Habitat use, body temperatures of the European pond turtles, *Emys orbicularis*, in four different locations of Switzerland using telemetry and temperatures of potential nesting sites

Project of Master Thesis in Parasitology and Eco-ethology

by

Charlotte Ducotterd, University of Neuchâtel, Switzerland

Supervisor: Dr. Sylvain Ursenbacher, University of Basel, Switzerland

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1. Abstract

Reptiles are facing difficult times. Indeed, in Switzerland more than three quarters of them are listed on the Red List of endangered species. In this context, conservation efforts are implemented. The European pond turtle (*Emys orbicularis*, Linaeus, 1758) is an emblematic endangered reptile of Switzerland. The European pond turtle has a wide distribution area, but is currently restricted in Switzerland to small populations in Geneva and Ticino. The European pond turtle lives in high-quality temperate aquatic habitats, rich in vegetation such as ponds, marshlands. Consumed in large quantities during the past centuries, populations of European pond turtle had decreased in many regions. Moreover, the loss of its habitat and pollution had lead to the strong decline of the populations. In Switzerland, two official reintroductions were made, first in the natural reserve of Jussy/Près-Bordon in the canton of Geneva in May 2010 and the second in the natural reserve of La Vieille Thielle in May 2013. All reintroduced individuals were genetically tested before reintroduction, equipped with transmitters and monitored by telemetry in order to determine success of reintroduction and behavior after reintroduction. Individuals were also weighed before reintroduction and recapture after one year, in order to determine growth rate of each individuals.

I intended to examine if any difference in habitat use exist between reintroduced populations in the cantons of Geneva and Neuchâtel and to determine if body temperature are identical between individuals from four different sites; individuals from Moulin-de-Vert, which is an extremely favorable thermic place; individuals in the natural reserve of La Vieille Thielle, which is assumed as a favorable thermic place; individuals from Menziken, which is a not very favorable thermic site and finally individuals from Orzens, which is a less favorable thermic site. I used individual body temperature from different sites to determine whether or not thermoregulation activity differed between individuals in different environments. To study the temperature of nesting site located in different sites of Switzerland, iButtons were placed in the soil.

Results demonstrated that released in the natural reserve of Jussy had a behavior significantly more explorative during the second year after reintroduction than reintroduced individuals in La Vieille Thielle, perhaps due to the environment poor in vegetation or in order to find the best place to live. Growth rate of individuals of La Vieille Thielle was similar from individuals from Jussy/Près-Bordon and significantly higher than individuals from Moulin-de-Vert and thermoregulation was found to be significantly similar in the four studied sites. Even individuals living in less favorable environment such as Orzens could manage to reach an optimal body temperature to growth normally. What would be the limiting factor for future reintroduction of European pond turtle in Switzerland is the temperature of nesting site. Temperatures of nesting sites were only optimal for hatchling in the canton of Geneva, and limit in the natural reserve of Neuchatel and not possible in other studied sites. The limited amount heat accumulated in the nests could be due to too heavily developed vegetation on the mound. Results demonstrated the importance for the maintenance of nesting.

Keywords: European pond turtles, body temperature, thermoregulation, growth, nesting sites

2. Introduction

2.1 Reintroduction

The human world’s population has almost doubled in fifty years and causes an increase pressure on the natural environment. The continual growing food requests imply deforestations to grow food to feed humans and livestock; primary forests account for 36% of total forest area in the world, but lost more than 40 million hectares since 2000 (Lindquist et al., 2012). The Amazon rainforest, which is the most emblematic example, disappears continuously to make farms, field to grow food, roads, etc. Numerous species struggle to subsist in a decreased living environment causing a conflict with humans. For example, livestock is grazing on additional areas every year, causing for instance in Namibia attacks by the baboons on the cattle’s (Bentley et al., 2011).

Indeed species have less space to live on the planet. Many threats such as destructions of natural habitat, poaching, global warming or conflicts arising between humans and animals, lead to the gradual disappearance of species. In 1964, as the threat increased, the International Union for Conservation of Nature (IUCN) created a Red List, which is the world's most comprehensive inventory of the global conservation status of plant and animal species (IUCN, 2012). Within the Red List, each species or subspecies can be classified in one of the following nine categories: Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD) and Not Evaluated (NE) (IUCN, 2012). Classification of a species in one of three categories of endangered species (CR, EN and VU) is fixed through a series of five criteria, which are based on different biological factors associated with extinction risk: population size, rate of decline, geographic distribution, degree of population and distribution fragmentation.

In 2000, a joint study by IUCN and the World Wildlife Fund found that 34% of the world’s fish species, 25% of amphibians, 24% of mammals, 20% of reptiles, 14% of plants, and 12% of bird’s species are under threat of extinction. IUCN counts 21’000 threatened species on 70’294 studied species in the entire world (IUCN, 2013). Some of them depend on conservation projects for their survival; others are considered as vulnerable, endangered or extinct. Moreover, many species have already disappeared, such as the Chinese white dolphin (*Lipotes vexillifer*) extinct in 2007 or the Tasmania tiger (*Thylacinus cynocephalus*) extinct in 1930 (IUCN, 2013).

The IUCN showed a consistent decline in average species abundance of about 40% between 1970 and 2000 (IUCN, 2013). When a species got extinct, sometimes an entire ecosystem is threatened. For instance, the death of the corrals in the Great Barrier Reef due to several aspects (increase of the temperature, pollution, direct destruction, etc.) could lead to its disappearance, and thus to the extinction of thousands of other endemic species (Berkelmans et al., 2004). International trades and travels between continents cause an unnatural translocations and further colonization in new environments, which promote an unnatural phenomenon: movement of new species into new environments. Accidental or intentional, migration of animal and plant species can seriously disrupt a stable environment. For instance, the introduction of the European fox (*Vulpes vulpes*) in North America and Australia resulted in the disappearance of some marsupial species (Kinnear, 2002).

To limit the growing number of species disappearance, conservation methods have been developed. The local protection of species and their habitats is an important tool in conservation biology. However when species disappeared locally, reintroduction of living individual has become a common practice. Reconstitution of populations relies on individual's transfers. These translocations are very variable in shape and scale, depending on the local and global status of the concerned species and the reintroduction protocol. But the impact and the applied methodology are different if the species is still present or not: In case of individuals issued from captive breeding or individuals transferred from an area where individuals lived in abundance and released into an area where the species was formerly present, the term of reintroduction is used. On the opposite, if the species of interested is still present in the environment, the term of reinforcement or restocking is used; finally if the species has never been found in the area, the term of introduction is used (Beck et al., 1994).

The main purpose of the reintroductions is to re-establish into the wild a viable population of the focus species (or subspecies) that have disappeared from its natural habitat (UICN, 1998). Reintroduction programs must take into account genetic, behavior and pathology of the studied species, restoration of habitat, etc. (Seddon et al., 2007). Moreover, success of reintroduction programs is never assured. Reintroduction of captive-born mammals such as carnivores is very difficult due to the lack of skills to hunt prey and consequently survive, or to poaching. In 1987, Wemmer and Derrickson found that at least four or five of the 20 mammalian reintroductions have been successful in establishing viable populations. Today, the success of reintroduction is higher due to example of success and failure of reintroduction in literature (Beck et al., 1994).

While a growing number of reintroduction projects have being undertaken around the world, the International Union for Nature Conservation, UICN (1987) raises some guidelines to increase species reintroduction success with a group of experts.

First, causes of extinction need to be identified and eliminated (pollution, poaching, …) and, in some cases, habitats have to be restore before release. Secondly, reintroduced species must have the same genetic characteristics than the native populations. Then, the chosen site needs to be in the natural range of the species (otherwise, it would be an introduction). The health of the reintroduced individuals must be ensured, especially for reinforcement program, in order to prevent the risk of spreading diseases. Finally, after the release, monitoring must be undertaken to study the ecology and demography of the reintroduced individuals, as well as a study of the long-term adaptation of individuals in the newly created population (UICN, 1998).

Generally, successful reintroductions are more frequently reported and failed events are consequently underrepresented in the literature. An example of failed reintroduction programs is the reintroduction of Oribi (*Ourebia ourebia*) in South Africa. Oribi is a small antelope, which live in open grasslands. The species listed as endangered and, to increase their populations, adult individuals were breed in captivity and then young individuals were reintroduced into the wild. Ten individuals were released and after two months, 7 of the 10 Oribi were found dead (the normal longevity for wild animals is 10-12 years; Grzimek, 1990), mostly due to predation by natural predators and humans (Grey-Ross et al., 2009). This case demonstrated the importance of reintroduce individuals in suitable habitats, where individuals are not hunt by humans to guaranty the success of a reintroduction project. However, many reintroduction programs meet a real success (Grey-Ross et al., 2009).

A positive and significant example of reintroduction is the bearded vulture (*Gypaetus barbatus*), which disappeared from the European Alps about one century ago. An international reintroduction program (which started in 1986 up to 2003) was able to grow 121 individuals in captivity and reintroduced them in the wild, with a first release in Austrian Alps, followed by releases in the Swiss Alps (Hirzel et al., 2004). The theoretical population size in 2011 reached 227 individuals on the entire Alpine habitat. In Switzerland, a bearded vulture hatched for the first time by the end of March 2007 above the Swiss National Park (Grisons) and another was born near Derborence (Wallis) in April 2007. These births in the wild demonstrated the success of the reintroduction project (International Bearded Vulture Monitoring, 2012).

In Europe, another successful reintroduction refers to the ibex (*Capra ibex ibex*). Its over-exploitation and poaching began in the 1500s and led to a massive decrease in the European Alps. By the early 1800s, less than 100 individuals survived in a single population in the Italian Gran Paradiso mountain massif (Stüwe, Nievergelt, 1991). In Switzerland, restoring the Alpine ibex population was an important goal. As no purebred individuals were available, several unsuccessful reintroductions of ibex-domestic goat-hybrids were made since 1815. In 1914, a second reintroduction failed in the Piz d'Ela Massif (Grisons), perhaps due to illegal hunting. Later, in 1920, 7 individuals were reintroduced into the Swiss National Park (Grisons), followed by releases in other favorable places of Switzerland. Between 1920 and 1933, 25 individuals were reintroduced in Italy (Argentera), a part of the population moved to France around 1950 (Krammer, 2013). In the 1980s and 1990s, four major reintroductions allowed the species to significantly increase its presence in France (Krammer, 2013). Today, the wild Alpine ibex populations count about 40'000 individuals occurring in the entire Alps (On line, WAZA Conservation Project).

The majority of reintroduction projects involved mammals and birds (Cadi, 2003) such as in Switzerland with lynx, wolves, ibex or bearded vulture. Two reasons could explain this phenomenon. The biological knowledge is more important for higher vertebrates. Indeed reintroduced species are in many cases flagship species (Cadi, 2011). The reintroduction of symbolic species provides great means of education for the conservation of endangered species, the protection of its habitat, in which others less symbolic species also lived, such as reptiles and amphibians.

In Switzerland, the Coordination center for the protection of amphibians and reptiles (KARCH) aims to promote and coordinate all activities related to the study and protection of native amphibians and reptiles. The main goal is to improve the living conditions of these species, to maintain populations and maintain their habitat. Furthermore, one essential task of the KARCH is to initiate and coordinate the harvest of field observations. The conservation of native species of amphibians and reptiles still present in Switzerland remains the first priority of the KARCH. The conservation of reptiles in Switzerland is based on two main conditions: first, the conservation of existing sites and then, when other approaches are not possible reinforcement of populations by reintroduction projects. Reinforcement of population and reintroduction are possible only with non-hybrid animals with same characteristics of the native populations (KARCH, 2011). For the rehabilitation of an extinct species, individuals are reintroduced into a habitat where it has disappeared for various reasons. It could be either a recently extinct species in a region (e.g. Tree frog, *Hyla arborea*, in the canton of Basel-Land) or a species, which disappeared in ancient times, on the order of a hundred years (e.g. the European pond turtle, *Emys orbicularis orbicularis* (Linnaeus, 1758), in the canton of Neuchâtel, Ticino) (KARCH, 2007).

The European pond turtle has a wide distribution area, but is currently restricted in Switzerland to small populations in Geneva and Ticino. During the past centuries, they were consumed in large quantities. Moreover, the pollution and loss of its habitat had lead to the strong decrease of the populations (Bonin et al., 1996).
Remains of shells dating back 7000 years (Mesolithic) have proved the presence of this species in Switzerland. More recently, several observations of this species have been reported between 1800 and 1930 in the lowlands of Switzerland (Hofer et al. 2001). The European pond turtle was considered as extinct on the Swiss Red List of threatened and rare amphibians and reptiles of 1982 and 1994 (Hotz and Broggi, 1982; Duelli, 1994). Its status changed on the new Red List of threatened reptiles in Switzerland (Monney and Meyer, 2005). The proof of the existence of a wild and viable population of *Emys* in the canton of Geneva (natural reserve of Moulin-de-Vert) and the uncertainty, which remains about the indigenous origin of observed individuals in different environment of Switzerland, are at the origin of this status modification. Today, the European pond turtle is ranking as “critically endangered” (CR) on the Swiss Red List of threatened and rare amphibians and reptiles (Monney and Meyer, 2005).
In 1999, Florence Nuoffer proved the presence of viable populations of *Emys* in our country. More precisely, she showed that a restricted population existed in the natural reserve of Moulin-de-Vert (canton of Geneva), which comes from released individuals in the 1950s. In 2001, Denis Mosimann conducted another study on this population, testing a new method of capture. The results showed that the population had more than 300 individuals.
The population of Moulin-de-Vert is the only established population of *Emys* in Switzerland. Unfortunately, individuals from different origins have been released there since 50 years. In 2010, Mattieu Raemy demonstrated that this population is composed by three different subspecies, *Emys orbicularis orbicularis* (mitochondrial haplotype IIa), *Emys orbicularis hellenica* (haplotype IVa) and *Emys orbicularis galloitalica* (haplotype Va) and that most individuals are hybrids, which are non-indigenous individuals. Because reinforcements of the European pond turtle populations of Moulin-de-Vert were made without previous genetic studies, we are unable to say whether indigenous individuals were present or not, but the presence of indigenous individuals at the origin is unlikely.

Reintroduction projects for the European pond turtle is based on these following conditions: first, before the installation of a reintroduction program, the essential obligation is to ensure the total absence of the species through the implementation of a research protocol and case detection on the site and the surrounding sites (Cadi 2003). Secondly, the choice of the reintroduction sites, which the altitude of sites must not be more than 500m, with at least one optimal nesting site. Sites need to be varied and vast (20-100ha). Then, define the local genetic pool; only the non-hybrid individuals, which are of the same haplotype as the indigenous populations, can be reintroduced. In north of Alps, the correct lineage is *Emys orbicularis orbicularis* (haplotype IIa). Finally, reintroduction has to take place during spring, to allow animals to adapt to their new environment (KARCH, 2011).

The canton of Geneva was the first to establish a reintroduction project of *Emys orbicularis*. The main aim was to increase the number of *Emys* populations in the canton of Geneva in order to reduce the threat level for this species. Thereby, a first released took place in the natural reserve of Jussy/Près-Bordon in 2010, followed by a second in 2011. Being of hybrid origins, individuals from Moulin-de-Vert could not be used for reintroduction and/or reinforcement projects. Therefore, individuals used for reintroduction need to come from other sources, as instance from breeding stations in Switzerland and genetic tests are made to prove that individuals are of right lineage (haplotype IIa).
However, before these reintroductions, the marshland of Près-Bordon and Rappes had to be partially restored, and an optimal nesting site has been built. A total of 22 individuals were released in this natural reserve, 14 individuals in the pond of Près-Bordon and 8 individuals in the pond of Rappes, which is distant of a few hundreds meters. All reintroduced animals were equipped with transmitters and monitoring by telemetry. The transmitters allowed to evaluate the success of reintroduction and to increase our knowledge about *Emys*, habitat use, basking sites, favorite vegetation, etc., which are essential information for future reintroduction projects.

A second reintroduction program was planed in Switzerland. In the canton of Neuchâtel, the natural reserve of La Vieille-Thielle was considered as an ideal area for the reintroduction of *Emys orbicularis*. This reserve was restored in 2009 and regroups all characteristics for a reintroduction program. After obtaining the cantonal and Federal authorizations, the first official reintroduction of *Emys orbicularis* in the canton of Neuchâtel took place on the 21th May 2013, where 10 individuals equipped with transmitters were released. As for Geneva, individuals used for reintroduction come from the Swiss-*Emys* breeding station and were all genetically tested before released. As for the reintroduction in Geneva, the use of transmitters allows following their individual movements and further capture sessions were planned in order to study their growth. This Master project aimed in the follow-up of the reintroduced individuals.

2.2 Aims of the project

General aims of this project were to study the habitat use and body temperatures of the released individuals of the European pond turtle and temperature of nesting sites located in different places of Switzerland to better understand the requirements for its reintroduction and conservation in Switzerland. By studying habitat use and body temperature with the help of radio telemetry, I intended to examine if any difference in habitat use exist between reintroduced populations in the cantons of Geneva and Neuchâtel and to determine if body temperature are identical between individuals from four different sites; individuals from Moulin-de-Vert (canton of Geneva), which is an extremely favorable thermic place; individuals in the natural reserve of La Vieille Thielle (canton of Neuchâtel), which is assumed as a favorable thermic place; individuals from Menziken (canton of Argovie), which is a not very favorable thermic site and finally individuals from Orzens (canton of Vaud), which is a less favorable thermic site. I used individual body temperature from different sites to determine whether or not thermoregulation activity differed between individuals in different environments. By studying temperature of nesting sites, I intended to examine if any difference in temperature exist in different potential nesting sites located in Switzerland and if hatchling could occur in every locations. Thus, my aims were: (1) Do individuals from La Vieille Thielle have the same behavior (displacement, habitat use) than individuals from Jussy/Près-Bordon after reintroduction? (2) Do individuals from different environments have the same mean body temperature and how body temperature affects their activity patterns? (3) What is the difference of temperature between different nesting locations in Switzerland and are all studied sites favorable for hatchling? And finally (4) how could we use these results to improve the reintroduction and conservation of the European pond turtle in Switzerland?

3. Materials and methods

3.1 Study Species - The European pond turtle

The European pond turtle is a small freshwater turtle (adult weight: 250-900gr and length: 11-19cm). Its appearance varies over its large range; this turtle is usually easily identifiable by the bright yellow or gold speckling on the dark carapace and skin of many juveniles and adults (Levine, 1993) (Figure 1). However, some populations can be nearly entirely black with very few yellow markings. In general, individuals from the north of the range tend to be darker and larger than their southern counterparts (Fritz, 2003). The color of the male's iris also varies geographically, from red, brownish-yellow and yellow to pure white, while the eyes of females are generally yellow, occasionally white (Ernst et al., 2006). However, a clear sexual dimorphism exists between females and males; females have a flat plastron and a small tail. Conversely, males have a concave plastron and long tail. There are currently 14 described regional subspecies, which differ in size, color and markings (Fritz, 2003), although there is still much debate over the validity of these divisions (Highfield, 2006).
The European pond turtle lives in temperate aquatic habitats, which are rich in vegetation, such ponds with muddy bottom or marshlands. Favorable habitats must also have basking places and nesting sites; for this aspect, females need dry, warm places with sandy soil and out of flooding to lay eggs (e.g. sand dune). Unlike its common name suggests, the European pond turtle is not restricted to Europe, but in fact has a wide distribution that also includes northern Africa and western and central Asia. In Europe, it is largely confined to southern and central countries (Cadi, 2003).

Fig. 1: European pond turtle (©Olivier Born).

3.2 Status

The European pond turtle is the only native species of turtles in Switzerland. The species is present in Switzerland since the Holocene, when melting glaciers. Indeed, remains of shells dating back 7000 years (Mesolithic) have proved the presence of this species in Switzerland (Fritz, 2003). More recently, several observations of this species have been reported between 1800 and 1930 in the lowlands of Switzerland (Hofer et al. 2001). First releases began in the 1950s, especially in the canton of Geneva, but also in the cantons of Fribourg, Bern and St. Gallen (Nuoffer, 2000). The majority of these reintroductions took place around the years 1970-1980 (see Table 1).

Date	Place	Canton	Number of individuals	Origin
1960'	Benkener Giessen	SG	4-5	Unknown
1972	Schulreservat Benken	SG	3	Unknown
1973	Selhofen-Zopfen Belp	BE	10	Italy
1975	Ponds of Fräschels	FR	36 including16 juveniles	France, NN CH
1977	Ponds of Fräschels	FR	7	Turkey
1977	Lake of Geist Längenbühl	BE	10	Yugoslavia?
1950	Moulin-de-Vert	GE	4	Italy
1964	Moulin-de-Vert	GE	21	Italy
1978	Gulf of Capite	GE	15	Italy
1978	Grand Miolan	GE	11	Korfu
1978	Pierre Grise	GE	6	Corsica
1978	Laconnex	GE	16	Korfu

Table 1: Releases of *Emys orbicularis* in Switzerland in the years 1950-1970 as listed in Hofer et al., 2001.

In whole Europe, populations of *Emys orbicularis* have decreased during the past centuries because they were regularly consumed (Bonin and al, 1996). Decrease is also due to others human factors, such as damming rivers, draining wetlands, habitat fragmentation, urbanization, pollution (such as pesticides), etc, which leads to a huge loss of habitat. Another problem is abandonment of nesting sites because females, which are searching for laying eggs, get run over on roads. Additionally, the local introduction of the red-eared turtle (*Trachemys scripta elegans*) and other aquatics turtles can be an aggravating factor. The red-eared turtle comes from USA, and this species is more aggressive and competitive than the European pond turtle; consequently, the red-eared turtle occupy the habitat of our native turtle (Cadi, 2000; Cadi, 2003).

The European pond turtle was considered as extinct on the Swiss Red List of threatened and rare amphibians and reptiles of 1982 and 1994 (Hotz and Broggi, 1982; Duelli, 1994). Its status changed in the Atlas of reptiles in Switzerland (Hofer et al., 2001) and more recently on the new Red List of threatened reptiles in Switzerland (Monney and Meyer, 2005). The proof of the existence of a wild and viable population of *Emys* in the canton of Geneva (natural reserve of Moulin-de-Vert) and the uncertainty, which remains about the indigenous origin of observed individuals in different environment of Switzerland, are at the origin of this status modification. Today, the European pond turtle is ranking as "critically endangered" (CR) on the Swiss Red List of threatened and rare amphibians and reptiles (Monney and Meyer, 2005) and is considered as one of the most threatened reptile in Switzerland. The European pond turtle becomes a priority species from the point of view of conservation and reinforcement of populations (Monney, 2009).

3.3 Study sites

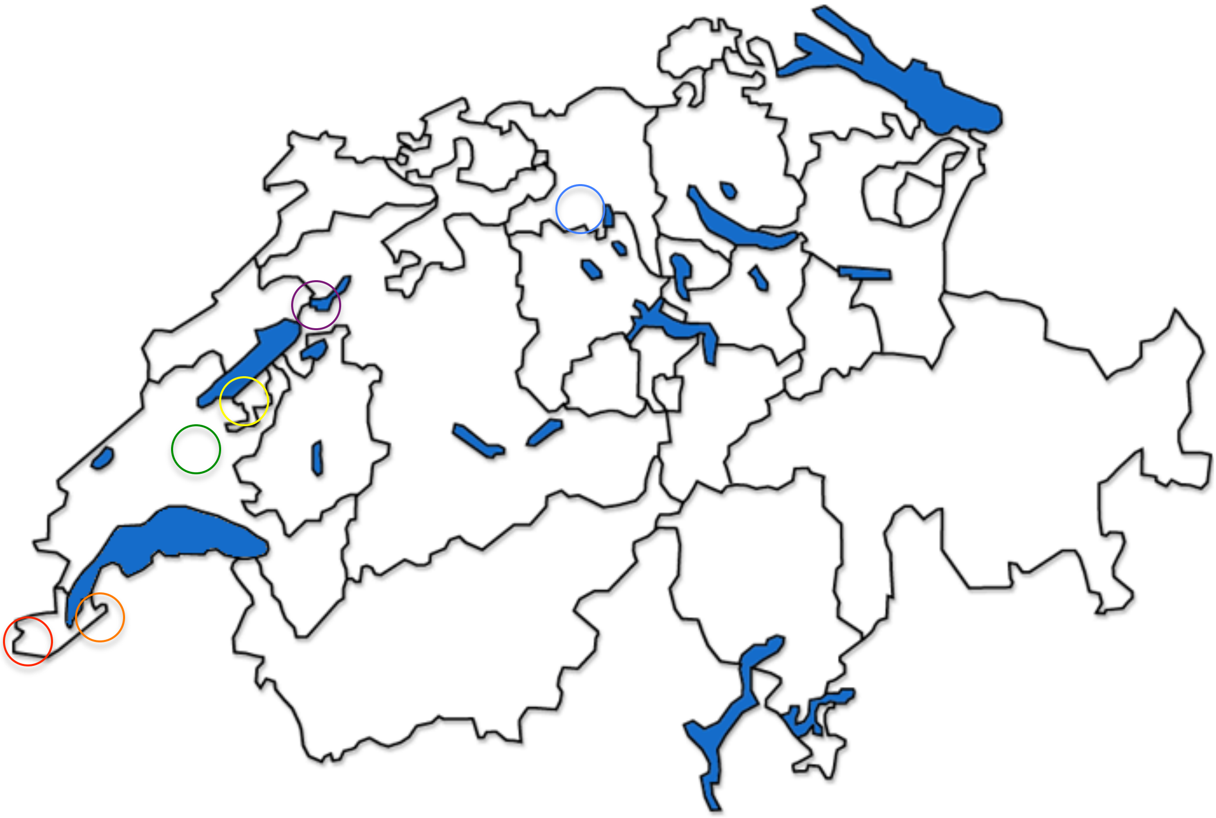


Fig. 2: Map of Switzerland showing the localization of the studied sites (1) Red circle = natural reserve of Moulin-de-Vert in the canton of Geneva, (2) orange circle = natural reserve of Jussy/Près-Bordon in the canton of Geneva, (3) green circle = Orzens in the canton of Vaud, (4) yellow circle = natural reserve of La Grande Cariçaie in the canton of Vaud (site of Font) and Fribourg (site of Châbles) (5) purple circle = natural reserve of La Vieille Thielle in the canton of Neuchâtel and (6) blue circle = Menziken in the canton of Argovie.

Sites	Localization	Body temperature	Nesting sites	Weight
La Vieille Thielle	**10 individuals** May-Oct 2013 / Mars-Oct 2014	**10 individuals** May-Oct 2013 / Mars-Oct 2014	**3 iBouttons** June-Oct 2014	**4 individuals** recaptured in August 2014
Moulin-de-Vert		**10 individuals** May-Oct 2013 / Mars-Oct 2014	**5 iBouttons** June-Oct 2014	**7 individuals** between 2001 and 2012
Près-Bordon	**10 individuals** May-Oct 2010 Mars-Oct 2011		**3 iBouttons** June-Oct 2014	**7 individuals** recaptured in 2011
Rappes			**3 iBouttons** June-Oct 2014	
Orzens		**2 individuals** May-Oct 2014	**2 iBouttons** June-Oct 2014	
Menziken		**2 individuals** July-Oct 2014		
Châbles			**2 iBouttons** June-Oct 2014	
Font			**2 iBouttons** June-Oct 2014	

Table 2: Table showing were data where collected. Localization and body temperature of each individual were found using telemetry in order to compare habitat use and difference of body temperature between different locations in Switzerland. Temperatures of nesting were calculated with iBouttons to show difference of temperature and determine if hatchling could be possible. Finally, weights of each individual were measured before reintroduction and one year after to compare growth rate in two different locations in order to compare growth rate in different locations.

3.3.1 Natural reserve of Moulin-de-Vert

The natural reserve of Moulin-de-Vert (46°10'46''N, 6°1'42''E) is located in the canton of Geneva near Cartigny and Aire-la-Ville, downstream of the dam of Verbois on the left bank of the Rhone with an altitude of 350 meters (Figure 3); this reserve is an ancient meander of the Rhone. This habitat is considered as the most favourable environment for the European pond turtle in Switzerland. Body temperature of individuals (2013-2014) and temperatures of nesting sites (2014) were studied in this location (Table 2).

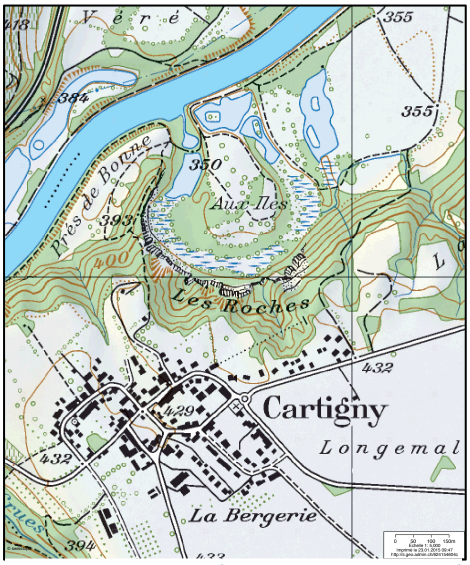


Fig. 3: Localization of the natural reserve of Moulin-de-Vert in the canton of Geneva, Switzerland. (©Swisstopo).

The Figure 4 showed the ponds of the natural reserve of Moulin-de-Vert. On the Figure 4, the pond n°1 is “Etang de L’Ouest”, which is directly connected to the Rhone by a small canal. Its average water area is 13’400m^2. The pond n°2 is called “Etang des Isles”, which has an average area of 10’200m^2 and the pond n°3 is called “Etang de l’Est, which has an average area of 8’500m^2. Finally, the pond n°4 is “Etang (Robert) Hainard”, which has an average water area of 15’700m^2 (Mosimann, 2002). The level of water in each pond depends on the aquifer and precipitation.

Fig. 4: Orthophoto of the ponds of the natural reserve of Moulin-de-Vert in the canton of Geneva, Switzerland. (1) “Etang de l’Ouest, (2) “Etang des Isles”, (3) “Etang de l’Est”, (4) “Etang Hainard” (©Swisstopo).

3.3.2. Natural reserve of La Vieille Thielle

The natural reserve of La Vieille Thielle (47°2'57''N, 7°2'51''E) is located in the canton of Neuchâtel near Cressier (Figure 5) at an altitude of 436 meters. This reserve is a very interesting habitat for many aquatic species. In addition, following the work of renaturation, the pond of La Vieille Thielle and the ancient dead arm of the river become ideal habitats for the European pond turtle. Its average water area is 7'700m^2. This site was considered as a favourable place for the European pond turtle (Cadi, 2011). Body temperature of reintroduced individuals (2013-2014), displacements (2013-2014) and temperatures of nesting sites (2014) were studied in this location (Table 2).

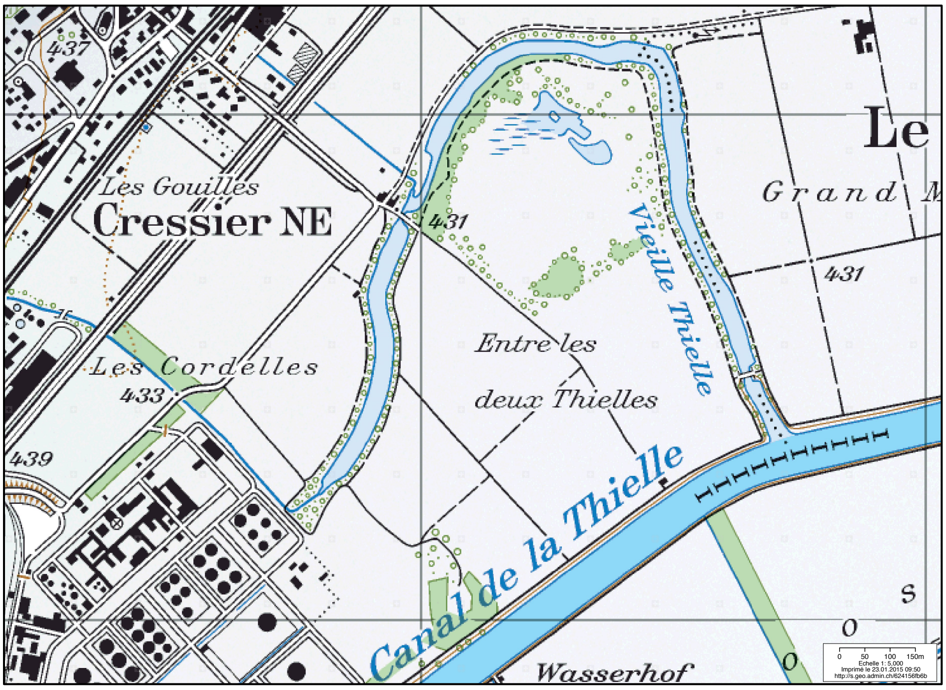


Fig. 5: Localization of the natural reserve of La Vieille Thielle in the canton of Neuchâtel, Switzerland (©Swisstopo).

Fig. 6: Orthophoto of the pond of the natural reserve of La Vieille Thielle in the canton of Neuchâtel, Switzerland (©Swisstopo).

3.3.3 Natural reserve of Jussy/Près-Bordon

The natural reserve of Jussy/Près-Bordon (46°15’8’’N, 6°16’52’’E) is located in the canton of Geneva between Jussy and the French border (Figure 7). Following renaturation work in 2009, ponds and marshes area of Près-Bordon were evaluated as being favourable to the European pond turtles (Gander, 2010). Displacement of reintroduced individuals (2010-2011) and temperatures of the nesting (2014) were studied in this location (Table 2).

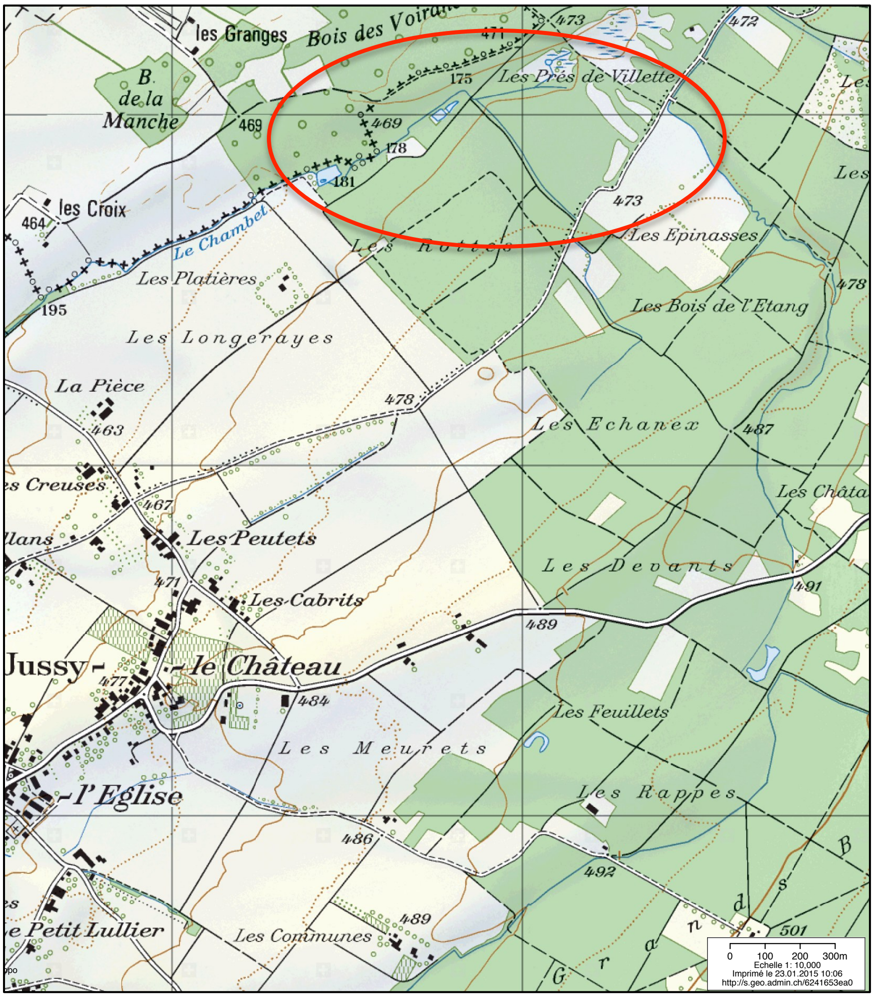


Fig. 7: Localization of the natural reserve of Jussy/Près-Bordon in the canton of Geneva, Switzerland (©Swisstopo).

The Figure 8 showed all the ponds from the natural reserve of Jussy/Près-Bordon in the canton of Geneva. The pond n°1 is called Rappes which is the biggest of the reserve and its average of water area is 2000m^2. The area n°2 is the marshes of Près-Bordon. Pond of Près-Bordon upstream (n°3) has an average of water area of 860m^2 and downstream (n°4) has an area of 1200m^2.

Fig. 8: Ponds of the natural reserve of Jussy/Près-Bordon in the canton of Geneva, Switzerland. (1) Rappes, (2) marshes of Près-Bordon, (3) Près-Bordon upstream and (4) Près-Bordon downstream (©DGNP).

3.3.4 Orzens

The pond is located in a private propriety in Orzens in the canton of Vaud, at an altitude of 623 meters (46°43’13’’N, 6°40’51’’E). The pond has two different water levels, one with a depth of 1m (hibernation site) and the other with a depth of 40-50cm, which is heavily vegetated (Figure 9). The water area is 15m^2. Tree trunks were placed at the edge of the pond in order to allow individual to bask. This site is considered as less favourable for the European pond turtle, hatchling in natural conditions were only possible during the very warm summer 2003. Body temperature of individuals (2014) and temperatures of potential nesting sites (2014) were studied (Table 2).

Fig. 9: Pond of Orzens, which is heavily vegetated (© Charlotte Ducotterd).

3.3.5 Menziken

The pond is located in a private propriety of Menziken in the canton of Argovie, at an altitude of 544 meters (47°14’39’’N, 8°11’30’’E). The pond of Menziken has a water area of 20m^2 the pond is heavily vegetated (Figure 10). Tree trunks were also placed at the edge of the pond in order to allow individual to bask. This site is also considered as a not favourable site such as in Orzens, hatchlings were only possible during the very warm summer in 2003. However, even if hatchlings are not possible, individuals are healthy and have a normal growth, similar for individuals located in Orzens. Body temperature of individuals (2014) was studied in this location (Table 2).

Fig. 10 : Pond of Menziken (©Hans Peter Schaffner).

3.3.6 Natural reserve of La Grande Cariçaie

Sites of Font (46°48’43’’N, 6°50’10’’E) and Châbles (46°49’44’’N, 6°48’10’’E) are located on the south shore of the Lake of Neuchâtel in the natural reserve of La Grande Cariçaie in the canton of Vaud and Freiburg, which have an altitude of 461 meters (Font) and of 478 meters (Châbles). The two sites, but more generally the whole natural reserve of La Grande Cariçaie could be potential favourable sites for the European pond turtles. Temperatures of potential nesting sites (2014) were studied in both locations (Table 2).

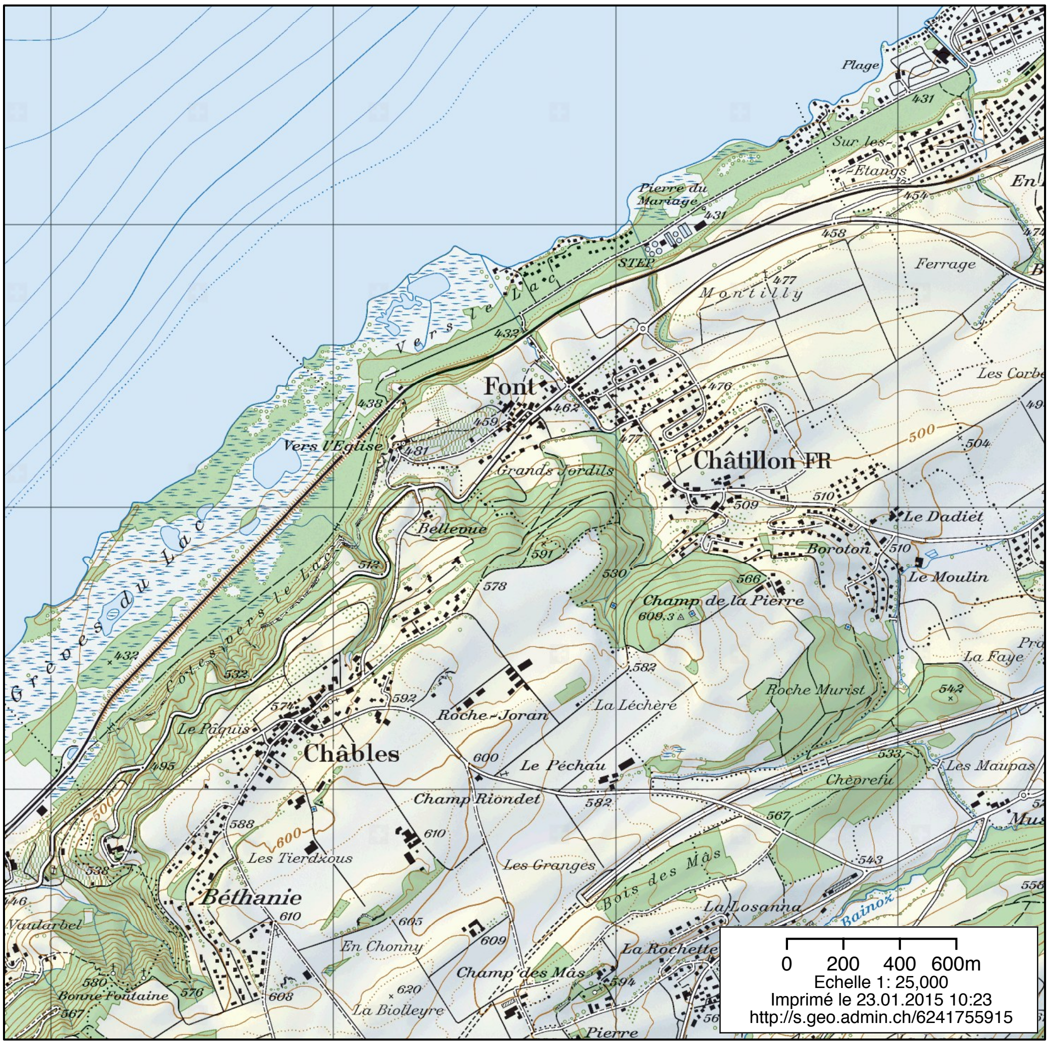


Fig. 11: Localization of site of Font and Châbles in the natural reserve of La Grande Cariçaie in the canton of Vaud and Fribourg, Switzerland (©Swisstopo).

3.4 Material

3.4.1 Telemetry data collection – localization and body temperature

Ten equipped individuals were release in May 2013 in the natural reserve of La Vieille Thielle. To compare thermic behaviour and habitat use between individuals from different habitats, ten additional turtles from Hainard pond in the natural reserve of Moulin-de-Vert were also equipped in August 2013, as well as two individuals from Orzens in May 2014 and from Menziken in July 2014 with similar transmitters. In the natural reserve of Jussy/Près-Bordon, ten individuals have been equipped before reintroduction in May 2010, Mattieu Reamy collected data in order to study habitat use (Table 2). Telemetry data, which were collected in Jussy/Près-Bordon, were analysed and used to compare behavior of individuals after reintroduction between Jussy/Près-Bordon and La Vieille Thielle.
In total, thirty-four R1100 reptile body implants (Advanced Telemetry Systems©, Isanti, Mennesota, USA), which weigh approximately 5 g, were glued with Araldit® to the front of turtle's carapace. All individuals equipped with transmitters weighed at least 100 grams, so the transmitters represent less than 5% of the total weight of the individual. After equipping individuals have been placed in a dry place during 1-2 days before release. Every transmitter was thermosensitive, thus, the rate of signal emission was a function of the transmitter temperature. Before glued, all transmitters have been calibrated in order to accurately calculate the temperature of each turtle during monitoring session. For the calibration, twenty pulses were timed for each transmitter at seven temperatures between 5 and 35°C. Between each calibration temperature, the transmitters were placed at the new temperature during about 60 minutes in order to give enough time to the transmitters to adjust to the new temperature. Then, a calibration curve was calculated for each single transmitter, allowing posterior evaluation of the body temperature (T_b) of each turtle throughout fieldwork season.

Individuals from La Vieille Thielle, Moulin-de-Vert and Orzens were located at remote distance using a lightweight portable scanning receiver Australia 26K (Tetley Scientific, Ballina, Australia) with an antenna. The same material was also used to determinate the T_b of each turtles. An advanced telemetry systems R4500S was used to determine T_b of two individuals in Menziken, canton of Argovie. The advanced telemetry system is an automatic system, which is used to monitor transmitters passing a site or presence/absence of transmitters. The time, frequency, transmitter pulse rate were stored and data were collected once in a month.

Telemetry data collection took place between March and October, which is the activity period of the European pond turtle. Once or twice per week, localization of individuals was made by triangulation using telemetry. When animals were found and localized, they were noticed on a map and exact geographic coordinate were determined late.
In La Vieille Thielle, Moulin-de-Vert and Orzens, the T_b of all individuals were taken once or twice per week, every hour following the last T_b recording, six times a day. As for the calibration, twenty pulses were counted each time. Time intervals were noticed on the field and real body temperatures were calculated later.

In order to compare T_b with the environmental temperature, the outdoor ambient temperatures were gathered using the closest weather forecast station of different study sites implemented by SwissMeteo.

3.4.2 Nesting sites

To measure and compare temperature of nesting sites and potential nesting sites in different locations of Switzerland, iButtons® (Maxim Integrated Products, Inc) were used. These dataloggers were placed in the soil at a depth of 8-10cm, which corresponds to the average depth of *Emys*'s nests and between late May to late September. Into the wild, the incubation period is of 98-117 days with an average temperature in the nest of 22.6 ° C (Fritz, 2001). iButtons recorded soil temperature and after data collection, we determine if the incubation temperature is reach in every locations.
iButtons were placed in the natural reserve of Jussy/Près-Bordon, Moulin-de-Vert, La Vieille Thielle, La Grande Cariçaie (Font and Châbles) and Orzens (Table 3). The varieties of locations assumed to be good enough for the hatchling, some unknows and some bad or suboptimals, iBouttons placed in the canton of Geneva, especially in the natural reserve of Moulin-de-Vert were considered as optimal for hatchling, because hatchling occurred each year in this location. Orzens was considered as the less favorable site because hatchling occurred in this site only during the very warm summer in 2003. The aim is to determine what is the optimal nesting site for the European pond turtle and determine in the reintroduction of *Emys* could be possible in other locations of Switzerland.

Sites	Description
Orzens	Less favorable site in a private propriety at an altitude of 623m
Font	Meadow of the natural reserve of La Grande Cariçaie (altitude of 461m)
Châbles	Embankment for the CFF, located in La Grande Cariçaie (altitude of 478m)
La Vieille Thielle 1	Meadow in the natural reserve La Vieille Thielle
La Vieille Thielle 2	Meadow in the natural reserve La Vieille Thielle
La Vieille Thielle 3	Mound in La Vieille Thielle, which heavily vegetated
Moulin-de-Vert 1	Near the observatory of Isles pond in the reserve of Moulin-de-Vert
Moulin-de-Vert 2	In the meadow between East pond and Hainard pond
Moulin-de-Vert 3	In the meadow between East pond and Hainard pond
Moulin-de-Vert 4	Slope under observatory of Hainard pond
Moulin-de-Vert 5	Slope on the right of the observatory of Hainard pond
Près-Bordon 1	Mound of Près-Bordon upstream in the fine gravel
Près-Bordon 2	Mound of Près-Bordon upstream in the large gravel
Près-Bordon 3	Edge of the downstream Près-Bordon pond (clayey soil)
Rappes 1	Down the mound near Rappes pond (gravel)
Rappes 2	Middle of the mound near Rappes pond (gravel)
Rappes 3	Top of the mound near Rappes pond (gravel)

Table 3: Description of sites where iBouttons were placed. Localizations of all studied nesting sites are showed on orthophotos on the Appendix 1.

3.4.3 Weight data collection

At the natural reserve of La Vieille Thielle, a capture session took place at the beginning of August 2014, in order to replace the transmitters and to weigh the individuals. This measurement allows evaluating the growth rate of each reintroduced individuals. In the natural reserve of Jussy/Près-Bordon, Céline Rochet also weighed the individuals in 2010 before the reintroduction and in 2011 after a capture session. In the natural reserve of Moulin-de-Vert, Denis Mosimann and Matthieu Reamy also weight the individuals between 2001 and 2012. The comparison will allow estimating the growth rate in two different reintroduction projects and compare the growth rate with an established population. Traps used during the capture session measure 4 meters and have nets with floats, which measure also 4 meters long and 58 centimeters high (Figure 12). Nets can fold individuals in the trap. In Neuchâtel, a total of 8 traps were placed in the part of the ponds where individuals were located.

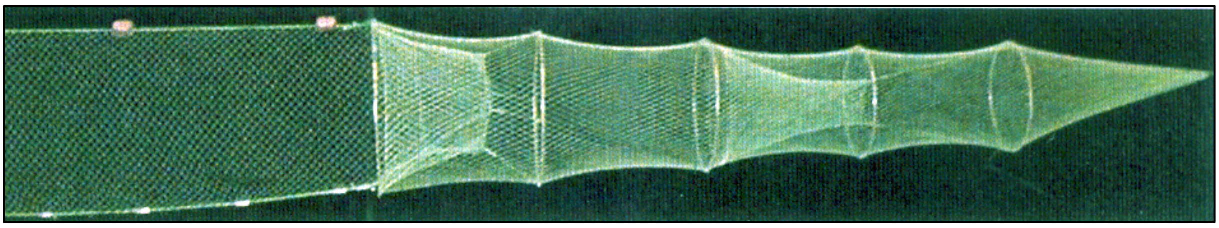


Fig. 12: Traps used during the capture session. A net guides individuals into a funnel that leads individuals in the traps. Once in the trap, individuals cannot go back and are forced to move further into the trap, in order to breathe in the part of the trap, which remains out of the water.

3.5 Statistical analyze

3.5.1 Displacements and home range

Distances traveled (m) and home ranges size (m^2) of each individual were calculated on QGIS. The normal distribution of variable was checked with a Shapiro-Wilk. In order to determine if the individuals moved after their first year of settlement, I compared home range size between 2013 and 2014 with a Two Sample t-test. Analysis for home ranges was calculated over the same period of time for two years (only June to October). Maximum distances traveled of the reintroduced individuals of La Vieille Thielle in 2013 and 2014 were compared to the distances traveled of the reintroduced individuals of Jussy/Près-Bordon in 2010 and 2011 with a Wilcoxon rank test in order to compare behavior after reintroduction. Maximum distances traveled of individuals from Jussy/Près-Bordon were taken from the report of the monitoring of reintroduced individuals in Jussy/Près-Bordon in 2010-2011 (Reamy, 2013).

3.5.2 Growth rate

The equality of variance was checked with a Fisher test and the normal distribution of the variable with a Shapiro-Wilk test. In order to determine if individuals reintroduced in La Vieille Thielle had a similar growth than reintroduced individuals of Jussy/Près-Bordon and if individuals from La Vieille had a similar growth rate than individuals of an established population (Moulin-de-Vert), growth rate of each individuals were compared between individuals with a similar weight (100-220gr) with a generalized least squares test (GLS). Growth from individuals from Moulin-de-Vert was measured between 2001 and 2012, individuals from Jussy/Près-Bordon between 2010 and 2011 and finally individuals from La Vieille Thielle between 2013 and 2014.

3.5.3 Body Temperature

In the natural reserve of La Vieille Thielle, to determine if the body temperature (T_b) of each reintroduced individual had an influence on their displacements, means T_b were analyzed with the home range size and distances traveled of individuals in 2013 and 2014 with a coefficient of Person's. In order to determine if the weigh of individuals had an influence on their T_b, I also used a coefficient of Person's.

The equality of variance was checked with a Bartlett test and the normal distribution with a Shapiro-Wilk test. To analyze if the means T_b of individuals from La Vieille Thielle between 2013 and 2014 was similar, means T_b of each individuals of 2013 and 2014 were compared with a Two Sample t-test.

To compare T_b of individuals in 2014 located in four different locations of Switzerland, I used model validation through graphical tools (Zuur et al. 2009). To allow defining both exploratory and categorical data, I used a generalized additive model (GAM). The best model was selected using a cross validation. Then the model was evaluated according to a combination of R2 and cross validation metrics. This will produce more robust models with better predictive powers (Zuur et al. 2009). Then means T_b of individuals from La Vieille Thielle and Moulin-de-Vert were compared during the same period of time (Mars-October 2014) with a Two-Samples t-test. As previously, the equality of variance was checked with a Bartlett test and the normal distribution with a Shapiro-Wilk test. In order to determine if individuals from the four studied locations (La Vieille Thielle, Moulin-de-Vert, Menziken and Orzens) had a similar T_b, means T_b of each individual were compared between the same period of time (end of July to end of August 2014) with a generalized least squares (GLS) with weights because the four groups were not homogeneous. In order to compare thermoregulation of individuals in each studied location, the Δt, which was difference between body temperature of each individual and outside temperature, was calculated and compare with an Analysis of variance (ANOVA).

3.5.4 Nesting sites

The sum of daily temperatures, calculated according to the model of Norbert Schneeweiss, showed sufficient and optimal temperature for hatchling (Schneeweiss, 2004).
Successful embryonic development of the European pond turtle takes place between 18 and 33°C (Schneeweiss, 2004). Embryonic development does not profit or is even disturbed by temperatures exceeding 33°C (Vasse, 1983), a temperature that is rarely reached in Switzerland nests.
Based on these observations, a mathematical model was designed to predict hatching success. Probability of hatching success is measured by the temperature sum which is defined as the sum of the differences between the recorded temperature (or the upper limit) and the minimum limit 18°C. Thus, the temperature sum uses all measurements of soil temperature above 18°C and below an upper limit that is set with 33°C for the incubation start (Schneeweiss, 2004).

The formula is as follows:

$$WSum_n = WSum_{(n-1)} + \bar{t}_n * f(T_n, OS_n, US)$$

$$f(T_n, OS_n, US) = \begin{cases} OS_n - US & T_n > OS_n \\ T_n - US & US \le T_n \le OS_n \\ 0 & T_n < US \end{cases}$$

$$OS_n = 34\,^{\circ}\mathrm{C} - \mathrm{e}^{WSum_{(n-1)}/200}$$

$$WSum_0 = 0$$

$$US = 18^{\circ}C$$

$WSum_n$: temperature sum for *n* measurements during incubation period.
t_n: frequency of measurement
T_n: *n* temperature measurements (in °C)
OS_n: maximum temperature limit for *n* measurements (in °C)
US: minimum temperature limit (18°C)

The obtained temperature sums WSumn allow to assess the suitability of nesting sites, and to predict hatching success for individual clutches according to climatic and local nesting site conditions. The temperature sums of each sites located in Switzerland were calculated using the following formula on Microsoft ® Excel 2011.

To determine if temperature sums of nesting sites was similar in each location, I used a Shapiro-Wilk test. The homogeneity of variance was checked with Bartlett test. To show that sites located in the canton of Geneva (Moulin-de-Vert, Rappes and Près-Bordon) were similar, I compare temperature sums for sites from Geneva with an analysis of variance (ANOVA). To determine if sites from the natural reserve of La Vieille Thielle were similar to sites in the natural reserve of La Grande Cariçaie and Orzens, I compare temperature sums of La Vieille Thielle with each site with a One Sample t-test. To explain the insufficient temperature sums in the nesting sites locations in the natural reserve of La Vieille, I intend to determine if the summer 2014 was colder than the ten previous summers with a generalized least squares (GLS) and a Wilcoxon signed-rank test.

All statistical analyzes were conducted on R 2.10.0 (R Development Core Team (2008), Vienna, Austria).

4. Results

The main information about the different characteristics of the released individuals in the natural reserve of La Vieille Thielle, as well as the evaluated home range size (m^2) and distances traveled (m) between the locations are presented in the Table 3 and Table 4.

				Year 2013 June-October 2013		Year 2014 Mars-October 2014	
N°	Individuals	Weight (gr) 2013	Weight (gr) 2014	Distance (m)	Home range (m^2)	Distance (m)	Home range (m^2)
1	148.021	150	205	57.3	113.5	284.3	1019.5
2	148.452	118	169	191.1	394.5	368.8	1036
3	148.472	109	-	117.5	106.5	386.9	1247.5
4	148.490	320	-	135.1	275.5	435.5	1619.5
5	148.492	164	276	133.2	301	383	1219
6	148.511	123	-	115.7	144	473	1189
7	148.512	213	-	166.1	222	431.4	1040.5
8	148.553	113	-	201.9	742.5	281	532
9	148.604	162	234	89.9	123	360.9	1174.5
10	148.605	404	-	178.1	366	461.7	778.5

Table 3: Summary of data collected on individuals of La Vieille Thielle between 2013 and 2014. Some individuals (3-4-6-7-8 and 10) were not captured during the capture session in August 2014; therefore their new weigh is unknown. The distance traveled (m) is the sum of all distances measured between two localizations, which were taken once or twice per week.

N°	Individuals	Means T_b 2013 (°C)	Means T_b 2014 (°C)
1	148.021	19.6 ± 1.05	19.4 ± 0.56
2	148.452	16.8 ± 0.86	18.2 ± 0.54
3	148.472	18.9 ± 1.12	19.2 ± 0.51
4	148.490	19.3 ± 1.06	21.9 ± 0.51
5	148.492	19.4 ± 1.10	19.4 ± 0.54
6	148.511	15.9 ± 0.97	15.3 ± 0.50
7	148.512	15.4 ± 0.91	16.2 ± 0.59
8	148.553	18.8 ± 1.14	19.6 ± 0.58
9	148.604	20.8 ± 1.41	18.2 ± 0.66
10	148.605	19.4 ± 1.04	18.8 ± 0.50

Table 4: Summary of means T_b 2013 and 2014 of individuals reintroduced in the natural reserve of La Vieille Thielle.

4.1 Displacements and home ranges size

One of the aims of my project was to determine if individuals from La Vieille Thielle had the same behavior (displacements, habitat use) than individuals from Jussy/Près-Bordon after reintroduction.

In general during the first year after release, all individuals reintroduced in the natural reserve of La Vieille Thielle have mainly stayed in the eastern part of pond, and moved around the reintroduction area (Figure 13), individual n°1 had the smallest distance traveled, with a distance of 57.3 meters and individual n° 8 had the biggest distance traveled, with a distance of 201.9 meters. None of them left to explore other part of the pond. After cutting the reed zone in the South part of the pond, all individuals, unless the individual n°8, have moved together in this open sunny and shallow area. It was then possible to visually observe several individuals (individuals n° 9 and 10).

Fig. 13: Localization in 2013 of all *Emys orbicularis* individuals released in May 2013 in the pond of the natural reserve of La Vieille Thielle. Individuals stayed in the eastern part of the pond. Red cross = Reintroduction site.

In 2014, all individuals were mainly stayed in the same part of the pond (Figure 14). They stayed in the eastern part of the pond. However, the distances traveled and home ranges size of all individuals increased significantly (Two Sampled t-test: p-value = 0.0033). Statistical analysis for home ranges size was performed over the same period of time for two years (June to October). Individual n°8 had the higher distances traveled and home range size in 2013 (distance: 201.9 meters and home range: 742.5 m^2) and the smaller distance traveled and home range size in 2014 (distance: 281 meters and home range: 532 m^2).

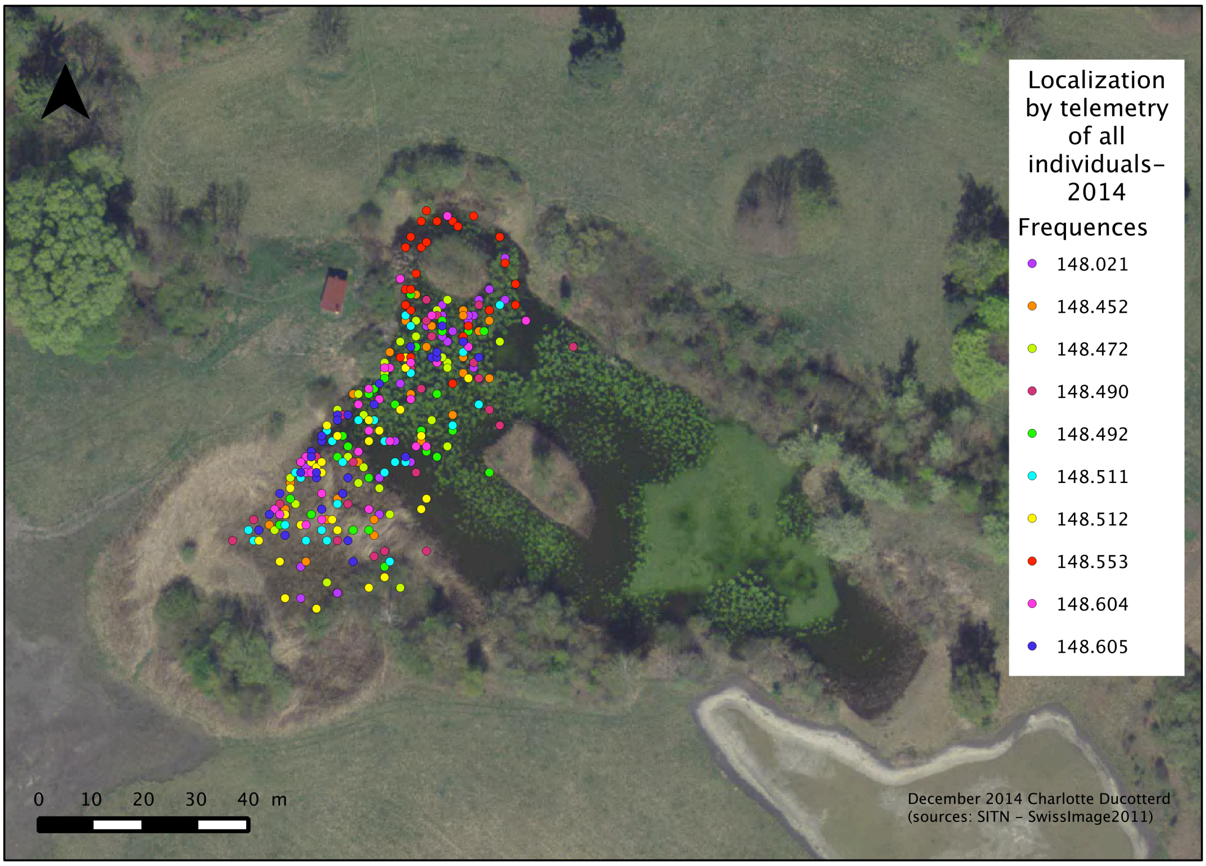


Fig. 14: Localization in 2014 of all *Emys orbicularis* individuals released in 2013 in the pond of the natural reserve of La Vieille Thielle. Individuals mainly stayed in the eastern part of the pond. However, their traveled distances and vital ranges increased compare to 2013.

Distances traveled and home ranges 2013-2014 of all individuals from La Vieille Thielle are shown in the Table 3. Appendix 3 and 4 present home ranges placed on orthophotos of all individuals from La Vieille Thielle in 2013 and 2014.

During the first year after reintroduction in the natural reserve of Jussy/Près-Bordon, all reintroduced individuals mainly stayed in Près-Bordon downstream pond. However, they have many displaced in the pond (Figure 15).

Fig. 15: Main localizations in 2010 of all *Emys orbicularis* individuals released in 2010 in the pond of Près-Bordon in the natural reserve of Jussy/Près-Bordon in the canton of Geneva (©swisstopo).

One year after the reintroduction, for 10 individuals localized in September 2011, only two individuals remained in the pond where they were introduced, while 2 moved to Près-Bordon upstream, 4 moved between Près-Bordon in the flood area and finally, 2 left the release site to reach others sites located several hundred meter (300-1000m) (Rappes pond and Près de Villette marsh, Figure 16).

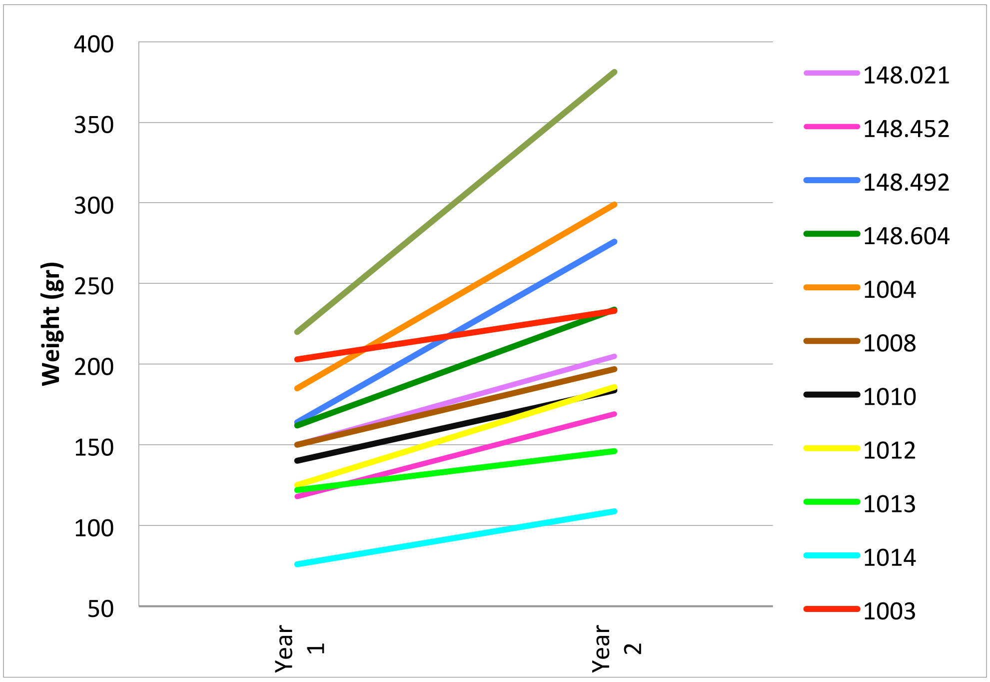
Fig. 16: Main localization in 2010 of all *Emys orbicularis* individuals released in 2010 in the pond of Près-Bordon in the natural reserve of Jussy/Près-Bordon in the canton of Geneva. Individuals moved in the marshes of Près-Bordon and to the Rappes pond (©swisstopo).

Main displacements of individuals reintroduced in the natural reserve of Jussy/Près-Bordon are shown in the appendix 2.

In order to compare distances traveled in both reintroduction locations, only maximum distances traveled between two localizations were compared. Maximum distances traveled of individuals from Jussy/Près-Bordon during the first year after reintroduction were not significantly different than maximum traveled distances of individuals from La Vieille Thielle (means max distances traveled: Jussy: 33.55m and Vieille Thielle: 25.02m; Wilcoxon rank test, p-value=0.0947). The behavior of individuals from Jussy was more explorative than individuals from La Vieille Thielle and maximum distances traveled by individuals from Jussy/Près-Bordon were significantly higher (means max distances traveled: Jussy: 130.73m and Vieille Thielle: 40.43m; Wilcoxon rank test, p-value=0.0947). Individuals from La Vieille Thielle stayed in the same part of the pond and even if their distances traveled and home ranges increased in 2014, they did not explore the entire pond while individuals from Jussy have explored the entire pond during the first year.

4.2 Growth rate

During the capture session in La Vieille Thielle in August 2014, 4 of the 10 individuals were captured during the week. They were measured, weight (Table 2) and equipped with a new transmitter. The aim was to determine if the growth rate of individuals of La Vieille Thielle was similar than reintroduced individual of Jussy/Près-Bordon.



Graph 1: Weight curve of individuals of La Vieille Thielle (148.021, 148.452, 148.492 and 148.604) and Jussy/Près-Bordon (1003, 1004, 1007, 1008, 1010, 1012, 1013, 1014). Year1 means the date of reintroduction and Year2 is the date of capture. In Jussy/Près-Bordon, individuals were reintroduced in 2010 and capture in 2011 and individuals were released in 2013 and captured in 2014.

The means growth rate in La Vieille Thielle calculated between the release in June 2013 and the recaptures (August 2014) was 48.15%. This growth rate was for more than one year (from May 2013 to August 2014). The individual 148.021 was released on 1st August 2013 because of its health problems. Its growth year for one year is exactly 36.61% (Graph 1).

The means growth rate of individuals released in Jussy/Près-Bordon (with a similar weight compare to La Vieille Thielle) was 40.53% from 2010 to 2011 and for individuals from Moulin-de-Vert (with a similar weight compare to La Vieille Thielle) was 37.65%. The difference between growth rates was not significant between the two reintroductions locations (GLS: p-value=0.4550) but the difference was significant between individuals from La Vieille Thielle and Moulin-de-Vert (GLS: p-value=0.0018).

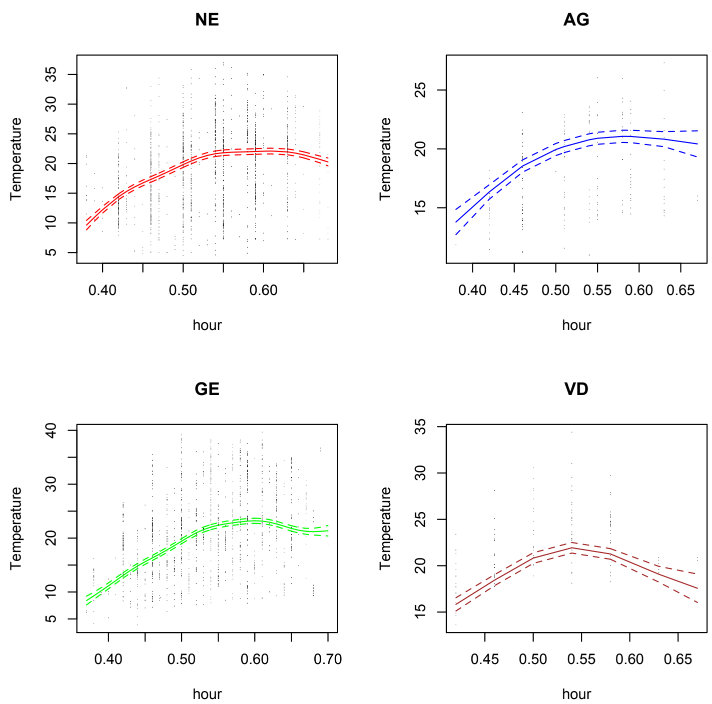
4.3 Body temperature

The aim of this part of the project was to determine if individuals from different locations in Switzerland had the same mean body temperature and how body temperature affects their activity patterns.

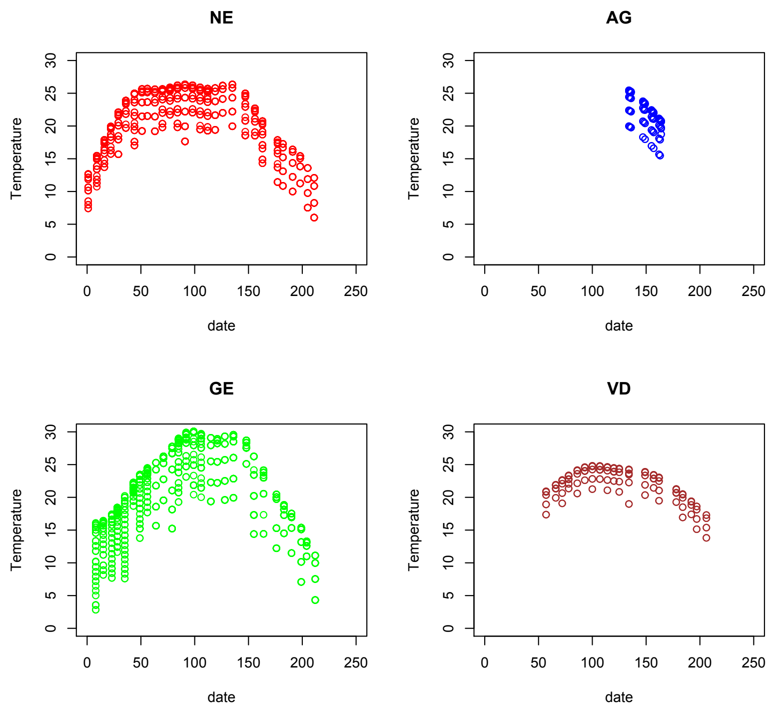
Concerning individuals from La Vieille Thielle, no impact of the body temperature on the distance traveled in 2013 (coefficient of Pearson's correlation; corr=-0.37, p-value=0.2813) and in 2014 (coefficient of Pearson's correlation; corr=-0.35, p-value=0.3164). No correlation was found between individual's weight and body temperature (coefficient of Pearson's correlation; corr=0.21, p-value=0.5527) and between the home range size and body temperature (coefficient of Pearson's correlation; corr=0.11, p.value=0.6606); The hypothesis, which assumed that individuals with a smaller body temperature had a higher traveled distance during the season, could be rejected.

The difference of outside temperature between the summer 2013 and 2014 in Cressier (the closest weather station to the natural reserve of La Vieille Thielle) was not significant (Wilcoxon signed-rank test: p-value=0.7). A two Samples t-test demonstrated that the means body temperature of individuals from La Vieille Thielle was not significantly different between 2013 and 2014 (mean T_b: 2013 – 18.43°C and 2014 – 18.63°C, p.value = 0.9611). The hypothesis of equal temperature in 2013/14 cannot be rejected.

The mean body temperature of individuals from different locations were plotted in 4 different graph to demonstrate temperature range reached by individuals throughout a day's time (Graph 2) and during the year (Graph 3). Results for the cross validation validated the best model (corr. value=0.7513, R^2-adjusted=0.5646).



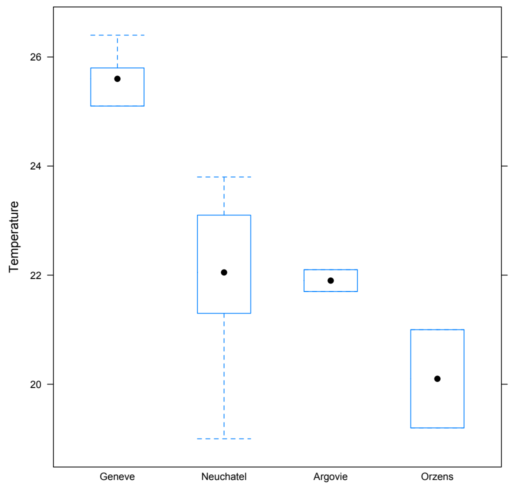
Graph 2: Variation of body temperature in 2014 through a day's time of individual from La Vieille Thielle (NE), from Orzens (VD), from Menziken (AG) and Moulin-de-Vert (GE). Data were collected between 9h and 17h (X scale: 0.40=9h30, 0.50=12h, 0.60=14h30, 0.70=17h) from Mars to October 2014 for individuals from Moulin-de-Vert and La Vieille Thielle, from May to October 2014 for individuals from Orzens and finally from the end of July to October 2014 for individuals from Menziken.



Graph 3: Variation of body temperature during all the season 2014 of individuals from La Vieille Thielle (NE), from Orzens (VD), from Menziken (AG) and Moulin-de-Vert (GE). In La Vieille Thielle and Moulin-de-Vert data were collected from Mars to October 2014. In Menziken data were collected from end of July to end of August 2014 and in Orzens form May to October 2014. (Scale: 0=Mars, 100=July, 150=August and 200=October).

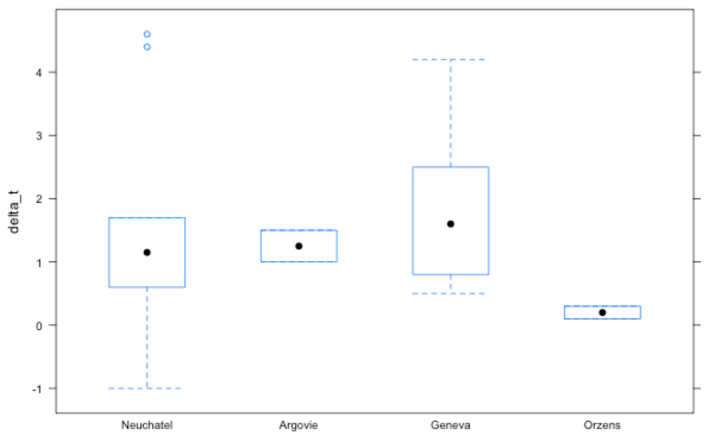
The difference of body temperature during the year 2014 of individuals from La Vieille Thielle and Moulin-de-Vert was significant (two Samples t-test: p-value=0.0009815) with a means body temperature of 18.63°C for individuals from La Vieille Thielle and a means body temperature of 21.52°C for individuals from Moulin-de-Vert.

In order to compare body temperature in the 4 different locations, analyzes were made during the same period of time, from the end of July until the end of August 2014 (Graph 4). Similarly to the results with the complete dataset, the difference of body temperature in this limited period was significant between La Vieille Thielle and Moulin-de-Vert (means T_b: GE 25.6°C and NE 21.9°C; p-value<0.0001). The difference between individuals from Menziken and La Vieille was not significant (means T_b: AG 21.9°C; p-value=0.898) and finally individuals from La Vieille Thielle had a higher body temperature than individuals from Orzens but the difference was not significant (means T_b: VD 20.1°C; p-value=0.0931).



Graph 4: Boxplot of the means T_b of individuals from Moulin-de-Vert (Geneva), La Vieille Thielle (Neuchatel), Menziken (Argovie) and Orzens. Data were analyzed from the same period of time from the end of July to the end of August 2014. Individuals from Moulin-de-Vert had a significantly higher T_b than individuals from La Vieille Thielle. Means T_b from individuals from La Vieille were not significantly different from the means T_b of individuals from Menziken and Orzens even if T_b from individuals reintroduced in La Vieille Thielle were higher.

In order to analyze thermoregulation of individuals in different location of Switzerland, Δt of each individual were compare (Graph 5). The thermoregulation (Δt) of individuals from La Vieille Thielle (means Δt=1.41°C ± 1.86) was not significantly different from individuals from Moulin-de-Vert (means Δt=1.80°C ± 1.21; ANOVA: p-value=0.8350), from individuals from Menziken (means Δt=1.25°C ± 0.35; ANOVA: p-value=0.1051) and from Orzens (means Δt=0.20°C ± 0.14; ANOVA: p-value=-0.949).

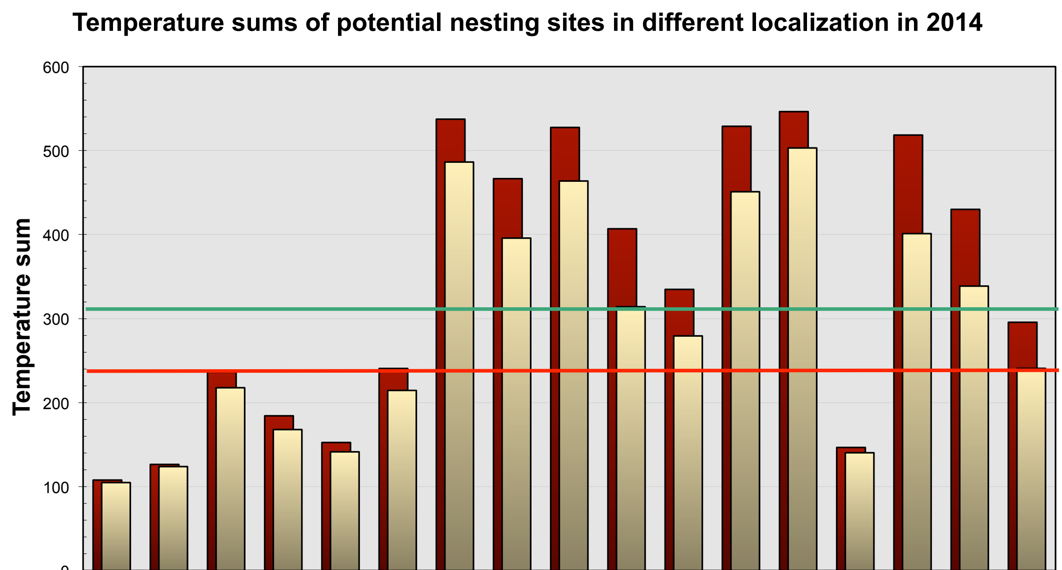


Graph 5: Boxplot of the delta t (difference between the T_b and the outside temperature) of individuals from the four studied locations. Even if delta t from individuals from Moulin-de-Vert was higher, the difference was not significant. (La Vieille Thielle=Neuchâtel, Menziken=Argovie, Moulin-de-Vert=Geneva).

4.4 iBouttons in nesting sites

The goal of using iBouttons was to show the difference of temperature between different nesting sites or potential nesting sites located in different areas of Switzerland and determine if eggs could potentially hatch in each site.

The temperature sums of nesting sites are illustrated in the graph 6. On the graph, the red line represented the limit temperature for hatchling, which means hatchling is possible and the green line corresponds to an optimal temperature for hatchling. Temperature curves were also plotted for each nesting sites (Appendix 5).

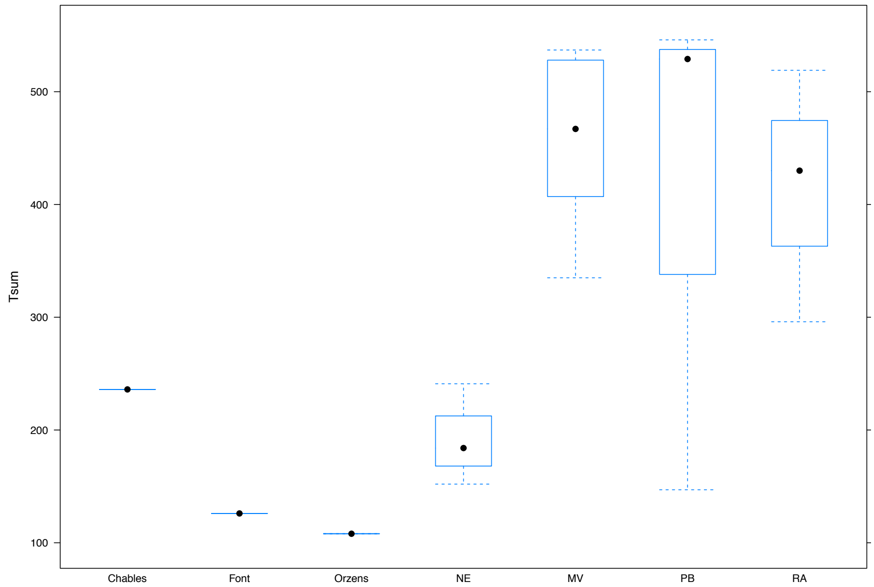


Sites	Orzens	Font	Châbles	NE_1	NE_2	NE_3	Moulin-de-Vert_1	Moulin-de-Vert_2	Moulin-de-Vert_3	Moulin-de-Vert_4	Moulin-de-Vert_5	Près-Bordon_1	Près-Bordon_2	Près-Bordon_3	Rappes_1	Rappes_2	Rappes_3
Tsum 1.6.-30.9.11	108	126	236	184	152	241	537	467	528	407	335	529	546	147	519	430	296
Tsum 1.6.-31.8.11	105	124	218	168	141	214	486	396	464	314	279	451	503	140	401	339	241

Graph 6: Temperature sums of nesting sites located in different areas of Switzerland. Temperature sums were calculated between the 1st June until the 31th August 2014 and the 1st June until the 30th September 2014. Red line=hatchling is possible and green line=hatchling is optimal.

The temperature sums of Orzens, Font, Près-Bordon 3 and on the meadow of La Vieille Thielle (NE_1 and NE_2) did not reach the red line, which means hatchling was not possible in 2014. The results showed that in Châbles and on the mound of La Vieille Thielle (NE_3) hatchling could be possible at the end of September 2014 but not certain. All other sites reached or exceeded the red line and some of them exceed the green line (all sites from the canton of Geneva, expected Près-Bordon_3, which was placed in an unfavorable sites), which means hatchling is certain.

Globally, sites of Moulin-de-Vert, Près-Bordon and Rappes, all located in the canton of Geneva, were significantly similar (ANOVA, p-value= 0.135, Graph 7).



Graph 7: boxplot of temperature sums of all potential nesting sites grouped by region. Sites from the canton of Geneva were significantly similar but different from the other sites. (MV=Moulin-de-Vert, NE=La Vieille Thielle, PB=Près-Bordon and RA=Rappes).

However, the difference of temperature sums between sites located in the canton of Geneva and other locations (La Vieille Thielle, Châbles, Font and Orzens) was significant (Two Sample t-test, p-value = 0.0003). Moreover, the difference of temperature sums was not significant between La Vieille Thielle and Châbles (One Sample t-test, p-value=0.2354), between La Vieille Thielle and Orzens (One Sample t-test, p-value=0.0835), and finally between La Vieille Thielle and Font (One Sample t-test, p-value=0.1256).

5. Discussion

Displacements and home range size

The monitoring since 2013 showed that released individuals from Jussy/Près-Bordon and La Vieille Thielle had similar maximum distance traveled during the first year after reintroduction and during the second year, individuals from La Vieille Thielle had a less explorative behavior than reintroduced individuals from Jussy/Près-Bordon. One hypothesis to explain why individuals from Jussy/Près-Bordon had a more explorative behavior is that sites of the natural reserve of Jussy/Près-Bordon were revitalized just before the reintroduction of individuals in 2010. Consequently, these ponds did not have a lot of vegetation. During the first year, all individuals moved a lot in the pond, perhaps they had to explore to find their food. The year after some of them left the reintroduction sites. On the opposite individuals of La Vieille Thielle were reintroduced in a highly vegetated environment. Therefore, they mainly stayed in the same part of the pond; we can assume that they need to do less displacement in order to find their food. Even if individuals from La Vieille Thielle were reintroduced in a better environment (highly vegetated) than individuals from Jussy/Près-Bordon, individuals reintroduced in both locations had a shy behavior during the first year. Then individuals from both reintroduction sites developed a colonizing behavior, which was significantly higher in individuals from Jussy/Près-Bordon, during the second year after reintroduction in order to find the optimal place to live. This dispersal could help to avoid competition for food and basking sites. We can assume that individuals reintroduced in a favorable environment will have a less explorative behavior than individuals reintroduced in a less favorable site.
Outside of Switzerland, European pond turtles were reintroduced in the natural reserve of Bagnas (France) in July 2008. In total 29 European pond turtles have been reintroduced, with 10 individuals from the marshes of Vigueirat (Camargue, France) and 19 individuals from Aigues-Mortes (Camargue, France). They were monitored by telemetry during the two years after their reintroduction. On the opposite to Swiss reintroduction programs, all individuals were adults. Results demonstrated that individuals had a more explorative behavior during the first year after reintroduction. Some individuals left the reintroduction site. Then during the second year, home range sizes were smaller. The assumption was consequently that European pond turtle had a more explorative behavior during the first in order to find the best site to live (Demay, 2008; Bugot, 2009). The observations in Switzerland were inverse, and my hypothesis to explain the completely opposite behavior is that individuals were all adults; therefore they had more explorative behavior in order to find a partner to reproduce.
In Lake Bourget (France), 35 adults European pond turtle were reintroduced in three groups between 2000 and 2002 in a complex of two ponds near the Lake, they were also monitored by telemetry but only for one year after reintroduction. Results demonstrated that most individuals stayed the whole year within the site of reintroduction and that several individuals (mostly females) explored part of Lake Bourget (1-6 km distance from the releasing site) (Cadi, Miquet, 2004).
While individuals from La Vieille Thielle and Jussy/Près-Bordon were almost all juveniles and they had less explorative behavior because they did not need to find a partner to reproduce or a favorable nesting site for the female but only explore to find their food and potentially they had a shyer behavior than adults because of the risk of predation on the juvenile

individuals. To conclude, we can assume that for settling indiviuals at the reintroduction site, reintroduction of juveniles or subadults is optimal. In the other hand, reproduction will occured later than with reintroduction of adults individuals.

Growth rate and body temperature

Brown et al. (1994) compared temperature selection and growth between two populations of the common snapping turtle (*Chelydra serpentina serpentina*) occupying habitats with different thermic patterns in Ontario, Canada. They predicted that individuals in a favorable thermic site would grow faster, select warmer temperatures than individuals in a less favorable thermic habitat. As they expected, turtles in the favorable thermic habitat grew more rapidly and had a higher reproductive output than those in the less favorable habitat. Turtles maintained higher body temperatures at the more favorable site, but this may be related to higher ambient temperatures than active selection of higher temperatures (Brown et al. 1994).
In this context, I expected that the growth rate from individuals of Jussy/Près-Bordon and from Moulin-de-Vert, which were considered as the most favorable places, would be significantly higher than individuals from La Vieille Thielle. But, the difference in growth rate was not significant between individuals from La Vieille Thielle and Jussy/Près-Bordon and individuals from La Vieille Thielle had a significantly higher growth rate than individuals from Moulin-de-Vert. In these three sites, the increase in weight was very important because captured individuals were all subadults or juveniles. When individuals become adults, the weight gain is expected to be minimal. The growth rate of individuals of individuals from La Vieille was similar or higher than individuals from the canton of Geneva. Even individuals from less favorable environment such as Orzens and Menziken had an optimal growth rate. This result could be explained by the thermoregulation patterns of each individual. Reptiles generate negligible amounts of body heat and have limited physiological control over body temperature; they regulate their body temperature largely through habitat selection and behavior (Dubois et al. 2009). The benefit of thermoregulation is the improvement in physiological performances such as locomotry (Weatherland, McCraken, 2003) and energy intake (Niu et al. 1999). Two costs of thermoregulation are predation risk (Huey, 1982) and the reduction in time for other activities such as foraging (Huey, Slatkin, 1976).
Concerning body temperature of studied individuals, individuals from Moulin-de-Vert, which is considered as the most favorable site for the European pond turtle, had a significantly higher body temperature than individuals from other studied locations of Switzerland (the natural reserve of La Vieille Thielle and the private pond of Menziken and Orzens). However, the Δt, which the difference between the body temperature of each individual and the outside temperature, was not significantly different even if some locations were considered as less favorable place such as Orzens. Knowledge pertaining to thermoregulation behavior can help to better understand the activity patterns of the European pond turtles in different location of Switzerland. To conclude even if individuals lived in less favorable environment, they managed to reach an optimal temperature to have a normal growth rate. These results demonstrated that individuals could live and growth normally in environment considered as less favorable.

A study conducted by Lefevre and Brooks (1995) on the painted turtles (*Chrysemys picta*) concluded that the difference of daily time spent basking and therefore the difference in body temperature was not significantly different between males and females. In this study, basking of male and female pained turtles may be similar because the energetic costs of males and females are not different, or because basking is not used primarily to maximize rates of digestion and assimilation, but rather to attain an optimum temperature for foraging and other activities (Lefevre et al., 1995)

For individuals located in the natural reserve of La Vieille Thielle, no correlation was found between body temperature and weigh and between body temperature and the size of the home range. We can assume that body temperature of individual is correlated with the sex (male or female). However, this hypothesis was not possible to test on the individuals reintroduced in La Vieille Thielle because seven of the ten reintroduced individuals were juveniles. I supposed that juveniles basked for a shorter period than adults, due to faster heating or possibly due to a more fearful behavior which make them return to the water faster when juveniles are disturbed because of higher risk of predation.

Nesting sites

Schneeweiss (2004) showed that incubation success depends at the northwestern border of the range of the European pond turtle on favorable climatic conditions, particularly on sufficient sunshine periods. However, the temperature sums corresponding to certain developmental embryonic stages or hatchling success could be influenced by others factors (Schneeweiss, 2004). Indeed, excessive humidity level (due to rain) at the end of the incubation period could be a huge problem. Eggs imbibed with water and may explode (Schaffner, Kutzli, 2010). Others studies demonstrated the importance of humidity level in embryonic development process. For example eggs of *Trachemys scripta elegans* or *Graptemys spp* have a longer incubation period when the nest is located in a humid site (Janzen et al. 1995; Tucker, Warner, 1999). On the other side, eggs of *Chelodina rugosa* have a smaller incubation period and newborns have a smaller size when the nest is located in a very humid environment (Kennett et al. 1998).
Hans Peter Schaffner and Markus Kutzli (2010) studied different potential nesting of the European pond turtle in Switzerland. Their results showed that a means temperature of 25°C is favorable for the nesting sites. Under 15-18°C, the embryonic development stopped and temperature higher than 35°C are tolerated during a few days. Females are generally adapted to the climate of their area. Indeed, Hans Peter Schaffner observed three captive females, which came from different origin, lay eggs on the same day. While the female of the haplotype IIa (corresponding to the European pond turtle released at the natural reserve of La Vieille Thielle and Jussy/Près-Bordon) chose a nesting site with a few vegetation, the two others females from southern Europe chose to lay eggs in the shade of tall grasses.
In Switzerland, the limiting factor to future reintroduction and for the survival of European pond turtle is the temperature of nesting sites (Schaffner, Kutzli, 2010). Indeed, all individuals from the different studied locations (the natural reserve of La Vieille Thielle, Moulin-de-Vert, Jussy/Près-Bordon and from private ponds in Menziken and Orzens) managed to reach a correct body temperature for their development demonstrating by a similar growth rate and a Δt even in site considered as less favorable. Effectively, the nesting

of the Moulin-de-Vert and Jussy/Près-Bordon were found to be optimal nesting for the European pond turtle but unfortunately in the other sites, the hatchling could only be possible on the mound of La Vieille Thielle and Châbles but impossible in the others sites in 2014. In the pond of Orzens, natural hatchlings were only observed during the very warm summer 2003 and similarly for the pond of Menziken. These two sites are located at an altitude higher than 500m. Even if the weather seemed bad this summer in Cressier (canton of Neuchâtel), it was not significantly colder than the ten previous summers; therefore hatchling in the mound of La Vieille Thielle could only be possible but not sure. The limited amount heat accumulated in the nests could be due to too heavily developed vegetation on the mound. Bushes, tall grasses trapped heat from the sun (Schaffner, Kutzli, 2010). In the natural reserve of La Vieille Thielle, the mound was covered with tall grasses and nettles (*Urtica dioica*). In order to favor hatchlings in the natural reserve of La Vieille Thielle, the mound must be maintained and the vegetation removed and replaced with sand and clay or leans ground such as the mound found in the natural reserve of Jussy/Près-Bordon. Concerning sites located in the natural reserve of La Grande Cariçaie, the mound of Châbles and the meadow of Font are also too heavily vegetated. There, maintenance of mound and meadow would be important in order to promote possible future the reintroduction of the European pond turtle in the natural reserve of La Grande Cariçaie. Cadi et al. (2002) demonstrated the efficiency of the maintenance of artificial nesting sites in Lake Bourget.
However, more studies need to be conduct on the nesting site located in the mound of the natural reserve of La Vieille Thielle after maintenance and in other potential nesting sites of Switzerland before reintroduction, maybe in including the measure of the humidity in addition to the temperature or by using a portable weather station in order to measure solar exposure. However, if nesting sites are located on well-drained sandy and south facing slopes, the influence of humidity is perhaps not too important (Schneeweiss 2002).

6. Concluding remarks

These results could be use to improve the reintroduction and conservation of the European pond turtle in Switzerland. I demonstrated that body temperature was different in every studied location and significantly higher for individuals from the natural reserve of Moulin-de-Vert. However, the Δt of individuals was similar in every studied location and the growth rate of individuals from La Vieille Thielle and Jussy/Près-Bordon was similar and individuals from La Vieille Thielle had a significantly higher growth rate than individuals from Moulin-de-Vert, which was considered as the most favorable place for the European pond turtle. These results demonstrated that even if individuals lived in less favorable environment such as Orzens or Menziken, they managed to reach an optimal body temperature for their development. Therefore, we can assume that the limiting factor for the reintroduction of the European pond turtles is the temperature of the nesting site. In the Orzens, even if individuals had a normal growth rate, hatchling was not possible. The results showed that even in the natural reserve of La Vieille Thielle, which was considered as a favorable site for the European pond turtle, the temperature of the nesting site did not reach the optimal temperature for hatchling. Maintenance of the artificial nesting site is obligatory in order to favor hatchling. Meaning that without human intervention for the maintenance of the artificial nesting site, "natural" hatchling would be difficult in the natural reserve of La Vieille Thielle. Before reintroduction of European pond turtles in other sites in Switzerland, mound for potential nesting site need to be build and maintain without vegetation and composed with sand, clay and gravel, which make the soil permeable to avoid an excessive humidity level. Once the mound for future nesting is built, studies of the temperature in the nesting sites (with iButtons) allow ensuring that the future reintroduction sites are really favorable. To conclude, in order to find favorable sites for future reintroduction of European pond turtle, potential reintroduction sites need to have a good aquatic habitat in order to favor optimal development of reintroduced individuals and a favorable terrestrial habitat, which included a mound for nesting sites located on well-drained sandy and south facing slopes.

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Appendix 1

Localizations of iBouttons placed in nesting sites and potential nesting sites of Switzerland – Year 2014

Fig. 17: Localizations of iButtons placed in 2014 in potential nesting sites of *Emys orbicularis* in the natural reserve of La Vieille Thielle in the canton of Neuchâtel. Red circle=iButton placed in the mound, which is supposed to be the future nesting sites of released individuals, orange circle=iButtons placed in the meadow near the pond.

Fig. 18: Localization of iBouttons placed in 2014 in potential nesting sites of *Emys orbicularis* in the natural reserve of Jussy/Près-Bordon in the canton of Geneva. Red circles=iButtons placed in the mound of Près-Bordon upstream pond, one in the fine gravel and the other in the large gravel, orange circle=iButton placed near Près-Bordon downstream pond (clayey soil).

Fig. 19: Localization of iButtons placed in 2014 in potential nesting of *Emys orbicularis* in the natural reserve of Jussy/Près-Bordon in the canton of Geneva. Red circles=iButtons were placed in the mound near the Rappes pond from the bottom of the mound to the higher point of the mound.

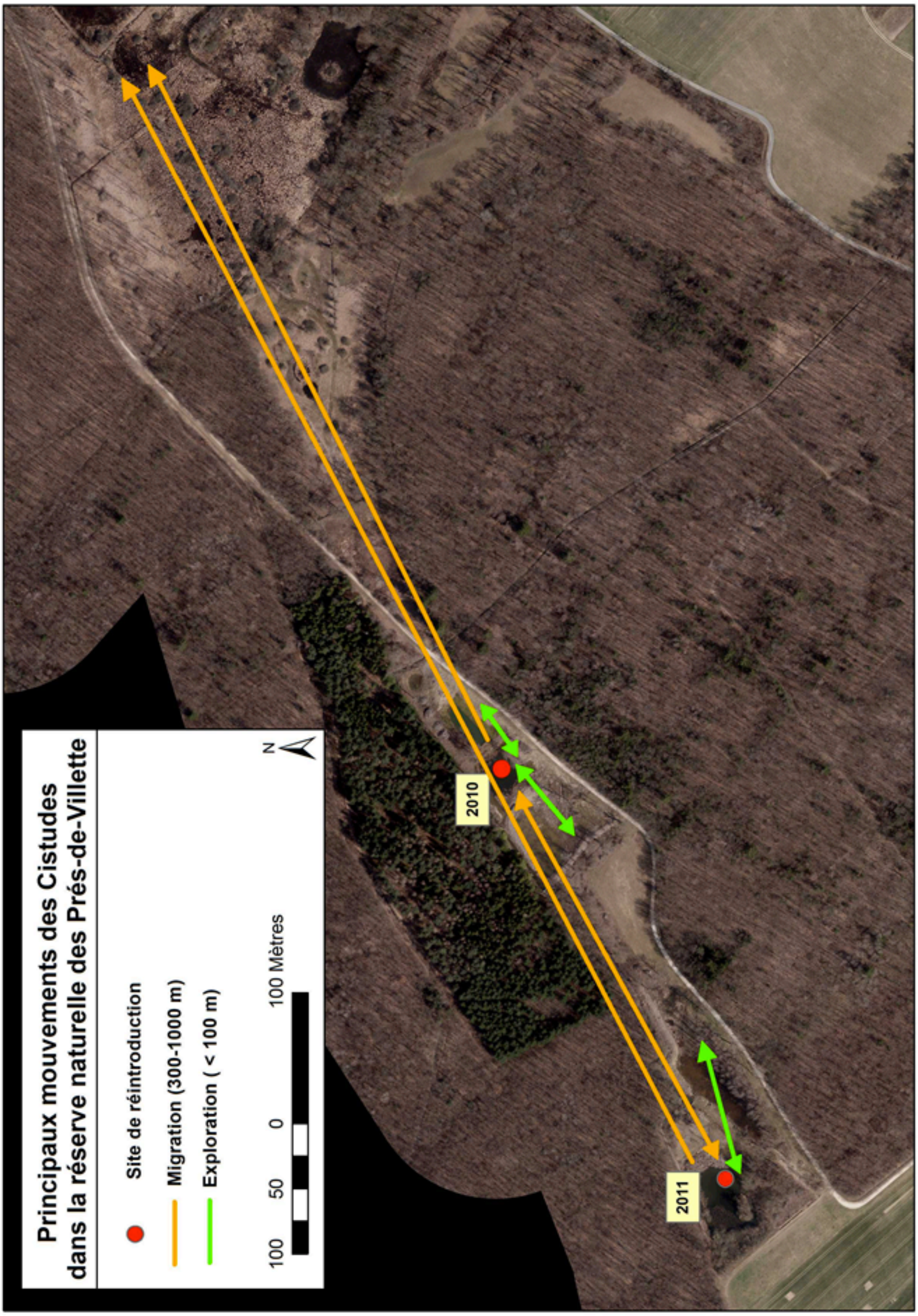
Fig. 20: Localization of iButtons placed in 2014 in nesting sites of *Emys orbicularis* in the natural reserve of Moulin-de-Vert in the canton of Geneva. Red circle=two iButtons placed under the observatory near the Hainard pond, orange circle=iButtons placed near the observatory of "Etang des Isles" and purple circles=iButtons placed in the dry meadow.

Fig. 21: Localization of iButtons placed in 2014 in potential nesting site of *Emys orbicularis* in the meadow near Font in the natural reserve of La Grande Cariçaie in the canton of Vaud (red circle)

Fig. 22: Localization of iButtons placed in 2014 in potential nesting site of *Emys orbicularis* near Châbles in the embankment for the train in the natural reserve of La Grande Cariçaie in the canton of Fribourg.

Appendix 2

Map showing the main displacement of individuals in the natural reserve of Jussy/Près-Bordon (Rochet, 2012).


Principaux mouvements des Cistudes
dans la réserve naturelle des Prés-de-Villette
Site de réintroduction
Migration (300-1000 m)
Exploration (< 100 m)
100
50
0
100 Mètres
N
2010
2011

Appendix 3

Maps of localization by telemetry and home ranges of all individuals – Year 2013

Fig 23: Localization by telemetry in 2013 of *Emys* individual 148.021 in the natural reserve of La Vieille Thielle.

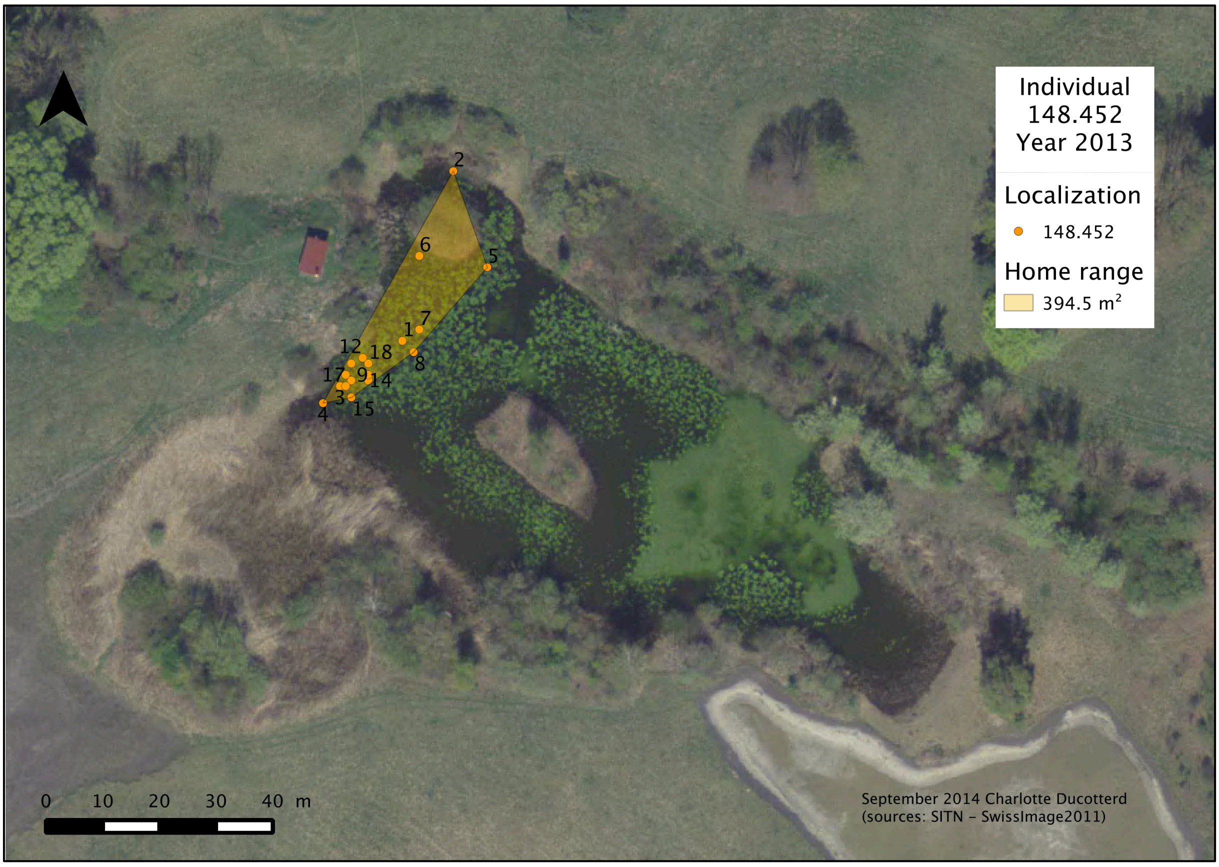


Fig 24: Localization by telemetry in 2013 of *Emys* individual 148.452 in the natural reserve of La Vieille Thielle.

Fig. 25: Localization by telemetry in 2013 of *Emys* individual 148.472 in the natural reserve of La Vieille Thielle.

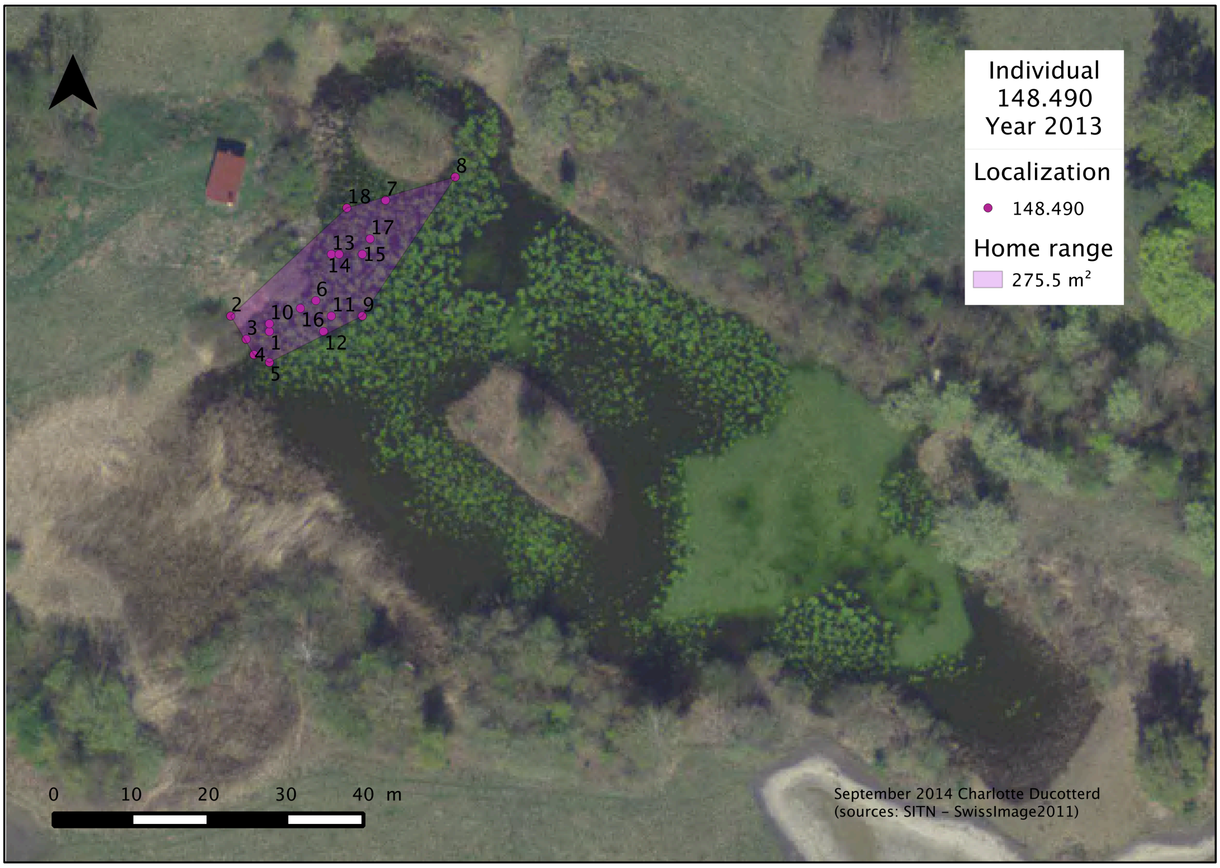


Fig. 26: Localization by telemetry in 2013 of *Emys* individual 148.490 in the natural reserve of La Vieille Thielle.

Fig. 27: Localization by telemetry in 2013 of *Emys* individual 148.492 in the natural reserve of La Vieille Thielle.

Fig. 28: Localization by telemetry in 2013 of *Emys* individual 148.511 in the natural reserve of La Vieille Thielle.

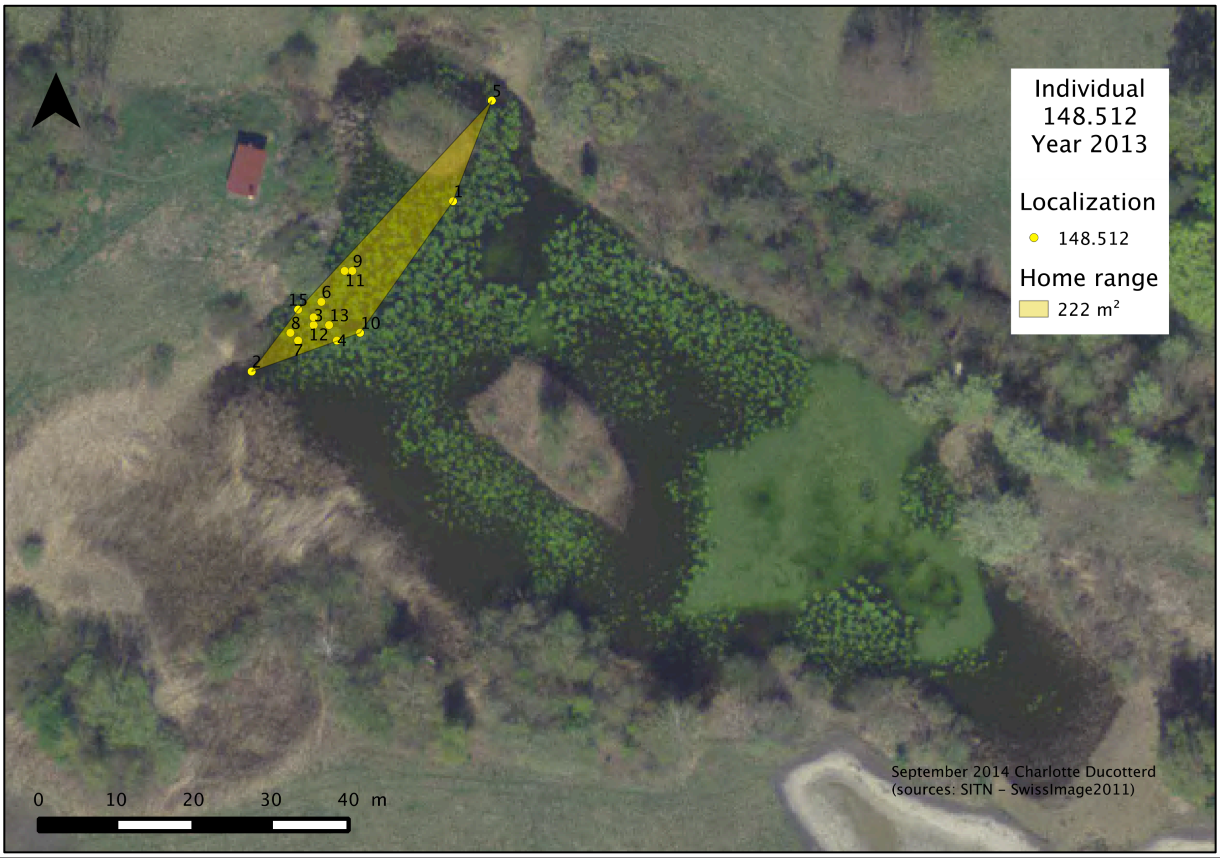


Fig. 29: Localization by telemetry in 2013 of *Emys* individual 148.512 in the natural reserve of La Vieille Thielle.

Fig. 30: Localization by telemetry in 2013 of *Emys* individual 148.553 in the natural reserve of La Vieille Thielle.

Fig. 31: Localization by telemetry in 2013 of *Emys* individual 148.604 in the natural reserve of La Vieille Thielle.

Fig. 32: Localization by telemetry in 2013 of *Emys* individual 148.605 in the natural reserve of La Vieille Thielle.

Appendix 4

Maps of localization by telemetry and home ranges of all individuals – Year 2014

Fig. 33: Localization by telemetry in 2014 of *Emys* individual 148.021 in the natural reserve of La Vieille Thielle.

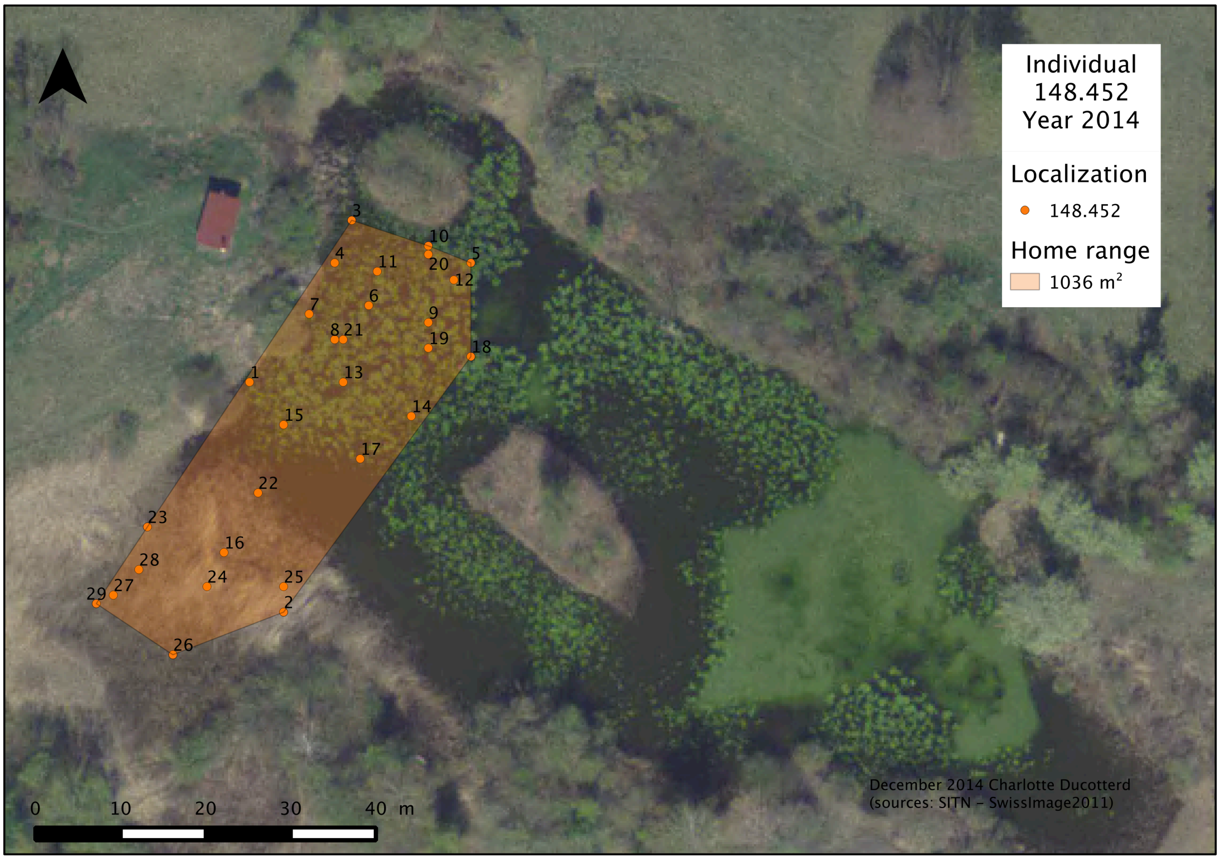


Fig. 34: Localization by telemetry in 2014 of *Emys* individual 148.452 in the natural reserve of La Vieille Thielle.

Fig. 35: Localization by telemetry in 2014 of *Emys* individual 148.472 in the natural reserve of La Vieille Thielle.

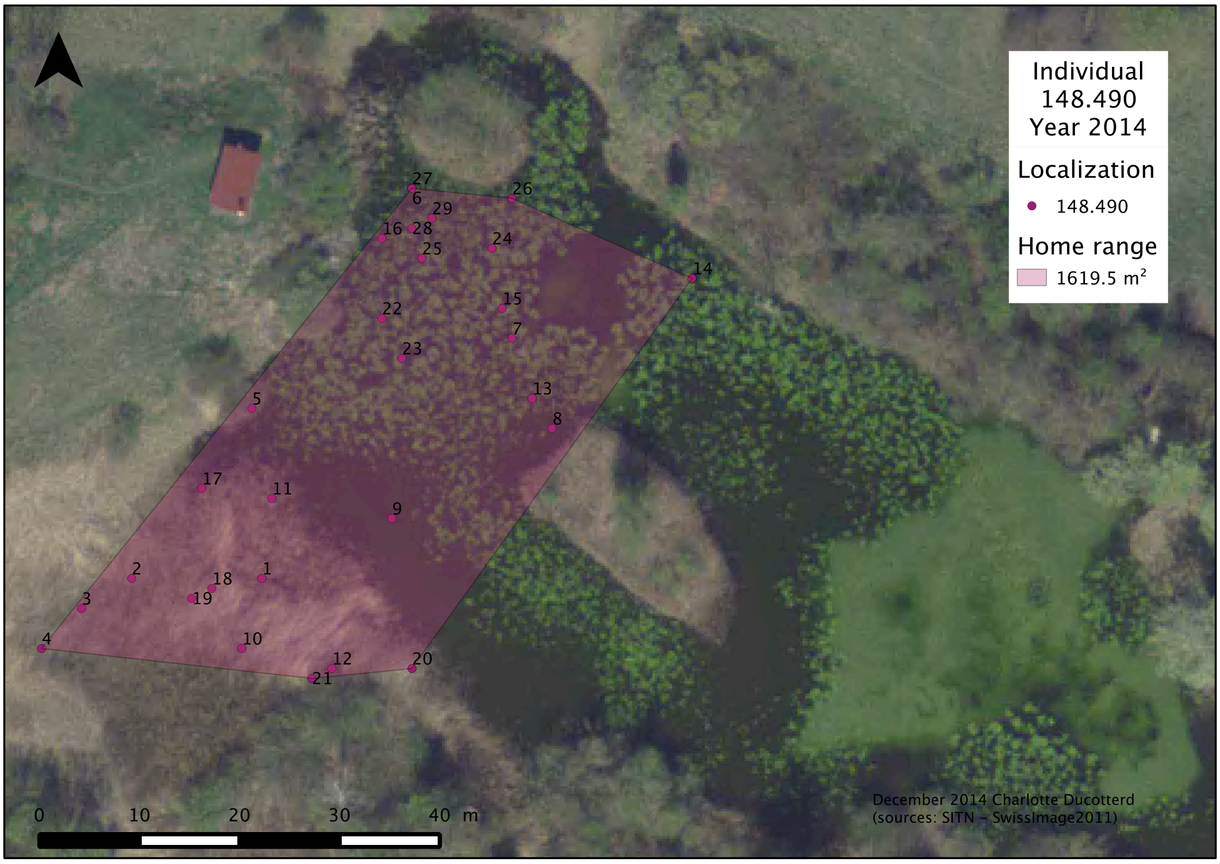


Fig. 36: Localization by telemetry in 2014 of *Emys* individual 148.490 in the natural reserve of La Vieille Thielle.

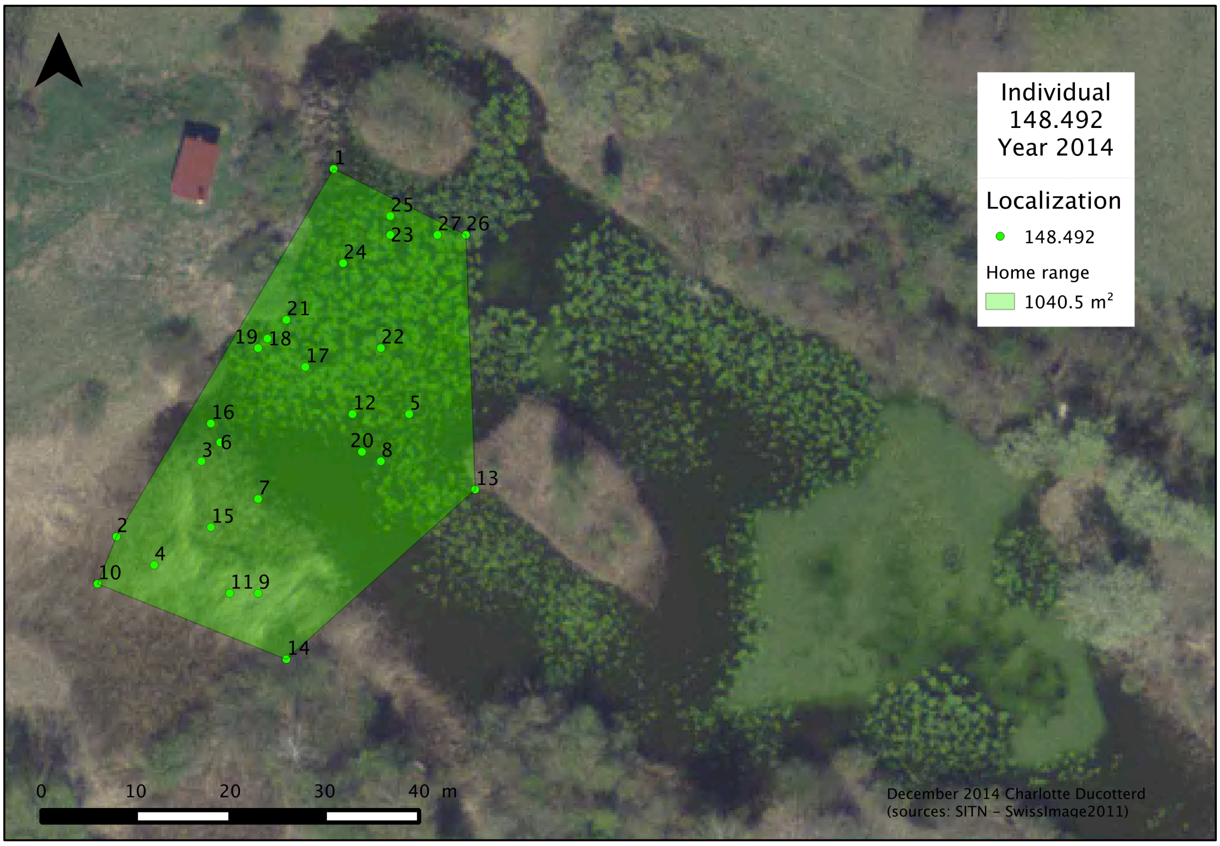


Fig. 37: Localization by telemetry in 2014 of *Emys* individual 148.492 in the natural reserve of La Vieille Thielle.

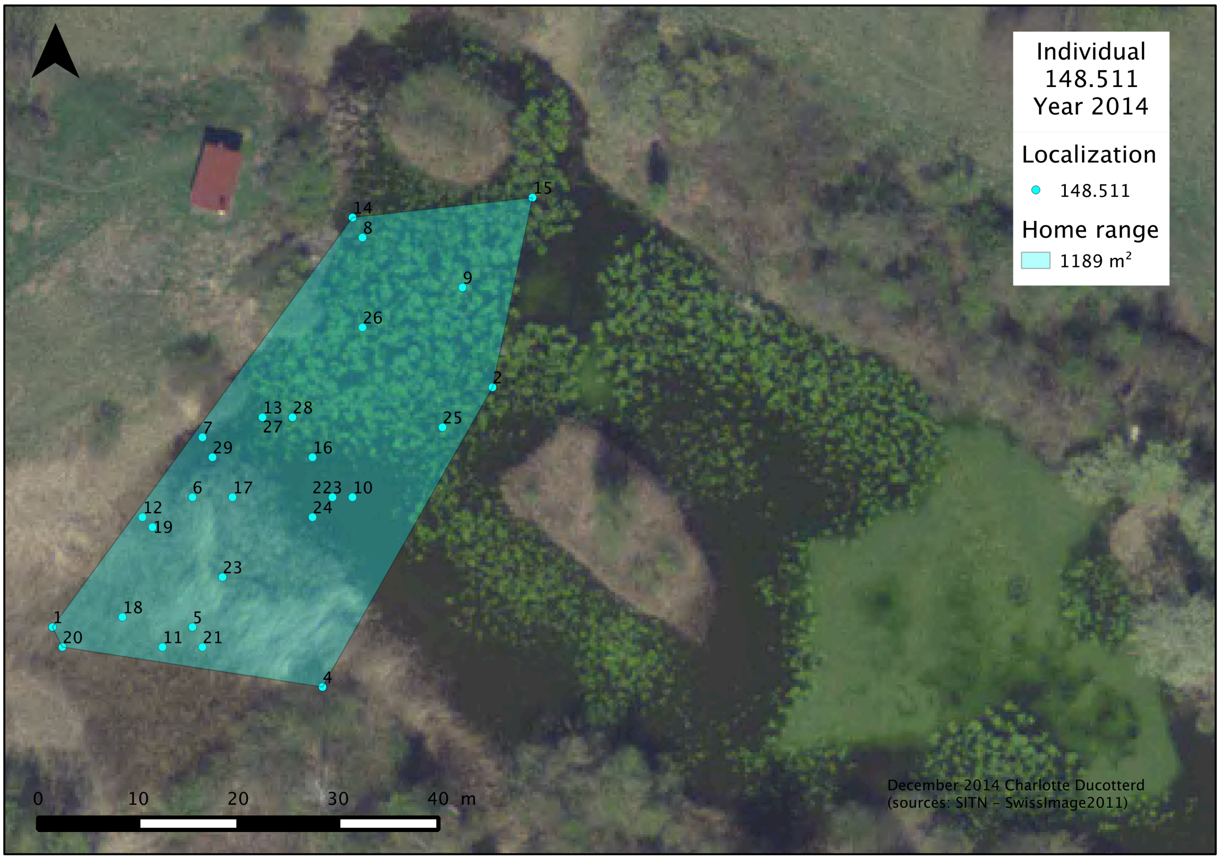


Fig. 38: Localization by telemetry in 2014 of *Emys* individual 148.511 in the natural reserve of La Vieille Thielle.

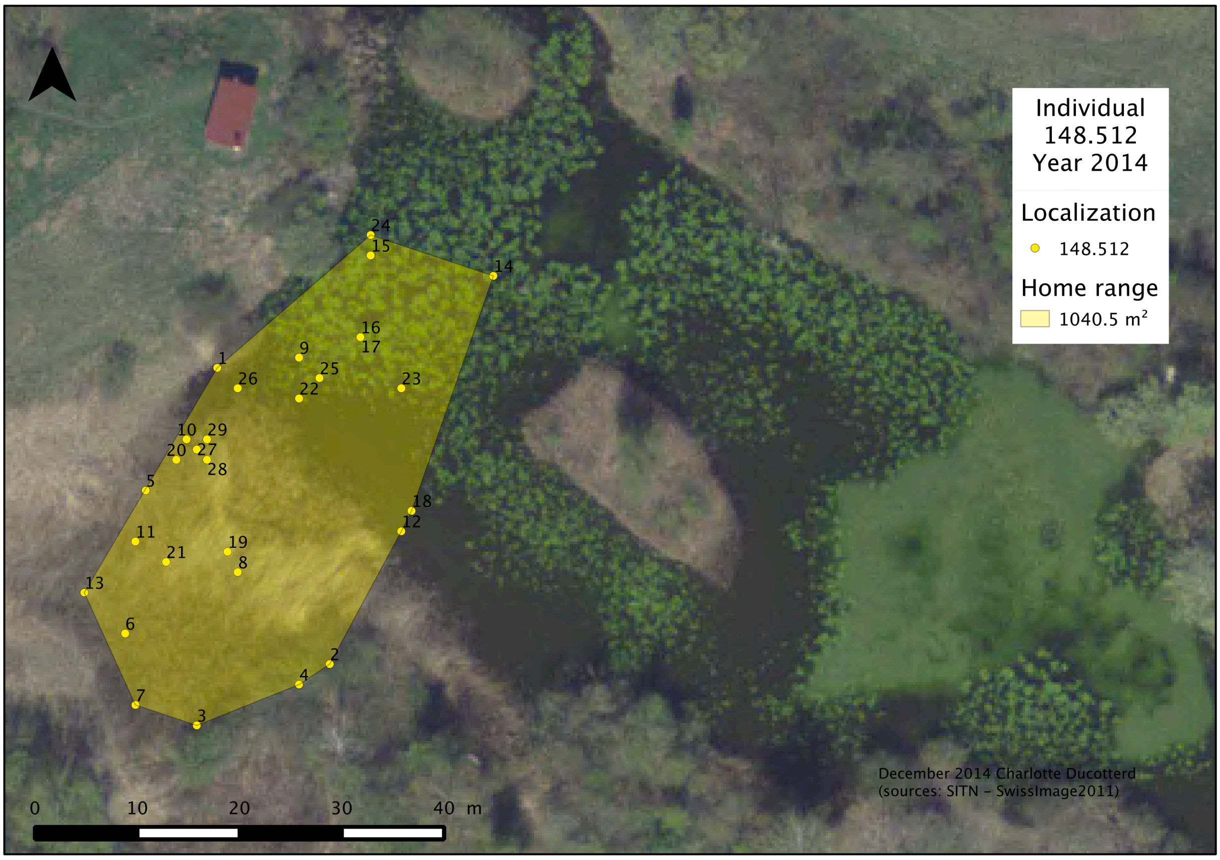


Fig. 39: Localization by telemetry in 2014 of *Emys* individual 148.512 in the natural reserve of La Vieille Thielle.

Fig. 40: Localization by telemetry in 2014 of *Emys* individual 148.553 in the natural reserve of La Vieille Thielle.

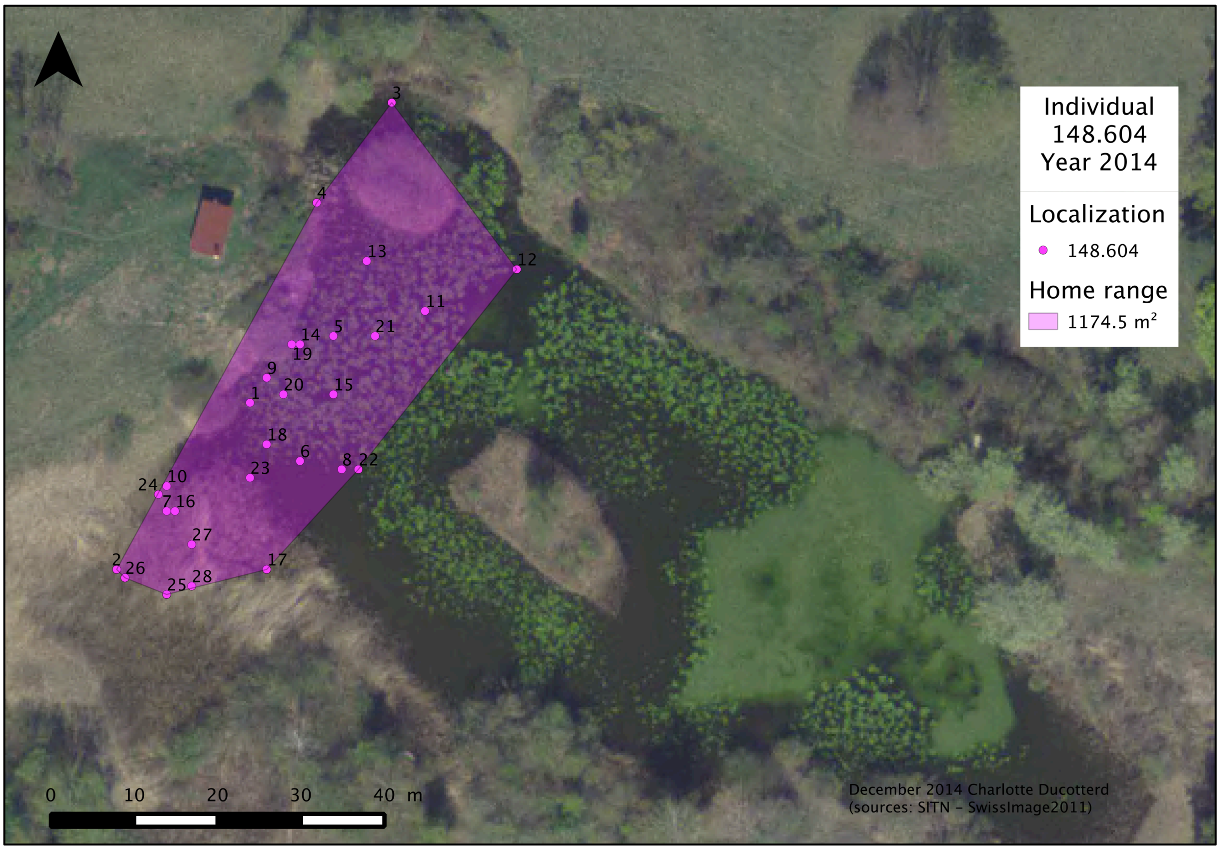


Fig. 41: Localization by telemetry in 2014 of *Emys* individual 148.604 in the natural reserve of La Vieille Thielle.

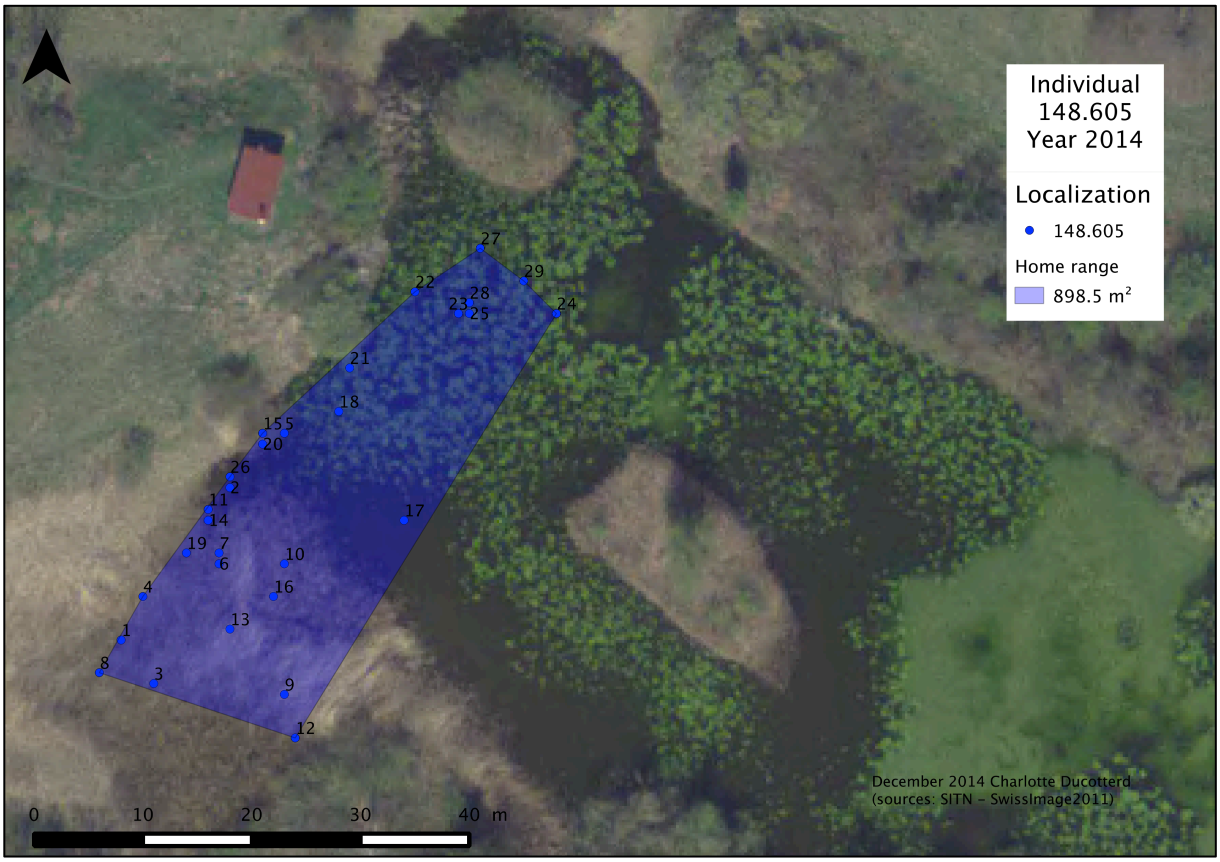
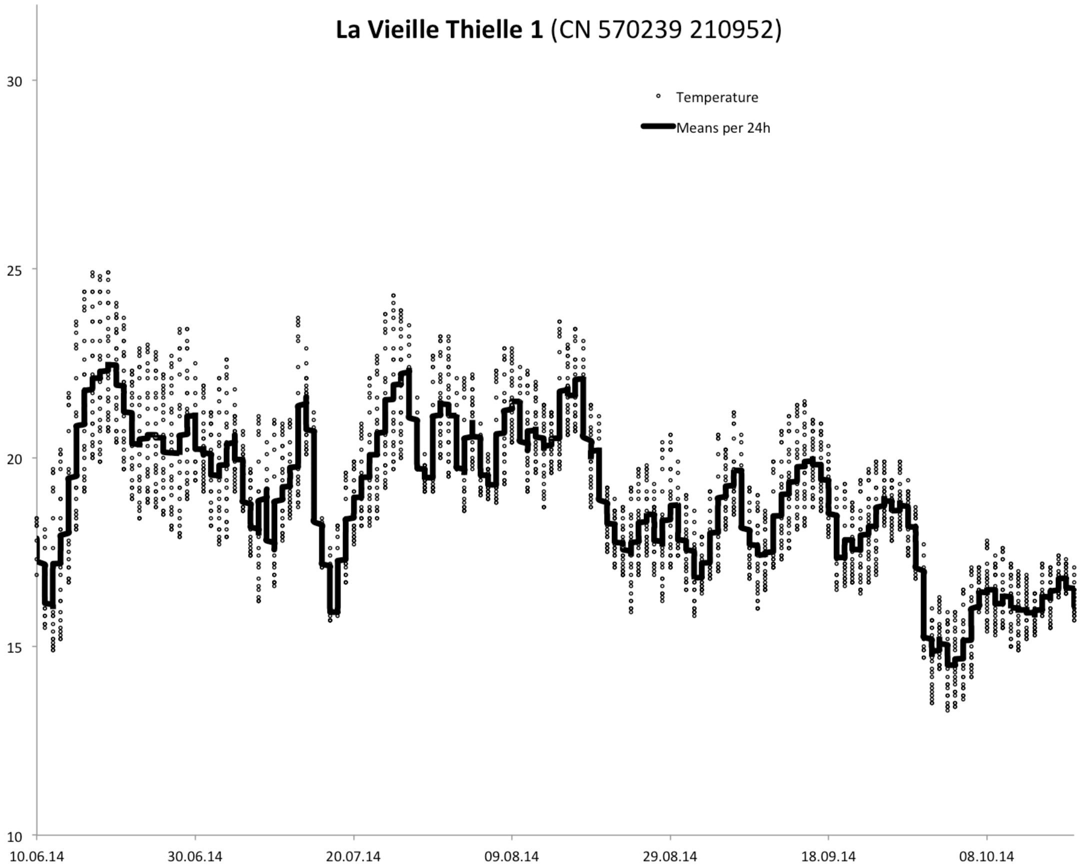


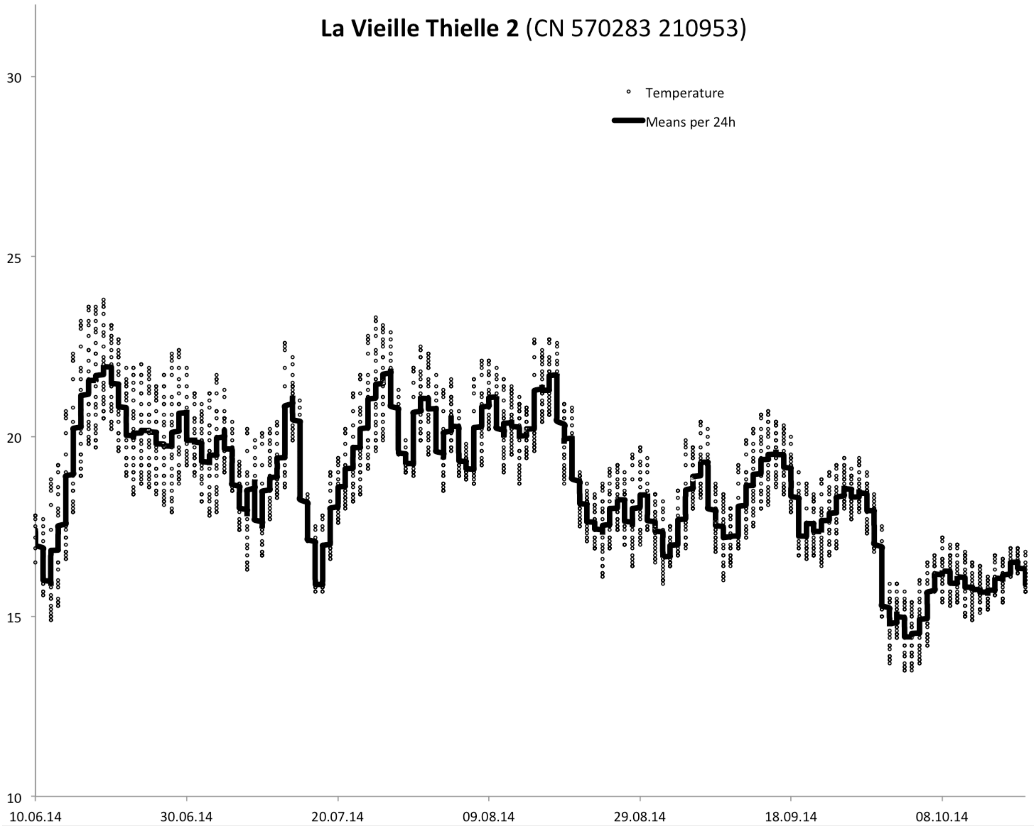
Fig. 42: Localization by telemetry in 2014 of *Emys* individual 148.605 in the natural reserve of La Vieille Thielle.

Appendix 5

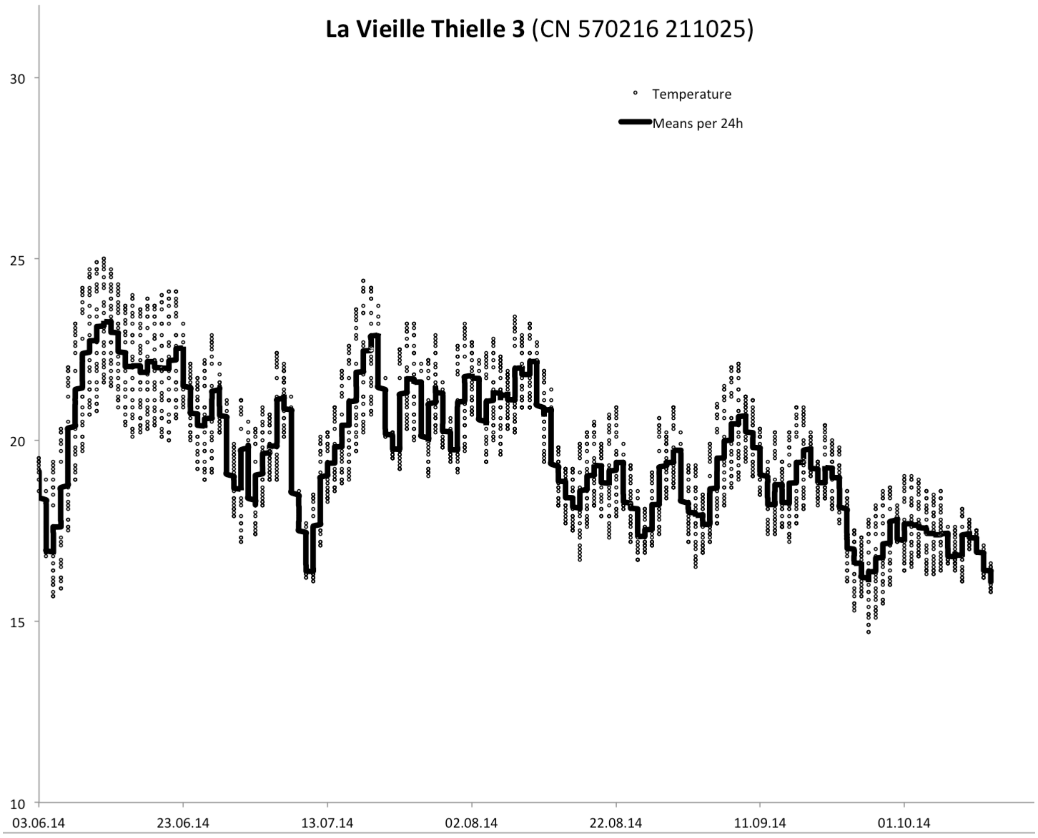
Temperature curves of all iBouttons placed in nesting sites in 2014



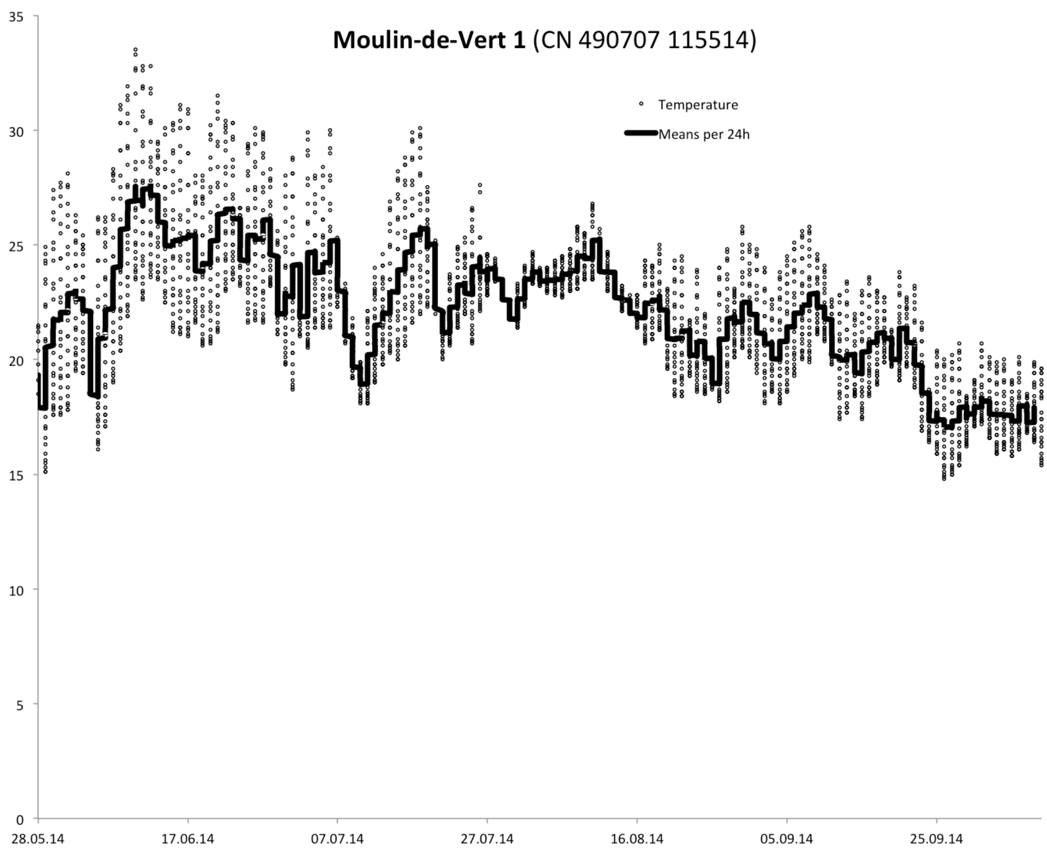
Graph 8: Temperatures and means temperatures per 24h of iButton placed in 2014 in the meadow of the natural reserve of La Vieille Thielle in the canton of Neuchâtel.



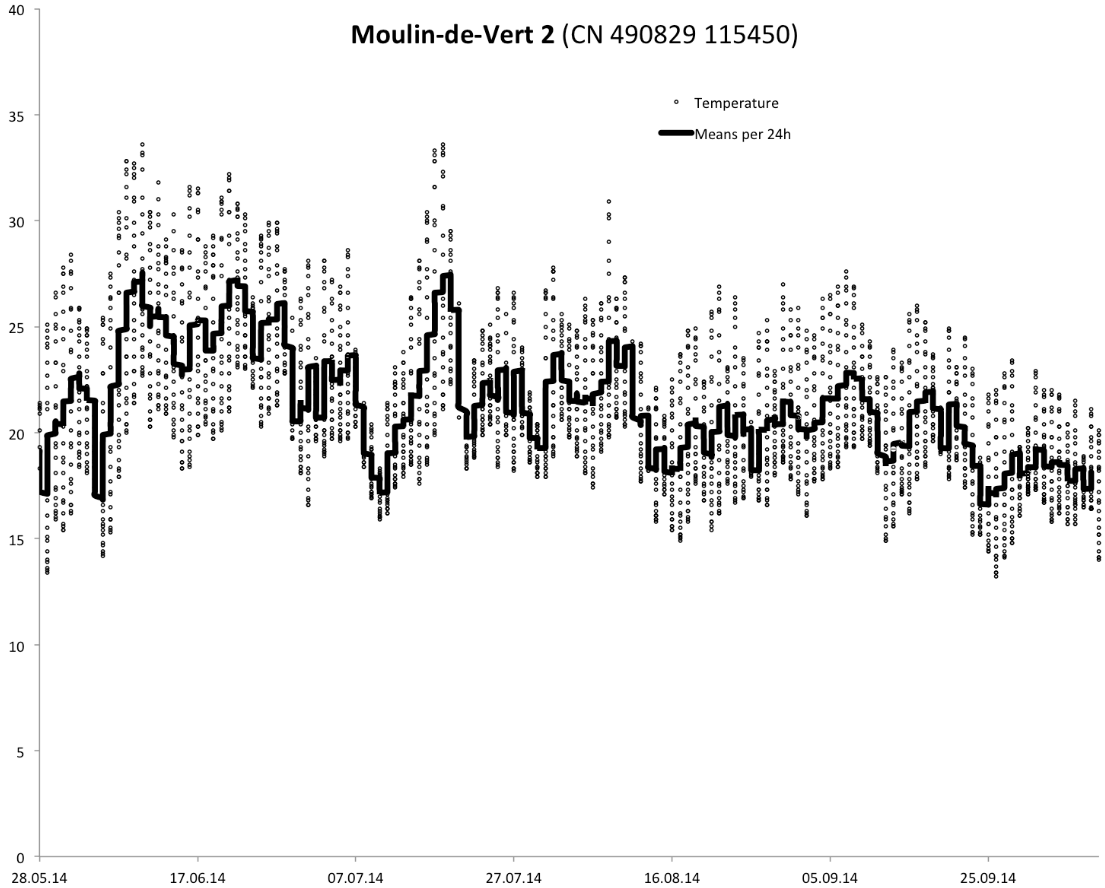
Graph 9: Temperatures and means temperatures per 24h of iButton placed in 2014 in the meadow of the natural reserve of La Vieille Thielle in the canton of Neuchâtel.



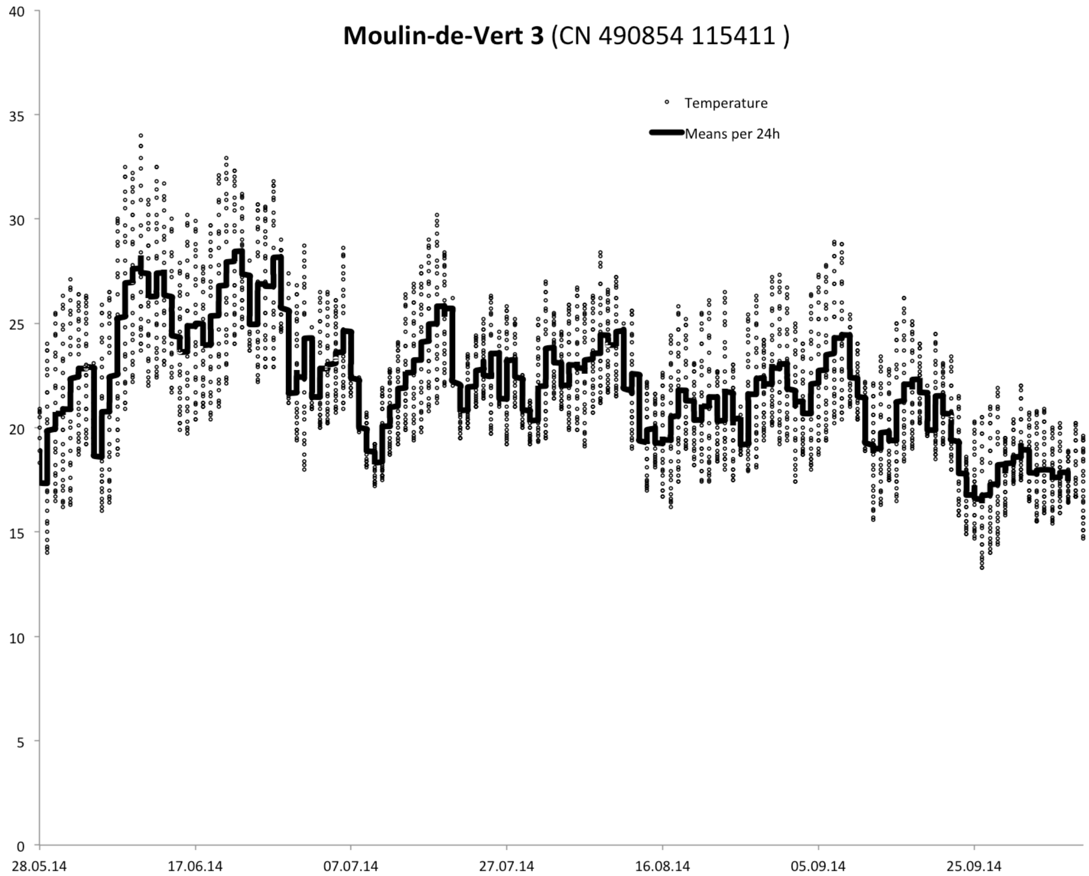
Graph 10: Temperatures and means temperatures per 24h of iButton placed in 2014 in the mound of the natural reserve of La Vieille Thielle in the canton of Neuchâtel.



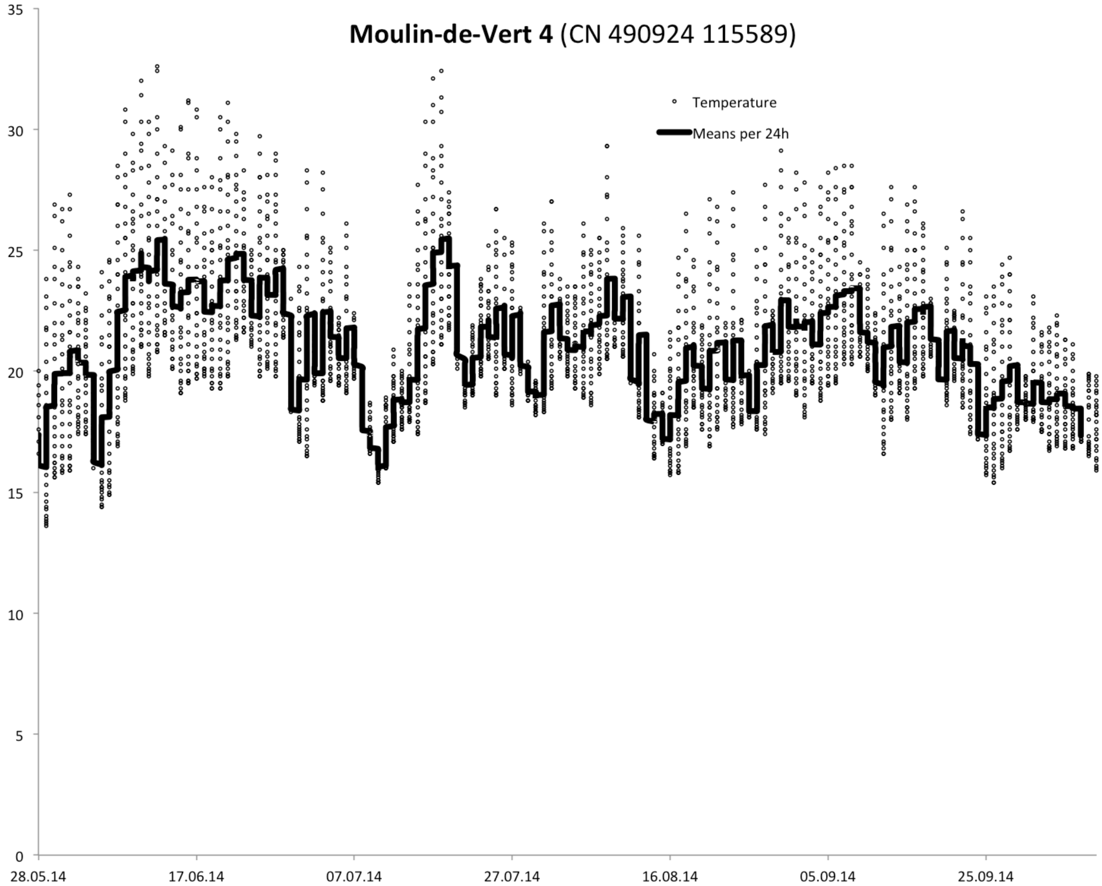
Graph 11: Temperatures and means temperatures per 24h of iButton placed in 2014 near the observatory of "Etang des Isles" in the natural reserve of Moulin-de-Vert in the canton of Geneva.



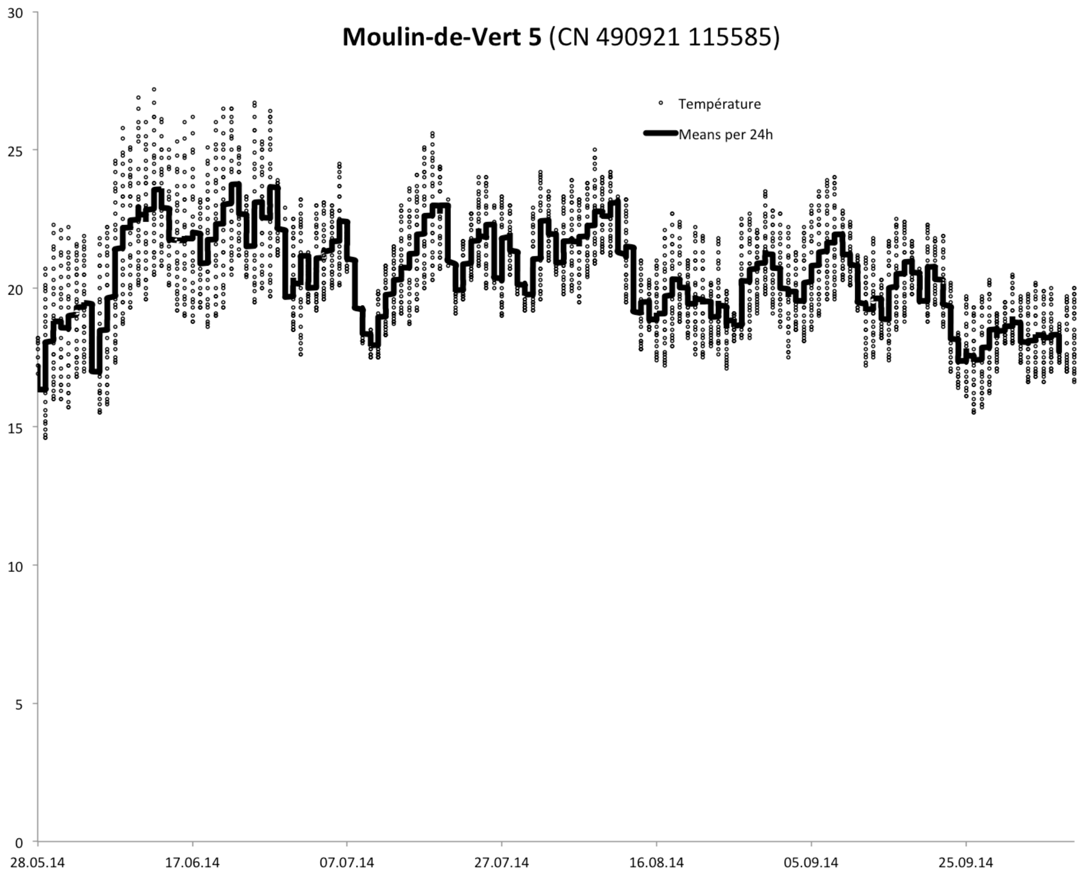
Graph 12: Temperatures and means temperatures per 24h of iButton placed in 2014 in the dry meadow near Hainard pond in the natural reserve of Moulin-de-Vert in the canton of Geneva.



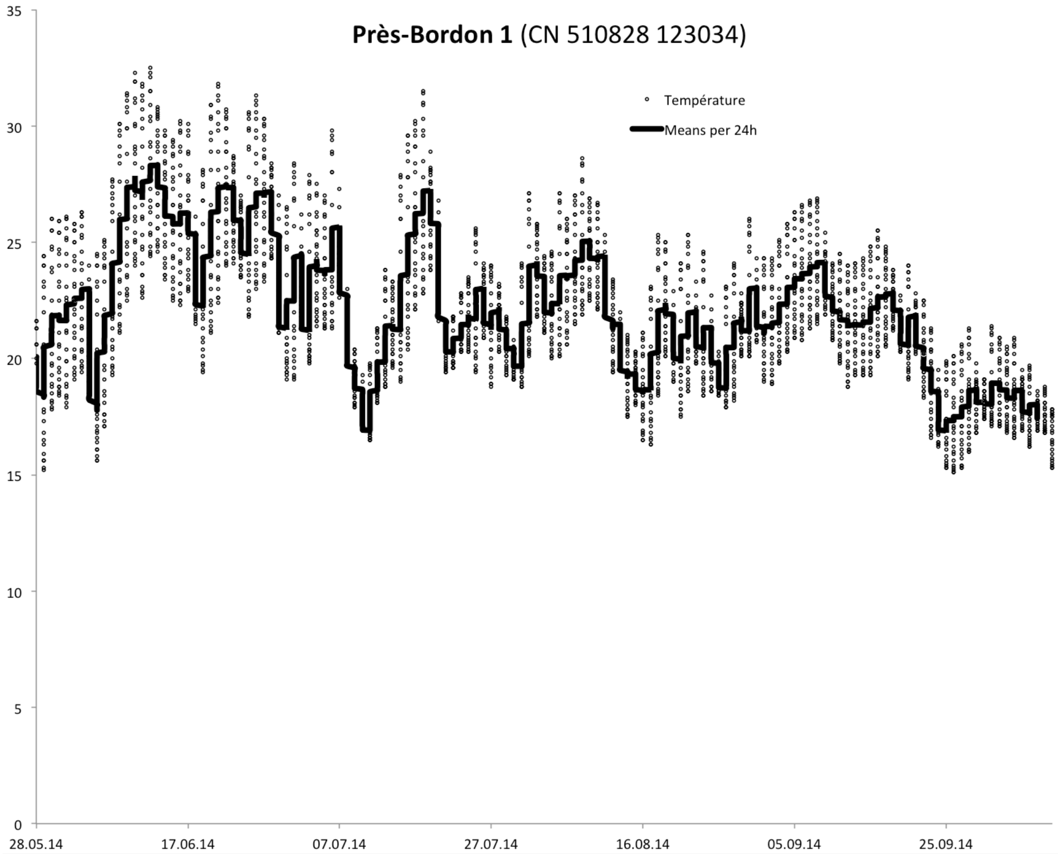
Graph 13: Temperatures and means temperatures per 24h of iButton placed in 2014 in the dry meadow near Hainard pond in the natural reserve of Moulin-de-Vert in the canton of Geneva.



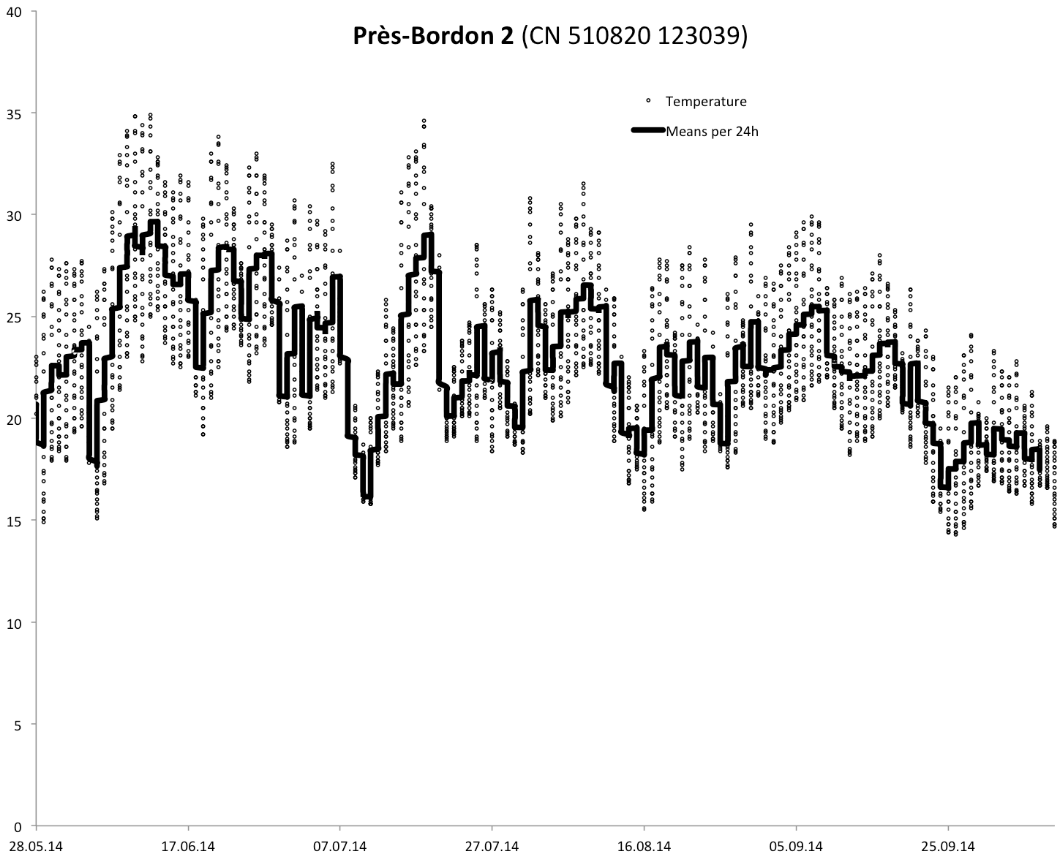
Graph 14: Temperatures and means temperatures per 24h of iButtons placed in 2014 under the observatory of Hainard pond in the natural reserve of Moulin-de-Vert in the canton of Geneva.



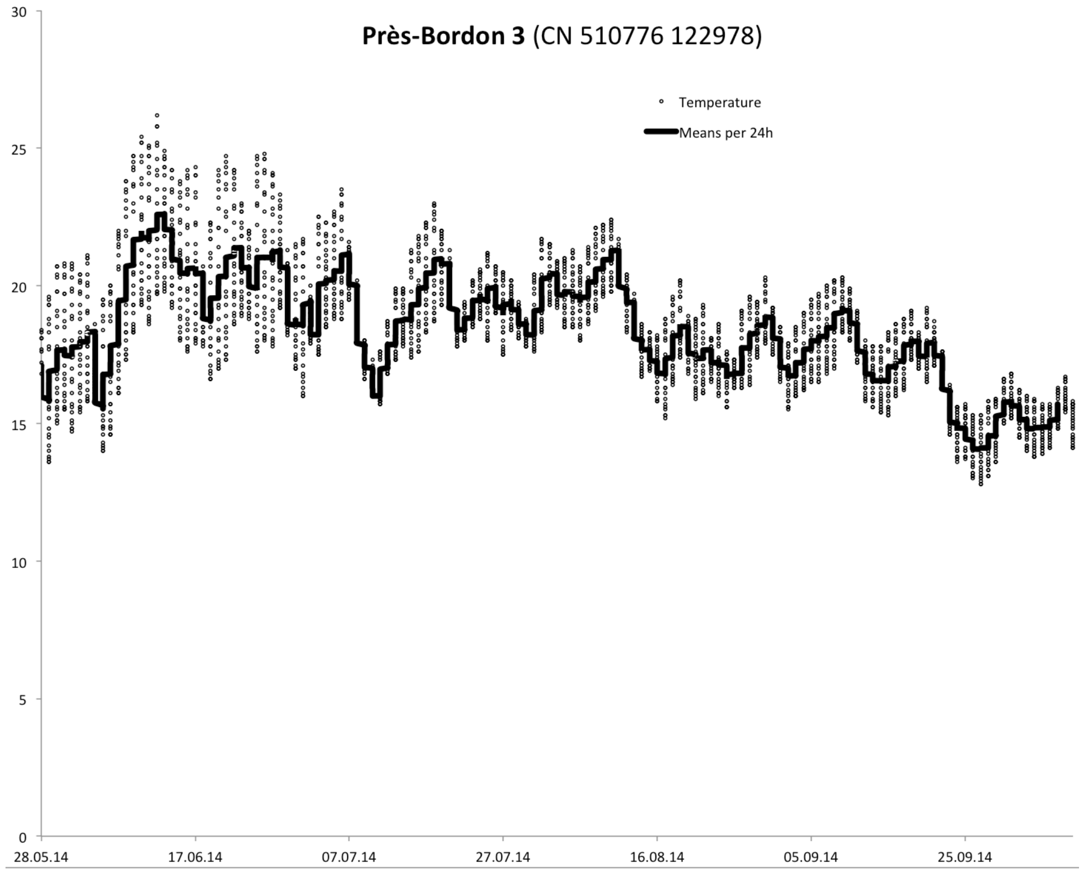
Graph 15: Temperatures and means temperatures per 24h of iButton placed in 2014 on the right of the observatory of Hainard pond in the natural reserve of Moulin-de-Vert in the canton of Geneva.



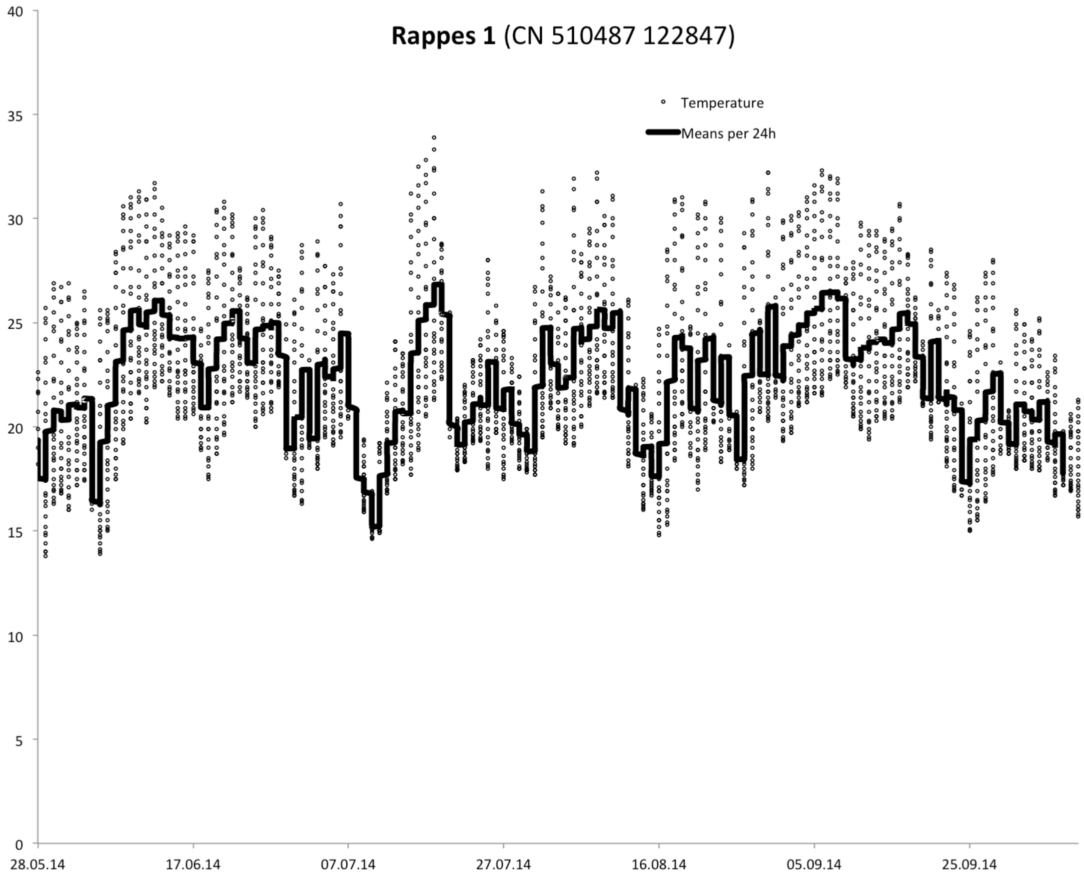
Graph 16: Temperatures and means temperatures per 24h of iButton placed in the fine gravel of the mound of Près-Bordon upstream pond in the natural reserve of Jussy/Près-Bordon in the canton of Geneva.



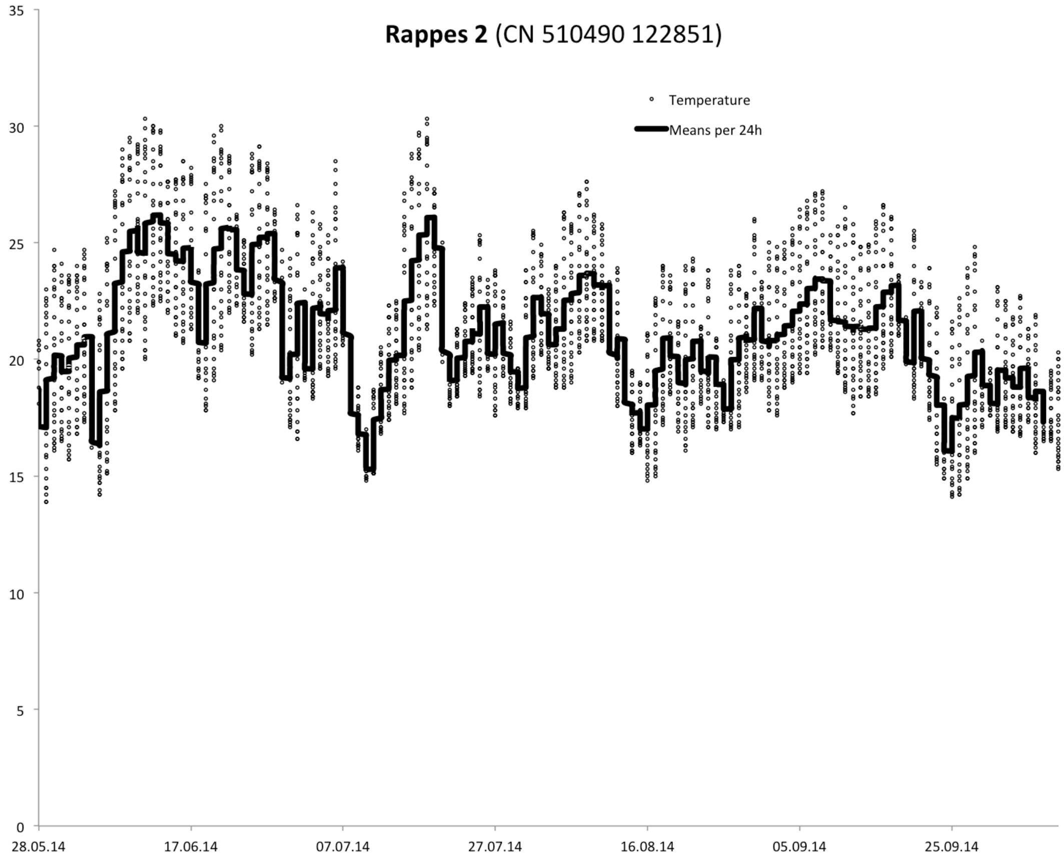
Graph 17: Temperatures and means temperatures per 24h of iButton placed in the large gravel of the mound of Près-Bordon upstream pond in the natural reserve of Jussy/Près-Bordon in the canton of Geneva.



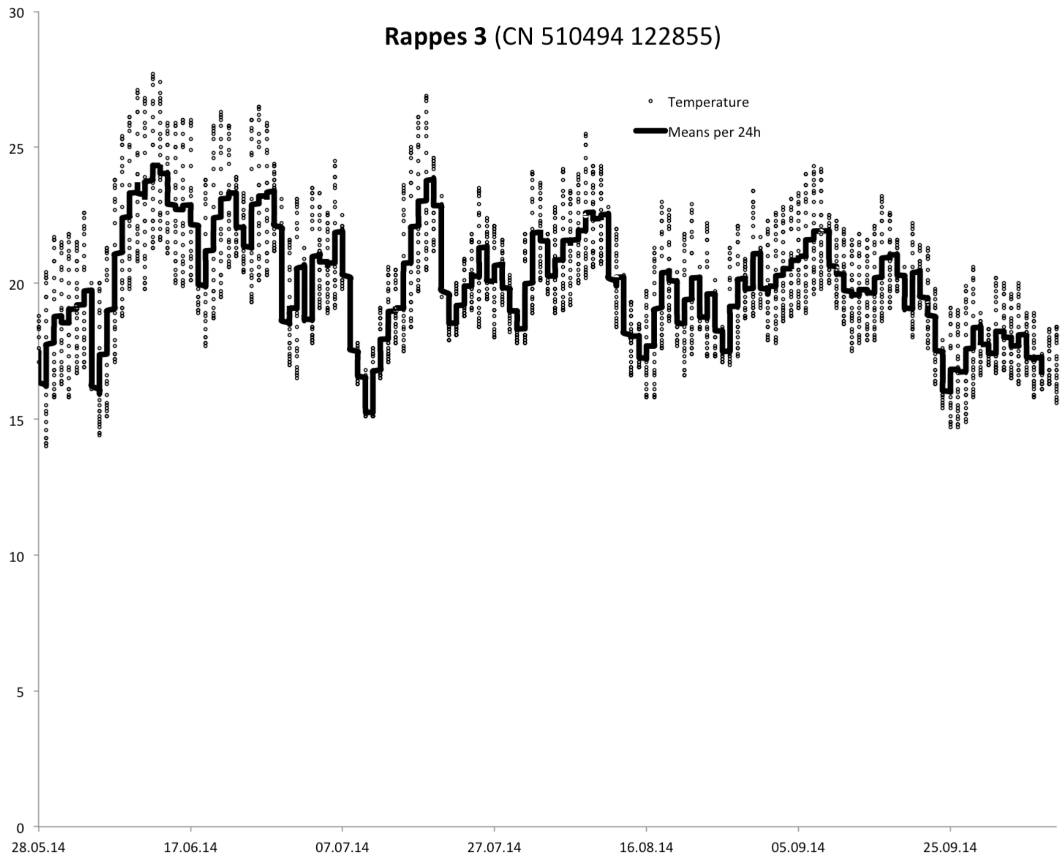
Graph 18: Temperatures and means temperatures per 24h of iButton placed at the edge of Près-Bordon downstream pond (clayey soil) in the natural reserve of Jussy/Près-Bordon in the canton of Geneva.



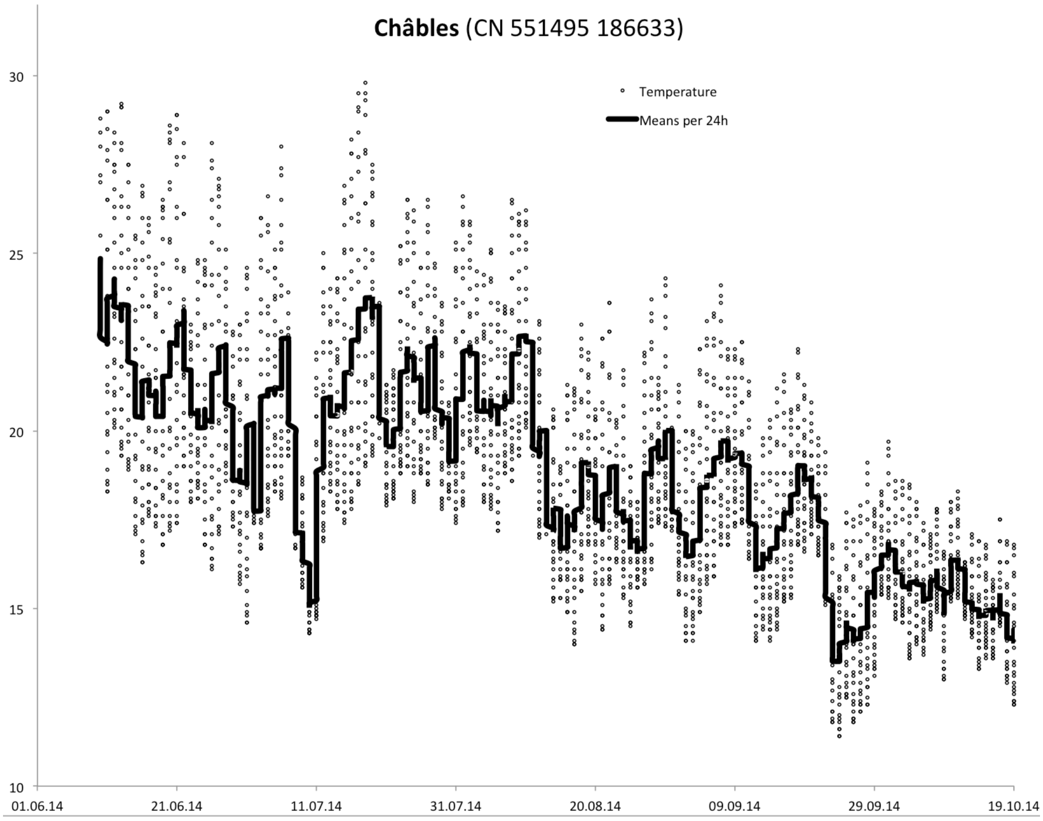
Graph 19: Temperatures and means temperatures per 24h of iButton placed on the bottom of the mound near Rappes pond in the natural reserve of Jussy/Près-Bordon in the canton of Geneva.



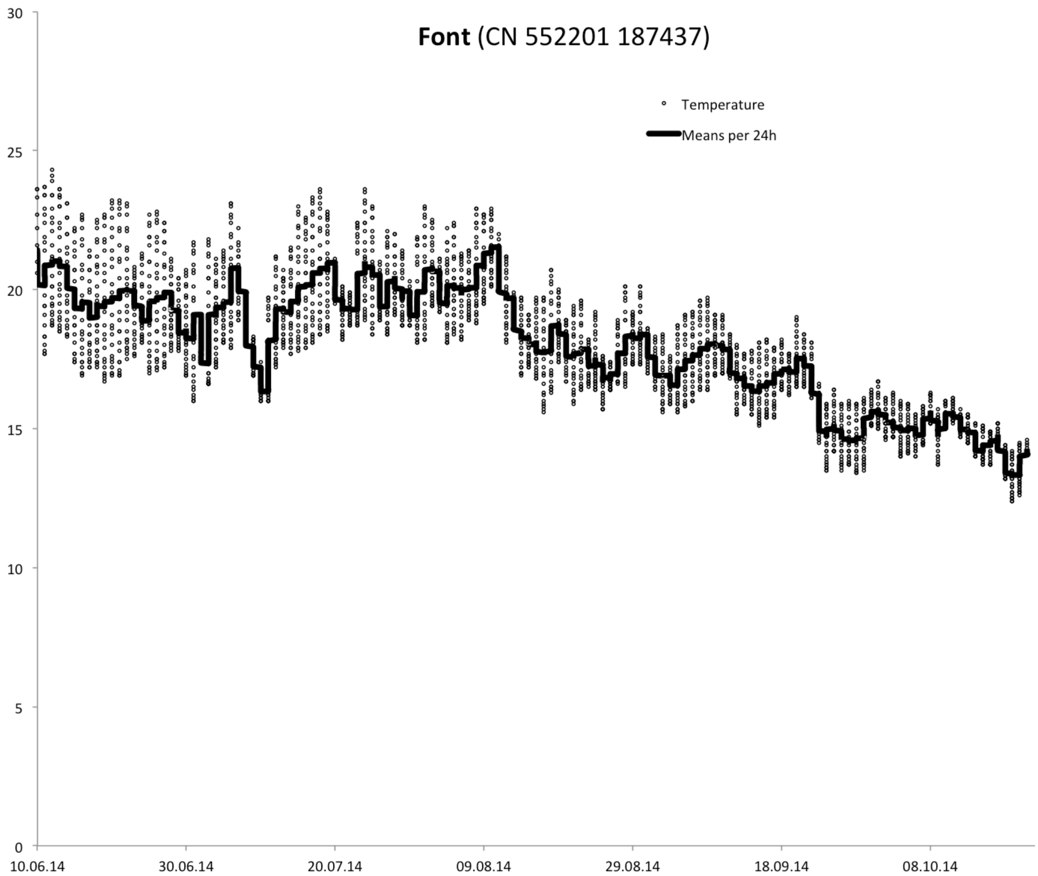
Graph 20: Temperatures and means temperatures per 24h of iButton placed in the middle of the mound near Rappes pond in the natural reserve of Jussy/Près-Bordon in the canton of Geneva.



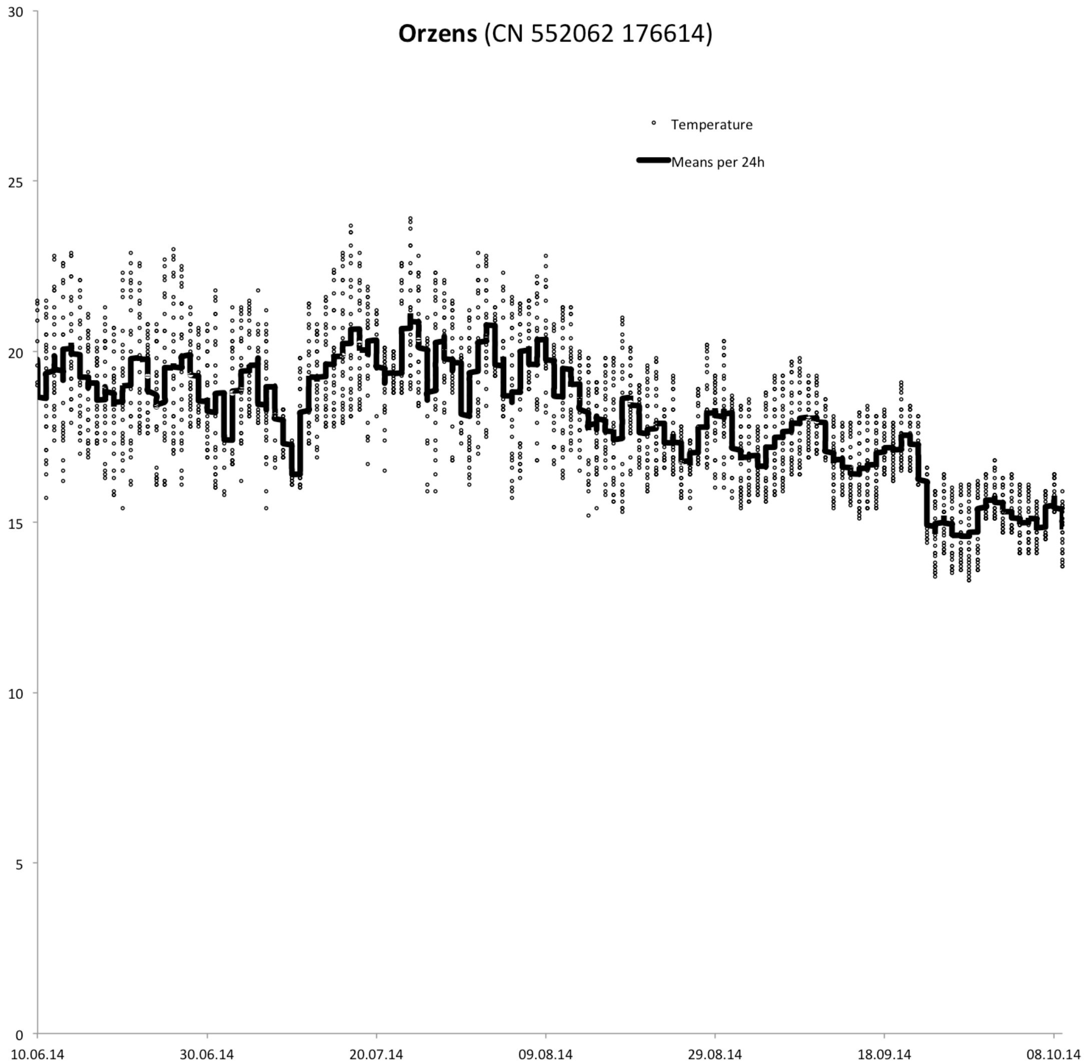
Graph 21: Temperatures and means temperatures per 24h of iButton placed on the top of the mound near Rappes pond in the natural reserve of Jussy/Près-Bordon in the canton of Geneva.



Graph 22: Temperatures and means temperatures per 24h of iButton placed in the embankment of the train near Châbles (canton of Fribourg) in the natural reserve of La Grande Cariçaie.



Graph 23: Temperatures and means temperatures per 24h of iButton placed in the meadow near Font (canton of Vaud) in the natural reserve of La Grande Cariçaie.



Graph 24: Temperatures and means temperatures per 24h of iButton placed in the private propriety of Orzens in the canton of Vaud.