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CHANGES IN THE NUMBER AND AREA OF ITALIAN ALPINE GLACIERS BETWEEN 1958 AND 1989

ABSTRACT: AJASSA R., BIANCOTTI A., BIASINI A., BRANCUCCI G., CARTON A. & SALVATORE M.C., *Changes in the number and area of Italian Alpine glaciers between 1958 and 1989*. (IT ISSN 0391-9838, 1997).

A comparison is made between the data for the year 1958 shown in the Register of Italian Glaciers and the updated Survey prepared from aerial photos taken in 1989 and published by the Ministry for the Environment in 1993. Variations in the number (+ 118 units) and area (– 2005 hectares) of the glaciers on the Italian side of the Alps are assessed to determine their relation to slope exposure. The conclusion is drawn that exposure provides the main explanation of the fluctuations in the glaciated areas during these 31 years.

KEY WORDS: Glacier fluctuations, Italian Alps.

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Gli autori prendono in considerazione i dati forniti dal Catasto dei ghiacciai italiani redatto nel 1958 e quelli aggiornati per conto del Ministero dell'Ambiente nel 1993. Viene effettuata un'analisi sulle variazioni numeriche ed areali dei ghiacciai del versante alpino italiano, al fine di individuare le relazioni esistenti tra le variazioni stesse e le esposizioni dei versanti. I dati evidenziano, nei 31 anni di intervallo considerato, differenze sia nella consistenza numerica (+ 118 unità) sia in quella areale (– 2.005 ha). L'esposizione appare il carattere che maggiormente influenza le variazioni delle coperture glaciali.

TERMINI CHIAVE: Variazioni glaciali, Alpi italiane.

INTRODUCTION

The Italian Glaciological Committee (Cgi) has recently completed a survey of Italian ice bodies on behalf of the Ministry for the Environment (Ajassa & Brancucci, 1993; Ajassa & *alii*, 1994). This survey was based on the «Volo Italia 1988-89» aerial photographic coverage of the country. Its main purpose was to update the register of Italian Glaciers prepared in 1958 and published by the Italian National Research Center and the Comitato Glaciologico Italiano in 1961.

Use has now been made of the register and the survey, together with the observations in the annual reports of glaciological campaigns conducted by Cgi operators in the Alps, to assess variations in the number and area of the glaciers on the Italian side of the Alps. It should be noted, however, that the superior features of the aerial photographic coverage (Biasini, 1995) have meant that the ensuing survey gave rise to operating standards which are considerably different from those behind the register, and may in some cases influence the results suggested below. Identification of the limits of ice bodies, in fact, in the 1989 survey, has always been based on air photos and hence, by examining all its points on the picture, with the same perspective, irrespective of a glacier's altitude.

The method employed for the survey, on the other hand, gives more precise results than «expeditious» surveying, since the coordinates of these limits are determined by means of digital photogrammetry in the Utm system and related to known points on the Italian Military Geography Institute's 1:25,000 maps. Another advantage is that the same points can be used to plot the corresponding limits derived from earlier or future aerial photos and thus very quickly obtain highly accurate area comparisons via computer (Biasini & Salvatore, 1993).

This paper takes a closer look at the relations between the areas covered by ice and the exposure of their slopes by reviewing the entirety of the data with geographical exposure as the common analysis factor. A comparison is made between the number of individual «active» glaciers in the Register and the Survey. An assessment is also made of those that have broken up and those that were classed as «extinct» on the register, or not detected, and now appear as «new glaciers» in the Survey (Ajassa & *alii*, 1993). Diffe-

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rences in area are considered and the data for single ranges of the Italian Alps are examined to see whether the fluctuations in number and area that have occurred are related to the location of a glacier as well as its exposure.

The results of this preliminary study show that the number of glaciers has increased by 118, whereas the total area has shrunk by 2005 hectares. Synoptic data for the single ranges are also provided as a basis for further investigation.

THE DATA

The number and area of the glaciers (divided by Alpine range and exposure) are illustrated in tables 1a, 1b (Register) and 2a, 2b (Survey), and compared in figs. 1 and 2. It can be seen that there were more glaciers on N, NW and NE slopes, and to a lesser extent on the SE, both in 1958 and in 1989, and that these covered the greatest areas. As already stated, the total number was higher in 1989, with maximum on the N (+20) and NW (+22) and a minimum on the W (+8). With the exception of the E and to a lesser extent the NE, there was a reduction in area, with maximum on the NW (–748 ha) and N (–564 ha) and a minimum on the S (–29 ha).

TABLE 1a - Number of glaciers on the 1958 Register

	N	NE	E	SE	S	SW	W	NW	Tot.
Marittime	2	3							5
Cottian	1	3		1		1	1	4	11
Graian	20	42	9	40	11	3	6	31	162
Pennine	3	10	6	13	12	14	3	9	70
Lepontine	2	7	6	4	1	2	1	1	24
Rhaetian	95	26	33	20	30	16	40	69	329
Norian	7	1	1	7	10	3	3	15	47
Dolomites	10	1		1			2	3	17
Julian	3								3
Tot.	144	93	55	86	64	39	56	132	669

TABLE 1b - Area (ha) of the Italian glaciers on the 1958 Register

	N	NE	E	SE	S	SW	W	NW	Tot.
Marittime	25	64							89
Cottian	15	161		81		4	6	35	302
Graian	1152	2895	818	4743	421	119	569	2695	13412
Pennine	353	829	387	1484	1372	2412	856	302	7995
Lepontine	79	640	452	128	10	51	14	30	1404
Rhaetian	6964	2220	2496	753	3393	1382	1382	4270	22861
Norian	762	48	5	336	467	158	287	546	2609
Dolomites	587	41		13			37	34	712
Julian	23								23
Tot.	9960	6898	4158	7538	5663	4126	3152	7911	49406

TABLE 2a - Total number of glaciers identified in the 1989 Survey

	N	NE	E	SE	S	SW	W	NW	Tot.
Marittime	2	3							5
Cottian	1	4		1		1	1	4	12
Graian	25	49	12	50	11	6	8	37	198
Pennine	3	10	8	15	13	16	3	9	77
Lepontine	2	9	6	4	1	2	1	1	26
Rhaetian	105	29	39	24	38	27	46	82	390
Norian	10	1	2	7	11	3	3	17	54
Dolomites	12	2		1			2	4	21
Julian	3								3
Tot.	164	107	67	102	74	55	64	154	787

TABLE 2b - Area (ha) of the glaciers identified in the 1989 Survey

	N	NE	E	SE	S	SW	W	NW	Tot.
Marittime	6	13							19
Cottian	2	61		7		4	2	12	87
Graian	899	3543	792	4564	401	99	516	1569	12383
Pennine	233	337	502	1352	1171	1973	865	191	6622
Lepontine	41	555	311	100	19	28	10	8	1072
Rhaetian	6937	2441	3527	745	3517	1738	1079	3713	23698
Norian	846	76	14	417	526	167	280	637	2963
Dolomites	413	43		26			22	34	538
Julian	19								19
Tot.	9396	7071	5146	7210	5634	4008	2773	6163	47401

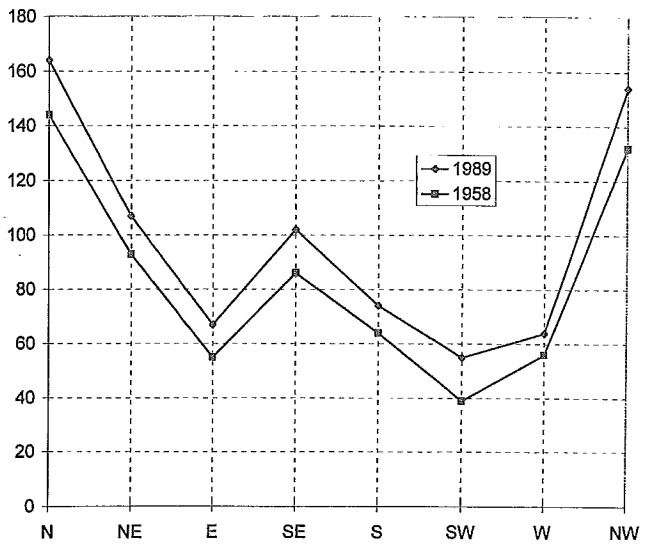

FIG. 1 - Number of glaciers in 1958 and 1989.

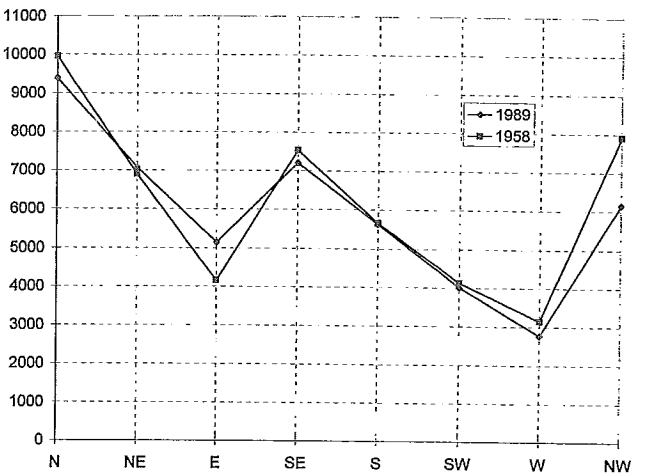

FIG. 2 - Area (ha) of glaciers in 1958 and 1989.

The increase in number is related to both the breaking up of some glaciers (tab. 3a) and the recording of «new glaciers» (tab. 4a) that were either not detected in 1958 or subsequently reformed after being classed as «extinct». Dismemberment mainly occurred on N and NW slopes, and to some extent on the SE, which had the third largest increase (+16). It is most marked in the Rhaetian Alps (all exposures) and the Graian Alps, and negligible in the Cottian Alps and the Dolomites, where there are fewer glaciers and smaller cover areas (tab. 3a).

TABLE 3a - Total number of glaciers «dismembered» between 1958 and 1989, as determined from the Survey

	N	NE	E	SE	S	SW	W	NW	Tot.
Marittime									
Cottian		1							1
Graian	5	4	3	10		3	2	4	31
Pennine			2	2	1	2			7
Lepontine		2							2
Rhaetian	10	3	3	1	5	4	3	8	37
Norian	1		1		1			2	5
Dolomites								1	1
Julian									
Tot.	16	10	9	13	7	9	5	15	84

TABLE 3b - Total area (ha) of glaciers «dismembered» between 1958 and 1989, as determined from the Survey

	N	NE	E	SE	S	SW	W	NW	Tot.
Marittime									
Cottian		13							13
Graian	93	55	31	98		48	9	53	388
Pennine			21	12	10	40			83
Lepontine		17							17
Rhaetian	38	24	875	6	42	454	16	44	1499
Norian	11		7		24			21	63
Dolomites								2	2
Julian									
Tot.	143	108	935	117	75	542	25	119	2064

TABLE 4a - Number of «new glaciers» identified in the Survey

	N	NE	E	SE	S	SW	W	NW	Tot.
Marittime									
Cottian									
Graian		3						2	5
Pennine									
Lepontine									
Rhaetian			3	3	3	7	3	5	24
Norian	2								2
Dolomites	2	1							3
Julian									
Tot.	4	4	3	3	3	7	3	7	34

TABLE 4b - Area (ha) of «new glaciers» identified in the Survey

	N	NE	E	SE	S	SW	W	NW	Tot.
Marittime									
Cozie									
Graian		41						19	59
Pennine									
Lepontine									
Rhaetian			24	43	50	47	17	104	285
Norian	89								89
Dolomites	14	11							25
Julian									
Tot.	103	52	24	43	50	47	17	123	459

The increase due to regeneration is much more uniform. There are increases of 3-4 units on all slopes except the SW and NW (7 units). The greatest increase is in the Rhaetian Alps (24 units).

We considered also the areal changes for each significant alpine sector (figure 3). The resulting diagrams show that in each mountainous group, excepted Rhetian and, subordinate, Norian Alps, the glaciers' development follows some preferential expositions. While in the Pennine Alps the glaciers are in the southern sectors, and in the Graian

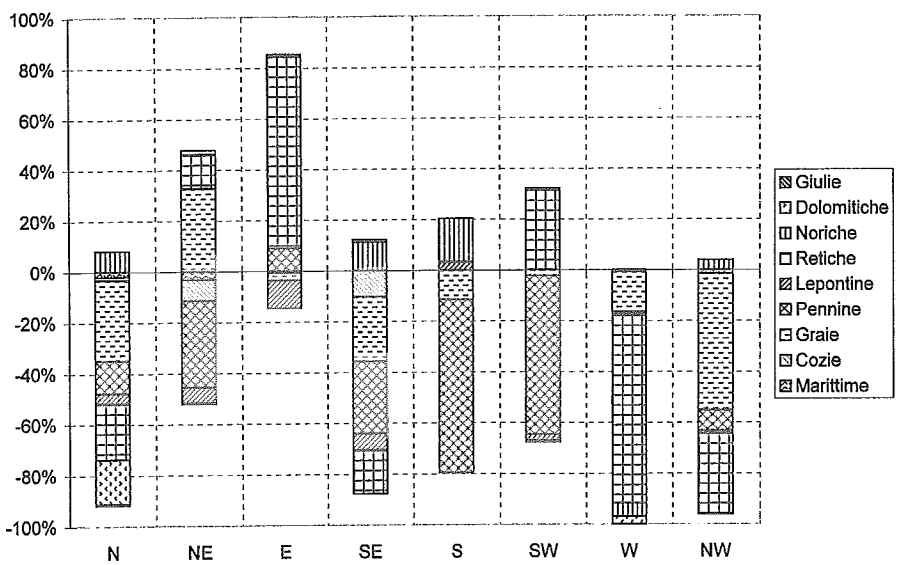

FIG. 3 - Changes in glacier area (ha) between 1958 and 1989 in individual Alpine ranges.

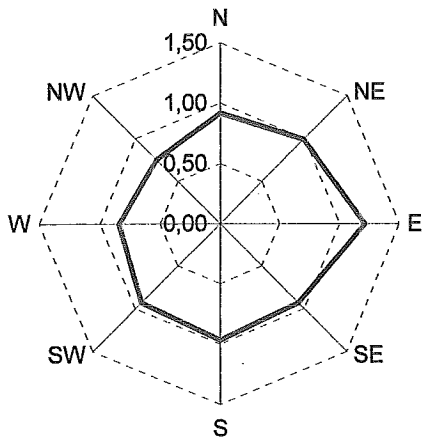

FIG. 4 - Area ratios between 1958 and 1989 ice covers in individual Alpine ranges.

Alps the preferred developing directions are NW-NE, and in the Lepontine Alps N-NE. In the Rhaetian and Norian ones we found enough wide glaciated surfaces in any direction.

The comparison between the covered surfaces in the 1958 and 1989 shows that the main variations chiefly interested all the northward expositions and rarely the SW one (Pennine), E (Lepontine and Rhaetian) and finally SE and S (Norian). Not appreciable variations have founded in the Julian Alps. It is clear, therefore, that there has been an increase in glaciated highland on slopes facing NE, E and SW, and to a lesser extent on those facing S, SE, N, and NW. Regression alone was confined to slopes facing W. A clearer and more comprehensive illustration of the changes in area in the Alps as a whole is provided in fig. 4.

Lastly, counts were made of the number of «glaciers» (area of 5 or more hectares) that have shrunk to glacieret

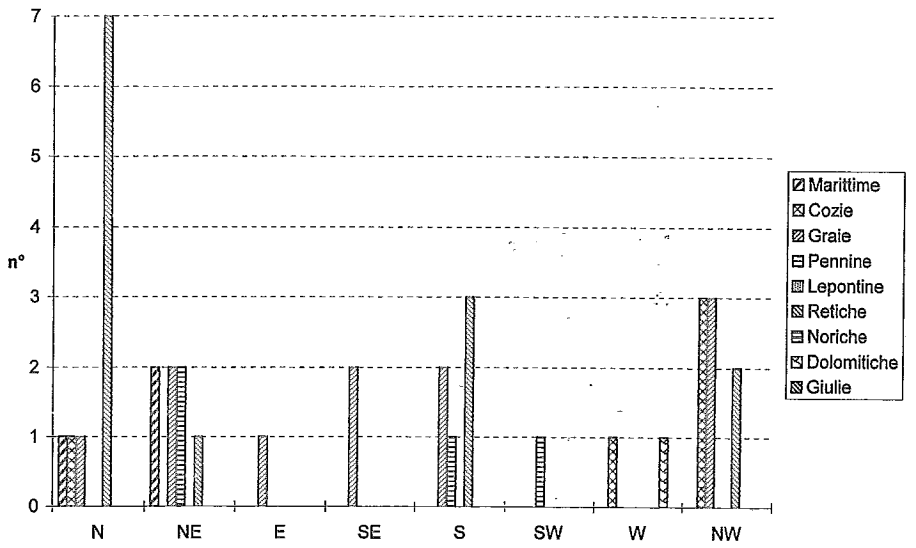

FIG. 5a - Number and exposure of ice bodies in each range measuring more than 5 ha in 1958 and less than 5 in 1989.

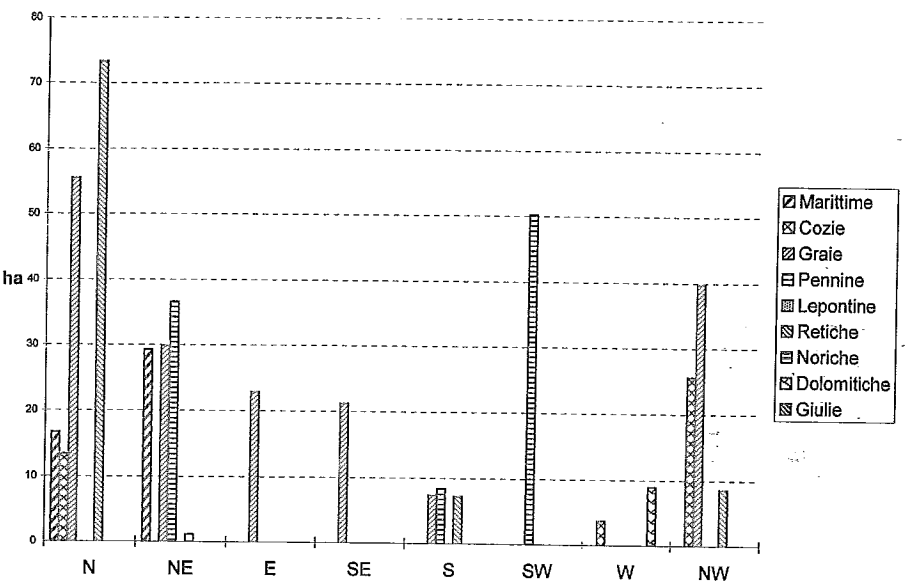

FIG. 5b - Reduction of glaciated area (ha) in relation to exposure due to shrinkage of ice masses from more to less than 5 ha in individual Alpine ranges between 1958 and 1989.

(ice-covered snowfields; less than 5 hectares) according to the terminology recently adopted in the World Glaciers Inventory. Comparison of figs 5a and 5b shows that downgradings were more numerous on slopes facing N. This is very clear in the diagram for the Alps as a whole (fig. 6) here again it is clear that glaciers facing N are more vulnerable to shrinkaye.

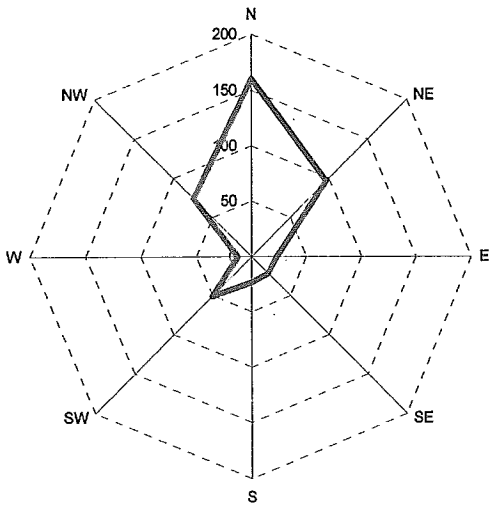

FIG. 6 - Reduction of glaciated area (ha) in relation to exposure due to shrinkage of ice masses from more to less than 5 ha in the whole of the Italian Alps between 1958 and 1989.

The reason why slopes with a lower average temperature, and threefore theoretically are best able to ensure the continuous existence of a glacier, are apparently the most vulnerable can best be sought through two (or perhaps more) kinds of survey:

– detailed surveys concentrating on the climate at high altitudes, with particular reference to the types of weather and the passage of atmospheric disturbances over the Alps;

– detailed surveys of the relations between glacier form and valley morphology, including such parameters as the axes of the main valleys, the ratio between valley slopes and height, and the ratio between the theoretical and actual radiation on the ice masses.

Investigations of this kind may lead to a better understanding of glacial dynamics and the elaboration of forecasting models.

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