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A hoverfly survey in the inner alpine municipality of Bergün-Filisur (Switzerland) by means of variable route sampling (Diptera, Syrphidae)

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https://zoobank.org/55995ED4-64F1-4277-BC2A-7FCED482B4F0

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Abstract

A field survey of hoverflies (Diptera, Syrphidae) was conducted in the municipality of Bergün-Filisur, Canton of Graubünden, in the inner Swiss Alps during 2023 and 2024. This study aimed at: (i) recording a high species richness using a comparatively low sampling effort by experienced syrphidologists along haphazardly selected routes; and (ii) setting a baseline reference for long-term future surveyance. The repeatability of the survey method was tested by comparing the survey results of 2023 with 2024 using rarefaction analyses, and found to be adequate. A total of 173 hoverfly species were recorded in the Bergün sampling area in 2023 and 2024, which is, respectively, 84% and 51% of the known species richness of the municipality of Bergün-Filisur (206 species) and the Canton of Graubünden (341 species). We recorded 3 species new to the Canton of Graubünden (*Platycheirus transfugus*; *Sphaerophoria estebani*; *Psilota exilistyla*), and 14 species that are on the European Red List of Hoverflies, by being endangered (11 species) or vulnerable (3 species). We propose a practical framework for future hoverfly surveyance in Bergün-Filisur, central Alps. The annual survey effort is minimal and can be achieved within the 15–30 June timeframe, requiring either six days of sampling by a single surveyor or three days by two surveyors.

Key Words

Biodiversity, faunistic surveyance, flower flies, Graubünden, Swiss Alps

Introduction

The Alps hold an extraordinary richness of hoverfly species, including a large number of endemic and threatened species (Vujić et al. 2022). Large parts of the Alps consist of pristine protected nature or natural habitats that are managed sustainably (e.g., forests, meadows). However, habitats for hoverflies in the Alps have been lost to urbanisation, infrastructure and agriculture in the past, and remaining habitats are under further pressure from these direct human activities. In various parts of Europe, a decline in hoverfly abundance or species richness in the last 50 years occurred (Powney et al. 2019; Gatter et al. 2020; Barendregt et al. 2022; Claude et al. 2025; Haris et al. 2025), as a result of habitat loss, habitat pollution, and global warming. The fragmented nature of alpine mountain habitats, combined with their large geographic and climatic gradients, may make both the habitats and the insects that inhabit them highly susceptible to global warming and extreme weather events (e.g., Haslett 1997; Keller et al. 2000; Beniston 2005; Shah et al. 2020; Halsch et al. 2021).

In order to establish short- or long-term trends in alpine hoverfly populations, sampling surveys need to be carried out. Compared to other species groups such as

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birds, butterflies, dragonflies or grasshoppers, hoverfly surveys in mountain areas are a laborious and challenging task. Hoverfly species richness in the Alps is very high, but many species have low detectability due to their small size or scarcity. Alpine hoverfly identification requires a high expertise as some genera contain numerous similar-looking species, such as the genus *Cheilosia* Meigen, 1822, represented by more than 70 species in the Swiss Alps (Fisler 2024; info fauna 2025a). Moreover, surveying (remote) alpine habitats often requires significant physical effort, especially on mountain slopes and above the tree line. Combined with the altitude- and season-specific flight periods of hoverflies and unpredictable weather conditions, this requires careful planning to maximize species richness detection within one season (see also Pellet 2023). Table 1 lists various factors affecting the recording of hoverfly species richness in mountain areas by experienced surveyors, and whether their impacts are expected to be large, medium, or small.

Observing long-term trends in hoverfly populations or phenology requires survey schemes that are replicable in the future, for example in 10 or 50 years. A standardized survey method to record species richness and number of individuals is by means of Malaise traps at fixed locations (e.g., Speight and Castella 2005; Sarthou and Sarthou 2010; Iler et al. 2013; Hassall et al. 2017; Claude et al. 2020; Hallmann et al. 2020; Koch et al. 2021; Uhler et al. 2021; Claude et al. 2025). Alternatively, standardized surveys can be generated through hand-net sampling in well-defined plots or along defined transects during a specified sampling time or by making a specified number of net sweeps (Nielsen et al. 2011; Hussain et al. 2018; Moquet et al. 2018; Walcher et al. 2020). However, in mountainous habitats, such as the Swiss Alps, the sampling effort with these standardized methods may become very high if all habitats and hoverfly flight periods at altitudes from 500 to 2500 m were to be covered. An example of such an “all-inclusive” study was carried out in the Dolomites (Italy) using sampling traps at 10 different altitudes between 500 and 2500 m (Sommaggio et al. 2021). In the French Alps, Malaise trap sampling in selected, representative habitats was shown to be effective in surveying hoverfly communities (Speight and Castella 2005; Sarthou and Sarthou 2010; Claude et al. 2020) and determining long-term population changes (Claude et al. 2025). Though possible, a large sampling effort could reduce the practical future repeatability of a study, as scientific insect surveys are often under economic and time constraints (see Field et al. 2005; Pellet 2023).

A second approach to determine long-term and regional trends in hoverfly species richness, populations, phenology and extinction is by means of analysis of centralized databases with hoverfly records, such as info fauna (info fauna 2025a). For instance, by making an advanced analysis of 417,856 citizen-science records in Britain, it was inferred that the occupancy of 214 hoverfly species in 1 km^2 grid cells had decreased significantly from 1986 to 2010 (Powney et al. 2019). Large changes in geographical distribution may also be directly visible from (citizen) science database maps, without the intervention of advanced data analysis. A clear example is the case of the shrinking distribution of the butterfly *Coenonympha tullia* (Müller, 1764) in Switzerland that becomes evident by plotting pre- and post-2000 records with distinct colours (info fauna 2025b). The extinction rates of hoverflies in the Netherlands between 1942 and 2022 was also determined from records in a private and museum collection and a citizen science database (Zeegers et al. 2024). Unfortunately, for the specific case of hoverflies in the (Swiss) Alps, the records in centralized collection databases (with old and new records) and in citizen-science databases (with mostly recent records) are too low and too unevenly distributed in time and space for the assessment of population trends.

Finally, a third possible approach to survey hoverflies in mountain areas is by means of hand-net sampling along haphazardly selected routes, i.e, during variable transect walks. In the case of solitary bees, variable transect walks were found to increase the probability of collecting a higher proportion of the bee species present in areas with a heterogeneous spatial distribution of floral resources (Nielsen et al. 2011). This method is commonly used by syrphidologists in explorative surveys of mountain areas (e.g., Mengual et al. 2020; Ricarte et al. 2021; Xavier et al. 2021; Van de Meutter 2022). Such explorative montane surveys are usually not conducted with a future repeatability of the survey in mind. The many influences on recording species richness in mountain surveys (see Table 1) may seem to make them unsuitable for long-term surveying purposes. However, a significant hoverfly

Table 1. Factors expected to impact hoverfly species richness in mountain areas, when recorded by experienced surveyors during (variable) mountain hikes or by using traps.

Factor	Effect	Magnitude
sampling effort	the likelihood of recording scarce species increases with field hours or number of traps and trapping duration	large
daily weather	hoverfly activity depends on temperature, sun/cloudiness, rain	large
habitat	different species prefer different habitats and micro-habitats in mountain areas	large
season	many species have a restricted flying time (e.g., May-June or July-August)	large
altitude	habitats and flying times change with altitude (500–2500 m)	large
method	Malaise trap or hand-net; systematic or variable sampling transects	medium
search bias	caused by many sources, e.g., knowledge of the sampling area, search for specific groups, search in specific habitats, location of paths, etc.	medium
identification	incorrect identifications, non-identifications, taxonomic obscurities	small

population decline would be expected to result in reduced recorded species richness, given a fixed sampling effort (e.g., number of field hours). In this paper we put this idea to the test and investigate if variable (haphazardly selected) survey hikes can produce repeatable results suitable for long-term surveyance purposes.

Survey area and methods

Survey area

Hoverfly surveys were carried out in 2023 and 2024 in the municipality of Bergün-Filisur, located in the centre of the Canton of Graubünden in the eastern part of Switzerland (Fig. 1). The sampling area is outlined by a yellow line in Fig. 1 and includes all sampling locations along two valleys in the municipality of Bergün-Filisur. These sampling locations followed from explorative hikes made by four surveyors along haphazardly selected routes. The encircled sampling area (ca. 34 km²) is 18% of the municipality size (ca. 190 km²). The sampling locations ranged in altitude from 1100 to 2300 m.

Below the tree line, the study area consists predominantly of spruce forests or smaller clusters of pine trees intermixed with cultivated meadows (see Fig. 2). In the lower part of the valley (1100–1500 m), a limited number of large deciduous trees mix in with the spruce trees. On the 5th of June 2024, the extent and variety of flowers in the area was low. In the third week of June (2023, 2024) there was a large variety and abundance of flowers in the area. Apiaceae, which are especially attractive for hoverflies, are common at altitudes between 1200 and 1600 m from mid-June, and between 1600 and 2000 m (up to the tree line) in July and August. Two high-alpine sites above the tree line were particularly well sampled: in the most south-western part of the study area around 2100 m (west of Albulapass), and in the north-eastern part between 1800 and 1900 m (Tuors Chants).

Field methods and identification

The field surveys in the Bergün area started in June 2023 with the objective of finding specific hoverfly species, but not to establish a long-term hoverfly survey. In 2024, the

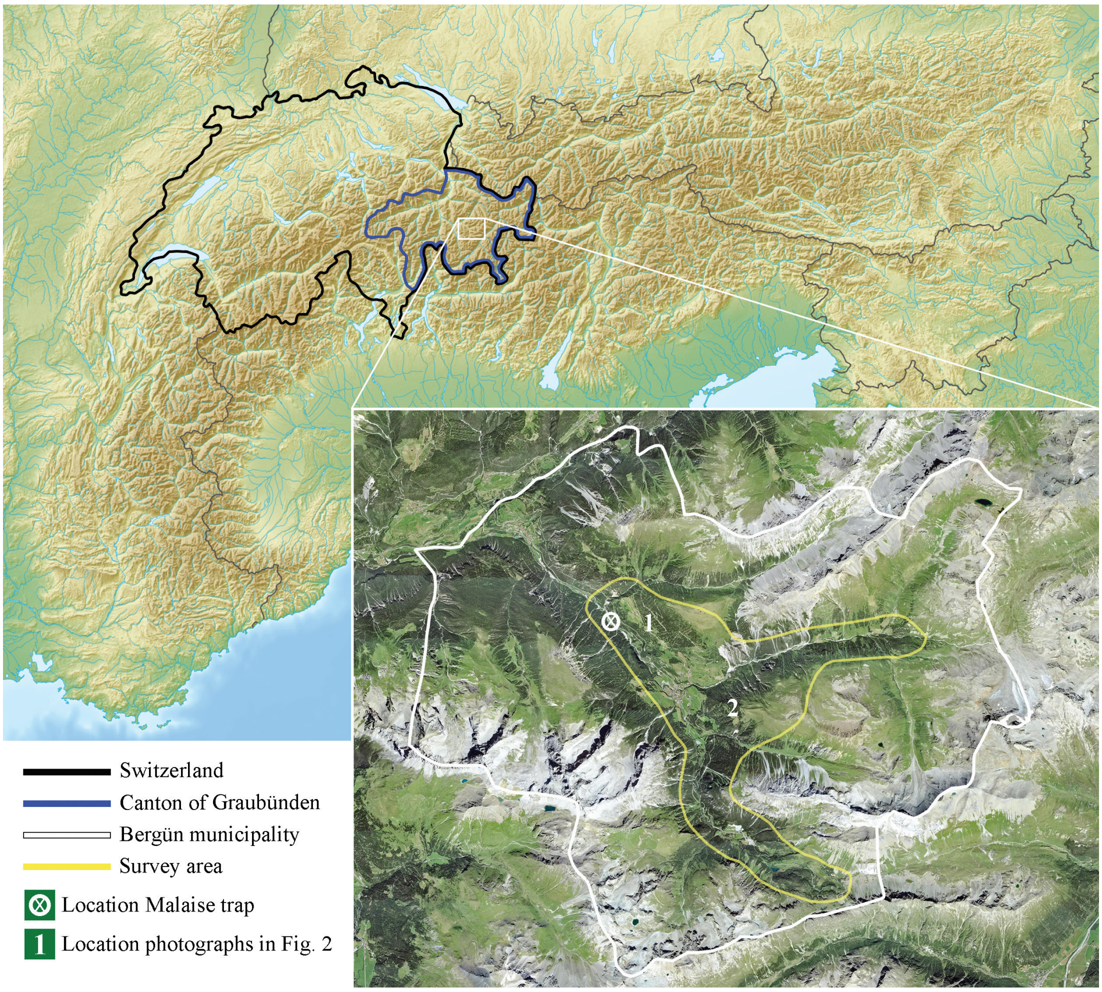

Figure 1. Geographical location of the survey area in the Alps in the municipality of Bergün-Filisur. The area encircled with a yellow line contains all the sampling sites in 2023 and 2024 and the location of the Malaise trap in 2023. The locations from where the photographs in Fig. 2 were taken are indicated by the numerals 1 and 2. Source of Alpine map: Wikipedia (Alps_location_map.png).

Figure 2. Views of the Bergün sampling area. **a.** Near Pros da Darlux at an altitude of 2100 m, looking towards the northwest into the survey area (15.07.2024) – location 1 in Fig. 1; **b.** Near Stugl at an altitude of 1550 m, looking towards the southeast into the survey area (24.06.2023) – location 2 in Fig. 1. Photos Jan Bisschop.

field surveys were partly planned with the aim to record high species richness over a longer period (June 5th - August 5th) while exploring more sites and habitats in the Bergün area. Sampling effort was expected to have a major impact on the recorded species richness, and therefore we estimated the number of field hours for each survey by each surveyor (see Table 2). The survey duration includes small breaks and travel time within the surveying area but excludes interruptions of more than ca. 30 minutes due to e.g., rain showers or cable car transport.

The survey routes and sampling method were chosen by the surveyors individually. Three surveyors sampled hoverflies by hand-net during their hikes. Some of the hoverflies caught were identified in the field and released thereafter. Collected hoverflies were pinned, labelled and identified under a binocular microscope using published keys such as Barkalov and Ståhls (1997), Claussen (1998) and Ståhls and Barkalov (2017) for *Cheilosia*, or Nielsen and Barkalov (2017) for *Platycheirus* Le Peletier & Audinet-Serville, 1828. Some of the collected *Cheilosia* and *Eupeodes* Osten Sacken, 1877 were sent to specialists in Europe (see Acknowledgments). All pinned hoverflies are stored in the following private and museum collections for future reference: (1) private collection of Lisa Fisler; (2) private collection of Gaël Pétremand (3) ZFMK - Museum Koenig, LIB, Bonn; and (4) MZL - Naturéum, Muséum cantonal des sciences naturelles, Département de zoologie, Lausanne. Excel files with standard record information of all collected flies are available upon request and were transmitted to the Swiss topic centre on fauna (info fauna) for inclusion in any future research related to this area and this Diptera family.

One surveyor sampled hoverflies by photographing them in the field using a Canon Eos 7D Mark II camera with a Sigma 150 mm 1:2.8 macro lens. Identification from field photographs was done using Bot & Van de Meutter (2019) and by consulting specialists. All records with field photographs were uploaded on observation.org and checked by experts – the hyperlinks to all records are available in Bisschop (2025). The latter method is biased towards recording larger species and species that can be identified from field photographs.

One Malaise trap was set up in this study at the location given in Fig. 1. It was situated along the river bordering a forest in the lowest part of the Bergün survey area (altitude 1130 m). The trapped flies were included in the ZFMK-collection (Museum Koenig, LIB, Bonn).

Data analysis methods

The compiled data consists of daily species counts with the number of sampled individuals for each surveyor, and the Malaise trap data. The sampling frequency of each species in 2023 and 2024 is shown by binning all species into 10 classes based on the number of sampled individuals. In the first class, species with 1–3 sampled individuals are represented, in class 2 species with 4–7 sampled individuals, and so on to class 10 with more than 28 sampled individuals. Rarefaction analyses based on individuals were performed to determine the species richness per 100 sampled individuals for each surveyor. These were carried out using the iNext package in R (Hsieh et al. 2016) based on 50 permutations of the datasets.

Table 2. Sampling effort of four surveyors and one Malaise trap in 2023 and 2024.

Surveyor / method	Surveying days & estimated field hours in bold between brackets
surveyor 1 (field photo)	23.vi.2023 (**3 h**); 24.vi.2023 (**7 h**); 12.viii.2023 (**6.5 h**); 05.vi.2024 (**8 h**); 18.vi.2024 (**10 h**); 29.vi.2024 (**8.5 h**); 15.vii.2024 (**9 h**); 05.viii.2024 (**8.5 h**)
surveyor 2 (hand-net)	21.vi.2023 (**3 h**); 22.vi.2023 (**7 h**); 23.vi.2023 (**7 h**); 24.vi.2023 (**7 h**)
surveyor 3 (hand-net)	22.vi.2023 (**5 h**); 23.vi.2023 (**7 h**); 24.vi.2023 (**4 h**); 20.vi.2024 (**4.5 h**); 21.vi.2024 (**6 h**)
surveyor 4 (hand-net)	20.vi.2024 (**4.5 h**); 21.vi.2024 (**6 h**)
Malaise trap	19.vi.2023 to 24.vi.2023 (5 days)
total 2023	10 field surveys (**57 h**); long surveys (≥4.5 h) between 15–30 June: 6 (**40 h**)
total 2024	9 field surveys (**65 h**); long surveys (≥4.5 h) between 15–30 June: 6 (**39.5 h**)
total 2023 & 2024	19 field surveys (**122 h**) & 1 malaise trap (5 days)

Rarefaction curves based on a sample-based collection were calculated for the total data of 19 surveys and for the years 2023 and 2024 separately. One sample unit represents one survey, i.e., the species day count of one surveyor. The main purpose of the rarefaction analyses was to investigate if selected field surveys in 2023 and 2024 produced a comparable species richness count. Only surveys between 15 and 30 June and with an estimated duration of 4.5 or more hours were used for the analysis. There were 6 surveys by 3 surveyors in 2023 and in 2024, totalling to an estimated 40 field hours for each year. The rarefaction curves were calculated with the iNext package in R (Hsieh et al. 2016) and plotted with their 95% confidence intervals. The extrapolations of the rarefaction curves, i.e., the predicted species richness of the surveying area, was also calculated using the same R package.

In this study we also compiled hoverfly species checklists for the municipality of Bergün-Filisur and the canton of Graubünden, which helped us evaluate our survey results. Most of the records originate from the Swiss national database info fauna, which includes museum records and records from entomologists and naturalists who shared their data with info fauna. These records are visible online (info fauna 2025a). Some additional records were found in the literature. The checklists are provided as supplementary data (Suppl. material 1) and are accompanied by notes in (Suppl. material 3).

Results

Species and surveyor data overview

The lists of hoverfly species recorded in the Bergün survey area in 2023 and 2024, including number of sampled individuals, are provided in Suppl. material 1. In total, 1438 hoverfly individuals comprising 173 species were caught or photographed. The total species counts per survey year were 134 in 2024 (including the Malaise trap results) and 135 in 2024. The number of unique species recorded in only 2023 or 2024, was 38 and 39 species respectively. Amongst the 42 species collected with Malaise trap, 6 species were not recorded during the field surveys.

Also provided as supplementary data are the compiled hoverfly checklists for the municipality of Bergün-Filisur and the Canton of Graubünden (Suppl. material 1). The Graubünden checklist contains 341 species, which corresponds to 69% of the 495 species currently known in Switzerland (Fisler 2024). We recorded three species that, as far as we are aware, are new for the Canton of Graubünden:

SWITZERLAND • 1 ♀; *Platycheirus transfugus* (Zetterstedt, 1838); Bergün (GR), Veja Val Tuors; 779460/168030; alt. 1600 m; 21 Jun. 2024; Lisa Fisler leg. & det.; in coll. Lisa Fisler; GBIFCH01102214 • 1 ♂; *Sphaerophoria estebani* Goeldlin de Tiefenau, 1991; Bergün (GR), Tuors Chants; 782955/168890; alt. 1837 m; 21 Jun. 2024; Gaël Pétremand leg. & det.; in coll. Gaël Pétremand; GBIFCH01311032 • 1 ♂; *Psilota exilistyla* Smit & Vujić, 2008; Bergün (GR), Fop Chanols; 776550/168150; alt. 1560 m; 24 Jun. 2023; Jan Bisschop leg. & det.; photographed: https://observation.org/observation/277812098/

Several species recorded during our surveys are listed as endangered on the European Red List of Hoverflies (Vujić et al. 2022): 11 species are categorized as endangered and 3 species as vulnerable (see Suppl. material 2). A few field photographs of scarce or endangered hoverflies in the Bergün area are presented in Figs 3–10. The Graubünden-checklist (including records previous to our study) includes one critically endangered species (*Platycheirus altomontis* Merlin & Nielsen, 2004), 32 endangered species, 6 vulnerable species and 18 near-threatened species at European level. Another seven species are categorized as Data Deficient. Out of the 341 species reported from the Canton of Graubünden, 277 species (= 81%) are not endangered (Least Concern).

To illustrate the species richness of the 2023–2024 survey data, we defined 10 abundance classes based on the number of collected and photographed individuals (see Fig. 11). For the two years combined, most species (76) fell into the first class with only 1–3 individuals recorded. Another 33 species had 4–6 individuals recorded, and so on, up to the final class consisting of 10 species with more than 28 individuals each. For the years 2023 and 2024, there were 78 and 81 species with 1–3 recorded individuals, respectively.

The sampling statistics for each surveyor are given in Table 3. The number of surveys and field hours differed significantly between the surveyors, which partly explains the differences in the species richness and number of individuals recorded. However, there is no good

Figure 3–10. Scarce or endangered hoverfly species photographed in the Bergün survey area. **3.** *Brachypalpus chrysites*, ♀, 1120 m, 18.vi.2024 (EU Red List status: VU); **4.** *Chalcosyrphus valgus*, ♀, 1960 m, 15.vii.2024; **5.** *Paragus punctulatus*, ♀ & ♂, 2130 m, 15.vii.2024; **6.** *Cheilosia hercyniae*, ♀, 1610 m, 05.viii.2024 (EU Red List status: EN); **7.** *Epistrophe diaphana*, ♀, 1580 m, 24.vi.2023; **8.** *Epistrophe leiophthalma*, ♀, 1750 m, 05.viii.2024 (EU Red List status: EN); **9.** *Xylota triangularis*, ♂, 1480 m, 18.vi.2024; **10.** *Xylota ignava*, ♂, 1120 m, 18.vi.2024. Photos: Jan Bisschop.

Table 3. Sampling statistics for each surveyor. The average number of species in a sample of 100 individuals was calculated with the iNext package in R (Hsieh et al. 2016).

surveyor	surveys	field hours	species	individuals	species in sample of 100 individuals	
					incl. common*	excl. common*
1	8	61	115	660	51	53
2	4	24	96	310	53	53
3	5	27	76	156	59	59
4	2	11	68	218	43	54

* the common species are: *Chrysotoxum arcuatum*, *Eristalis tenax*, *Melanostoma mellinum*, *Sphaerophoria scripta*

correlation between the number of field hours and the recorded number of individuals, and this illustrates the differing sampling strategies or intensities among the surveyors. Indeed, some surveyors estimated the number of individuals of common species present at certain locations (without collecting them). To account for this, an individual-based rarefaction analysis was performed, to calculate the number of species observed per 100 individuals, with and without the common species. Of the four commonest species [*Chrysotoxum arcuatum* (Linnaeus, 1758), *Eristalis tenax* (Linnaeus, 1758), *Melanostoma mellinum* (Linnaeus, 1758), and *Sphaerophoria scripta* (Linnaeus, 1758)], surveyors 1–4 recorded respectively 94, 24, 15, and 86 individuals. If these four common species are omitted from the rarefaction analysis, the surveyors 1–4 collected 53–59 species per 100 sampled individuals. This shows that all surveyors aimed at recording a high species richness and refrained from repeatedly collecting the same species.

Rarefaction analyses

A rarefaction analysis of the daily species counts (surveys) was carried out to investigate how the recorded species richness depends on the number of survey days. Fig. 12 shows three different curves: one for all 19 field surveys carried out in this study and two curves for the periods 15–30 June in 2023 and 2024 for surveys with 4.5 or more field hours (see Table 2). Also shown (by dotted lines) are the extrapolations based on the approach by Chao et al. (2014) as implemented in the iNext package (Hsieh et al. 2016). The 2023, 2024 and all 19 survey rarefaction curves are very close, almost crossing or overlapping at 6 surveys (see inset in Fig. 12). The number of recorded species during the 15–30 June period is 108 in 2023 and 111 in 2024, despite the 37 and 40 (respectively) unique species recorded in these years. The extrapolated curves for 2023 and especially for 2024 stay close to the blue curve that includes all 19 survey datasets. The predicted maximum species richness for 50 sampling surveys using the approach of Chao et al. (2014) is 205, 172 and 192 based on the 2023, 2024 and all 19 survey datasets, respectively. As these rarefaction curves may function as a baseline reference for future surveying (see Discussion), the data points and standard deviations are given in Table 4 as well.

Table 4. Data points of the 2023 and 2024 rarefaction curves in Fig. 12, including standard deviations for the 6 surveys (≥4.5 h) between 15–30 June 2023 and 2024. S = Surveyor, with the number of surveys per surveyor in brackets.

number of surveys	2023 surveys: S1(1); S2(3); S3(2)	2024 surveys: S1(2); S3(2); S4(2)
	average species number ± σ	average species number ± σ
1	28.83 ± 15.22	39.33 ± 8.29
2	50.53 ± 16.93	63.40 ± 7.30
3	68.25 ± 16.79	79.80 ± 6.86
4	83.27 ± 15.39	92.20 ± 6.24
5	96.33 ± 12.61	102.33 ± 5.24
6	108	111

Discussion

In this paper we investigate if hoverfly surveys along haphazardly selected routes by different observers can produce repeatable survey results in mountain areas. The advantage of this approach is that the (experienced) surveyors can follow their own strategy or intuition for finding as many species as possible. Moreover, the different habitats and elevation zones in mountain areas can potentially be covered in this way by a comparatively low sampling effort, compared with other methods, such as Malaise trapping. For the evaluation of the survey data, we used the approach used by Barendregt et al. (2022). The reproducibility of this approach does not (only) stem from a replicability of the sampling method itself, but from sufficient averaging of the survey results using rarefaction analyses. The result of this approach is a recorded species richness for a given sampling effort, which is a statistical index for the overall population size of the hoverfly community in an area, averaged over many species.

The 2023 and 2024 rarefaction curves obtained from the hoverfly surveying in the Bergün area between 15 and 30 June were similar (see Fig. 12). After 6 days, the curves almost reach the same average species richness, 108 and 111 species, respectively. The recorded species richness was higher in 2024, possibly because of the larger area covered, the larger time window of the surveys (18–29 June vs. 20–24 June), and/or more hoverflies being present or active in the area.

While the total species counts during the six surveys differed by only three species in 2023 and 2024, the species list compositions differed significantly: 71 species

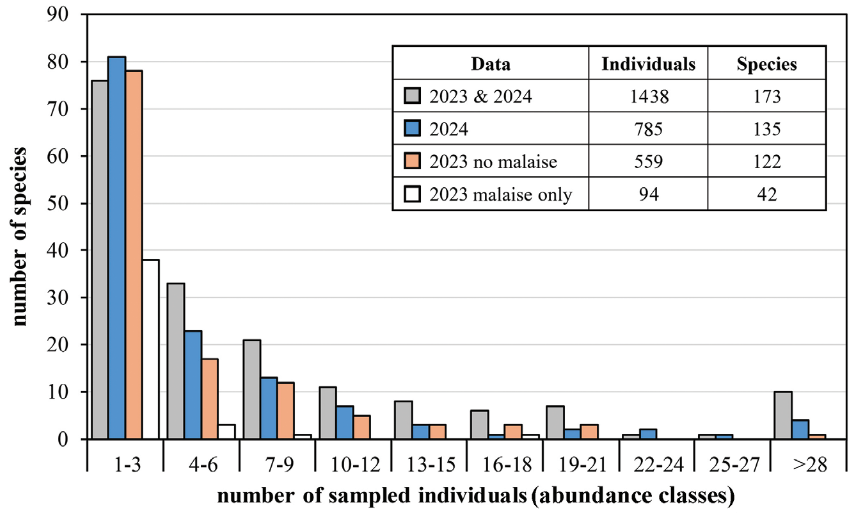

Figure 11. Summary of the recorded Syrphidae. A total of 1438 individuals, consisting of 173 species, were recorded in the Bergün survey area in 2023–2024.

were recorded in both years, whilst 37 and 40 species were recorded only in 2023 and 2024, respectively. This shows that the similarity of rarefaction curves in 2023 and 2024 was not a result of sampling the same species in both years but follows from sampling a matching proportion of species with the same detection probability.

A large proportion of the recorded species were represented by a low number of individuals. For example, around 80 species in 2023 and 2024 were represented by only 1–3 sampled individuals (see Fig. 11). The total species richness of the Bergün-Filisur municipality is 206 species (see Suppl. material 1) and only 71 species were recorded in both 2023 and 2024 during the survey period from 15–30 June. This implies that 135 species (206-71) fall below the annual detection threshold for that time window. Part of the annual fluctuation in species list compositions could reflect biological and meteorological factors. However, from a statistical perspective, it is also expected that each year a different subset of the 135 low-detectability species is sampled due to random variation in detection. Therefore, the 37 and 40 species sampled only in 2023 and 2024 respectively, are likely a result of sampling probability rather than of a complete absence of these species in the other years.

Species that are scarcely sampled could: (i) be genuinely scarce or rare in the field due to small population sizes; (ii) have a low detectability, for example because of their small size or because they occur in densely vegetated or inaccessible habitats; or (iii) have peak flight periods outside the survey window of 15–30 June. Regardless of the reason for the scarcity of certain species in the surveys, the probability of detecting these “scarce” species depends on the sampling effort and on the population size of these species. If the population size of a scarcely sampled species would decline by 50%, for example, then the probability of sampling this species would reduce accordingly for a given sampling effort.

A rarefaction curve expressing species richness according to the number of surveys seems to be a relatively robust index for the overall (average) hoverfly population size in a surveying area, because: (i) it does not depend on the number of sampled individuals per species as one sampled individual for each species per day (survey) is enough; (ii) it does not depend on recording specific species, and the precise reason for the scarcity of species in the sample is also irrelevant as explained above; and (iii) it records the average trend of the entire hoverfly community, and therefore is relatively insensitive to sampling biases or deviating trends shown by single species. Interestingly, in this study the species sampling of the four surveyors was very similar (53–59 species / 100 sampled individuals) when the four common species were omitted from the analyzed data. This could indicate that among experienced syrphidologists the averaged sampled species richness is similar and not strongly influenced by the personal choices of the surveyors (method, route, intuition).

In mountain areas, annual fluctuations in hoverfly phenology and temporal abundance may be linked to the flowering phenology of the plants they visit, which in turn can be influenced by the timing of snowmelt (Iler et al. 2013). Such interannual variations can potentially affect rarefaction curves if many species are impacted simultaneously. The extent of these yearly fluctuations may become clear if surveys are regularly repeated. However, the feasibility of repeating a survey regularly decreases with increasing sampling effort, especially under the economic and time constraints that funded science projects often face (Field et al. 2005; Pellet 2023). Therefore, it is advantageous to employ a method that requires a relatively low sampling effort (40 field hours), can be carried out in a narrow time window (15–30 June), and permits a certain degree of survey flexibility (method choice, route selection).

We hope that our survey rarefaction curves for 2023 and 2024 (data points in Table 4) can function as a baseline reference for future surveys of the Bergün-area or motivate to set up a similar survey elsewhere.

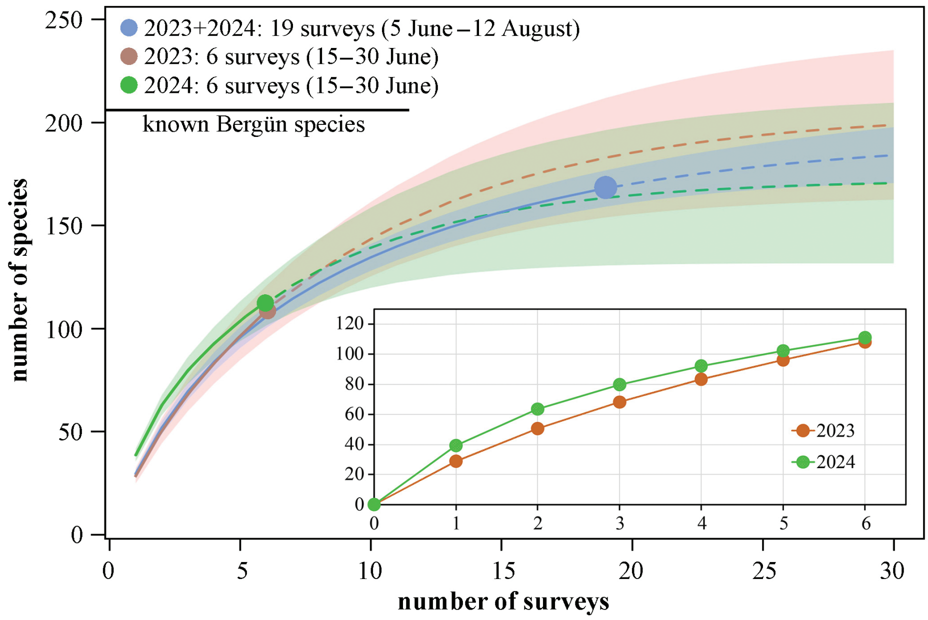

Figure 12. The sampled species richness versus the number of surveys, i.e., rarefaction curves determined from a sample-based collection, and extrapolation to 30 surveys using the approach of Chao et al. (2014). The shaded areas give the 95% confidence intervals of the calculations. The known species richness of the Bergün municipality (n = 206) is also shown. The inset shows enlarged curves for the first 6 surveys (standard deviations are given in Table 4).

To facilitate a replication of our survey, we summarize the recommended survey conditions in Table 5. We propose to make a minimum of six surveys per year for obtaining results that can be compared to ours. The yearly survey can be carried out during, for example, a week by 1–2 persons or during three consecutive days by 2–3 persons.

Barendregt et al. (2022) found a long-term (1979–2021) hoverfly population and species decline in a Dutch forest by means of rarefaction analyses of survey results. In addition to comparing rarefaction curves from different years, they also illustrated the hoverfly community decline by plotting the species richness in five randomly selected sampling days as a function of the year between 1979 and 2021. Another way to present rarefaction analyses results is to calculate the sampling effort required to record 50% of the known species richness in a survey area (see Nielsen et al. 2011). In our study this would be 103 recorded species, which required ca. 5.6 surveys (≈ 37 field hours) in 2023 and ca. 5 surveys (≈ 33 field hours) in 2024.

Conclusions

- In this work we provide a baseline measurement and guidelines for long-term hoverfly surveyance in the municipality of Bergün-Filisur in the central Alps. The required sampling effort for an annual measurement is relatively small and can be carried out, for example, by one surveyor over 6 days or by two surveyors over 3 days within the surveying period of 15th to 30th of June.
- A total of 173 hoverfly species were recorded in our survey in the Bergün area, including three species new for the Canton of Graubünden. The 173 species comprise 84% and 51% of the currently known species richness of the municipality of Bergün-Filisur (206) and Graubünden (341), respectively.
- 14 species recorded in the 2023 and 2024 Bergün surveys, and 39 of the species recorded in Graubünden are on the European Red List of Hoverflies, by being critically endangered (CR), endangered (EN) or vulnerable (VU).

Table 5. Recommendations for repeating the survey study presented in this paper.

Survey parameter	Recommendation
area	The Bergün surveying area as outlined in Fig. 1
time window	15 to 30 June
number of surveys	at least 6, spread over at least 3 days
number of field hours	ca. 40 hours divided over 6 surveys (at least 4.5 hours per survey)
number of surveyors	1–4 experienced syrphidologists
route	free to choose, but covering many habitats and altitudes; at least one trip above tree line with sunny weather
weather	reasonable to good weather with sun, or thin or partly cloudy
methods	hand-net, field observations and/or field macrophotography
sampling intensity	normal with breaks; survey primarily focused on Syrphidae and on recording as many species as possible.

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Supplementary material 1

Checklists of hoverfly species

Authors: Jan Bisschop, Lisa Fisler, Gaël Pétremand, Ximo Mengual

Data type: docx

Explanation note: Checklists of hoverfly species recorded in (i) the Bergün survey area (173 species); (ii) the municipality of Bergün-Filisur (206 species); and (iii) the Canton of Graubünden (341 species) in Switzerland.

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Link: https://doi.org/10.3897/alpento.9.170334.suppl1

Supplementary material 2

European Red-List species (Vujić et al. 2022) recorded in the Canton of Graubünden and the Bergün area (B)

Authors: Jan Bisschop, Lisa Fisler, Gaël Pétremand, Ximo Mengual

Data type: docx

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Supplementary material 3

Notes on the municipal and cantonal checklists, acknowledgements and references

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Data type: docx

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