

Collection of Fire Salamander (*Salamandra salamandra*) and Alpine Salamander (*Salamandra atra*) distribution data in Austria using a new, community-based approach

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Abstract

The Fire Salamander (*Salamandra salamandra*), a black amphibian with yellow spots or stripes, is the best-known salamander species in Europe. Fire Salamanders are endangered because they require small springs or brooks in their habitats and each year some of these bodies of water are destroyed. The Alpine Salamander (*Salamandra atra*) is a small pitch-black amphibian endemic to the European Alps and strictly protected under the EU FFH directive. Their population status and distribution in Austria and Salzburg has not yet been monitored extensively and despite its central role in the ecosystem, existing scientific records are scarce. Using a new, community-based scientific approach on our website www.alpensalamander.eu, we collect and present data about occurrence, population size and distribution of the Fire and the Alpine Salamander in Austria. From the actual data (more than 5 600 records since July 2009) we have already obtained a good overview of the present distribution and data quality. We also collected an oral history of Fire and Alpine Salamander observations in the past 50 years by conducting interviews in the local community. The data are an excellent basis for detailed scientific studies on these remarkable amphibians. With this new and highly interactive approach, science and education are combined to initiate protective measures with the public.

Introduction

Fire Salamander (*Salamandra salamandra*)

The Fire Salamander (*Salamandra salamandra*), order Caudata, family Salamandridae, is a black amphibian with varying amounts of yellow spots or stripes (Figure 1). Characteristic for the Fire Salamander are the yellow parotids on the head and the two dorsal gland lines on the left and right side of the backbone. In our regions, the Fire Salamander weighs between 20 and 45 g and measures up to 20 cm in length. Fire Salamanders have a venomous dermal secretion consisting of three neurotoxic components (Samandarin, Samandaridin and Samanderon), which is mainly excreted through the parotids and the dorsal gland lines. This venom is used as a defence mechanism against parasites on the skin and against predators. Fire Salamanders can live up to 20 years. Typical habitats are mixed broadleaf forests (mostly beech and mixed beech forests). They prefer the edge of the forests near woodland brooks. Fire Salamanders are ovoviviparous amphibians, so they require small springs or brooks in their habitats for their 30 to 60 larvae to develop. The reproduction cycle is annual and larvae are found from February to October. The development of the larvae takes place in an expanded part of the oviduct, called uterus. After mating, the sperms are stored in the "spermatheka". This allows the storage of sperms for up to two years. The duration of the larval period varies from a few months to more than a year. The larvae metamorphose into a juvenile salamander a few months later (Grossenbacher & Thiesmeier 2003).

Fire Salamanders are food generalists, they mostly feed on slugs and arachnids. Fire Salamanders are nocturnal animals, their diurnal activity depends on air temperature, air humidity and air flow. They usually leave their



Figure 1 – Fire Salamander (*Salamandra salamandra*)



Figure 2 – Alpine Salamander (*Salamandra atra*)

lairs at more than 85% relative air humidity. They hibernate underground, for example in crevices, caves or mine tunnels, in places with constant temperatures and air humidity (Grossenbacher & Thiesmeier 2003).

Distribution

The Fire Salamander occurs across large parts of Central, Western and Southern Europe. The distribution stretches from Portugal, Spain, France, Belgium and Germany across the Czech Republic and Slovakia, Italy and Hungary, all the way to Greece. It is not found in Great Britain, Ireland, Scandinavia, Poland, Belarus, the Baltic States and Russia (Grossenbacher & Thiesmeier 2003).

In Switzerland and Austria, the Fire Salamander is widely distributed at altitudes between 200 and 700 m and it is also found at up to 1300 m. In the core area of the Alps, there is a significant gap in occurrence (Grossenbacher 1988; Cabela et al. 2001). In Austria, no Fire Salamanders have been reported in Vorarlberg, in most of the Inn valley, in the High Alps, in Murau nor are they reported in northern Alto Adige (Grossenbacher & Thiesmeier 2003). Despite its central role in the ecosystem, our actual research records on the Fire Salamander in Austria are scarce. In fact, we know very little about its exact distribution in the Austrian Alps, its habitat, its ecology and most importantly the population trends. The Fire Salamander is on the Red List of amphibians and reptilians in Austria (classified as “near threatened”) (Kyeck & Maletzky 2006). Like most other amphibians, Fire Salamanders suffer from severe habitat destruction brought on by modern agriculture, road construction and river regulation (Grossenbacher & Thiesmeier, 2003).

Less than 1600 observations are on record for the last 80 years (Cabela et al. 2001). This project aims to fill the gap by collecting salamander observations from the public using a community-based Web 2.0 approach on www.alpensalamander.eu. Over the next few years, this approach will be extended to the whole of Europe. The main objective is to map occurrence, population size and development as well as the genetic structure of the Fire Salamander and to use these findings to initiate and design protective measures preventing the disappearance of this remarkable amphibian.

Alpine Salamander (*Salamandra atra*)

The Alpine Salamander (*Salamandra atra*) is a small, dainty black amphibian. It lives in alpine regions at altitudes between 600 m and up to 2400 m. Males and females measure up to 14.4 cm and 15.1 cm, respectively. The distance head to body length is about 1.5 times the length of the tail. To the right and left of the spine there are two rows of glands. The skin looks even and glossy. The Alpine Salamander has comparatively large eyes located lateral at the front of the head. The head is slightly elongated and has two large kidney-shaped parotid glands. The mouth is short, round and quite broad (Kyeck & Maletzky 2006; Thiesmeier & Grossenbacher 2004; Nöllert & Nöllert 1992; Klewen 1991)

S. atra spends most of its time under ground, it is very retiring and quite abundant. Its activity above ground is highly dependent on the climate as it prefers humid

conditions. This is striking after heavy rainfall or in the early morning hours when the animals become active and leave their lairs. Densities of 120 individuals per hectare have been known (Klewen 1991).

The typical habitat of the Alpine Salamander is alpine meadows and woodlands. It lives in cracks, crevices or burrows, only to emerge at night or after rainfall. The species hibernates, depending on the altitude, for a period of 6–8 months (Nöllert & Nöllert 1992). The lowest known sites are at altitudes of 430 m in Austria and Switzerland, although south of the Alps the species is rarely found below 900 m. The highest altitude records are at 2430 m in Switzerland and 2800 m in Austria (Thiesmeier & Grossenbacher 2003).

Its specific adaptation to the harsh alpine environment manifests itself in its remarkable position as a viviparous amphibian, which does not require water for reproduction. Mating involves a complex behaviour taking up to 2 hours, culminating in the male depositing the spermatophore. One embryo develops in each of the two uteri. The developing young firstly feed on fertilized and later on unfertilized ova in the uteri. Subsequently, a zona trophica develops on the boundary between oviduct and uterus, which provides a continuous supply of cellular material as food for the young. At between 650 m and 1000 m altitude, gestation takes 2 years. At between 1400 m and 1700 m, it takes 3 years. The terrestrial, fully metamorphosed young evolve with a total length of 40–50 mm upon birth (Thiesmeier & Grossenbacher 2003; Greven 1998).

Distribution

S. atra is endemic in the Alps and on some isolated areas in the Dinaric Alps. It shuns some parts of Switzerland (Valais and Engadin) and Italy (Val Telline and Vintschgau) because of their predominantly dry climate. Distribution stretches across Albania, Austria, Bosnia and Herzegovina, Croatia, France, Germany, Italy, Liechtenstein, Montenegro, Serbia, Slovenia and Switzerland. In Bosnia, Montenegro and Albania (Dragoby) only some isolated massifs are colonized (Thiesmeier & Grossenbacher 2003; Klewen 1991).

There are two subspecies in Italy: *Salamandra atra aurorae* has a bright colouring on the back, the head and the dorsal side of the extremities. The distribution of the subspecies *S. atra aurorae* is extremely small (less than 50 km²) and confined to the southern edge of the area between Trento and Asiago in Italy. The habitat consists of mixed deciduous and coniferous forests on cretaceous limestone at altitudes between 1300 m and 1800 m. In 2005, Bonato and Steinfartz discovered a new, partly yellow-spotted subspecies of *S. atra* on Monte Pasubio in Italy and named it *S. atra pasubiensis* (Bonato & Steinfartz 2005).

The Alpine Salamander is on the Red List of endangered animals in Austria (Kyeck & Malezky 2006) and strictly protected under the EU FFH directive. The subspecies *S. a. aurorae* is critically endangered in its

very small area. Consequently, efforts to research its habitat and ecology, as well as measures for its conservation have highest priority.

Material and methods

The main aim of this project is to map occurrence, population-size and development of the Fire Salamander and Alpine Salamander in Salzburg and Austria. During summer 2009, we established the website www.alpensalamander.eu, where everybody can report Fire and Alpine Salamander observations. This web 2.0 approach is a new step to involve the population actively in the research and protection of these vulnerable amphibians and their habitats.

A second aim is to record an oral history of Fire and Alpine Salamander observations in the past 50 years by conducting interviews in the local community and to identify stable or decreasing populations. We interviewed alpinists, farmers, national park staff, mineral collectors and hunters to preserve their excellent local knowledge of the Fire and Alpine Salamander. In addition, we alerted the local population to the Fire and Alpine Salamanders through reports in national and local newspapers. This community-based approach allows a combination of research, education and dissemination through interactive participation. We also work with national parks (Hohe Tauern, Berchtesgaden) and museums to disseminate this project in schools, wildlife and mountaineering organizations.

We also carried out field studies to observe Fire Salamander populations in the right conditions, rainfalls and high air humidity in the Tennengebirge (Lat.: 47.508938°, Lon.: 13.211575°), the Hochkönig (Lat.: 47.424309°, Lon.: 13.067207°) and the Hohe Tauern (Lat.: 47.081688°, Lon.: 12.663116°).

Results

To date, we have more than 5800 Fire and Alpine Salamander reports in total. The biodiversity database at the Natural History Museum in Vienna only holds 1546 records of the Fire Salamander and 958 records of the Alpine Salamander from the last 80 years (Cabela et al. 2001). Compared with this collection, our method is very successful:

- for the Fire Salamander there were 3200 reports throughout Europe and 2455 records in Austria, which are displayed as 650 clusters (Figure 3);
- for the Alpine Salamander there were 2600 reports throughout Europe and 2117 records in Austria, which are displayed as 578 clusters (Figure 4).

By now there are 1300 users, 80 of them charted more than 5 times, 860 users charted more than once. Although the project is still in the initial stages, the data already give a preview of the Fire and Alpine Salamander distribution in Austria and allow for a preliminary analysis including the assessment of data quality. All records were evaluated manually. Clearly questionable

reports, such as coordinates in a lake, were checked by contacting the user and corrected or deleted. These aggregated data are the basis for our preliminary analysis where we consolidated the data with different maps. The results are shown on the following pages and relate distribution to different aspects.

Fire Salamander

- There have been about 60 Fire Salamander reports around the city of Salzburg (Lat.: 7.799488°, Lon.: 13.044891°), on the city's Kapuzinerberg (Lat.: 47.804529°, Lon.: 13.056693°) alone, 10 Fire Salamanders were observed. This shows that a coexistence of Fire Salamanders and humans is possible, as long as there are adequate spawning waters. In the Pongau, in the area of Werfen (Lat.: 47.477289°, Lon.: 13.189344°) and Bischofshofen/Pöham (Lat.: 47.417445°, Lon.: 13.217497°), there have been about 80 Fire Salamander reports during the last summer.
- Through our interviews we found out that there is a significant decrease, at least by half, of Fire Salamanders over the last 40 years.
- The scarcity (only about 20 in total) of Fire Salamander reports in the mountain valleys, e.g. Stuibachtal (Lat.: 47.264871°, Lon.: 12.566814°), Rauris (Lat.: 47.229703°, Lon.: 12.990646°), Gastein (Lat.: 47.175587°, Lon.: 13.100510°), Großarl (Lat.: 47.238856° Lon.: 13.199730°) and Kleinarl (Lat.: 47.278732°, Lon.: 13.319035°), raises the question about historic developments in this regions that may have destroyed important habitats of Fire Salamanders in the Salzachtal region. This finding will be investigated further in a research project.
- We were unable to fill in the gaps of distribution in Vorarlberg and most of the Inn valley.

We also evaluated our data from Fire Salamander reports in Austria with maps of land cover areas, altitude, climate types and geology (Figures 3a–3d).

Geology

Generally, the Fire Salamanders are distributed more or less across all geological areas found in Austria. The visible trend is that most Fire Salamanders are found in the Northern Limestone Alps, in the flysch and Grauwacken Zones and at the edge of the Central Alps (Figure 3a). The visible trend is that most Fire Salamanders are found in the Northern Limestone Alps, followed by the flysch zone, the southern and north-eastern edge of the Central Alps and the graywacke zone. No Fire Salamander has been found at the eastern foothills of the Alps.

The percentage analysis shows that most of the Fire Salamanders, i.e. 40.37%, have been found in the Northern Limestone Alps, followed by 22.19% in the flysch zone, 15.41% in the Central Alps and 7.40% in the graywacke zone. 4.77% of the Fire Salamanders in Austria have been found in the south-eastern foothills of the Alps, 3.54% in the granite and gneiss uplands

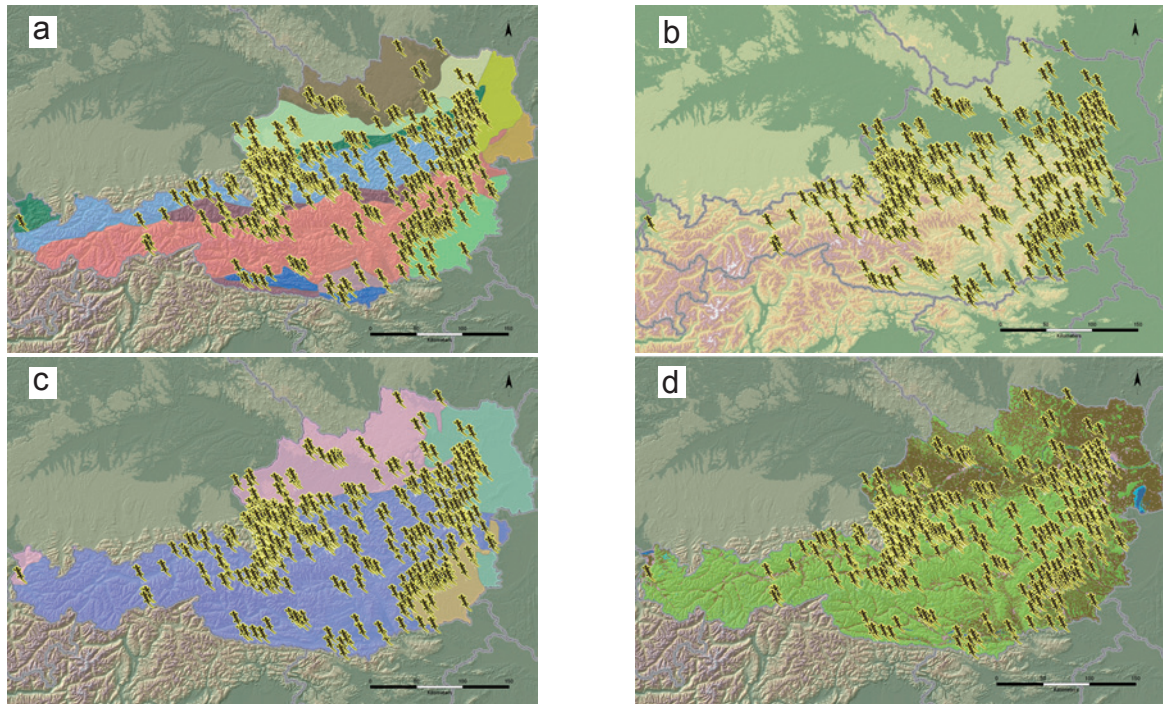


Figure 3 – Distribution of *Salamandra salamandra* in Austria. Dataset recorded from June–November 2009.

- 3a – Across Austrian geological regions: Red: Central Alps; Yellow: Vienna Basin; Light green: South-eastern alpine foothills; Light brown: Eastern alpine foothills; Dark blue: Southern Limestone Alps; Light blue: Northern Limestone Alps; Purple: Grauwacken zone; Mauve: Klagenfurt basin; Light yellow: carpathian foothills; Olive green: granite and gneiss uplands; Ocean blue: Fyisch zone; Turquoise: alpine foothills
- 3c – Across Austrian climate types: Blue: alpine climate; Rose: Central European transitional climate; Turquoise: pannonian climate; Light brown: illyric climate
- 3b – Across altitudes: Olive green: 115–500; Light green: 500–1000; Yellow: 1000–1500; Orange: 1500–2000; Brown: 2000–2500; Purple: 2500–3000; White: 3000–3798
- 3d – Across land-cover classes: Brown: agricultural; Pink: artificial non-agricultural; Green: forest and semi-natural; Blue: bodies of water; Light blue: wetlands

and 3.24% in the foothills of the Alps. Only 1.08% of the Fire Salamanders in Austria, have been found in the Vienna basin, followed by 0.92% in the Klagenfurt basin, 0.77% in the Southern Limestone Alps and 0.31% in the foothills of the Carpathians.

Altitude

60.45% of the Fire Salamanders are found between 500 and 1000 m altitude. 25.10% are found between 115 and 500 m, 12.62% between 1000 and 1500 m, 1.68% between 1500 and 2000 m, and only 0.15% between 2000 and 2500 m (Figure 3b).

Climate types

Fire Salamanders are found in four climate types: alpine, Central European transitional, pannonian and the closely-related illyric type (Figure 3c). 79.39% of the Fire Salamanders are found in alpine climate areas. 13.54% in transitional climate areas, 3.39% in pannonian climate areas and 3.69% in illyric climate areas.

Land-cover areas

Fire Salamanders populate four land cover classes: agricultural areas, artificial non-agricultural, forest and semi-natural areas and bodies of water (Figure 3d).

67.25% of the Fire Salamanders live in forests and semi-natural areas, 24.00% in agricultural areas, 8.60% in artificial non-agricultural areas and only 0.15% are found in bodies of water.

Alpine Salamander

Climate types

On the first map (Figure 4a), the distribution of *Salamandra atra* is compared with the Austrian climate types. 95.8% of the recorded salamanders can be found in an alpine climate. This climate dominates in the alpine regions of the Austrian federal states of Vorarlberg, Tyrol, Salzburg as well as in parts of Styria, Upper and Lower Austria.

The other 4.2% were recorded in regions with a Central European transitional climate. These observations took place in Lower Austria, some sites in Upper Austria and in the west of Vorarlberg.

Land-cover areas

The second map (Figure 4b) shows the distribution of *Salamandra atra* across types of land cover. Over 91.5% of the alpine salamander prefer forests or semi-natural areas. Only 5% were found on agricultural areas and 3.1% were found on artificial non-agricultural areas.

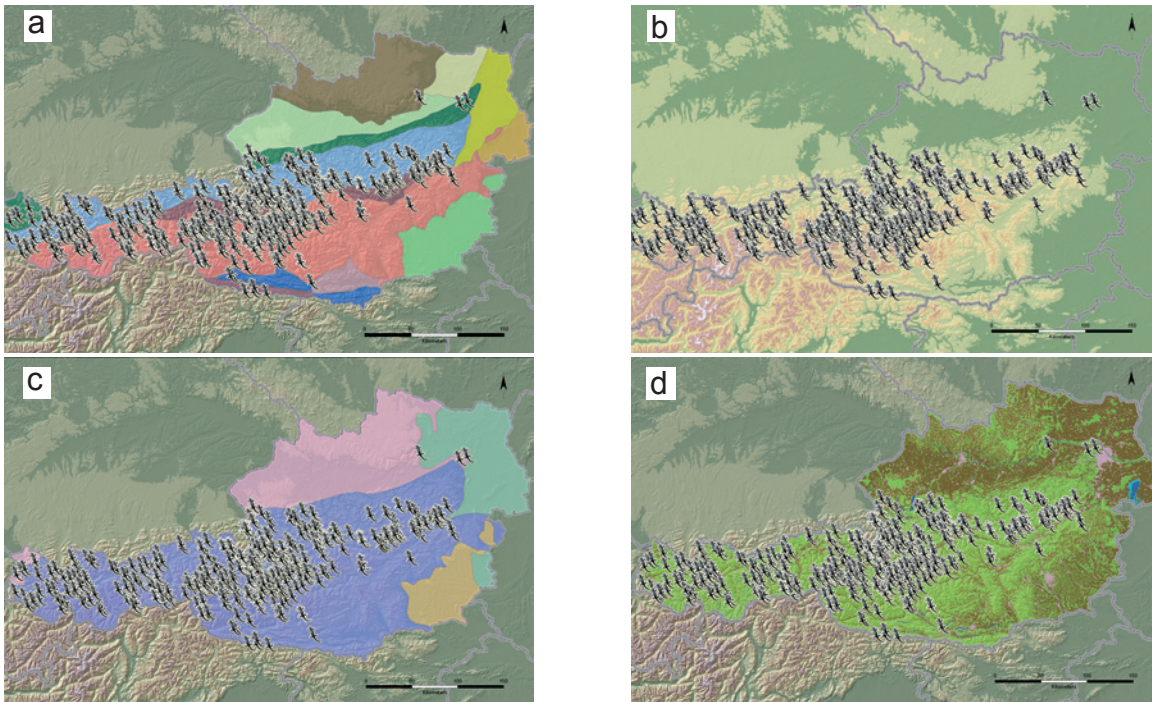


Figure 4 – Distribution of *Salamandra atra* in Austria. Dataset collected from June–November 2009. Legend see Figure 3

Altitude

The third map (Figure 4c) shows the distribution of *Salamandra atra* by altitude. Most of the Alpine Salamanders (42.6%) were found at altitudes between 1 500 and 2 000 m, 33.8% were found on lower slopes at 1 000–1 500 m. Only 0.3% were observed at high altitudes between 2 500–3 000 m. In lower regions, ranging from 115–500 m, five Salamanders (0.9%) were recorded. The best altitude for Alpine Salamander observations seems to be between 1 500 and 2 000 meters.

Geology

In terms of geology (Figure 4d), the main distribution of the Alpine Salamander is in the Central Alps. They were also observed in the Northern and Southern Limestone Alps as well as in the Grauwacken and the flysch zone. There are no records for the Vienna Basin or for the south-eastern and north-eastern foothills of the Alps.

Discussion

The number of records on our website increased with the popularity of our project. To get even more attention, we started publishing reports in different national and local newspapers. In these articles we invited the population to report salamanders wherever they found any. The feedback has been amazing.

We have shown that the web portal www.alpensalamander.eu allows collecting salamander observations by the public for two main purposes – a) data collection for new scientific projects and b) education of the public through direct and interactive dissemination. We believe that protection of amphibians and

their habitats is only possible by actively involving the population in participatory research.

We aim to work with national parks and museums throughout Europe to disseminate the project and its results in wildlife and mountaineering organizations but also in schools and universities. Salamanders are among the heraldic animals of Europe and we must put every effort into its research to preserve the significant moment of observing these amazing animals for future generations.

Fire Salamander

Since July 2009, we have recorded 3 200 Fire Salamander reports and established an initial distribution map for the Fire Salamander in Austria. The map correlates very well with the literature (Grossenbacher & Thiesmeier 2003), underlining the high quality of the data received from the public.

In general, the Fire Salamander is very difficult to monitor. With the hot spots of salamander occurrences, we will develop an effective monitoring method for these animals, for example monitoring the spawning waters of Fire Salamander larvae. We will include other amphibians, such as the Alpine Salamander and the Alpine Newts (i.e. *Triturus alpestris*) to investigate the ecological relationships between these species. In addition, we will analyse the genetic structure of the Fire Salamander to learn more about its evolutionary history.

According to the geological maps, the distribution of the Fire Salamander in Austria in terms of altitude is characteristic because most Fire Salamanders live at between 500 and 1 000 m altitude, which correlates with the literature (Grossenbacher & Thiesmeier 2003). The number of salamanders decreases with increasing

altitude. The Fire Salamander is distributed across all Austrian climate zones. Most of the salamanders were observed in the alpine climate zone which covers most of Austrian territory.

Further investigation is required to find out why in some places, especially in the south-western valleys of the Salzkachal, Salzburg, Austria, the Fire Salamander has almost completely disappeared within the last 40 or 50 years. Presumably, this is because of the loss of deciduous forests, which have been widely replaced with conifers in past centuries. Agricultural use in these valleys intensified significantly over the past 50 years, resulting in additional habitat destruction through skiing slopes, the construction of forest roads and drainage of natural wetlands. According to our data, most Fire Salamanders live in forests or agricultural areas. The destruction of these habitats directly results in a dramatic loss of whole Fire Salamander populations.

Alpine Salamander

Overall, our new approach involving the community in a scientific project has been very successful for monitoring the Alpine Salamander in Austria. We have recorded 2117 salamander reports since July 2009.

We have about 300 recordings of Alpine Salamanders in Salzburg from the last 80 years stored at the biodiversity database at the Natural History Museum in Vienna. The GBIF Austria database network of the Environment Agency Austria has only 21 matches for the Alpine Salamander.

Our community-based approach generates much more data and makes it immediately available to the public. On our website, anybody may report sightings of salamanders. In the short time since July 2009 we have gathered more than 2100 sightings in Austria alone, which is a good basis for monitoring projects to obtain a detailed distribution. Generally it is very difficult to find the Alpine Salamander; they only surface in suitable weather, i.e. in the early morning hours or during/after summer rain. With the vast amount of records it is possible to plan further monitoring activities much more efficiently. Some positive effects of these data are:

- A salamander distribution map for Austria was generated at extremely low cost.
- The map is being updated continuously and allows monitoring salamander populations.
- Salamander hotspots and peculiar observations (like high-altitude populations) can be used for research such as genetic monitoring to analyse the relations between the individuals.

With the different geological maps, which are shown in the results, it becomes obvious that these animals essentially occur in alpine climate at altitudes between 1500 and 2000 m. This corresponds to results in the literature (e.g. Steinfartz & Grossenbacher 2003), underlines the high quality of the data from the public and points to the fact that misuse of the database is negligible. The main distribution area of the Alpine

Salamander is in Austria (Kyek & Meletzky 2006). So it is necessary to fuel the population's, and especially the children's interest for these amazing animals. We aim to work with national parks and museums throughout Europe to disseminate the project and its results in wildlife and mountaineering organizations but also in schools and universities.

Based on our initial data, we will also develop a monitoring method to evaluate the emigration rates between the subterranean and surface populations and determine which parameters influence them. For this monitoring project, we have selected locations in geographically and geologically different alpine areas. These areas will be monitored periodically and we will also observe other amphibians like the Fire Salamander (*Salamandra salamandra*) to investigate the ecological relationship between these species.

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