Heatwaves and physiological discomfort: the strange case of the year 2022 on the 'Kiss Pass' of Portofino Natural Park, Italy

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Introduction

Just like any other outdoor activity, hiking is greatly affected by the weather, and detailed planning of an excursion has to consider meteorological conditions and the weather forecast. In temperate countries, particularly impactful weather events associated with hiking are snowfall, frost, strong winds (Hugenholtz and VanVeller, 2016) and fog mainly in autumn and winter months, while thunderstorms, lightning (Elsom and Webb, 2014) and heatwaves are usually associated with spring and summer months (Próchniak and Próchniak, 2022). Due to the higher number of hikers in the spring and summer months, incidents associated with heat strokes are very frequent, and their number is set to grow as temperatures rise due to global climate change (Liu *et al.*, 2020). Health risks associated with heat strokes are highly subjective depending on a person's physical conditions and age, as well as their equipment and clothing. Bodily reactions include extreme fatigue, dehydration and heart failure (Ebi *et al.*, 2021). Such serious conditions can be exacerbated if hot temperatures are associated with intense sunlight and high humidity, the latter being particularly significant in hiking areas near bodies of water at low elevations. The combination of heat and humidity levels and its consequence to the body is defined by the Humidex, an index developed by Masterton and Richardson (1979), which establishes the level of discomfort ranging between none and risk of death.

Although generally characterised by mild climates that allow hiking all year round, Mediterranean areas are increasingly affected by heatwaves between late spring and mid-autumn with serious consequences on tourist and outdoor activities. This is true of the Portofino Natural Park in the northwestern Italian region of Liguria. The Park, which dates back to 1935 and is the oldest of Liguria, is located some 20km from the region's capital, Genoa, along the Eastern Riviera. It covers the Promontory of Portofino, a peninsula of conglomeratic rock masses, which stretches for ~2km in a WNW–ESE direction, breaking the continuity of the coast between the towns of Camogli and Rapallo (Figure 1). The promontory and park own their name to the picturesque village of Portofino, where elite tourism dates back to the second half of the nineteenth century as the area was frequented by an increasing number of foreign visitors, British in particular (Piana et al., 2021).

In more recent times, the area has been partly preserved from mass tourism of the rest of the Riviera by the Park. Today, the area is characterised by a combination of natural and cultural heritage, which contribute to shaping an almost unique cultural landscape. Along the southern slopes, the scenery is dominated by steep conglomeratic rocks and Mediterranean vegetation, while the northern side is shadier and covered by dense deciduous woodland. In terms of cultural elements, the area features traditional settlements and buildings (fishing villages, mills and watchtowers) and religious architecture including the Benedictine abbeys of Cervara (thirteenth century) and San Fruttuoso (*c.* tenth century).

The Park of Portofino, which covers an area of 1061ha, is characterised by over 70km of trail network with diverse difficulty and technical features, from sea level up to the top of Monte di Portofino (610m asl), with slopes up to >100% (Figure 2). In terms of technical features, most of footpaths are unpaved, with occasional concrete and dirt tracks, while the most strenuous trails have steep staircases and exposed stretches on rock secured with chains. Visits to the Park have been constantly on the rise over recent decades (Faccini *et al.*, 2018) with a sharp increase in the post-COVID period. As a result, public safety due to accidents on the trails is an urgent issue. This is particularly true of the Passo del Bacio (Kiss Pass) trail between the locality Batterie and the Abbey of San Fruttuoso, along the southern slope of the Promontory, which is the focus of this research. During 2022, ~32 500 passages were recorded at Passo del Bacio (Parco di Portofino, 2023). The trail is increasingly affected by accidents and rescue operations, which have been particularly numerous in spring and summer 2022, when Liguria was repeatedly hit by a series of heatwaves with very high temperature and humidity levels.

The climate of the Portofino Natural Park

Monte di Portofino (610m asl), located along the western side of the main watershed, is the highest elevation of the Promontory, while other minor elevations are Monte Tocco (543m asl), Monte delle Bocche (506m asl) and Monte Pollone (465m asl). The orientation of this ridge, subparallel to the southern coastal stretch, means that the slopes aspect in the area is particularly diverse: the southern side between Punta Chiappa and Punta di Portofino mainly faces south and southwest; the western slope between Punta Chiappa and Camogli faces west and northwest; the eastern side between Punta di Portofino and Rapallo faces east and southeast, while to the north of the main ridge, between Monte Tocco and Monte Pollone, the area faces north and northeast (Figure 1a). Due to its diverse climatic conditions, the area constitutes the limit between two different areas (B and C) of the regional meteo-hydrological alert system (Figure 1b).

Rainfall and temperature values are typical of a Mediterranean climate with hot and dry summers and mild winters, *Csa*

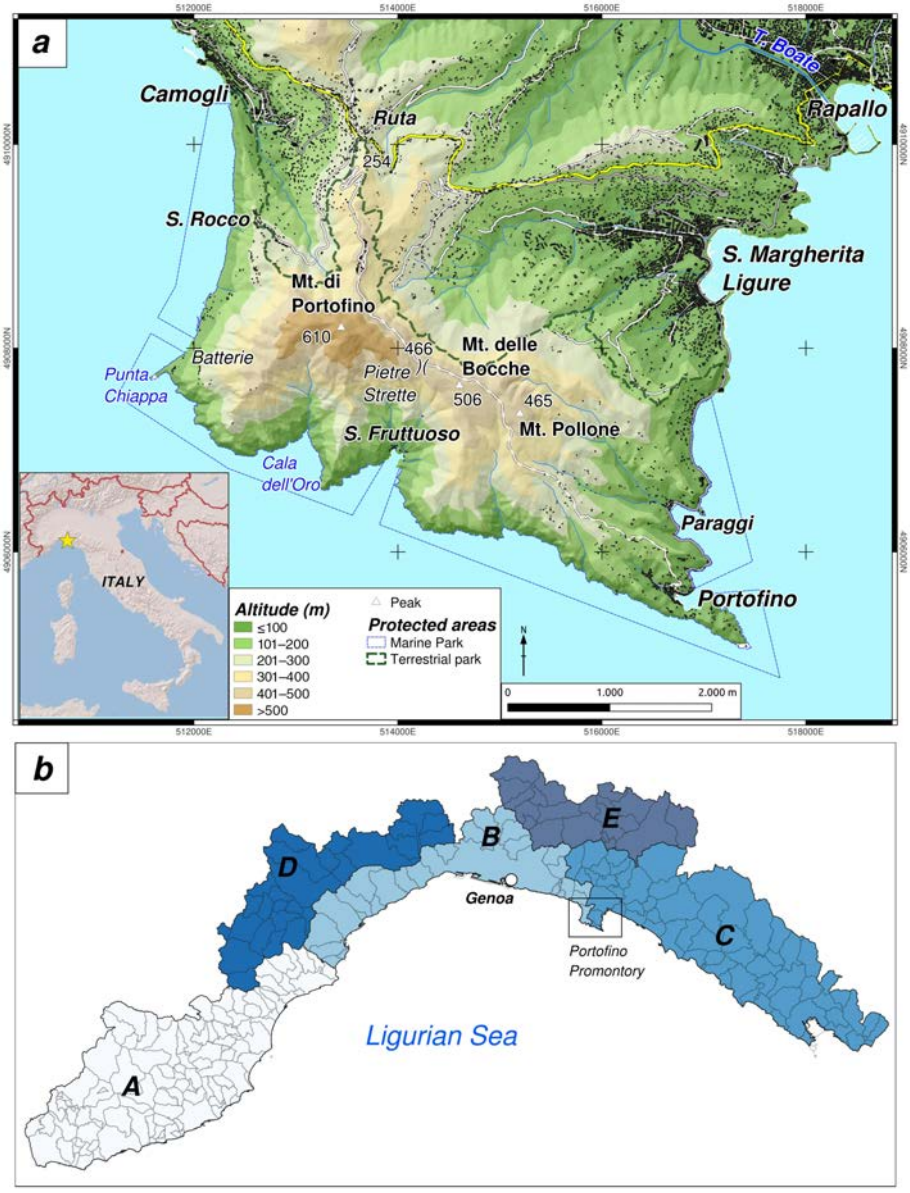

Figure 1. (a) Geographical setting of the Portofino Promontory. (b) The meteo-hydrological alert zones of Liguria. The Portofino Promontory is on the border between zone B and zone C. Raster and vector data are taken from the Ligurian Geoportal (https://geoportal.regione.liguria.it/; CC BY 3.0).

type (hot-summer Mediterranean climate). According to the Thornthwaite classification, the climate ranges from humid in the southern sector of the promontory to very humid in the internal and northern sectors and in the neighbouring coastal areas (Brandolini *et al*., 2006).

Due to geographical features, particularly elevation and slope aspect, the Promontory is characterised by several microclimates and a high level of biodiversity (Coratza *et al*., 2019). Three different microclimate areas can be summarised as follows: (a) the southern slope, characterised by Mediterranean climate with hot and dry summers, mild winters, long periods of insolation and hot, southerly winds; (b) the northern slope, with a more continental climate featured by mild summers, colder and rainier winters due to the exposition to northerly winds; (c) summit climate, above 400/500m, characterised by high rainfall and orographic clouds in the summer months (the 'hat' of Monte di Portofino) generated by the contrast of warm and humid southerly winds and drier and colder winds from the north.

Average rainfall ranges from 1200mm along the coast to more than 1700mm at high elevations (Terrone *et al*., 2021) and precipitation is spread year-round, with a peak in autumn and a minimum in summer. Average temperature varies between 15°C along the coast up to just less than 13°C on the top. Annual extremes range between a few degrees below zero on the top in the winter to 40°C along the coast in the summer. The coastal area is characterised by ~75% humidity on average, which increases to ~80–85% at higher elevation. Southerly winds are very rich in water vapour: as they meet the natural barrier of the Promontory and gain elevation the temperature drops causing the condensation of a significant amount of water, particularly in the summer. This process partly feeds high-altitude perennial springs (Terrone *et al*., 2021). Land use is characterised by large stretches of high and rocky coast with Mediterranean shrubs in the southern side and localised terraced areas with olive trees and occasional conifer woods. The vegetation of the northern side reflects its cooler climate, with widespread distribution of deciduous species.

The year 2022 in the Portofino Park area

Several weather stations are located in the Portofino area, which enable the monitoring of climate data in the different sides of the Promontory. The oldest ones are those of Camogli and Santa Margherita Ligure, managed by ARPAL (Agenzia Regionale per la Protezione dell'Ambiente Ligure). During the H2020 RECONECT project, new stations were installed at Portofino town, Agririfugio Molini and Mulino del Gassetta. One further station in the locality Semaforo Nuovo was installed by CIMA (Centro Internazionale di Monitoraggio Ambientale) Foundation. For the purpose of this research, data from four stations (Agririfugio Molini, Mulino Gassetta, Semaforo Nuovo and Portofino) have been analysed as they are located along the southern side of the Promontory, and they are the closest to the Passo del Bacio path. In general, 2022 was a particularly hot year, with temperatures well above average (17.5°C at Agririfugio Molini and 17.1°C at Mulino del Gassetta). Rainfall was lower than average (905mm annual rainfall at Agririfugio Molini and 864mm at Mulino del Gassetta), while relative humidity (RH) was generally high. Figure 3 shows the profile of maximum daily temperature (T_{max}) and RH for 2022 in the four weather stations. We can see how 2022 was characterised by unusually mild T_{max} early in the year: in the stations of Agririfugio Molini, Mulino del Gassetta and Portofino, T_{max} above 20°C was recorded as early as February.

From April, several heatwaves of increasing intensity took place, with peaks in June, July and August. For the four weather stations analysed, the T_{max} during the summer months was consistently over 30°C except for Semaforo Nuovo, located on a windy ridge at a higher elevation. Peaks of T_{max} over 37°C were recorded at the Agririfugio Molini station. Such periods of positive temperature anomalies lasted several months into the first part of autumn, with T_{max} around 30°C even in the last 10 days of

October. Hot temperatures were associated with high levels of RH, often >90% during the hottest periods.

Starting from *T* and RH data, we calculated the Humidex (*H*) index developed by Masterton and Richardson (1979). This index provides an indication of heat perceived by the human body for given temperature and humidity conditions. Humidex is calculated with the following formula:

$$H = t + 5/9 \times (e - 10)$$

where *e* is water vapour pressure, based on *T* and RH:

$$e = 6.112 \times 10^{[7.5 \times T/(237.7+T)]} \times \mathrm{RH}/100$$

Based on the value of *H*, the level of discomfort of an individual carrying out physical activity in high *T* and RH conditions can be assessed. The threshold of physical discomfort is usually at $H = 30$, while with $H > 35$, there is a potential health risk (Masterton and Richardson, 1979; Dankers and Hiederer, 2008; Lukić *et al*., 2019).

Humidex was calculated on an hourly basis for the whole of 2022 using data from the Agrirufugio Molini and Mulino Gassetta stations (Figure 4). Values of $H > 30$ were recorded as early as April and as late as October. Summer months were characterised by extreme *H* values, constantly >40 with peaks >50 in mid-July, providing evidence of hazardous conditions on particularly hot and humid days.

Of the 32 500 passages recorded at the Passo del Bacio in 2022, about two thirds took place between April and October under particularly unfavourable meteorological

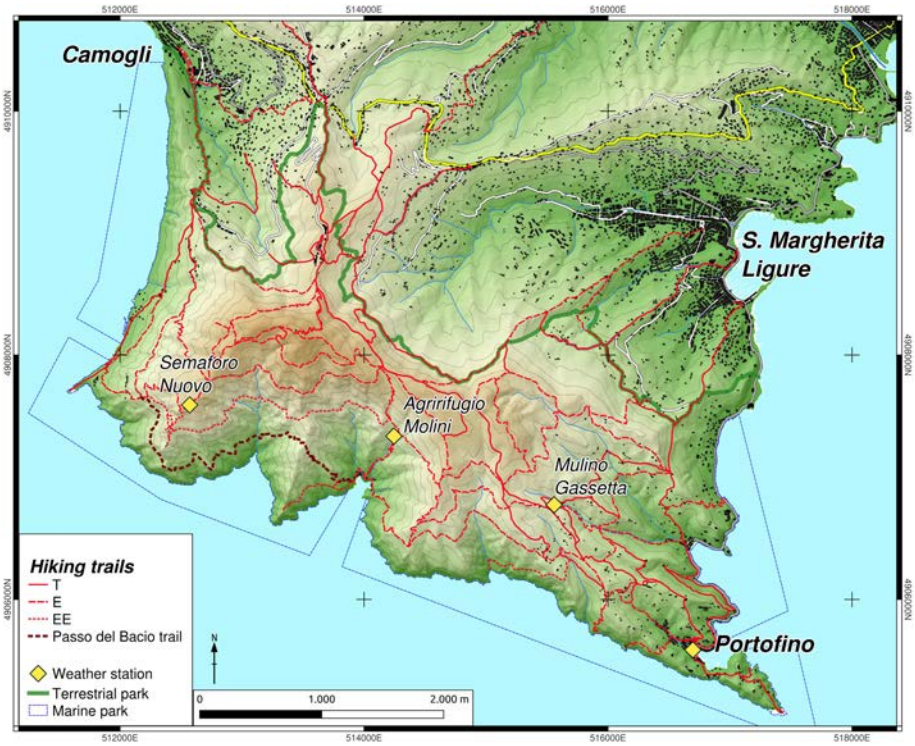

Figure 2. Hiking trail network of the Promontory of Portofino with indication of weather stations. Footpaths are classified based on the difficulty level: T = tourists; E = medium-level hikers; EE = expert hikers. Raster and vector data are taken from the Ligurian Geoportal (https://geoportal.regione.liguria.it/).

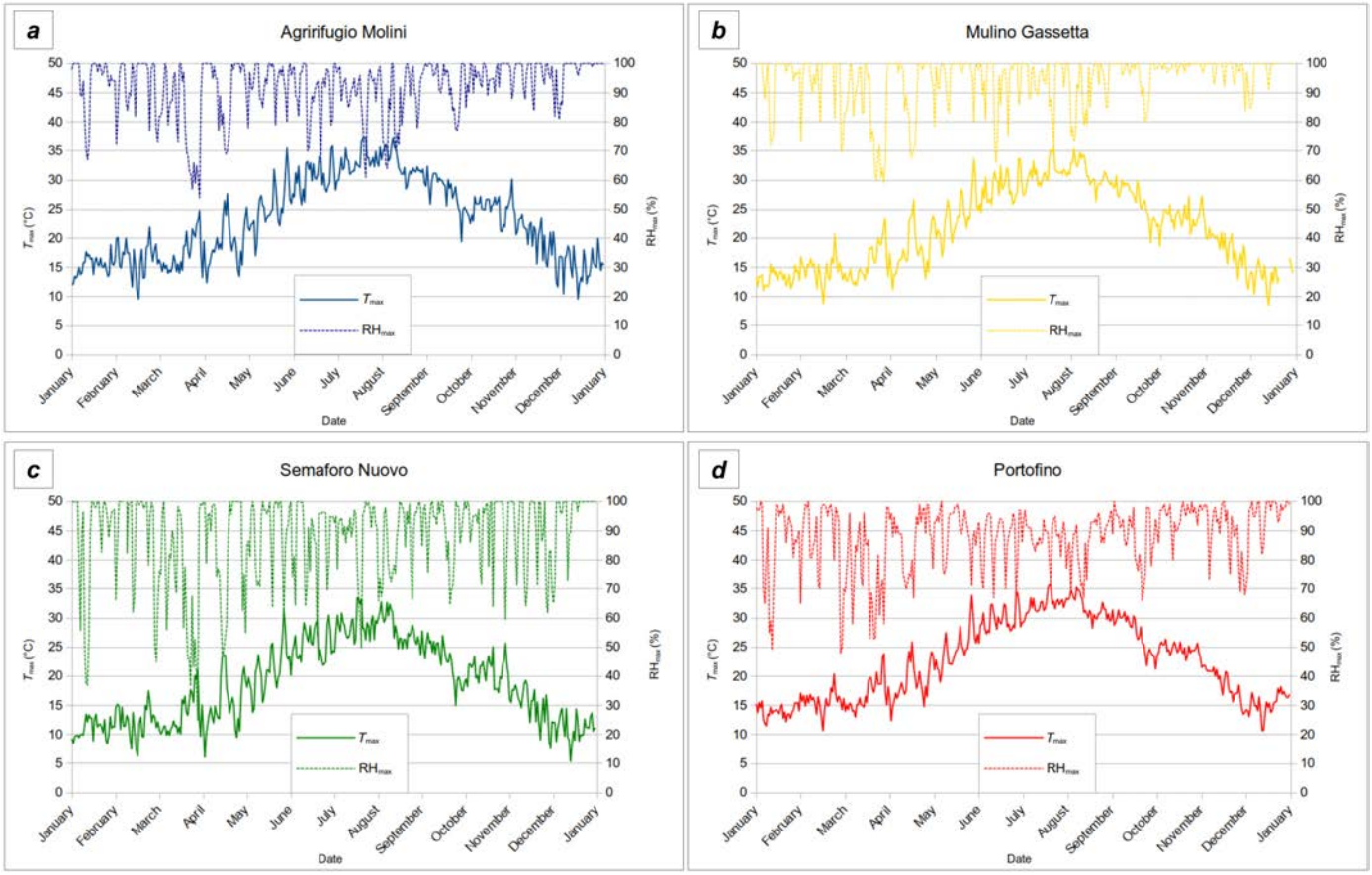

Figure 3. Time series of daily T_{max} and RH_{max} in 2022 recorded at four stations of the Promontory of Portofino: (a) Agrirufugio Molini, (b) Mulino Gassetta, (c) Semaforo Nuovo and (d) Portofino.

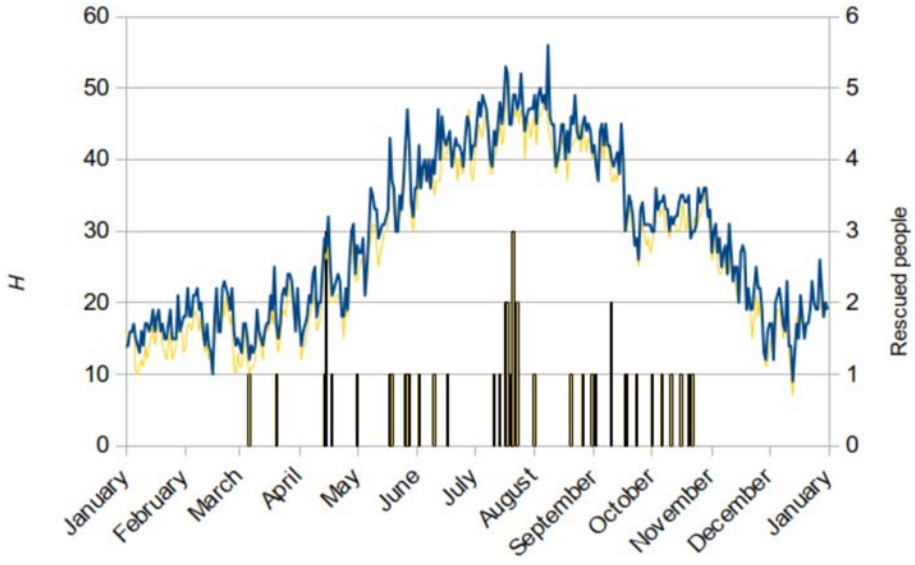

Figure 4. Rescue interventions at Passo del Bacio in 2022 and Humidex at Agririfugio Molini (blue) and Mulino Gassetta (yellow). The black columns represent the date of the accident (x-axis) and the number of people rescued (y-axis on the right-hand side).

Table 1.

The number of rescue interventions and the number of rescued people carried out on the Passo del Bacio hiking trail in 2022, in situations of physical discomfort due to heat ($H \geq 30$) and no physical discomfort ($H \leq 30$).

	Discomfort	*No discomfort*
Rescue interventions	24	13
Number of rescued people	29	15

conditions as described above. In 2022, the National Corp of Alpine and Speleological Rescue (Corpo Nazionale Soccorso Alpino e Speleologico [CNSAS]) carried out 39 rescue operations in the Portofino Natural Park, 37 of which occurred along the Passo del Bacio footpath and areas nearby. The first operation took place on 6 March, the last on 22 October. The most frequent causes were illness (33%) and falls (27%), followed by searches for missing persons (22%), persons in trouble (13%) and other causes (5%). In general, rescue operations involved only one person, but in some cases, two or three people were rescued in the same incident. The highest concentration of operations was in the period between June and September, when the most unfavourable weather conditions were recorded (Table 1). On average, operations in July were characterised by a higher number of people involved (Figure 4).

One last parameter taken under consideration was the number of daily hours, where *H* was above the hazard threshold (Figure 5), which is considered of great importance to understand how persistent unfavourable weather conditions are throughout the day. The parameter was calculated from the data of Agririfugio Molini station. In the June–August period, when most of the accidents occurred, *H* has been above the threshold for more than 10h per day. Figure 6 shows the hourly values of *T* and RH, which correspond to the maximum daily Humidex (H_{max}), for each day when a rescue operation occurred. Most accidents occurred in very unfavourable meteorological conditions, well above the thresholds of heat discomfort ($H = 30$) and danger ($H = 35$).

Considerations and final remarks

In the last few decades, the Park of Portofino has become one of the most popular natural areas of Liguria (Mangano, 2007), often frequented by visitors not adequately prepared in terms of knowledge of the area, experience, skills and equipment (Brandolini *et al*., 2006). Based on more than two decades of monitoring, it can be observed that rescue operations by CNSAS are almost exclusively limited to Passo del Bacio, both because of the exposure of the trail, on the edge of the cliff, and because of weather conditions, as this section is entirely south facing and with high humidity.

The trail is characterised by strenuous ups and downs, and there are no water springs. For this reason, the park authority has installed specific signs at Batterie Visitor Center and at San Fruttuoso, and to facilitate rescue operations, it has installed 16 SOS markers with progressive numbering (Figure 7). Recently, a general exacerbation of the situation has been associated with the post-COVID-19 pandemic and the augmented need or will for open-air activities, not just amongst expert hikers but also beginners, including families with children (Mangano and Piana, 2023). In addition, the year 2022 was marked by the emergency

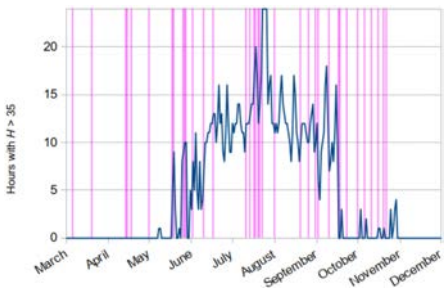

Figure 5. Daily hours with Humidex >35 (danger threshold) at Agririfugio Molini. Violet bars indicate days with rescue interventions in 2022.

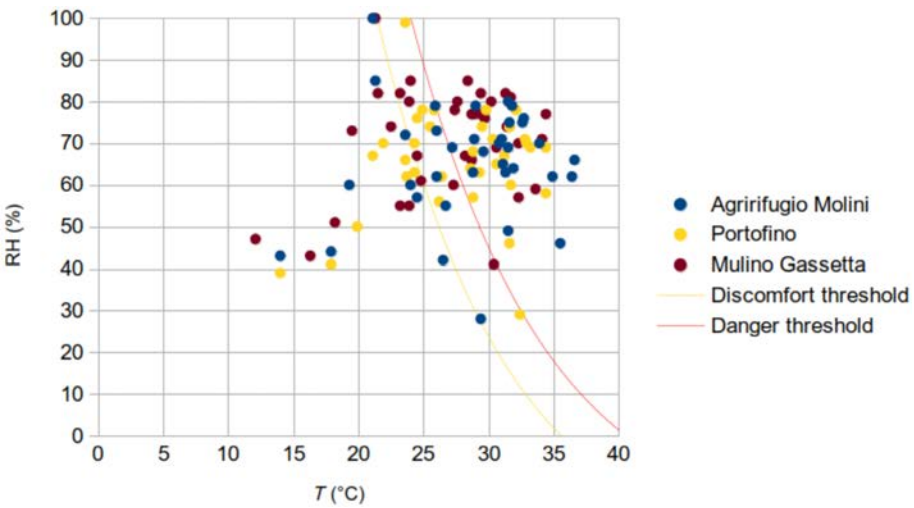

Figure 6. Maximum daily Humidex of days when rescue operations took place in the weather stations of Agririfugio Molini, Portofino and Mulino Gassetta. The discomfort threshold corresponds to H = *30, while the danger threshold is* H = *35.*

Figure 7. (a) Signboard at Batterie, before the stretch on the south-facing slope and equipped with chains; (b) additional signboard placed in September 2022 before Passo del Bacio; (c) one of 16 SOS markers located along the path between Batterie and San Fruttuoso and (d) passage with chains along the Kiss Pass.

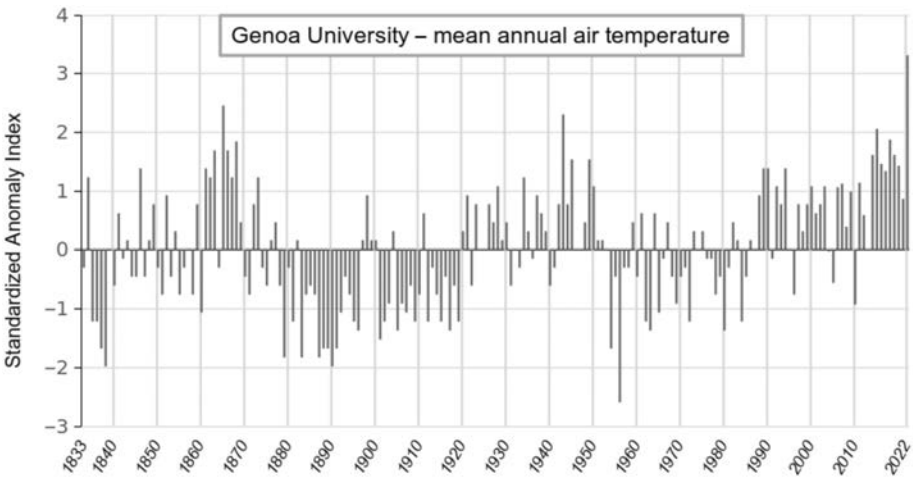

Figure 8. Standardised anomaly index of annual average temperature in Genoa, 1833–2022.

of a swine flu outbreak in the Genoa area, which meant the complete interdiction of green areas in the city surroundings in order to stop the spread of the disease. As the Portofino Promontory was located outside this area, more tourists/excursionists from Genoa frequented this area, increasing the number of non-expert hikers in the footpaths. The number of presences recorded by eco-counter sensors in some areas of the Park provides data on what can be defined as 'minimum' number of visitors, showing how this value has increased by a quarter between 2019 (the last pre-pandemic year, 126 814 minimum presences) and 2022 (158 721 minimum presences), while 2021 (129 098 minimum presences) was slightly higher than 2019.

The increased number of visitors, particularly non-experts, alongside a general temperature increase as shown by standardised anomaly index on average temperatures in Genoa (Figure 8), is very likely associated with the rise in rescue operations along the Passo del Bacio footpath, historically one of the areas most affected by accidents (Brandolini *et al*., 2006). This is particularly true of days with very high Humidex levels, as shown in Figure 5. Due to the peculiar co-occurrence of such events, which indeed might become common in the near future, it is possible to define 2022 as an 'unusual year'. Excessive numbers of non-expert hikers in the Portofino Promontory, combined with a general warming due to global climate change, suggest a potential trend in hiking-related accidents in the future. This is also confirmed by several accidents occurred in early 2023 including a fatality along the Passo del Bacio footpath on 12 March.

Since summer 2022, the Portofino Park Authority has promoted a campaign to raise awareness on hiking-associated risks establishing *ad hoc* panels in two highly frequented areas (Batterie and San Fruttuoso di Camogli) with a 'hiker's handbook'[1] and publishing a 'decalogue' of hiking in the Park of Portofino.[2]

The handbook emphasises that '*Hiking in Portofino Park is challenging and must be approached with proper equipment, clothing and preparation. Some trails require experience*'. It summarises with a checklist that, in addition to usual recommendations on how to behave in a natural park, has some specific advice on how to hike safely with reference to weather conditions. It is underlined that in case of an emergency,

[1] http://www.parcoportofino.com/parcodiportofino/resources/cms/documents/Vademecum_PORTOFINO_INGLESE.pdf.

[2] http://www.parcoportofino.com/parcodiportofino/resources/cms/documents/Decalogo_escursionista_a_Portofino.pdf.

the number to call is 112 and that '*giving up is better than risking*'. The decalogue has specific reference to weather conditions: '*do not undertake a hike in case of bad weather or unfavourable weather conditions, the Park has many exposed areas and in case of rain or humidity the soil can be very slippery*' (Figure 8). This advice refers in particular to rainy and/or foggy days and not to the extreme heat conditions that caused the majority of accidents in 2022. Raising awareness amongst hikers is surely a way to make them more conscious of the risks associated with not following such basic roles, and of the importance of knowing weather conditions and the forecast for the visitors' own safety.

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Author contributions

Pietro Piana: Data curation; investigation; resources; validation; writing – original draft. **Andrea Ferrando:** Data curation; formal analysis; investigation; methodology; writing – original draft. **Stefania Mangano:** Data curation; investigation; resources; validation. **Francesco Faccini:** Conceptualization; data curation; investigation; project administration; validation; writing – original draft.

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