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ENHANCEMENT OF THE ECOLOGICAL VALUE OF FORNI GLACIER (CENTRAL ALPS) AS A POSSIBLE GEOMORPHOSITE: NEW DATA FROM ARTHROPOD COMMUNITIES

ABSTRACT: PELFINI M. & GOBBI M., *Enhancement of the ecological value of Forni Glacier (Central Alps) as a possible geomorphosite: new data from arthropod communities*. (IT ISSN 1724-4757, 2005).

Forni Glacier is the most important Italian valley glacier and could be considered to be a new geomorphosite because of its richness in natural elements, geomorphologic evidence and the co-presence of historical elements. Scenic, cultural, socioeconomic and scientific attributes are well represented. Scientifically, geomorphologic evolution, didactic exemplarity, paleomorphological evidence, and ecological support are among the most significant aspects. In this paper we highlight the ecological value of Forni Glacier using arthropod communities as biological indicators. We collected supraglacial arthropods with different wing morphological characteristics from the glacier surface and lateral moraine. Some wingless insect species known to be very sensitive to environmental changes could contribute proxy data related to climatic change by living on supraglacial debris. Here they prey on flying arthropods drifted by upward winds; they therefore strictly depend on Glacier evolution and support the glacier's ecological value.

KEY WORDS: Geomorphosite, Forni Glacier, Supraglacial arthropods, Wing morphology, Central Italian Alps.

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Il Ghiacciaio dei Forni rappresenta il più imponente ghiacciaio vallivo italiano ed è considerabile un potenziale nuovo geomorfosito grazie alla ricchezza di elementi naturali, di evidenze geomorfologiche e di documentazione storica che lo caratterizzano. Gli attributi scenico, culturale, socio-economico e scientifico sono ben rappresentati. Il Ghiacciaio dei Forni inoltre è tra gli elementi più rappresentativi per quanto riguarda l'evoluzione geomorfologica, la testimonianza paleoclimatica e l'esemplarità didattica. Nel presente lavoro si vuole evidenziare l'interesse ecologico del ghiacciaio, rappresentato dalle comunità di artropodi epiglaciali. Sono state individuate specie con differente morfologia e funzionalità alare sia sulla superficie glaciale sia sulle morene laterali. Alcune specie di insetti non alate risultano correlate alle variazioni climatiche in quanto vivono nel detrito epiglaciale, si nutrono di specie alate sospinte dai venti, e sono pertanto strettamente dipendenti dall'evoluzione del ghiacciaio stesso. Questo conferma l'interesse del ghiacciaio dal punto di vista ecologico.

TERMINI CHIAVE: Geomorfosito, Ghiacciaio dei Forni, Artropodi epiglaciali, Morfologia alare, Alpi Centrali.

INTRODUCTION

Forni Glacier can be considered to be one of the most important glacial environments in upper Valtellina (Central Alps, Sondrio, Italy) and its historical and scientific prominence justifies the pending application to UNESCO for including it in the «GEOSITES» list of international environmental assets. In fact, owing to the richness of natural elements, the Forni Valley is an important area distinguished by geomorphological features with the co-presence of historical content.

The historical documentation (fig. 1) shows how Forni Glacier has been frequented since the mid 19th century. Since 1995, hikers have walked a trail called the «Sentiero Glaciologico al Ghiacciaio dei Forni» (Forni Glacier Trail), proposed during the centenary of the Italian Glaciological Committee (Pelfini, 1995; Pelfini & Smiraglia 1998), to enjoy the glaciological, geomorphological and biological elements along the route.

The aim of our paper is to highlight the value of Forni Glacier as a new possible geomorphosite, emphasizing its ecological value in terms of arthropod communities found

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FIG. 1 - Tourists on Forni Glacier in 1893 (Clementi collection, Bormio).

on the glacier surface and on the lateral moraine. Original data on invertebrates inhabiting the site are presented here for the first time.

THE VALUE OF FORNI GLACIER AS A GEOMORPHOSITE

The importance of Glaciers as geomorphosites has been highlighted in Pelfini & Smiraglia (2003). The proposed definition of Forni Glacier as a geomorphosite is based on a cumulative value derived from the sum of values of different attributes (scientific, cultural, socio-economic and scenic value) (Pelfini & Carnielli, in press).

In terms of the *scenic attribute*, Forni Glacier's value derives from its particular environment; it is Italy's largest valley glacier, easily reached and seen in its winter and summer aspects thanks to the presence of Branca Hut, located just a few hundred metres from the glacier. This Hut and the Forni Hotel, very close to the trail, are important photographic vantage points, making the collection of important documentation of glacier evolution in space and time easier (figs. 2 e 3). Concerning the *cultural attribute*, two aspects seem to be of major importance. Firstly, Forni Glacier has always been the focus of many researchers, including naturalists, historians and people generally interested in glacial environment studies (Mariani, 1908, 1915; Stoppani 1865, 1876, 1882). Secondly, wartime has left visual and historical documentation of the battles fought in the Ortles-Cevedale Group (Viazzi, 1967). All this has made it possible to trace the historical fluctuations of the glacier (Orombelli & Pelfini, 1985; Pelfini, 1988, 1996; Pelfini & Smiraglia, 1992). For example, the first document found dates back to Omboni (1861), who visited the glacier in 1850-60 and described a door as: «un'apertura ad arco, una grotta aperta nell'estremità inferiore di un ghiacciaio dal quale escono le acque del Frodolfo e che è detta Forno» («an arched slot, an open cave in the lower part of a glacier where the Frodolfo waters are disgorged, called Forno»). Referring to a visit in 1873, Stoppani (1880) observed that the glacier door was knocked down and wrote: «il ghiacciaio stesso si era accorciato e abbassato d'assai. Dalla morena laterale, che io avevo già trovata abbandonata nel 1864, bisognava discendere per 30 m per giungere alla superficie del ghiacciaio…», («the glacier had retreated and lowered considerably. From the lateral moraine, which I had found aban-

FIG. 2 - Print «Ghiacciajo del Forno sopra S. Caterina Valfurva» before 1875 from «Il Bel Paese», by Stoppani, 1876.

FIG. 3 - Forni Glacier, Summer 2004 (photo by Gobbi).

doned in 1864, you had to go down another 30 metres to reach the glacier surface…»). These descriptions are important because they can be used, together with the photographic material, to determinate the position of the glacier front (Pelfini, 1984 unpublished material).

From a *socio-economic* point of view, Forni Glacier is an important tourist spot because of its easy access to interesting and fascinating landscapes. Branca Hut, for example, can be comfortably reached by jeep, also by people unaccustomed to mountain environments. In addition to the tourist-related aspect, the economic importance of Forni Glacier lies in the collection of the meltwaters used to supply the hydroelectric power stations in Valtellina (AEM, 1997).

From the *scientific point of view*, all valences are present on Forni Glacier such as geomorphologic evolution, didactic exemplarity, paleomorphological evidence and ecological support: moraine ridge sequences document the glacier's history, as well as paleo-geomorphological and paleo-climatic evidence (Panizza, 1988; Panizza & Piacente, 2003; Pelfini & Smiraglia, 2003).

Recent geomorphologic evolution is documented by the moraines deposited. The Holocene moraine systems, witnessed by linear ridges characterised by different soil cover and different granulometry, different lichen colonisations (Pelfini, 1992) and different epigeal insect settlement (Gobbi, unpublished data) delimit the glacier's advances of the last 3000 years, especially concerning the different phases of the Small Ice Age.

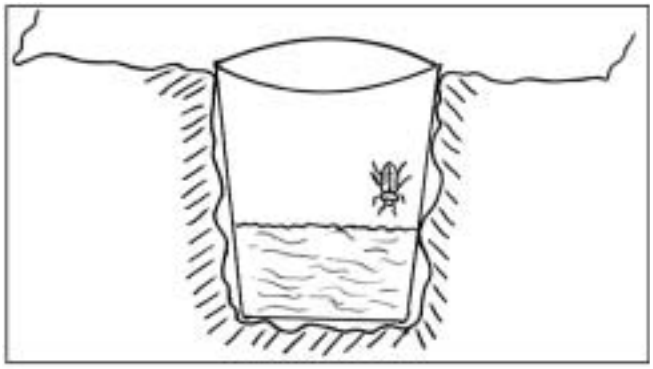

FIG. 4 - Pitfall trap (drawn by Gobbi).

THE ECOLOGICAL VALUE OF FORNI GLACIER

Observing the proglacial area bared by the glacier front, we note that global warming is inducing several environmental changes and one such example is that vegetation and arthropods are colonising the proglacial area in primary succession (Kaufmann, 2001; Gobbi, unpublished data). The glacial environment appears to be adverse for living organisms, but there are some reliable exceptions: some species are highly specialised for living in this habitat and thus the glacier may be an important microhabitat for such species. Consequently, these mostly microtherm species need this kind of environment to live and slight changes in the microhabitat may lead to their local extinction.

A study by Buzzini & *alii* (2005), conducted on Forni Glacier has demonstrated the presence of culturable yeasts in unfrozen subglacial sediment as a significant part of subglacial microbial communities.

In Italy, few studies have been carried out on invertebrate communities living in the glacier environment and in general no studies have been found on Alpine glacier invertebrates published in international scientific reviews. The only Italian studies dealing with invertebrates, and particularly insects, living near glaciers are those by Brandmayr & Pizzolotto (1987) and Focarile (1976).

During the Summer of 2004, we started a study on Forni Glacier about the arthropod communities that have settled in the proglacial area of Forni Glacier. Arthropods were collected using pitfall traps. Pitfall traps (fig. 4) are globally used for studying epigeal arthropods (Lövei & Sunderland, 1996), and also allow the occasional collecting of flyer arthropods; they consist of a 7 cm diameter, plastic jar, containing vinegar and salt. We could also have used traps (i.e. Malaise traps or light traps), specific for flyer arthropod collection, but this proved impossible due to substrate conditions (it is impossible to lock up a Malaise trap on the glacier as this trap is similar to a Canadian tent and the wind could break it) and the impossibility of reaching the glacier during the night (a light trap must be used during the night). We selected three sampling stations: the debris free glacier surface (2,600 m a.s.l.) (fig. 5), the debris covered glacier surface (2,600 m a.s.l.), and the lateral moraine (2,612 m a.s.l.) (fig. 6). At each station, 6 traps were set in the substrate and during the summer, we collected the arthropods falling into the traps every 15 days.

THE NEW DATA

One important preliminary finding is that we observed arthropod species on the glacier surface with different dispersal power at the different collecting stations on the glacier. We found both winged species (flyer colonisers) and well as wingless ones (*per pedes* colonizers). Flying Arthropods demonstrate good dispersal capacity and in the high mountain environment they use upwards winds to colonise new environments (Coulson & *alii*, 2003). Some Arthropod taxa arriving on upward winds land on the glacier surface and die because the temperatures are too low for their metabolism. On the other hands *per pedes* colonisers are known to have low dispersal power. Flying species were collected on the glacier surface and on the ridge of the lateral moraine. We found that these arthropods included insects such as flies (Diptera n.d.), bees (Imenoptera n.d.), and click beetles (Coleoptera: Elateridae). Concerning click beetles, we collected twelve specimens of *Fleutiauxellus maritimus* (Curtis, 1840) (Coleoptera: Elateridae).

In the pitfall traps positioned in the glacier ice, we also collected two additional species, belonging to two different taxa, but showing the same important morphological characteristic: they have no wings. Wingless species are very sensitive to environmental changes. They have a low dispersal capacity and thus live in stable environments; unstable habitats lead to their extinction (Brandmayr, 1983). These wingless species consisted of seven ground beetle specimens, *Nebria (Oreonebria) castanea* (Duftschmid, 1812) (Coleoptera, Carabidae) (fig. 7), and one wolf-spider specimen, *Pardosa saturatior* (Simon, 1937) (Arachnida, Lycosidae). These data are very important not only owing to the low dispersal capacity of these species, but also in

FIG. 5 - Collecting stations on the glacier (photograph by Gobbi).

FIG. 6 - Collection station on the moraine (photograph by Gobbi).

light of their trophic role. *N. castanea* and *P. saturatior* are predators of smaller arthropods. We believe that they prey the smaller flying insects transported by the upward winds to the glacier surface. The low ice surface temperature induces these species into primary torpor, making for easy predation.

The question is this: where do the *N. castanea* and *P. saturatior* on the glacier surface come from? Thaler (1997) found that *P. saturatior* lives on bare ground close to the glacier and in fact, we collected this species also in the debris cover and in the lateral moraines. *N. castanea* is a microtherm and hygrophilous species typical of pioneer and

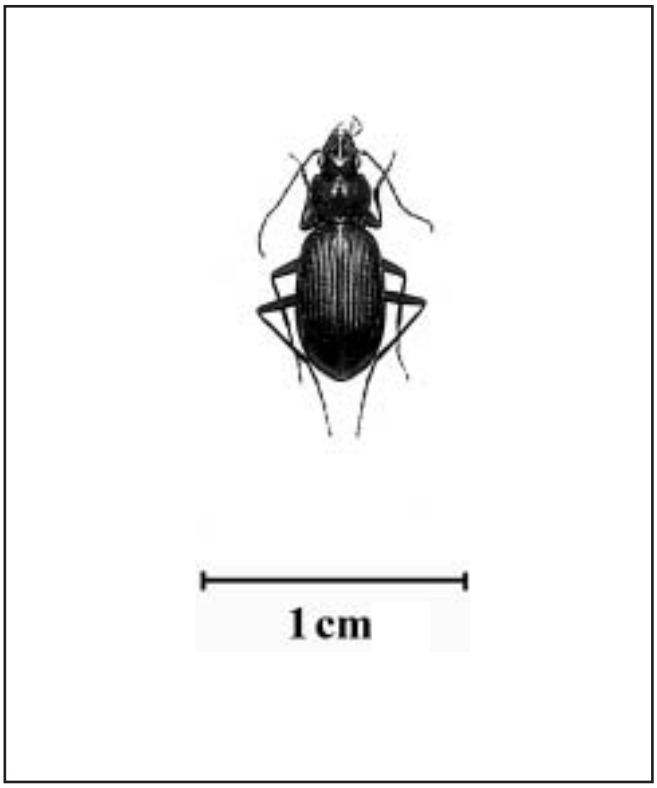

FIG. 7 - Ground Beetle (*Nebria castanea*) (photograph by Ferretti).

wet environments and lives mostly in stony soils (Focarile, 1976; Brandmayr & Zetto Brandmayr, 1988). We postulated that micro-habitats such as a lateral moraine and debris cover, where found in this study, may be an important «source of arthropods» where they take refuge, while for *N. castanea* the glacier surface represents an important and particularly stable trophic resource because of the presence of allochthonous food. Our hypothesis is that the increased debris cover, brought about by glacier reduction and ice ablation, can support glacier surface arthropod colonisation, and thus the increased presence of wingless specimens can constitute an index of increasing glacier debris cover.

In the lateral moraines, we found other ground beetle species; *Amara lunicollis* (Schiodte, 1837), *Ocydromus bipunctulatus* (Linné, 1761), and *Carabus (Orinocarabus) silvestris* (Panzer, 1793). In particular, species of arthropods typical of unstable environments such as *A. lunicollis* and *O. bipunctulatus,* i.e. flying ground beetles, were found on lateral moraine ridges, frequently used by ungulates and groups of trekkers. These environments are selected by flying species with generalised diets, species that can live in geomorphologically unstable and ephemerous habitats (Brandmayr & Pizzolotto, 1994). Consequently, the presence of such species may indicate the degree of stability of these environments.

CONCLUSIONS

This paper points out that Forni Glacier has all the required attributes and valences for candidature as an official geomorphosite and not «merely» an important site of naturalistic interest.

Studying arthropods living in this environment has not only led to defining the glacier's ecological value, it also affords more insight in the information that arthropods can provide about the effects of the environmental changes. Wingless arthropods results very sensitive to environmental changes and could be considered proxy data related to climatic change because they live on supraglacial debris, they eat flying arthropods went with the upwards winds therefore they strictly depends on glacier evolution. This supports the ecological value of the glacier.

Moreover, we are currently conducting a study to investigate correlations between glacier retreat phases and the modes of primary colonisation by arthropod communities in the proglacial area. This may provide important information about the possibility of using arthropods as biological indicators for knowledge about glacier dynamics in the past.

Lastly, the species collected on the left lateral moraine, a typically unstable environment, could perhaps confirm the degradation that is affecting geosites in the upper Alpine environments, but only after further studies.

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