Apollo (*Parnassius apollo*) in Italy – Alpine biogeographical region

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Step 1.1 Biology of the species

In Italy *Parnassius apollo* (L., 1758) occurs throughout the Alpine chain and the major Apennine massifs of Liguria, Tuscany, Latium, Abruzzo and Aspromonte. Concerning the Alps, the absence of this species from the mountains of the easternmost part of Alto Adige can only be explained by insufficient prospecting, since very few spots mapped in Huemer (2004) were recorded from this area. Records from the Sila Mountains of Calabria are old and unconfirmed. In Sicily *P. apollo* is restricted to the Madonie Mts (Figure 1).

P. apollo occurs mainly in mountain stony screes, sunny slopes with sparse vegetation. In the Alpine biogeographical region, it flies from 600 and more than 2000 m of altitude (Balletto *et al.*, *in prep.*). The species has very narrow ecological requirements.

Larvae are oligophagous and feed on *Crassulaceae*, generally on species of *Sedum*. Female leaves singular eggs on or near the food plants (*Sedum* spp.) and caterpillars can be roughly classified as "albophagus" for *S. album* (Nakonieczny *et al.*, 2007), although they can feed on other species of *Crassulaceae* such as *S. rupestre, S. montanum* and *S. acre* (Balletto *et al.*, *in prep.*).

Adults forage early in the morning or late in the afternoon (Nikusch, 1996), mainly on violet or violet-blue flowers such as those of *Centaurea*, *Cirsium*, *Origanum*, *Scabiosa*, *Eryngium*, *Epilobium*, *Thymus*, *Valeriana* etc., but sometimes also on *Narcissus* or on some yellow *Cruciferae* (e.g. *Biscutella*), as well as on *Sedum*.

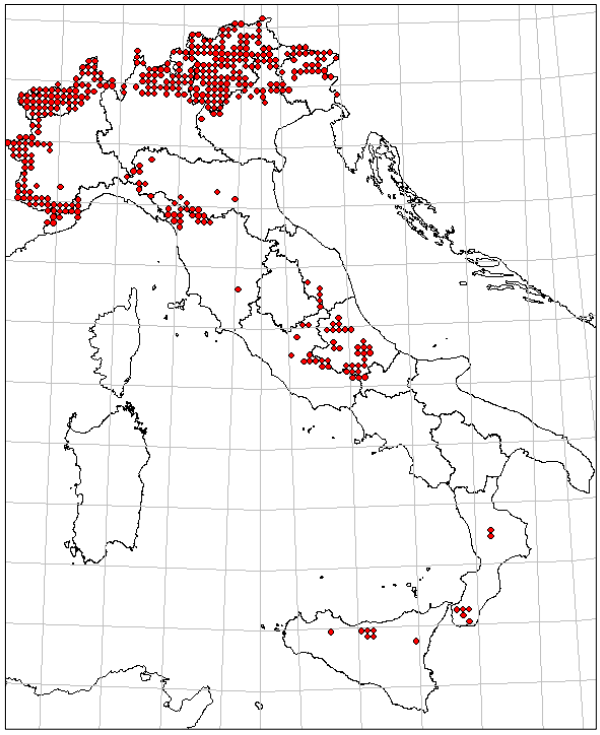

Figure 1 – Occurrence of P. apollo *in Italy (CKMap data, Balletto et al. 2007)*

Adults fly in a prolonged single generation, which in Italy generally occurs from (June) July until August, but may appear even in April, at the lowest elevations in the Alps, or may be on the wings until mid-September, in some years. In the Apennines adults occur only over about 20 days, from mid-July to the beginning of August (Verity, 1947). Males start to fly several days before females.

Each individual specimen may survive for 2-4 weeks and may be active for 10 hours every day, in fine weather (Lafranchis *et al.*, 2015). Larval development takes 3-12 weeks, depending on the weather.

P. apollo larvae generally hibernate within the egg (Nardelli *et al*., 1989). Larvae generally hatch only in the following spring. Pupation begins in middle May and occurs in a sort of lax cocoon, normally under a stone, or in the litter. Pupae develop for about 2-3 weeks, depending on temperature, but up to 7 weeks, in very cold weather (Lafranchis *et al.*, 2015).

Step 1.2 Spatial scale of functioning

Apollo has a modest movement capacity, of usually at most 1-2 km (Brommer & Fred, 2001), so it occurs in discrete management units (disjunct populations or local metapopulations) scattered over the Alps. Indeed, *P. apollo* can fly between habitat patches containing suitable food plants over distances up to 1840 m (median 260 m). The co-occurrence of adult and larval resources is important to determine patch quality and can drive female movements between patches (Fred *et al*., 2006).

Todisco *et al.* (2010) have highlighted a strong phylogeographic structure, revealing a number of distinctive mtDNA lineages occurring in different regions or in separate mountain chains. A first lineage inhabits Anatolia, Northern Greece and East-Northern Europe. A second main clade occurs in Central and Southern Spain. Specimens from the Alps, the Apennines, the Pyrenees, the Massif Central, Sicily, and the mountains of Peloponnesus form a third group of closely allied lineages. A distinct haplotype, however, occurs in the Madonie mountains of Sicily. In contrast, electrophoretic techniques showed that the population of the Massif Central is fairly distinct and those from mainland Iberia share a separate haplotype (Descimon *et al.*, 2001; Nève, 2009).

This species could be listed under population category **S6**, small species with low mobility with scattered distribution (Table 4.1a in Bijlsma *et al.*, 2018).

Step 1.3 Historical perspective: what happened to the species?

Quantitative data on the species are very scarce. No historical references can be easily identified for population size but the species was certainly distributed through the Alps in the past. So, in the Italian Alpine biogeographical region, the natural range of the species is the whole Alpine area.

On the contrary, in some parts of the Apennines (Mediterranean biogeographical region) a number of populations are strongly declining or have altogether disappeared (Bonelli *et al.*, 2018). The *P. apollo* decline is primarily linked to the reduction and progressive isolation of habitat patches, mainly due to environmental modifications, related to both land-use and climatic changes.

Step 1.4 Analysis of distribution and trends

For Italian alpine populations, detailed information on population parameters are not available yet and there is no current estimate of the population size, expressed as number of individuals. Data on the species are limited to presence-only data (Table 1), characterized by variable precision (from localities to 10x10 km grid cells). As a consequence, in the previous reporting, the population size (247) was given as 'number of map 10x10 km grid cells (grids10x10)'. For the next reporting round, data on the population will be expressed as 'number of map 1x1 km grid cells (grids1x1)', as recommended.

The distribution of the species in the Alpine biogeographical region seems to be rather stable (no clear evidence of short-/long-term trends) and sightings of the species are reported throughout the Alps (i.e. throughout the natural range). Nevertheless, there is no certainty on whether the local populations could be viable or not and there are concerns on potential distribution shifts in the future (e.g. because of climate change). Moreover, the data available when the Directive came into force enabled only a qualitative estimate of the range and of the population size.

For these latter reasons, the stepwise approach did not end with the setting of Favourable Reference Values (FRVs) = Habitats Directive Values (HDVs), but continued through a mixed reference/model based approach to define the Favourable Reference Population (FRP) and hence the Favourable Reference Range (FRR).

Table 1 – Available data on the occurrence of P. apollo *in the Alpine biogeographical region, IT*

Source	**Total number of records**	**Number of used records**
Atlas CKmap	104 cells 10x10 km, 274 points	69 cells 1x1 km, 81 points
Natural and National Parks	348 points	178 cells 1x1km, 348 points

Occurrence data have been mainly provided by Parco del Monviso, Parco del Gran Paradiso, Parco dello Stelvio, Parco Val Grande, Parco delle Dolomiti Bellunesi, Parco Alpi Cozie, Aree protette dell'Ossola. Most of these data have been collected in the framework of the project "Monitoring of Animal Biodiversity in Mountain Ecosystem" (Viterbi *et al.*, 2013), leaded by PNGP (http://www.pngp.it/node/218).

Step 2 Set Favourable Reference Values

Taking into account the limits of actually available data on *P. apollo,* in order to define the Favourable Reference Population (FRP) we used a habitat suitability modelling approach, partly similar to the one adopted by Di Marco *et al.* (2016) to scale up population targets to the species level. The steps of our approach can be summarised as follows (see also Figure 2):

(a) we modelled habitat suitability for the species in the Alpine biogeographical region using MaxEnt (Philips *et al.*, 2006). The environmental conditions at the available downscaled records (Table 1) were contrasted to a set of pseudo-absence (background) points. Environmental variables used for the analysis were chosen taking into account the available knowledge on the species ecology (see Step 1.1) and they included topography (slope, aspect, elevation), climate (isothermality, seasonal precipitation, April-May

precipitation, solar radiation) and habitat characteristics (percentage of land cover within each grid cell, connectivity of suitable open areas);

(b) on the map resulting from the Species Distribution Modelling (SDM), we applied a clumping procedure which enabled to identify discrete patches of suitable habitat. The SDM map was used as an inverted resistance surface, setting thresholds to discriminate between low, intermediate and high resistance values (Rodder *et al.*, 2016). We then used the available information on the species dispersal ability to identify group of cells characterized by low resistance, corresponding to potential population clumps. Low resistance cells were considered contiguous if they were within the dispersal range of the species (1-2 km - Brommer & Fred, 2001; see also above Step 1.2) or if they were separated from other low resistance cells by intermediate resistance habitat spanning at most for the same range. We finally selected only those clumps satisfying the Minimum Area Requirement (MAR) for the species (Baguette & Stevens, 2013). These clumps thus provide the minimum amount of functional, connected habitat necessary for the population persistence, and each clump corresponds to a potentially viable local (meta)population. Ultimately, a clump was thus defined as a spatial population unit, i.e. an area satisfying the requirements of at least one viable (meta)population of the species in terms of habitat availability and connectivity, and clearly separated from other clumps because of the presence of an interposed matrix of unsuitable or high resistance habitat.

(c) to scale up the population targets to the biogeographical level, we compared the number of available clumps to the number of actually occupied clumps (Figure 3 and Figure 4) and we verified the distribution of the latter with respect to the natural range of the species. The number of clumps that should be occupied by *P. apollo* to meet favourable conditions depends on the ecological and genetic variations within the species range. Therefore, we aimed at identifying the minimum number of clumps to cover this range, along latitudinal, longitudinal and altitudinal gradients.

According to our first results, 40 clumps are occupied by the species. Their distribution along the longitudinal gradient is rather close to the distribution of available clumps, whilst a main gap was identified at the largest latitudes, where several clumps seem to be available but none of them is occupied by the species, at least according to the available data.

Taking into account these preliminary findings, we concluded that the 40 occupied clumps are fairly well distributed within the natural range, but that at least one additional clump should be occupied by *P. apollo* in order to completely cover the environmental variation along the latitudinal gradient. So, the FRP could be expressed as a minimum number of 41 clumps (although the analyses along the altitudinal gradient are still in progress and they could allow us to identify further gaps).

The Favourable Reference Range (FRR) could subsequently be estimated as the envelope including these 41 clumps, adopting the procedure outlined in the guidelines for the definition of the species range.

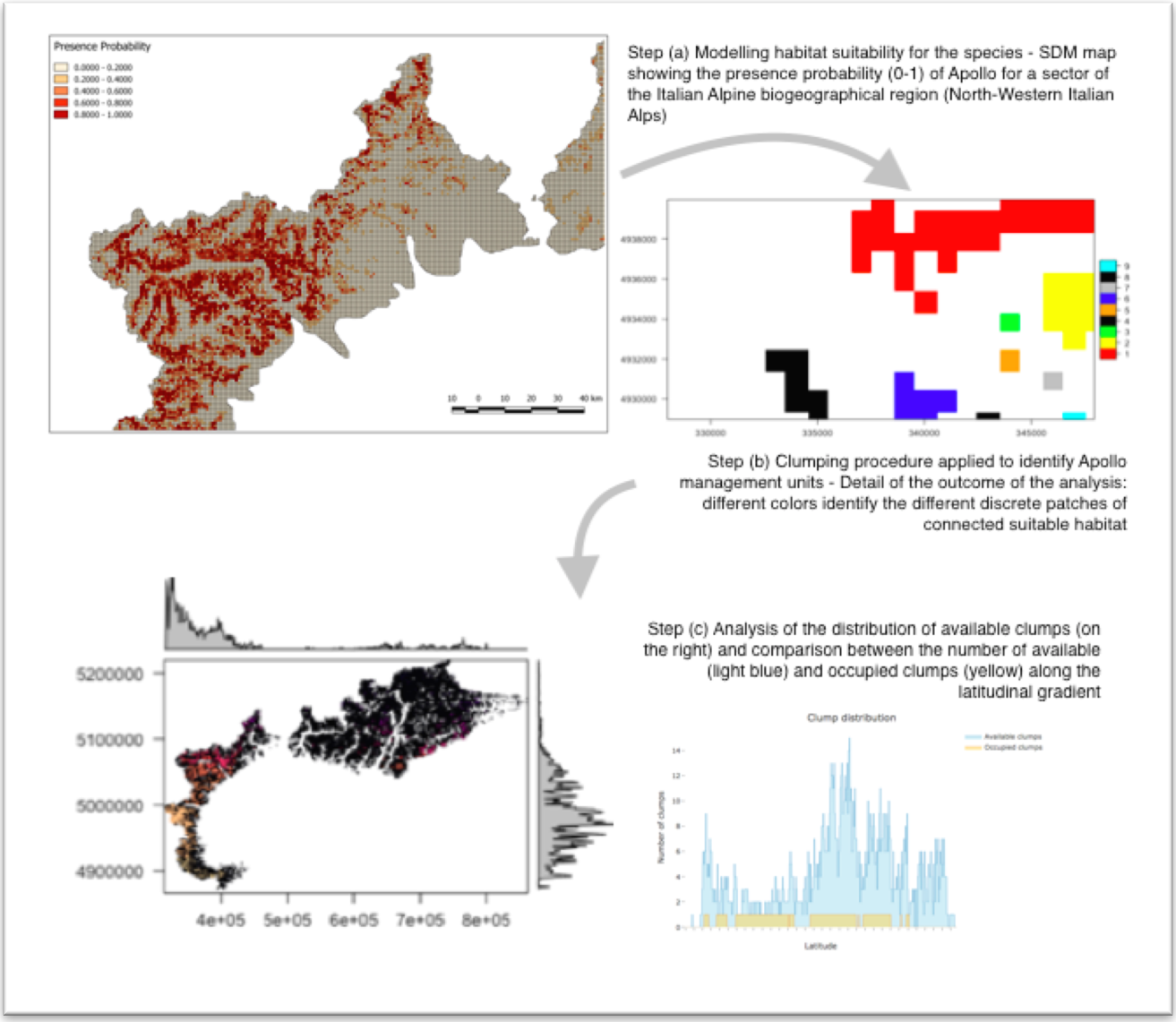

Figure 2 – Steps of the modelling approach adopted to define the FRP for P. apollo, Alpine biogeographical region, IT.

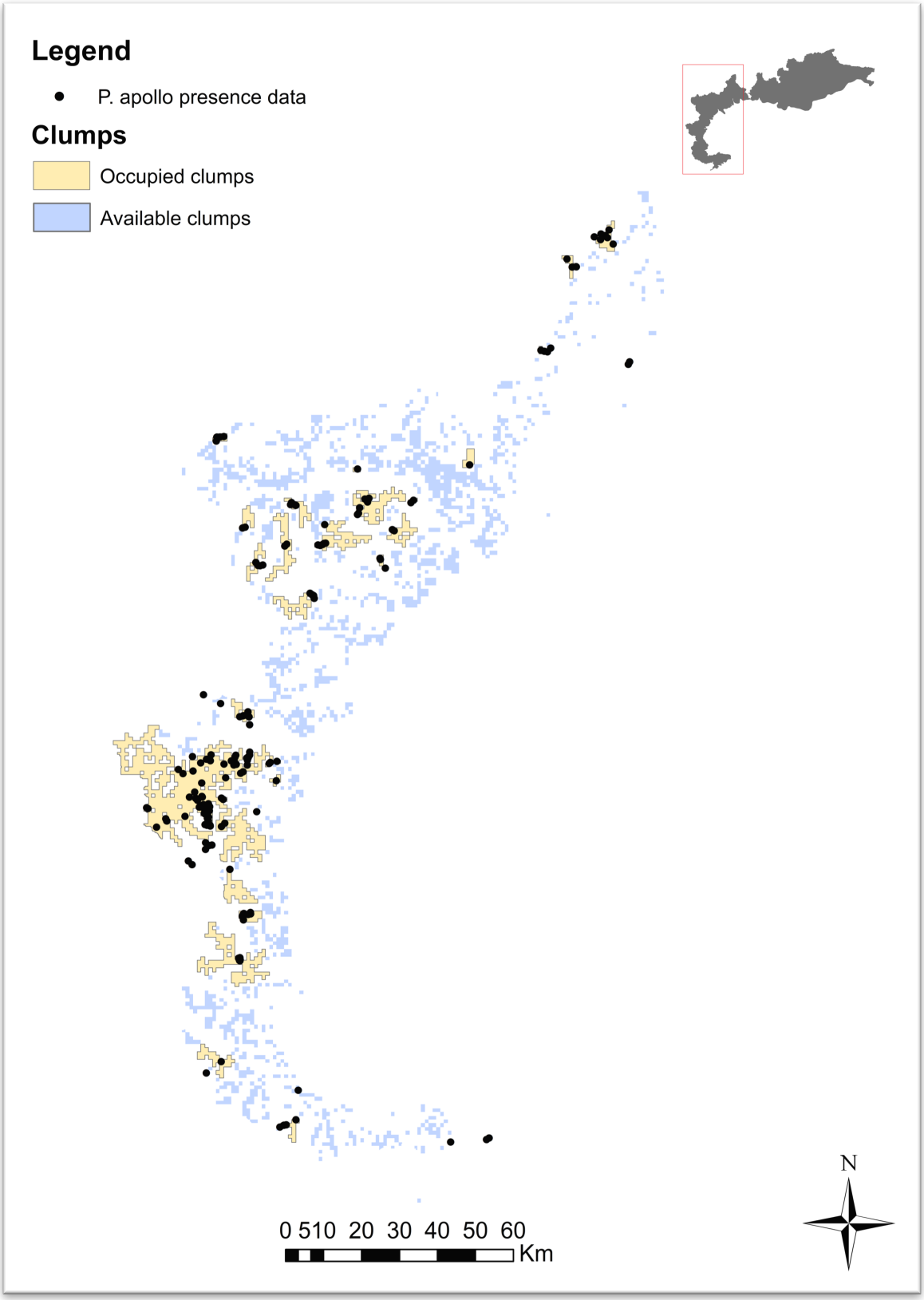

Figure 3 – Available vs. actually occupied clumps and P. apollo records – the map shows the detail of the clump distribution for the Western Italian Alps.

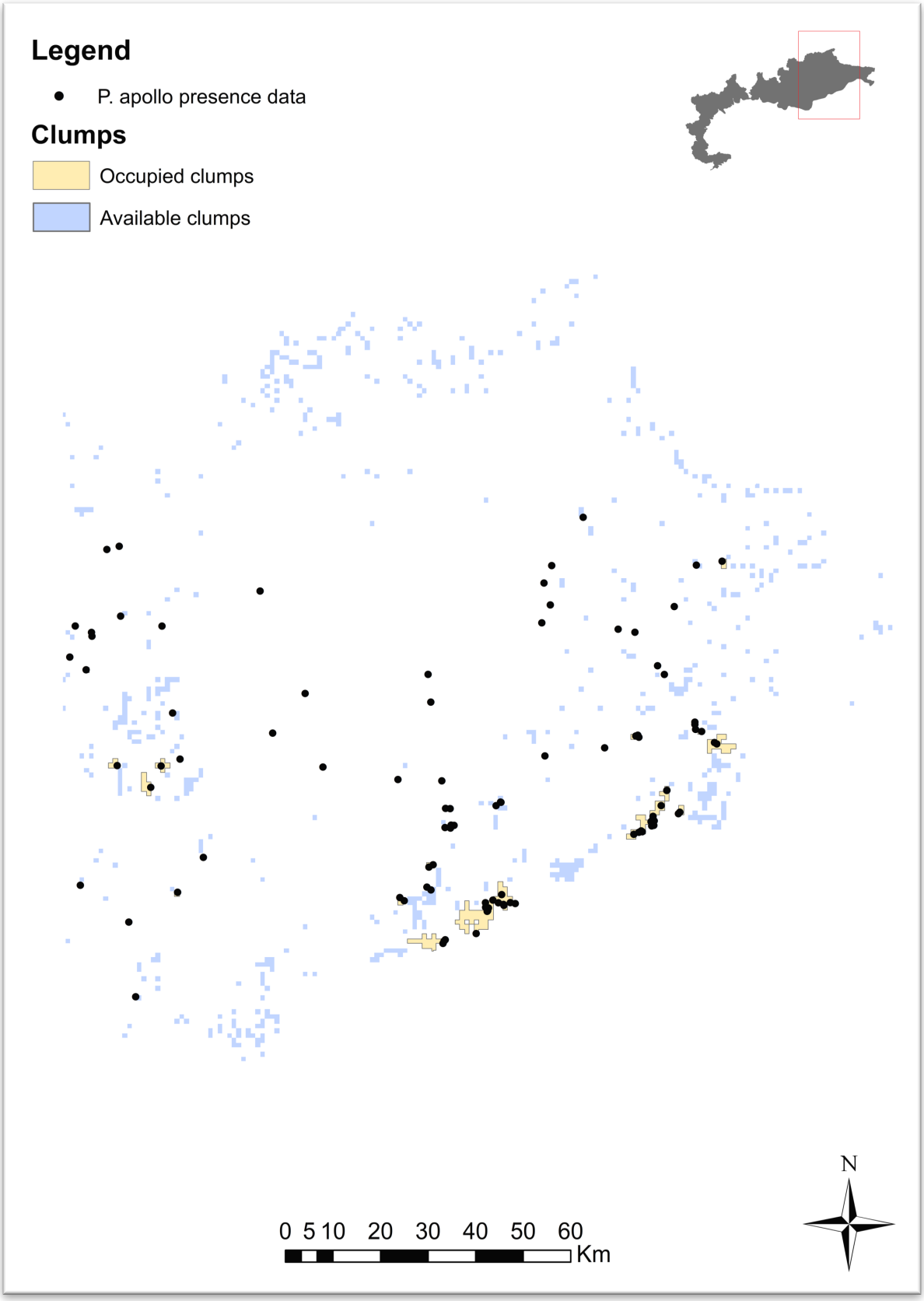

Figure 4 – Available vs. actually occupied clumps and P. apollo records – the map shows the detail of the clump distribution for the Eastern Italian Alps.

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