels to rise by more than 60 metres, threatening coastal populations and ecosystems on a planetary scale.

At a regional level, the Alpine Arc is emerging as one of the most vulnerable environments to the impacts of climate change. Both seasonal and annual temperatures are rising steadily across the Alps, with the most pronounced warming occurring in summer and autumn. Recent studies confirm that the Alpine region experienced a warming rate of about 0.5°C per decade during the period 1991-2020. Projections indicate that the 2001-2030 climate normal will be on average 1.5°C warmer than the 1961-1990 baseline. This accelerated warming trend has a direct impact on the mass and distribution of Alpine glaciers. WGMS data consistently show that Alpine glaciers are among the most severely affected globally, with shrinking volumes and surface areas indicating a dramatic trajectory of loss.

Glaciers are physical landmarks, as well as fundamental components of mountain ecosystems. Their retreat actively reshapes hydrological cycles, influences soil development and alters microclimatic conditions. All this has profound consequences for biodiversity. If current trends continue, it is estimated that the area of glaciers in the Alps will decrease by about 48% by 2050. By the end of the century, it is predicted that up to 90% of the glacier mass in the Alps could disappear. These changes are expected to intensify in the coming decades.

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Figure 1 Bonne Pierre glacier - Glacial lake siphon. © Parc National des Écrins - Sabatier Olivier

For APAs, whose core mission is to protect natural habitats and species, this change poses unprecedented ecological and management challenges, especially with the designation of 2025 as the United Nations International Year of Glacier Conservation. As glaciers retreat, they expose newly deglaciated terrain that provides a clean environment for primary ecosystems to develop. Indeed, these emerging environments are the birthplace of new ecosystems, providing unique opportunities to study how life colonises and evolves in response to newly

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available habitats. Understanding these processes is essential for anticipating changes in biodiversity, guiding adaptive management strategies and supporting long-term conservation planning.

In this evolving context, APAs hosting the 41% of the total glaciers of the Alps[1] have a crucial role to play. The report is based on the following hypothesis of work:

- APAs are model sites for studying and preserving new environments emerging from glacier retreat.
- The global nature of glacier retreat calls for coordinated and shared management actions.

For all these reasons, ALPARC conducted a study to explore the ecological impacts of glacier retreat in APAs, focusing on landscape changes, species colonization, and adaptation. It aims to identify key interactions in post-glacial ecosystems and to propose communication and conservation strategies to support emerging biodiversity.

To achieve these goals, ALPARC assessed the glacier retreat within the APAs since the LIA and launched a survey among APAs of different categories (national parks, nature parks, biosphere parks, geoparks) to obtain information on ongoing glacier monitoring actions, observed impacts and changes on biodiversity due to glacial retreat, and communication of these phenomena to the public from APAs. Finally, a workshop was held online to exchange ideas on a common management strategy and future perspectives.

1.2 Project contributors

In total, 15 stakeholders including 14 protected areas participated in the project, by filling out the survey or exchanging data and ideas by emails and during the workshop. The stakeholders contributed belong to the following categories: 6 nature / regional parks (5 Italy – 1 of which is also UNESCO Global Geopark, 1 Switzerland), 5 national parks (1 Austria, 1 France, 1 Italy, 1 Slovenia, 1 Germany), 1 nature reserve (France), 1 nature reserve network – that manages 9 nature reserves – (France), 1 UNESCO World Heritage Site (Switzerland), and 1 university (France). All APAs participating in the project are ALPARC Members.

[1] Only considering national parks and nature / regional parks

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Table 1 Alpine Protected Areas and other stakeholders contributing to the project

ID	NAME	TYPE	NATION
1	Stelvio National Park– South Tyrolean sector	National Park	Italy
2	Hohe Tauern National Park (Carinthia)	National Park	Austria
3	Triglav National Park	National Park	Slovenia
4	Prealpi Giulie Regional Park	Regional Park	Italy
5	Orobie Valtellinesi Regional Park	Regional Park	Italy
6	Contamines Montjoie Nature Reserve	Nature Reserve	France
7	UNESCO World Heritage Site Swiss Alps Jungfrau-Aletsch	UNESCO World heritage site	Switzerland
8	Nature Park Adamello Brenta Geopark	Nature Park and UNESCO Global Geopark	Italy
9	Vanoise National Park	National Park	France
10	Alpi Marittime Regional Park	Nature Park	Italy
11	Pfyn-Finges Nature Park	Nature Park	Switzerland
12	ASTERS	Nature reserve network	France
13	Berchtesgaden National Park	National Park	Germany
14	Adamello Regional Park	Regional Park	Italy
15	Savoie Mont Blanc University	University	France

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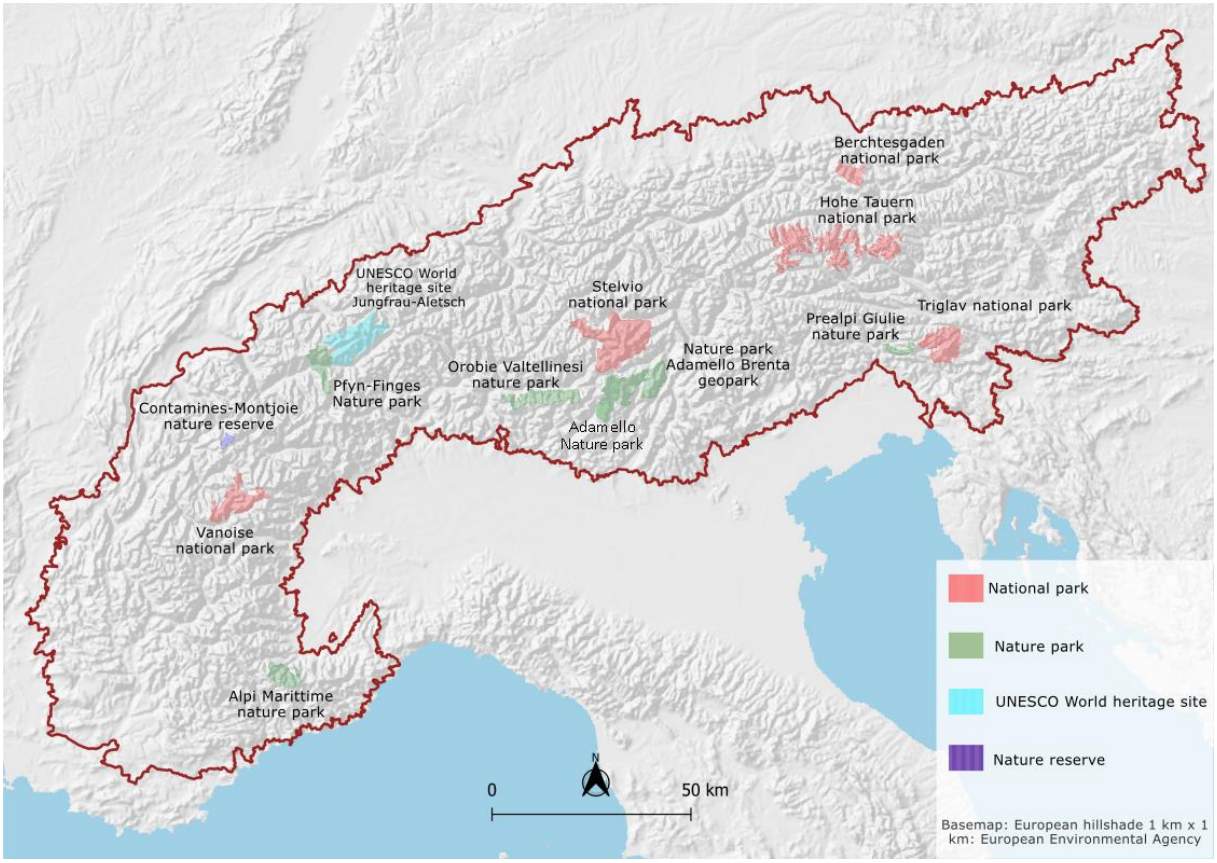
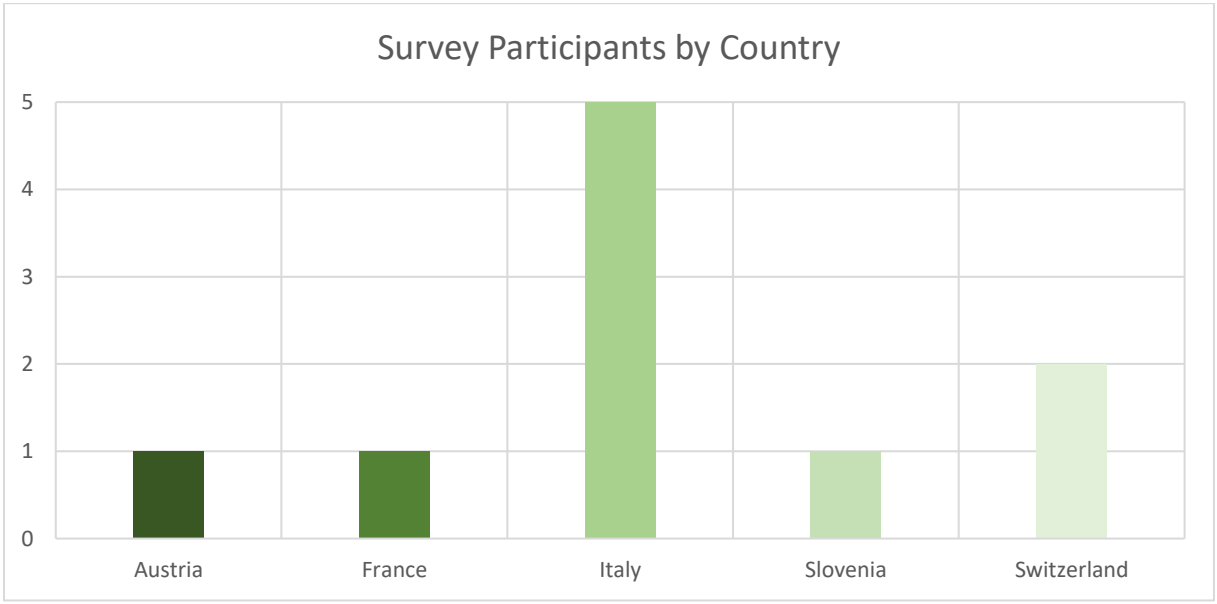


Figure 2 Map of the Alpine Protected Areas contributing to the project

Specifically, for the survey a total of 24 APAs administrations were contacted, of which 10 returned a complete response: 5 nature / regional park (4 Italy – 1 of which is also UNESCO Global Geopark, 1 Switzerland), 3 national park (1 Italy, 1 Austria, 1 Slovenia), 1 nature reserve (France), 1 UNESCO World Heritage Site (Switzerland). The survey consisted of 9 questions: 3 closed-ended, 2 multiple-ended and 4 open-ended.



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2. Report and Mapping of observed glacier retreat and consequences on biodiversity within Alpine protected areas

2.1 Collection of measurements and observations of glacier retreat in Alpine protected areas

The following section focuses on estimating the extent of glacier retreat within APAs. A significant number of glaciers are located within APAs. More than 40% of the glaciated area in the Alpine Arc lies within nature / regional parks, and national parks. This percentage increases further when including additional protection categories such as nature reserves and UNESCO World Heritage Sites.

Table 2 Glaciated area in the Alpine protected areas

COUNTRY	NAME	Glaciated area	
		Year	Area (ha)
Switzerland	UNESCO World Heritage Site Swiss Alps Jungfrau-Aletsch	2016	28300
Austria	Hohe Tauern National Park (Carinthia, Tyrol, Salzburg)	2021	12600
France	Vanoise National Park	2016	9200
Austria	Ötztal Nature Park	2020	8925
France	Écrins National Park	2020	6000
Italy	Stelvio National Park: South Tyrolean sector	2017	3482
Italy	Stelvio National Park: Lombard sector	2016	2413
Switzerland	Pfyn-Finges Nature Park	2016	1820
Switzerland	Valley of Trient Regional Nature Park	2016	1080
Italy	Nature Park Adamello Brenta Geopark	2022	1053
France	ASTERS - Haute-Savoie Conservatory of Natural Areas	2022	697

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Italy	Stelvio National Park: Trentine sector	2022	597
Italy	Adamello Regional Park	2021	400
Switzerland	Parc Ela	2016	220
Switzerland	Binntal Landscape park	2016	200
Switzerland	Beverin Nature Park	2016	150
Italy	Alpe Veglia e Devero Nature Park (Aree Protette dell'Ossola)	2022	176
Italy	Orobie Valtellinesi Regional Park	2022	118
Italy	Prealpi Giulie Regional Park	2016	117
Italy	Alpi Marittime Regional Park	2022	44
Italy	Alta valle Antrona Nature Park (Aree Protette dell'Ossola)	2022	28
Switzerland	Val Calanca Nature Park	2016	20
Italy	Paneveggio Pale di San Martino Nature Park	2022	20
Germany	Berchtesgaden National Park	2018	5.20
Slovenia	Triglav National Park	2022	0.70
Switzerland	Swiss National Park	2016	0
Switzerland	Biosfera Val Müstair	2016	0

The following analysis evaluates ice loss from the maximum extent of glaciers during the LIA, approximately around the year 1850, up to 2015. The assessment was conducted at both the Alpine-wide scale and specifically within the boundaries of APAs, considering only national parks and regional/nature parks. In addition to this broad overview, more detailed analyses were carried out for selected protected areas using more recent datasets.

By 2015, the entire Alpine arc had lost approximately 57.5% of its glacier cover since the peak of the LIA (~1850), shrinking from 4,248.09 km² to 1,805.88 km².

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Table 3 Temporal comparison of glaciated area in the Alps and Alpine protected areas

	Km²		
Considered area	**1850**	**2015**	**Ice Loss 1850-2015**
Entire Alpine arc	4,248.09	1,805.88	57.49%
Alpine Protected Areas[2]	2,075.57	754.65	63.64%
Alpine National Parks	1,053.01	350.14	66.75%

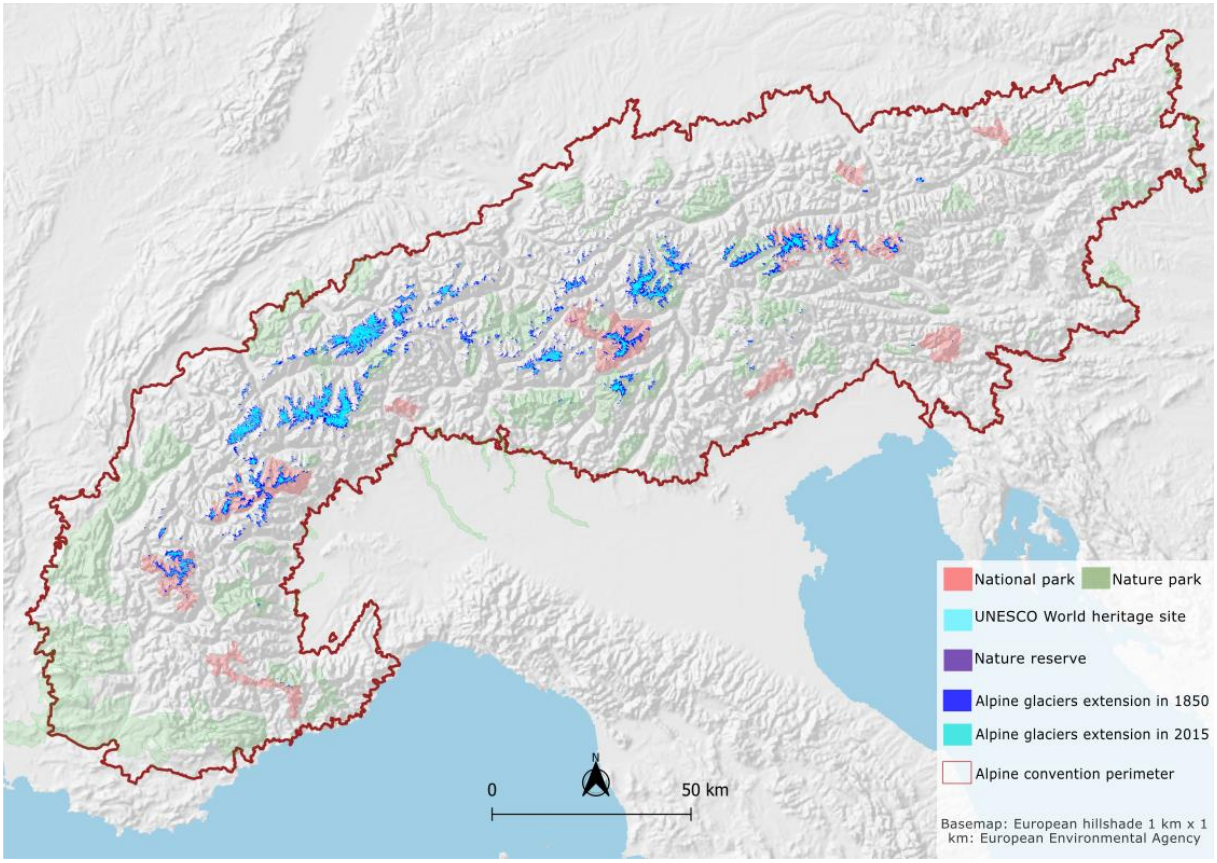

Figure 3 Map of the LIA glaciers compared to the 2015 glacier extents within the Alpine protected areas. This map does not claim to be exhaustive.

Within this broader context, APAs show a similar rate of retreat: the glaciers within APAs lost 63.6% of their area, while those located in national parks alone experienced an even greater reduction of 66.8%. These findings suggest that, although protected areas are essential for

[2] Only considering nature / regional parks and national parks

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conservation and implement several protection measures, they are not inherently more resilient to glacier loss.

This trend is confirmed, if not even increased, by an insight of glacier coverage across a selection of APAs at three time points (1850, 2015, and 2022) along with percentage ice loss for two periods: 1850-2015 and 2015-2022.

Table 4 Focus on the evolution of glaciated area in selected APAs

	Km^2					
NAME	**1850**	**2015**	**2022**	**Ice Loss 1850-2015**	**Ice Loss 2015-2022**	**Ice Loss 1850-2022**
ASTERS	46.55	14.45	6.97	68.96%	51.76%	85.03%
Nature Park Adamello Brenta Geopark	83.97	31.66	10.53	62.30%	66.74%	87.46%
Parco Naturale Alpi Marittime	3.04	0.55	0.44	81.91%	20.00%	85.53%
Hohe Tauern National Park (Carinthia)	373.7	143,84	126	61.51%	12.40%	66.28%
UNESCO World Heritage Site Swiss Alps Jungfrau-Aletsch	449.9	287.47	x	36.10%	x	x
Triglav National Park	0.95	0.05	0.007	94.74%	86.00%	99.26%

Figure 4 Agola Glacier, 2019. © PNAB - Michele Zeni

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Several key observations and trends emerge from this analysis:

1. **Consistent and Severe Long-Term Ice Loss**
   Since 1850, all analysed APAs have had considerable glacier retreat, with total ice loss by 2022 ranging from 66% to more than 99%. The individual data for these protected areas are therefore confirmation of a trend that can be said to be general for the Alpine region as a whole.
2. **Accelerated Retreat in Recent Years**
   The 2015–2022 period, though much shorter, shows a notable acceleration of ice loss in many parks. For example, Nature Park Adamello Brenta Geopark lost nearly 67% of its remaining glacier area in just seven years; while Triglav National Park stands out, with an alarming 86% reduction in glacier cover between 2015 and 2022 alone.
3. **Differences in Retreat Rates**
   Some protected areas show more moderate recent declines. For example, Hohe Tauern National Park (Carinthia), while having lost over 61% of its glacier mass by 2015, shows a comparatively modest 12.4% retreat in the subsequent years. Moreover, the UNESCO World Heritage Site Swiss Alps Jungfrau-Aletsch recorded the lowest long-term loss (36.1% by 2015), possibly due to its higher average elevations and larger glacier volumes.
   These differences are most likely due to scale: larger glaciated areas such as Hohe Tauern National Park (Carinthia) and UNESCO World Heritage Site Swiss Alps Jungfrau-Aletsch tend to retain more ice in both absolute and relative terms than smaller, lower-elevation parks such as Alpi Marittime Regional Park or Triglav National Park, which are nearing the end of their glaciation. This demonstrates the influence of altitude, topography and glacier size on resilience to warming; but while they may be more resilient, these statistics show that they will not be saved by this phenomenon.

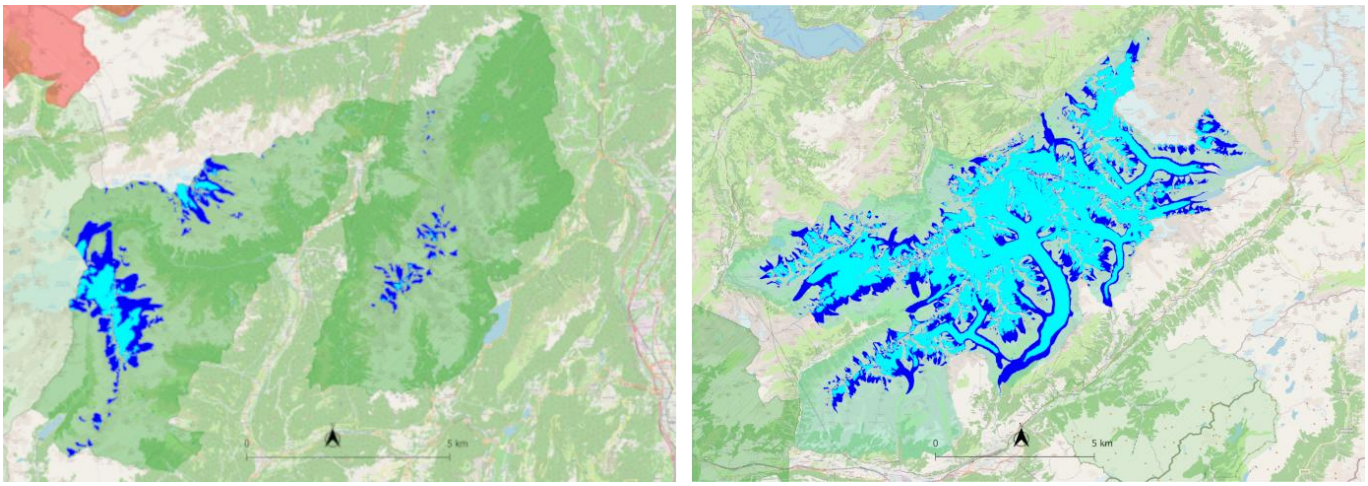

Figure 5 Comparative image on glaciers evolution. On the left, glacier evolution in the Nature Park Adamello Brenta Geopark. On the right, glacier evolution in the UNESCO World Heritage Site Swiss Alps Jungfrau-Aletsch. In dark blue is the extension of glacier in 1850. In light blue is the extension of glaciers in 2015.

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In addition, although the table does not present overall data for 2022 for the UNESCO World Heritage Site Swiss Alps Jungfrau-Aletsch, specific insights were obtained using updated data for 2023 on a particular glacier within this protected area — the Grosser Aletschgletscher, which is the largest glacier mass in the entire Alps. In terms of area, it reaches approximately 78 km², and in volume 12 km³. Changes in the length of the Grosser Aletschgletscher have been measured since 1870.

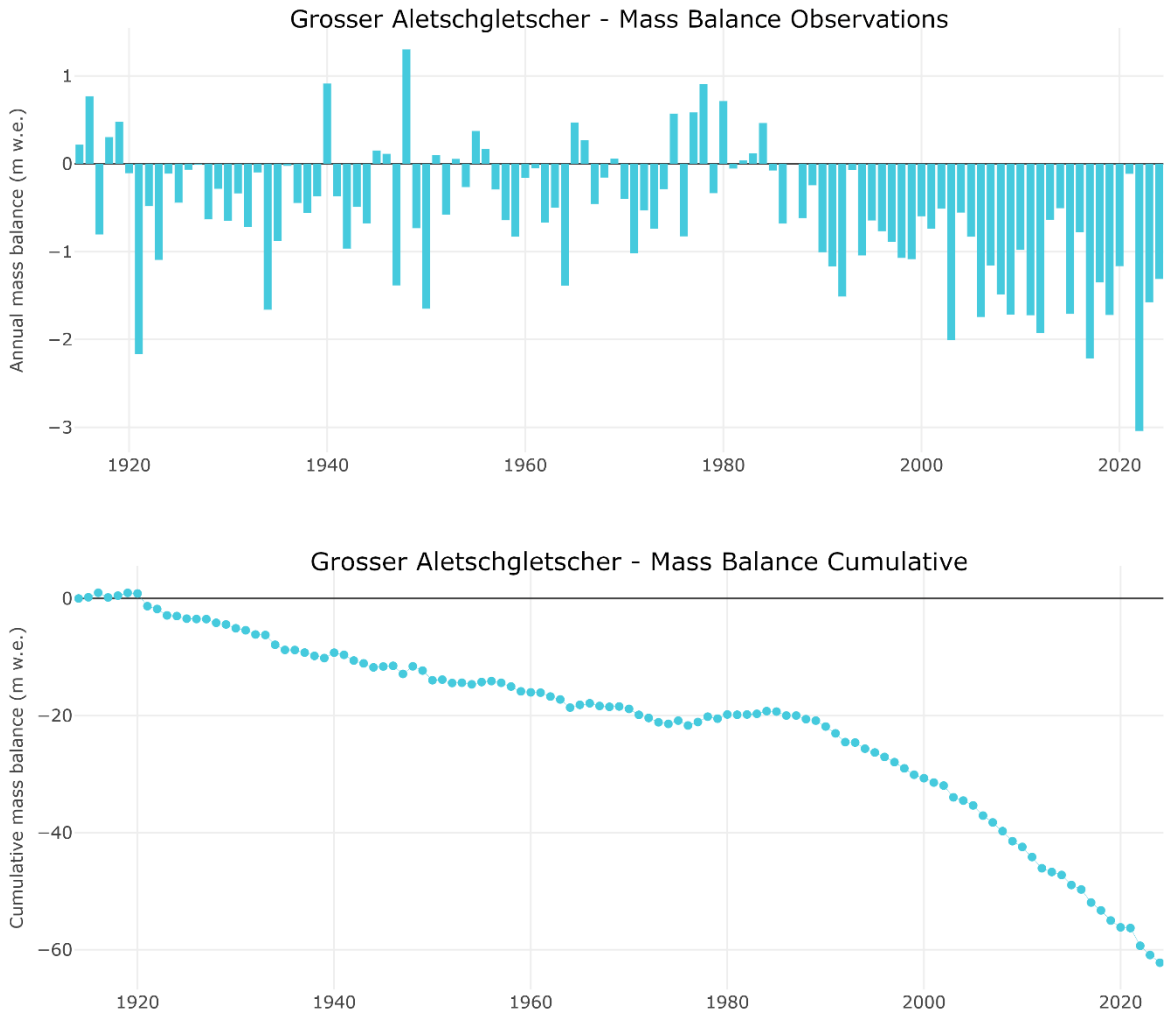

Figure 6 Mass balance observations and cumulative of the Grosser Aletschgletscher. Data and images from GLAMOS: https://glamos.ch

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Figure 7 The Jungfrau Aletsch glacier during the summer. © Martin Bächer

Annual observations of both the annual and cumulative mass balance continue to confirm the overall glacial trend observed across the Alpine region: a marked and accelerating loss of glacier mass. Between 1870 and 2023, the Grosser Aletschgletscher retreated by approximately 3.3 km, with the pace of retreat increasing significantly over the last 30 years. In 2023–2024 alone, the glacier recorded a mass balance of -1.311 m w.e., highlighting the severity of the current situation. This figure is particularly notable considering that the region hosting the glacier has experienced the highest mass loss across the Alpine arc, with an average of -0.90 ± 0.20 m w.e. per year between 2000 and 2016.

This section has provided an overview that, while not unexpected, confirms the alarming retreat trends of glaciers across the entire Alpine region, with no glacial sector spared. The report now continues by presenting selected examples of how APAs are actively monitoring and, most importantly, managing this ongoing phenomenon.

2.2 Current glacier retreat monitoring and management.

The responses from APAs highlight a diverse range of glacier monitoring practices, each shaped by local conditions, institutional partnerships, and scientific priorities. At a broad overview, the majority of APAs surveyed conduct glacier monitoring through direct field surveys and measurements and webcam surveillance and photo comparison, frequently complemented by remote sensing techniques to enhance spatial and temporal analysis. Less commonly applied—though still significant—are climate modelling and predictive tools, which are used by fewer than half of the respondents.

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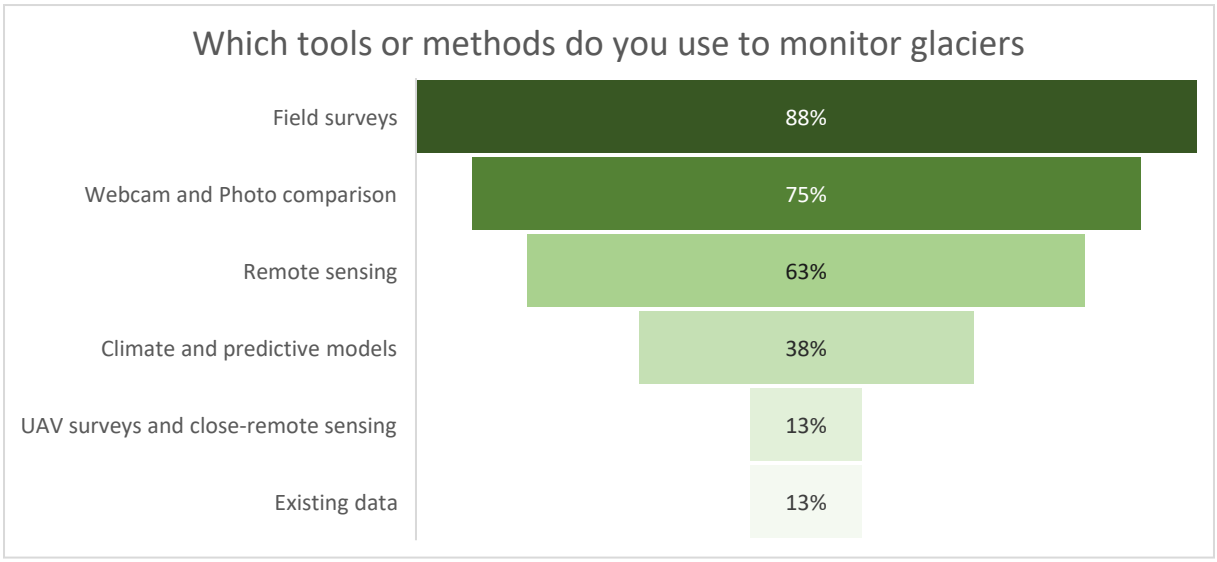

Only a small number of APAs report relying solely on external datasets or open-access databases for glacier monitoring within their territories. To deepen the analysis, we examined specific cases of current glacier monitoring within APAs, grouped here by country:

Germany

The German glaciers are concentrated in the Bavarian mountains, including the Berchtesgaden National Park, where the glaciers cover now an area of 0.052 km^2, representing only 0.025% of the park area. Here, in cooperation with external institutions such as the Bayerische Akademie der Wissenschaften, monitoring is made through laser scanning and real-time kinematics at shorter observation intervals of approximately 5 years. The results are published in public reports.[3]

France

Among the protected areas of the French Alps, specifically those managed by ASTERS, and particularly within the Contamines Montjoie Nature Reserve, glacier monitoring currently includes an annual mass balance measurement conducted since 2024, as well as thickness loss measurements using DGPS and webcams for photographic monitoring.

A different approach is used in the Vanoise National Park, where the photographic observatory has some observation points dedicated to glaciers. Here, photos taken from the same locations and during the same season, but in different years, document the ice loss.

Italy

Among the Italian protected areas, a common strategy for glacier monitoring is to cooperate with external institutions tasked with monitoring selected glaciers and providing mass balances, as well as the use of webcams.

[3] E.g., https://badw.de/fileadmin/userupload/ Files/BADW/Neuigkeiten/2021/04-21/Bayerischer_Gletscherbericht_2021_bf_low-DS_n.pdf

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In particular, Orobie Valtellinesi Regional Park and Adamello Regional Park cooperate with volunteers from the Lombardy Glaciological Service, who proide both photo surveys from fixed stations and mass balance data for selected glaciers every two to three years. Moreover, local webcams are installed to observe these glaciers. Adamello Regional Park also conducts analysis on its glaciers, such as photographic historical comparisons, evaluation of equilibrium line altitude, assesment of surface extent from satellite data images, and mass balance measurements using ablation stakes and SWE monitoring.

Since 2022, a webcam for glacier monitoring has also been installed in the Prealpi Giulie Regional Park. Here, the park cooperates with the Alpine-Adriatic Meteorological Society, the Institute of Polar Science - CNR, and the University of Trieste, that perform field campaigns in spring and early autumn to set the winter, summer and annual mass balances.

Also, Nature Park Adamello Brenta Geopark cooperates with external institutions, particularly the Trento province administration, to get the mass balances of some selected glaciers within the park.

Finally, the mass balance for one selected glacier is calculated every year also by the Stelvio National Park - South Tyrolean sector, through the direct glaciological method. The park also performs frontal variation measurements on several selected glaciers, geo-radar depth measurements on major glaciers, deglaciation projections analysis, and, as for the other Italian parks, photo-webcam monitoring.

Austria

Hohe Tauern National Park (Carinthia) follows projects for the long-term monitoring of the ecosystem processes evolution related to the cryosphere, and for permafrost monitoring. Moreover, the park, as well as all other Austrian protected areas, benefits from the work of the ÖAV, that regularly conducts length measurements on numerous glaciers across Austria[4]. Data from the glacier measuring service can be accessed in an open online database.

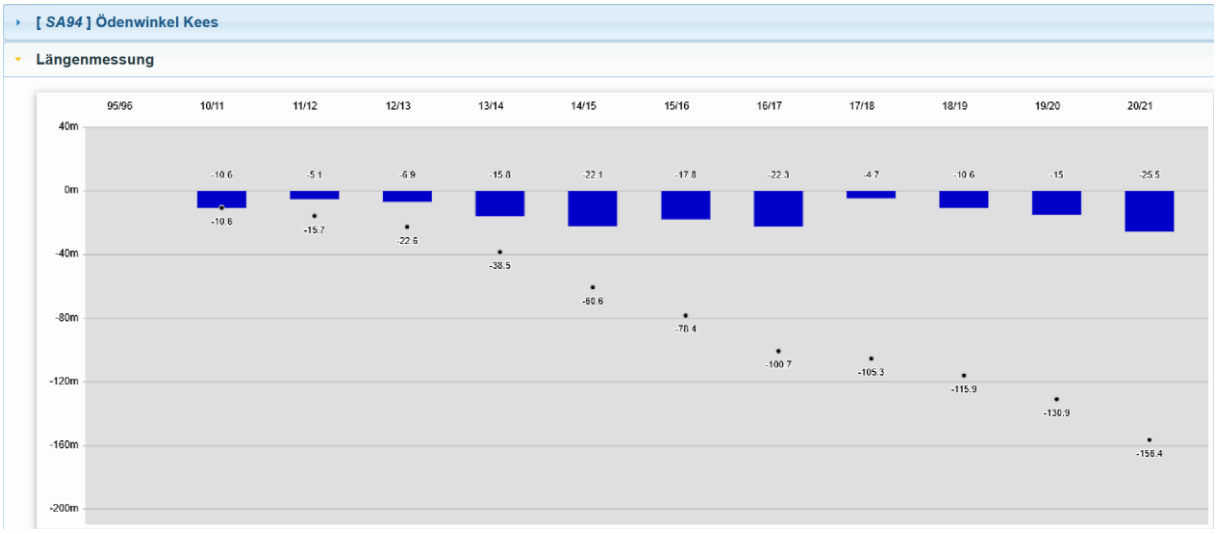

Figure 8 Example of glacier mass balance provided by the ÖAV. Source: https://www.gletscherwandel.net/

[4] https://www.gletscherwandel.net/

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Switzerland

Similarly, as for Austria, the Swiss protected areas are supported by an up-to-date and publicly accessible database for Glacier Monitoring in Switzerland (GLAMOS). This database systematically documents and monitors long-term glacier changes in the Swiss Alps. GLAMOS is operated jointly by the ETH Zurich and the Universities of Fribourg and Zurich and is in close contact with the SCC.

For example, the UNESCO World Heritage Site Swiss Alps Jungfrau-Aletsch and the Pfyn-Finges Nature Park do not have their own glacier monitoring system but can rely on updated data from GLAMOS.

Figure 9 Home page of the GLAMOS service: https://www.glamos.ch/

Slovenia

Glacier monitoring in Triglav National Park has a long-standing tradition, beginning in 1946 with classical measurements based on the position of the glacier front using offset or distance from marked reference points at the glacier's edge.

Over time, the monitoring methods have evolved and expanded significantly:

- 1995: Introduction of geodetic measurements to assess glacier area more precisely.
- 1999, 2000, 2013, and 2022: Implementation of GPR surveys to measure glacier volume and estimate mass balance.
- 2005: Acquisition of aerial imagery (ortho-photos) to document surface changes.
- 2012: Use of airborne LiDAR scanning for detailed surface modelling of the glacier.
- Since 2013: Installation of a web camera (Triglav Glacier Camera: http://ktl.zrc-sazu.si/) providing continuous visual monitoring.

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- Since 2018: Deployment of UAV/drone-based imaging for high-resolution glacier mapping.
- 2022: Collection of ice core samples for various analyses and dating.
- Ongoing: Meteorological data monitoring and modelling from the Kredarica weather station (2,513 m a.s.l.), focusing on selected climatic indicators relevant to glacier dynamics.

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2.3 Databases providing information on glacier retreat measurements and observations within protected areas

Table 5 A selection of open databases on glacier data for the Alps.

NATION	DATABASE	LINK	NOTES
Global	WGMS	https://wgms.ch/data_databaseversions/	
Global	GLIMS	https://nsidc.org/data/glims/data	
Alps	Glacier inventory of the Alps from Sentinel-2	https://doi.pangaea.de/10.1594/PANGAEA.909133	Created in 2015
Switzerland	Glamos	https://www.glamos.ch/#/B45-04	
Austria	Gletscherwandel	https://www.gletscherwandel.net/	
Italy	Inventario Nazionale dei Ghiacciai	https://repo2.igg.cnr.it/ghiacciaiCGI/ghiacciai_new.html	
Italy	Trentino glaciological data	https://www.meteotrentino.it/index.html#!/content?menuItemDesktop=152	Only for Trentino province

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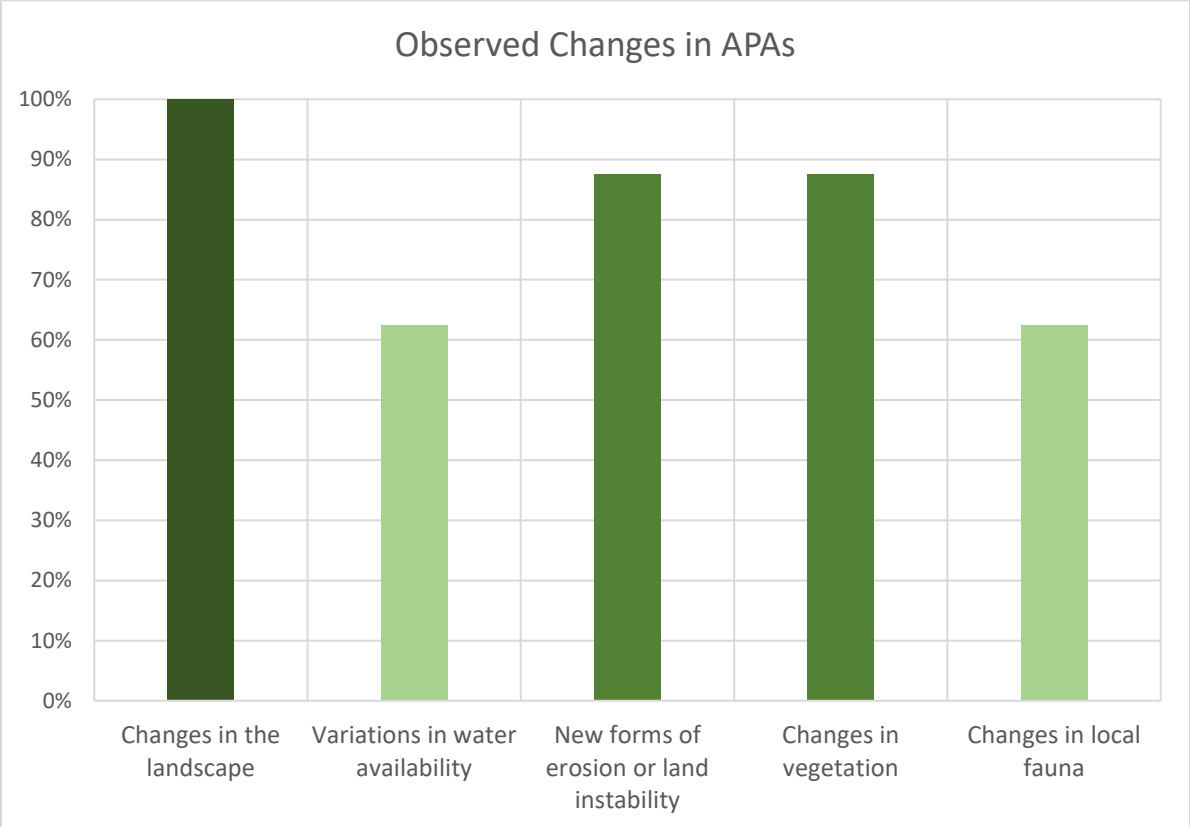
3. Collection of observed environmental changes and biological responses within protected areas due to glacier retreat

3.1 Main results of the survey

The survey responses from the participating protected areas reveal a consistent set of environmental changes linked to glacier retreat. Most notably, all APAs reported noticeable alterations to the landscape. Among the most frequently observed impacts are increased geomorphological instability in newly deglaciated areas and shifts in vegetation patterns, including an upward migration of species. Additionally, more than half of the respondents noted changes in local fauna and variations in water availability, underscoring the broader ecological consequences of glacial loss.



Going deeper into the analysis, the participating APAs responded, either via the survey or by email, to the following question: **Can you briefly explain the changes you're observing in your protected area either in landscape, flora, fauna or water availability, due to glacier retreat?** Table 6 summarizes the answers:

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Table 6 Changes observed in Alpine protected areas in relation to climate change. This table does not claim to be exhaustive.

APAs	**Changes in the landscape** (more rocky outcrops, more glacial lakes, etc.)	**Changes in fauna** (increasing numbers of species at high altitude, more species at risk of extinction, etc.)	**Changes in vegetation** (vegetation expansion to higher altitudes, beginnings of individual green areas, etc.)	**More instability phenomena** (lateral moraines slides, rockfall, etc.)	**Changes in the track of marked mountain paths**	**Changes in water availability** (Less water in summer, more in winter)
Orobie Valtellinesi Regional Park	x	x	x	x	x	x
Prealpi Giulie Regional Park	x			x		
Contamines Montjoie Nature Reserve	x	x	x	x		
UNESCO World Heritage Site Swiss Alps Jungfrau-Aletsch	x		x			
Triglav National Park	x	x	x	x	x	x
Hohe Tauern National Park (Carinthia)	x	x	x	x		x
Nature Park Adamello Brenta Geopark	x		x	x		
Stelvio National Park - South Tyrolean sector	x		x	x		x
Adamello Regional Park	x	x	x	x		x
Pfyn-Finges Nature Park	x					

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3.2 Detailed changes observed in protected areas

Landscape

Among the most evident effects of glacier retreat, the aesthetic view is surely one of the most reported by APAs. As shown in Chapter 2.2, many protected areas monitor the glacier retreat through photo surveys or webcams, clearly demonstrating how visibly the glaciers recede year after year. In particular, the Vanoise National Park conducts photo surveys through its Photographic observatory for Vanoise landscapes[5] in which certain observation points are specifically focused on glaciers. Comparing recent photos with photos taken just a few years earlier (sometimes even less than ten years ago) clearly shows how rapidly the glaciers are retreating – a phenomenon that is evident even at first glance.

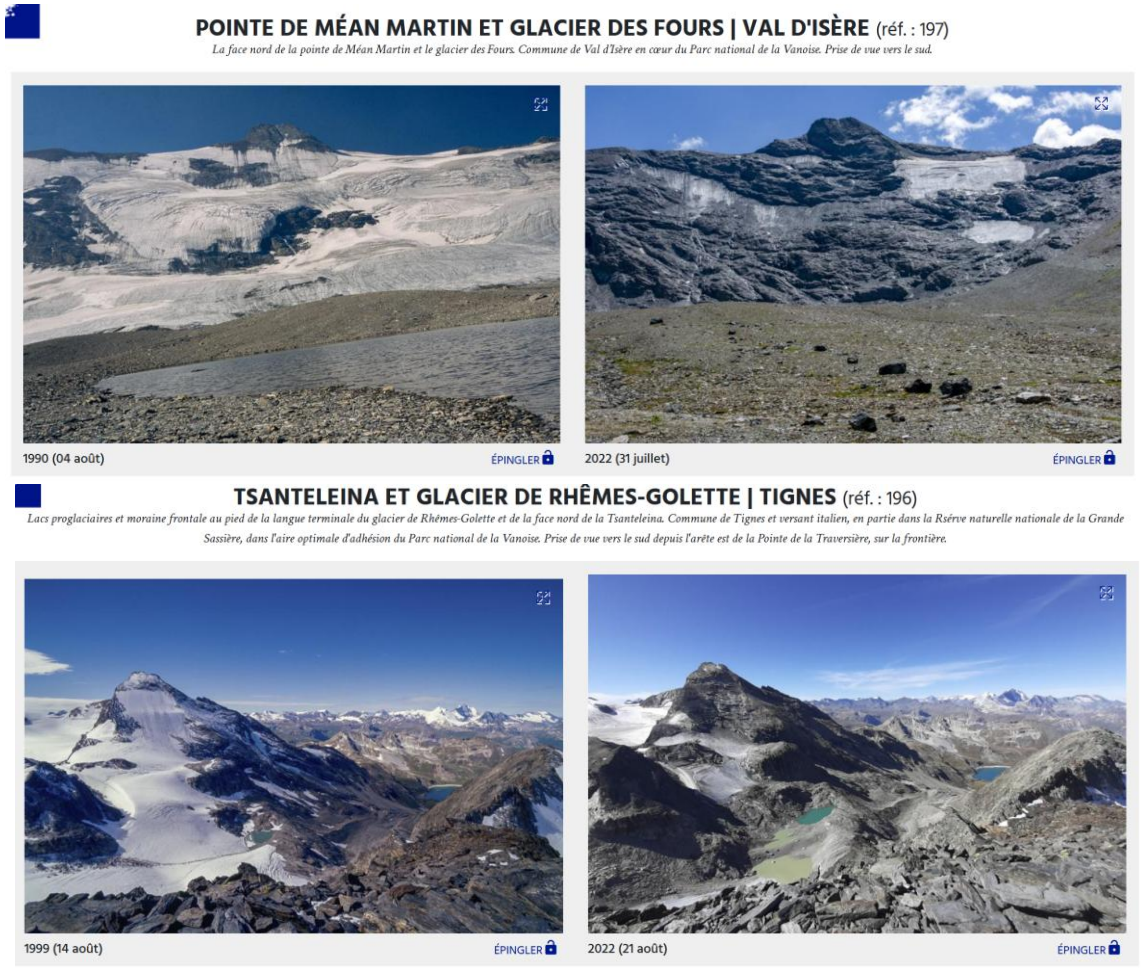

Figure 10 Changes in the glacial landscapes of the Vanoise. Photo from http://paysages.vanoise-parcnational.fr/. © Parc Nationale de la Vanoise

Another commonly reported impact among APAs is the increased geomorphological instability of post-glacial environments. This trend is evident across the entire Alpine arc and has been

[5] Available at http://paysages.vanoise-parcnational.fr/

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documented with specific examples by several protected areas. The Prealpi Giulie Regional Park and the Contamines Montjoie Nature Reserve both highlighted the growing instability of moraines, attributing it to intensified erosion processes and the reduced structural support previously provided by glacial ice.

Figure 11 Slides of lateral moraine in Oasi Faunistica del Monte Rosa, in front of the Belvedere glacier - Macugnaga. © ALPARC - Michele Guerini

Triglav National Park, on the other hand, emphasized a notable increase in rockfalls from adjacent slopes, likely a consequence of both glacier retreat and permafrost degradation.

Additionally, Hohe Tauern National Park (Carinthia) reported the formation of new glacial lakes as another emerging feature in these rapidly changing landscapes.

Vegetation

APAs reported noticeable changes in vegetation dynamics linked to glacier retreat. A widespread observation is the general increase in vegetation cover, as climate change enables plants to colonize newly exposed post-glacial areas that were previously inhospitable. This expansion has been observed in several APAs, including Stelvio National Park – South Tyrolean sector, Hohe Tauern National Park (Carinthia), Alpi Marittime Regional Park, Triglav National Park, UNESCO World Heritage Site Swiss Alps Jungfrau-Aletsch, Contamines Montjoie Nature Reserve, Adamello Regional Park and Orobie Valtellinesi Regional Park.

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In particular, the UNESCO World Heritage Site Swiss Alps Jungfrau-Aletsch reports an upward shift in the treeline, with trees from the Aletsch Forest progressively growing at higher elevations since 1850. Similar trends of vegetation ascent to higher altitudes have also been noted in Stelvio National Park – South Tyrolean sector and Hohe Tauern National Park (Carinthia).

Additional reported changes include:

- The early establishment of pioneer vegetation (e.g., mosses and Alpine flowers) on formerly bare, rocky substrates, as observed by Triglav National Park.
- Grazing by wild ungulates such as chamois and ibex in increasingly higher areas, also reported by Triglav National Park.
- Colonization of post-glacial areas by pioneer species in the Contamines Montjoie Nature Reserve, Alpi Marittime Regional Park, and Hohe Tauern National Park (Carinthia).

Fauna

Several APAs have reported noticeable changes in local fauna associated with glacial retreat and related environmental transformations. These changes were highlighted in particular by Nature Park Adamello Brenta Geopark, Triglav National Park, Contamines Montjoie Nature Reserve, Orobie Valtellinesi Regional Park, Adamello Regional Park and Hohe Tauern National Park (Carinthia).

Figure 12 Ptarmigan. © National Park Hohe Tauern - Gunther Gressmann

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In addition to observations on larger wildlife species, Alpi Marittime Regioanl Park and Nature Park Adamello Brenta Geopark have also conducted specific studies on insect populations, indicating a broader ecological focus that includes invertebrate biodiversity—a component often underrepresented in faunal monitoring but crucial for understanding ecosystem dynamics.

Water availability

Stelvio National Park - South Tyrolean sector reported increased water availability during winter, primarily due to reduced snowfall and a higher share of winter precipitation occurring as rain. In contrast, Triglav National Park observed reduced water availability during the summer months, likely linked to the same altered precipitation patterns. These findings point to a broader seasonal redistribution of water resources across the Alpine region. This shift is already affecting protected areas: in Triglav National Park, for instance, water abstraction from glacial melt for a nearby mountain hut is occurring increasingly earlier each year. Once the remaining ice disappears, water availability during dry summers will become critically limited.

Table 7 Summary of specific changes reported by the APAs categorized in Landscape, Vegetation, Fauna, and Water.

Landscape	Vegetation	Fauna	Water
Glacier Retreat (Visible/Aesthetic)	Vegetation expansion	Studies on insects	Less availability in summer
Geo-morphological instability	Altitudinal shift	Changes in local fauna	More availability in winter
New lakes	Establishment of pioneer vegetation	Upward shift of specie	
		Species at risk of extinction	

The table above summarizes the main changes observed in APAs due to the glacier retreat. All these changes together have led APAs to face two main consequences:

1. **New risks**: Geomorphological risks have notably increased due to more frequent slope instabilities and the destabilization of lateral moraines, which are no longer supported by the glaciers. Additional hazards arise from the increased frequency of ice collapses and the formation of new glacial lakes. In particular, newly formed lakes that are temporarily dammed by glacial ice present a significant risk: as the glacier continues to melt, the structural integrity of the ice dam may fail, leading to a GLOF. Field-based monitoring may be considered as a best practice for risk mitigation. Regular monitoring of glacier dynamics, such as ice flow velocity, debris movement, and serac stability,

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using fixed cameras and on-site observations by trained guides provides critical early warnings and facilitates timely communication of risks to the public.

2. **Development of new ecosystems**: While the beneficial role of glaciers in supporting social, ecological, and hydrological systems (geo-ecosystem) is declining, their retreat is simultaneously exposing vast areas of Alpine terrain. This deglaciation process is expected to trigger one of the most rapid and extensive ecosystem shifts observed on Earth, reshaping landscape dynamics and opening up new, yet highly sensitive, environmental niches.

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Table 8 Type of changes observed by APAs contributing to this report due to glacier retreat.

APAs	Glacier Retreat (Visible/Aesthetic)	Geomorphological Instability	Vegetation Expansion	Altitudinal Shift (Vegetation)	Faunal Changes	Biodiversity Impact Studies	Seasonal Water Redistribution
Vanoise National Park	Yes – Photo observatory	Not mentioned	Yes	Not mentioned	Not mentioned	Yes	Not mentioned
Prealpi Giulie Regional Park	Yes – Webcam	Yes – Moraine instability	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned
Contamines Montjoie Nature Reserve	Yes – Webcam	Yes – Moraine instability	Yes – Pioneer spp.	Not mentioned	Yes	Not mentioned	Not mentioned
Triglav National Park	Yes – Webcam	Yes – Rockfalls	Yes – Pioneer spp., Grazing	Yes – Treeline shift, Grazing at higher elevation	Yes	Not mentioned	Yes – Less water in summer
Hohe Tauern National Park (Carinthia)	Yes	Yes – New glacial lakes	Yes – Pioneer spp.	Yes	Yes	Not mentioned	Yes
Parco Nazionale dello Stelvio – South Tyrolean sector	Yes – Webcam	Not mentioned	Yes	Yes	Not mentioned	Not mentioned	Yes – More winter rain
Parco Naturale delle Alpi Marittime	Yes	Not mentioned	Yes – Pioneer spp.	Not mentioned	Yes	Yes	Not mentioned
UNESCO World Heritage Site Swiss Alps Jungfrau-Aletsch	Yes	Not mentioned	Yes	Yes – Treeline shift	Not mentioned	Not mentioned	Not mentioned

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Orobie Valtellinesi Regional Park	Yes – Webcam	Not mentioned	Yes	Not mentioned	Yes	Not mentioned	Yes
Nature Park Adamello Brenta Geopark	Yes	Not mentioned	Yes	Yes	Yes	Yes	Not mentioned
Pfyn-Finges Nature Park	Yes	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned
Berchtesgaden National Park	Yes	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned
Adamello Regional Park	Yes – Webcam and photo observatory	Yes – Rockfalls	Yes	Yes	Yes	Yes	Yes
ASTERS	Yes – Webcam	Yes	Yes	Not mentioned	Yes	Not mentioned	Not mentioned

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3.3 New ecosystems in Alpine protected areas

As previously noted, all APAs have experienced changes as a result of glacier retreat. This process has led to the exposure of new land surfaces, where emerging mountain ecosystems are beginning to develop. It is a recent and ongoing phenomenon, therefore, several APAs are in the early stages of launching targeted research. However, comprehensive study results remain limited at this time. Nonetheless, a few APAs have already conducted preliminary investigations and obtained initial findings, albeit in a sporadic manner.

Scientific studies have shown that by 2100, depending on greenhouse gas emission scenarios, global deglaciated surfaces are projected to increase by 149,000 to 339,000 km². These zones will be predominantly terrestrial (78%), with additional submarine depressions (14%) and continental basins (8%). The newly exposed landscapes will support diverse ecosystems, including mineral zones, grasslands, heathlands, forests, fjords, wetlands, lakes, and rivers.

It is already known that biodiversity in glacier forelands increases rapidly following glacier retreat. In particular, micro-organisms such as bacteria and fungi are among the first colonizers of these newly exposed proglacial areas, appearing almost immediately after ice retreat. Their diversity is already relatively high at this early stage and tends to stabilize within 50 to 100 years. In contrast, the colonization of animals, such as insects, worms, and springtails, as well as plants, typically begins around 10 years after deglaciation. However, their biodiversity continues to increase over time, with no signs of stabilization even after 150 years.

Figure 13 Lobbia and Mandrone Glaciers, 2022. © PNAB, Michele Zeni

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In the Alpi Marittime Regional Park, a significant retreat of glaciers over the next thirty years is envisaged, alongside a strong expansion of two plant communities into higher elevations: the *Alnus viridis*, and altimontane beech forest, which were previously unable to grow at such altitudes. Direct consequences of global warming include the rise of the zero-degree isotherm, reduced snow persistence, and a substantial decrease in glacier recharge, which may also affect Alpine springs and associated habitats. Rising temperatures further promote the upward shift of forest species such as *Fagus sylvatica*, *Alnus viridis*, *Acer pseudoplatanus*, and tall herb communities. In general, in Alpi Marittime Regional Park, Mediterranean glacial habitats are facing threats from rapid species turnover, which increases the extinction risk for cold-adapted and endemic species closely tied to these environments.

Reports published by the Hohe Tauern National Park (Carinthia) highlight the severity of the ongoing changes, describing them as extremely serious. A profound transformation of the Alpine natural environment is underway, particularly evident in processes such as glacier retreat and permafrost degradation, which are significantly altering the conditions for other geomorphic and ecological dynamics. Focusing specifically on the relationship between geomorphology and vegetation, the reports indicate that, despite being influenced by geomorphological activity, vegetation is actively colonizing deglaciated areas and progressively expanding upward into previously inhospitable high-altitude zones.

One of the major studies carried out by protected areas on the emergence of new ecosystems in mountainous regions following glacier retreat is the *Ice&Life* project, led by ASTERS[6]. Some preliminary results of this project highlight that between 200 and 900 new freshwater lakes could form in the Alps alone. Initial surface composition analyses indicate that approximately 28% of the deglaciated zones are dominated by mineral substrates: rock outcrops (57%), scree slopes (20%), and moraines (16%). Emerging forests account for 4.5% of the proglacial margins (3.8% coniferous, 0.8% deciduous), while aquatic features currently represent less than 0.25%. These post-glacial ecosystems play a vital role in climate regulation and adaptation. They contribute to carbon sequestration, freshwater purification, and biodiversity conservation. Depending on local climatic conditions, some ecosystems will serve as refuges for specialist species under extreme ecological stress, while others will offer more favourable environments for generalist species and broader ecological development. The *Ice&Life* project highlights the urgent need for proactive conservation strategies, including the establishment of new protected zones and the integration of post-glacial environments into national and international environmental policies.

Other studies have already shown that, without protection, these newly exposed areas are impacted by humans. In Nature Park Adamello Brenta Geopark traces of pesticides, synthetic fragrances and polycyclic aromatic hydrocarbons have already been observed in two glacier-fed streams (Amola, Mandrone) and one spring (Grostè). In addition, at least ten pollutants have contaminated the aquatic larvae of chironomids, which are part of the biodiversity of proglacial areas.

[6] https://www.iceandlife.com/

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It is therefore essential to ensure the protection of these areas, which constitute primary ecosystems of high ecological value. Safeguarding them is critical for monitoring vegetation succession, enabling the undisturbed progression of natural ecological processes, and mitigating potential pressures from emerging interests or anthropogenic impacts. The following sections examine how APAs can contribute to these objectives, highlight existing initiatives, and provide strategic recommendations for enhancing their protection.

Table 9 A selection of studies on the development of new ecosystems in proglacial areas within APAs. For full bibliography information, cfr References section

Title	Journal	APAs
Glacial biodiversity of the southernmost glaciers of the European Alps (Clapier and Peirabroc, Italy)	Journal of mountain science	Parco Naturale Alpi Marittime
Vegetation and Glacier Trends in the Area of the Marittime Alps Natural Park (Italy)	Climate	Parco Naturale Alpi Marittime
Glacier foreland insect uptake synthetic compounds	Environmental Science and Pollution Research	Nature Park Adamello Brenta Geopark
The development of terrestrial ecosystems emerging after glacier retreat	Nature	Several – Entire Alpine arc
Ice&Life - Rapport d'activité 2022 - 2024	//	ASTERS
Langzeitmonitoring von Ökosystemprozessen im Nationalpark Hohe Tauern	//	Hohe Tauern National Park (Carinthia)
Interaktionen zwischen der Geomorphologie und Vegetation im Gletschervorfeld des Ödenwinkelkees	//	Hohe Tauern National Park (Carinthia)
Global impacts of glacier retreat on ecosystem services provided by soil and vegetation in mountain Regions: A literature review	Ecosystem Services	Several – Entire Alpine arc

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4. Use of the phenomenon for communication and awareness-raising purposes within protected areas

Survey responses from participating APAs highlight a wide array of communication strategies addressing the ongoing retreat of glaciers and the consequent expansion of pro-glacial zones where new ecosystems are emerging. In fact, while the APAs acknowledged in the survey that reversing glacier retreat is beyond their regional capacity, given its global scale and systemic causes, they emphasized their crucial role in raising awareness. Communication efforts aim to raise awareness among various audiences, ranging from the general public to scientific and policy-making communities, about the importance of these transformations and the need for ecological protection.

Events

Events remain one of the most effective tools for engaging diverse audiences. A landmark initiative in this domain is the "Agir pour les glaciers" festival, co-organized by ASTERS and the Vanoise National Park, held in Bourg-Saint-Maurice – Les Arcs from 20 to 22 March 2025[7]. Closely linked to the "Ice&Life" project, the festival focused on the urgent need to strengthen protection measures for glaciers and their successor ecosystems. Open to both academics and the general public, the event recorded high participation and impact.

Figure 14 Entrance to the 1st edition of the festival "Agir pour les glaciers", 21-03-2025. © ALPARC - Michele Guerini

[7] https://agirpourlesglaciers.org/

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Smaller-scale events are also widespread across the APAs. These include public scientific seminars, lecture series, and educational projects. A notable example is the initiative organized by the Écrins National Park, which involved four local schools in a dedicated pedagogical program on glacier-related themes. In addition, temporary exhibitions and displays in visitor centres serve as key platforms for public education.

Among the most recognizable and widely disseminated events in the Alpine region is the Carovana dei Ghiacciai (Caravan of Glaciers)[8], organized by Legambiente and the Italian Glaciological Committee. This traveling campaign depends heavily on the cooperation of APAs, with key stops in parks such as Triglav National Park, Orobie Valtellinesi Regional Park, Adamello Regional Park, and Nature Park Adamello Brenta Geopark.

Brochures – Flyers - Books

Printed and digital materials play an essential role in public outreach. Newsletters are the most common and accessible format, used extensively by APAs to inform stakeholders and local communities. Other publications, such as brochures, flyers, and educational handbooks, are also widely distributed.

An example of a more substantial publication is the book “Utlimi Ghiacciai” (“Last Glaciers”), published by the Alpi Marittime Regional Park, which documents glacier retreat and its broader implications for Alpine ecosystems.

Reports

Scientific reporting is a fundamental communication tool within APAs, though these materials are often tailored for expert audiences or decision-makers rather than the general public. Reports may be published directly by APAs or by external research institutions conducting studies within protected areas.

Hohe Tauern National Park (Carinthia), for instance, has released multiple reports on glacier retreat and its ecological consequences, particularly concerning vegetation dynamics and aquatic geodiversity[9]. An external example includes a Greenpeace report documenting the presence of microplastics in new glacial lakes in the Austrian Alps.

Other

Several additional initiatives contribute to raising awareness about glacial changes:

- **European glacier Manifesto**: Numerous APAs have endorsed this initiative, including Ente di Gestione delle Aree Protette della Valle Sesia, UNESCO Global Geopark Sesia

[8] https://www.legambiente.it/campagna/carovana-dei-ghiacciai/
[9] https://www.parcs.at/npht/mmd_fullentry.php?docu_id=38558

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Val Grande, Prealpi Giulie Regional Park, Gran Paradiso National Park, Stelvio National Park – Lombardy sector, Val Grande National Park, and Triglav National Park.

- **Ongoing scientific and other projects**: Research efforts such as *"A First Assessment of the Biodiversity of the Adamello Glacier"*, conducted within Adamello Regional Park, exemplify long-term commitments to understanding emerging ecosystems. Other ongoing projects, such as the WATERISE Alpine Space Project, in which Contamines Montjoie Nature Reserve is a pilot area, show the commitment to find effective solutions in water managing after glacier retreat.
- **Thematic trails**: Interpretive trails dedicated to glaciers are increasingly implemented as tools for public education and engagement. Notable examples include glacier-themed trails in Triglav National Park, Orobie Valtellinesi Regional Park and Hohe Tauern National Park (Carinthia), but several of these trails are present in the Alps. These trails are designed for broad audiences and effectively illustrate past, present, and projected glacial dynamics as well as the ecological transitions underway.

Table 10 Selection of communication actions by APAs and Alpine Organisations to communicate the importance of glaciers

Events	Brochures – Flyers - Books	Reports	Other
Festival "Agir pour le glacier" - *ASTERS, Vanoise National Park, Écrins National Park*	"Ultimi ghiacciai" - *Parco Naturale delle Alpi Marittime*	Alpine Glaciers and New Ecosystems in Protected Areas – *ALPARC Report*	European Glacier MANIFESTO – *6 APAs*
Scientific meetings for the general public, conferences and Pedagogical project – *Several APAs*	Protected areas newsletters – *Several APAs*	Alpine protected areas report on glaciers- *Several APAs including Hohe Tauern National Park (Carinthia)*	Ongoing scientific projects Adamello glacier biodiversity – *Adamello Regional Park*
Carovana dei Ghiacciai – *Several APAs*	Photo comparison – *Several APAs*	MIKROPLASTIK IN GLETSCHERSEEN – Greenpeace Report - *Austrian Alps*	Thematic trails – *Triglav National Park and Hohe Tauern National Park (Carinthia)*

and newly emerging ecosystems.

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5. Workshop

Glaciers are vital to Alpine ecosystems and act as key indicators of climate change. Protected areas, due to their significant glacier coverage, play a crucialrole in monitoring these changes and implementing actions. The ALPARC Team has developed activities addressing this subject, and the results were shared during this workshop (see APPENDIX) These activities also facilitated exchanges with APAs regarding recommendations to protect glaciers and emerging ecosystems in proglacial areas.

5.1 Participants

-Michele Guerini – ALPARC

-Guido Plassmann – ALPARC

-Oriana Coronado – ALPARC

-Pietro Merzi – ALPARC

-Jean Baptiste Bosson – marge sauvage

-Miha Pavšek - ZRC SAZU and Triglav National Park

-Katharina Aichhorn - Hohe Tauern National Park

-Angelika Riegler – Hohe Tauern National Park

-Jessica Oehler - Stiftung UNESCO-Welterbe Schweizer Alpen Jungfrau-Aletsch (SAJA)

-Peter Oggier - Naturpark Pfyn-Finges

-Margherita Stumvoll-Schmaltz - National Park Berchtesgaden

-Jacques Mouray – ASTERS- CEN74

-Luigina Armani – Parco Naturale Adamello Brenta Geopark

-Michele Care - Parco Naturale Adamello Brenta Geopark

-Richard Bonet – Parc National des Écrins

-Emma Denise – Parc National de la Vanoise

-Adrien Guerou – USMB

-Maja Kogovšek – CIPRA

-Noémie Fort – CBNA

-Sophie Vallée – CBNA

-Marco Giardino – Comitato Glaciologico Italiano

-Laura Cantounet - POW

-Ann Winkler - WWF

-Isabelle Paillet

-Laurence DAYET - DREAL AURA

-Andreas Bartel - Austrian Environment Agency

-Mathias Ulrich - German Environment Agency

-Tommaso Bastiani - Italian Presidency of Alpine Convention

-Claire de Kermadec - Alpine Convention

-Valerio Comple - Italian Delegation of Alpine Convention

-Živa Novljan – Alpine Convention

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Figure 15 Screenshot of the online workshop. © ALPARC

5.2 Discussion

The ALPARC team presented their ongoing work on the current status and future evolution of glaciers in the Alpine region, with a focus on protected areas. ALPARC shared the results of a survey conducted across different protected areas, detailing the activities implemented on protected areas regarding glacier monitoring and conservation. A comparison of glacier retreat over time (between 1850, 2015, and 2022) among selected protected areas and strategic recommendations addressing the challenges on glacier conservation were presented.

APAs have been actively involved in raising awareness about these challenges through different initiatives. As a key project, Ice&Life, was presented to the participants by Jacques Mouray and Jean-Baptiste Bosson. It aims to produce new scientific data and recommend policy actions to address glacier retreat. The French Alps have lost 66% of their glaciated surface since 1850, underscoring the urgency of protecting postglacial ecosystems. The project emphasizes glaciers as irreplaceable, "last wilderness areas" in the Alps, calling for urgent action to mitigate climate change effects.

The meeting also addressed the complexity of glacier conservation, stressing the need to combat scepticism, communicate positive messages to policymakers, and promote large-scale protective actions. Raising awareness, sharing expert knowledge, and involving citizen science were identified as key strategies for building a shared understanding of the issue.

Representatives from other protected areas highlighted the importance and complexity of implementing actions oriented towards glacier areas protection outside of national parks or strong protected areas.

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Figure 16 Screenshot of the online meeting. © ALPARC

The participants also emphasized challenges like balancing natural processes with human intervention, managing water flow changes, and monitoring emerging ecosystems in post-glacial areas. The increasing risk of geohazards, such as glacial lakes and floods, was also discussed, with a focus on how protected areas can help manage these risks and raise awareness among policymakers without spreading fear.

To strengthen glacier monitoring, similar methods (such as remote sensing and monitoring altitudinal shifts in species) were suggested. The importance of cross-regional communication was emphasized to ensure that monitoring results are shared and acted upon across the entire Alpine region.

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6. Implementation of protective measures – Recommendations for conservation and management within protected areas

The last question of the survey for APAs was: **In your opinion, what actions should be taken to protect glaciers or manage the consequences of their retreat?** The responses to this question were analysed and integrated with the results of the workshop, leading to the following recommendations for the protection of the glaciers and emerging ecosystem:

- **Strengthen the protection**: Glaciers and newly emerging proglacial areas within APAs require robust and coordinated protection to safeguard both glacial and foreland-related biodiversity and to ensure the natural development of new ecosystems. However, the degree of legal and practical protection varies significantly across different protected areas. In this context, it is recommended to advance the proposal presented by Jean-Baptiste Bosson during the workshop and within the Ice&Life project: the establishment of an international treaty dedicated to the protection of glacial and post-glacial environments. Such a treaty would provide a harmonized framework for strong protection across the Alpine arc and should be integrated into national biodiversity strategies to ensure long-term ecological integrity and resilience.
- **Strengthen the monitoring:** Monitoring is widely recognised as good practice to prevent hazards and has gained increasing importance in the current phase of accelerated climate change. It is therefore recommended to strengthen the monitoring of glacier masses and their dynamics within APAs, both to assess their current status and to anticipate potential collapses or related geohazards. Additionally, enhanced monitoring of key environmental indicators affected by glacier retreat, such as flora, fauna, and freshwater availability, is essential. In fact, although various observations are already being conducted within APAs, systematic and long-term monitoring programs remain limited on the subject, not least because the phenomenon is relatively recent and rapidly evolving.
- **Planning for visitor management:** Under current climatic conditions, tourism in glacial and proglacial areas has become increasingly hazardous due to natural risks such as landslides, ice collapses, and reduced water availability in regions most affected by deglaciation. To mitigate these risks and protect emerging ecosystems, it is recommended that APAs implement adaptive tourism planning strategies. These may include limiting visitor numbers, rerouting existing trails to ensure greater safety, and enforcing strict protection measures—such as access restrictions—in particularly hazardous zones or in areas where new, fragile ecosystems are forming. Such measures are essential to balance visitor access with environmental safety and ecological conservation.
- **Improve communication actions:** While communication efforts are already underway in many APAs, it is strongly recommended to expand these initiatives to enhance public awareness of the high ecological value of glacial and proglacial zones. Given that glacier retreat is a relatively recent and evolving phenomenon, the importance and fragility of these emerging ecosystems may not yet be fully understood by the general public. APAs are encouraged to increase research and monitoring projects in these areas (many of

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which are already planned) and to communicate their findings in accessible, engaging formats. This includes organizing more public-facing events such as conferences, festivals, and exhibitions, as well as implementing educational tools like school programs and thematic trails that explain the significance of glaciers and the changes occurring in mountain environments. Communication should convey a hopeful, solution-oriented message: glaciers are critical to the balance of Alpine ecosystems, and with appropriate policies and protective measures, it is still possible to preserve them and safeguard the post-glacial ecosystems newly developing. Raising public awareness in this way can also help generate broader political and institutional support for conservation efforts.

- **Increase cooperation between APAs:** Although all APAs are affected by the phenomenon of glacier retreat, they are not all at the same stage of this transition. Some still retain significant glacial mass, others are on the verge of losing it, while some have already undergone complete deglaciation. This variation presents a valuable opportunity: by fostering comparison and collaboration across APAs, it becomes possible to assess and understand the evolution of mountain environments at different phases. Such cooperation enables the development of tailored protective measures and enhances the collective capacity to adapt to ongoing climatic changes. It is therefore recommended that APAs actively initiate and participate in international cooperation projects aimed at building a coordinated, Alpine-wide strategy for the protection of glaciers and emerging proglacial ecosystems.

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APPENDIX

Program - 24 April 2025, 14h00 – 15h30

1) **PRESENTATIONS**: - Alpine glaciers in protected areas – ALPARC
- Ice&Life – ASTERS and marge sauvage

2) **DISCUSSION**: - How to protect and manage new post-glacial areas in protected areas ?
- How to communicate to public ?
- Future Perspectives

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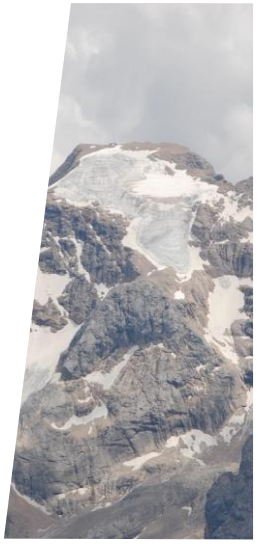
Alpine glaciers in protected areas – ALPARC

COUNTRY	NAME	Glaciated area	
		Year	Area (ha)
Switzerland	UNESCO World Heritage Swiss Alps Jungfrau-Aletsch	2016	28300
Austria	Hohe Tauern (Carinthia, Tyrol, Salzburg)	2021	12600
France	Vanoise National Park	2016	9200
Austria	Ötztal Nature Park	2020	8925
France	Les Ecrins National Park	2020	6000
Italy	Stelvio National Park: South Tyrolean part	2017	3482
Italy	Stelvio National Park: Lombard part	2016	2413
Switzerland	Pfyn-Finges Nature Park	2016	1820
Switzerland	Valley of Trient Regional Nature Park	2016	1080
Italy	Adamello Brenta Nature Park	2022	1053
France	ASTERS - Conservatoire d'espaces naturels Haute-Savoie	2022	697
Italy	Stelvio National Park: Trentine part	2022	597
Italy	Parco dell'Adamello	2021	400
Switzerland	Parc Ela	2016	220
Switzerland	Landschaftspark Binntal	2016	200
Switzerland	Beverin Nature Park	2016	150
Italy	Alpe Veglia e Devero Nature Park (Aree Protette dell'Ossola)	2022	176
Italy	Orobie Valtellinesi Nature Park	2022	118
Italy	Prejulian Alps Nature Park	2016	117

ALPARC – Glaciated Areas in Protected Areas - February 2023



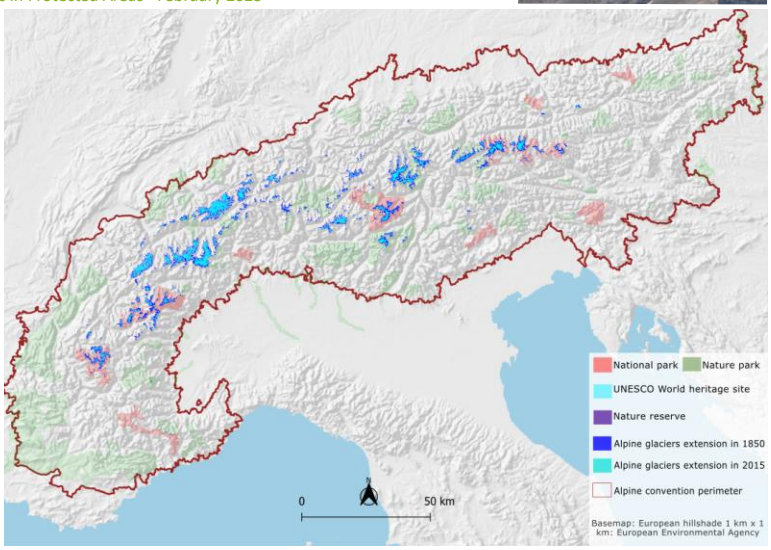
Alpine glaciers in protected areas – ALPARC

COUNTRY	NAME	Glaciated area	
		Year	Area (ha)
Italy	Aree Protette Alpi Marittime	2022	44
Italy	Alta valle Antrona Nature Park (Aree Protette dell'Ossola)	2022	28
Switzerland	Val Calanca Nature Park	2016	20
Italy	Paneveggio Pale di San Martino Nature Park	2022	20
Germany	Berchtesgaden National Park	2018	5,20
Slovenia	Triglav National Park	2022	0,70
Switzerland	Swiss National Park	2016	0
Switzerland	Biosfera Val Müstair	2016	0

ALPARC – Glaciated Areas in Protected Areas - February 2023

Alpine glaciers in protected areas – ALPARC

Map of the evolution of glaciers in the Alps from 1850 to 2015



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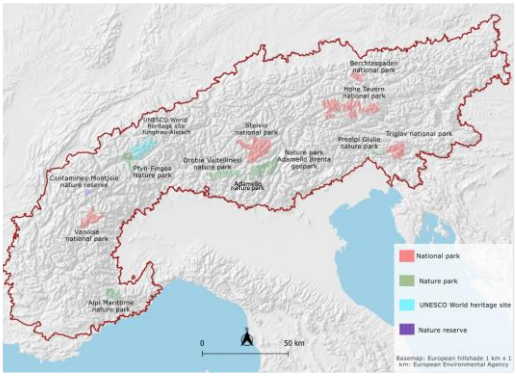
Alpine glaciers in protected areas – ALPARC

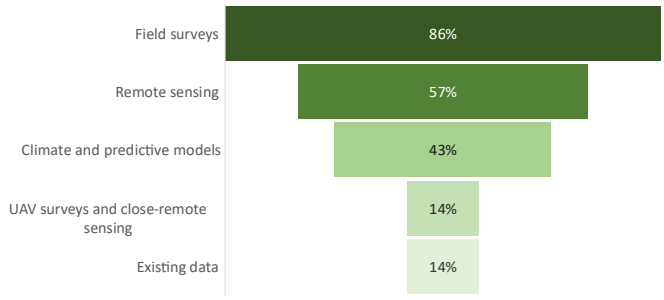
Survey participants

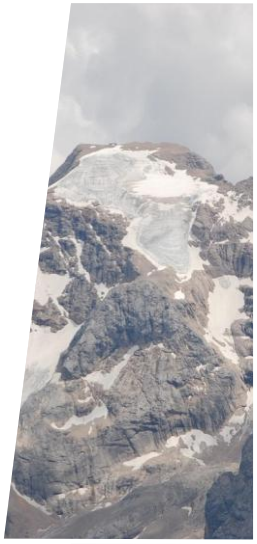
ID	NAME	TYPE	NATION
1	Parco Nazionale dello Stelvio – South Tyrolean	National Park	Italy
2	Hohe Tauern National Park (Carinthia)	National Park	Austria
3	Triglav National Park	National Park	Slovenia
4	Prealpi Giulie	Regional Park	Italy
5	Orobie Valtellinesi	Regional Park	Italy
6	Réserve Naturelle des Contamines Montjoie	Nature Reserve	France
7	UNESCO World Heritage Swiss Alps Jungfrau-Aletsch	UNESCO World heritage site	Switzerland
8	Parco naturale Adamello Brenta Geopark	Nature Park and UNESCO Global Geopark	Italy
9	Parc National de la Vanoise	National Park	France
10	Parco Naturale Alpi Marittime	Nature Park	Italy
11	Naturpark Pfyn-Finges	Nature Park	Switzerland
12	ASTERS	Nature reserve network	France
13	Berchtesgaden National Park	National Park	Germany
14	Parco regionale dell'Adamello	Regional Park	Italy
15	Université Savoie Mont Blanc	University	France



Alpine glaciers in protected areas – ALPARC

Glaciers monitoring in protected areas



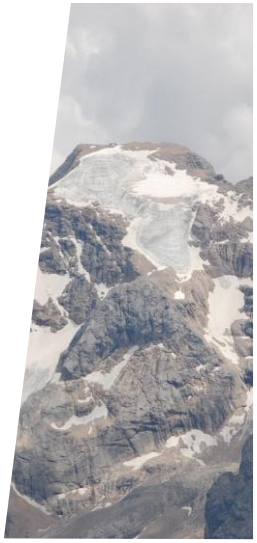


Alpine glaciers in protected areas – ALPARC

Glaciers retreat

	Km²		
Considered area	**1850**	**2015**	**Ice Loss 1850-2015**
All Alpine arc	4248,09	1805,88	57,49%
Alpine Protected Areas[1]	2075,57	754,65	63,64%
Alpine National Parks	1053,01	350,14	66,75%

[1] Only considering nature / regional parks and national parks



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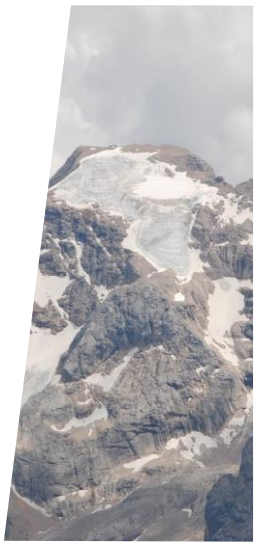
Alpine glaciers in protected areas – ALPARC

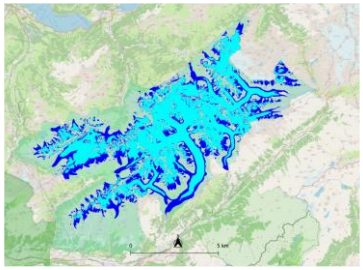
Glaciers retreat – protected areas

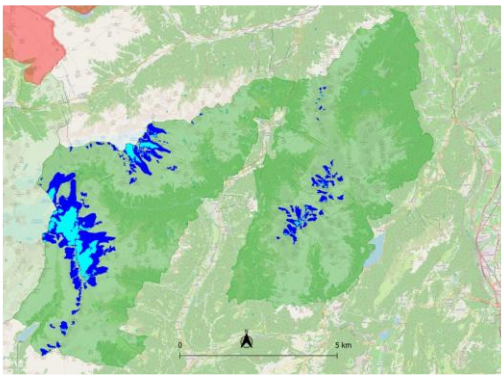
	Km²					
NAME	1850	2015	2022	Ice Loss 1850-2015	Ice Loss 2015-2022	Ice Loss 1850-2022
ASTERS	46,55	14,45	6,97	68,96%	51,76%	85,03%
Parco Naturale Adamello Brenta Geopark	83,97	31,66	10,53	62,30%	66,74%	87,46%
Parco Naturale Alpi Marittime	3,04	0,55	0,44	81,91%	20,00%	85,53%
Hohe Tauern National Park (Carinthia)	373,7	143,84	126	61,51%	12,40%	66,28%
UNESCO World Heritage Swiss Alps Jungfrau-Aletsch	449,9	287,47	x	36,10%	x	x
Triglav National Park	0,95	0,05	0,007	94,74%	86,00%	99,26%



Alpine glaciers in protected areas – ALPARC

Comparison of glacier extent in 1850 and 2015 in the Swiss Alps Jungfrau-Aletsch UNESCO World Heritage Site and Parco Naturale Adamello Brenta Geopark

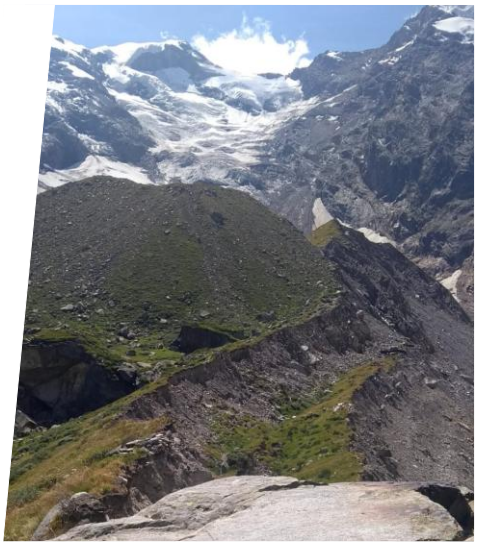




Alpine glaciers in protected areas – ALPARC

Changes observed in protected areas

Landscape	Vegetation	Fauna	Water
Glacier Retreat (Visible/Aesthetic)	Vegetation Expansion	Studies on insect	Less availability in summer
Geo-morphological Instability	Altitudinal Shift	changes in local fauna	More availability in winter
New lakes	Establishment of pioneer vegetation	Species higher up	
		Species at risk	



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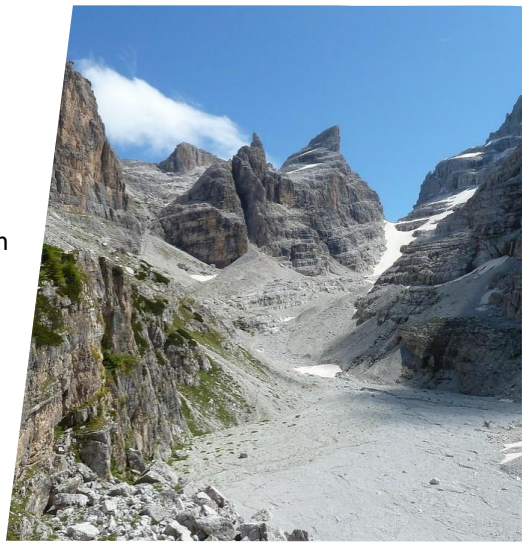
Alpine glaciers in protected areas – ALPARC

Main consequences

1) New Risks : necessity for visitor management and communication

2) New ecosystem developing: necessity for management and protection strategy

These areas are recognized as critical areas for preserving biodiversity and supporting ecosystem resilience



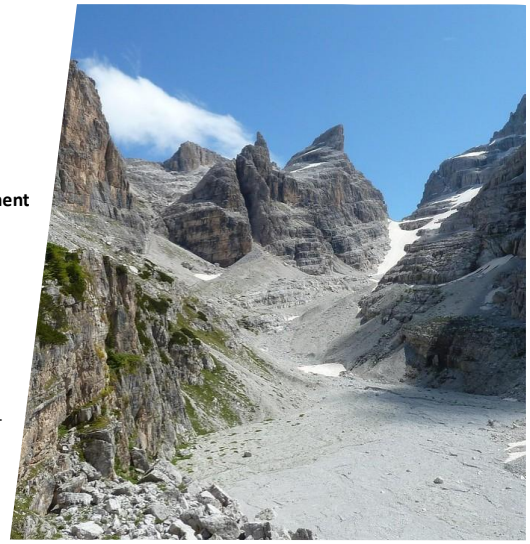
Alpine glaciers in protected areas – ALPARC

Galcier retreats and mountain ecosystems

Loss of biodiversity Vs New ecosystem developement

The beneficial role of glaciers for social, ecological and hydrological systems is in decline (Geo-ecosystem)

The retreat of glaciers is releasing large portions of alpine territory. Important to understand these post - glacial ecosystems: glacier melting will lead to one of the most rapid shifts of ecosystems on Earth.



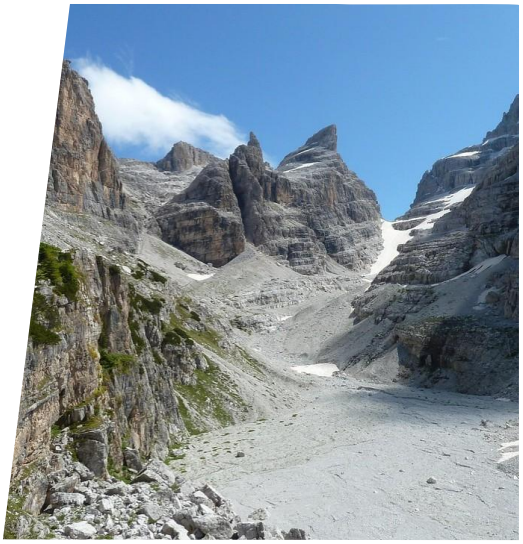
Alpine glaciers in protected areas – ALPARC

Galcier retreats and mountain ecosystems

New need in protected areas:

Protection of sites to monitor vegetation succession stages and allowing the free development of ecological processes, to prevent these sites from several interests and impacts which may emerge.

What can Protected areas do?



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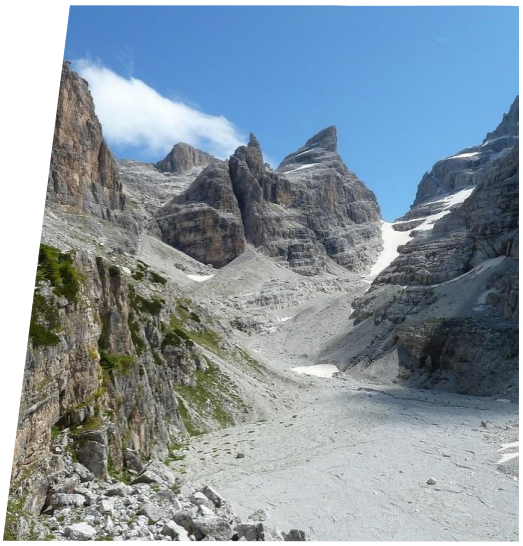
Alpine glaciers in protected areas – ALPARC

Sensibilization: one of the main tasks of protected areas

Events	Brochures – flyers - books	Reports	Other
Festival « Agir pour le glacier »	« Ultimi ghiacciai » (Alpi Marittime)	ALPARC report	European Glacier MANIFESTO (6 APAs)
Scientific meetings for the general public and Pedagogical project (e.g., Parc des Ecrin)	Protected areas newsletters	Alpine protected areas reports on glaciers (e.g. Hohe Tauern national park)	Ongoing scientific projects: Adamello glacier biodiversity
Carovana dei Ghiacciai	Photo comparison (e.g. Parc Vanoise)	MIKROPLASTIK IN GLETSCHERSEEN – Greenpeace Report on Austrian Glaciers	Thematic trails (e.g. Triglav)

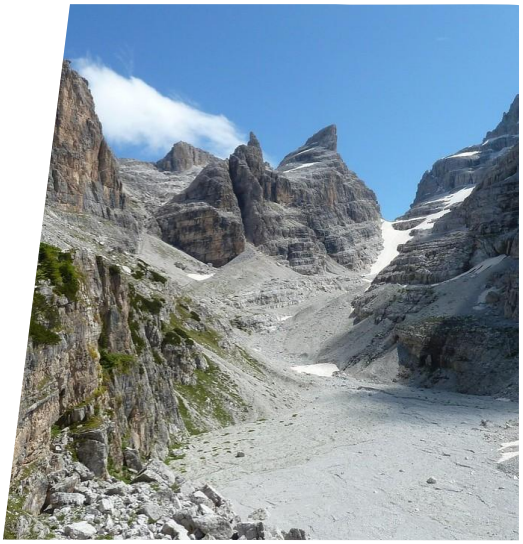


Alpine glaciers in protected areas – ALPARC

Glacier monitoring? Yes

Mitigation? Difficult

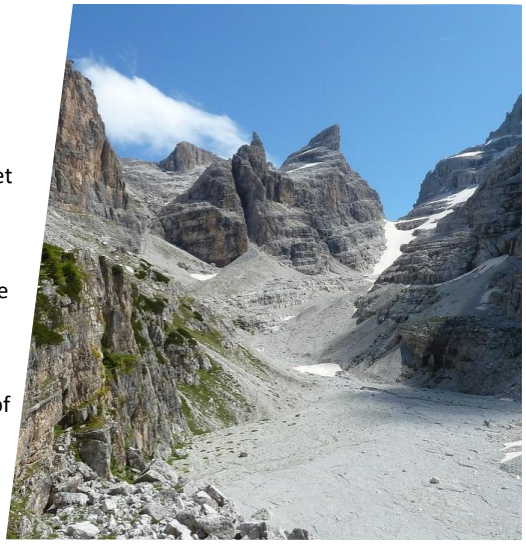
Adaptation strategy? Essential



Alpine glaciers in protected areas – ALPARC

Adaptation strategy

- Strongly protect deglaciated areas: “let nature be nature” and protect glacier forefield
- Increase the research projects in these areas and cooperation between PAs
- Better visitor management (e.g., daily limitation of visitors or arrangement of the wastewater)
- More awareness raising – Environmental education



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2. Ice&Life – ASTERS and “marge sauvage”

3. How to protect and manage new post-glacial areas in protected areas ?

3. How to protect and manage new post-glacial areas in protected areas ?

Strong protection: Let nature be nature, or actively act?
How to protect from other uses?

-

Protect species at risk or « welcome » new species?

-

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3. How to protect and manage new post-glacial areas in protected areas ?

Strengthen glacier monitoring or not?

-

Common strategy for APAs?

-

4. How to communicate to public ?

4. How to communicate to public ?

Effective awareness-raising tools: events or scientific reports ?

-

How can people really understand the importance of new ecosystems / climate change?

-

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4. How to communicate to public ?

How can citizens be involved ?

-

5. Future perspectives?

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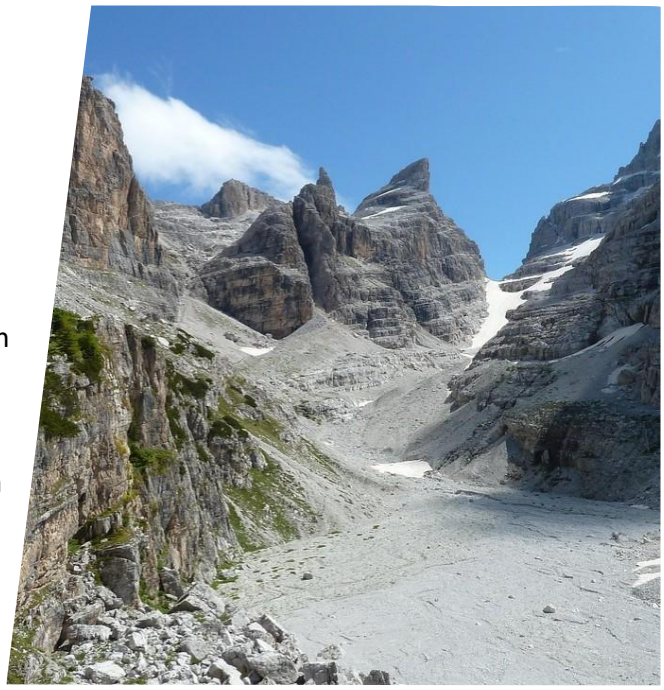
Future perspectives

- Alpine Glacier are going to completely melt – scenario without glaciers possible

- Necessity to understand the protection needs and the new risks : Cooperation among PAs is essential

- Ideas on project to develop a common strategy to protect and manage new post-glacial areas and new ecosystem developing? Or a project on tourism management / environmental ed.?



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- Thank you
- Merci
- Grazie
- Danke
- Hvala

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