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

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Salzburg, 8 June 2010
Statutory Declaration

Herewith I, Magdalena Meikl, declare that this submission is my own work, except where due acknowledgement has been made in the text. Furthermore, I confirm that no sources have been used in the preparation of this thesis other than those indicated. I also certify that this thesis has not been submitted to any other organization for an academic qualification and has not been previously published. The document submitted represents a verbatim copy of the version graded by the academic advisor (or digital version).

Salzburg, 8 June 2010

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Table of contents

1. Figure and table legend .............................................................. 7
2. Abstract .................................................................................. 11
3. Introduction .............................................................................. 12
  3.1. Aim of this Master thesis .................................................... 12
  3.2. Taxonomy ........................................................................... 13
  3.3. Description of the Fire Salamander (Salamandra salamandra) .... 13
    3.3.1. Blood characteristics ................................................... 15
  3.4. Phylogeny of “true” salamanders (family Salamandridae) ......... 15
    3.4.1. Ancestors of “true” salamanders .................................... 15
    3.4.2. Species level differentiation .......................................... 15
    3.4.3. Subspecies level differentiation ....................................... 16
  3.5. Distribution .......................................................................... 19
  3.6. Areal dynamic and endangerment ......................................... 21
    3.6.1. Endangerment of larvae ............................................... 22
  3.7. Geographical variation and subspecies-classification ............... 22
    3.7.1. Short overview of the subspecies .................................... 23
          Salamandra salamandra almazoris (Müller and Hellmich, 1935) .... 23
          Salamandra salamandra bejarae (Wolsterstorff, 1934) ...................... 23
          Salamandra salamandra bernardezi (Wolterstorff, 1928) ................. 23
          Salamandra salamandra alfredschmidtii (Köhler and Steinfartz, 2006) . 24
          Salamandra salamandra crespoi (Malkmus, 1983) .......................... 24
          Salamandra salamandra fastuosa (Schreiber, 1912) ...................... 25
          Salamandra salamandra gigliolii (Eiselt and Lanza, 1956) ............. 25
          Salamandra salamandra galleaca (Seoane, 1884) .......................... 25
          Salamandra salamandra longirostris (Joger and Steinfartz, 1994) .... 26
          Salamandra salamandra morenica (Joger and Steinfartz, 1994) ....... 26
          Salamandra salamandra salamandra (Linnaeus, 1758) .................... 26
          Salamandra salamandra terrestris (Lacépède, 1788) ...................... 26
3.8. Ecology ............................................................................................................. 27
3.8.1. Habitat ........................................................................................................... 27
3.8.2. Altitude-distribution ....................................................................................... 29
3.8.3. Summer habitats, diurnal hideouts ................................................................. 29
3.8.4. Wintering grounds .......................................................................................... 30
3.8.5. Herpetocoenosis .............................................................................................. 30
3.8.6. Nutrition .......................................................................................................... 30
3.8.7. Casting of the skin .......................................................................................... 32

3.9. Reproduction ...................................................................................................... 32
3.9.1. Sexual dimorphism .......................................................................................... 33
3.9.2. Spawning waters .............................................................................................. 33
3.9.3. Development .................................................................................................... 34
3.9.4. Larval development ........................................................................................ 35
3.9.5. Adaptation to alternative larval habitats ......................................................... 36
3.9.6. Disposal of larvae ........................................................................................... 37
3.9.7. Malformations of larvae .................................................................................. 37
3.9.8. Metamorphosis ................................................................................................. 38
3.9.9. The evolution of terrestriality in “true” salamanders ....................................... 38
3.9.10. The evolution of viviparity in Salamandra salamandra .................................... 38
3.9.11. Multiple paternity within and between annual reproduction cycles .............. 40

3.10. Population density and population dynamic ..................................................... 41
3.10.1. Age ................................................................................................................ 41
3.10.2. Enemies ........................................................................................................... 42
3.10.3. Migration patterns .......................................................................................... 42

3.11. Behavior .......................................................................................................... 43
3.11.1. Diurnal activity ............................................................................................... 43
3.11.2. Annual activity ............................................................................................... 44
3.11.3. Water-stay of adult animals ................................................................. 45
3.11.4. Daily ranges ....................................................................................... 45
3.11.5. Philopatry and “home-finding behavior” .............................................. 45
3.11.6. Venom ................................................................................................. 46
3.11.7. Defensive behavior ............................................................................ 47
3.11.8. Prey-catching behavior ....................................................................... 47
3.11.9. Territorial behavior ........................................................................... 48
3.11.10. Communication, vocalizations ......................................................... 48
3.11.11. Mating behavior .............................................................................. 48
3.11.12. Larval behavior .............................................................................. 51
3.11.13. Parasites .......................................................................................... 51

3.12. Man and Fire Salamander ...................................................................... 51
3.12.1. Historical development ..................................................................... 51
3.12.2. Endangerment and protection today .................................................. 53

4. Material and Methods ................................................................................ 55
4.1. The project .............................................................................................. 55
4.2. The website - www.alpensalamander.eu .................................................. 56
4.3. To report a salamander .......................................................................... 57
4.4. Reports in the newspapers ..................................................................... 58
4.5. Field studies ........................................................................................... 59
4.6. Data analysis .......................................................................................... 59

5. Results ........................................................................................................ 60
5.1. Data and Users ....................................................................................... 60
5.2. Feedback to the reports in the newspapers ............................................ 60
5.3. Observed trends .................................................................................... 61
5.4. Outcome of the field studies .................................................................. 63
5.5. The distribution of the Fire Salamander in Austria, consolidated with maps of altitude, land cover areas, climate types and geology .................................................................................. 64
5.5.1. Altitude ............................................................................................... 65
5.5.2. Land cover areas ............................................................................... 67
6. **Discussion** .................................................................................................................76

6.1. **Distribution map from www.alpensalamander.eu compared to the map from the „Umweltbundesamt“** ..................................................................................................................78

6.2. **Discussion of the results** ..........................................................................................79

6.2.1. **Observed trends in Austria** ................................................................................... 79

6.2.2. **Observed trends in Salzburg** ................................................................................ 80

6.2.3. **The Fire Salamander distribution in Austria consolidated with different maps** 81

6.3. **Summary and Outlook** .............................................................................................82

7. **References** ..................................................................................................................84

**Web references:** .............................................................................................................87
1. Figure and table legend

Figure legend:

Figure 1: The Fire Salamander. Salamander pictures 2009. Available at: www.alpensalamander.eu. p. 13

Figure 2: Fire Salamander with continuous red parts. Salamander pictures 2009. Available at: www.alpensalamander.eu. p. 14

Figure 3: Albino form of S. s. terrestris. Available at: http://www.caudata.org/cc/images/articles/Salamandra/terrestris_albino_Wallays.jpg (accessed: 29/01/2010). p. 14

Figure 4: Simplified distribution map of S. salamandra. p. 21

Figure 5: S. s. bejarae. Available at: http://www.euroherp.com/Resources/Trips/011109_259.jpg (accessed: 22/01/2010). p. 23

Figure 6: S. s. bernardezi. Available at: http://www.dominics-tiere.de/Medien/Fotos/bernardezi.jpg (accessed: 22/01/2010). p. 23

Figure 7: S. s. alfredschmidti. Available at: http://www.caudata.org/cc/images/species/Salamandra/S_s_bernardeziMARTINEZ.Large.jpg (accessed: 25/01/2010). p. 24

Figure 8: S. s. fastuosa. Available at: http://www.ojodigital.com/foro/1536707-post1.html (accessed: 22/01/2010). p. 25

Figure 9: S. s. gallaica. Available at: http://i.olhares.com/data/big/241/2410225.jpg (accessed: 22/01/2010). p. 25

Figure 10: S. s. morenica. Available at: http://farm3.static.flickr.com/2418/2166330411_df3f365b1b.jpg (accessed: 22/01/2010). p. 26

Figure 11: S. s. terrestris. Available at: http://farm4.static.flickr.com/3226/2979740683_2d10689418.jpg (accessed: 22/01/2010). p. 26
Figure 12: The Fire Salamander in a beech forest. Salamander pictures 2009. Available at: www.alpensalamander.eu. p. 27

Figure 13: Hiding places of the Fire Salamander. Salamander pictures 2009. Available at: www.alpensalamander.eu. p. 29

Figure 14: The Alpine Salamander. Salamander pictures 2009. Available at: www.alpensalamander.eu. p. 30

Figure 15: Fire Salamander feeding on a worm. Available at: http://www.tierfotograf.com/media/600-600-76295-0-0/042696_feuersalamander.jpg (accessed: 27/01/2010). p. 31

Figure 16: Male and female Fire Salamanders. Salamander pictures 2009. Available at: www.alpensalamander.eu. p. 33

Figure 17: Spawning waters of the Fire Salamander. Available at: http://www.waldwissen.net/themen/waldekoologie/tierkoologie/wsl_feuersalamander_DE (accessed: 27/1/2010). p. 34

Figure 18: Fire Salamander larvae. Salamander pictures 2009. Available at: www.alpensalamander.eu. p. 36

Figure 19: Juvenile Fire Salamander. Salamander pictures 2009. Available at: www.alpensalamander.eu. p. 38

Figure 20: The glands-rich parotids of the Fire Salamander. Salamander pictures 2009. Available at: www.alpensalamander.eu. p. 46


Figure 22: S-shaped body position. Salamander pictures 2009. Available at: www.alpensalamander.eu. p. 47

Figure 23: Mating process of Fire Salamanders. Salamander pictures 2009. Available at: www.alpensalamander.eu. p. 48


Figure 26: Male salamander on the lookout for females. Salamander pictures 2009. Available at: www.alpensalamander.eu. p. 50

Figure 27: A 16th century image of a salamander. Available at: http://en.wikipedia.org/wiki/File:Salamander_from_The_Story_of_Alchemy_and_the_Beginnings_of_Chemistry.jpg (accessed: 03/02/2010). p. 52


Figure 30: Distribution map of *S. salamandra* in Austria per altitude. Producer: Elisabeth Weinke. p. 65

Figure 31: Bar diagram of the Fire Salamander distribution per altitude. p. 66

Figure 32: Pie chart of the Fire Salamander distribution per altitude. p. 66

Figure 33: Distribution of *S. salamandra* across Austrian land cover areas. Producer: Elisabeth Weinke. p. 68

Figure 34: Bar diagram of the Fire Salamander distribution across Austrian land cover areas. p. 69

Figure 35: Pie chart of the Fire Salamander distribution across Austrian land cover areas. p. 69
**Figure 36:** Distribution of *S. salamandra* across Austrian climate types. Producer: Elisabeth Weinke. p. 71

**Figure 37:** Bar diagram of the Fire Salamander distribution across Austrian climate types. p. 71

**Figure 38:** Pie chart of the Fire Salamander distribution across Austrian climate types. p. 72

**Figure 39:** Distribution of *S. salamandra* across Austrian geological regions. Producer: Elisabeth Weinke. p. 74

**Figure 40:** Bar diagram of the Fire Salamander distribution across Austrian geological regions. p. 75

**Figure 41:** Pie chart of the Fire Salamander distribution across Austrian geological regions. p. 75

**Figure 42:** Comparison between the map of the “Umweltbundesamt” (modified according to Cabela, A. & H. Grillitsch & F. Tiedemann 2001. *Atlas zur Verbreitung und Ökologie der Amphibien und Reptilien in Österreich*: p. 176. Umweltbundesamt, Wien) and the map of www.alpensalamander.eu. p. 78

**Table legend:**

**Table 1:** The geological era Cenozoic, with a precise description of the phylogenetic events of the genus *Salamandra* that happened in the single series. p. 18

2. 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 threatened because they require habitats with small fonts or brooks prone to destruction by agriculture. Furthermore its population status and distribution in Austria and Salzburg has not yet been monitored extensively and despite its central role in the ecosystem our actual academic record is small. Hence, efforts to research its habitat and ecology, as well as measures for its conservation have highest priority. 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 Salamander in Austria. From the actual data (more than 5600 records since July 2009), we already obtained a good overview about the present distribution and data quality. We also collected an oral history of Fire Salamander observations in the past 50 years by conducting interviews in the local community. This project is only in the initial phase, but the hitherto collected data are an excellent basis for detailed scientific studies on this remarkable amphibian in the future. Using this new and highly interactive approach, science and education are combined to initiate protective measures including the public.
3. Introduction

3.1. Aim of this master thesis

The population status and distribution of the Fire Salamander in Austria has not yet been monitored extensively, so only few Fire Salamander observations are on record for Austria. The current distribution picture states that there is a significant areal gap of the Fire Salamander in the core area of the Alps. In Austria, there are no Fire Salamander reports from Vorarlberg, most of the Inn valley, the High Alps, Murau and northern Southtyrol. There are less than 1600 observations on record in the last 30 years in the biodiversity data base of the “Naturhistorisches Museum” and the “Umweltbundesamt” in Vienna, Austria. The last official release of Fire Salamander records is 1996 for Austria (Cabela et al. 2001) and 2005 for Salzburg (Kyek & Maletzky 2006). In fact we know close to nothing about the present distribution and the population tendency of the Fire Salamander in Austria because the existing dataset is small and outdated.

The main goal of this master thesis is to map occurrence, population-size and development of the Fire Salamander and to use these findings for the initiation and design of protective measures against the disappearance of this remarkable amphibian. Therefore, this project collects salamander observations from the public using a new, community based Web2.0 approach on www.alpensalamander.eu. In the next years this completely new effort will be developed further and extended throughout Europe. The first, theoretical part of this master thesis comprises all existing literature and research studies about the Fire Salamander. The second part of this master thesis shows the methodology and results of our new, community based approach.
3.2. Taxonomy

The Fire Salamander, *Salamandra salamandra salamandra* (LINNÆUS, 1758), belongs to the genus *Salamandra*, family Salamandridae, order Caudata, class Amphibia. The family Salamandridae contains the “true” salamanders, genera *Salamandra*, *Mertensiella* and *Chioglossa*, and the newts with 12 genera. The genus *Salamandra* contains six species, *Salamandra algira*, *Salamandra atra*, *Salamandra corsica*, *Salamandra infraimmaculata*, *Salamandra lanzai* and *Salamandra salamandra*.

3.3. Description of the Fire Salamander (*Salamandra salamandra*)

The Fire Salamander (*Salamandra salamandra*), in the Austrian dialect also called “Regenmandl”, “Erdsalamander” or “Gelber Schneider”, is a black amphibian with yellow spots or stripes to a varying degree (Fig. 1). In some subspecies, the coloration also shows continuous orange and red parts (Fig. 2). Characteristic for the Fire Salamander are the kidney-shaped yellow parotids on the head and the two dorsal gland lines on the left and right side of the backbone. In Austria and Germany, the Fire Salamander weighs between 20 and 45 g and measures up to 20 cm in length. The tongue of the fire salamander is big, circular and arched like a pillow. The form of the palatal teeth, which make two S-shaped lines, characterizes the genus *Salamandra*. The muzzle of Fire Salamanders is rounded, the head is even and broad, the eyes are clearly jutted. With the big head and clearly jutted eyes, the Fire Salamander matches the Lorenzsche scheme of childlike characteristics (“Lorenzsche Kindchenschema”). The upper jaw overtops the under jaw. The pupil is...
round, the iris is black. The characteristic bulges with the ear-glands (parotids) are found on the head, directly behind the eyes. The throat is separated from the body through a cross-standing skin fold. The body is cylindric, the stronger developed hindlimbs have five toes, the less developed forelimbs have four fingers. The third and fourth toe are the same in length, the third finger is the longest. The formula of the phalanges for the hand is: 2, 2, 3, 2 and for the leg 2, 2, 3, 3, 2. From the parotids range two lines of glands on the dorsal side of the salamander. Populations from South-East Europe and Portugal include many larger-sized salamanders, smaller salamanders are found in the Pyrenees, in Calabria, in Salamanca and Sierra de Gredos (Böhme et al. 2003).

Color pattern:

The characteristic color pattern finishes in two to three years after the metamorphosis. There are four basic types of color patterns:

1. Striped. There are two not or just somewhat disconnected yellow longitudinal stripes on the dorsal side of the salamander, the center of the back is black.
2. Spot-striped: The two yellow lines on the back are often disconnected through longer sections, the center of the back is black.
3. Stripe-spotted: The stripes are just somewhat longer than broad, often round, but there are clearly two lines of stripes. The center of the back is disconnected in places with yellow spots.
4. Spotted: The yellow spots on the back are distributed continuously, clearly not arranged in two lines of stripes. A completely black center of the back does not exist (Böhme et al. 2003).
There are many reports about albinism (Fig. 3), partly albinism or other color aberrations (Böhme et al. 2003).

3.3.1. Blood characteristics:

The blood of the Fire Salamander has two components of hemoglobin. The more acid component covers 25% of the whole pigment, the second component covers the remaining 75%. The hemoglobin of the Fire Salamander does not show a Bohr-effect, but sometimes even a contrary effect.

The karyotype of the Fire Salamander is, as for all other European salamanders, diploid, $2n = 24$ chromosomes. The chromosomes are relatively large and they can be divided into six bigger and six smaller pairs of chromosomes (Böhme et al. 2003).

3.4. Phylogeny of “true” salamanders (family Salamandridae)

3.4.1. Ancestors of “true” salamanders:

*Salamandra*-like urodels are already known from the Upper Paleocene and the Lower Eocene of France and Belgium. The Upper Eocene and Oligocene *Megalotriton filholi* (Zittel 1890) may be the possible ancestor of the Oligocene and Miocene *Salamandra sansaniensis* (Laret 1851). They must have been common throughout Central Europe since their fossil remains are known from many sites of France, Germany, Czech, Slovakia and Switzerland. No fossil “true” salamanders are recorded from Spain prior to the Lower Miocene period, which explains well the absence of “true” salamanders on Sardinia. 14-15 million years ago, a newly created mountain chain stretched from the Alps through the Dinarides and the Hellenides to Anatolia. Ancestors of the present species could have settled large parts of Europe, using this mountain bridge between Europe and Asia, where the genus *Salamandra* probably originated from (Veith et al. 1998).

3.4.2. Species level differentiation:

The genus *Salamandra* forms a well supported monophyletic group. *Salamandra* is split into at least six definite species, namely *S. salamandra*, *S. algira*, *S. infraimmaculata*, *S. corsica*, *S. atra* and *S. lanzai*. *Salamandra* diverged from the sister group *Mertensiella* 25 million years ago (Steinfartz et al. 2000).
At this time, the formation of continuous landmass separated Tethys and Paratethys and allowed a distribution throughout the Mediterranean, from East to West and vice versa (Veith et al. 1998). The Near East species *S. infraimmaculata* separated from the rest 13 million years ago. The African species *S. algira* separated from the European *S. salamandra* 8 million years ago. These two groups seem to already have been separated before the flooding of the strait of Gibraltar, 5 million years ago. An alternative geological event that could have separated these species is the expansion of the northern Betic Sea, which could have resulted in a northern clade *S. salamandra* and a southern clade *S. algira*. The separation of the major *Salamandra* species therefore happened in the Pleistocene glaciations cycles (Steinfartz et al. 2000).

3.4.3. Subspecies level differentiation:

Allozyme analysis suggests a separate recolonization of *S. salamandra* from western and eastern refugia that may have occurred after the last ice age and these populations now show a zone of overlap in Central Europe. Within *S. salamandra*, the subspecies can be resolved into geographical subgroups. One group contains the populations from southern Spain, namely *S. s. longirostris*, *S. s. morenica* and *S. s. crespoi*. These populations come from a Pleistocene refugial area in the south of Spain, they separated from the remaining *S. salamandra* clades about 2-4 million years ago. The second separable unit within *S. salamandra*, the populations from northern Spain (subspecies *S. s. bernardezi*) together with a population from southern Italy (*S. s. gigliolii*), are remnants of a former population that had covered the whole of Central Europe in a previous interglacial period. The third group is a large polytomy of taxa, including all remaining subspecies of *S. salamandra*, which come from the whole Central, Western and Eastern Europe, including the taxa from the former Yugoslavia, Bulgaria and Greece. The founder population that has given rise to this group could have existed approximately 400.000 years ago. This would suggest that the current population had already successfully colonized Central Europe in previous interglacial periods. With the beginning of new glaciations, they would have been forced back into refugial areas in Southern Europe and the Balkans, from where recolonizations would have started again. This could imply that only the salamanders from this group had been capable of recolonizing after the retreat of the ice. Therefore, the existing remnants in northern Spain and southern
Italy could constitute refugial populations that were unable to spread further. It seems that there had been a new competitive advantage acquired by the third group that has caused this shift in colonizing ability. It seems that a specific source population has been most successful at a former time, while a different, but closely related source population (group three) has been successful at later times and has largely displaced the first one (group two) (Steinfartz et al. 2000).

All the phylogenetic events that led to species- and subspecies differentiations are summarized in the following table (Table 1).
Table 1: The geological era Cenozoic, with a precise description of the phylogenetic events of the genus *Salamandra* that happened in the single series. mya = million years ago

<table>
<thead>
<tr>
<th>Era</th>
<th>System</th>
<th>Series</th>
<th><em>Salamandra</em>-events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cenozoic (65.5-0 mya)</td>
<td></td>
<td>Holocene</td>
<td>400.000 years ago: a founder population gave rise to the remaining <em>S. salamandra</em> subspecies from Central, Western and Eastern Europe</td>
</tr>
<tr>
<td></td>
<td>Quaternary</td>
<td>Pleistocene (2.6 mya – 9.660 BC)</td>
<td>Interglacial periods: <em>S. s. bernardezi</em> and <em>S. s. gigliolii</em> are remnants from a population that covered Europe during interglacial periods</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2-4 mya: <em>S. s. longirostris</em>, <em>S. s. morenica</em> and <em>S. s. crespo</em> separated from the remaining <em>S. salamandra</em> clades</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Neogene</td>
<td>Pliocene</td>
<td>8 mya: <em>S. algira</em> separated from <em>S. salamandra</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Miocene (23.3-5.2 mya)</td>
<td>13 mya: <em>S. infraimmaculata</em> separated from the remaining <em>Salamandra</em> species</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>14-15 mya: ancestors of the present <em>Salamandra</em> species settled large parts of Europe</td>
</tr>
<tr>
<td></td>
<td>Palaeogene</td>
<td>Oligocene (33.9-23.03 mya)</td>
<td>25 mya: <em>Salamandra</em> diverged from the sister group <em>Mertensiella</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Eocene</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Paleocene</td>
<td>---</td>
</tr>
</tbody>
</table>
3.5. Distribution

The Fire Salamander is distributed in large parts of Middle-, West- and Southern Europe. Not populated are Great Britain, Ireland, Scandinavia, Poland, White Russia, the Baltic states and Russia (Fig. 4). *Salamandra corsica* lives on Corsica. The Fire Salamander cannot be found on other big Mediterranean islands such as Sardinia, Crete or Cyprus. In 1998, the Fire Salamander was rediscovered on Sicily. In the core area of the Alps, there is also a significant areal gap (Böhme et al. 2003).

Portugal is populated nearly area-wide, the key points of distribution in Spain are in Galicia, Asturias, Kantabria, the Basque region and in the Pyrenees. There are large parts in the East of Spain and in the center of the country where the Fire Salamander cannot be found.

Fire Salamanders are also widespread in France, except for the Atlantic coastline.

Some small, isolated populations appear close to the coast of the English Channel.

The south of Belgium and Luxembourg are densely populated, but the Fire Salamander populations do not reach the coast.

There are only single populations in Holland.

Fire Salamanders can be found throughout West and Southwest Germany (Böhme et al. 2003).

The Fire Salamander is widely spread in the Czech Republic and Slovakia, but it lacks in the Southwest of the Czech Republic. The key points of the distribution are in the western and northern low mountain range and in the east of the country. In Slovakia, the South is not populated (Böhme et al. 2003).

In Switzerland and Austria, the Fire Salamander is widely distributed at altitudes between 200 and 700 m. The core area of the Fire Salamander distribution in Austria is located in the hill country and limestone Alps between the North of Salzburg and the Vienna Woods, as well as in Styria and Carinthia. The distribution area in Austria largely corresponds with the occurrence of the copper beech (*Fagus silvatica*). There are no Fire Salamander reports from Vorarlberg, most of the Inn valley, the High Alps, Murau, northeastern and eastern Lower Austria and northern South Tyrol. Fire Salamander reports in Austria are existent at altitudes between 200 and 2000 m. The
lowest location is in Vienna, with 170 m, the highest location is in Carinthia above 2000 m (Cabela et al. 2001). The core area of distribution in Salzburg is located in the region of the flysch-zone (foothills of the Alps) on the western border area of the “Osterhorn”-mountains, in the outer “Salzach”-valley, as well as in the foreland of the “Untersberg” (Kyek & Maletzky 2006).

The key points of the distribution in Italy are in the northern country, on the southern flap of the Alps and in the Ligurian Alps around Genoa. The change from S. s. salamandra to S. s. gigliolii is in Liguria. Worth mentioning are some isolated areas along the Po Valley: Colli Berige (444 m) and Colli Euganei (602 m), where S. s. salamandra can be found very often. The Fire Salamander is pretty rare in the center of Italy (Böhme et al. 2003).

In Hungary, the mountain ranges near the Slovakian boarder are also populated, as well as some isolated areas close to Budapest.

The Fire Salamander in Slovenia can be found area-wide up to altitudes of 1500 m.

Fire Salamanders are widely distributed throughout Croatia, Bosnia, Serbia, Montenegro and Macedonia, partly even numerous. In Serbia, the Fire Salamander can be found even in warm, submediterranean regions, in mountain regions between 1600 and 1700 m, mostly in subalpine beech forests. In Montenegro, it is also found in deforested karst regions (Böhme et al. 2003).

The Fire Salamander occurs in Albania in all climate zones up to over 2000 m, and also in Romania at the arc of the Carpathians.

The Fire Salamander in Bulgaria lives on the woody hillsides of the Planina-mountain and the mountain ranges of Rila, Pirin and Rhodope. In the Pirin mountains, the Fire Salamander lives at altitudes up to 2350 m.

In Greece, the Fire Salamander is also widely distributed, but probably in many small, isolated habitats. The eastern part of Greek-Thrace is populated and also the central mountain Dirfis on the island Euböa (Böhme et al. 2003).
Fig. 4: Simplified distribution map of *Salamandra salamandra* including the 11 subspecies (without *S. s. alfredschmidti*) and the most important distribution points in Europe. 1 North-France, 2 Holland, South-Limburg, 3 Germany, North Rhine-Westphalia, Ahaus, 4 Germany, Lower Saxony, Bremen, 5 Germany Lower Saxony, Hamburg, 6 Germany, Northeastern Lower Saxony, 7 Germany, Saxony-Anhalt, 8 Germany, Western Saxony, 9 West-Poland, 10 South-Poland, 11 Southwestern Ukraine, 12 North-Romania, 13 East-Romania, 14 Southwest-Romania, 15 West-Bulgaria, 16 East-Bulgaria, 17 Southeast-Bulgaria, 18 Northeast-Greece, Thrace 19 North-Greece, 20 Greece, Thessaly, 21 Greece, Island Euböa, 22 Greece, Peloponnesus (Taigetos-mountains), 23 Greece, Peloponnesus, 24 Italy, Sicilia (region Mount Etna). FF = “fundfrei” → regions without Fire Salamander observations.

### 3.6. Areal dynamic and endangerment

The current endangerment of the Fire Salamander in Europe is low. But the Fire Salamander is on the pre-endangered species list in Germany and Austria. This list comprises species, which are not currently endangered, but it is to worry that they will get endangered in the next ten years. The assets are decreasing regionally because they are linked to habitats that are getting rare. In the case of the Fire Salamander, it is the combinations of brush-rich habitats, which are pervaded with small headstreams. Like most other amphibians, Fire Salamanders suffer from severe habitat destruction brought about by modern agriculture, road building and river regulation. The Fire Salamander is on the Red List of amphibians and reptilians in Austria, classified as near threatened (NT), and on the Red List of amphibians and reptilians in Germany.
reptilians in Salzburg, classified as vulnerable (VU). On the European level, the Fire is protected according to Article III in the “Convention on the conservation of European wildlife and natural habitats (Bern, 19.9.1979)” (Kyek & Maletzky 2006).

Besides, field studies often lead to wrong conclusions because Fire Salamanders have a very long life span. This makes it difficult to observe the populations because the animals are migrating (Böhme et al. 2003).

3.6.1. Endangerment of larvae:

Numerous studies document that the larval phase is the most critical and vulnerable part for the population. Besides natural mortality factors, anthropogenic changes to the flowing water systems are of extreme importance. That includes leading-in of effluents, the displacement of substrate-forming structures and the stocking with predatory fish. All these factors have negative effects on the salamander populations. Acid pH-values also influence salamander larvae, as it has been shown in experiments. Till pH 4.1, there are no visible damages or behavior changes in salamander larvae. At pH 3 and 3.2, all larvae died after 72 hours (Böhme et al. 2003).

Adult salamanders are able to survive temperatures of -1.7°C to -2.2°C without any harm. They can even survive temperatures as low as -5.2°C, if the animals freeze only for a short time. After being frozen for a few hours, the salamanders die (Böhme et al. 2003).

3.7. Geographical variation and subspecies-classification

There are 14 subspecies of the Fire Salamander, but the subspecies S. s. beschkovi and S. s. werneri are controversial. S. s. alfredschmidtii was newly discovered in 2006. Four former subspecies are accepted as independent species today (Böhme et al. 2003).
3.7.1. Short overview of the subspecies:

**Salamandra salamandra almazoris** (Müller and Hellmich, 1935):

It is a smaller, spotted form with reduction of the yellow coloration. As of several different research reports, there are very long larval periods and because of that, above average size specimens can occur. The typical habitat is Laguna Grande de Gredos in the center of Spain, at 2027 m altitude (Böhme et al. 2003).

**Salamandra salamandra bejarae** (Wolsterstorff, 1934):

It is a small, spotted subspecies. The tail is very short and high, the head is bulged. The muzzle is sharp rounded and elongated. The parotids are short and broad. In their western habitats, the salamanders show a red coloration, especially in the region of the parotids (Fig. 5). The black fraction is overbalanced. The typical habitat is the province of Salamanca in Spain. *S. s. bejarae* is distributed in Middle and East Spain (Böhme et al. 2003).

**Salamandra salamandra bernardezi** (Wolterstorff, 1928):

This subspecies is relatively small and feathery. The coloration is black with two yellow stripes on the back (Fig. 6). This subspecies is not easy to discriminate from the subspecies *fastuosa*. *S. s. bernardezi* is viviparous and because of that totally independent from waters. They show astonishing variations of coloration eastward of Oviedo, Spain: there are animals with continuous cross-foliation, animals with yellow to red heads and uniform olive to brown bodies. The yellow fraction of the coloration is often high. The typical habitat is Oviedo, Asturias, Northwest-Spain. Their habitats are in...
Asturias and Kantabrien. The borderline to *S. s. fastuosa* is not clear (Böhme et al. 2003).

*Salamandra salamandra alfredschmidti* (Köhler and Steinfartz, 2006):

![Fig. 7: *S. s. alfredschmidti* from the Tendi valley, Spain.](image)

The Fire Salamanders of the Rio Tendi valley (Asturias, Spain), which have long been considered as *S. s. bernardezi*, differ from individuals from the type locality Oviedo of *S. s. bernardezi* and all remaining recognized Iberian subspecies with regard to their coloration and mitochondrial sequence composition. They exhibit a wide range of individual variability with regard to their body coloration. The ground color varies amongst these specimens from dirty yellow through grayish yellow, olive, olive brown, grayish brown, grayish orange to chocolate-brown. A black dorsolateral stripe seems to be absent in all specimens. A dark brown to brownish black dorsal stripe is expressed in several specimens (Fig. 7). Such an expression and range of color variation cannot be observed in Fire Salamanders from other parts of Asturias. The Fire Salamanders of the Tendi valley clearly differ from *S. s. bernardezi* and all other known Iberian subspecies. The populations from the Tendi valley are an example for the manifestation of genetic and morphological local differentiation. So far, these locally restricted populations of *S. salamandra* can be considered as a separate subspecies: *Salamandra salamandra alfredschmidti* ssp. nov. (Köhler & Steinfartz 2006).

*Salamandra salamandra crespoi* (Malkmus, 1983):

This subspecies is relatively big with a conspicuous long, flat head and strong jutting eyes. The tail is relatively long and high. The extremities are very long with extremely long, narrow fingers and toes. The typical habitat is Serra de Monchique, Portugal. *S. s. crespoi* is distributed in South-Portugal (Böhme et al. 2003).
**Salamandra salamandra fastuosa** (Schreiber, 1912):

It is relatively small and feathery, just a little larger than *S. s. bernardezi* and always striped longitudinal (Fig. 8). The tail is relatively long and very low. The head is small and the muzzle is round and short. The parotids are extremely small and the fingers are relatively long. The typical habitat is Bilbao, Northwest Spain. *S. s. fastuosa* is distributed in eastern Asturias (Böhme et al. 2003).

**Salamandra salamandra gigliolii** (Eiselt and Lanza, 1956):

It is relatively small, slender and with delicate limbs. The tail is long and high, the head is broad and flat. The extremities, fingers and toes are elongated. The yellow spots are often broad and netlike connected. Black often only appears as spots. The head shows a lot of yellow, which surrounds horseshoe-shaped a small, central black spot. The typical habitat is Monte Pecoraro in South-Italy. The distribution stretches across the Apennines east of Genoa to the southern tip of Italy (Böhme et al. 2003).

**Salamandra salamandra galleica** (Seoane, 1884):

This subspecies is closely related to *S. s. crespoi, S. s. morenica* and *S. s. bejarae*. It is bigger than *bejarae* and shows hook-, horseshoe- or ring shaped spots and patterns. The coloration on the back is spotted or striped. The yellow spots often show a red coloration in the center, the throat and the head are sometimes completely red (Fig. 9). The typical habitat is in Galicia, Northwest Spain. The distribution stretches from middle and northern Portugal to the Northwest of Spain (Böhme et al. 2003).
*Salamandra salamandra longirostris* (Joger and Steinfartz, 1994):

It is larger sized (over 22 cm) with big, leonly yellow spots. There are always four big yellow spots on the parotids and before the eyes on the upper side of the head. The muzzle is acuminated, the mouth-cleft is overtopped. The typical habitat is Sierra de Ronda in the South of Spain (Böhme et al. 2003).

*Salamandra salamandra morenica* (Joger and Steinfartz, 1994):

It is closely related to *S. s. gallaica* and larger sized (up to 20 cm) with small spots, which show a high red-fraction on the head and a lesser red-fraction on the rest of the body (Fig. 10). The typical habitat is Sierra Morena, southern Spain. It is distributed in the Sierra Morena, Sierra de Alcaras and Sierra de Cazorla (Böhme et al. 2003).

*Salamandra salamandra salamandra* (Linnaeus, 1758):

It is a middle to big sized, strongly build salamander. The tail and extremities are relatively long. The head is moderately arched, the muzzle is acuminate rounded. The back is irregular to cross spotted. The animals in the Northwest show mostly stripe-spotted or spot-striped patterns. The typical habitat is Nürnberg, Germany (Böhme et al. 2003). The specific distribution is described above (see chapter 3.5. Distribution).

*Salamandra salamandra terrestris* (Lacépède, 1788):

It is a middle sized, striped form (Fig. 11), stronger build than *S. s. fastuosa*. Tail, extremities and toes are relatively short, the parotids are broad. A red coloration is rarely found. Their typical habitat is the Normandy, France. This subspecies is distributed in Catalonia, on the north facing part of
the Pyrenees, in France, in the southern part of Belgium, in the southern part of the Netherlands, and in the North and West of Germany (Böhme et al. 2003).

*Salamandra salamandra beschkovi* (Obst, 1981) (controversial):

They have an extremely short tail and very short legs. Very characteristic is an accumulation of yellow spots along or on the spine. The typical habitat is the Pirin-mountain in southern Bulgaria. *S. s. beschkovi* is probably a site-modification of *S. s. salamandra* (Böhme et al. 2003).

*Salamandra salamandra werneri* (Sochurek and Gayda, 1941) (controversial):

The body and the tail is elongated and set on edge. The ventral side is unicolored black, the tail is moderately spotted, throat and neck are totally yellow. The extremities are spotted lively with some red-brown tones in between. Glasses-coloration: on the flanks and on the tail are many elongated elevated yellow spots. On the areal of the yellow spots are also many small red spots. The typical habitat and distribution is the Pelion-mountain in Greece (Böhme et al. 2003).

### 3.8. Ecology

#### 3.8.1. Habitat

**Central and western Europe:**

The typical habitats of Fire Salamanders are humid mixed deciduous forests (mostly beech- and beech mixed forests) at altitudes of 200 to 400 meters. The forests have to be pervaded with small headstreams. The species *S. s. salamandra* shows great plasticity according to their habitats. They like nutrient-poor, fresh beech-forests (Fig. 12), alder-forests, humid oak-birch forests and oak-hornbeam-forests. They prefer the outskirts of forests in the regions where brooks are running through (Böhme et al. 2003). Some typical terrestrial habitats of Fire Salamanders are shown in Table 2. On the northern part of the Alps, Fire Salamanders prefer beech forests, in Austria, they
prefer copper beech (*Fagus sylvatica*) forests. Less frequently, Fire Salamanders are observed in coniferous forests. Normally, Fire Salamanders do not like coniferous forests, they only live in coniferous forest regions which are humid and exhibit an herbal layer of mosses and ferns (Günther 1996). Fire Salamanders are often observed at the edge of forests, on forest roads and paths, in caves, canyons, on rocks and ruins, on clear cuttings and clearings. In case of hillside situation, Fire Salamanders are distributed equally over all exposure-directions. Compared with all other amphibian species, the Fire Salamander prefers northeastern and southeastern exposed hillsides and is observed more rarely at southern exposed hillsides. (Cabela et al. 2001). Apparently, Fire Salamanders are able to survive extensive changes in their existing habitats and they are very adaptive to different habitat conditions. They just require adequate spawning waters and microclimatic convenient hiding places to survive (Böhme et al. 2003).

Table 2: Some terrestrial habitats of Fire Salamanders (recorded in Saxony, Saxony –Anhalt and Thuringia).

<table>
<thead>
<tr>
<th>Habitat</th>
<th>% dispersal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beech-/deciduous beech forests</td>
<td>44.5</td>
</tr>
<tr>
<td>Oak-hornbeam and maple-ash forests</td>
<td>16.7</td>
</tr>
<tr>
<td>Hillside-spruce forests/spruce forests</td>
<td>14.1</td>
</tr>
<tr>
<td>Gardens</td>
<td>7.3</td>
</tr>
<tr>
<td>Bog-, valley- and hillside grasslands</td>
<td>4.8</td>
</tr>
<tr>
<td>Parks</td>
<td>4.0</td>
</tr>
<tr>
<td>Riverine vegetation of brooks</td>
<td>2.6</td>
</tr>
<tr>
<td>Stone quarries and gravel-pits</td>
<td>2.4</td>
</tr>
<tr>
<td>Graveyards at outskirts of towns</td>
<td>1.9</td>
</tr>
<tr>
<td>Ruderal areas (banks, walls, dumps)</td>
<td>1.9</td>
</tr>
</tbody>
</table>
Iberian Peninsula:

The plasticity of this species appears especially on the Iberian Peninsula. If there are adequate spawning waters, the Fire Salamander populates all types of forests (except Eucalyptus-monocultures) in Portugal. They even live in maquis, garrigue, heather and agrarian areas. The most extreme habitat types are found in the high mountains of central Spain, like the Sierra de Gredos and the Sierra de Guadarrama. These mountains do not have forests, they are shaped by clifffy detritus and talus. The only vegetation is a scarce alpine sward (Böhme et al. 2003).

3.8.2. Altitude-distribution:

In Germany, the Fire Salamander lives at altitudes between 0 and 900 to 1000 m, in Switzerland on the northern side of the Alps mostly up to 950 m, in the Jura Mountains up to 1310 m, in the central alpine Wallis up to 1285 m. In Austria, the Fire Salamander is found frequently between 200 and 700 m, often up to 1100 m. Southern side of the Alps: In Piedmont, the Fire Salamander can be found up to 1700 m, in Carinthia up to 2000 m and even higher. In the Sierra de Guadarrama on the Iberian Peninsula, the Fire Salamander reaches altitudes of 2280 m. Also in the Balkan states, it can live at altitudes of 2000 m and higher (Böhme et al. 2003).

3.8.3. Summer habitats, diurnal hideouts:

Salamanders use crevices under stumps or acclivities, holes under large stones, deadwood or fallen leaves as hideouts (Fig. 13). These hideouts are often connected with deeper holes through the aisles of small mammals. They also use walls, stone- or compost piles. Usually, they return to their hideouts after their nocturnal excursions (Böhme et al. 2003).
3.8.4. Wintering grounds:

The wintering grounds of Fire Salamanders often are in the same region as their summer habitats. They hibernate underground, for example in crevices, caves, treeholes or in mine tunnels because of the stable temperature (between 9 and 12°C) and air-humidity (between 92 and 99%) (Böhme et al. 2003).

3.8.5. Herpetocoenosis:

**Germany:** Fire Salamanders are socialized with nearly all local amphibian species. Their larvae can co-exist with newts. Grass frog larvae can also be found beneath salamander larvae.

**Switzerland:** Along the northern foothills of the Alps at altitudes between 700 and 900 m, there is a region with some kilometers latitude, where Alpine (Fig. 14) and Fire Salamanders populate the same forests, although they do not exist syntopic. But at 950 m, they live together quite frequently and even use the same hideouts. In habitats of the midwife toad, Fire Salamanders are also found (Böhme et al. 2003).

**Austria:** Most frequently, *S. salamandra* was observed sympatric with the common toad, *Bufo bufo*, the grass frog, *Rana temporaria*, the northern crested newt, *Triturus cristatus*, the Italian crested newt, *Triturus carnifex* and the yellow-bellied toad, *Bombina variegata*. *S. salamandra* was observed syntopic with *Rana temporaria*, *Bufo bufo*, *Bombina variegata*, *Triturus carnifex* and with the agile frog, *Rana dalmatina* (Cabela et al. 2001).

3.8.6. Nutrition:

Fire Salamanders are food-generalists in all states of their development. They mostly eat snails (gastropods), arachnids, centipedes, beetles and annelids (Fig. 15). Juvenile salamanders feed on smaller prey than adult salamanders. Between one and 19 prey animals were found in stomach analyses of salamanders. This is a cue
that Fire Salamanders feed relatively irregular. Young salamanders are also more selective than adults (Böhme et al. 2003).

The prey of salamander larvae mainly reflects the offer of food in their spawn waters. Larvae prefer the larvae of stone flies. The larvae of standing water bodies prefer copepods (53%), cladocera (19%) and ostracods (12%). Brook-larvae prefer ostracods (55%), followed by copepods (19%).

Standing water bodies in forests with a high fraction of fallen leaves are poor of species. Fallen leaves are also very oxygen-wasting. In these waters, older salamander larvae use young newt-larvae for their nutrition.

In pools, salamander larvae prefer crustaceans (84%), whereas in font waters they feed on crustaceans, larvae of insects and invertebrates in nearly the same amount. They also feed on prey animals that fell onto the water surface (Böhme et al. 2003). Cannibalism in salamander larvae has often been described. Cannibalism primary appears when the number and density of prey gets low, with high larvae density at the same time. There is one report of a Fire Salamander that captured a night butterfly at bound.

The predated animals in waters with low streams or stream-free brooks are not enough to guarantee the whole development of the salamander larvae. In these waters, the larvae are dependent on drifting organisms from other regions of the brook.

In fish-free font-brooks of Central and West Europe, salamander larvae as consumers of second order belong to the top predators on the top of the trophic

Fig. 15: Fire Salamanders are often observed when they feed on worms (annelids) because they require a very long time to eat them up.
pyramid. Fire Salamander larvae are very important to characterize waterbodies and to categorize the water quality (Böhme et al. 2003).

3.8.7. Casting of the skin:

Fire Salamanders have to shed in certain intervals, especially growing juveniles. During this process, the defense through the skin venoms is limited, so the animals go through this process at hidden places. The casting of the skin is initiated through rubbing of the head on stones, wood or other substrates. After the head is freed of the old skin, the skin is pushed together at the neck. In extreme cases, this can also lead to death through suffocation, especially in young juveniles. Through undulating and jerkily movements, the salamander tries to detach the skin from the neck above the thorax to the shoulder girdle. In the end, the salamander frees himself of the skin with his forelegs. In many cases, the old skin is eaten up after the casting. The new skin is soft and very sensitive, so sometimes the salamanders remain with stretched arms and legs. After the casting, the colors contrasts are most noticeable (Thiesmeier & Günther 1996).

3.9. Reproduction

Fire Salamanders are the only recent caudate that deposit larvae. Fire Salamanders are ovoviviparous or larviparous, some subspecies (S. s. berardezi and S. s. fastuosa) are viviparous. The “birth” of larvae is named “Larviparie”, the “birth” of metamorphosed juveniles is named “Juviparie”. In Central and West Europe, the reproduction cycle is annual. In the Pyrenees, at altitudes between 500 and 1000 m, the reproduction cycle of S. s. fastuosa is biennial. Fire Salamanders normally start to reproduce after 3-5 years (Steinfartz et al. 2007). In typical headstreams of low mountain ranges, larvae are found between March and September. In not typical headstreams, larvae are found throughout the year. Besides the main spawning season in spring, there is also a possible second spawning season in autumn. Generally, larvae are found from February to October in Central Europe (Böhme et al. 2003). Mating and fertilization of ova are decoupled in the Fire Salamander. Females store the sperm in a spermatheca until they complete the vitellogenic cycle and the eggs are ready to be fertilized. Fertilization then occurs after ovulation.
Ovulation occurs during the first week of July in ovoviviparous and viviparous female salamanders. Ovoviviparous females ovulate between 20 and 60 eggs (Buckley et al. 2007).

3.9.1. Sexual dimorphism:

During their active breeding period, male Fire Salamanders can be distinguished from females through their clearly pre-bulged cloaca. Those secondary sex characteristics are only distinguishable in animals with 7 to 10 g weight and with 100 to 120 mm total length (Günther 1996). In the wintering grounds, the differentiation between males and females is not that clear. Adult males remain smaller than females, and females are also heavier than males (Fig. 16). Adult animals that weigh less than 20 g are mostly males (Böhme et al. 2003). The mating process is described later in chapter 3.11.11. Mating behavior.

In some subspecies, the yellow coloration of the back and the flanks passes through a characteristic development with some changes until the salamander reaches sexual maturity (Böhme et al. 2003).

3.9.2. Spawning waters:

Central and western Europe:

Typical spawning waters of Fire Salamanders have relatively low temperatures throughout the year, between 8 and 11°C. The spawning waters are waters with high oxygen content, like brooks, streams, fonts or other waters with spring water (Fig.
17). Outside of the low mountain range, Fire Salamanders also use small, shallow standing water bodies to deposit the larvae (e.g. ponds, pools, backwaters, barrier lakes, wheel tracks or puddles) (Böhme et al. 2003).

**Portugal:**

Many creeks, brooks and smaller rivers with submersed vegetation, which allow a co-existence of salamander larvae and fish, are populated in Portugal. Font basins, which are connected with fonts or font-brooks, are also very important. In these waters, salamander larvae are with 40% the most frequent amphibians.

In the high mountains of central Spain, the salamanders deposit their larvae in small lakes, which evolved of glacial glaciers, or in small, flowing brooks (Böhme et al. 2003).

**3.9.3. Development:**

The development of the larvae takes place in an expanded part of the oviduct (“Müllerscher Gang”), it is called uterus. After the mating, the sperms are stored in the “Spermatheka” (= Receptaculum seminis). This allows the storage of propagable sperms up to two years. With this method, mating and fertilization can be widely separated in time. The fertilization of the 5 mm large eggs most likely happens in the middle part of the oviduct. In the uterus, the eggs get encircled by a jelly-cover. The eggs grow for five months in the uterus, they feed on their own yolk-resources (lecitotrophy). In Central Europe, the main spawning season is in April and May. If the larvae are born in the middle of October or later, they are called “winter-larvae”. At this state, the larvae normally hibernate intrauterine. The duration of the deposition of
the larvae alternates between one and 18 days. In Germany, female Fire Salamanders deposit 32.0 larvae on average (Böhme et al. 2003).

Females with many larvae consume more body resources during the winter than females with lesser larvae. The reproduction success for the future is determined by the physical constitution of the female at the moment of ovulation. The food intake in the weeks after giving birth to the larvae, when the ovaries of the female get to full development, is the critical period which determines the reproduction success in the following year (Böhme et al. 2003).

According to Kopp and Baur (2000), later deposited clutches show larger larvae than earlier deposited clutches.

3.9.4. Larval development:

The duration of the larval period varies, from a few months to more than a year. 30-60 larvae are produced at some stage before metamorphosis is complete, with yolk being their only source of nutrition (Buckley et al. 2007). Three main factors influence the larval development: water temperature, water condition and food supply. The larvae of Fire Salamanders prefer cooler waters. At an average water temperature of 10.0°C in a headstream, the larvae need about 120 days from birth until completion of metamorphosis. In dependency of the oxygen content of the water, the chill-branches have different lengths (Fig. 18). In standing water bodies it was observed quite often that larger larvae would swim on the water surface to draw air. This could be an indication that the lungs of the larvae are already fully functional before metamorphosis (Böhme et al. 2003).
3.9.5. Adaptation to alternative larval habitats:

Populations of *S. salamandra* in Central Europe are derived from two postglacial invasion waves, one from the east and one from the west. The populations from West Germany, which are restricted to old broadleaf forests characterized mainly by *Quercus* spp. and *Fagus sylvatica*, are derived from one single recolonization wave after the last glaciations approximately 6000-8000 years ago. There are found regional differences with respect to the deposit of the larvae. Fire Salamander populations (e. g. in the Eifel and Kottenforst forest) use streams and ponds as larval habitats. The mean energetic value of potential food organisms is more than three times higher in streams than in ponds. Besides, the mean salamander larval density is higher in ponds than in streams because in streams a density regulation by drift occur (Weitere et al. 2004). However, the pond larvae display several adaptations, including higher weight at larval deposition, capacity to cope with a lower quality of food and an early metamorphosis under limited food conditions, which can occur in ponds. The pond larvae metamorphose early because they have to leave the water before the risk of drying of the pond becomes too high in summer. Stream larvae are not exposed to this threat. The adaptations of pond larvae allow them to survive in an ecologically very different environment. The area of the Eifel and Kottenforst forest was colonized only once and the habitat-specific adaptations and genetic
differentiation have occurred within the area. Besides, these adaptations suggest the possibility of rapid evolution of genetic adaptations when new habitats are exploited. The evolution of the adaptations of larvae to ponds or streams could be coupled with the evolution of cues for assortative mating (Steinfartz et al. 2007). The stream-adapted females prefer males from the same habitat type, pond-adapted females do not prefer males from their own population. So habitat adaption correlates with female preference in Fire Salamanders and habitat-dependent female preference of a specific pond-reproducing population may have been lost during adaptation to the novel environmental conditions of ponds (Caspers et al. 2009).

3.9.6. Disposal of larvae:

At about the time the yolk is exhausted and larval form is achieved, hatching and/or birth in ovoviviparous Fire Salamanders takes place in the time span in which viviparous forms have reached terrestriality. Ovoviviparous embryos hatch after 80-90 days of development, just prior their release into water (Buckley et al. 2007). There are differences between populations who dispose their larvae in small headstreams, and populations who dispose their larvae in standing water bodies. During the disposal of the larvae, which mainly happens during the night, the female submerges into the water and presses the larvae out of the cloaca. Sometimes, the female only places the abdominal part of her body into the water and stays on shore with her prosoma. The hind legs are contorted at 90° in such a way that the surface of the feet points outwards. The knee joints are pointed upward. During the birth of the larvae, faint contractions are visible. Mostly, the larvae break up the amnion before birth and the little salamanders leave the cloaca with the head or the tail first. The larvae can be disposed at once, but sometimes the process can take several nights (Böhme et al. 2003). The larvae have fully developed gills, limbs, eyes and ventral and dorsal tail-fins and are between 25 and 35 mm large (Buckley et al. 2007).

3.9.7. Malformations of larvae:

Often, malformed larvae, retarded embryos or not fertilized eggs can be found in the uteri of females. That could be caused by chemical, physical or trophic developmental disorders. Also the mechanical pressure caused by so many embryos and larvae grouped together could cause such malformations (Böhme et al. 2003).
3.9.8. Metamorphosis:

The metamorphosis is completed after approximately four months. On average, the total length of metamorphosed animals is about 51 mm (Fig. 19). Larvae which hibernate in water can metamorphose with much higher total lengths and body measurements. Hibernating larvae with up to 8 cm in length after metamorphosis are not uncommon. The hibernation of larvae can be deployed by late depositing of the larvae in autumn, constant low water temperatures of 10°C and lower, and also lack of nutrients. There are reports of larvae that remained in water for up to 8 years (Böhme et al. 2003).

3.9.9. The evolution of terrestriality in “true” salamanders:

Ancestral salamandrids were probably restricted to montane habitats and therefore, their reproduction was adapted to running water. Adaptations for terrestriality in montane habitats caused them to evolve characteristics that distinguish them from their more aquatic sister taxon (newts). Therefore, the more terrestrial life-cycle of “true” salamanders required a further specialization of the mating behavior, viviparity and anatomy and physiology of the feeding-apparatus (Veith et al. 1998).

3.9.10. The evolution of viviparity in Salamandra salamandra:

In S. salamandra, two distinct modes of reproduction exist: the common mode, ovoviviparity and a phylogenetically derived reproductive strategy, viviparity. This lecitotrophic viviparity may be considered as a key innovation that enabled some populations to reproduce outside water and thus allowed them to live in high mountains or extremely dry habitats without water. The first split within “true” salamanders (Chioglossa, Mertensiella and Salamandra) that presumably resulted in an ovoviviparous and viviparous lineage must have occurred during the Early Oligocene period. Since Salamandra is the most widely distributed taxon of “true”
salamanders, the plasticity related to the reproductive mode may have enabled *Salamandra* to spread much further than any of the other genera and more easily to survive periods of unfavorable climatic conditions (Veith et al. 1998). Therefore, in some Fire Salamander populations (subspecies *S. s. fastuosa* and *S. s. bernardezi*) of the Pyrenees and the Iberian Peninsula, the salamanders give birth to fully metamorphosed juveniles (Böhme et al. 2003). These viviparous populations are surrounded by ovoviviparous populations of salamanders. Intraspecific lineage divergence within *S. salamandra* exists because of vicariant processes in the late Pliocene. Most likely, the viviparity arose in the isolated populations on the northern slopes of the Cantabrian Mountains. Large demographic expansions, possibly favored by a selective advantage of the newly evolved reproductive mode, might have led to the homogenization of previously differentiated genomes, which might have resulted in the spread of viviparity (Buckley et al. 2007).

Many such modifications are heterochronic, which means that there is a shift in the relative timing of developmental events in a descendant organism compared to the timing of the same events in an ancestor. Viviparity in *S. salamandra* is characterized by the early hatching of the embryos within the maternal oviducts, the phenomena of oophagy and adelphophagy (intra-oviductal ingestion of eggs or larvae) and the accelerated developmental rate of viviparous embryos. Viviparous females also ovulate numerous eggs, but they develop through metamorphosis entirely within the maternal genital tract and only a few (between 1 and 15) fully metamorphosed terrestrial juveniles are born after 80-90 days of gestation (Buckley et al. 2007).

**Differences to ovoviviparous development:**

- The development is arrested in many eggs (about 50%) in viviparous females. In each arrested egg, a yolk plug obliterated the blastopore, that may reflect a dysfunctionality of the neurulation process.

- After 8 or 9 days, the cephalic and pharyngeal regions of the viviparous embryos are enlarged and advanced.

- The mouths of viviparous embryos open and the balancers are resorbed early.

- The yolk mass is drastically reduced and the anterior part of the digestive tract is developed.
• The embryos start to feed actively within the maternal oviduct. They are capable of predation on arrested eggs (oophagy) and other embryos (adelphophagy). As a result of the intrauterine cannibalism, the embryos quickly attain the larval morphology, while retaining a large amount of yolk in their digestive tracts. The supplementary nutrients enable them to reach metamorphosis and birth after 90 days of intrauterine development.

• Viviparous juveniles are smaller than the ovoviviparous ones (Buckley et al. 2007).

Compared to the developmental program of ovoviviparous Fire Salamanders, the program of viviparous Fire Salamanders is accelerated. Development of viviparous salamanders takes 90 days so far. In the same amount of time, ovoviviparous larvae hatch and are born into water, with metamorphosis occurring months later. The increased developmental rate in viviparous salamanders must be determined intrinsically. Cephalic, pharyngeal structures, the mouth and the digestive tract develop earlier (Buckley et al. 2007). Dopazo and Korenblum (2000) formalized an evolutionary scenario: the number of eggs produced and fertilized per female is a trait under strong selection. The co-option of eggs for nutrition creates a new intrauterine environment in which selection would favor the acceleration of developmental rates and cannibalism. So the co-option of unfertilized and abortive eggs could have triggered the evolution of viviparity.

3.9.11. Multiple paternity within and between annual reproduction cycles:

Multiple paternity under natural conditions suggests the possibility of sperm competition. Long-term sperm storage in special reproductive organs of females can lead to this competition between sperm received from different males during different reproductive cycles. Under captive conditions, a single female of *S. salamandra* stored sperm for more than 2.5 years in the spermathecal epithelium. During the entire annual reproductive cycle, spermatozoa were found in large numbers in the spermathecae of female salamanders. Multiple paternity occurs under natural conditions in *S. salamandra*, so females use sperm from multiple males to fertilize their eggs. At the beginning of the reproductive season, females try to make sure they fertilize their eggs and even mate with potentially low-quality males. Later in the season, they only mate with high-quality males. At the time of fertilization, when the
eggs pass the spermatheca, the sperm of the high-quality males is then used for fertilization. There also could be a “topping off” mechanism, where females mate with the first male and store as much sperm as possible. Additional sperm from inseminations from different males is then used to fill up the spermathecae. Sperm is then mixed and used for fertilization. Stored sperm seems to be less often used if females have more males to choose from, indicating cryptic female choice. Long-term sperm storage under natural conditions does not occur in *S. salamandra*. Therefore, sperm from a past reproductive season is normally not used in a following reproduction cycle. The female strategy may be not to degrade all of the stored sperm before mating success of the following reproductive season is known (Steinfartz et al. 2005).

3.10. Population density and population dynamic

Central and western Europe: The population density is about 80 animals per hectare. In optimal habitats with many hideouts, 406 to 445 animals per hectare can be found (Böhme et al. 2003).

Seifert (1991) observed a population of 1300 animals in Thuringia with 56% adult salamanders. The average annual mortality rate was 9.6%, with 70 salamanders dying every year.

Generally, during most time of the year, Fire Salamanders are on their way as loners (Kyek & Maletzky 2006).

There is an extremely high mortality rate during the juvenile period, only 14% of the animals reach the age of 6 years and therefore sexual maturity. In Central Europe, Fire Salamanders seem to be typical K-strategists: they have a low mortality rate during the pubescent phase, a long lifespan, few enemies and brood-care (intrauterine embryonic development) (Böhme et al. 2003).

3.10.1. Age:

Some Fire Salamanders can live up to 20 years. The average age of males is 7.9 years, of females 8.2 years. In terrarium, ages of 43 and more than 50 years are documented (Böhme et al. 2003).
3.10.2. Enemies:

Larvae: In headstreams in Central Europe that carry no fish, there are only a few predators that catch salamander larvae. Potential predators are dragonfly larvae, crayfish, water-shrew, water-blackbird, blackbird and song thrush. As the water flow in fonts increases, predating fish pose a threat to salamander larvae. Under special conditions, syntopic existence of fish and salamander larvae is possible. In southern Europe, water snakes hunt for salamander larvae (Böhme et al. 2003).

In some standing water bodies, invertebrates like beetles, dragonflies and bugs, or newts are predators of salamander larvae. With many newts present, the salamander larvae often show mutilations on the tail and the extremities.

Juvenile and adult animals: New metamorphosed salamanders are often eaten by carabid beetles and shrews. The dermal toxins of the salamanders are not yet fully functional, they only reach full maturity during juvenile development (Böhme et al. 2003).

The observations of predators and adult salamanders are very rare. Presumably, the venomousness of salamanders is increasing with age, or more likely, the bad taste of the excreted secretion increases with age. Predators are hedgehogs, badgers, wild pigs, rats, some birds and snakes. Sometimes the grass snake feeds on salamanders. The mortality rate as a result of predation is very low in adult Fire Salamanders (Böhme et al. 2003).

3.10.3. Migration patterns:

Terrestrial salamanders are generally portrayed as amphibians with low migratory activity. New studies suggest that Fire Salamanders show a higher migratory activity than commonly thought. This may be because the spatial extent of salamander populations is underestimated or because there is a large exchange of individuals between populations. Many amphibian populations may be characterized by high proportions of transients and/or floaters. Transients are animals that are encountered only once (Schmidt et al. 2007). According to Schulte et al. (2007), the mean home range size of Fire Salamanders is estimated to be 494 ± 282 m² as the minimum distance. Some salamanders even have a home range size of 1295 ± 853 m² in the time span of two years. Besides, site fidelity is stronger expressed in males than in
females because males show a return rate almost twice as high as for females. These data suggest that *S. salamandra* adults display site fidelity, but use a much larger area than hitherto thought for this and other terrestrial salamander species.

### 3.11. Behavior

#### 3.11.1. Diurnal activity:

Generally, Fire Salamanders are nocturnal animals. The diurnal activity depends on air temperature, air humidity (rainfall), and wind. Also the time of year plays an important role. Heavy rain that soaks the forest soil in midsummer is more important than rain in spring and autumn. According to Klewen (1985), Fire Salamanders leave their hideouts at outside conditions of less than 10 lux light irradiation between 9:00 p.m. and 0:00 a.m. and return to their hideouts at dawn between 5:00 a.m. and 6:00 a.m. More than 50% of the animals leave their hideouts after 11:00 p.m. at light values between 0 and 2 lux. That accounts for the severe night activity of those animals. Rain preconditioned, Fire Salamanders are active at night temperatures between 5°C and 8°C in May, in July between 9°C and 12°C, and in September between 3°C and 4°C. No Fire Salamander observations have been made when the temperature dropped below 2°C. They only leave their hideouts at 85% relative air humidity, most of the salamanders only come out at a relative air humidity of 92% or higher. During strong wind conditions, they remain in their hideouts. They look for areas protected from the wind even when there is only a light breeze. The highest activity can be found at temperatures of 8°C to 12°C (Böhme et al. 2003).

As soon as the temperature rises, the females migrate to the spawning waters. The migration is also associated with rainfalls and temperatures of 2°C to 3°C at night. The main migration happens at a night temperature of at least 6°C.

On a sunny and dry afternoon on the 2nd of March 2002, A. Meyer found 30 females of *S. s. salamandra* at a brook, depositing their larvae.

In Catalonia, 74.8% of the Fire Salamanders are active at an air humidity of 96% to 100% (Böhme et al. 2003).
3.11.2. Annual activity:

Central and western Europe: Along the Atlantic part of Europe, Fire Salamanders are active more or less all-season long. Only heavy freezing periods or drought can cause limitations. During warm winters with no heavy freeze, single active animals can be observed quite often, even on snowfields. They are mostly females who deposit their larvae very early. Reports of observed salamanders in January and February are quite frequent. The main activity period starts with the spawning season in March, whereas the main spawning season is in April and May. After reproduction, the females take a rest for a month. From the end of May, mainly males can be found. During the summer months, the activity is controlled by rainfalls, air humidity and wind. A second high level of activity can be found in autumn (September/October). That can be associated with the migration to the wintering grounds. In autumn, mostly males or not sexually mature animals are active. Adult females who carry mature larvae only show limited activity in autumn (Böhme et al. 2003).

If the salamanders live in habitats with adequate spawning waters that do not freeze in winter, the populations show an all-season activity pattern. The deposit of the larvae starts in September and lasts throughout autumn and winter (mild temperatures assumed) until the following June. Most likely, the larvae are metamorphosing during the winter months. Also copulations can happen during the winter months because the male testes produce sperms from September to May (Böhme et al. 2003).

Southern Europe: The annual activity of the Fire Salamander shifts to autumn and winter months because of the arid climate along the coast of the Mediterranean Sea.

The main activity and reproduction period in Portugal is during the first part of the rainy season (October to December).

In Galicia, the salamanders get active in September. September through December, mostly male salamanders are active. After December, mostly female salamanders are moving around. The proportion of the sexes is 1:1.

In Catalonia, the activity of the Fire Salamander starts with the first rainfalls in autumn (end of September/beginning of October) and ends in May. Single animals can be
found in summer. In autumn, there are more males than females. This reverses in spring (Böhme et al. 2003).

3.11.3. Water-stay of adult animals:

Fachbach (1972) reported the discovery of a Fire Salamander (S. s. salamandra) in the western part of Styria that was caught in a composed font that was 1 meter deep and had a temperature of 6.5°C. The Fire Salamander stayed under water without problems at the same low temperature in the laboratory. Under the same conditions, Fachbach was able to maintain S. s. almanzoris and S. atra under water. With a good supply of oxygen, the animals seem to be able to cover their oxygen demand only through the dermis and the “Buccopharyngeal” (mouth-bottom)-respiration.

3.11.4. Daily ranges:

Fire Salamanders remain outside their hideouts between 1 h 35 min and 7 h 15 min. They cover a distance of 35 m to 350 m at night. Pregnant females cover distances of 87 m to 375 m between their daytime hideout and their spawning water (Böhme et al. 2003).

3.11.5. Philopatry and “home-finding behavior”:

Fire Salamanders have a distinct philopatric behavior. They have a “home-finding behavior”. With a shipment of around 10 m, 87.8% of the animals return directly to their hideouts. Visual orientation is responsible for this behavior. Eventually, the assumption of a “moon-compass-orientation” could be given in Fire Salamanders (Böhme et al. 2003).

Fire Salamanders also have the „Jacobsen-organ“ or vomeronasal organ. This is a chemoreceptor organ which is completely separated from the nasal cavity the majority of the time, being enclosed in a separate bony capsule which opens into the base of the nasal cavity. It is a tubular crescent shape and split into two pairs, separated by the nasal septum. It is mainly used to detect pheromones between individuals of the same species. Probably, this organ supports the finding of mating-partners and helps the Fire Salamander to navigate. The home-finding behavior and philopatry of the Fire Salamander could also be connected with the vomeronasal organ (Døving & Trotier 1998).
3.11.6. Venom:

Fire Salamanders have a venomous dermal secretion, which is mainly excreted through the parotids (Fig. 20) and the dorsal gland lines. This dermal secretion consists of three neurotoxic components, Samandarin \( (C_{19}H_{31}NO) \), Samandaridin \( (C_{21}H_{31}NO) \) (Fig. 21) and Samanderon \( (C_{22}H_{31}NO_2) \). These organic compounds are alkaloids. The venomous dermal secretion is used as a defense-mechanism against parasites on the moist skin, like bacteria and fungi, and predators.

The dermal secretions cause a light burning of the skin in humans. In very sensible persons or children, the secretions can cause nausea, breathing difficulties and regurgitation. Especially young dogs or cats which play with salamanders more often show symptoms of poisoning. The consequences are lockjaw, stiff neck and salivation, in very few cases death (Habermehl 1994).

Fig. 20: The glands-rich parotids of the Fire Salamander.

Fig. 21: Chemical structure of Samandarin \( (C_{19}H_{31}NO) \) (on the left) and Samandaridin \( (C_{21}H_{31}NO) \) (on the right).
3.11.7. **Defensive behavior:**

Naturally, the most important defense mechanism of adult Fire Salamanders is the venomous dermal secretion, connected with the yellow-black warning-coloration. The characteristic defensive demeanor of a salamander is the S-shaped body position (Fig. 22). The dermal secretions are mainly excreted when the animals are captured or squeezed ruggedly. In rare cases, the poison can be squirted as far as 20 cm from the glands. Salamanders from Poland and Italy can squirt the poison between 44 and 200 cm. The secretions are only squirted from the dorsal gland lines, with more than 300 cm/sec. In open areas, this kind of behavior is rarely seen. The toxic dermal secretions are not as effective in young animals, so they try to escape from their predators. Adult animals lower their head and present their poison-glands-rich parotids to the predator (Böhme et al. 2003).

3.11.8. **Prey-catching behavior:**

Immediately after birth, salamander larvae are able to snap at their prey (“suck-snapping”). After metamorphosis, the salamanders catch their prey with their jaws and adult animals are also able to expel their tongue from their mouth about 1 cm. During the first month after metamorphosis, Fire Salamanders get imprinted with a certain food. Young salamanders that are only used to motionless prey later react more frequently to motionless prey than other salamanders that have always been fed with moving prey. Salamanders are able to identify and localize their prey only through their olfactory sense. The smell of the prey is learned and is noticed as whole, not through single components (Böhme et al. 2003).
3.11.9. **Territorial behavior:**

The high age and the high philopatry of adult Fire Salamanders to their hiding places, wintering grounds and spawning waters indicate interactions within species (Böhme et al. 2003).

3.11.10. **Communication, vocalizations:**

Freytag (1955) describes the vocalizations of Fire Salamanders as squeaky and whistling, but always very quiet. These vocalizations seem to be made in relaxed situations or when the salamanders are alarmed. The vocalizations of Fire Salamanders were also described as quiet beeps, similar to mice, but more subtle and not as loud. Some Fire Salamanders in their wintering grounds give off a quiet, but clearly noticeable bright snarling sound (Böhme et al. 2003). Currently, Veith (2000) ascertained an acoustical enemy defending behavior in the closely related Lyciasalamandra (*Mertensiella luschani*).

3.11.11. **Mating behavior:**

There are the following mating behavior patterns in the Fire Salamander:

1. **Prosecution:** The male runs after the moving female.

2. **Head butting:** The male presses his bent head against the body of the female and rubs his nostrils against the dermis of his mate (Fig. 23).

   The two following behavior patterns rarely occur in the Fire Salamander, but regularly in the Alpine Salamander (*Salamandra atra*).

3. **Dorsal clasping (“Amplexus”):** The male crawls on the female and embraces the back of the female. His forelegs lie on the neck or the body of the female.
4. **“Chin rubbing”:** The male moves his head back and forth and presses it down, so that his chin rubs the head and throat of the female.

5. **Ventral crawling under:** The male presses his head beneath the body of the female and crawls from behind or sideways up to her forelegs (Fig. 24a-c). Are his forelegs arranged under the forelegs of the female, the male swings them upwards and forwards (Fig. 24d), and encompasses the forelegs of the female from behind (Fig. 24e).

6. **Ventral clasping (“Amplexus”):** The male reclines parallel beneath the female and encompasses the female with his forelegs. The male huddles his forelegs against the anterior surface of the forelegs of the female. During this clasping, the following behavior patterns can be discriminated:

6a) **Body movements, body shifting:** The male shows slow undulant movements of the backbone. Tail and sacrum are swayed. Thus, the whole dorsal surface of the male rubs against the underside of the female. Through elongation of the hind legs, the male body is moved sideways or the pair is moved forwards. In addition, the hind legs are raised and lowered alternately (Fig. 25a).

6b) **Undulated tail-movements:** The male shows slow undulated movements with the tail (Fig. 25b). The undulated movements flow backwards.

6c) **Head-swinging:** The male moves his head sideways forwards and backwards and thereby rubs the chin of the female with the surface of his head (Fig. 25c).
6d) Spermatophore-disposal (Fig. 25d-e): During the ventral “Amplexus”, the spermatophore is disposed under the abdomen of the female. The male maintains his hind legs still and presses his underside against the basement. He shows undulant movements of his tail and begins with head-swinging. These movements end in a steady forward and backward movement. The head-swinging grows continuously, in the end the head describes a curve of 90°. Afterwards, the male ends the undulant movements of the tail, but continues with the head-swinging.

6e) Displacement of the sacrum: Directly after disposing the spermatophores, the male moves his sacrum and tail sideways away from the female. He retains the ventral “Amplexus” with his forelegs. The head-swinging is stopped. In the end, the male moves his body completely away from the body of the female (Fig. 25f).

(Böhme et al. 2003)

After Himstedt (1965), a male Fire Salamander who is in the mating mood, reacts to every moving object and pursues it incessantly. This behavior pattern is primary activated optical because other salamanders, like the Alpine Salamander, are prosecuted too. The spermatophore is a laterally compressed jelly-done of 5-6 mm height, with a surface of 5 x 3 mm.
Courtship and mating exclusively happen on shore. There are repeated reports of males who stand up high on their forelegs to be on the lookout for females (Fig. 26) (Böhme et al. 2003).

3.11.12. Larval behavior:

Larvae that developed in small flowing waters are not really able to assert themselves against increasing flow velocities. Normally, they are found in small, natural accumulations and bulges that do not show flow velocities or only little flow velocities between 0 and 3 cm/sec. Only few larvae are found in flow velocities of up to 15 cm/sec, these are mostly larger larvae of more than 35 cm total length. At syntopic occurrence of Fire Salamander larvae and brown trouts, the Salamander larvae linger in micro habitats where brown trouts do not have access to (Böhme et al. 2003).

3.11.13. Parasites:

Gut parasites of larvae are *Pomphorhynchus laevis* (Acanthocephala), but they do not harm the larvae. The alternate host of the parasite is the sand hopper *Gammarus sp.*, the principal food of salamander larvae in small headstreams (Böhme et al. 2003).

3.12. Man and Fire Salamander

3.12.1. Historical development:

The origin of the scientific name “Salamandra” is unclear. Probably, it is an Arabian-Persian loanword. The Persian “samandar” comes from “samand”, which means as much as “fire red” (Günther 1996). The Fire Salamander has been known by humans for a long time because of its eye-catching appearance. Pre-modern authors often ascribed fantastic qualities to salamanders. The legendary salamander is often depicted like a typical salamander in shape, but with a lizard like form. A large body of legend, mythology and symbolism has developed around the salamander over the centuries. In one of the earliest surviving descriptions of a salamander, Pliny the Elder (A.D. 23-79) noted that the salamander is “an animal like a lizard in shape and with a body starred all over; it never comes out except during heavy showers and
disappears the moment the weather becomes clear." Pliny even made the important distinction between salamanders and lizards. Pliny recounts several other traits which are less credible, such as the ability to extinguish fire with the frigidity of the bodies of salamanders, a quality which is also reported by Aristotle (Bostock & Riley (eds.) 1855). Pliny also notes medical and poisonous properties, although the extent of these properties is greatly exaggerated, with a single salamander being regarded as so toxic that by twining around a tree it could poison the fruit and so kill any who ate them. By falling into a well, a salamander could slay all who drank from it (White 1992). In Medieval European bestiaries, fanciful depictions of salamanders include a “satyr-like creature in a circular wooden tub” (eighth century), a “worm penetrating flames” (twelfth century), a “winged dog” (thirteenth century) and a “small bird in flames” (thirteenth century) (McCulloch 1962). The illustrations of the Fire Salamander at these times show high similarity with a reptile or a dragon-like creature. Renaissance depictions are more realistic, adhering more closely to the classical description. All of these traits are consistent with the golden Alpine Salamander (Salamandra atra aurorae) and the Fire Salamander. The traits relating to fire have stood out most prominently in salamander lore (Fig. 27). This connection probably originates from a behavior common to many salamanders, hibernating in and under rotting logs. When the wood was brought indoors and put on the fire, the salamanders “mysteriously” appeared from the flames. According to some writers, the milky substance that a salamander excludes when frightened and which makes its skin very moist gave rise to the idea that the salamander could withstand any heat and even put out fires (Bulfinch 1913). Seeing that, the name “Fire Salamander” can be traced back to these events. Leonardo da Vinci wrote the following on the salamander: “This has no digestive organs, and gets no food but from the fire, in which it constantly renews its scaly skin. The salamander, which renews its scaly skin in the fire, - for virtue.” (Richter 1880). Paracelsus suggested that the salamander was the elemental of fire. Marco Polo believed that the “true” salamander was an incombustible substance found in the earth.
Because of all that erroneous beliefs and the mystic histories about salamanders, people long believed that salamanders are bad creatures and threw the animals into the fire. This portrayal of the Fire Salamander changed only in the middle of the 17th century. In the beginning, even Carl of Linné classified the Fire Salamander incorrectly as “Lacerta salamandra”, with “Lacerta” meaning lizard (Thiesmeier and Günther 1996). In early heraldry, the salamander was depicted as somewhat like a short-legged dog, surrounded by fire. More recently it is depicted as a lizard or a natural salamander, but still always amidst flames. The salamander became a symbol of enduring faith which triumphs over the fires of passion. It was the badge of Francis I of France, with the motto “I nourish the good and extinguish the bad.” The salamander also became the traditional emblem of the smith (Friar 1987).

Even today, people are somewhat skeptical about Fire Salamanders. They still believe that salamanders are very poisonous and therefore dangerous, probably still influenced by the numerous mystic stories that exist about these cryptic animals. This skepticism has to be obliterated, so that these animals can be experienced as the amazing and beautiful creatures they are.

3.12.2. Endangerment and protection today:

As mentioned above (see chapter 3.6. Areal dynamic and Endangerment), the Fire Salamander is on the Red List of amphibians and reptilians in Austria and Salzburg. Fire Salamanders suffer from severe habitat destruction brought about by modern agriculture, road constructions and river regulation. During the past 50 years, streams and fonts suffered heavy damages. Many fonts have been drained or obstructed. Micro habitat structures, like holes under trees, caves, stone-clefts and the cavity-systems in the ground, have to be preserved. The following protection measures are very important for the survival of the Fire Salamander:

- Preserving caves and tunnels in forests as summer- and winter-hideouts.

- Protecting existing spawning waters and recreating lost spawning waters. For example, fishpond-management is an extensive invasion to the natural habitats of Fire Salamanders.

- The loss of deciduous forests, which have been widely replaced with conifers in the past centuries, has to be stopped.
• Temporary blocking of forest-roads to any kind of traffic at the time of migrations of female salamanders in spring.

• In short, rebuilding destroyed habitats and preserving current habitats of Fire Salamanders.

The “natural habitats, terrestrial or aquatic areas distinguished by geographic, abiotic and biotic features, whether entirely natural or semi-natural” (e. g. waterbody-habitats), mentioned in Article I of the European Habitats Directive on the conservation of natural habitats and of wild fauna and flora (European Union Law 2010, online) are extremely important to the Fire Salamander.

By means of the theoretical part in the introduction it is quite obvious that there exist plenty of literature about the Fire Salamander. But this literature mainly concentrates on Germany, France or Switzerland. Studies about the Fire Salamander in Austria are outdated or simply do not exist. Therefore, the following practical part of this master thesis presents a completely new approach of Fire Salamander research in Austria.
4. Material and Methods

The aim of this new project, which started in July 2009, is to record the present distribution of the Alpine Salamander (*Salamandra atra*) and the Fire Salamander (*Salamandra salamandra*) in Salzburg and Austria. The applied approach is new and based on a website and the participation of the public. The developed project is described on the following pages.

4.1. The project

The main goal of this project is to map occurrence, population-size and development of the Fire and Alpine Salamander in Salzburg and Austria. During the summer 2009, we established the website www.alpensalamander.eu, on which everybody can report salamander observations. This web 2.0 approach is a new step to actively involve the population into the research and protection of these vulnerable amphibians and their habitats. This community based approach enables the combination of research, education and dissemination through interactive participation, as we believe that protection of amphibians and their habitats is only possible through actively involving the population. As mentioned above (see chapter 3.11. Behavior), the Fire Salamander only leaves its hideouts at times of extremely high air humidity and wet weather conditions, when people normally stay inside and do not go out. Therefore, it is extremely difficult to observe Fire Salamanders. Thus, the only way to collect many Fire Salamander data and to establish an area-wide distribution map is to involve as many people from the local communities as possible and to additionally involve people who are outdoors at different weather conditions (e.g. hunters, rangers, alpinists, mineral collectors, farmers, etc.).

A second goal of this project is to record an oral history of Fire Salamander observations during the past 50 years by conducting interviews in the local community to see where populations are stable or decreasing. The hitherto existing data of the “Biodiversitätsdatenbank” do not give an insight into the development of Fire Salamanders during the past 50 years. But many old people still know occurrences of Fire Salamanders from former times which have disappeared without a trace today. For this purpose, we interviewed alpinists, farmers, Nationalpark staff,
mineral collectors and hunters from Werfen, Tenneck, Werfenweng, Pfarrwerfen, Bischofshofen, Pöham, Hüttau, Mühlbach am Hochkönig, St. Johann im Pongau, Großarl, Gastein, Kleinarl, Wagrain, Flachau, Reitdorf, Abtenau and St. Martin am Tennengebirge to preserve their local knowledge of the Fire Salamander and to cover the whole area of mountain valleys as good as possible with Fire Salamander observations.

To summarize, this community based approach enables the combination of research, education and dissemination through interactive participation. We also collaborate with national parks (Hohe Tauern, Berchtesgaden) and museums to effectively disseminate this project in schools, wildlife and mountaineering organizations. For that purpose, we visited the Symposium of the “Nationalpark Hohe Tauern” in Kaprun. We presented a poster with a description of the website, the project and our goals.

4.2. The website - www.alpensalamander.eu

Our website features three different languages: German, English and Español. Different information items can be selected on the side bar: how to report a salamander, descriptions of the Alpine Salamander, Lanza’s Alpine Salamander and Fire Salamander, and a description of the research project. Besides, there is information about the protection of amphibians in general. Additionally, the team, partners, openings, internships, contact and the news releases are presented. Furthermore, we had a salamander picture contest to collect as many beautiful salamander pictures as possible. Everybody had the chance to upload his salamander picture. The three best pictures in the year 2009 of each, Alpine and Fire Salamander, were nominated and the winners got a T-shirt with an Alpine Salamander on it. These pictures can also be viewed on the website. The picture contest will be continued in 2010.

The activities from the last months, starting with June 2009, can be seen in the archives.
4.3. **To report a salamander**

Certainly, the most important activity on the website is to report a salamander. For this purpose, the core of the website is formed by a “Google-Maps” map of Europe, where everybody can chart his salamander observations. Everybody can post observations, through clicking on the map, which then opens a second window. The map can be selected in four different modes: normal map, satellite map, terrain map with contour lines and hybrid map (a mix between normal and satellite map). Everybody just has to zoom in and find the exact location of the salamander observation. There is also a search option of “Google-Maps” available, which helps to find a particular location. One just has to enter the location (e.g. Salzburg) and the map automatically zooms to this place. With another click on the exact location, an entry mask for the salamander report appears (Fig. 28). The charting person has to enter name, email address, salamander type (Alpine or Fire Salamander), a picture (when available), accurate time (e.g. 09:00) and date (e.g. 15.01.2010), number of salamanders, location (e.g. stony, humid forest bottom) and remark. The remark contains precise descriptions of the weather conditions, sex or special behaviors of the salamanders. After saving the entry, a small black Alpine Salamander or a yellow spotted Fire Salamander appears on the map and everybody can view his “own” salamander report (Fig. 29).

**Fig. 28: An example of the entry mask for salamander reports. The search option of Google-Maps is red encircled.**
4.4. Reports in the newspapers

Furthermore, we published articles in nationwide and local newspapers to raise the attention of the local population to the salamanders. The articles were printed in several newspapers, like the “Standard”, the “Salzburger Nachrichten”, “Die Presse”, the “SVZ”, the “Pongauer Nachrichten” and the “Pinzgauer Nachrichten” during the middle of August until the middle of September 2009. The articles were also on the websites of the newspapers and on the website of the University of Salzburg. People were invited to report their salamander observations on the website, to call us or write an email or letter.

We also designed a standardized questionnaire to record the data of people who reported us their salamander observations. We additionally dispersed this questionnaire during our tours to alp-shack-hosts or to other nature-minded people we met.

The questionnaire is structured as following:

- **Name** of the person who makes the salamander report.
- **Phone number/Email address** of the person.
- **What type of salamander was observed?** (mark with a cross): O Fire Salamander or O Alpine Salamander.
• **When?** (accurate date, eventually time)

• **Where? Where accurately?** (place, mountain pasture, path or road, altitude range)

• **Number** of observed salamanders.

• **Other remarks.**

To make it easier for the people to distinguish between the two salamanders, the questionnaire shows also one picture of a Fire Salamander and one of an Alpine Salamander.

### 4.5. Field studies

We also conducted field studies in the “Tennengebirge”, the “Hagenengebirge”, the “Hochkönig” and the “Hohe Tauern” to observe Fire Salamander populations under the right conditions - rainfalls, relatively low temperatures and high air humidity. We mostly went out early in the morning and we were on the way for four or five hours. All in all, we made about 10 tours during the summer 2009. It is to say that the summer 2009 had many warm and dry days, so the conditions for observing Fire Salamanders often were not the best.

### 4.6. Data analysis

For the precise analysis of the salamander data, we combined the map of the salamander observations in Austria on the website with maps of climate types, land cover classes, altitude and geology. Besides, we evaluated our data with Microsoft Excel. The numbers of salamanders observed in the particular climate types, land cover classes, altitude ranges and land cover classes are shown via a bar diagram in the results. The percentage of salamanders observed in the particular regions mentioned before was calculated and the results are shown via pie charts. For the creation of the diagrams, the number of Fire Salamander cluster shown on the map on the website, namely 650 (649 for the geological regions), was used.
5. Results

Since July 2009, we have established an initial distribution map of Fire and Alpine Salamander. This map can be viewed on www.alpensalamander.eu. Up to now, our project is very successful and finds great favor with the people and the local communities. The hitherto existing results are shown in the following paragraphs.

5.1. Data and Users

Since July 2009, we have collected 5800 Fire and Alpine Salamander reports altogether. There have been 3200 Fire Salamander reports throughout Europe and 2455 reports in Austria, which are displayed as 650 clusters. We had 2600 Alpine Salamander reports throughout Europe.

Until now, there are 1300 users, 80 of them charted more than 5 times, 860 users charted more than 1 time.

Although the project is still in the initial stages, the data already picture a good preview of the Fire Salamander distribution in Austria and allow a preliminary analysis including the assessment of data quality. All records were evaluated manually and obviously questionable reports (e.g. coordinates in a lake) were checked by contacting the user and corrected or deleted. These aggregated data are the basis for our preliminary analysis for which we consolidated the data with different maps.

5.2. Feedback to the reports in the newspapers

After the reports in the newspapers, which started in the middle of August 2009, the number of charting users and also the entries of salamander observations on our website www.alpensalamander.eu increased steadily. The people are more attentive to the salamanders than ever before.

The reports in the “Pongauer Nachrichten” were printed on the 3rd and 10th September 2009 and supplied with a phone number. Older people often do not have access to the internet or they simply are not able to chart their salamander
observations on the website because it is too complicated for them. Therefore, we put down a phone number with the reports in the newspapers. After the publication of the two reports, the feedback of the local people in Pongau was astonishing and really great.

The results of the phone calls, recorded on the standardized questionnaires, are shown in the following listing:

- Altogether, 40 persons called their salamander observations in, some of them even several times.
- All in all, 48 Fire and Alpine Salamander observations were reported. 8 persons announced both, Fire and Alpine Salamander observations.
- Number of reported Fire Salamanders in the year 2009, after the reports in the “Pongauer Nachrichten”: 56. The Fire Salamanders were observed scattered and for the most times, 6 Fire Salamanders were observed together. On average, 2 Fire Salamanders were observed together.
- Number of reported Alpine Salamanders in the year 2009, after the reports in the “Pongauer Nachrichten”: about 50. It is worth mentioning that Alpine Salamanders, unlike Fire Salamanders, often were observed in congregations of 10 to 20 salamanders, assuming the right weather conditions, meaning rainfalls and relatively low temperatures, like after a thunder storm.

5.3. Observed trends

So far, the following distribution trends, concerning the Fire Salamander in Austria, have been observed:

The distribution map of the Fire Salamander in Austria on www.alpensalamander.eu, generated by making use of a new, innovative approach involving the public, conforms very well to the already existing distribution map of the “Umweltbundesamt” and the “Naturhistorisches Museum” in Vienna, Austria. The reports center on the northeastern part of Austria and on Salzburg, with a total of 2455 reports. Salzburg has the highest number of Fire Salamander reports, namely 261. Many reports have
also been in Styria, with 118 entries, followed by Upper Austria with 102 entries, and Lower Austria with 101 entries. Unfortunately, we were not able to fill in the breaches of distribution in Vorarlberg and most of the Inn valley up to now. We have one Fire Salamander report from Buchebrunnen near Feldkirch, Vorarlberg, from the 15th of August 2009. Throughout Tyrol, there have been 20 Fire Salamander reports. In the Inn valley, there have only been 7 reports. The distribution gap in eastern and northeastern Lower Austria was filled in with at least 12 Fire Salamander reports.

So far, the following distribution trends, concerning the Fire Salamander in Salzburg, have been observed:

Salzburg has with 261 Fire Salamander reports the most reports throughout Austria. There have been around 60 Fire Salamander reports around the city of Salzburg, for example only on the “Kapuzinerberg”, 10 Fire Salamanders have been 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/Pfarrwerfen and Bischofshofen/Pöham, there have been around 80 Fire Salamander reports during the last summer.

Fire Salamanders were active for a long period in the year 2009, namely until the middle of November. The last report of an active, naturally fairly rigid Fire Salamander, was made on the 9th of November 2009. Probably, this salamander appeared on the surface because of a short mild temperature period in November and was on its way back to the wintering grounds.

The following report from Hüttau is very interesting and worth mentioning: Fire Salamanders have been observed regularly since 10 years in the copper mine in Hüttau. The total developmental process of the Fire Salamander, beginning with the deposit of the larvae, the larval development till the metamorphosis to a juvenile terrestrial salamander, can be observed in the proximity of this copper mine. Also the hibernation of Fire Salamanders has already been observed inside the copper mine.

Unfortunately, we also could find out through our interviews that there is a significant decrease, at least by half, of Fire Salamanders in the last 40 years. Places of decreasing Fire Salamander observations in the last 40 years are:
• **Blühnbach, Tenneck:** During the last 40 years, roads and forest-roads were built in this region.

• **Tenneck:** 40 years ago, Fire Salamanders were observed quite frequently along the railway. Today, the Fire Salamanders seem to have disappeared. During this period of time, the highway has been constructed.

• Besides, there are only few Fire Salamander reports (only about 20 in all valleys) in the mountain valleys, like Stubachtal, Rauris, Gastein, Großarl and Kleinarl. According to many reports of the local community, Fire Salamanders have populated the valley of Kleinarl, also the pathway to the “Tappenkarsee”, 20 to 40 years ago. Nowadays, the Fire Salamanders have disappeared. These results open the question about historic developments in these regions that may have destroyed important habitats of Fire Salamanders in the Salzachtal region.

5.4. Outcome of the field studies

To observe the salamanders (Fire and Alpine Salamander) by ourselves, we conducted field studies under the right weather conditions, meaning after or during a rainfall, at relatively low air temperatures, at high air humidity and often early in the morning. We discovered some locations, where Fire and Alpine Salamanders can be observed quite frequently. We have also been at places, where the conditions and the habitat were “salamander-like”, but where we were not able to observe a single salamander. The following paragraphs describe some of the most important or most striking field studies we made.

1. **“Tennengebirge”:** The “Tennengebirge” provides perfect habitats for both, Fire and Alpine Salamanders and according to our interviews, both salamander species are observed frequently in the morning on the footpath to the “Oedlhaus” and the world’s largest ice cave in Werfen.

2. **Edge of the “Tennengebirge”:** On the beginning of the way to the “Mahdegg”-mountain pasture, there is a perfect habitat for Fire Salamanders, which provides small fonts and brooks, a beech forest, humid forest soil and
meadows. People reported that they have always observed Fire Salamanders in this area under the right weather conditions. Therefore, we went out early in the morning in the middle of August at a day with light rainfalls and very high air humidity. Our tour lasted about two hours and during this short time, we observed 15 Fire Salamanders. Some were on their way quite fast and tried to hide in caves or under trees as soon as they noticed our presence. We observed male and female salamanders. This tour was a great success because it gave us a good insight into the behavior of Fire Salamanders.

3. “Gainfeld”, at the edge of “Manndlwänd”, “Hochkönig”: After many reports of Fire Salamander observations in Bischofshofen, Gainfeld, at the edge of the “Hochkönig”, we went there to check this location for Fire Salamanders. The habitat there is perfect, with a small brook and a beech forest. So we expected to see many Fire Salamanders. But despite the perfect habitat, time and weather conditions, we did not observe a single Fire Salamander. This showed us, that even when we can be sure that the salamanders live in a certain place or habitat it cannot be taken for granted that the salamanders can be observed. This is probably due to their cryptic existence.

4. “Tappenkarsee”, “Radstädter Tauern”: We had many reports of Alpine Salamander observations from the “Tappenkarsee” in Kleinarl, which belongs to the “Radstädter Tauern” and is therefore part of the “Hohe Tauern”. Sometimes people even observed 50 or more salamanders during one hike. Our field studies helped us to confirm these observations. On the “Tappenkarsee”, there must be a big Alpine Salamander population because even on a hot, dry day, we observed two Alpine Salamanders in mountain pines.

5.5. The distribution of the Fire Salamander in Austria, consolidated with maps of altitude, land cover areas, climate types and geology

As mentioned above, the data of 3200 Fire Salamander reports in Austria, displayed as 650 cluster, were consolidated with maps of altitude, land cover areas, climate
types and geology. The maps were created on the 9th of December 2009 by Elisabeth Weinke, also a member of our project, and member of the UNIGIS professional team of the University of Salzburg. The maps are based on the European Terrestrial Reference System 1989 (Lambert Azimuthal Equal Area) and are created in the scale 1:1.100.000.

5.5.1. Altitude:

On the altitude-map (Fig. 30), it can be seen, that most Fire Salamanders are distributed at altitudes between 500 and 1000 m (also Fig. 30). This is also shown with the bar diagram (Fig. 31), which was created with 650 Fire Salamander cluster. Though, 398 out of 650 Fire Salamander cluster are found between 500 and 1000 m, followed by 163 cluster between 115 and 500 m and at least 83 cluster between 1000 and 1500 m. Above 1500 m altitude, only few Fire Salamanders can be found.

More precisely, 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 (shown in a pie chart, Fig. 32)
Fig. 31: Bar diagram of the Fire Salamander distribution in Austria per altitude. This diagram was created with 650 Fire Salamander cluster.

Fig. 32: Pie chart of the percentage of Fire Salamander distribution in Austria per altitude.
5.5.2. Land cover areas:

For the creation of this map, the CORINE land cover classification of the year 2000 was used. The CORINE program (Coordination of Information on the Environment) is a program of the EU, founded in 1985, for the data ascertainment of environmental data, especially land covers and land utilization. Therewith, integrative and comparable data of land covers for the whole area of Europe with focus on environment are available.

CORINE land cover is available in three classification-levels. For this map, level 1 was used. Level 1 comprises with 5 classes the most important land cover units of the earth’s surface. Those are: Forests and semi natural areas, agricultural areas, artificial surfaces, waterbodies, and wetlands.

In the following passages, the land cover classes are delineated more precisely:

Artificial surfaces: This class comprises urbanized areas, industrial sites, industrial real estates, traffic areas, dumpsites, building lots, wasting assets and artificial constructed areas, which are not used for agricultural purposes (for example urban grasslands or leisure facilities) (Hölzl 2003, online).

Agricultural areas: This class comprises agricultural crop lands (for example paddy fields), permanent crops (for example olive groves or viniculture areas), grasslands like meadows and pastures, and heterogeneous agricultural areas, meaning agricultural used land covers (Hölzl 2003, online).

Forests and semi natural areas: This class comprises forests like deciduous forests, mixed forests and coniferous forests, herb and bush vegetation like natural grassland, moorland and plant cover with hard leaves, and areas without or with little vegetation like beaches, dunes, sand-areas, rock-surfaces, burning-areas and glaciers (Hölzl 2003, online).

Wetlands: This class comprises wetlands on the coast such as salt mines, salt meadows and areas in the intertidal zone, or wetlands inland such as bogs and peatlands (Hölzl 2003, online).

Waterbodies: This class comprises waterbodies inland like water-courses, and ocean waterbodies like lagoons, estuaries, seas and oceans (Hölzl 2003, online).
There are four types of land cover classes that are populated by Fire Salamanders: Agricultural areas, artificial surfaces, forests and semi natural areas, and waterbodies (Fig. 33). The bar diagram (Fig. 34) shows that Fire Salamanders prefer forests and semi natural areas (437 out of 650 cluster), followed by agricultural areas (156 out of 650 cluster) and artificial surfaces (56 out of 650 cluster). Only one cluster is found in waterbodies.

The percentage analysis shows the same results. Most of the Fire Salamanders, namely 67.25%, live in forests and semi natural areas, 24.00% live in agricultural areas, 8.60% live in artificial surfaces and only 0.15% are found in waterbodies (Fig. 35).

Fig. 33: Distribution of *S. salamandra* (clustered) across Austrian land cover areas.
5.5.3. Climate types:

There are four climate types where Fire Salamanders can be found in Austria: alpine climate, middle-european transitional climate, pannonian climate and illyric climate (Fig. 36). 516 out of 650 Fire Salamander cluster are found in alpine climate areas. 88 cluster are found in middle-european transitional climate areas, followed by 24 cluster in illyric climate areas and 22 cluster in pannonian climate areas (Fig. 37).
The percentage analysis is as follows: Most Fire Salamanders, namely 79.39%, are found in alpine climate areas, 13.54% in middle-european transitional climate areas, 3.69% in illyric climate areas and 3.39% in pannonian climate areas (Fig. 38). Below, the different climate types are described in detail.

**Alpine climate:** The alpine climate is characterized by short and rather cool summers and long, cold winters. Especially on the northern edge of the Alps high precipitation rates occur. The climate in the valleys is milder and there are less precipitations. Characteristic for the alpine climate is also the foehn and the temperature inversion in cold-lakes during the winter (Salzburg Portal 2010, online).

**Middle European transitional climate:** The influence of the oceanic climate is declining from East to West and the influence of the continental climate is increasing. In the West, there are higher precipitation rates than in the East. In higher regions, the climate is colder and more humid (Salzburg Portal 2010, online).

**Pannonian climate:** In this climate zone, the influence of the continental climate is perceptible. It is drier than in the rest of Austria. Summers are hot and dry, winters are cold and poor of snow (Salzburg Portal 2010, online).

**Illyric climate:** This climate zone shows influence of the subtropical climate (Mediterranean climate). There are many sunny days, mild autumns and strong precipitations from the Mediterranean region during winter (Salzburg Portal 2010, online).
Fig. 36: Distribution of *S. salamandra* (clustered) across Austrian climate types.

Fig. 37: Bar diagram of the Fire Salamander distribution across Austrian climate types. This diagram was created with 650 Fire Salamander cluster.
5.5.4. Geology:

The geological map of Austria is derived from the Hölzel Atlas (Birsak et al. 1999).

Generally, the Fire Salamander is distributed more or less in all geological regions that are found in Austria, except the Eastern foothills of the Alps. These are: the Central Alps, the Vienna Basin, the Southeastern foothills of the Alps, the Southern Limestone Alps, the Northern Limestone Alps, the Grauwacken zone, the Flysch zone, the foothills of the Carpathians, the Granite- and Gneiss Upland and the foothills of the Alps.

The visible trend is that most Fire Salamanders are found in the Northern Limestone Alps, followed by the Flysch zone, the southern and northeastern edge of the Central Alps and the Grauwacken zone (Fig. 39). More precisely, 262 out of 649 Fire Salamander cluster are found in the Northern Limestone Alps, 144 in the Flysch zone, 100 in the Central Alps and 48 in the Grauwacken zone. Several cluster, namely 31, 23 and 21, are also found in the South-eastern foothills of the Alps, the Granite- and Gneiss upland and at the foothills of the Alps. In the remaining four regions, the number of observed Fire Salamanders is low (Fig. 40). No Fire Salamander is found at the Eastern foothills of the Alps.
The percentage analysis is as follows (Fig. 41): Most of the Fire Salamanders, namely 40.37%, are 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 Grauwacken zone. 4.77% of the Fire Salamanders in Austria are found at the South-eastern foothills of the Alps, 3.54% in the Granite- and Gneiss upland and 3.24% at the foothills of the Alps. Only 1.08% of the Fire Salamanders in Austria can be found in the Vienna Basin, followed by 0.92% in the Basin of Klagenfurt, 0.77% in the Southern Limestone Alps, and 0.31% at the foothills of the Carpathians.

The four geological areas, where most of the Fire Salamanders can be found, are described in detail below:

Northern Limestone Alps: The Northern Limestone Alps are characterized by limestone, for example the main dolomite, the “Wetterstein”-lime and the “Dachstein”-lime, which form limestone high plateaus. The Limestone Alps are ranges with cliffy, woodless rockfaces. Since lime is permeable to water, the basement has low water storage capacity and therefore desiccates very easily. The Limestone Alps often show karst formations. Furthermore, there are numerous large cave systems, and also some ice caves. The land utilization in the area of the Northern Limestone Alps is mainly meadows, forests (forestry) and uncultivated area (M-Th. 2009, online).

Flysch zone: The Flysch zone only occurs on the northern edge of the Alps. “Flysch” means “flowing”. The relief is formed by sand- and clay-like sediments, which often leads to hillside slides. The summits of the Flysch zone have altitudes between 600 and 900 m. The sandstone is not permeable to water and so a dense water network exists. After strong rainfalls, floodwaters often occur. The hillsides of the Flysch zone are characterized by deciduous forests, mixed forests and meadows (M-Th. 2009, online).

Central Alps: The Central Alps are located between the Northern and Southern Alps and contain the highest mountain of Austria, the Großglockner. From West to East, the Alps show declining altitude. The valleys become broader and larger basin landscapes are found. In the West, the summits are mostly glaciated. In large part, the Central Alps consist of crystalline stone (granite, gneiss, schist) and partly of dark lime. The West consists of granite, therefore cliffy shapes and narrow valleys occur. In the East, schist and gneiss predominate, and weather and erosion led to the
formation of stretched ridges and stump summits. The Central Alps consist of water-impermeable stone, hence, a dense water network is existing (M-Th. 2009, online).

**Grauwacken zone:** The Grauwacken zone is the geological basis of the Eastern Alps and is found between the Northern Limestone Alps and the Central Alps. The Grauwacken zone features mountains of median altitudes. The stone of the Grauwacken zone, schist, weathers very quick, and therefore leads to round, soft shapes with flat hillsides. The Grauwacken zone is sparsely wooded and consists mainly of grasslands and pastures. The Grauwacken zone is used for livestock farming, mountain pastures and is rich in resources (iron ore, copper ore, magnesite, wolfram) (M-Th. 2009, online).

Fig. 39: Distribution of *S. salamandra* (clustered) across Austrian geological regions.
Fig. 40: Bar diagram of the Fire Salamander distribution across Austrian geological regions. For the creation of this diagram, 649 Fire Salamander cluster have been used.

Fig. 41: Pie chart of the percentage of Fire Salamander distribution across Austrian geological regions.
6. Discussion

In July 2009, we decided to collect data of Fire- and Alpine Salamander observations by making use of a completely new and different approach. After a glance into the already existing data-bases, we were really astonished that there exist only few records of these amphibians, although these animals are observed quite often during hiking tours. Later we discovered during our field studies that salamanders are very difficult to map and observe in general. As described above (see chapter 3.11. Behavior), salamanders only appear on the surface at times of extremely high air humidity. That means after rainfalls or thunderstorms and frequently in early morning hours. Otherwise, they have a very cryptic existence. We experienced during our own observations that you do not necessarily have to come across a salamander, although you know that the habitat is perfect and you can be sure that salamanders live in this place. Because of all those obvious reasons, we decided to collect more data about salamander observations by making use of a completely new, community based approach. Only with the help and involvement of the local population, and therefore with the help of people, who are on the move outdoors in nature under every weather condition, it is possible to get more data about these cryptic animals and to cover as many distribution areas as possible.

We were confronted with many critical voices right from the beginning of the new project, especially from those people who have been engaged in this domain for a long time and who are not open to new methods because they cramp too much to their old methods. But when one considers the cryptic existence of salamanders, it rather cannot work to simply go out with a data entry form and map the animals. Few observers can only map few animals, and when observers always map the same locations, there are certainly only data points of these locations. This trend is also reflected in the already existing distribution maps of Austria (data state 1996) and Salzburg (data state 2005).

In the “Atlas und Rote Liste der Amphibien und Reptilien Salzburgs“ (Kyek & Maletzky 2006), it is asserted that only single observations of isolated Fire Salamander sources exist from the region around Bischofshofen (Pongau). We were able to clearly disprove this statement through our new approach. After the publication of the reports in the local newspapers and on the basis of our own
interviews with the local people, we were able to declare that many locations in the area of the Pongau exist where healthy Fire Salamander sources can be found. Besides, we had at least 80 Fire Salamander reports for the Pongau within half a year. Thus, we definitely do not have the case of isolated single Fire Salamander observations in the area of the Pongau. This is a good example that the hitherto existing Fire Salamander data in the “Biodiversitätsdatenbank” were only recorded at those locations, where the people who are connected with the “Biodiversitätsdatenbank” observed Fire Salamanders by themselves. The distribution map of the Fire Salamander for Salzburg from 2005 clearly displays that the few existing data center on the Flachgau and that there are hardly any data after the “Pass Lueg”.

Our attempt to reach the local communities by means of the media and to let the people chart the data on a website worked very well. Anyhow, we managed to establish a community of 1300 Users and an amount of more than 5000 data within a very short time. This community is still growing and the people will continue to help with the data collection of Fire Salamander observations. Certainly, it is easier for the people to access the internet right after a hiking tour, and to deliver their salamander observations right away. Nearly no hikers, or only few, carry a data entry form with them during a hike, as it exists of the “Biodiversitätsdatenbank”. Moreover, such a data entry form is structured much too complicated, and it takes about 10 to 15 minutes to complete the form, and hardly anyone takes his time for doing that during a hike.

Critics will surely always exist, but our success proves them wrong. The people are very enthusiastic about the project and they are more attentive to salamanders than ever before. After the presentation of our project and the new approach, many unbiased scientists were excited about our findings, as we could see at the symposium of the “Nationalpark Hohe Tauern” in Kaprun in September 2009. So we can say that we have reached our goals for the first step.
6.1. Distribution map from www.alpensalamander.eu compared to the map from the „Umweltbundesamt“

Fig. 42: Comparison of the distribution area of the Fire Salamander between the altitude-map from the „Umweltbundesamt“ (1996) (above) and the altitude-map from www.alpensalamander.eu (below). The distribution area of the Fire Salamander in Austria of the map from www.alpensalamander.eu seems to conform very well to the map from the „Umweltbundesamt“.
When drawing a comparison between the distribution map of the Fire Salamander on www.alpensalamander.eu and the already existing distribution map of the “Naturhistorisches Museum” and “Umweltbundesamt” in Vienna (data state 1996, “Biodiversitätsdatenbank”) (Cabela et al. 2001) (Fig. 42), it can be seen, that the distribution areas of the Fire Salamander from our map conform very well to the distribution areas of the map from the “Umweltbundesamt”. This result shows that this new approach provides exact data and also data of high quality.

The “Biodiversitätsdatenbank” only provides 1546 Fire Salamander data altogether, collected during the last 30 years. Until 1979, 505 data were recorded, and between 1980 and 1996, during a period of 16 years, only 1041 Fire Salamander (Cabela et al. 2001) data have been recorded. The recent distribution map is dating back to 1996, so it is imperative to generate a new, up-to-date distribution map for the Fire Salamander. With the help of the public, we were able to collect 2455 Fire Salamander data within half a year for Austria. Certainly, our data are not as exact as the data of the “Biodiversitätsdatenbank”, but the animals do not remain always at the same location, and if there is a finding point, the animal surely will not be found at exact the same location the next time the place is visited.

For the beginning, it is essential to know the most important distribution areas of salamanders. This approach is only possible with the help of the public. After establishing an initial distribution map, it is possible to search the salamanders on our own or with a group, and the hot spots of the distribution areas can be examined more precisely and the salamanders can be monitored. Only by doing so, an area-wide distribution map of salamanders can be established step by step. The same applies probably for all other amphibian species, which lead such a cryptic life as the Fire Salamander does.

6.2. Discussion of the results

6.2.1. Observed trends in Austria:

Unfortunately, we were not yet able to fill in the distribution breaches in Vorarlberg and the Inn valley. This may be so because our project has just started half a year ago and is therefore not as well-established throughout Austria as it is in Salzburg
and for that reason we did not reach enough people in Tyrol and Vorarlberg. Or it might also be that there are simply no, or only few Fire Salamander occurrences in these regions. This question remains to be clarified during the sequel of this project. Until now, we were able to record at least one Fire Salamander observation in Vorarlberg and 20 observations in Tyrol, thereof 7 in the Inn valley. The distribution breach in eastern and northeastern Lower Austria could be filled in with at least 12 Fire Salamander reports (101 throughout Lower Austria). The distribution breach in Murau could also be filled in with at least 118 reports throughout Styria.

6.2.2. Observed trends in Salzburg:

In Salzburg, our project is already well-established due to the intensive media work. Therefore, Salzburg has with 261 entries the most Fire Salamander reports throughout Europe. However, there are only few reports from the mountain valleys in the Pongau and Pinzgau, namely from the Stubachtal, Rauris, Gastein, Großarl and Kleinarl. We know that in the Pongau many roads, forest-roads, railways and highways have been built within the last 40 years. Besides, several skiing regions were opened up, hydroelectric power stations were built, and many humid areas were drained. All those things could have had an influence on the decrease of Fire Salamanders within the last 40 years. Especially river regulations and drainage of humid areas have great influence on the deposition of larvae because Fire Salamanders need intact spawning waters for that. As mentioned in the introduction, the larval phase is the critical phase during the life of a Fire Salamander, relating to population sizes. In Kleinarl, we know for sure that there have been many Fire Salamanders 40 years and probably also 20 years ago. In this valley, many farmers have drained and flattened their fields, and removed several streamlets, which again points to destruction of spawning waters.

As aforementioned, Fire Salamanders are extremely adaptable animals, and as we have seen through our results, they are able to exist even around cities (like Salzburg), as long as adequate spawning waters are available. Therefore, it is of utmost importance that especially in the mountain valleys, where Fire Salamanders definitely have been in the past, measures are taken to stop the destruction of habitats. Additionally it would be good to build new habitats.
6.2.3. The Fire Salamander distribution in Austria consolidated with different maps:

**Altitude:** The altitude distribution, which arises from our map, correlates very well with the declared values in the literature (Böhme et al. 2003, Cabela et al. 2001, Nöllert & Nöllert 1992, Günther 1996). The typical distribution area of the Fire Salamander in Austria is at altitudes between 200 and 700 m. Our data show that most Fire Salamanders live at altitudes between 500 and 1000 m, followed by altitudes between 115 and 200 m. Over 1500 m, only few Fire Salamanders can be found because they are not as used to such high altitudes as for example the Alpine Salamander. Besides, at altitudes above 1500 m, the Fire Salamander does not find the best habitats because red beeches, which provide the favorite habitat of Fire Salamanders on the northern side of the Alps, only exist up to 1600 m.

**Land cover areas:** This map also correlates very well with the values in the literature (Böhme et al. 2003, Nöllert & Nöllert 1992, Günther 1996). As expected, most Fire Salamanders live in forests and semi natural areas. This land cover area comprises with deciduous forests, mixed forests, herb and bush vegetation, meadows and pastures ideal habitats for Fire Salamanders. Many Fire Salamanders can be found in agricultural areas too, which also house habitats for Fire Salamanders with meadows and pastures. The occurrence of yet many Fire Salamanders in agricultural areas points out that changes in these habitats, as it probably happened in some mountain valleys in Salzburg, may have fatal outcomes for the populations of Fire Salamanders. Only a handful of Fire Salamanders live in artificial surfaces because these areas do not really match the natural habitats of Fire Salamanders.

**Climate types:** The larger part of Austria is influenced by the alpine climate type, therefore it is logical that most Fire Salamanders can be found within this climate type. With the rather cool summers and high precipitation rates, this climate zone is ideal for the Fire Salamander. The long winters are not a problem for Fire Salamanders because they find enough possibilities for hibernation in their habitats. Many Fire Salamanders are also found in the Middle European transitional climate areas because this climate is humid and also high precipitation rates occur. Only a small part of Austria is influenced by the illyric and pannonian climate type, and therefore the fraction of Fire Salamanders in these regions is also small.
**Geology:** Fire Salamanders definitely prefer the region of the Northern Limestone Alps. The Northern Limestone Alps comprise with their numerous, large cave systems enough hiding places for the cryptic existence of the Fire Salamander. The utilization of this region is mainly meadows and forest, hence, the Fire Salamander finds its perfect habitat in this geological region. The Flysch zone is characterized by deciduous forests, mixed forests and meadows. This explains why also many Fire Salamanders can be found in this geological area of Austria. A large part of Austria is covered by the Central Alps, and for that reason, also numerous Fire Salamanders live in this geological region. But the Fire Salamander appears in rather low regions of the Central Alps, only up to altitudes of about 1500 m. The Grauwacken zone provides with grasslands and pastures habitats for Fire Salamanders. Furthermore, the Grauwacken zone features mountains of only median altitudes, which is also ideal for Fire Salamanders.

All in all, the results of the different maps correlate excellently with the declared values in the literature and conform to all conditions that habitats of Fire Salamanders have to provide. This proves that our distribution data are of high quality.

### 6.3. Summary and Outlook

The main goal of this master thesis has been to establish an initial distribution map of the Fire Salamander in Austria and to show that the data collection of Fire Salamander observations by making use of a new, community based approach and involving the public, is possible. We successfully showed that the web portal www.alpensalamander.eu allows the collection of many Fire Salamander observations by the public within the shortest possible time. On the basis of different maps, it could be demonstrated that the data are not condemnable and of low quality, but that they a) correlate very well with the literature, b) provide data for new scientific project initiatives, and c) educate the public through direct and interactive dissemination. The project is still in the initial steps, but the success supports this new scientific approach. The initial distribution map is the basis for the development of an efficient monitoring method for salamanders and presumably, for amphibians in general. Fire Salamander populations for example could be mapped very well by searching spawning waters with constant larvae populations. On the basis of those
larvae populations, it will be possible to infer to the population size of adult Fire Salamanders in the region of the investigated spawning water.

In future, the hot spots of the Fire Salamander distribution map will be visited, to learn even more about the ecology of the Fire Salamander, the ecological relationship between Fire and Alpine Salamander, and the distribution of this cryptic animal. The project will be disseminated to whole Europe and the intention of this project is to have an area-wide distribution map of the Fire Salamander throughout Europe someday.

Furthermore, we plan genetic analyses to clarify the degrees of kinship between different isolated populations, to analyze the population sizes and dispersion rates of individuals, and to analyze the characteristics of specially adapted populations. Up to now, there have been no genetic studies done in Austria - neither for the Fire Salamander nor for the Alpine Salamander. So this will be a completely new area of research in Austria. Very interesting in terms of genetic regards is also the special ability for regeneration of salamanders. Salamanders are able to renew detached extremities within a short time. This ability can possibly be applied to medicine for the healing of paraplegic people someday.

In conclusion, we believe that the protection of amphibians and their habitats is only possible by actively involving the public, as participatory research has shown. The Fire Salamander is one of the heraldic animals of Europe and it is the obligation of mankind to put every effort into its research in order to preserve the significant moment of observing these amazing animals for future generations.
7. References


Web references:


