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Movements and home range of the Eurasian Griffon Vulture (*Gyps fulvus*) in the eastern Alps and Adriatic region, in relation to food availability.

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Key words
Conservation, Eurasian Griffon Vulture, satellite-tracking, home-range, spatial ecology, eastern Alps

Movimenti e home range del grifone (*Gyps fulvus*) nell'area delle Alpi orientali e nella regione adriatica in relazione alle disponibilità alimentari.

Parole chiave
Conservazione, Grifone, home-range, uso dello spazio, Alpi orientali

Riassunto
Il grifone è una specie sociale che nidifica su pareti rocciose nell'Europa del sud, Africa del nord, Medio Oriente e Asia centrale, con maggior diffusione nei paesi del Mediterraneo. Come molti avvoltoi ha subito un marcato declino negli ultimi anni e si è estinto in varie aree. In Italia era distribuito in Sicilia, Sardegna e diversi settori delle Alpi e degli Appennini. Attualmente la sua presenza è legata a progetti di conservazione che hanno consentito di creare quattro popolazioni e salvare gli ultimi avvoltoi sardi. La popolazione italiana (Sardegna, Friuli, Abruzzo, Sicilia e Calabria) è di circa 170 coppie. Sulle Alpi orientali i grifoni sono tradizionalmente presenti in primavera e estate, estivando in una vasta area che include la Regione Friuli Venezia Giulia e parte delle Alpi Slovene e Austriache. Un progetto di conservazione è stato attuato nella "Riserva naturale regionale del Lago di Cornino" (Udine-Italia 46°13'N, 13°01'E) alla fine degli anni '80 allo scopo di consolidare la presenza della specie e creare colonie nidificanti. Queste contano attualmente un minimo di 120-150 uccelli in inverno e più di 250 in estate, quando molti grifoni arrivano dalla Croazia e da altri paesi. Le coppie nidificanti sono circa 50.

I grifoni seguono tradizionali percorsi di spostamento tra la Croazia e le aree di estivazione sulle Alpi e frequentano un sito di alimentazione nella Riserva naturale che fornisce una grande quantità di cibo tutto l'anno. Nelle altre aree, in Slovenia, Austria e Croazia, la disponibilità trofica è associata alla presenza del bestiame al pascolo.

Risulta importante studiare l'effetto di un punto di alimentazione sui movimenti di questa specie tra siti tradizionalmente usati in diverse stagioni (Alpi e area del Quarnero), sui relativi spazi famigliari e sui tempi di permanenza.

La ricerca si propone di definire le aree utilizzate dai grifoni (Home Range) nei diversi mesi e stagioni e nei diversi paesi e le modalità con cui si spostano in funzione delle strategie di ricerca trofica, in particolare rispetto alla situazione in Italia

(punto di alimentazione costantemente rifornito) Croazia, (disponibilità di ovini al pascolo tutto l'anno) e Austria (disponibilità di bestiame al nel periodo estivo).
Sono stati catturati e marcati con anelli e apparecchiature satellitari GPS PLUS 1C BIRD GPS-GSM tracking units (Vectronics Aerospace Gmbh-Germania) 12 grifoni, dal 2005 al 2014. Gli home range i movimenti ed i tempi di permanenza sono stati stimati sulla base di un numero di fix variabile per individuo (da 127 a 4.586).
Gli home range su base mensile e rispetto alle diverse aree, Austria, Italia e Croazia, sono risultati tra loro diversi. Per il MCP: in Croazia è mediamente pari a 1142 $km^2 \pm 1042$, in Italia 336 $km^2 \pm 325$ ed in Austria 389 $km^2 \pm 255$. Questi valori appaiono influenzati dalla presenza del mare in Croazia, dove i grifoni frequentano diverse isole e la costa. Gli home range (HR_{95}: Kernell al 95%;, HR_{50} Kernell al 50%) depurati delle zone di mare, appaiono diversi tra Croazia ($HR_{95=}$188 km^2 e HR_{50} 28 km^2) e Italia (HR_{95} 215 km^2 e HR_{50} 42 km^2) rispetto all'Austria (HR_{95} 49 km^2 e HR_{50} 19 km^2), che risulta inferiore.
Le Alpi Austriache vengono visitate solo in estate (da giugno all'inizio di ottobre) mentre le presenze sono distribuite su tutto l'anno nelle aree croate e italiane. Il tempo di permanenza totale su base mensile appare maggiore in Italia (18,71 ±10,68) rispetto a Croazia (14,03 ±10,15) e Austria (15,08 ±11,65), mentre la permanenza media (numero di giorni medi di residenza per visita) (Italia 17,25 ± 11,25, Croazia 13,13 ± 9,94, Austria 16,62 ±11,33) e le frequenze di visite mensili non sono statisticamente diverse per le tre aree (Italia 1,29 ± 0,79, Croazia 1,23 ±0,69, Austria 1,00 ±0,57), anche se l'Italia viene visitata più frequentemente e per periodi più lunghi. Le distanze medie percorse mensilmente nelle singole aree non appaiono tra loro significativamente diverse anche se mediamente sono più elevate in Croazia (482 km ±328), rispetto a Italia (335 km ±263) e Austria (246 km ±176). Tutte le variabili studiate variano in funzione della stagione: con un numero maggiore di giorni di presenza in autunno e inverno, stagioni in cui ci sono minori movimenti e home range più piccoli, soprattutto in inverno.
La presenza di un punto di alimentazione appare non ridurre significativamente le superfici esplorate dai grifoni, almeno in confronto con le altre realtà considerate. Il carnaio risulta essere uno strumento efficace dal punto di vista conservazionistico. La telemetria satellitare si dimostra uno strumento in grado di fornire dettagliate informazioni sui movimenti e l'uso dello spazio e quindi fondamentale per pianificare le strategie di conservazione per gli avvoltoi.

Abstract

The Griffon Vulture (*Gyps fulvus*) is a colonial cliff-nesting raptor inhabiting Southern Europe, Northern Africa, the Middle East and Central Asia, being mainly distributed in the countries around the Mediterranean sea. Like many vultures and raptors, the species has suffered sharp declines in recent decades and has disappeared from some countries while generally decreasing in the few populations remaining. In Italy the species was distributed in Sicily, Sardinia and in different sectors of the Alps and the Apennines. Actually, in Italy the presence of this vulture is closely tied to conservation projects that have allowed the creation of four colonies as well as saving the last Italian colony in Sardinia. The Italian populations (Sardinia, Friuli, Abruzzo, Sicily and Calabria) amount to 170 breeding pairs.
In the Eastern Alps griffon vultures are usually present in spring and summer, spending the warmer months of the year in a huge area covering the region Friuli Venezia Giulia and part of the Slovenian and Austrian Alps. A conservation project began in the "*Riserva naturale regionale del Lago di Cornino*" (Udine-Italy 46°13'N,

13° 01’E) at the end of the 1980s with the aim of consolidating the species’ presence in the Alps and creating nesting colonies. The local population actually numbers a minimum of 120-150 individual in winter and more than 250 in summer, when many birds arrive from Croatia and other countries; there are about 50 breeding pairs.

The griffons vultures follow traditional flyways to move between Croatia and the most important sites in the Alps. The birds are strictly dependent upon one feeding point in the natural reserve that provides a large amount of food throughout the year and especially during the winter months. In the other areas they depend on grazing animals.

The research aims to define the areas used by vultures in different months and seasons, in different countries and the ways in which they move and stay as a function of their feeding search strategies; in particular with respect to Italy (a constantly replenished feeding point supplied all year), Croatia (the natural availability of sheep throughout the year) and Austria (the natural availability of cattle that graze during the summer months).

12 griffon vultures were captured and marked with rings and GPS PLUS 1C BIRD GPS-GSM satellite tracking unit equipment (Vectronics Aerospace Gmbh-Germany), from 2005 to 2014. The home range movements and lengths of stay were estimated based on 127 to 4,586 fixes, depending on the individual.

The home ranges on a monthly basis and with respect to the different areas, Austria, Italy and Croatia, differed from each other. With regard to the Minimum Convex Polygon (MCP), Croatia is, on average, equal to 1142 $km^2 \pm 1042$, Italy 336 $km^2 \pm 325$ and Austria, 389 $km^2 \pm 255$. These values appear influenced by the closeness to the sea in Croatia, where the griffon vultures frequent a range of islands and the coast. The home range (HR_{95}: kernel densituy estimation at 95%; HR_{50} kernell density estimation at 50%) minus the sea areas appear to differ between Croatia ($HR_{95=}$188 km^2 e HR_{50} 28 km^2) and Italy (HR_{95} 215 km^2 e HR_{50} 42 km^2) compared to Austria (HR_{95} 49 km^2 e HR_{50} 19 km^{22}), where it is lower.

The Austrian Alps are visited only in summer (from June to early October), while the birds’ presence is distributed throughout the year in the Croatian and the Italo-Slovenian areas. The total residence time on a monthly basis is greatest in Italy (days=18.71$\pm$10.68) compared to Croatia (14.03$\pm$10.15) and Austria (15.08$\pm$11.65), while the average length of stay (average number of days of residence per visit) (17.25$\pm$11.25 Italy, Croatia 13.13$\pm$9.94, Austria 16.62$\pm$11.33) and the frequency of monthly visits are not statistically different for the three areas (Italy 1.29$\pm$0.79, Croatia 1.23$\pm$0.69, Austria 1.00$\pm$0.57), even if there is a more extended period of stay and frequency of visits to Italy. The average distance travelled each month in each area does not significantly differ from each other even though, on average, they are higher in Croatia (482 km $\pm$328), compared to Italy (335 km $\pm$263) and Austria (246 km $\pm$176). All the variables studied vary according to the season, with a greater number of days of presence in autumn and winter, seasons in which there are fewer movements and smaller home ranges, particularly in winter.

The presence of a feeding point does not appear to significantly reduce the areas explored by griffon vultures, at least in comparison with the other situations under consideration, even if the residence times and the frequency of utilization appear higher. The presence of a feeding site appears to be an effective tool from the conservation point of view.

1. Introduction

The Eurasian Griffon Vulture (*Gyps fulvus*) is a colonial cliff-nesting raptor inhabiting southern Europe, northern Africa, the Middle East and central Asia, being mainly distributed in the countries around the Mediterranean. Like many vultures and raptors, the species has suffered sharp decline in recent decades (Cramp & Simmons 1980).

The problems and persecution that affected birds of prey in the past are described by M. Bijleved (1974):"The persecution began in the seventeenth century and reached appreciable proportions in the eighteenth century. During the last two hundred years, the European continent has seen a period of intensifying persecution of birds of prey". Vultures, even if they have no negative interaction with human activities, have been heavily persecuted, due to ignorance and an incorrect interpretation of their behaviour. Wilbur (1983) mentions, for that time, a widespread use of strychnine and poison, shooting, disturbance of nests and shortage of food related to changing livestock management practices. Scavengers are regarded as one of the most threatened groups of birds (Sekercioglu 2006).

Fig. 1.1 – Griffon Vulture.

The serious crises among avian scavengers in the Old World during recent decades have revealed the sensitivity of vulture populations to the appearance of non-natural mortality factors. In Asia and Africa, the massive decline in several species should force managers and policy-makers to seek urgent conservation measures (Green *et al*. 2006; Thiollay 2007). Some of the most serious concerns from a conservation point of view are related to veterinary drugs (Blanco *et al*. 2009), the illegal use of poisoned baits (Hernandez & Margalida 2008), electrocution and collision with power-lines and wind turbines (Carrete *et al*. 2009) as well as lead poisoning as a result of the ingestion of prey killed using lead shot (Hernandez & Margalida 2009; Andreotti & Borghesi 2012; Pesaro *et al*. 2013). In addition to this, another important factor is the impact that restrictive public health policies may have on avian scavenger populations as a result of the reduction in the amount of food available for these birds (Margalida *et al.,* 2014). A typical example of this was the outbreak of bovine spongiform encephalopathy a few years ago. As a consequence most carcasses of domestic ungulates were removed, limiting food resources for avian scavengers (Margalida *et al*. 2010). In Europe domestic ungulates provide most of the carcasses available to scavengers and changes in traditional animal-rearing practices and especially in sheep farming have lead to a general decrease in scavenger carrying capacities (Donazar 1993; Margalida *et al*. 2011). As a result of this situation vultures have exhibited large decreases in many parts of their ancient distribution range, especially in Europe. The Griffon Vulture has disappeared from some countries while generally decreasing in the few remaining populations.

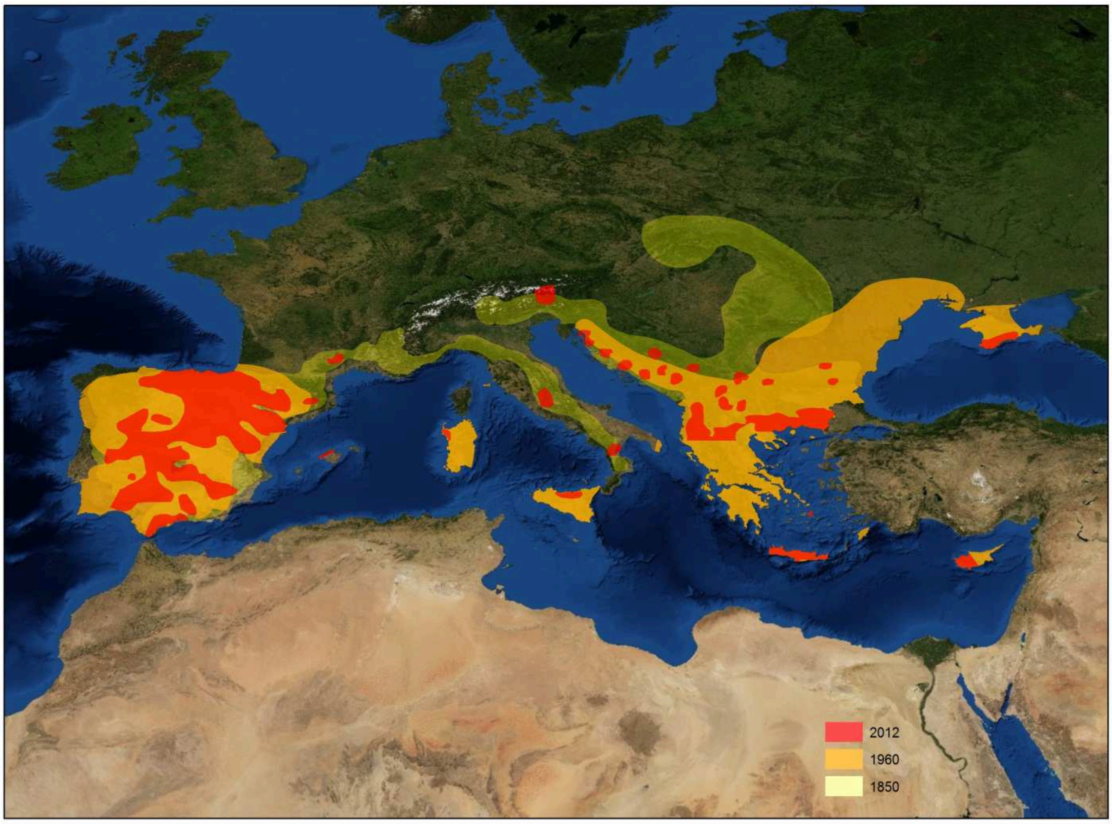


Fig. 1.2 – Present and historical distribution of the Griffon Vulture in the Mediterranean countries (VCF).

In Italy the species was distributed in Sicily, Sardinia and probably in different sectors of the Alps, the Apennines and other suitable areas. The Griffon Vulture probably disappeared a long time ago from peninsular Italy, from Sicily in 1965, while in Sardinia (where it was widely distributed in the past) just a small colony survived in the NW of the island (Genero 1992).

Currently, the presence of the Griffon Vulture in Italy is closely tied to conservation projects that have allowed the creation of 4 colonies as well as the survival of the last Italian colony in Sardinia. Between 1992 and 2008 a total of 388 griffon vultures were released. The Italian populations (Sardinia, Friuli, Abruzzo, Sicily and Calabria) amount to 535-540 individuals with 100-115 breeding pairs (Genero 2009; *unpubl.*).

2. Study area

The main study area is situated in the central part of the Region Friuli Venezia Giulia (NE Italy) at the southern edge of the eastern Alps. Griffon Vultures are usually present in spring and summer, spending the warmer months of the year in a huge area covering the Region and part of the Slovenian and Austrian Alps (Genero, 1985; 2002; 2009). A conservation project began at the end of the 1980s with the aim of consolidating the species' presence in the Alps and of creating nesting colonies (Genero & Perco 2002). The colony actually numbers a minimum of 120-150 individual in winter and more than 200 in summer, when many birds arrive from other countries. There are 25-30 breeding pairs nesting in five separate areas a few kilometers apart. The main breeding sites are also the most important roosts, situated on vertical limestone cliffs at an altitude ranging from 400 to1000 m. The birds are strictly dependent upon one feeding point that provides a large amount of food throughout the year and especially during the winter months. The colony exercises a strong attraction for griffon vultures summering in or crossing the Alps (Genero, 2009). These birds mostly arrive from Croatia, where there is a population of about 140 pairs distributed on the main islands of Qvarner Gulf (Sušic 2013). Part of the Croatian population and the young born in Friuli cover long distances in autumn, reaching wintering areas in SE Europe or even in the Middle East and Northern Africa (Sušic, 2000). Interactions between the griffon populations of the eastern Alps and Croatia are increasing and Croatian vultures regularly visit the feeding point with a range of strategies. The distance between the two areas is 180-220 km and the lack of food on some of the islands in recent years (particularly on Cres) has lead to an increase in Croatian griffon vultures in the Alpine region. Other Griffon Vultures colonies are located about 600 km SE and 500 km W. The vultures follow traditional flyways to move between Croatia and the most important sites in the Alps (Friuli, the Julian Alps in Slovenia and the Hohe Tauern in Austria) (Mihelič & Genero 2005).

The griffon vultures present in Friuli perform movements of various types. Some remain in the area between Friuli and Slovenia, while others regularly visit the Hohe Tauern in Austria during the summer. During the winter, some of the birds remain in the eastern

Fig. 2.1 – The "Riserva naturale regionale del lago di Cornino". The most important area for the conservation and management of the alpine population of Griffon Vulture.

foothills of the Alps, others move to the Croatian islands whilst the majority of Croatian griffon vultures move away south. The knowledge of these movements allows us to investigate the trophic search strategies, the influence of the area's morphology and the climatic parameters that characterize it, as well as the incidence and dangers represented by the various forms of infrastructure in the area.

The feeding site, located within the Nature Reserve of the *Lago di Cornino* is the only one in the Alpine region and is located at a considerable distance from other similar sites established to favour the conservation of carrion-feeding birds. In autumn and winter the griffon vultures are highly dependent on the food provided, whereas in spring and summer a proportion of the carcasses are found in the surrounding area. The management of the feeding point and the possibility of increasing the food in the area are indispensable elements for the management of this species in this as in many other areas (Niebuhr *et al*., 1997).

Observations at the feeding point have permitted the collection of a range of information concerning marked birds which come from various colonies, data barely available from elsewhere in Europe. The available data involve the observations made since 1992, for a total of 239 marked individuals. Up until now (2012) observations have been made for griffon vultures coming from Croatia (n = 258), France (17) Spain (5), Greece, Bulgaria and Israel (4) as well as from Austria (1), Hungary (1) and Serbia (1) (Genero, 2009; *unpubl.*).

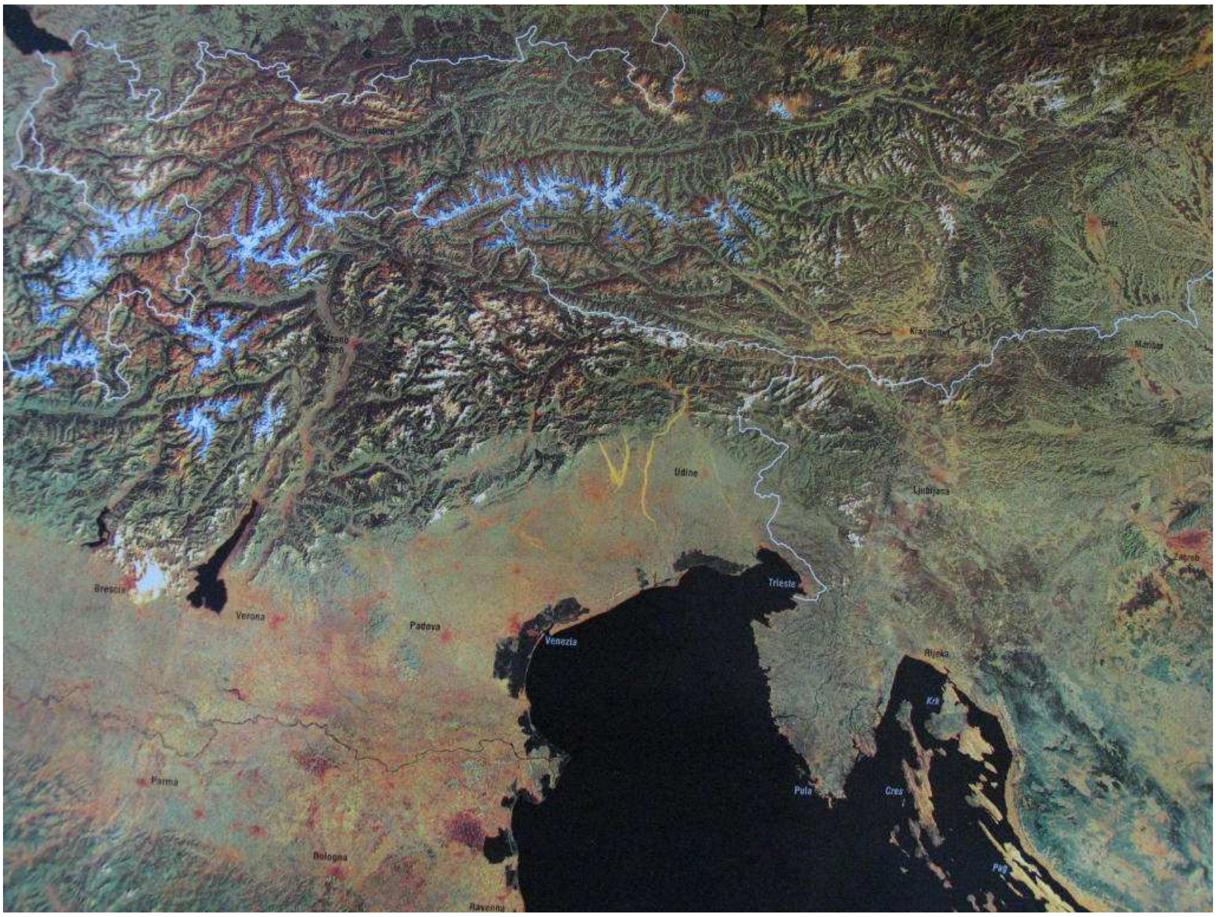


Fig. 2.2 – Study area, including the breeding colonies in the islands of Croatia and Friuli (Tagliamento Valley) and estivation areas in Italy, Slovenia and Austria (Google earth).

The parameters which characterize the species’ reproductive biology are very important in understanding the evolution of a population and its adaptation to the environment. In the Friulan colony nesting was first recorded in the 1990s, with a subsequent slow increase in pairs until it reached the current 25-30 pairs established along the middle tract of the River Tagliamento Valley (Genero *unpubl.*).

The situation of this colony - the only one along the entire Alpine chain - is very special in geographical and climatic terms. It is actually one of the most northerly colonies of Griffon Vulture in the entire Palearctic and is situated at the distribution limit of the species and, in particular, in unfavourable climatic conditions characterized by prolonged periods of cold and rainy weather that hinder the movement of the species (Genero 2004). The area is subject to heavy rain and receives an annual precipitation of about 2000 mm, mostly in spring and autumn. These conditions and the presence of a single feeding point pose important questions for research and comparison with other populations investigated, particularly in France and Spain, and on the movement strategies and use of space in this population.

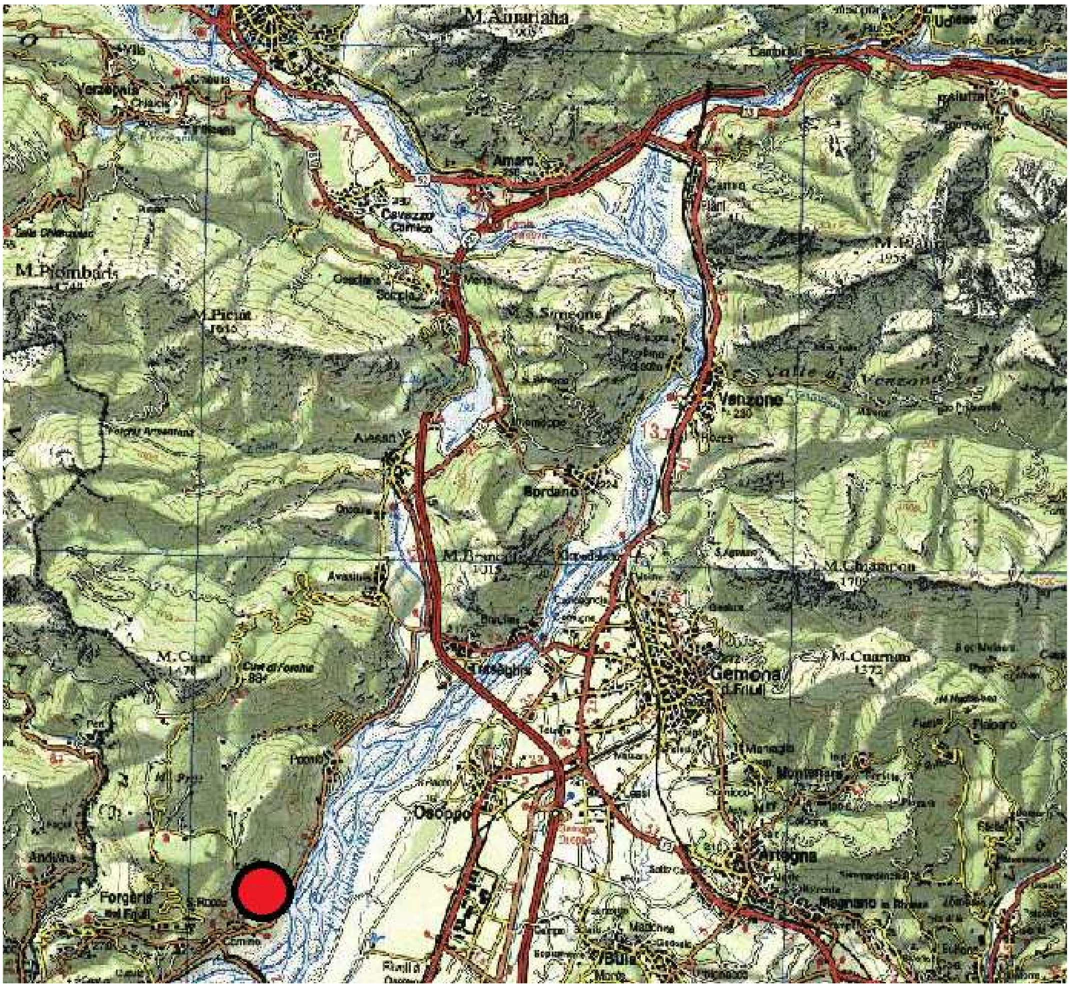


Fig. 2.3 – The Tagliamento Valley represents the most important area for the Griffon Vulture in FVG. The red spot represents the reintroduction area and the feeding point location (Map Ed. Tabacco).

Fig. 2.4 –The nearest population of Griffon Vultures, distant about 160-200 km from the feeding point, is located In Northern Croatia (Kvarner).

Fig. 2.5 – Traditional estivation area in the National Park Hohe Tauern; Salzburg, Austria.

3. Techniques used for the study of movements and the use of space

Griffon Vultures use gliding flight and, under favorable conditions, move over large distances using winds and updrafts. The manner in which the movements take place and the areas visited vary according to the geographical areas, seasons, and the individuals concerned (Cramp & Simmons 1980). Several techniques are used for individual recognition of birds including rings, bands, dyes and paints, tags, wing, neck and nasal markers (Day *et al.*, 1980).

3.1 Ringing

Scientific ringing was applied for the first time in Denmark in 1889. Subsequently, it has evolved as an important research technique able to monitor the situation of a range of species, to study their habitat use and migrations (Berthold 1993). The activity of temporary capture for the ringing of birds for scientific purposes is organized and coordinated for the whole of Italy by I.S.P.R.A, the State's Institute for Environmental Protection and Research. The metal rings can provide information in the event of the recovery or capture of the animal, but are not useful for observations from the distance. Colored rings in plastic or metal are used with or without alphanumeric initials. For these vultures rings 35-45 mm high and with an internal diameter of 25-28 mm are usually adopted. Colour-ringing was used for the first time on vultures in Africa in 1973 (Friedman & Mundy 1983). The plastic rings, however, have a limited life span, as they are lost after a few years. The problem was highlighted by Donazar (1993) and Piper *et al.* (1999) for the Cape Vulture *G. coprotheres*. For *G. fulvus* these losses were valued at around 4% for the first year and 9% for adult subjects (Duriez *unpubl.*). These rings can be read, with a good telescope, at a distance of up to about 300-400 m (Genero *unpubl.*).

Fig. 3.1 – Metal and plastic rings used to ring Griffon Vultures.

3.2 Bleaching feathers

The de-pigmentation of some wing and/or tail feathers is a valid system for the recognition of birds in flight, even at great distances. For vultures this technique was used for the first time for the Bearded Vulture (*Gypaetus barbatus*) in 1986 (Frey &

Roth-Callies 1994). This marking technique enables individual recognition only until the first moult (i.e. until 2–3 years of age). In addition to the limited number of marking combinations available, the difficulty of reading markings accurately, particularly by inexperienced observers, has generated some confusion about sighting records (Zink 2002). Feather bleaching has nevertheless illustrated the dispersal potential of different species (Hirzel *et al.* 2004). The methodology involves the use of products which act in a few minutes depending on the room temperature. The marking schemes must be designed in such a way as to avoid confusion between different individuals and with other species (Zink 2002). This method has also been used as part of the Griffon Vulture project in Friuli (Genero *unpubl.*).

Fig. 3.2 – Bleaching some feathers for the recognition at far distances.

3.3 Wing tags

Patagial wing streamers made of various plastic materials have been used widely on many species of birds. A major advantage of patagial tags is that the markers are usually more conspicuous than leg markers or back tags. The markers can encircle the wing between secondaries and scapulars or pierce the patagium (Wallace *et al.* 1980). Some concern has been expressed about impeding flight, but this appears related to the species and the methodologies used to apply them (Sanford 1980). Wing tags are used in many projects and monitoring plans, with a range of materials, shapes and codes. A long term marking project was carried out in Croatia where the marking of young griffon vultures on the islands of Cres, Plavnik, Prvic and Krk took place in the years after 1990 (Sušic 1994). The white markers are made of plastic with dimensions 140 x 87 mm and on each there are blue numbers or letters of 70 x 60 mm. After 4-6 years the marker drops off as a result of wear and material failure. No ill effects were observed as a result of carrying the wing tag. About 40-50 young were marked every year in the nest. The programme ceased a few years ago (Sušic 2000; pers. com.). Wing tags for vultures with various shapes and more resistant materials have been available for a few years and already used in various countries such as Spain, Portugal and Bulgaria (www.maquiaambiental.com). It is necessary to improve cooperation at a European level to avoid the risk of confusion between the different countries' marking programmes.

3.4 VHF telemetry

Wildlife telemetry encompasses a variety of techniques associated with obtaining measurements at a distance from the subject(s) and involves different techniques for radio transmission and reception (Cochran 1980). This system only works for animals in direct line-of-sight and is associated with various problems linked to the fact that radio waves are subject to reflection, refraction, diffraction, interference and polarization and their intensity diminishes with distance from the source (Kenward 1987). It is of little use in tracking vultures as it requires a number of operators in the field and the quantity data obtained is greatly reduced by the rapid movements of the birds.

4. Satellite tracking of birds

Researchers have always sought to follow birds in their movements, especially on their distant travels on migration. Nonetheless the documentation of such long migration routes, as well as the detailed knowledge of movements and home range has only become possible since the advent of satellite telemetry. With the introduction of GPS technology it is possible to study not only bird migration and movements, but also some other applications such as behaviour and activity, to analyse home range size, habitat use, foraging methods, territorial and seasonal behaviour, mortality and so forth, and as a tool to provide information for the planning of vulture conservation strategies (Meyburg & Meyburg 2009).

Tags for tracking by satellite have been used since the early 1970s on Wapiti (*Cervus canadensis*), Polar Bears (*Ursus maritimus*) and other species (Kenward, 1987). The early tags weighed 5-11 kg and were therefore only suitable for large animals. Satellite telemetry was used on raptors for the first time in 1984. On that occasion a Bald Eagle (*Haliaeetus leucocephalus)* was the first bird to be fitted with a satellite transmitter (PTT= platform transmitter terminal, weighing 170 g) (Fuller *et al.* 1984). Since that time satellite telemetry has undergone strong development, especially since the start of the '90s.
Satellite telemetry utilizes a platform transmitter terminal (PTT) attached to an animal which sends an ultra-high frequency signal via NASA satellites. PTTs are attached by collars, harnesses, subdermal anchoring, harpooning with a connected float, or by fur bonding. The satellites calculate the animal's location based on the Doppler effect and relay this information to receiving/interpreting sites on the ground. Polar orbiting satellites flying 850 km above the earth pick up the signals and store them on-board and relay them in real-time back to earth. The location signal sent from the PTTs is relayed to receiving stations where researchers record and interpret the data (Taillade 1992).
At the moment, the most used GNSS (Global navigation satellite system) is the global positioning system (GPS) network. GPS is a system comprising 24 satellites operated by the US Defense Department which has functioned since 1963. This technology represents a powerful tool for wildlife studies. GPS tracking systems can record huge numbers of highly accurate animal locations with minimal work by operators, thus allowing reduced sampling intervals, and increased accuracy and performance when compared with very high-frequency (VHF) radio-tracking systems.

Furthermore, data can be remotely transferred to operators (e.g. using GPS for mobile communications with the GSM network, or the Argos satellite system), making near-real-time monitoring of animals possible. GPS tracking datasets can be used to address questions on animal ecology (e.g. resource selection, animal movement, foraging behaviour) from a completely new perspective. GPS tracking routinely generates larger datasets than software tools commonly used by biologists in the recent past could handle (Urbano *et al.* 2010). In some studies vultures were equipped with high-resolution GPS and accelerometers tags (GPS-ACC).GPS data combined with acceleration measuring in three perpendicular axes allow estimation of energy expenditure and behavior, specifically of feeding events (Spiegel *et al.*, 2013; Spiegel *et al., in print*).

Fig.4.1 – Satellite transmittent (Vectronics GPS GSM) used in the present study and fitted on a bird.

Battery powered PTTs present the problem that battery life is not long enough for long term studies. To solve this problem solar-powered PPTs were generated and used for the first time on birds in 1993 on a White-tailed Eagle (*H. albicilla*) nestling in Germany. In time these transmitters became smaller and lighter and were used for large numbers of species. The weight of the PTT, including harness, should not exceed 3% of the bird's body weight (Meyburg & Meyburg 2009).

A team at the University of Amsterdam (UvA) have worked to develop a flexible, **Bi**rd **T**racking **S**ystem: the UvA-BiTS. The system includes a solar-powered, light weight GPS tag with rechargeable batteries, a tri-axial accelerometer, two way data-communication to a ground station network, automated data processing and visualization in the Virtual Lab. Researchers from multiple organizations are working with this system to study migration, navigation, foraging strategies on land and at sea. This system is able to provide many locations (as often as every few minutes in the summer months) and detailed activity indices although it has a lower precision. The data is downloaded to a ground station equipped with antenna when the birds are less than 1 km from it (http://www.uva-bits.nl). This system has already been used in France on griffon vulturess (Monsarrat *et al.*, 2013) and on the Red Kite (*Milvus milvus*) in Italy (Ceccolini *et al.* 2013).

4.1 Movements and land use: results obtained with different methods

Observations, traditional ringing schemes, wing tags and radio-tracking studies have shown that the Griffon Vulture ranges extensively, particularly juveniles and immatures and, to a lesser extent, adult birds (Elosegui & Elosegui 1977; Bahat *et al.* 1993; Sušić 2000). Griffon Vultures are obligate-soaring birds whose populations are partially migratory, with juveniles particularly prone to long distance movements. They are reluctant to make water crossings, being limited by their wing shape (Bildstein *et al.* 2009). Elosegui & Elosegui (1977) showed that in the Griffon Vulture population of Pyrenees adults are sedentary while juvenile birds mostly disperse to the S-SW as far as Morocco and Africa. Griesinger (1998) found that 30% of juvenile spanish griffon vultures migrate to Africa every year.

For the eastern Alps the studies produced by G. Sušić (1994, 2000, 2002, 2013) using rings and wing tags are particularly important. Marking with wing tags demonstrated that the Croatian population undertakes large movements at different times of the year. On the islands usually mostly adult birds are present, while juveniles and immatures spend the winter in SE Europe, the Middle East and North Africa. During the spring and summer they are sometimes observed at the natal colonies and some spend most of the time in the Alps. This trend has become less pronounced in recent years since one or two feeding sites were established on the island of Cres. In Croatia more than 90% of juvenile birds migrate long distances in all directions (Sušic 2013).

Such research has provided a lot of information on movements and spatial parameters but does not provide accurate data with regard to spatial ecology and ranging behaviour. Detailed data on these topics has been collected using different methodologies such as the detailed observations of marked birds, VHF telemetry, satellite telemetry and data loggers.

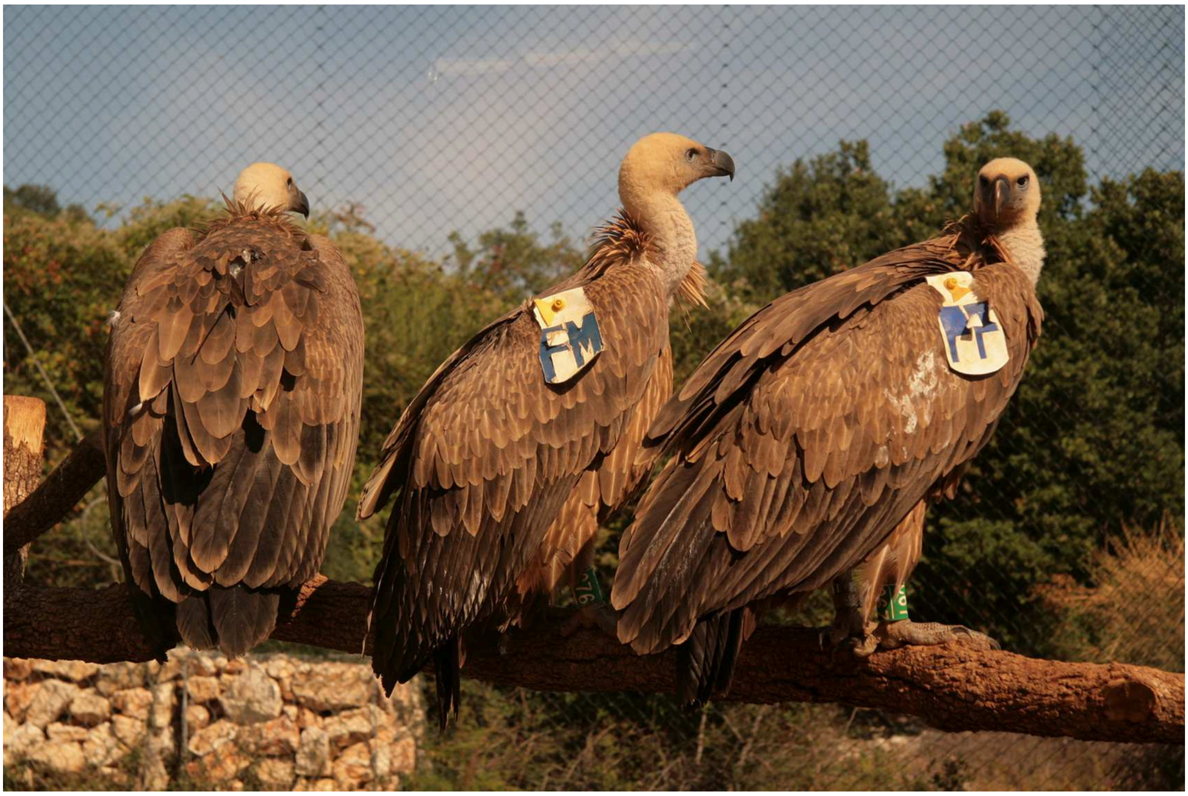


Fig.4.2 – Wing tags used in the past in Croatia.

The first studies were based on observations in the field and VHF radiotracking, with only a few fixes per day and low spatial precision. For instance, in Crete (Xirouchakis & Andreou 2009) the mean foraging range of Eurasian griffons from the colonies based on direct observations was estimated using kernel density estimation (KDE) 95% as 380 km² (range 195-527 km²). The foraging range size estimated by radio tracking (7 Griffon Vultures) was 692 km² (range 387-1,385 km²), 54.6% larger than the corresponding estimates derived from direct observations.

In the Cevennes (F) in a study carried out with 22 vulturess equipped with VHF telemetry provided a home range (Fixed Kernel Method) area in summer of 708±184 km² (Gault 2006). In Aragon-Spain (9 griffon vultures with VHF telemetry) the core area was 92 km² (Gil *et al*. 2009).

The first available data regarding Griffon Vulture ranging behaviour was based on the Argos satellite tracking of one juvenile tracked for two months in the early '90s (Berthold *et al*. 1991): the bird covered a total distance of about 2000 km from the Pyrenees to Valencia with a maximum of 80 km per day. Since then only a few papers based on satellite tracking have been published. Studies were based on the Argos system and later also on the Global Positioning System (GPS) that provides more accurate locations than Argos technology (Garcia-Ripolles *et al*. 2011).

The most extensive study was made in France. 42 griffon vultures of known origin (to the natal nest) and age (individually ringed) were equipped with GPS units. The solar-powered UvA-BiTS were programmed to get a fix every 5-10 minutes during the day in summer, every 16-60 minutes in winter and at night. The transmitters worked for two years and 28 vultures sent suitable data (Monsarrat *et al*. 2013). The home range area (within 95% UD isopleths) was 962±623 km² and the core area (within

50% UD isopleths) 109±80 km². Home range size was maximal in spring (1272±752 km²) and minimal in winter (473±237 km²), with large variations between individuals both in terms of size, shape and position.

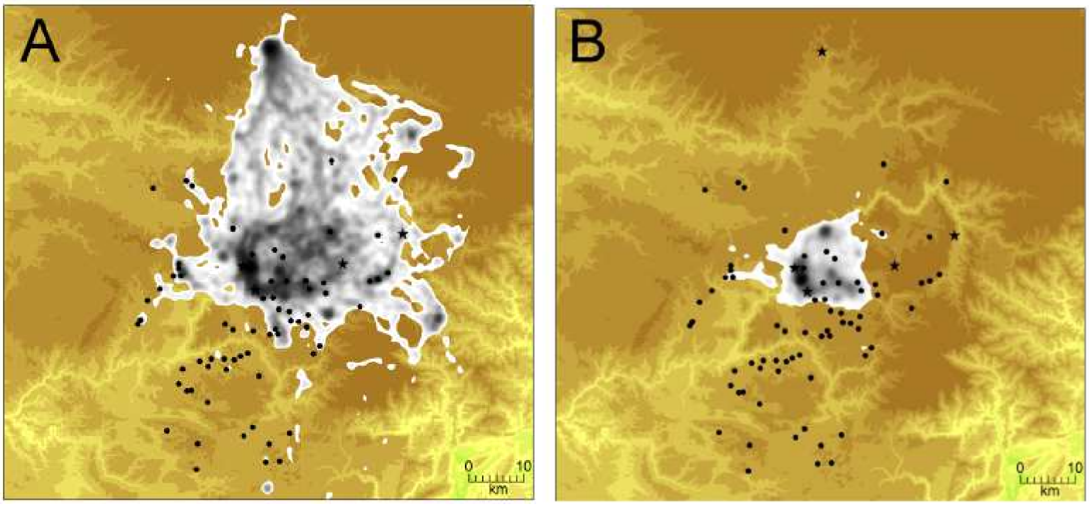


Fig. 4.3 – Examples of home ranges of two griffon vultures in summer in France (black dots are feeding points) (Monsarrat *et al.,* 2013).

Garcia-Ripolles *et al.* (2011) using satellite telemetry in Spain describe a median home range of 4,078 km² and core area of 489 km²; such high values could be due to the sample of 8 non-breeding adult birds in an impoverished trophic context. Foraging ranges of 930-8695 km² have been reported in Spain on 16 Eurasian griffons equipped with satellite transmitters (Arroyo & Garza 1996). Bigger home ranges are reported for 4 breeding birds in Navarra, ranging from 4,737 to 8,369 km², although 75% of the kernel areas were restricted to between 291 and 1,551 km² (Fernandez & Akona 2011). Data for a single Griffon Vulture in Israel show that the bird decreased its total foraging area from 1,383 km² in 1992 to 664 km² in 1993 suggesting that used areas can change with age and local conditions (Bahat *et al.* 1992; Bahat & Kaplan 1995).

In Central Italy in the period 2010-2012 16 satellite transmitters were fit and 9 birds gave suitable data. The Home Range obtained was 3,044±1,481 km² (MPC Method) with considerable variations between summer (2,623±1,098 km²) and winter (1531±1,326 km²) (Altea *et al.* 2013). First results of studies carried out on 3 griffon vultures with satellite telemetry in Friuli (Genero *et al. unpubl.*) show a mean home range (method KDE, 95% and 50%) of 8,624±4,437 km² and 1,364±842 km². These values are relatively high, due to the large movements of the birds and especially of one individual that went to France. Excluding this bird the values are similar to those obtained in Spain. In such situations, the seasonal movements of some birds play an important role.

Other data achievable using GPS technology relates to the behaviour of the birds and concerns different parameters include the **hourly flight distance**, calculating the straight-line distance between consecutive locations separated by one hour within the same day; **mean daily distances**, the sum of the previous parameter; **daily acitivity** as the frequency of segments for which an effective movement is recorded and **foraging time budget,** the hours spent foraging as well as the **mean foraging**

radius and range size, this being the distance and area of food survey (Garcia-Ripolles *et al*. 2011).

In France (Duriez *unpubl.*) the mean distance covered in a day by vultures was 77.0± 40.1 km, higher in summer (121.9±4.4 km) and lower in winter (28.6±6.4 km), with a maximum of 360 km. The mean speed was 19.7±8.7 km/h with a maximum of 141 km/h. The mean altitude over the ground was 301±139 m (maximum 2,577 m).

In Crete (Grece) Xirouchakis & Andreu (2009) the cross-country speed was calculated at 18.4 km/h (maximum 180 km/h) and the mean elevation of soaring griffon vultures over the ground was 248±112.3 m (ranging from 96 to 440 m). The mean foraging radius was 14.9 km (11.2-20.4 km). The foraging time budget was 7.6±1.1 hours/day and varied significantly between months and among seasons, with a minimum in December (6.4 hours/day) and maximum in June (9.3 hours/day). The time when the birds left the colony occurred 1.57±0.22 hour (range 1.33-1.77 hours) after sunrise in winter and 2.58±0.72 hours in summer. The birds returned to the colony *ca.* 2.3 hours before sunset.
In Spain the median daily distances ranged from 2.79 to 47.62 km with the maximum distances covered in a day ranging from 37.17 to 119.98 km, with significant differences among individuals. Daily activity was concentrated between 11:00 and 17:00 h (66.78%) with the median hourly distances ranging from 0.39 to 3.95 km (maximum 19.72-48.38 km) (Garcia-Ripolles *et al*. 2011). In Aragon Gil *et al*. (2009) calculated a mean foraging radius from the colonies to the feeding points of 9.7 km. In Abruzzo the mean daily distance measured was 26.9±7.8 km (37.0±13.4 km in summer and 19.5±6.8 km in winter) (Altea *et al*. 2013). In NE Italy Genero *et al*. (*unpublished*) reported that flying altitudes (calculated only for the region FVG) were associated with the height and morphology of the ground and were on average below 200 m from ground level (57% of locations). Flight altitude over the ground is higher in summer and within valleys. In Israel Spiegel *et al.,* (2013) obtained, in relation with food availability, a mean daily distance of 75,05 km and a mean elevation above ground of 336.50 m.

A comparison of home range size and distances in different situations must be considered with caution since the topography, local weather conditions, nesting sites, the quantity and distribution of food as well as the vulture population size may play an important role (Monsarrat, 2011). An important role is played by personal and social components in the prospecting behaviour, with great variability in the foraging strategies chosen by individuals. Griffon Vultures probably use a “traplining strategy” in which vultures use personal knowledge of food availability and visit priority spots with a high probability of finding carrion (Monsarrat 2011). Mobility and distances covered can change over the years, especially in recently reintroduced populations, as a result of changes or better knowledge of the food supply in the territory (Bonanni *et al*. 2013). Also important are the age and sex of the birds and their breeding status. Adult breeding Griffon Vultures range across a relatively small foraging area, being typical central-place foragers, obliged to return to their breeding colony (Zuberogoitia *et al*. 2012). Immatures move more and are less selective with regard to foraging habitat compared to adults, they may also prefer habitats with predictable resources but try to limit competition with adults. Females show more repeatability in their foraging routes than males and concentrate their activity around feeding stations (Monsarrat 2011). In Abruzzo (n=9) no significant differences were found between sexes (Altea *et al*. 2013).

Griffon vultures make regularly short-term spatially extended movements in which individuals depart from their traditional area, travel to remote locations and return to the original core area. Such movements seem to reflect an adaptive exploratory strategy for exploiting remote food patches and possibly other resources or different movements such as migration and dispersal (Spiegel *et al.*, 2014). These authors found out that in Israel females wander more and search for a mate at remote colonies prior to the breeding season (Spiegel, *Ined.*). Movements of juveniles resemble the long-range movements of adults in their spatial scale and in the timing of departure, but not in duration and frequency. Vultures are known to form mixed-age flocks (Mundy et al., 1992) probably adult vultures accompany young birds on exploratory forays.

In Israel Spiegel *et al.*, (2013), found out how hunger affects the movements of 47 adult Griffon Vultures. Food deprivation provocate, in the first five days, a clear response for daily flight distances, maximal displacements and flight elevation; when hungry vultures are more active, depart earlier from their roosts and invest more in foraging. After five days vultures reduce activity to conserve energy.

Feeding stations can heavily influence the behaviour of vultures and in any case enable vultures to adjust their foraging strategy to their current energy needs and flight conditions (Bosè *et al.* 2012; Garcia-Ripolles 2011; Monsarrat *et al.* 2013). In addition, the position and features of roosting places play an important role. Roosts are normally located on rock faces and are chosen to provide protection from weather condition and disturbance but are also related to the distribution of food supplies. Vultures forage mainly within 10-12.5 km of their roosts (Olea & Mateo-Tomas 2009).

GPS telemetry has also been used for other species of the genus Gyps in Africa and Asia where vultures usually move much larger distances and therefore have huge home-ranges. The main aims in Africa were to analyze the use of protected areas and interactions with the power-line network. Studies were made on G. coprotheres (Phipps *et al.* 2013) and G. africanus (Phipps *et al.* 2013). In Asia research on G. bengalensis was carried out in order to reduce diclofenac-related mortality by managing vulture restaurants (Gilbert *et al.* 2007). GSM-GPS transmitters were also used to study mortality in different species of vultures in Kenya (Kendall *et al.*, 2012).

Area/Period	N. Birds	Study methods				Home range (95%)	Core area (50%)	Mean distance day	MCP	Literature
		Observations	VHF	GPS satellite	Data logger					
Israel/1992-1993	1		X			664-1.383 km²		72,5 km (31,5-143,5 km)		Bahat, *et al.,* 1993
Spain/1996	16			X		930-8.695 km²	71-590 km²			Arroyo & Garza, 1996
Crete (Gr)/1997-2005	7	X	X			Obser: 380 km² (195-527 km²) Telem: 692 km² (387-1385 km²	Telem: 64.3 km²	472 (291-851) km²		Xirouchakis & Andreou, 2009
Grand Causses (F)/ 2003-2004	22		X			Summer 708±184 km²				Gault, 2006
Aragon (E)/2000-2005	5		X				92 km² (23-161 km²)			Gil *et al.*, 2009
Spain/2007-2010	8			X		4078 km² (613-8075 km²)	489 km² (94-810 km²)	2.79-47.62 km (max 120 km)	7419 km²	Garcia-Ripolles *et al.,* 2011
Navarra (E)/2011	4			X		4737-8369 km²				Fernandex & Azkona, 2011
Grand Causses (F)/ 2010-2011	28				X	962±623 km² Spring 1272±752 km² Winter 473±237 km²	109±80 km²	77.0±40.1 km Summer 121.9±4.4 km Winter 28.6±6.4 km (max 360 km)		Monsarrat *et al.,* 2013
NE Italy/ 2006-2010	3			X		8624±4437 km²	1364±842 km²			Genero *et al.,* (unpublished)
Abruzzo (I)/2010-2012	9			X				26,9±7,8 km (3,5-37,8 km) Summer 37,0±13,4 km Winter 19,5±6,8 km	3044±1481 km² Summer 2623±1098 Winter 1531±1326 km²	Altea *et al.,* 2013
Israel 2008/2011	53			X		3716±13199 km² 13028±15507 km² (Negev)	411±93 km 1049±628 km	75,05 km		Spiegel *et al.,* 2013

Tab. 4.1 – Home-range and distance parameters obtained in different studies.

Area/Period	Cross country speed	Elevation above ground	Foraging time badget	Mean foraging radius	Literature
Aragon (E)/2000-2005				9,7 km (4,3-23,3 km)	Gil *et al*., 2009
Israel/1992-1993	Mean 34 km/h (6,9-144) Max 216 km/h		Mean 6 h/day		Bahat, *et al.,* 1993
Crete (Gr)/1997/2005	Mean 18.4 km/h Max 180 km/h	248±112,3 (96-440 m)	Mean 7.6±1.1 h/day	14,9 km	Xirouchakis & Andreou, 2009.
Grand Causses (France)/ 2010-2011	Mean 19.7±8.7 km/h Max 141 km/h	Mean 301±39 m Max 2577 m			Monsarrat *et al.,* 2013
Spain/2007-2010				14,05 km	Ripolles *et al.,* 2011
Abruzzo (I)/2010-2012					Altea *et al.,* 2013
NE Italy/ 2006-2010		40-60 % ‹ 200 m			Genero *et al.,* (unpublished)
Israel 2008/2011		336,50 m		13,65 km	Spiegel *et al.,* 2013

Tab. 4.2 – Flight characteristics and foraging behaviour in different studies.

5. Feeding and food resources

Scavenging has evolved in several different phylogenetic groups, with a common factor being to minimize energy expenditure. Carrion is unpredictable both in space and time and scavengers need to develop an optimal searching strategy that maximizes successful encounter rates with the resources available. Since vultures can fly over huge areas with low energy costs, they are much more efficient than other animals (Ruxon & Huston 2004). Vultures of the genus Gyps are exclusively scavengers, typically feeding in large groups, using social foraging strategies, on a resource that is clumped and unpredictable in space and time (Donazar 1993; Mundy *et al*. 1992). The Griffon Vulture mainly feeds on soft tissues (muscle and viscera) of medium to large mammals and occasionally feeding on other vertebrates and insects. The species feeds almost exclusively by scavenging: there have been a few reports of taking prey too weak to defend itself, but there have been no reliable reports of Griffon Vultures attacking or killing healthy animals. Gyps vultures have reduced olfactory abilities and detect food by vision (Cramp & Simmons 1980). Studies have shown that Griffon Vulture regularly fast for several days between successive meals and are capable of saving energy by decreasing their metabolic rate and modifying thermoregulation (Bahat, 1995). Vultures usually spend a few hours at a carcass site and are passive most of the time, with short bursts of eating and fighting (Spiegel et al., 2013).

Fig. 5.1 – Griffon are typical social birds that can congregate in large number at carcasses.

The costs and benefits of foraging and feeding in groups have been widely investigated (Bosè *et al*. 2012). Foraging behaviour largely depends on the nature of the exploited resources.

In Europe Griffon Vultures can be considered as commensal with humans, and even though they can feed on wildlife carrion, their food source is largely provided by domestic animals, mainly sheep and cattle (Gault 2006). Vultures have always provided humankind with an essential service by eliminating carrion and reducing the related sanitary risks (Donazar *et al.* 2009; Niebuhr *et al*. 1997). Being dependent on such an unpredictable and ephemeral food supply, griffon vultures have to travel extensively and cooperate in order to forage successfully. Normally birds fly out from the colonies in the morning and search for food in a gregarious fashion with each individual exploring different areas while maintaining visual contact with neighbours.

When a source of food is found all congregate at the carcass. In fact, once an individual discovers a resource, it will circle over it, before and while descending. Circling vultures are visible from far away and other individuals are attracted to the area (Houston 1974).

The results of radio-tracking in Israel show that Griffon Vultures do not forage randomly, but selectively choose open grazing areas intensively used by ungulates, where these raptors expend most of their foraging efforts (Bahat 1995). Studies on three species in Africa show that the mortality of ungulates may be a more important driver of vulture habitat use than prey abundance (Kendall *et al.,* 2014).

Vultures are known to forage opportunistically and concentrate near reliable food sources. Griffon vultures can use personal information, derived from previous experience, or social information, acquired from interacting with conspecifics. (Deygout *et al.* 2010).

In the Mediterranean area Eurasian griffons depend mainly on extensive livestock and there is a clear correlation between the distribution and abundance of vultures and the density of cattle (De Juana & De Juana 1984). Wild ungulates are normally not very important, but can have importance in areas where game is well-managed. In the Pyrenees, and probably also in the Alps, biomass from wild ungulates may form an important integration to the diet of the Griffon Vulture (Margalida *et al*. 2011).

Fig. 5.2 - In the Mediterranean area Eurasian griffons depend mainly on extensive livestock (Estremadura, Spain).

Scavengers provide one of the most important ecosystem services of any avian group (Sekercioglu 2006). Recycling carcasses from livestock and wildlife, scavengers maintain energy flows higher in food webs and limit the spread both of diseases and of undesirable mammalian scavengers. Changes in human practices have reduced both the quantity and the safety of their trophic resources with a reduction in livestock mortality through veterinary progress, livestock sanitary treatments through to changes in agro-pastoral practices or legislation dealing with organic waste imposing the systematic destruction of carcasses (Camina 2004). As a result, traditional sources of food for vultures have declined dramatically in the last century. In Spain the European regulations concerning bovine spongiform encephalopathy enforced the closure of traditional feeding places ('*muladares*') and many feeding points which had a negative impact on vulture populations. This sudden lack of food led to a change in vulture feeding behaviour patterns with decreasing numbers of breeding pairs, lower productivity and higher mortality. In addition more human conflicts with vultures were reported in which they were accused of becoming aggressive towards livestock (Camina & Yosef 2012; Dupont *et al.* 2012). The reduction or disappearance of traditional grazing activities can cause ecosystem degradation through negative effects on vegetation cover and wild fauna. The strong relationship between scavengers and transhumance has been demonstrated in Spain. Transhumance activity may represent a useful tool in the sustainable management of vulture populations with many other advantages for the environment and local cultural traditions (Olea & Mateo-Tomas 2009).

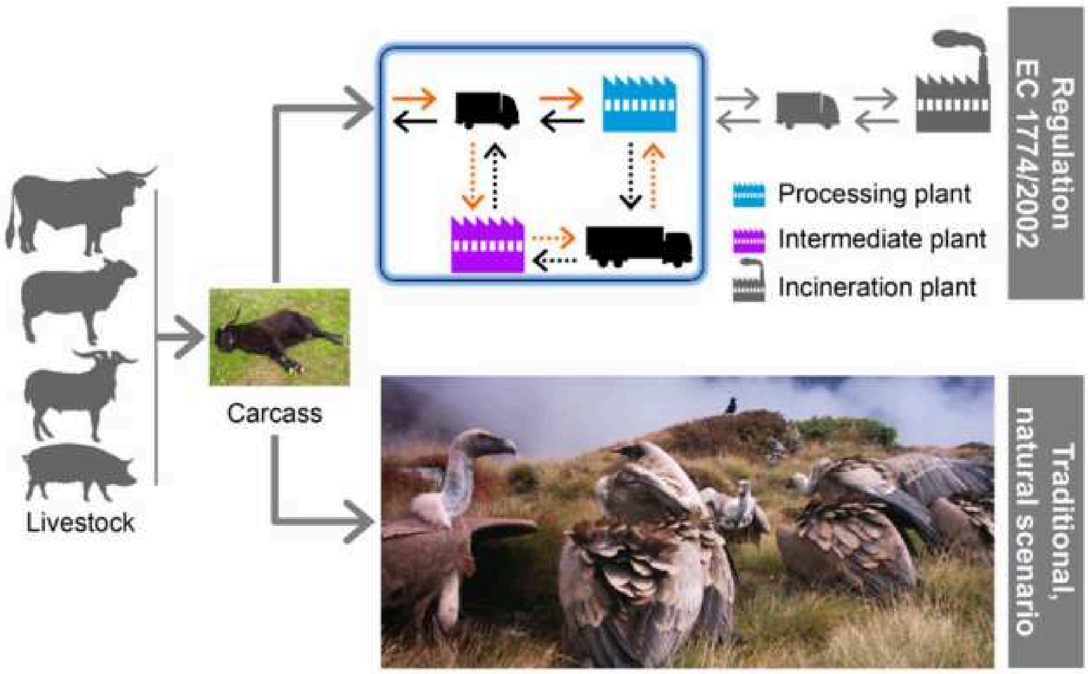


Fig. 5.3 – Schematic representation of the application of European sanitary regulation 1774/2002 and ecosystem services provided by vultures (From Morales-Reywes *et al.,* 2015 modified).

Foraging over great areas makes griffon vultures more susceptible to human-induced changes in the landscape and exposes them to greater dangers, like those of ever-increasing numbers of wind farms, poisoning and the ingestion of lead-shot (Camina & Yosef 2012). Foraging behaviour depends on food availability and predation risk, being humans the main potential predator (Zuberogoitia *et al.* 2010).
Dominance at food seems to depend more on the degree of hunger than any stable rank-order based on individual recognition (Kruuk 1967; Houston 1988). If food items or feeding places at a carcass are limited, disputes break out and a hierarchy is established (Cramp *et al.* 1980). Bosè & Sarrazin (2007) found that old adult vultures

are more aggressive and dominant than younger individuals, so the age structure of the group has great importance for understanding vulture feeding ecology. They observed that old adults were mostly present at the beginning of the feeding event and the proportion decreased with the arrival of young and immature birds. Thus adults, who arrived first, could gain access to the carcasses and the most nutritious tissues. Juveniles and immatures, arriving later, may get no food. In northern Spain Zuberogoitia *et al*. (2012) found out that adult griffon vultures use relatively small foraging areas in comparison with young and immature birds. Studies carried out by Duriez *et al*. (2012) came to the conclusion that, in general, vulture hierarchy is based on age. On average birds feed until they reach satiation (1-2 kg of meat). Generally vultures need a daily amount of food that corresponds to 5-10% of body weight. Captive Griffon Vultures need, on average, about 450 g of meat while wild birds need 472-627 g (Donazar 1993).

6. Feeding points and their role in vulture conservation

The presence of vultures in Europe is strictly connected with certain traditional human activities such as sheep farming and livestock rearing. Changes in traditional management techniques have brought a decline in vulture populations and, as a consequence, the provision of supplementary food has been advocated. Furthermore, current European sanitary laws are tending to promote the concentration of livestock carcasses in limited locations called feeding stations or vulture restaurants in order to safeguard human health (Cortes-Avizanda *et al*. 2010). Vulture conservation has often entailed the establishment of feeding stations, to help overcome the shortages of food that are thought to negatively impact 10 of the 12 vulture species considered at risk by the IUCN (Deygout *et al*. 2009).

Fig. 6.1 – Feeding point managed from “Gobierno de Navarra”, following the recent european rules.

Fig. 6.2 - The feeding point in the Riserva naturale regionale del Lago di Cornino UD – Italy.

The first "vulture restaurant" was organized in South Africa in 1966 (Friedman & Mundy 1983) and within Europe in France in 1969 by the Pyrenean National Park, many others being established later in different countries (Terrasse 1983). Feeding points have many advantages and can achieve some important aims (Piper 2006) including:

- the provision of supplementary food;
- the provision other dietary supplements, e.g. calcium;
- the establishment of safe places for birds to feed;
- monitoring;
- public awareness.

These effects can be very important or even essential in the conservation of vulture populations. Feeding points can change long–term population dynamics, facilitate the recolonization of abandoned areas, allow the recovery of endangered populations and provide safe food in areas where carcasses are baited with poison to control carnivores as well as improving the acceptance of these birds by farmers and the general public (Oro *et al. 2008).*

On the other hand, there are also negative effects of artificial feeding stations on population dynamics and demographic parameters of some species, especially for territorial species, like Bearded and Egyptian Vulture (Neophron percnopterus) and fewer for social species like the Griffon Vulture, which generally feed in large numbers(Carrete *et al.* 2006). Various authors (Gault 2006; Deygout *et al.* 2009) claim the disruption of social foraging behaviour, as individuals who use feeding stations may no longer need to interact with conspecifics to gain information regarding food location. In this way vultures' behaviour and ecology may change. Regular use of feeding stations can influence the area prospected by vultures. Radio tracking in France shows that the area prospected by vultures was determined by feeding point locations. Vultures may still exploit unmanaged resources, but are generally limited to those areas close to feeding stations (Monsarrat *et al.* 2013).

Food should be placed at sites that will maximally benefit the target species and ideally both the spatial and temporal location should be random to discourage habituation. An economic analysis of feeding stations must consider the effect on the increase and conservation of populations and aspects related to other ecosystem services provided by the species (Becker *et al.* 2009). The economic and environmental costs of their maintenance is likely to be low compared to the usual industrial disposal of carcasses, which entails their transport and incineration. Eliminating carcasses in this natural fashion also appears important in relation to the limitation of CO_2 emissions, reduced pollution and energy demand. The loss of scavengers can greatly affect ecosystem functioning, human health and well-being (Dupont *et al.* 2011). Usually feeding points have to be fenced to avoid access of potential disease vectors to the carcasses provided. In 2011 the European Union loosened restrictions in certain circumstances and as a result carcasses may be left in the wild without the obligation of placing them within a fenced area (Moreno-Opo *et al.* 2012)

With regard to the conservation project in Friuli, a single feeding point was established from the beginning of the project. In this environmental context the feeding point is vital, providing nearly all the food needed by the vultures in autumn and winter and an important if variable amount in spring and summer (Genero 1992; Genero & Perco 1997). In 2012 the total weight of carcasses provided amounted to 43 tonnes (Genero *unpubl.*).

It is important to establish more feeding points in the Region, if we want to favour a further increase of the Griffon Vulture population in the eastern Alps. This aim is not easy to achieve, because of the economic and organizational aspects related to the management of feeding points. A good solution would be a network of feeding points self-managed by farmers. The best example in this direction is provided by France where currently more than 250 small feeding places are supplied directly by local farmers (LPO, France). Involving farmers by allowing them to establish their own feeding stations enables them to spread the same amount of resources across larger areas and thus reduces the predictability of the resources available to vultures, thus preserving their use of social information (Bosè & Sarrazin 2007; Deygout *et al.* 2010). The composition of the groups of vultures landing is different at large feeding stations when compared to small feeding points, allowing the late arrivals easier access to high-quality food for younger vultures (Duriez *et al.* 2012). Another potential source of food is linked with increasing populations of wild ungulates and the possibility, during hunting management of leaving the viscera or part of the carcass in the field. In this context the use of unleaded munitions is fundamental.

Fig. 6.3 - Feeding points are frequented from large numbers of vultures, Spain.

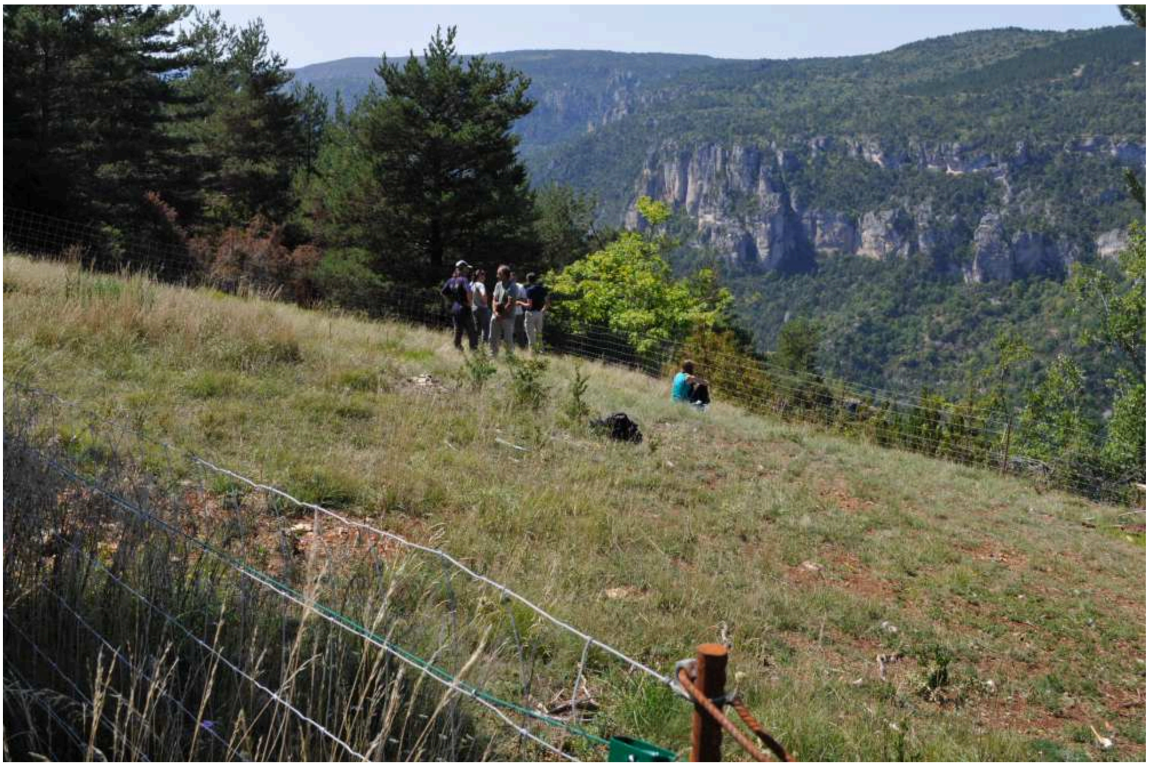


Fig. 6.4 – Small feeding points, managed directly from farmers, in France.C

7. Research Objectives

The population of Griffon Vulture present in the eastern Alps presents unusual aspects as it is located on the edge of the distribution range of the species in a climate that is unfavorable to its ecological requirements. The presence of a single feeding point also determines unusual conditions that are not encountered in other areas. These factors merit special investigations to evaluate how the griffon vultures survive in these conditions and to identify the limiting factors that may influence colonization, both of the Alps and other non-optimal environmental contexts. It is therefore important to use tools and analyses to study the movements and use of space by these birds as a function of the seasons, the manner in which they move and their activity rhythms in relation to the morphology of the area and climatic factors. The analysis should examine local movements in depth as well as those between Croatia, Friuli, Slovenia and Austria together with those undertaken over long distances. The main objectives are:

- definition of the home range and core area used by griffon vultures in different periods and geographical areas;
- flight paths and heights in relation to the characteristics of the territory and climate parameters;
- how the movements take place in relation to the various foraging strategies and the location of the feeding point;
- parameters related to movement: daily and hourly distances covered, daily activity, altitude of flight, cross-country speed, seasonal and daily activity pattern;
- location of night roosts and changes in their use over time;
- Identification of risk factors (infrastructure, human activities) and critical elements (food availability, climatic factors);
- monitoring of marked individuals and research on their origins;
- population size;
- identification of nesting areas and nest sites;
- reproductive biology (no. of pairs, no. of pairs which lay eggs, n. young hatched, n. fledged) and the calculation of productivity and reproductive success;
- general assessment of health conditions and health status of the birds.

8. Methods

8.1 **Vulture captures**

The study was based in the Riserva naturale Regionale del lago di Cornino (Forgaria nel Friuli, Udine-Italy - 46°13'N, 13° 01'E) where all the birds were marked, equipped with GPS-transmitters and released. We used data obtained by satellite telemetry on 12 birds equipped between 2005 and 2014. From 2005 to 2012 six birds were recovered in different situations and countries (I, A, CZ) of different age (3 adults and 3 immatures) were used. In 2013-2014 a project was carried out financed by the Hohe Tauern National Park (Salzburg – A). In 2013, some attempts to capture vultures were made in the Home Tauern Mountains (A) with different trapping methods but without any success. Vultures were caught at the feeding point for avian scavenger in the natural reserve. A walk-in cage trap (3x5x1,50m) constructed from a lightweight wood frame and overlaid with wire mesh and baited with domestic or wild ungulates carcasses was used to catch the vultures (Bamford et al., 2009).From May 2013 to July 2014 forty-nine Griffon.

Fig. 8.1 – Attempts to catch griffon vultures, with different methods, in the National Park Hohe Tauern (A) were unsuccessful, Stubachtal 13.07.2013.

Vultures were caught, ringed with official metal rings (I.S.P.R.A./Euring), alphanumeric green plastic rings and bleaching of some wing and/or tail feathers. Numbers of vultures per age class: 18 immature (2-3 calendar year), 16 subadults (4-5 cy) and 15 adults (>5 cy). Origin of the birds: 7 from local colony, 12 from Croatia, 2 from other countries (Spain and France), 28 unknown (no ringed). Six griffon vultures were fitted with GPS-GSM tracking units: 5 in summer 2013 and 1 in summer 2014. All birds were non-breeders and had Croatian rings, three in the second calendar year, two in the third and one in the fourth. Birds were aged according to plumage characteristics and with ringing data got from G. Sušic. Blood samples were taken during the vulture trapping for sexing and sanitary investigation.

Fig. 8.2 – Catching of griffon vultures in the National Park Hohe Tauern in 2013 (Salzburg – Austria).

Fig. 8.3 – The carcass of a cow in the National Park Hohe Tauern.


Fig 8.4 - Building of the “walk in” trap on the feeding point of the Natural Reserve, 2013.


Fig. 8.5 – Griffon vultures inside the trap, 28.05.2013.

Tab. 8.1 – Griffon vultures captured from May to August 2013.

28.05.2013

Plastic ring	Metal ring	Year/Age	Weight kg	GPS radio	Origin	Notes
F19* sx	M4571* dx	2010	8.6		Local	Born in captivity
F21* dx	M4572* sx	2012	8.7		Local	Born in captivity
F22 sx	UA3052* dx	2011	8.6	13124	CRO	Lost ring in Sicily nov 2011
F23 sx	M4573 dx	4-5° year	8.9		?	
F24 sx	M4575 dx	2012	8.3		?	
F25 dx	UA03197* sx	2012	8.8	13121	CRO	
F26 sx	M4574 dx	4-5° year	8.6		?	
F27 sx	M4311* dx	1988	8.6		Local	Ex AOR

10.05.2013

Plastic ring	Metal ring	Year/Age	Weight kg	GPS radio	Origin	Notes
AOA* sx yellow	M4335* dx	2001	-		Local	Released
F28 dx	M4576 sx	adult	“		?	Released
F29 sx	M4577 dx	subadult	“		?	Released
F30 dx	UA03187* sx	2012	7,7	13125	CRO	Released 17.07
C68* dx	UA03103* sx	2012	8,0		CRO	Released 17.07
F44 sx	M6407 dx	2010/11	7,7		?	Released 17.07
F45 sx	M6408 dx	2010	7,9		?	Released 17.07
F46 sx	M6409 dx	2011	8,4		?	Released 17.07

16 and 17.07.2013

Plastic ring	Metal ring	Year/Age	Weight kg	GPS radio	Origin	Notes
F31 dx	UA03153* sx	2012	7,4	13120	CRO Cres	Released 17.07
F32 dx	UA3070* sx	2011	8,5	13122	CRO Krk	Released 17.07
F33 sx	M4578 dx	subad	7,2		?	Released 17.07
F34 sx	M4579 dx	1996	6,7		CRO Cres	Released 17.07 Ex UA0035
F35 sx	M4580 dx	2010/11	6,8		?	Released 17.07
F36 dx	UA03169* sx	2012	7,0		CRO Krk	Released 17.07
F37 sx	M6401	2012	7,5		?	Released 17.07
F38 dx	M6402 sx	2010/11	8,7		?	Released 17.07
F39 sx	M6403 dx	2010	8,5		?	Released 17.07
F40 sx	M6404 dx	2011	9,0		?	Released 17.07
F41 dx	UA3002* sx	2010	6,6		CRO Cres	Released 17.07

F42 sx	M6405 dx	adulto	9,2		?	Released 17.07
F43	M6406	adulto	-		?	Released 17.07
F5A sx yellow	M4556	2003	8,9		Local	Released 17.07 Ex AOM
CEW dx	UA1885* sx	2006	7,8		CRO Cres	Released 17.07
CFO dx	UA2295 sx	2008	7,6		CRO Cres	Released 17.07

* - birds already ringed

Tab. 8.2 – Griffon vultures catched between May and August 2014.
05.06.2014

Plastic ring	Metal ring	Year/Age	Weight kg	GPS radio	Origin	Notes
F50	M6412	~2012	7,4		?	Released 5.06.2014
F51	M6413	~2011	8,5		?	Released 5.06.2014
F52	M6414	subad	9,2		?	Released 5.06.2014
F53	M6415	2011/12	9		?	Released 5.06.2014
F54	UA3073	2011	8	13123	CRO Cres	Released 11.06.2014
F55	M6416	2013	7,5		?	Released 5.06.2014
F56	M6417	~2011	8,8		?	Released 5.06.2014
F57	M6418	ad			?	Released 5.06.2014
F59	M6419	2011/12	7,3		?	Released 5.06.2014
F60	M6420	ad	8,4		?	Released 5.06.2014
F61	M6421	subad	8,6		?	Released 5.06.2014
F58	TY 1902	1995	8,9		France	Released 5.06.2014
CFD	no	2008	8,3		CRO Cres	Released 5.06.2014
20	A002 Burg	2008	8,8		Austria	Released 5.06.2014
F38	M6402	2010/11	8,6		Ricapture	Released 5.06.2014
F42	M6405	ad	8,8		Ricapture	Released 5.06.2014
F62	M6422	~2011	7.0		?	Released 10.06.2014

If we exclude the two recoveries, 47 vultures were caught, including 5 of the colony, 12 from Croatia, one from Austria, one from France and the other of unknown origin (without rings).

Satellite transmitters were applied to 6 subjects, 45 were marked with depigmentations of wind and/or tail feathers. 39 plastic rings and 30 metal rings (EURING scheme for Italy) were applied.

Fig. 8.6 – Griffon vulturess captures in the trap, 2013 (Webcam Riserva naturale regionale del Lago di Cornino).

Tab. 8.3 – Age classes of captured vultures.

Age	2013	2014	Tot.
Imm. (2-3° y)	14	4	18
Subad. (4-5° y)	9	7	16
Ad. (> 5° y)	9	6	15

Tab. 8.4 – Origin of the birds.

Origin of the birds	2013	2014	Tot.
Local colony	5	2	7
Unknown (no marks)	17	11	28
Croatia	10	2	12
Other countries		2	2

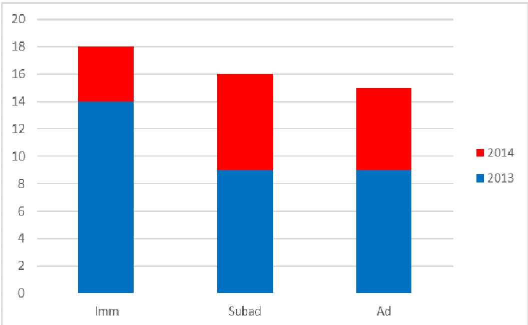


Fig. 8.7 – Age classes of captured vultures.

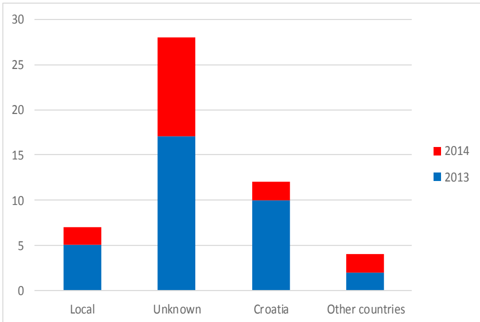
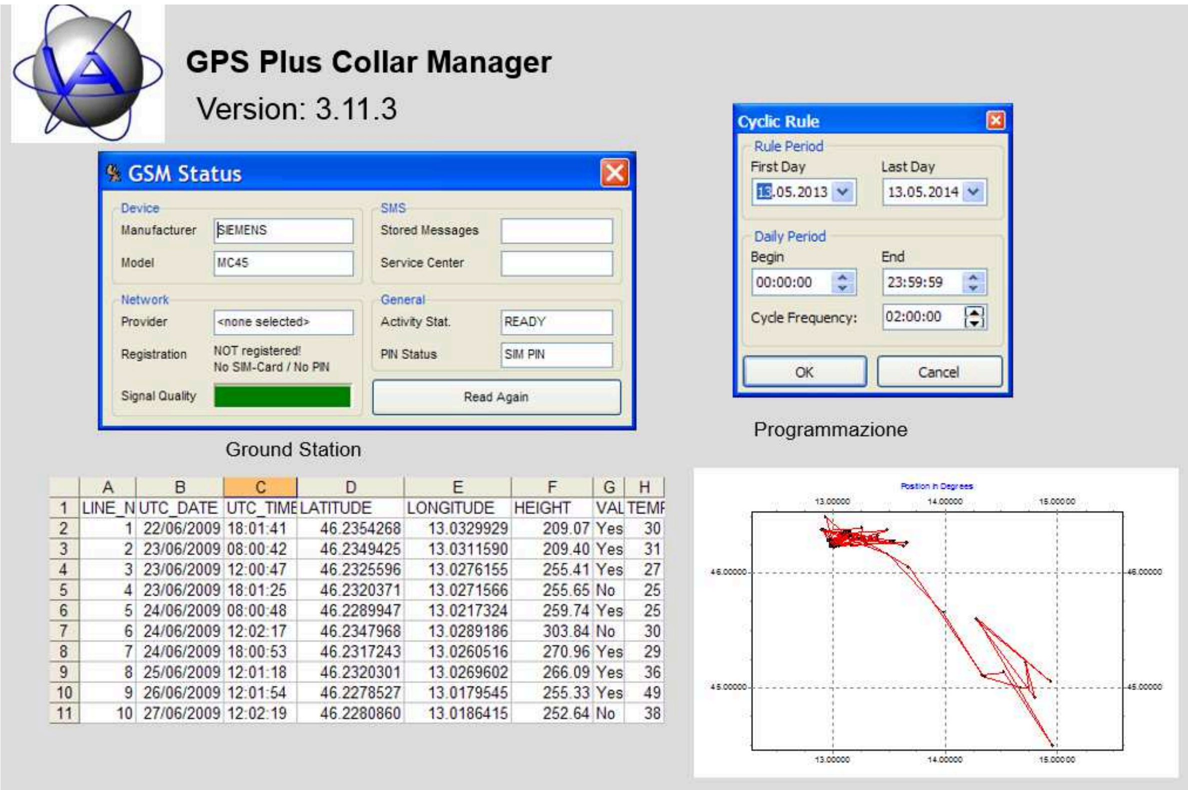


Fig. 8.8 – Origin of the birds.

8.2 GPS-GSM tracking units

12 griffon vultures were outfitted with GPS PLUS 1C BIRD GPS-GSM tracking units (Vectronics Aerospace Gmbh-Germany), using a Teflon ribbon backpack-style harness enclosed in flexible plastic tubing to prevent skin abrasion (Diekmann et al., 2004). Each unit weighed 190 g (ca. 2.5% of the mean mass of a Griffon Vulture) and was encased in hardened epoxy resin for protection and waterproofing. A cotton ribbon allows birds to lose the harness after the end of transmitters life. Units were set to record GPS locations (~ 25 m accuracy), date, time, altitude above sea level, temperature and mortality logging, positional dilution of precision (DOP), batteries charge and validation test. The data were transmitted daily by SMS (7 fixes per SMS) to an online database via GSM network. The first 6 griffon vultures were equipped with non solar units with few locations for day. In the last two years solar units were used, locations were taken more regularly every hour, from 5:00 to 18:00 and at 22:00 hours (UTC Time) in summer and three times per day in winter: 7:00, 10:00, 12.00. Regulations were made between seasons regarding the solar energy available. Transmitters have a life expectancy of 2-4 years.

Fig. 8.9 – Main features of the transmittents used in this research (Vectronic Aerospace GPS Plus manual).



	A	B	C	D	E	F	G	H
1	LINE_N	UTC_DATE	UTC_TIME	LATITUDE	LONGITUDE	HEIGHT	VAL	TEMF
2	1	22/06/2009	18:01:41	46.2354268	13.0329929	209.07	Yes	30
3	2	23/06/2009	08:00:42	46.2349425	13.0311590	209.40	Yes	31
4	3	23/06/2009	12:00:47	46.2325596	13.0276155	255.41	Yes	27
5	4	23/06/2009	18:01:25	46.2320371	13.0271566	255.65	No	25
6	5	24/06/2009	08:00:48	46.2289947	13.0217324	259.74	Yes	25
7	6	24/06/2009	12:02:17	46.2347968	13.0289186	303.84	No	30
8	7	24/06/2009	18:00:53	46.2317243	13.0260516	270.96	Yes	29
9	8	25/06/2009	12:01:18	46.2320301	13.0269602	266.09	Yes	36
10	9	26/06/2009	12:01:54	46.2278527	13.0179545	255.33	Yes	49
11	10	27/06/2009	12:02:19	46.2280860	13.0186415	252.64	No	38

Fig. 8.10 - To collect, schedule and store data we used the GPS Plus Collar Manger program from Vectronics (Vectronic Aerospace GPS Plus manual).

Tab. 8.5 - Data collected with GPS satellite tracking from 2006 to 2012.

Ring	N. radio	Released	Origin	Working Time	TOT Months	N locations valid	Age	Movements
F10	2161	20.05.06	Caught near feeding point	20.05.06-7.11.06	5,5	198	Born 2000-2001	Friuli, 2 times CRO; Hohe Tauern
CBR	5985 *	22.06.09	Shot BS 9.10.2005. Ringed Croatia	22.06.09 – 22.02.10 (dead Krk)	7,2	2019	Born 2005	Friuli, CRO
F18	5986	22.06.09	Recovered Czeck Republic 1.7.2007	22.06.09-22.04.10	10	314	Born 2006	Friuli, Slo, 1 Austria, from 12.10 France.
Z10	5987	12.06.11	Recovered in Tirol (A) 23.6.2009	12.06.11/1.1.12	6,5	248	Adulto	Friuli, CH, F e SP.
F19	5984	12.06.11	Born in captivity 2010	12.6.11/12.8.11	2,5	160	Born 2010	Friuli
F20	85*	14.06.12	Recovered in Cornino. Ringed Croatia	14.6.12/03.03.13	8,5	193	Born 2011	Friuli, SLO, CRO

* transmitter recovered and used again.

The tab. 8.6 summarizes the data from 12 griffon vulturess equipped with GPS-GSM. For GPS used until 2011 the data are not sufficient to calculate the distances in a way comparable with those used later, while providing significant indices for the Home Range calculations and MPC.

8.3 - Characteristics and history of the Griffon Vultures equipped with satellite transmitters

In the next pages, the characteristics of all the vultures marked are described, with a summary of the results obtained. Information for different individuals are not homogeneous: they are complete for those previously ringed while for others the origin and the age can be only estimated.

TAG	Ring	Age	Transmission dates		Tracking days	N valid fixes	Distance	Daily distance (km)		Hourly distance (km)		Home-range size (km2)		MPC (km²)
		Year	Start	End			Tot. Km	Median	Max	Median	Max	95% Kernel	50% Kernel	
85	F20	2011	14.06.2012	03.03.2013	179	193					8.33	962.58	71.29	9298.03
2161	F10	2000	22.05.2006	07.11.2006	120	198					37.37	1477.04	176.19	13556.2
5984	F19	2010	22.06.2011	12.08.2011	61	160					14.76	539.26	50.14	17808.75
5985	CBR	2005	22.06.2009	22.02.2010	198	209					55.93	2157.55	328.97	11041.72
5986	F18	2006	23.06.2009	22.04.2010	205	314					8.2	2250.46	223.88	78804.78
5987*	Z10	adult	02.06.2011	01.01.2012	159	248					37.74	2810.43	360.71	307279.88
13120	F31	2012	17.07.2013	26.07.2013	10	127	1508.70	120.86	360.6	1.3	58.57	1880.91	245.9	39826.99
13121	F25	2012	29.05.2013	31.12.2014	469	4586	19388.63	8.44	231.27	0.33	60.81	2710.98	221.16	31747.37
13122	F32	2011	15.07.2013	31.12.2014	532	3854	14371.30	6.30	230.08	0.2	59.12	2632.07	242.42	30160
13123	F54	2011	11.06.2014	31.12.2015	203	1933	9090.95	16.54	230.01	0.36	53.64	2698.09	325.86	19648.93
13124	F22	2011	29.05.2013	08.10.2014	495	3461	19527.00	8.58	279.86	0.4	60.92	4089.53	250.2	127142.62
13125	F30	2012	17.07.2013	06.08.14	380	2568	14494.02	8.47	324.93	0.4	66.76	4828.53	279.31	107608.27
TOT.					3011	17851	78380.6	169.19	1656.75	2.99	522.15	29037.43	2776.03	793923.54
Mean					250.92	1487.58	6531.72	14.10	138.06	0.25	43.51	2419.79	231.34	66160.30
Median					279.5	1380.5	14494.02	8.47	324.93	0.4	37.545	2895.555	175.3	58453.15

Tab. 8.6 – Data obtained with GPS equipment.

F20 green ring. Metal ring: UA3034 CRO. Radio n. 85. Age: born in 2011.
Griffon of Croatian origin, recovered in a courtyard in Cornino during a period of heavy rain on 21.05.2012 (weight 7.8 kg). Released on 14.06.2012 (8.1 kg) after a period of control and clinical analysis. Followed for 8.5 months for a total of 390 fixes. 15 days after his release he moved to Croatia, where he remained for 18 days before returning to Friuli and staying at least until the end of the battery life (03.03.2013). This griffon is linked to traditional sites visited by griffon vultures in Friuli, visiting regularly Slovenia and only a few times moving to the Austrian Alps. In Croatia, he attended in particularly Krk but also moves on Velebit and south in Pag.

F10 green ring. Metal ring ISPRA: M4560. Radio n. 2161. Estimated age: born 2000-2001.
Griffon captured and ringed on 4.10.2003, released the same day (unknown origin). Recaptured on 07/05/2005 and, after a period of control, released on 20.05.2006 with a satellite radio. Followed for 5.5 months. This individual made several trips between Italy and Croatia and spent the summer in Austria. After released he stayed 11 days in Italy, then 10 in Croatia, 9 in Italy, 8 in Croatia, still 3 in Italy and from 27.06.2010 to 15.10.2010 (111 days) in Austria. Back to Friuli he spent at least 2.5 months, when the GPS stops to work. In Friuli he frequents regularly the areas of the Natural Reserve and Venzone. In Croatia it is regularly in Krk and Cres. Interesting are the movements in Austria concerning several sectors of the National Park Hohe Tauern on the side of Salzburg, in particular the areas of Uttendorf, Kaprun and Rauris.

Fig. 8.11 – Managing a captured Griffon Vulture before releasing.

F19 green ring. Metal ring ISPRA: M4571. Radio n. 5984. Age: born in 2010.
Griffon Vulture born in captivity in the aviaries of the Natural Reserve. Released on 12.06.2011 with satellite radio. Due to technical problems, the radio worked only for about two months for a total of 160 fixes. It stays throughout the period in Friuli, with

frequent movement in Slovenia and a unique location in Carinthia and later in Croatia right at the end of the radio. In subsequent years he was regularly observed at the feeding point.

CBR green ring. Metal ring UA0360. Radio n. 5985. Age: born in 2005.
This Griffon Vulture was recovered from a gamekeeper of the Province of Brescia on 10/09/2005 and taken to the rescue center Valpredina WWF (BG). Victim of of poaching, he had 45 shots in the head that was not possible to remove. Born on the island of Plavnik (CRO) and ringed at the nest on 16.05.2005, name Selena (G. Sušic). Brought in the natural reserve on 29.11.2005 and released on 22.06.2009 (weight 8.9 kg). He was followed for almost 8 months with a total of 209 valid fixes. The 22/02/2010, when he was found dead at the seaside. After 16 days from releasing he travels to Croatia where stays 26 days, before returning 69 days in Friuli and from 10.12.2009 again in Croatia for 72 days. Thanks to the mortality signal the remains of the Griffon were found on a beach on the island of Krk. The in-depth health checks carried out in Croatia made it impossible to make a reliable diagnosis; the most credible hypothesis is lead poisoning.

F18 green ring. Metal ring M4570. Radio n. 5986. Estimated age: born in 2004.
Bird recovered July 1, 2007 in the Czech Republic (locality Pelhrimov) in weak conditions. Without rings and therefore of unknown origin. Brought in the rehabilitation center near Vienna he is healed and brought to Friuli on 10.09.2007. Released on 22.06.2009 (weight 8.3 kg) after rehabilitation and re-growth of right-wing primary feathers that for unknown causes were missing. The radio worked for approximately 10 months allowing to collect 314 valid fix. The Griffon stays regularly on Julian and Carnic Alps with only two locations in Austria. On 11.10.2009 he moves to the west, along the foothills of the Alps arrives in 5 days in Provence (F). He stays on Baronnies (Drome) joining the local colony of Griffon Vultures for 6 months and after he moves to the south.

Z10 green ring. Radio n. 5987. Estimated age: adult.
Griffon recovered in Tyrol (A) 0n 23.06.2009, the origin is unknown. Brought in Friuli and released on 12.06.2011. Followed for 6.5 months for a total of 248 valid fix. On July 2 (after 20 days)he moves away to the west. After 2 days he arrives in Switzerland (linear distance between points 513 km). On 17th, he moves to France where he spends about ten days in the Baronnies. From July 26 to October 9, he spends about 2.5 months on the French Maritime Alps, including Italian areas near the border. He moves to the southwest arriving on 18th October in Catalonia. Following the Pyrenees to the west it appears in Navarra-Pais Vasco on 21st October. When the radio stops to work (01.01.2012) he is still in that area. Data related to this bird were not considered for some calculations because it left the area moving to the west.

Fig. 8.12 – Marked immature Griffon Vulture after releasing.

F31 green ring. Metal ring UA0315. Radio n. 13120. Estimated Age: born in 2012.

Griffon of Croatian origin, caught and released on 17/07/2013. The radio has been working only 10 days with 127 valid fix. This bird makes big movements, in 10 days he travels 1508 km with a 39,827 km² MPC. Two days after released he moves to Austria then back 2 days in Friuli and then 4 days in Austria, again in Friuli and after Croatia. From 23 to 25.07 he makes a long and quick tour in Austria (Styria, Lower Austria), performing in 3 days at least 629.5 kilometers.

F25 green ring. Metal ring UA03197. Radio n. 13121. Estimated Age: born in 2012.

Bird born in Croatia, captured and released on 05/29/2013. The radio works up to 29.09.2015 (26 months), allowing to collect until 31.12.2014 (the study period) 4,586 valid fix. He travels long distances between Italy, Croatia and Austria with a minimum total calculated distance of 19,389 km and a 31,747 km² MPC. In the study period he visits 15 times Italy, 9 Croatia and 5 times Austria. After released, he stays 33 days in Friuli and nearby Slovenia and afterward he begins a period of rapid and significant movements. It moves to Croatia where it stays 7 days, then he crosses again in Friuli going for 6 days in Austria. Back two days in Friuli, then 1 in Austria, 1 in Friuli, 1 in Austria, 2 in Friuli and 6 in Croatia. In summer he stops 27 days in Friuli and then returns 4 days in Croatia, 3 in Friuli and 13 in Austria, other 12 in Italy, 8 in Croatia, 3 in Friuli, 3 in Croatia. He spends the winter in Friuli (177 days) with a single visit by one day in Croatia. On 12/06/2014 he moves for 37 days in the Austrian Tauern, then he returns 29 days in Italy, 30 in Croatia and from 10/19/2014 in Italy. In Croatia regularly he attends the islands of Cres and Krk, Plaunik, Pervič and Rab. To move to the north he uses both classic routes that follow the mountains of Cicarjia and Velebit-Gorski Kotar; apparently the first way going or coming from Cres and the second to Krk. The movements from the south to Austria take place on a broad front that affects the entire border between Friuli and Carinthia. This Griffon went to the Hohe Tauern in both years: 4 times in 2013 (for a total of 21 days) and once (37 days) in 2014. In both winters he spent long periods in Friuli (141 days in 2013/14 and 102 in 2014/15). It has made one displacement outside the usual areas on 23.2.2014, when in one day he reached the area of Valdobbiadene (TV) 90 km and went back.

F32 green ring. Metal ring UA3070. Radio n. 13122. Estimated Age: born in 2011.

Croatian Griffon captured and released on 17/07/2013. The radio works up to 06/04/2015 (22.5 months), allowing us to collect 3,854 fix valid in the study period. He moves regularly between Italy and Croatia visiting Austria only in the second summer. The displacements occur along the usual routes using, similarly to others, Cicerjia to and from Cres and internal chains for Krk. Runs in total 14,371 km with a 30.160 km² MPC. The areas visited are very similar to 13121 with less regularity in Austria. After releasing, he spends 68 days in Italy, after he moved to Croatia where it stayed 37 days and returned to Italy to spend the winter (129 days, from 31.10.2013 all'8.03.2014). Then 23 days in Croatia, 25 in Italy, 14 in Croatia, 13 in Italy, 16 in Croatia, four in Italy, 7 in Croatia. He spends the whole summer 06/19 to 15/09/2014 (88 days) on the Austrian mountains. Crossing Friuli he flies to Croatia where he spends 33 days, then 51 days in Italy. On 12/09/2014 the bird moves to Croatia where he spend the winter time until 29.03.2015. On 23 and 24 September 2014 he makes an unusual tour in central Croatia. Regular attendance of Velebit at different periods of spring 2014.

F54 Green Ring. Metal ring UA3073. Radio n. 13123. Estimated Age: born in 2011.

Croatian bird marked on 06.11.2014 (the only in 2014). 1933 Valid fixes were collected. Also this bird uses the traditional sites and fly areas. The day after releasing he moves to Croatia for five days, then Italy (2 days), Croatia (3), Italy (4), Croatia (9), Italy (27). From 1st .08 to 8.09 he stays in Austria (45 days) and then back 7 days in Italy, 7 in Croatia, 10 in Italy and winters in Croatia from 03.10.2014 to 20.05.2015 (229 days). Also this bird uses different sites in the Hohe Tauern in relation to food availability. The total distance is 9,091 km with a 19,649 Km² MPC. The data are affected by only one year of operating

F22 green ring. Metal ring UA3052. Radio n. 13124. Estimated Age: born in 2011.

Croatian bird marked on 05/29/2013. This Griffon has performed the greatest movements with a total distance of 19,527 km, a MPC of 127,142 km² and a high KDE 95% (4,089 km²). That's the result of frequenting different areas in Austria and a long tour in central Europe. The radio worked up to 8.10.2014 (14.5 months) with 3,461 valid fix. After releasing, until the beginning of November he visits 7 times Italy, 4 Croatia and 2 Austria, where it spends 14 days in July and 55 in August and

September. On 11/07/2013 he moves to Croatia where he winters until 20.03.2014 (133 days). In the next period, until the radio stops to work (10.08.2014) he moves 11 times between Friuli and the Croatian islands, with short periods of stay of 8-10 days. In Austria he frequents not only the traditional site of the National Park Hohe Tauern, but also the area of Bertesgaden National Park (D). From 12.05 to 06.06.2014.It made an interesting long tour leaving on 6.12.2014 Bertesgaden, flying along the Bavarian Alps to the west, entering in Switzerland and then Germany until the Karlsruhe region, coming back to Switzerland and into Italy in Veneto, returning directly in Friuli. In this 14 days' journey he supposedly flew at least 1,507 kilometers.

F30 green ring. Metal ring UA3187. Radio n. 13125. Estimated Age: born in 2012.

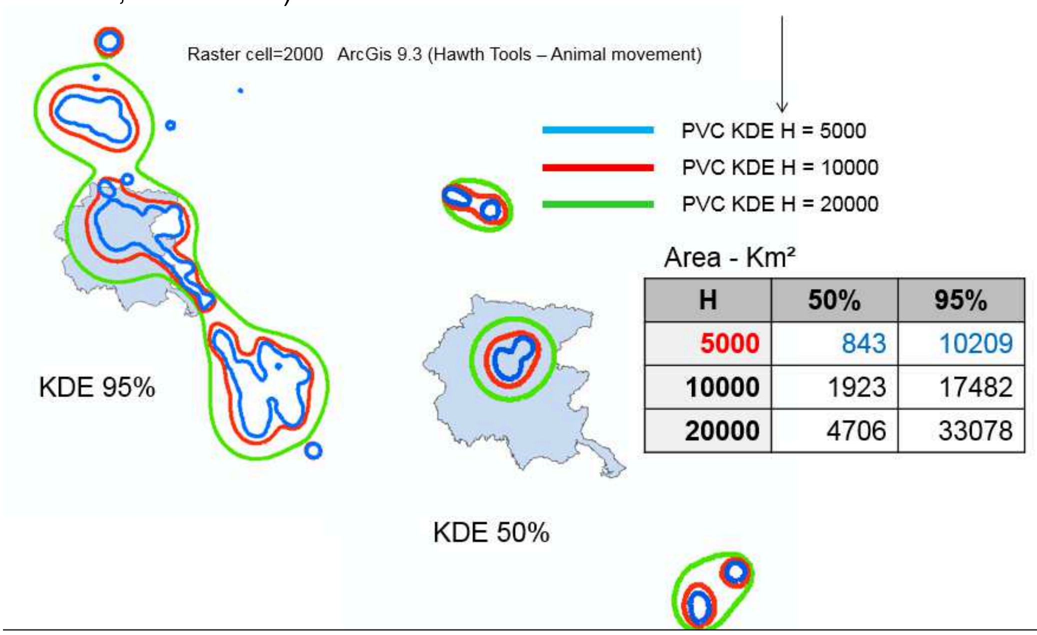
Released on 17/07/2013, the radio of this Croatian bird works up to 08.06.2014 (a little over a year) providing 2,586 valid fixes. This is the only Griffon Vulture who has wintered in Greece. It performed a total distance of 14.494 km and a 107,608 km² MPC. He moves frequently between Italy and Croatia and he has never reached the Hohe Tauern (only one location in Carinthia). One day after releasing he moves to Croatia. In the next 3 months he moves 3 times between Croatia and Italy. On 1.10.2013 it begins a long journey to the south that led him to spend the winter in Greece in an area north of Patrai moving for some periods about 50 km to the southeast and to the northeast. An interesting area that hosted in the past breeding colonies of Griffon Vultures and roosting places. The few birds left are threatened by the construction of wind farms. On 9th May the bird begins his northward travel along Albania's inland, the coastline of Montenegro and Croatia and on 18th May he arrives in Krk (CRO). The return path is very similar, even if it moved about 30 kilometers to the west in some parts of Albania and Croatia. His wintering in Greece has therefore lasted over seven months, where he used a 3.913 km² MPC. In the following period he moves 3 times between Croatia and Italy. This Griffon does not show a preference to estivate in a certain area, moving frequently, both years, between Italy and Croatia.

Fig. 8.13 – Marking and preparation of a Griffon Vulture after captured (Photo Bruno Dentesani).

9. Data analysis

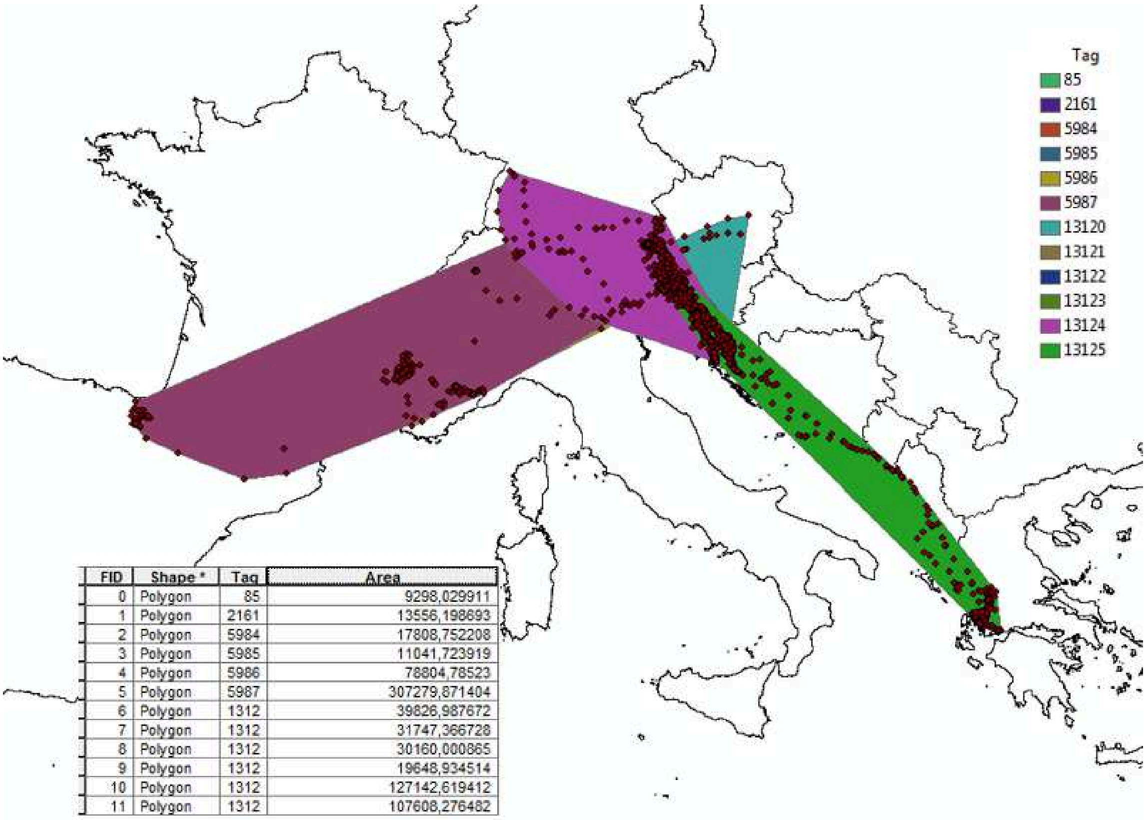
For all spatial analyses the GPS locations were projected to the UTM coordinate system (WGS 1984 UTM Zone XXN) using the program ArcGIS 10.1. Daily activity was computed as the frequency of segments for which an effective movement was recorded, considering the nominal accuracy of the GPS (±25m) and assuming 50 m for the altitude. Hourly flight distances were obtained by calculating the straight-line distance between consecutive locations (segments) that were separated by one hour within the same day, or with the hourly average distance in case of greater interval time. Daily and monthly distances were calculated as sum of straight-line distances covered between consecutive locations in the same day or month. For each vulture, the total distance travelled, the mean distance between consecutive locations, and the mean and maximum distance travelled per day were calculated. Estimates of the foraging ranges traversed by each vulture during different periods of tracking were calculated. To describe the individuals' space use we applied the minimum convex polygons (MCP 100%, Mohr 1947) and and estimated their home-ranges and core areas using the fixed Kernel density estimation (KDE) to delineate 95% and 50% of the area encompassed within UD isopleths (Worton 1989, 1995). Calculation were made with ArcMap version 9.3, Fixed Kernel Density Estimator with Smoothing Factor H=5000, Raster cell size = 500 and Quartic, to estimate the UD with a finer spatial resolution. Individual's data were partitioned among months and different periods of the year. Differences between age classes and sexes were not computed due to low sample size. Nocturnal roosting places were obtained by filtering the night locations (22:00 UTC Time). Cartography was elaborated in ArcMap 10.1 (ESRI Inc., www.esri,com). Other software used for data analysis: EsriArcGis 9.3 (Hawth Tools – Animal Movement), IBM SPSS Statistics Version 20, Geospatial Modelling Environment (Spatial Ecology.com), Homeranger (KDE calculation), Global Mapper. Satellite tracking data were integrated with regular monitoring information mostly collected on the feeding station. Data were regularly exchanged with other countries for comparison.

For seasonal analyses we define Winter (months December, January, February), spring (March, April, May), summer (June, July, August) and autumn (September, October, November).



H	50%	95%
5000	843	10209
10000	1923	17482
20000	4706	33078

Fig. 9.1 – Influence of Smoothing factor (H) on the calculation of Home Range (KDE 95%) and Core Area (50%) (Arc Gis 9.2).



FID	Shape *	Tag	Area
0	Polygon	85	9298,029911
1	Polygon	2161	13556,198693
2	Polygon	5984	17808,752208
3	Polygon	5985	11041,723919
4	Polygon	5986	78804,78523
5	Polygon	5987	307279,871404
6	Polygon	1312	39826,987672
7	Polygon	1312	31747,366728
8	Polygon	1312	30160,000865
9	Polygon	1312	19648,934514
10	Polygon	1312	127142,619412
11	Polygon	1312	107608,276482

Fig. 9.2 – MCP Minimum Convex Polygon 100% for all data (Arc Gis 9.2).

We compared the observed flight characteristics of griffon vultures, daily activity, daily and monthly distances, altitude of flight, cross country speed. Home range and core area in different periods and areas, frequency and patterns of the movements and land use in the most important zones (Croatian islands, Friuli and Hohe Tauern) were calculated. To consider the three main areas (Friuli, Croatian islands, Hohe Tauern) only the local movements were considered, excluding the locations related with long distance travels between those areas.

9.1. **Statistical analysis**

To compare different areas, seasons and areas and seasons, we used the Kolmogorov-Smirnov test which assesses the type of distribution and the significance of the data. This non-parametric test is used to test the normality of the data, also considering the distribution of difference between two groups (paired test). In particular, if $p < 0.05$ the distribution is not normal, while it is normal for $p >= 0.05$. We considered the significance of various parameters calculated in the different areas: KDE 50%, KDE95% KDE, KDE50/95% ratio, MPC, total days (total days per month spent in the areas), average period (average period of stay in the different areas), number of times (number of times per month that an area is visited), distance. Statistical processing didn't consider Greece due to the limited number of data.
The results are used to comment the charts referring to different parameters depending on the areas and seasons. In the graphics the standard deviation (SD) is only reported for the mean values.

10. Results

In the "Riserva naturale del Lago di Cornino" (Udine, Italia. Lat. 46,226832°, Long. 13,0230301°) we tagged 12 Griffon Vultures with GPS GSM transmitters from 2005 to 2014. During the study period a total of 17.855 valid locations were collected (Tab. 1). Mode of operation and timelife of transmitters has been variable, with high difference between the first six not solar units and the others used in 2013-2014. The first worked between 2 and 10 months with 922 total numbers of locations. We got better results with solar units: one tag worked only 10 days, 2 stop to work after about one year and the others 3 sent regularly data until the end of the study for about 1.5 years. Birds were tracked on average during 250 days with an average number of 1487 locations for bird.

10.1 Movements and spatial references

The home range area, with all individuals and seasons pooled, was 7515,76 km², the core area 397,62 km² and the Minimum Convex Polygon (MCP) 1.161.019.18 km². The annual average value for Kernel 50% contour was 275,37 Km², 2895,39 Km² for 95% contour and 35073,04 Km² for MCP. Results present variations between individuals both in terms of size, shape and positions, especially for tree birds that made long movements across Europe and one Griffon Vulture wintering in Greece.

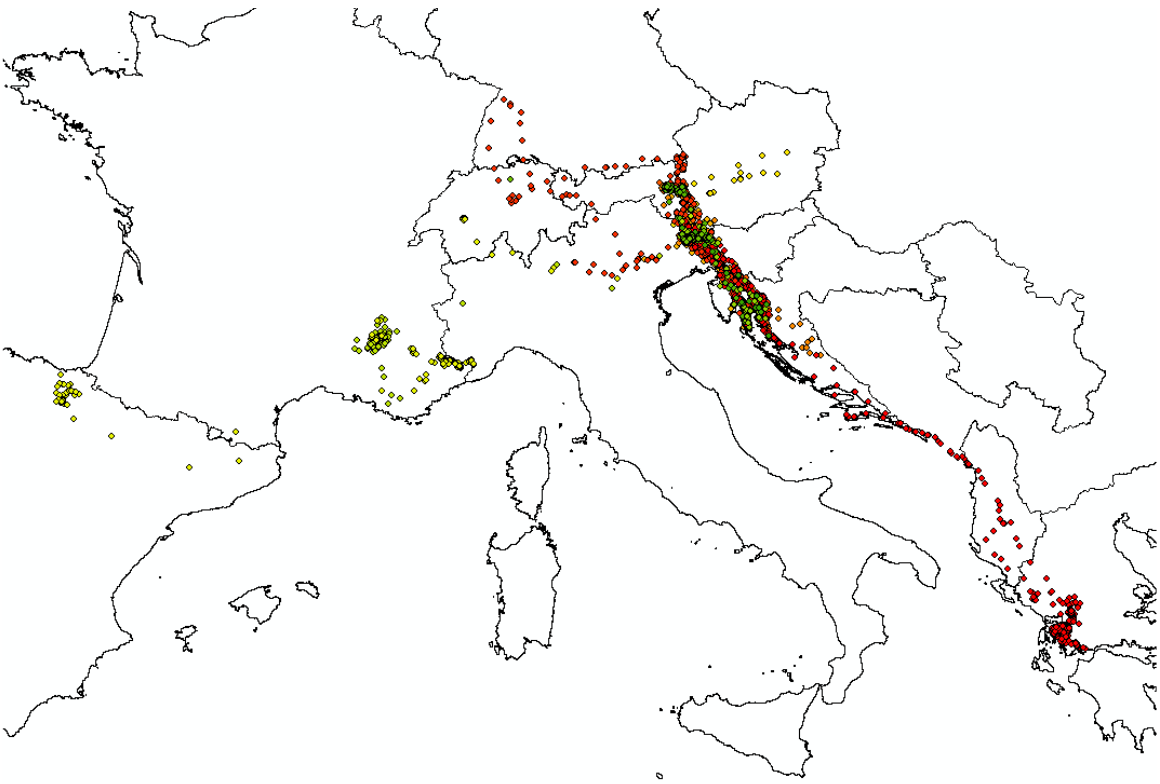


Fig. 10.1 – GPS locations for 12 Griffon Vultures, period 2006-2014.

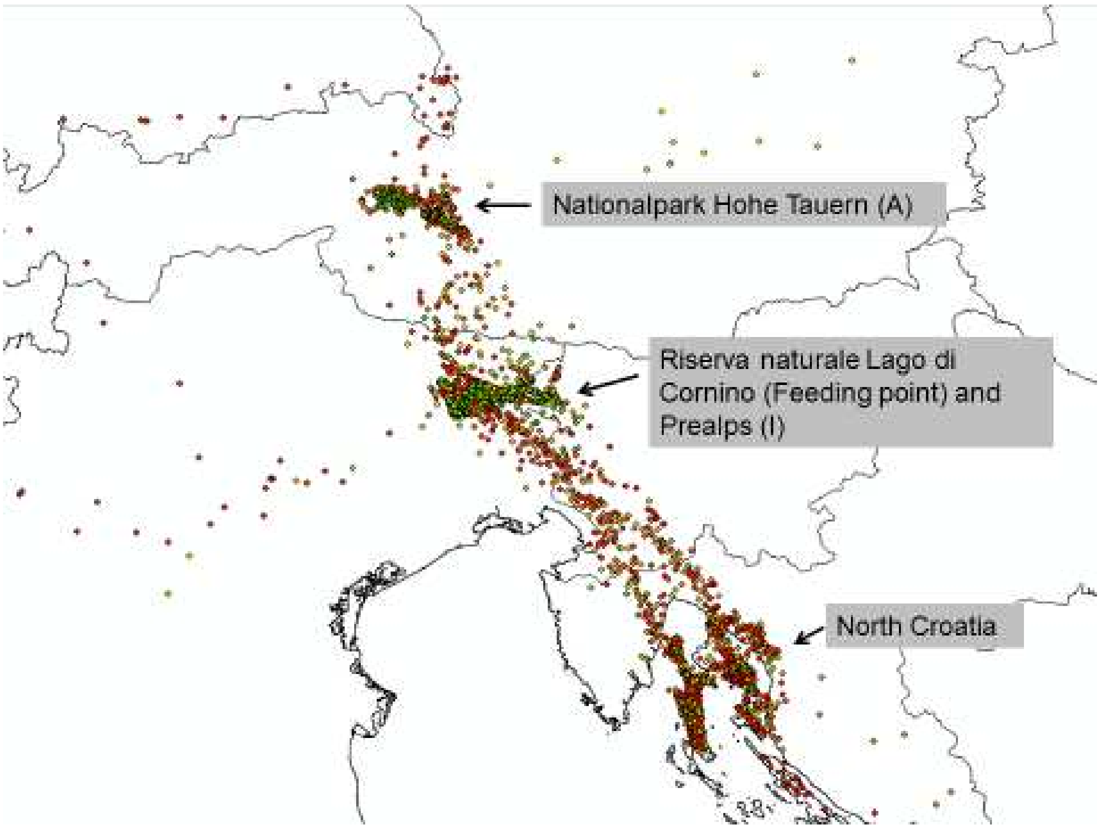
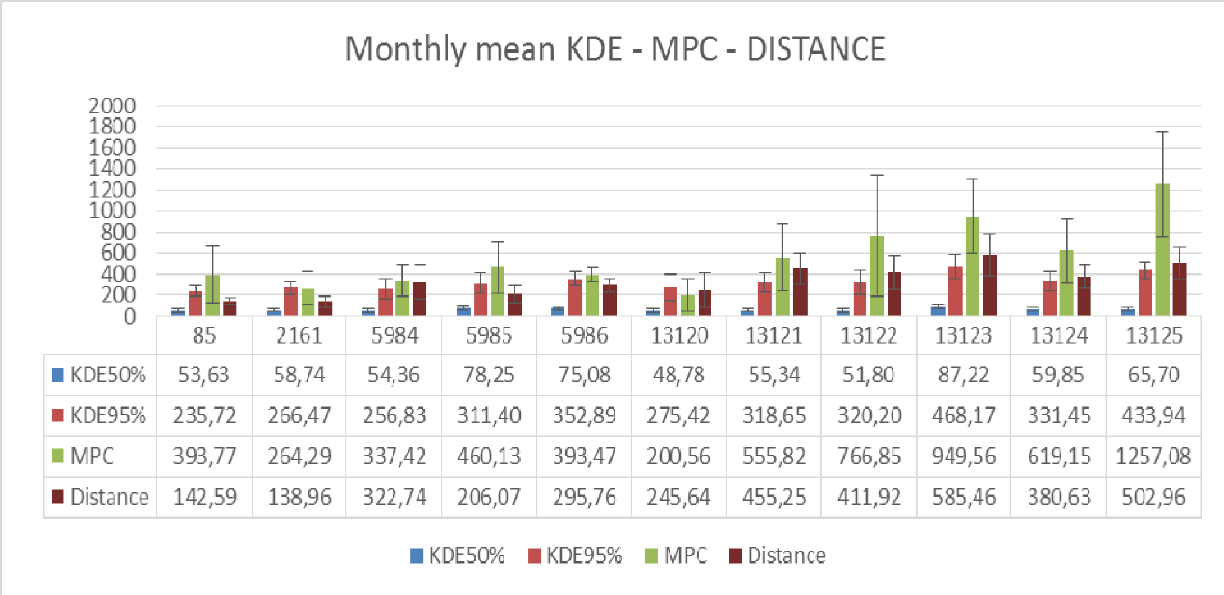


Fig. 10.2– GPS locations in the study area with the three most important zones.

In the Tab. 10.1 the mean yearly values of KDE and MCP for all the individuals with the number of fixes and the periods are reported.

TAB. 10.1 - Annual values of KDE 50% and 95% and MPC for all the individuals.

Griffon	year	KDE 50%	KDE 95%	MPC	N. Fix
85	2012	89,84	1068,47	9298,03	144
	2013	42,17	203,44	113,31	49
2161	2006	176,18	1477,04	13556,20	198
5984	2011	50,14	539,26	17808,75	160
5985	2009	313,14	2101,68	11041,72	185
	2010	45,59	201,82	290,42	24
5986	2009	223,87	2250,46	78804,78	314
	2010	131,14	1085,59	7164,29	105
13120	2013	245,90	1880,91	39826,99	127
13121	2013	129,15	2277,19	17348,56	2009
	2014	223,37	2072,95	30983,95	2578
13122	2013	141,21	1253,13	10752,32	1337
	2014	219,25	2620,00	30160,00	2518
13123	2014	325,86	2698,09	19648,93	1934
13124	2013	207,93	1996,66	17818,98	2066
	2014	177,83	4230,40	123421,88	1396
13125	2013	209,07	3241,10	101077,94	1428
	2014	316,37	3702,36	102197,68	1140



	85	2161	5984	5985	5986	13120	13121	13122	13123	13124	13125
KDE50%	53,63	58,74	54,36	78,25	75,08	48,78	55,34	51,80	87,22	59,85	65,70
KDE95%	235,72	266,47	256,83	311,40	352,89	275,42	318,65	320,20	468,17	331,45	433,94
MPC	393,77	264,29	337,42	460,13	393,47	200,56	555,82	766,85	949,56	619,15	1257,08
Distance	142,59	138,96	322,74	206,07	295,76	245,64	455,25	411,92	585,46	380,63	502,96

Fig. 10.3 – Total values of KDE 95% and KDE 50% calculated for Italy, Austria, Slovenia and Croatia (Calculation made with ArcMap version 9.3, Fixed Kernel Density Estimator with Smoothing Factor H=5000, Raster cell size = 500 and Quartic).

The analysis of the monthly values of the entire period for the selected 11 vultures shows higher values for birds which have more data (time and fixes) available, particularly for MPC and distances. The Core Area (KDE 50%) is of 50-80 km², the Home Range (KDE 95%) is of 230 to 430 km², the MPC 260-1260 km², while distances vary between 140 and 585 km. The total monthly average values for all the griffon vultures are respectively 61.16 km², 338.62 km², 682.18 and 69.81 km². Larges values of Home Range, MCP and distances, concern the griffon vultures that have moved far away to Greece (13125) or in central Europe (13123).

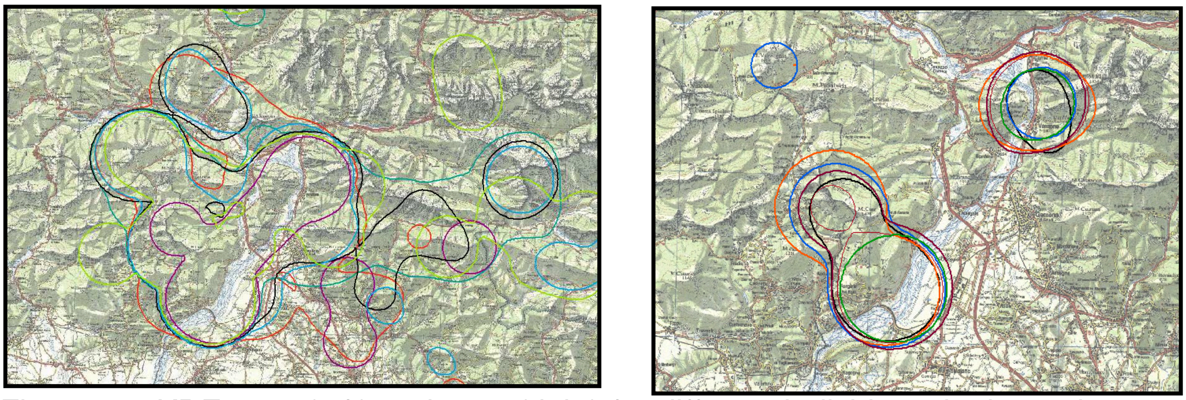


Fig. 10.4 - KDE 95% (left) and 50% (right) for different individuals in the main area in FVG.

10.2 Flight altitude

Analysis of data and the calculation of the flight altitudes (processed with DEM cards http://gdem.ersdac.jspacesystem.or.jp/search.jsp) allows to get useful information on the behavior of the birds and the use of different areas. The subsequent processing concerns 6 individuals, in the period 2013-2014, for which a greater number of data is available.

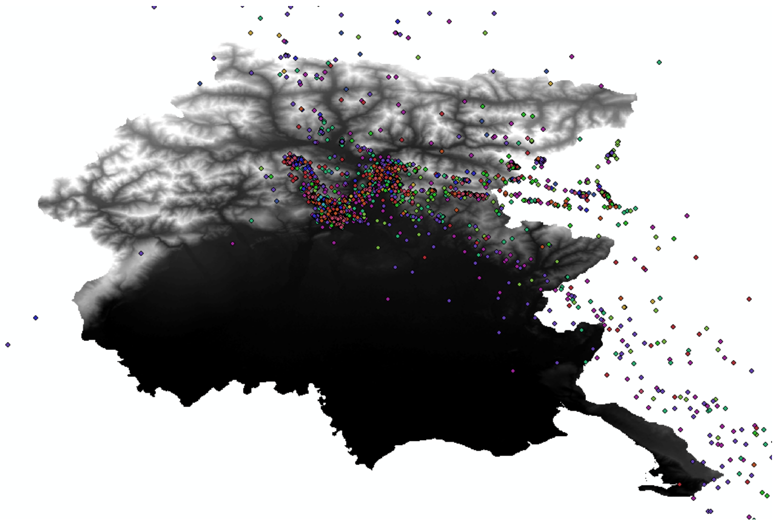


Fig. 10.5 – DEM maps for the calculation of flight altitude.

Flight altitude calculation
Using Aster GDEM (Global Digital Elevation Map) (METI & NASA) it's possible to calculate the elevation of the birds above the ground.

Hf=Hgps – Hdem ± (DOP * 10) + 20

Hf = flight altitude above the ground
Hgps = height measured by GPS transmitter
Hdem = elevation from GDEM
DOP = dilution of precision satellite collar
10 = precision of the trasmitter (Vectronics)
20 = average precision of Aster GDEM

The flight altitude (Tab. 10.6) results relatively low, with a large majority of locations within 100 m from the ground. That's related with the typical soaring flight of vultures, using the thermal currents near the ground. High altitude flights are normally performed to cross valleys or in long distance movements when wind or thermics are favorable.

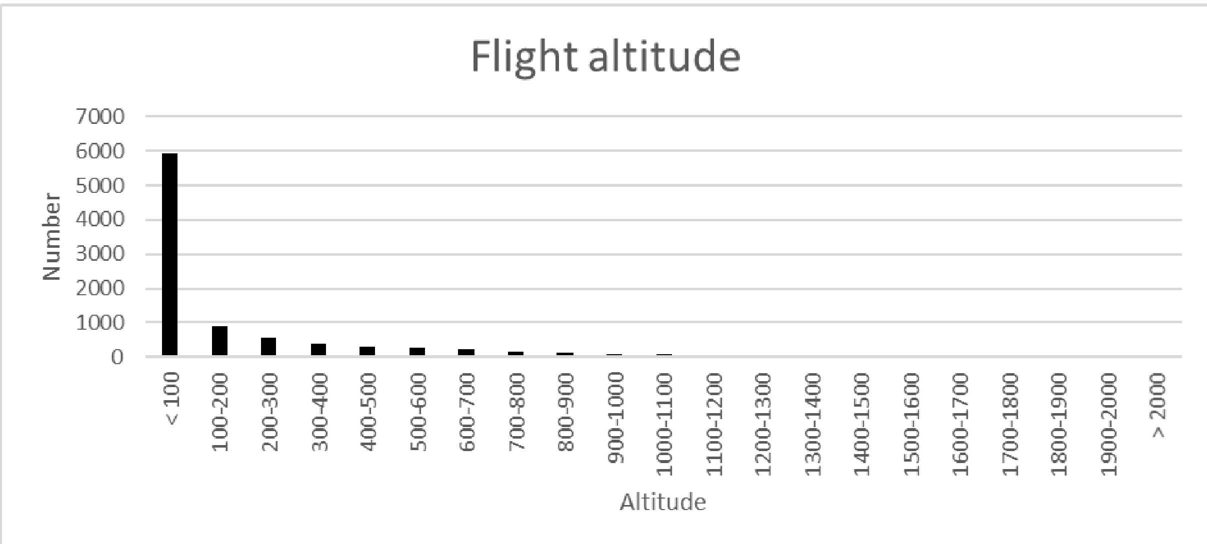


Fig. 10.6 – Elevation of soaring griffon vultures above the ground.

Fig. 10.7 shows a preference for low-level flights in all months of the year, higher from December to February and, to a lesser extent, during spring and summer.

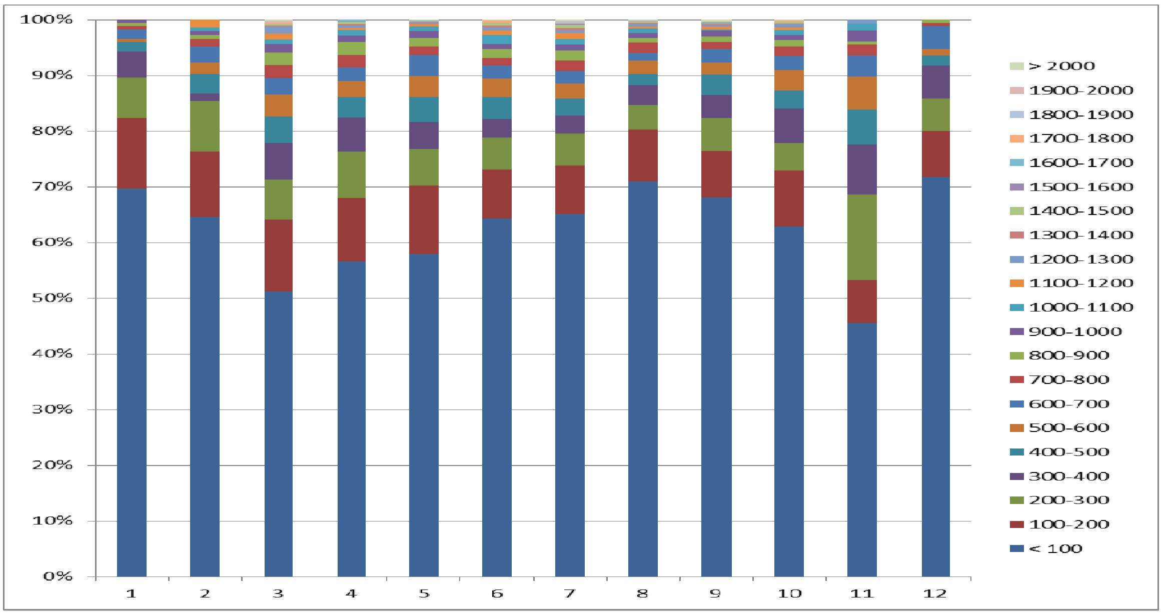


Fig. 10.7 – Monthly distributions of flight altitudes.

Considering the locations where the altitude of birds corresponds to that of the ground (assuming a certain percentage of error), it was possible to determine the points where they are placed on the ground. Limiting the analysis to the nocturnal hours it was possible to identify the roosting places.

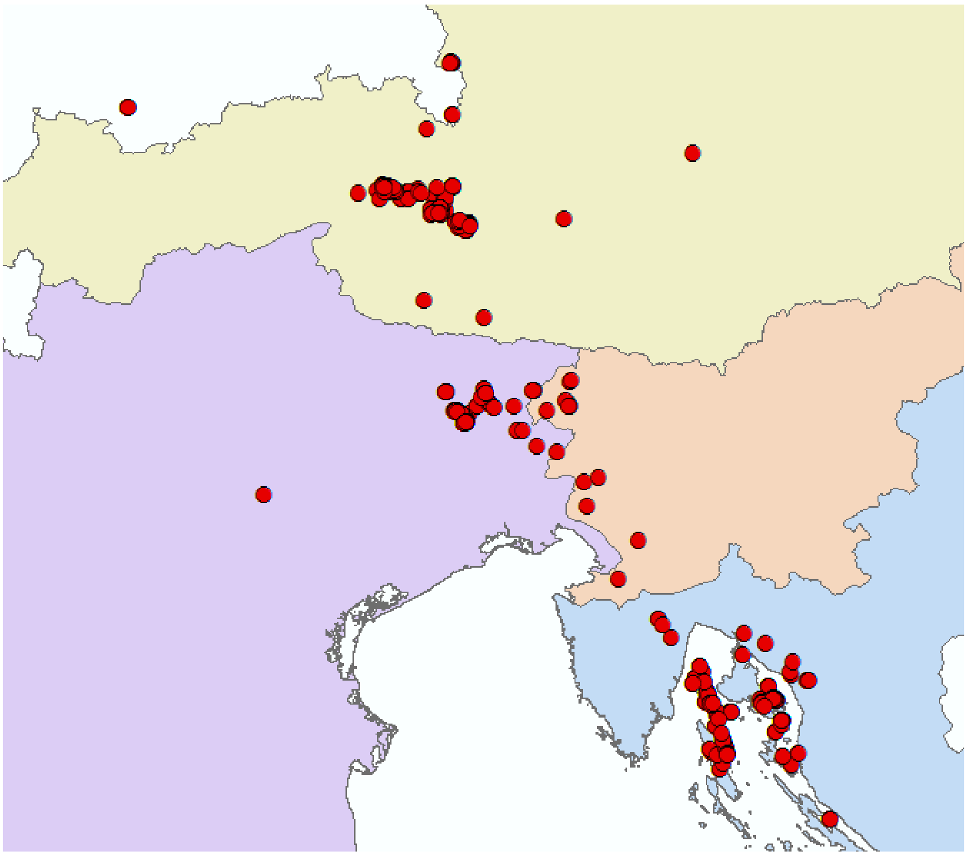


Fig. 10.8 – Sites where the birds spend the night (red points)

The obtained results are very interesting as they demonstrate that nearly all roosting places are located in the three considered main areas; only in few cases the birds spend the night in other sectors. Furthermore, the griffon vultures perch only rarely outside those areas, since they are probably forced by rapid weather changes or unsuitable flying conditions.
Griffons vulture's movements and habits are better known in Friuli and Croatia, where they can be easily observed and there is more information about roosts and food distribution. This research allowed to find out their habits in Austria, where the monitoring is very complicate due to the altitude and complexity of the mountains and the food resources are variable and unpredictable.

The locations of the 5 vultures who frequented the Austrian mountains (Fig. 10.9) showed that the birds visited some traditional areas; on the other hand, differences related to the availability and distribution of carcasses were highlighted. The events that cause high mortality in cattle and sheep livestock (usually lightning) can result in concentrations of up to hundred individuals for a few days.

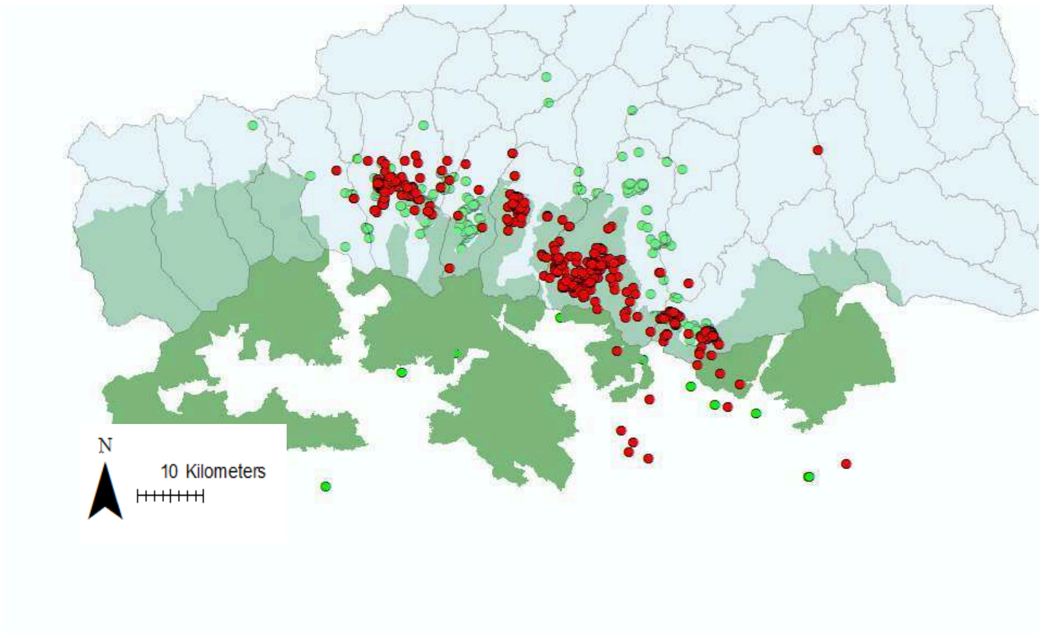


Fig. 10.9 - Locations of griffon vultures in the National Park Hohe Tauern in 2013 (green) and 2014 (red).

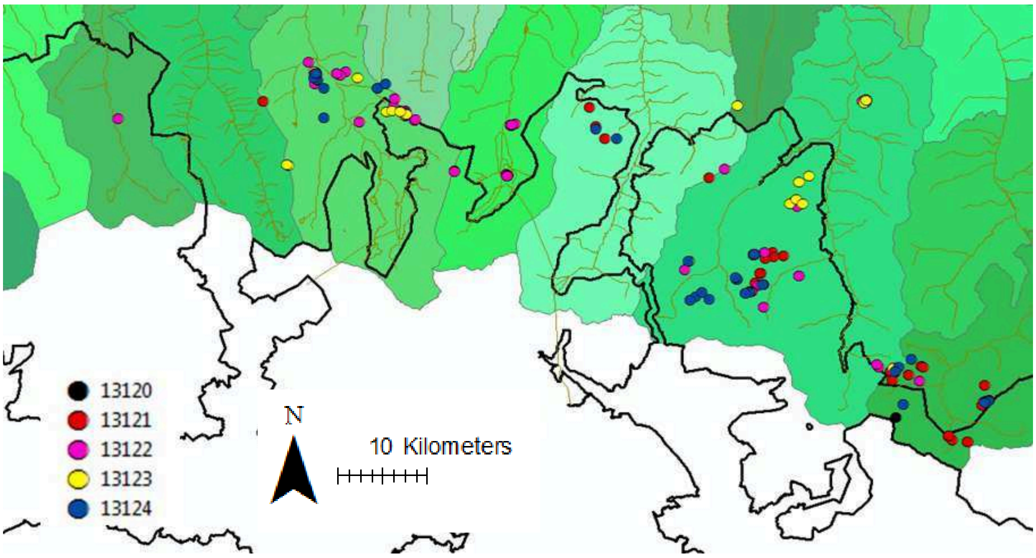


Fig. 10.10 – Roosting places of 5 individuals in the NPHT (in green the municipalities of the Salzburg Region).

All night roosting places are located in the Salzburg sector of the Park, in the valleys traditionally frequented by the griffon vultures. Some roosting places, however, were unknown and their discovery is important for improving monitoring and conservation actions.

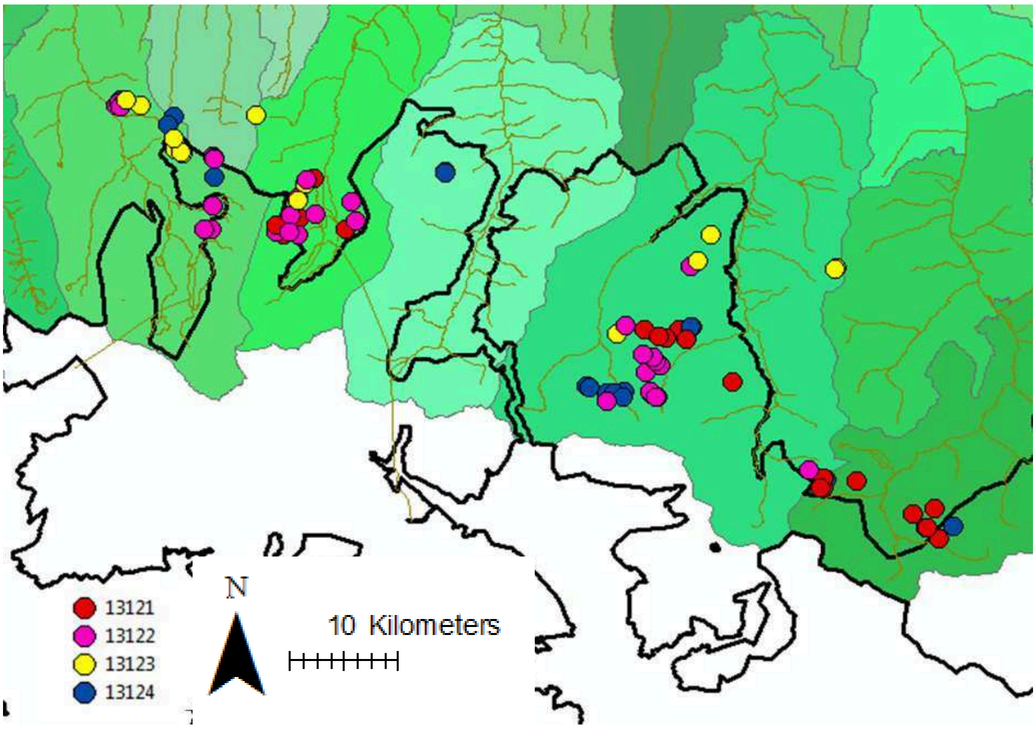


Fig. 10.11 – Sites where probably Griffon Vultures probably found carcasses.

Selecting locations where more griffon vultures perched together for hours on the ground, we can assume that these sites have been used for feeding. These data help to identify the distribution of the main food resources and the most important areas for the birds.

10.3 Analysis in the three main areas.

In order to better define how Griffon Vultures use the three main areas in Croatia, FVG and Austria, only the locations whitin these areas were considered, excluding the movements between them and other movements over long distances. For this purpose only data related to local daily movements were considered.
The mean number of areas visited (Croatia, Italy, Austria, Greece) per month in is 1.5, with monthly average periods of staying generally included between 12 and 25 days. The results for the bird n.13120 are interesting, but related to a short time.

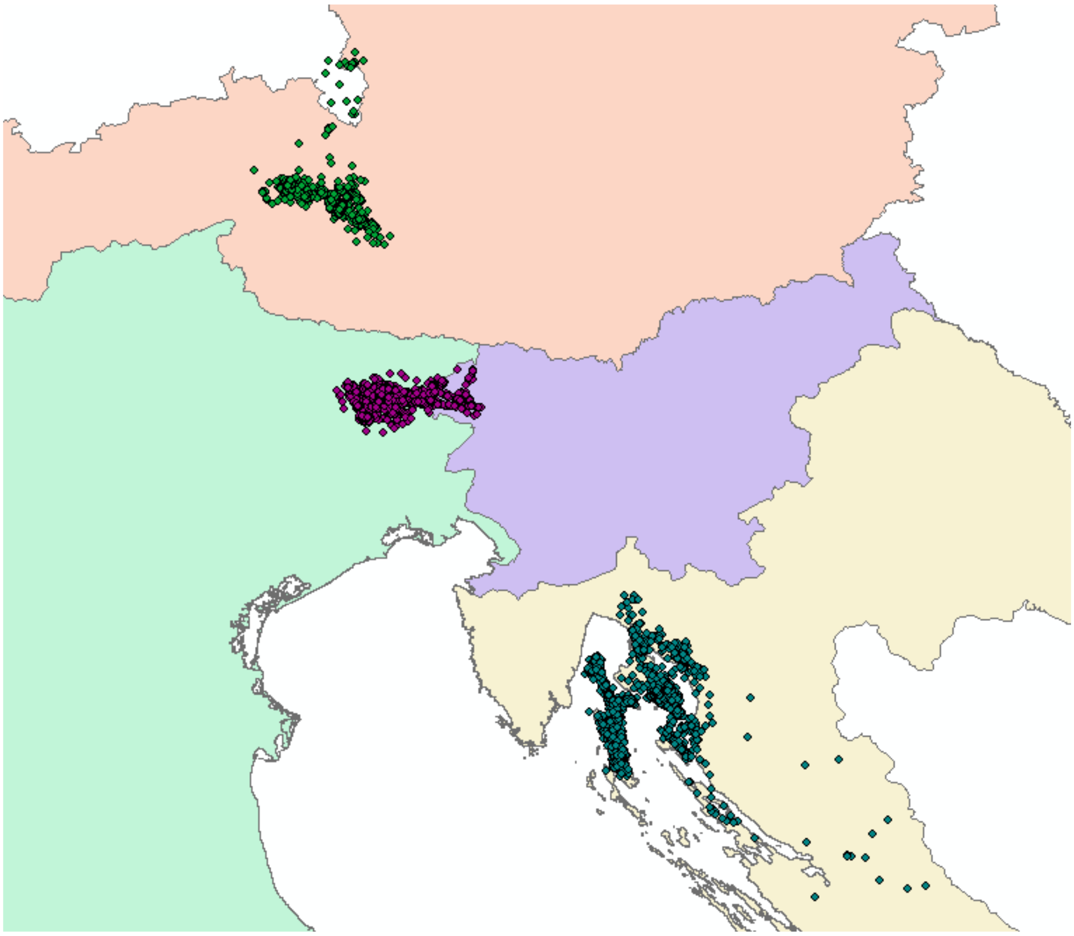
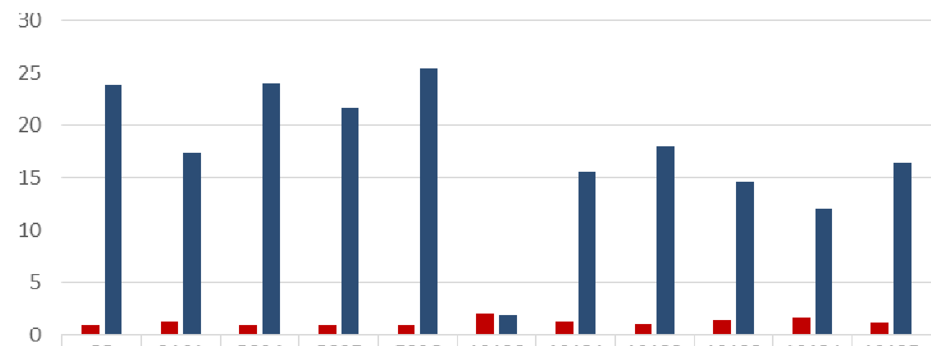


Fig. 10.12 - Selection of three main areas regularly used by griffon vultures, excluding the intermediate points related with direct movements between them or long flights.



	85	2161	5984	5985	5986	13120	13121	13122	13123	13124	13125
N visits	1,00	1,38	1,00	1,00	1,00	2,00	1,33	1,14	1,38	1,63	1,23
Duration monthly periods	23,82	17,33	24,00	21,70	25,50	1,94	15,63	18,07	14,56	12,11	16,43

Fig. 10.13 - Mean monthly number of visits and duration of periods in the 3 main areas for all individuals.

Movements between the different areas vary during seasons: the Austrian Alps are used only in summer (from June to beginning of October). Greece was reached only from one bird from October 2013 to beginning of May 2014. More regular were the connections between the Croatian colonies and the eastern Alps. Fig. 10.14 shows that birds (mostly immature birds born in Croatia) spend generally more time in the Alps than in Croatia with individual variations (Fig. 10.15; 10.16; 10.17; 10.18).

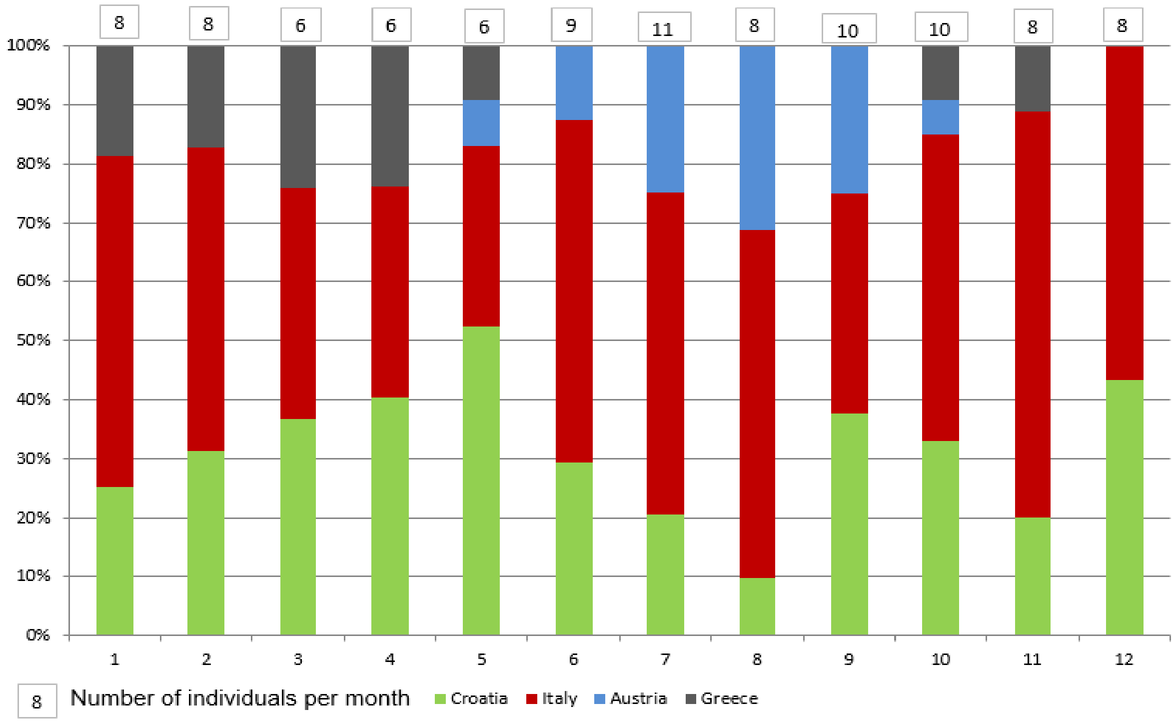


Fig. 10.14 - Percentage of time spent in the different areas from different individuals (In squares, the number of individuals for every month).

In the following graphs the individual variability found in 4 vultures, for which we have a long time series of data, is presented.

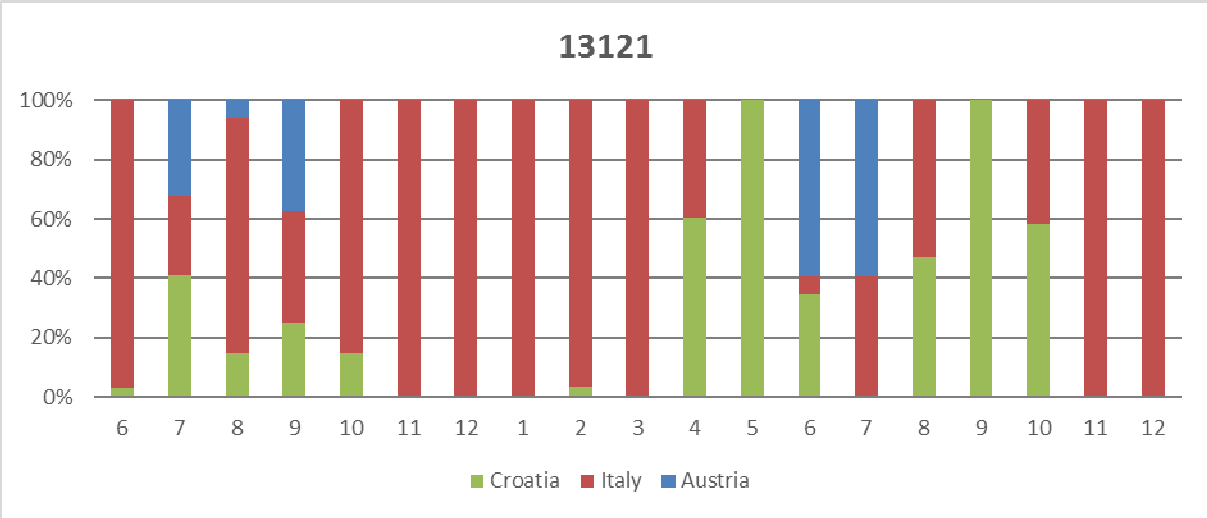


Fig. 10.15- Areas visited in the months from 13121 (2013 - 2014).

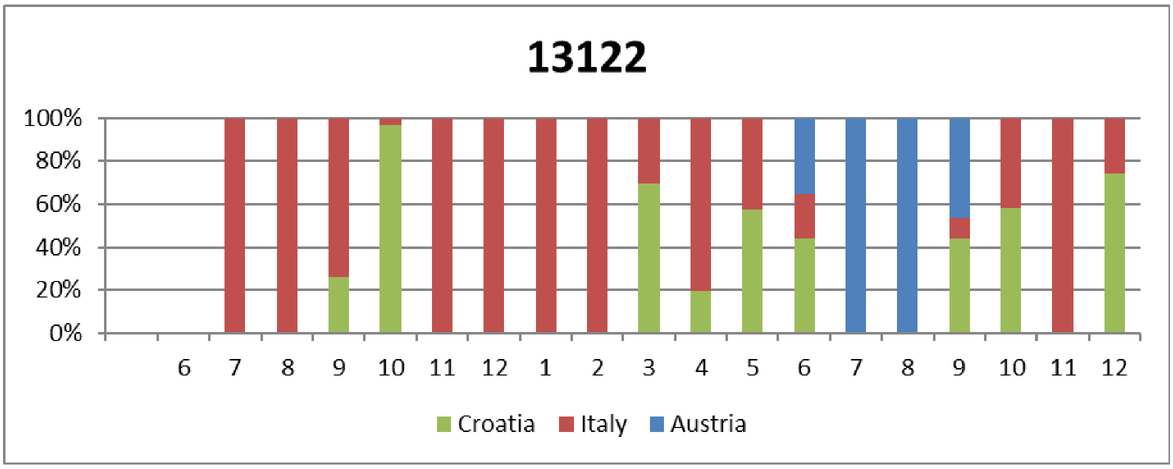


Fig. 10.16 - Areas visited in the months from 13122 (2013 - 2014).

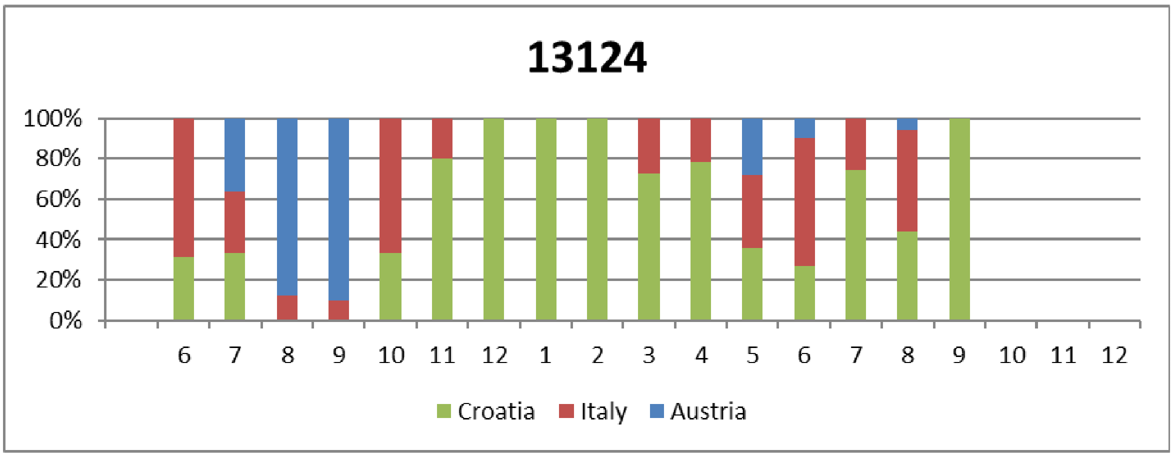


Fig. 10.17 - Areas visited in the months from 13124 (2013 - 2014).

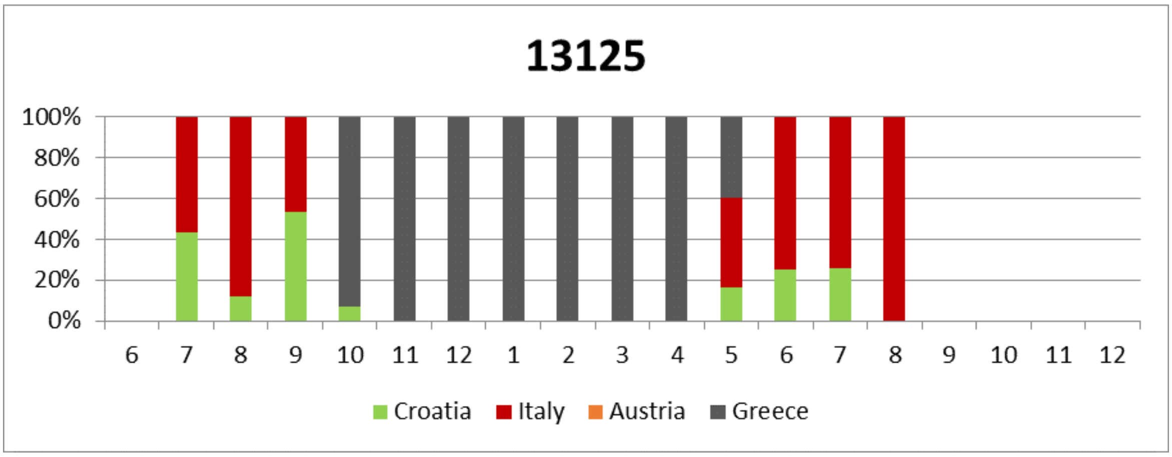


Fig. 10.18 - Areas visited in the months from 13125(2013 - 2014).

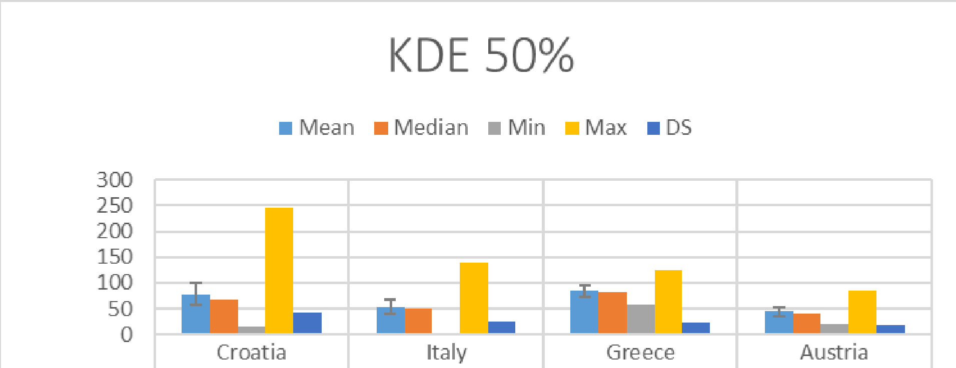
The previous graphs show a high variability between different individuals who may prefer different locations in the seasons; preferences also vary in the same seasons in different years.

Comparison between areas

The results show a normal distribution for certain parameters, while the majority is not normally distributed. In the tab. 10.2 the results obtained for areas with the Kolmogorov-Smirnov test are reported. In all the graphics standard deviation is reported for the mean values. The numbers in the columns correspond to the different zones.

Tab. 10.2 - Comparison of the distribution in pairs (significance Kolmogorov-Smirnov test) for the different areas (p values).

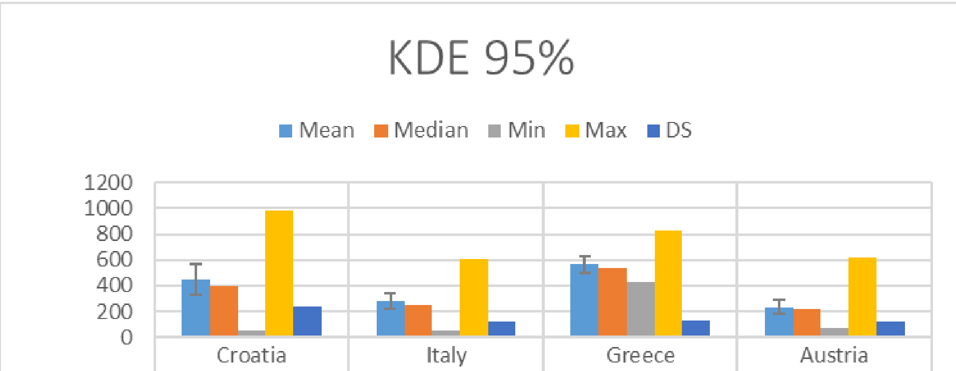
Parameters	Croatia-Italy	Croatia-Austria	Italy-Austria
KDE50	0,000	0,010	0,102
KDE95	0,000	0,000	0,160
Ratio KDE50%/95%	0,219	0,284	0,840
MPC	0,000	0,000	0,319
Total days for month	0,560	0,763	0,873
Duration of monthly periods	0,186	0,258	0,999
N. visits for month	0,989	0,400	0,846
Total distance for month	0,100	0,001	0,195



	Croatia	Italy	Greece	Austria
Mean	77,56	53,67	84,02	44,08
Median	66,46	50,25	82,41	39,22
Min	16,15	2,12	58,12	19,08
Max	245,3	139,32	124,67	85,86
DS	42,6	26,13	21,82	16,65

Fig. 10.19 - Core areas for different countries.

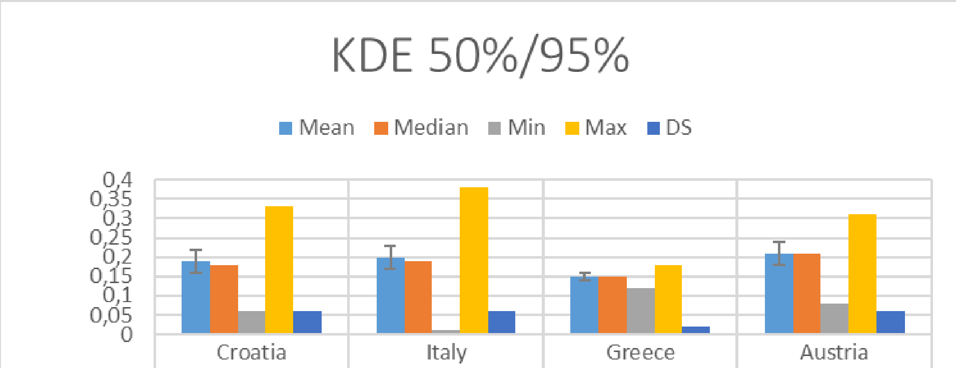
Distribution of data shows a significant difference between the size of the Core Area of Croatia (77.56 km²) compared to those of Italy (53.67 km²; $p \leq 0.001$) and Austria (44.08 km²; $p = 0{,}01$). The largest monthly range was recorded in Croatia (245.30 km²) and appear much higher than in Italy (139.32 km²) and Austria (85.86 km²).



	Croatia	Italy	Greece	Austria
Mean	450,28	276,5	565,2	234,09
Median	400,92	246,13	539,55	216,35
Min	50,15	55,9	426,92	69,29
Max	981,8	606,66	822,15	618,09
DS	235,07	119,75	130,19	117,63

Fig. 10.20 - Home Range for different areas.

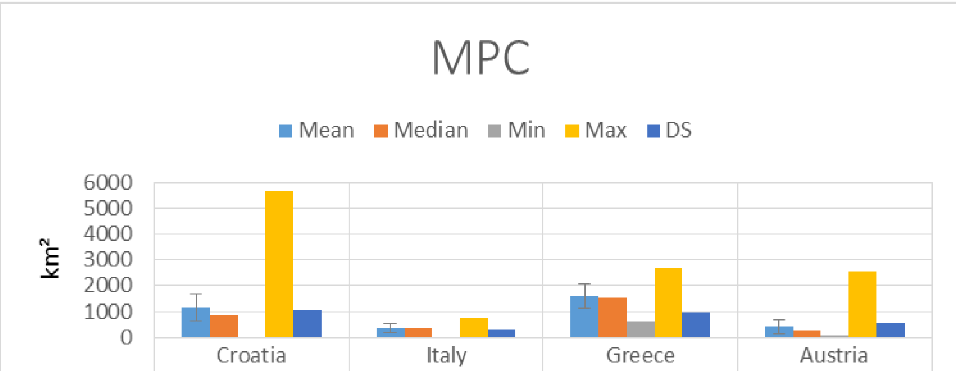
The KDE 95% test provides very similar values to the previous and therefore confirms the significant difference between the size of Croatia's Home Range (450.28 km²) compared to those of Italy (276.50 km²; $p \leq 0.001$) and Austria (234.09 km²; $p \leq 0.001$) with a maximum range of up to 981.80 km² in Croatia.



	Croatia	Italy	Greece	Austria
Mean	0,19	0,2	0,15	0,21
Median	0,18	0,19	0,15	0,21
Min	0,06	0,01	0,12	0,08
Max	0,33	0,38	0,18	0,31
DS	0,06	0,06	0,02	0,06

Fig. 10.21 - Ratio KDE 50%/KDE 95% for different areas.

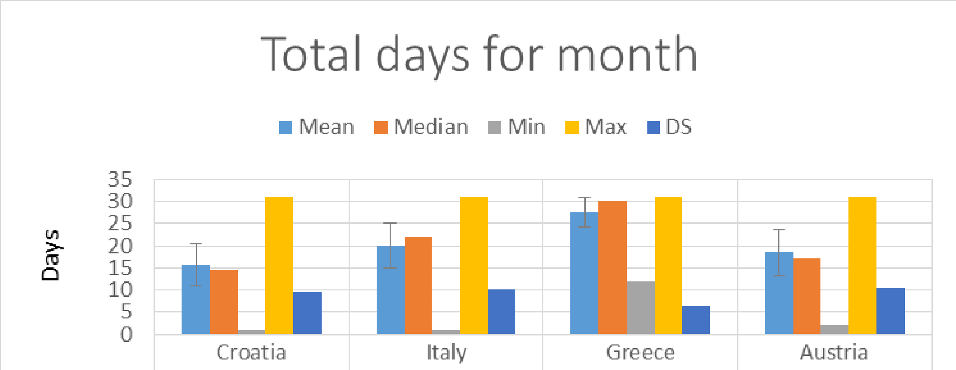
Data distribution doesn't show significant differences between areas. The values are quite similar and show a Core Area (KDE 50%) about 5 times smaller than the Home Range (KDE 95%).



	Croatia	Italy	Greece	Austria
Mean	1160,33	351,6	1603,25	406,98
Median	851,84	378,11	1523,48	255,33
Min	0	0	590,92	23,77
Max	5650,48	759,28	2683,33	2541,53
DS	1049,37	330,39	968,29	538,61

Fig. 10.22 - MPC for different areas.

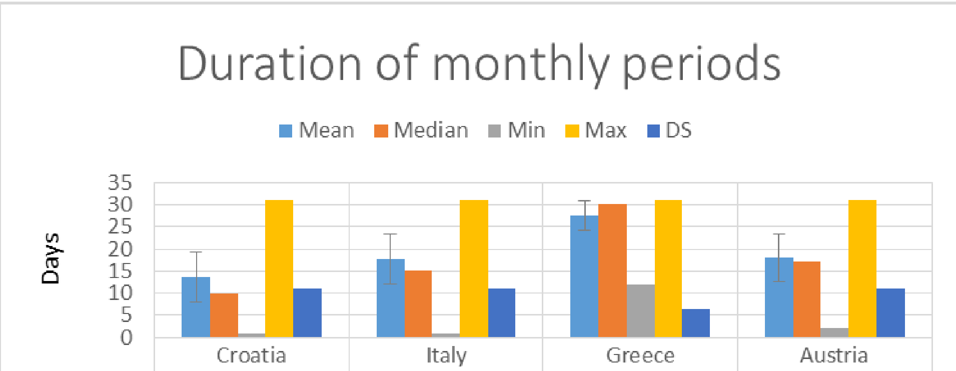
Analysis provides similar results to KDE with significant differences between Croatia (1,160.33 km² and the other countries ($p \leq 0.001$) and values rather similar between Italy (351.6 km²) and Austria (496.98 km²). Maximum high values were obtained for Croatia (5,650 km²), while relatively small values for Italy (759.28 km²).



	Croatia	Italy	Greece	Austria
Mean	15,76	20,08	27,5	18,43
Median	14,5	22	30	17
Min	1	1	12	2
Max	31	31	31	31
DS	9,48	10,12	6,44	10,38

Fig. 10.23 - Total days for month for different area.

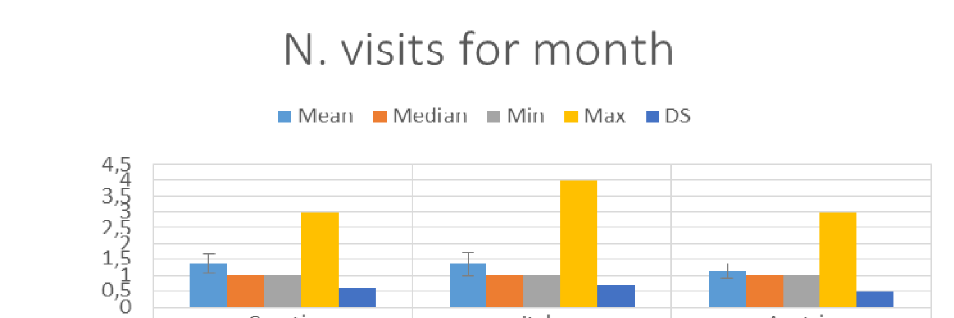
There are no significant differences in the mean number of days spent in the different areas. The mean values show a tendency to stay longer in the Italian Alps, with mean periods ranging between 15.76 and 20.08 days in the three areas considered. The maximum values (n = 31) show that in all areas griffon vultures can linger for a whole month as well (minimum values) for a few days.



	Croatia	Italy	Greece	Austria
Mean	13,67	17,72	27,5	17,96
Median	9,75	15	30	17
Min	1	1	12	2
Max	31	31	31	31
DS	11,14	11,11	6,43	10,93

Fig. 10.24 - Duration of monthly periods for different areas.

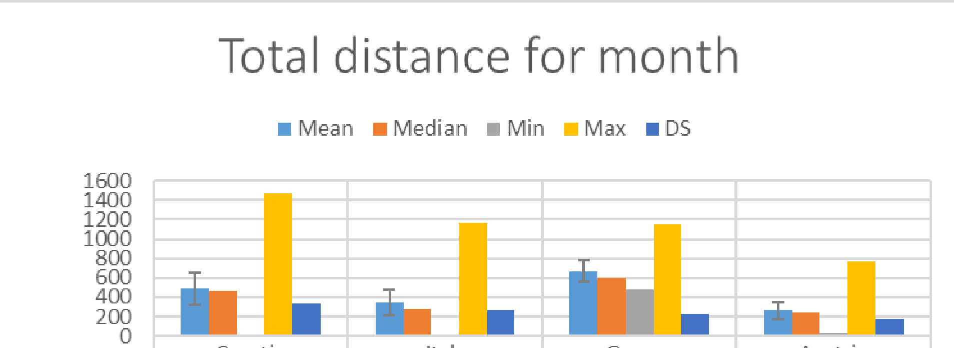
There are no significant differences in the monthly periods of permanence. The mean values show a tendency to stay for shorter periods in Croatia (13.67 days) than in Italy (17.72) and Austria (17.96), with maximum values of one month for all areas.



	Croatia	Italy	Austria
Mean	1,37	1,34	1,14
Median	1	1	1
Min	1	1	1
Max	3	4	3
DS	0,59	0,68	0,48

Fig. 10.25 - Number of visits for month for different areas.

There were no significant differences in the number of monthly visits to the various areas. Austria has significantly lower mean values (1.14) than Croatia (1.37) and Italy (1.34). The maximum values indicate that in periods of maximum movements birds can come back 3-4 times in the area concerned.



	Croatia	Italy	Greece	Austria
Mean	488,03	349,42	665,37	260,73
Median	458,8	283,98	598,86	234,89
Min	0,18	12,3	478,41	23
Max	1470,37	1168,29	1149,95	763,27
DS	327,41	264,41	223,76	176,07

Fig. 10.26 - Total distance for month for different areas.

The trend is similar to the figure recorded for Home Range and MPV, as a parameter related to the size of the areas visited. Significant differences ($p \leq 0.001$) are recorded between Croatia and Austria. The maximum values are relatively high in Croatia (1,470.37 kilometers) and lowest in Austria (763.27 kilometers).

Comparison for seasons

The same test is repeated for the seasons, considering the same parameters and excluding Greece from the analysis. The following tables express the statistical distribution of the data and significance tests comparing seasons.

Tab. 10.3 - Comparison study of the distribution in pairs (significance Kolmogorov-Smirnov test) in the different seasons (p values).

Parameters	Winter - Spring	Winter-Summer	Spring-Summer	Winter-Autumn	Spring-Autumn	Summer -Autumn
KDE50	0,300	0,131	0,959	0,314	0,910	0,696
KDE95	0,00	0,014	0,187	0,029	0,013	0,411
Ratio KDE50%/95%	0,003	0,035	0,011	0,465	0,037	0,377
MPC	0,001	0,001	0,290	0,064	0,033	0,202
Total days for month	0,010	0,000	0,874	0,002	0,333	0,549
Duration of monthly periods	0,001	0,00	0,290	0,00	0,145	0,084
N. visits for month	0,690	0,053	1,000	0,999	0,117	0,054
Total distance for month	0,000	0,423	0,052	0,131	0,040	0,741

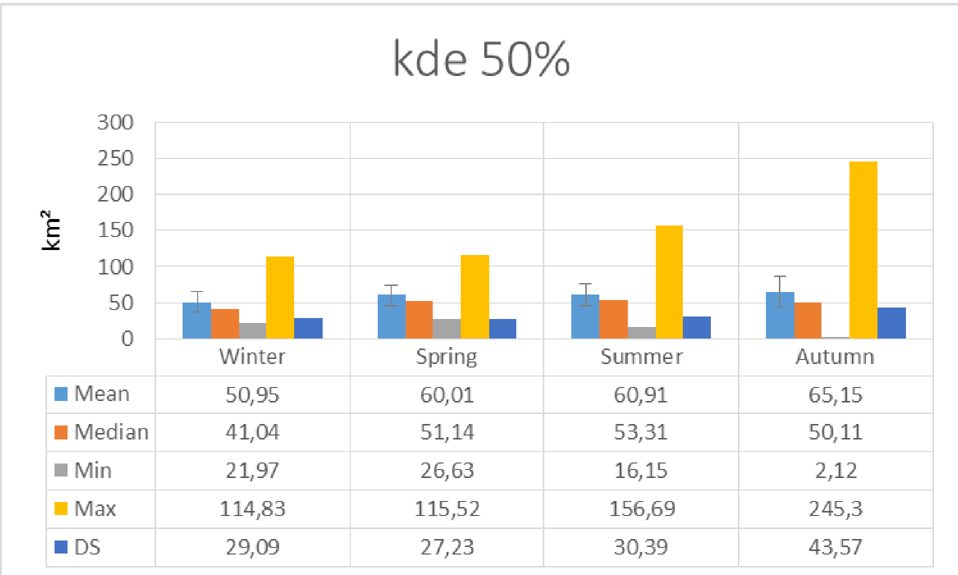
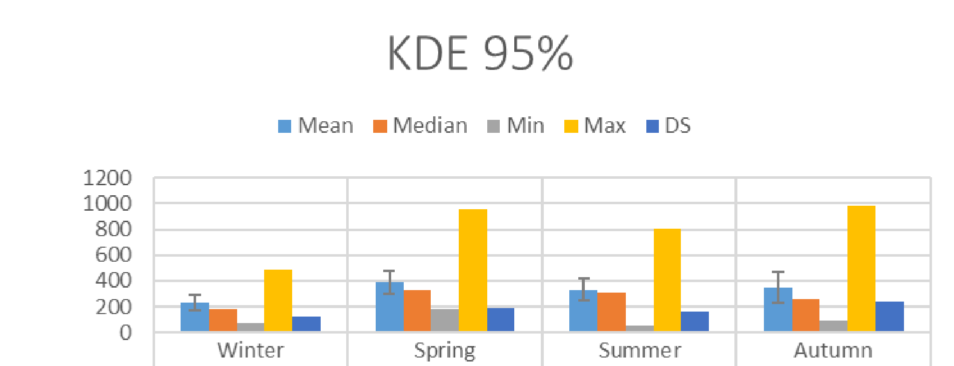


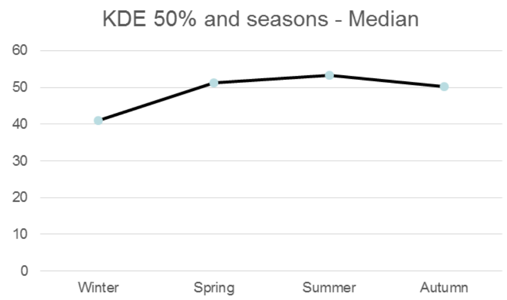
Fig. 10.27 - Seasonal monthly Core Areas.

Data distribution does not allow highlighting significant differences between seasons. The winter mean values (50.95 km²) are lower than other seasons, (60.01-65.15 km²) which appear similar.



	Winter	Spring	Summer	Autumn
Mean	228,82	389,61	331,87	352,26
Median	181,52	333,52	313,3	261,92
Min	71,3	184,43	50,15	92,65
Max	487,77	950,22	809,91	981,8
DS	122,06	185,46	164,87	235,54

Fig. 10.28 - Seasonal monthly Home Ranges.



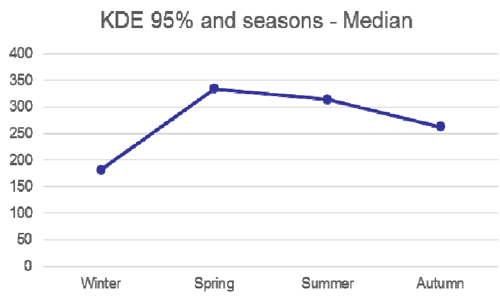
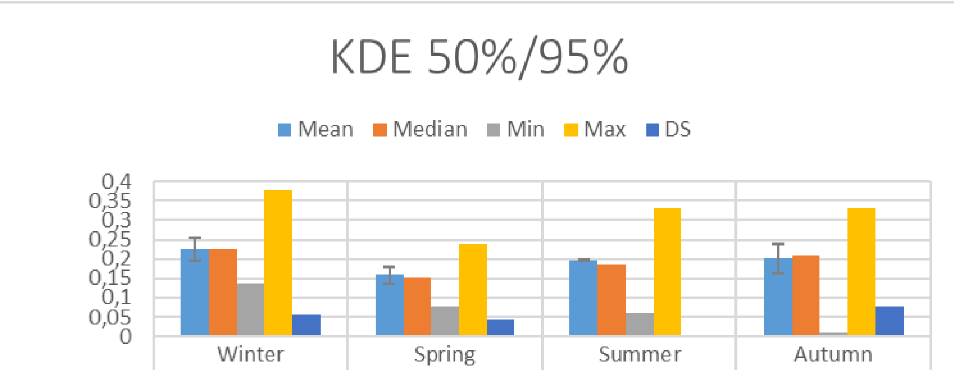


Fig. 10.29-10.30 - Trend of KDE in the seasons (Median).

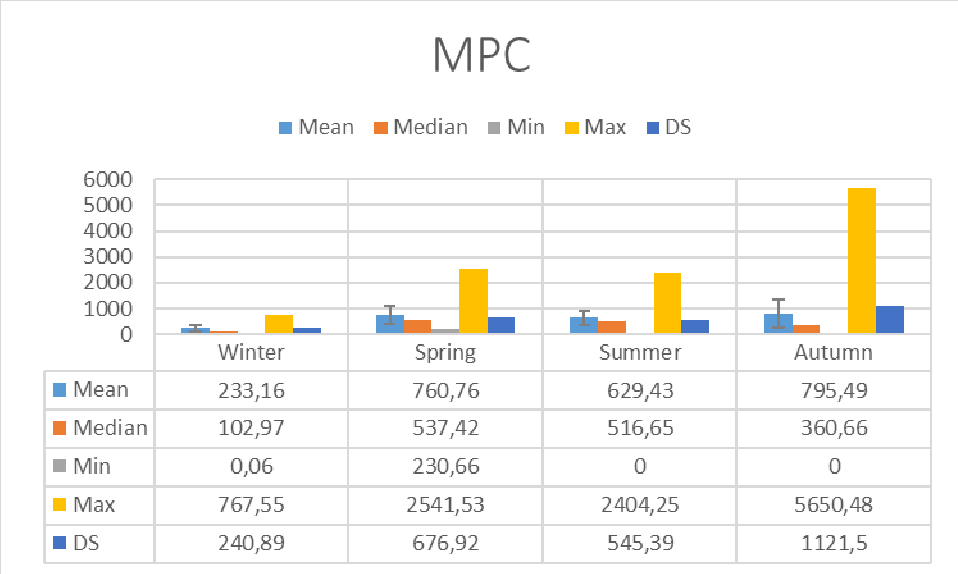
Significant differences in the Home Range between winter (228.82 km²) and all the other seasons ($p = 0.00 - 0.029$) and between the spring and autumn ($p = 0.013$) are highlighted. The highest mean values refer to spring (389.61 km²) and autumn (352.26 km²) has higher values then summer (331.87 km²).



	Winter	Spring	Summer	Autumn
Mean	0,225	0,159	0,197	0,201
Median	0,226	0,151	0,185	0,208
Min	0,136	0,078	0,059	0,011
Max	0,379	0,24	0,33	0,33
DS	0,057	0,043	0,003	0,076

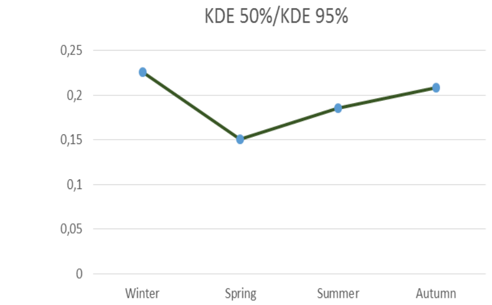
Fig. 10.31 - Seasonal monthly ratio KDE 505/ KDE 95%.

Difference is statistically significant between winter and spring (p = 0.003) and summer (p = 0.035) and also between spring and summer (p = 0.011) and autumn (p = 0.037). The mean varies between 0.16 in spring and 0.225 in autumn.



	Winter	Spring	Summer	Autumn
Mean	233,16	760,76	629,43	795,49
Median	102,97	537,42	516,65	360,66
Min	0,06	230,66	0	0
Max	767,55	2541,53	2404,25	5650,48
DS	240,89	676,92	545,39	1121,5

Fig. 10.32 - Seasonal monthly MPC.



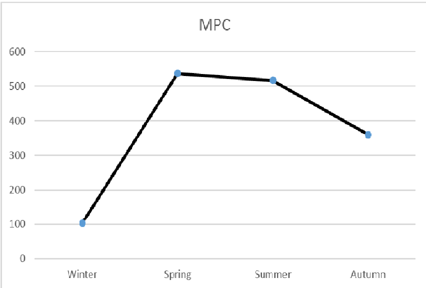
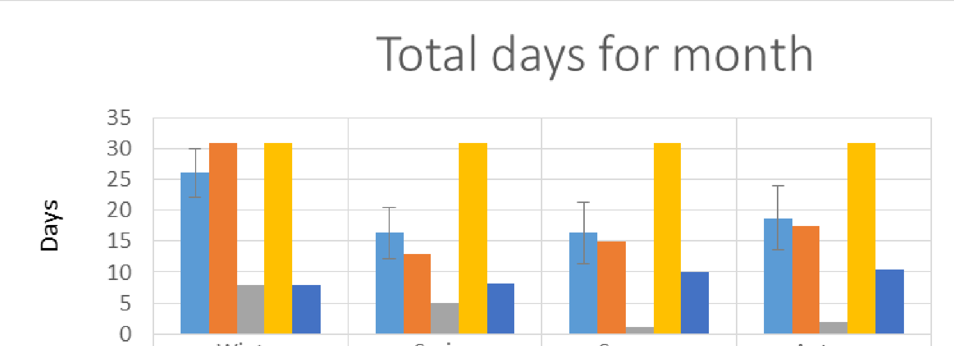


Fig. 10.33 – 10.34 - Trend of KDE 50%/KDE95% and MCP in the seasons (Median).

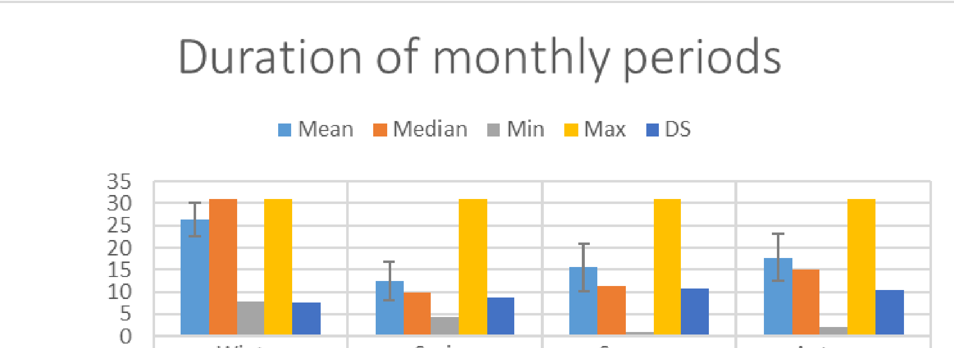
Significant differences were found between winter (233.16 km²) and spring (760.76 km²; p = 0.001), winter and summer (629.43; p = 0.001) and spring and autumn (795.49 km²; p = 0.033), with a trend very similar to that reported for KDE 95%. The maximum values are reached in the fall (5,650.48 km²) and minimum in winter (767.55 km²).



	Winter	Spring	Summer	Autumn
Mean	26,11	16,37	16,38	18,76
Median	31	13	15	17,5
Min	8	5	1	2
Max	31	31	31	31
DS	7,894	8,2	9,946	10,37

Fig. 10.35 - Seasonal total days for month.

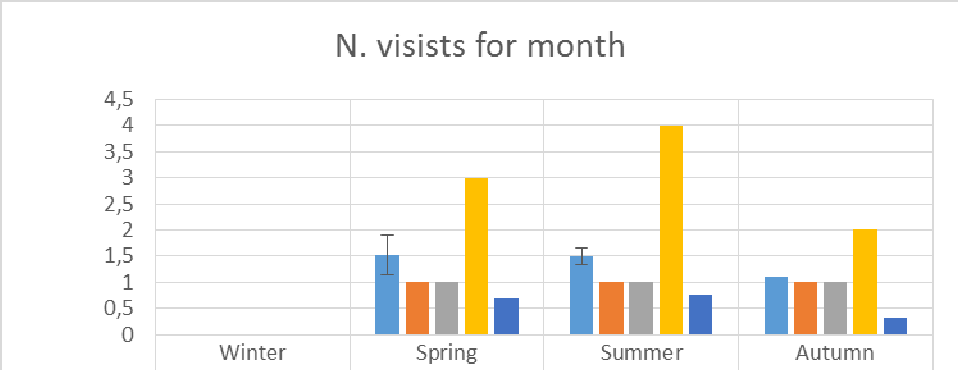
A Significant difference was revealed between winter and other seasons (p= 0.00 - 0.01). In winter (mean 26.11 days) griffon vultures remain in the chosen area. In other seasons (mean = 16.37 - 18.76 days) they move between different areas while being able to remain in these areas a full month (max = 31).



	Winter	Spring	Summer	Autumn
Mean	26,42	12,51	15,55	17,79
Median	31	10	11,25	15
Min	8	4,33	1	2
Max	31	31	31	31
DS	7,67	8,66	10,65	10,59

Fig. 10.36 - Seasonal duration of monthly presence.

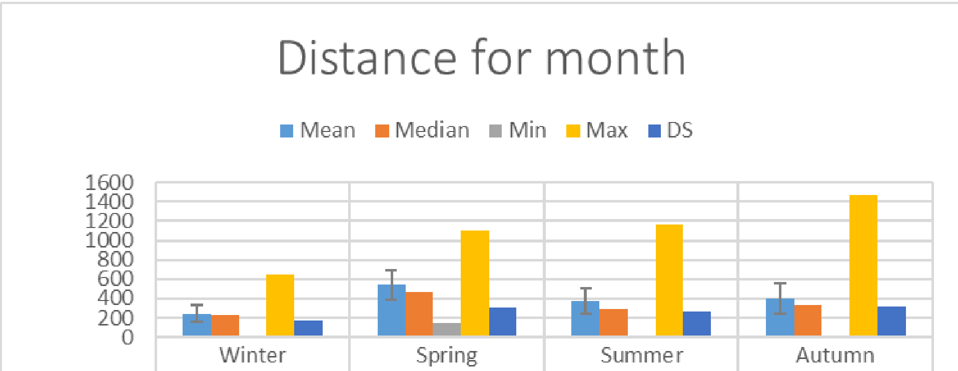
A statistically significant difference was revealed between winter and other seasons (p = 0.00), similar to that obtained with the previous parameter. In winter the mean period of visits is 26.42 days, while it is lower in other seasons with minimum in spring (12.51 days). Again vultures can remain whole months in the same areas in all seasons (max = 31 days).



	Winter	Spring	Summer	Autumn
Mean		1,53	1,5	1,11
Median		1	1	1
Min		1	1	1
Max		3	4	2
DS		0,697	0,763	0,315

Fig. 10.37 - Seasonal number of visits for month.

The comparison between the results is not statistically significant. The higher mean values in spring and summer show the tendency of griffon vultures to move more and therefore to stay for shorter periods in different areas, as evidenced by previous analyses.

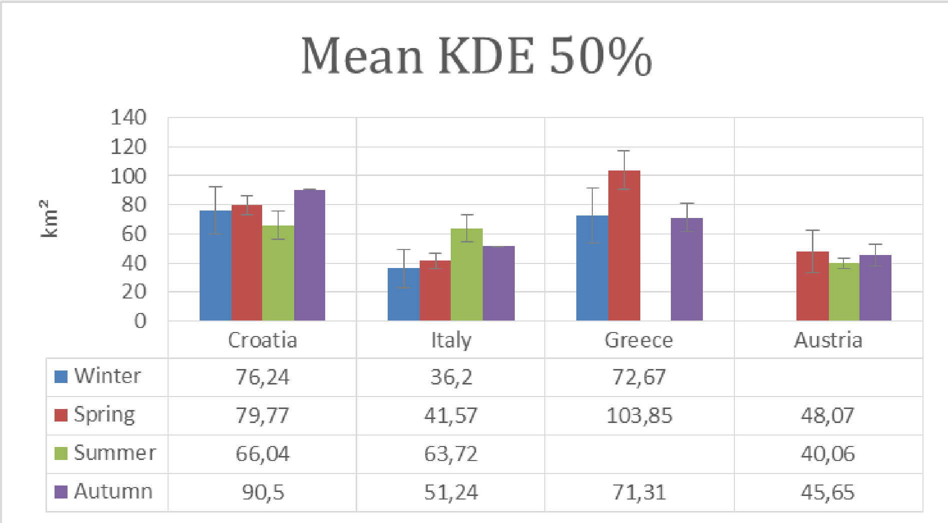


	Winter	Spring	Summer	Autumn
Mean	245,61	542,36	372,7	400,43
Median	228,52	468,79	290,4	331,33
Min	14,27	145,93	0,18	12,3
Max	645,79	1094,36	1168,29	1470,37
DS	174,43	301,24	272,48	319,48

Fig. 10.38 - Season monthly distance.

Significant the difference between winter and spring ($p \leq 0.001$) and between spring and autumn ($p = 0.04$). The mean winter distances (245.61 Km) are significantly lower than other seasons (372.7 - 542.36 km).
In conclusion, the comparison between seasons highlight that areas frequented (KDE, MPC) and distances are significantly lower in winter than in other seasons. In winter griffon vultures stay longer periods in the different areas, resulting in a minor movements between them.

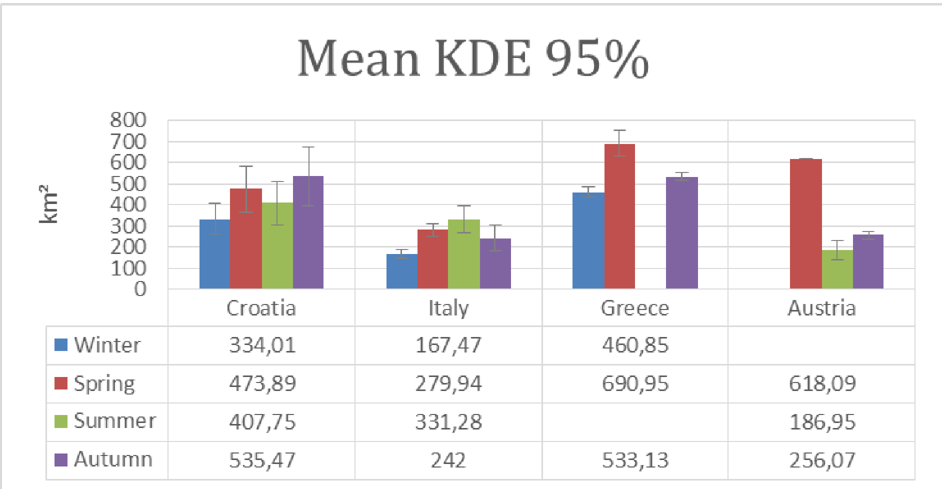
Comparison for zones and seasons
This comparison considers the monthly series of mean data referring to areas and seasons for all variables considered.



	Croatia	Italy	Greece	Austria
Winter	76,24	36,2	72,67	
Spring	79,77	41,57	103,85	48,07
Summer	66,04	63,72		40,06
Autumn	90,5	51,24	71,31	45,65

Fig. 10.39 - Seasonal variation of KDE 50% for areas (mean values).

Core area varies slightly in the seasons in Croatia and Austria, where cattle is grazing. In Italy, areas are limited in winter (36.2 km²), while in the summer (63.72 km²) are similar to Croatia (66.04 km²) and larger than in Austria (40.06 km).



	Croatia	Italy	Greece	Austria
Winter	334,01	167,47	460,85	
Spring	473,89	279,94	690,95	618,09
Summer	407,75	331,28		186,95
Autumn	535,47	242	533,13	256,07

Fig. 10.40 - Seasonal variation of KDE 95% for areas(mean values).

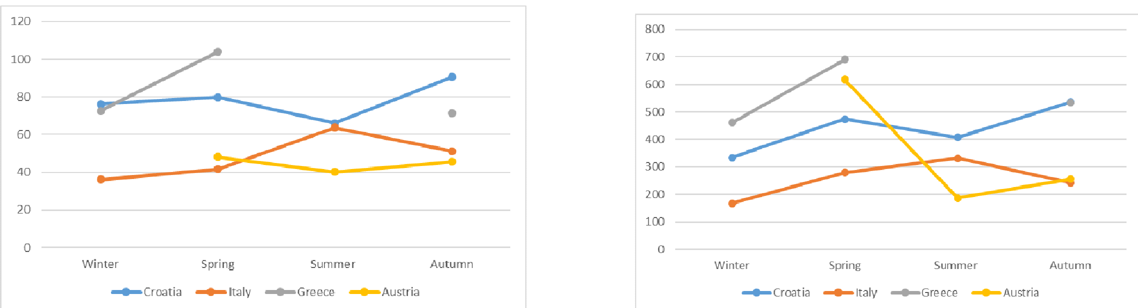
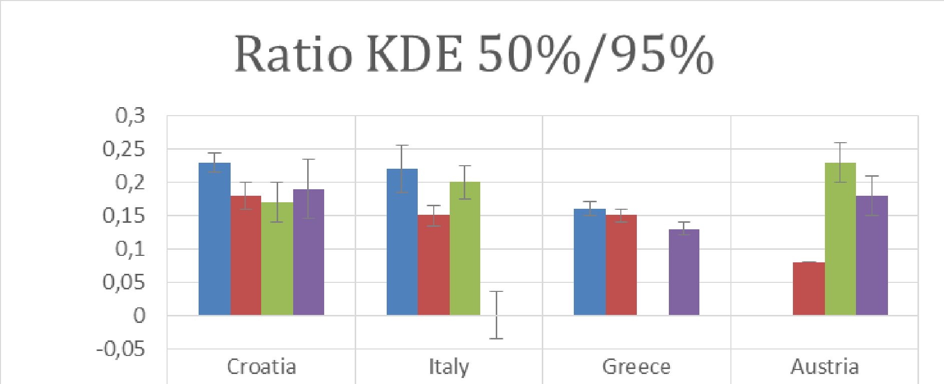


Fig. 10.41 - 10.42 - Trend of KDE 50% and KDE 95% for areas and seasons.

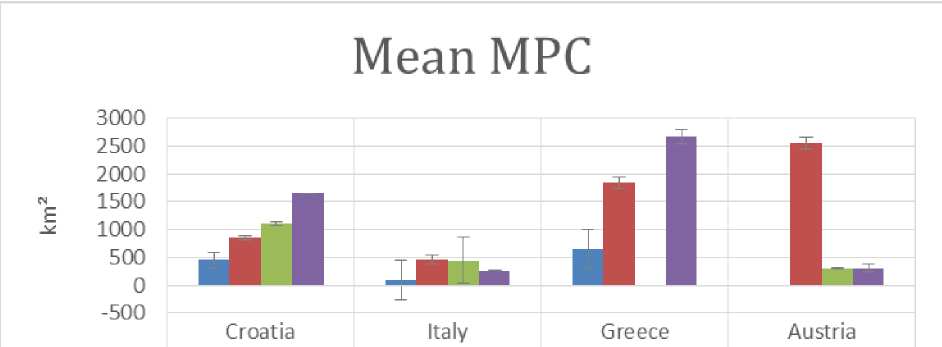
Home Range trend is similar to the Core Area, with greater seasonal differences in Croatia and high values in Austria in spring (value related to a single individual). Rather low values were obtained for Italy in winter and autumn.



	Croatia	Italy	Greece	Austria
Winter	0,23	0,22	0,16	
Spring	0,18	0,15	0,15	0,08
Summer	0,17	0,2		0,23
Autumn	0,19	0	0,13	0,18

Fig. 10.43 - Seasonal variation of ratio KDE 50%/KDE 95% for areas

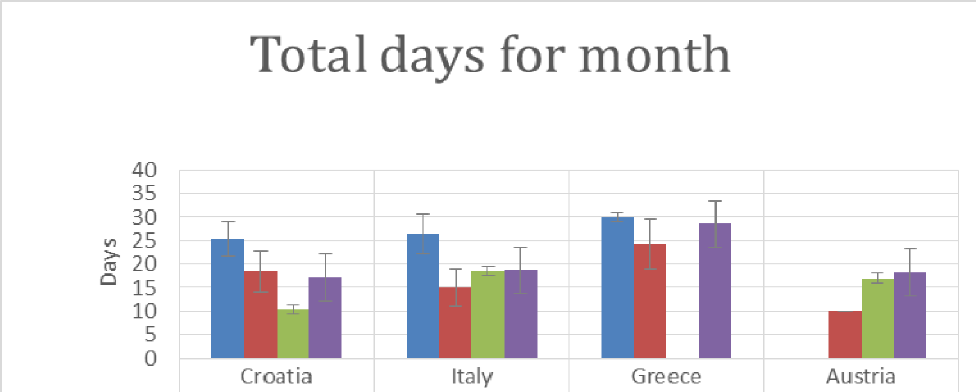
This ratio does not show any particular differences (mean values).



	Croatia	Italy	Greece	Austria
Winter	456,52	102,87	648,82	
Spring	853,89	469,78	1843,53	2541,53
Summer	1107,39	444,91		302,93
Autumn	1654,93	257,25	2674,49	311,78

Fig. 10.44 - Seasonal variation of MPC for areas.

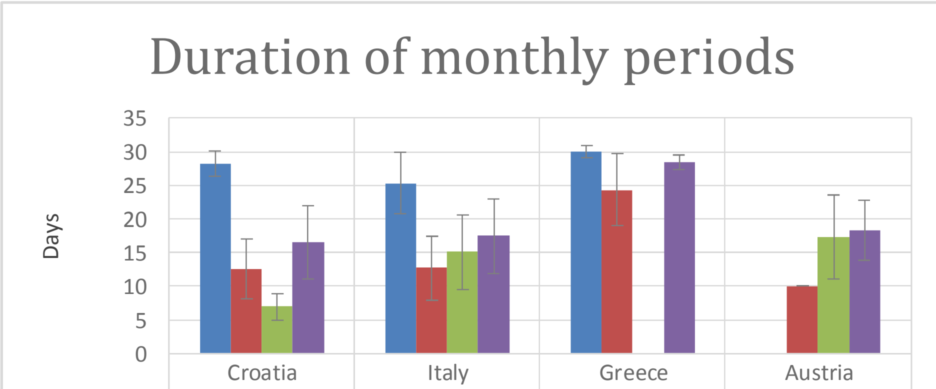
The MPC provide the highest values in summer and autumn in Croatia and in the spring and summer in Italy. The highest value in the spring recorded for Austria is related to a single individual, nevertheless highlights that due to little food in the pastures at high altitude early in the season, birds make large movements.



	Croatia	Italy	Greece	Austria
Winter	25,43	26,5	30	
Spring	18,44	15	24,33	10
Summer	10,29	18,6		17
Autumn	17,17	18,69	28,5	18,33

Fig. 10.45 - Seasonal variation of total days for month for areas (mean values).

The longer monthly periods are recorded in winter, while the shortest periods in summer in Croatia (10.29 days) and in spring in Italy (15 days) and Austria (10 days).



	Croatia	Italy	Greece	Austria
Winter	28,29	25,33	30	
Spring	12,59	12,7	24,33	10
Summer	7	15,09		17,28
Autumn	16,47	17,44	28,5	18,33

Fig. 10.46 - Seasonal variation of the duration of monthly periods for areas (mean values).

The average time spent seasonally from the birds in the different areas show a clear tendency to winter in one place and to visit different areas in spring and summer and to a lesser extent in autumn. Shorter periods were recorded in summer for Croatia (7 days) and in spring for Italy (12.7 days) and for Austria (10 days).

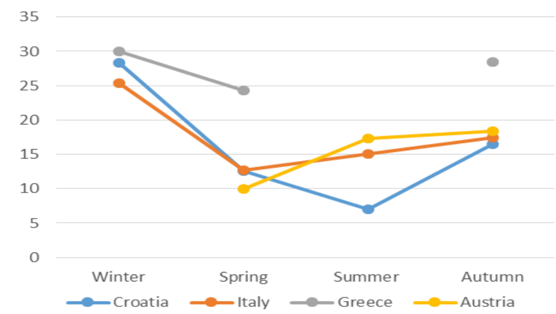


Fig. 10.47 - Seasonal variation of the duration of monthly periods.

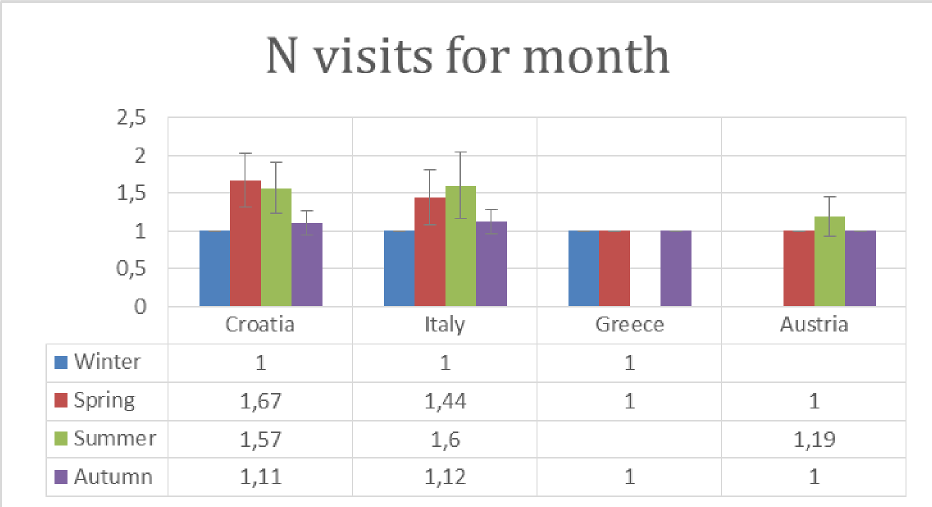


Fig. 10.48 - Seasonal variation of the number of visits for month for areas (mean values).

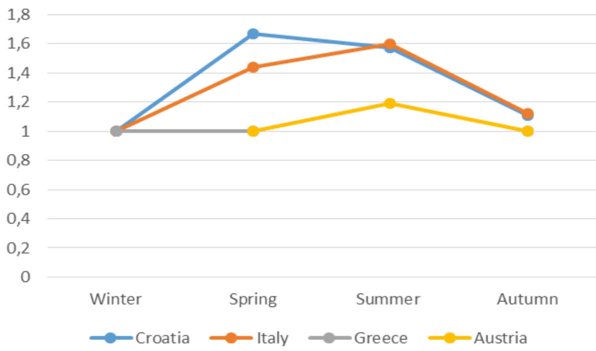


Fig.10.49 - Number of visits for month.

The mean number of visits per month is higher in spring in Croatia (n = 1.67) and in summer in Austria (1.19) and Italy (1.6). Movements are more frequent in spring and summer between Italy and Croatia.

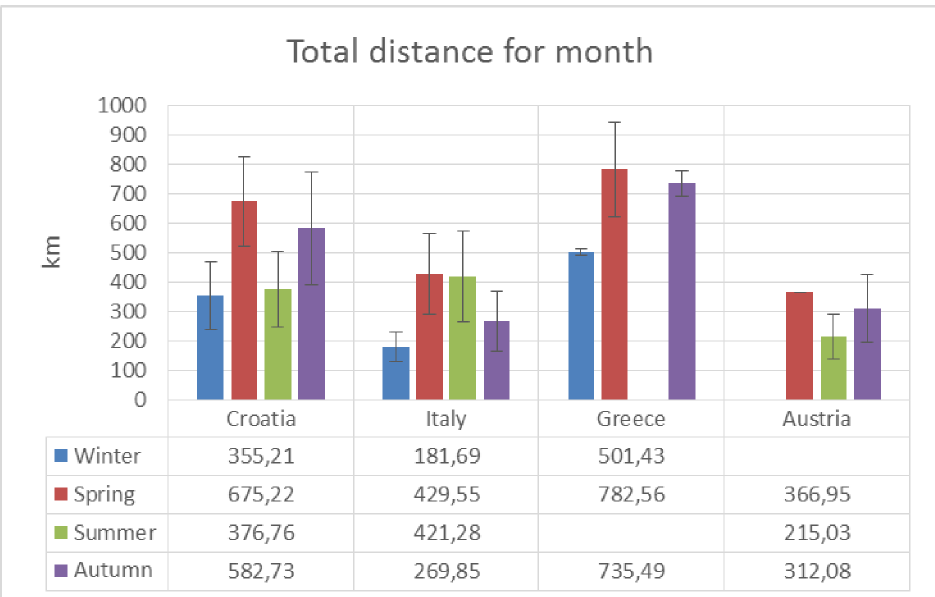


Fig. 10.50 - Seasonal variation of the monthly distance for areas (mean values).

Trend of distances is similar to KDE and MPC, with higher values in spring. The highest values were recorded in Croatia in spring (675.22 km) and autumn (582,73km), in Italy in spring (429.55 km) and summer (421.28 kilometers). In Austria birds move less in summer (215.03 kilometers). The distance covered by vultures is strongly influenced by the number of available fixes over the year.

10.4 Linear mixed models

The parameters (KDE, MCP, Distance, Mean time and number of visits) have been analysed with the mixed model, using as fixed factors the season and area (Croatia, Italy and Austria) and as random factor the different individuals.

Area
-Croatia
-Italy
-Austria

Season
-Winter
-Spring
-Summer
-Autumn

Fixed factors: season and area
Random effect : individual

Tab. 10.4 – Mixed model to test correlations between areas and seasons.

Dependent variable	Akaike	Model (p<)	Area (p<)	Season (p<)	Mean estimated for area	Mean estimated for season
KDE 50%	233,065	0,000	0,000	0,136	76,553[a] 51,809[b] 38,809[c]	44,333 54,243 58,792 58,347
KDE 95%	222,546	0,000	0,000	0,001	427,960 [a] 259,460 [b] 201,587[c]	195,921[b] 337,339[a] 311,318[a] 306,593[a]
MCP	376,089	0,000	0,000	0,000	1026,326[a] 284,841[b] 299,984[b]	174,149[b] 720,289[a] 580,198[a] 535,359[a]
KDE 50%/95%	109,828	0,018	0,353	0,011	0,186 0,200 0,206	0,228[a] 0,163[b] 0,198[ab] 0,205[a]

Distance	348,533	0,000	0,001	0,012	378,076^{a} 283,850^{b} 201,156^{a}	183,777^{b} 374,723^{a} 298,985^{a} 291,933$_{a}$
Mean time	335,594	0,000	0,034	0,000	14,665^{b} 17,545^{a} 23,094^{a}	29,465^{a} 15,006^{b} 13,107^{b} 18,571^{ab}
N visits	169,253	0,000	0,012	0,000	1,246^{a} 1,267^{a} 0,958^{b}	0,920^{c} 1,332^{ab} 1,382^{a} 1,024^{bc}

From the tab. 10.4 we can obtain the main conclusion of all the different combinations of factors.

KDE 50% - All three areas are significantly different, while there are no significant differences between the seasons. The results are similar to that obtained with the Kolgomorov-Smirnov test, however, noted a non-significant difference between Italy and Austria.
KDE 95% - Significantly different the areas and, for the seasons, winter from the others. The Kolgomorov-Smirnov test finds similarities between Austria and Italy and between spring-summer and summer-autumn.
MCP – Croatia is different from other areas and winter from other seasons. Similar results were obtained with the Kolgomorov-Smirnov test, with less difference between the seasons.
KDE 50%/95% - This parameter does not detect differences between areas. Significant difference of spring in relation with fall and winter was revealed. Very similar results with Kolgomorov-Smirnov.
Distance - Italy and winter significantly different from the others. Kolgomorov-Smirnov gave minor differences.
Mean time -Spring and summer are different from winter. Kolgomorov-Smirnov provides similar results.
N visits - Austria is different from other areas. Winter is different from spring and summer; spring different from autumn. Kolgomorov-Smirnov provides the same results for the areas and similar for the seasons.

In order to obtain more precise values, the analysis described in the paragraph 10.4 was repeated, this time after removing the sea surface in Croatia.

Tab. 10.5 – Mixed model to test correlations between areas and seasons, excluding the sea surface in Croatia.

Dependent variable	Akaike	Model (p<)	Area (p<)	Season (p<)	Mean estimated for area	Mean estimated for season
KDE 50% *no sea surface*	240,321	0,040	0,050	0,051	58,809 [a] 53, 354 [a] 40,290 [b]	39,045 [b] 48,064 [ab] 54,358 [a] 53,882 [a]
KDE 95% *no sea surface*	411,818	0,020	0,064	0,018	281,756 [a] 228,795 [ab] 172,972 [b]	145,645 [b] 261,746 [ab] 285,713 [a] 228,710 [a]
MCP *no sea surface*	212,283	0,000	0,000	0,000	458,407 [a] 244,574 [b] 252,856 [b]	117,45 [b] 488,346 [a] 395,799 [a] 380,764 [a]
KDE 50%/95% *no sea surface*	119,541	0,032	0,583	0,010	0,222 0,231 0,242	0,270 [a] 0,194 [b] 0,224 [b] 0,245 [b]

In the analysis carried out after removing the sea surface, the difference in the KDE and MCP values among the three areas is lower than the one obtained in the previous analysis. In particular, KDE 50% and 95% are still different from those calculated for Austria but significantly similar to those for Italy.

11. Discussion

11.1 Areas exploited by vultures

The foraging area of the griffon vultures appears very large and encompassed different European countries. Mostly of the birds equipped with GPS-transmitters are immature, born in the biggest colonies in the Croatian islands and it is known that in such populations young and immature birds covers long distances moving far to the south in Autumn-Winter and to the North and other directions in Spring-Summer (Sušic G. 2013). Our results show that the majority of the griffon vultures moved mostly between the birth colonies in Croatia and the Alps. The foraging area of vultures appears well identifiable and relatively constant for most of the individuals, including three important sectors: the islands of Krk, Cres, Plavnik, Prvič with part of the Velebit Mountains in Croatia, the Prealps-southern Alps in Friuli and part of Slovenia (West Julian Alps) and the Hohe Tauern in Austria (Salzburg Region). This fact is known since a long time (Perco *et al.*, 1983; Sušic G. 1994) and detailed observations were made in recent years (Genero & Knollseisen, 2013), but this is the first time that this population is studied in the details, showing modalities and frequency of movements and use of foraging areas and roosting places. GPS locations show that griffon vultures move between these three areas directly and fast using only rarely the intermediate territories for roost or foraging. They can be very fast, covering the distance between the feeding point in Friuli and the islands (160-200 km line air), with good weather conditions, in 5-6 hours. Similarly they can cross the Alps from Cornino to the Hohe Tauern (about 100 km) in 2.5-3 hours. During the direct flights between these areas they reach the maximum speed of about 65 Km/h (calculated as distance between two consecutive points in one hour time difference). In other studies, with equipments giving the speed of the birds, values of 140 km/h in France (Monsarrat *et al.*, 2013), 180 km/h in Crete (Xirouchakis & Andreou, 2009), and 216 km/h in Israel (Bahat, *et al.*, 1993) were obtained, probably in particular conditions. Only two vultures of unknown origin (recovered in Tirol (A) and Czech Republic), showed a different pattern, moving after a short time far to the west reaching France and Spain.

11.2 Movements

Movements between the main areas are much more frequent in late spring-summer than in autumn. They are sporadic in winter, when griffon vultures tend to stay in a selected area. Weather conditions in winter are less favourable, for such big soaring birds, with reduced ascending thermal currents and short days. Overwintering occurs in Croatia and Friuli and for only one individual in Greece in 2013/2014. This bird covered the distance from Croatia to Greece in four days (about 1,000 Km). It remained in Greece seven months and 10 days.

The Hohe Tauern in Austria were frequented from most of the birds (8 out of 12), only during the summer period. These high mountains are covered with snow in winter when flight conditions for griffon vultures are very bad; furthermore there is shortage of food due the absence of grazing cattle. Griffon vultures arrive in May and leave in September (Genero & Knollseisen, 2013). In our study the first arrival occurred on 4th June and the last bird left on 15th September.

Movements between Friuli and Croatia are frequent from May to October, while they decrease in autumn and are rare in winter. There is a strong individual variation in the time and frequency of movements and in the periods the birds spent in the different areas. From autumn to early spring, griffon vultures remain some months in the chosen areas and don't undertake long travels. Apart from the bird wintering in

Greece, the others stayed in Friuli or in Croatia, and did also change their wintering location over the years. Only one bird (n. 13122) moved in winter from Friuli to Croatia on 09.12.2014. In 2 occasions long movements were observed for different individuals with modalities described as LRF (Long range forays) by Spiegel *et al.* (2015). in July 2013, griffon vulture N.13120 covered at least 450 Km in Austria in 4 days. In June 2014 vulture N.13124 covered at least 1,100 Km in Austria, Swiss and Germany in one week. Such LRF are relatively short-term spatially extended movements in which individuals depart, travel to remote locations and come back. They reflect an adaptive exploratory strategy for exploiting remote food patches and other resources (Conradt *et al.*, 2003; Lopez-Lopez *et al.*, 2013).
Results show that mean daily distance varies widely (from 6.3 to 16.5 km) depending on the daily number of locations. Maximum daily distances varies between 230 Km and 360 Km.
For individual foraging areas we didn't observe large differences, like recorded in other studies in France and Israel (Monsarrat *et al.*, 2013; Spiegel *et al.*, 2015). Apart from differences in movement frequency and permanence in the areas, and the partial use of the Austrian mountains in summer and wintering in SE Europe, all individuals tend to frequent the same areas in the Alps and Croatia.
The flight altitude is relatively low, with a large majority of locations within 100 m from the ground. Griffon vultures use the thermal currents near the ground. High altitude flights are normally performed to cross valleys or in long distance movements when wind or thermics are favorable. Xirouchakis & Andreou (2009) in Creta found that the elevation of soaring vultures above the ground ranged from 96-440 m, mean 248 m. In the Grand Causses the mean was 301 m (Monsarrat *et al.*, 2013).

11.3 Home Range, Core Area, MCP
Considering all data for 10 individuals (the birds with a significant number of locations) the total mean value of KDE 50% is 265.5 Km², KDE 95% 2,753.6 Km² and MCP 76,681.7 Km². Comparisons with other studies are not simple due to different techniques used in the research and for data analysis. Home range and Core Area data are bigger than in Grand Causses (F) and Creta (GR) and lower, but comparable, to Spain and Israel (Tab. 1.1, 1.2). In general exploited areas appear smaller in islands (Creta) or situations with abundance of feeding points (France) and bigger where vultures move between different areas (this study and Israel) and are immature or non-breeders (this study and Spain), notoriously more erratic (Garcia-Ripolles *et* al., 2011; Monsarrat *et al.*, 2013; Xirouchakis & Andreou, 2009; Bahat, *et al.*, 1993). Results obtained with MCP method gave values much larger than other areas (Abruzzo and Spain), due to regular movements of vultures on long distances, comparable only with data obtained with *Gyps coprotheres* in Namibia (Bamford *et al.*, 2007) and *Gyps bengalensis* in Asia (Gilbert *et al.*, 2007). Our results, in fact, are clearly related to the strong seasonal movements of immature Croatian birds, fact that was not found in other researches done on this species in Europe. Adult birds, in comparison, move through relatively small foraging areas (Sušic, 2009; 2013; Zuberogoitia *et al.*, 2012)
Comparing the annual mean values for different individuals (TAB. 2), we observe high values of MCP, and, to a lesser extent, of KDE values, for the griffon vulture
s that have done long movements. For the others differences are not so evident, while variations between different years (for GPS that worked 2 years) are significant.
Griffon vultures' foraging strategy seems characterized by movements between the different areas, probably in relation with availability of food, choosing periods and patches where food is abundant and possibly concentrated in relatively small areas

(Duriez *et al.,* 2012). In our study, movements vary over years and countries, but exploited areas are relatively small and well known by the birds. Some spots (feeding point, roosting places, areas with good food resources) are well known and regularly used by the birds.

11.4 Food availibility and distribution in the different areas

To better understand the results of the analysis, the trophic situation in the three most important areas is here described. In Friuli there is a feeding point, stocked with about 50 tons of meat per year, which represents the major attraction for griffon vultures. The nearby mountains (Friuli-Slovenia) offer limited and variable food resources, regularly used by griffon vultures. In Croatia, the main diet consists of mainly sheep grazing on the islands. In this area the main mortality of the sheep occurs in early spring and autumn. The food availability is falling sharply due to the reduction in sheep farming, particularly in the island of Cres (Sušic 1983; 2013; Ivankovicl et al., 2012). In Austria the cattle is brought to the pastures during summer. Mortality is rather irregular and linked to the weather conditions. With high mortality events (when a large number of cows or sheep dies), usually because of lightning), many griffon vultures aggregate in the area.
GPS locations and movements in the three main areas show that in Croatia griffon vultures explore regularly some areas of the island of Cres (avoiding almost completely Lošinj), Prvič and Plaunik, the southern part of Krk and the coastal part of the Velebit-mountains. In Austria, birds concentrate where livestock mortality happens. In Friuli they move around the feeding point, regularly exploring the Prealps and the Slovenian Alps, which represent the traditional areas of summering (Perco *et al*., 1983; Genero, 1985). Other local regular movements observed along the Tagliamento and Arzino Valley are related with the presence of important nesting and roosting sites.

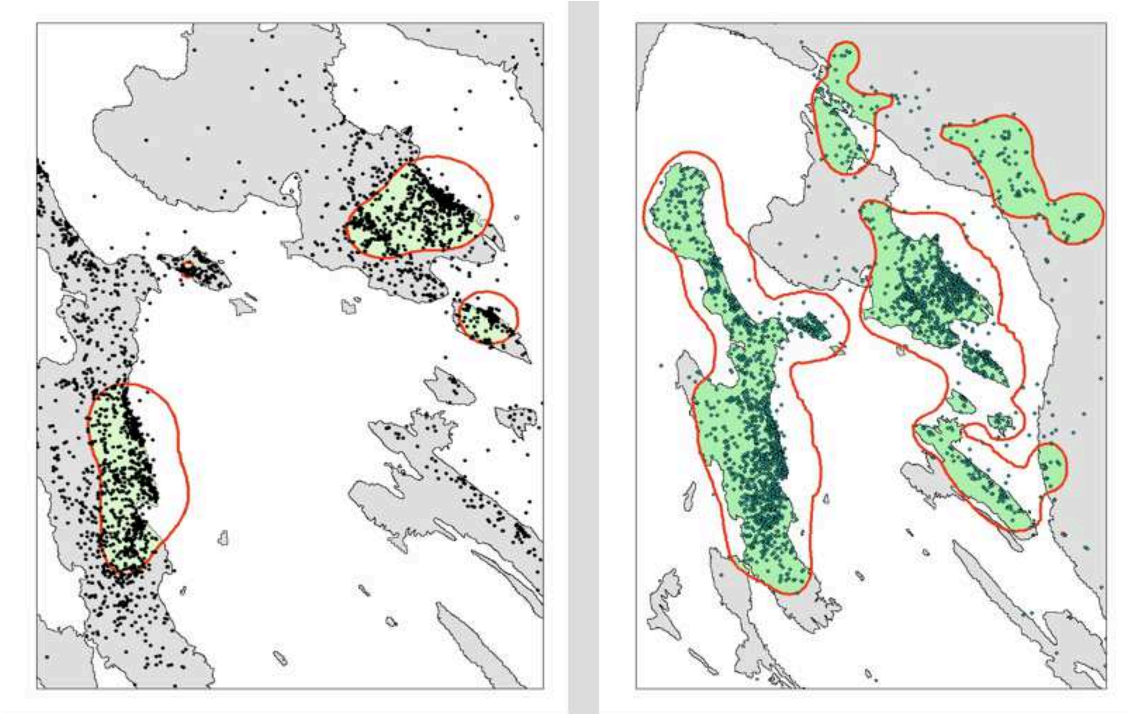
11.5 Importance of the feeding point

The feeding point of Cornino (active since 1988) has strongly modified the griffon vultures habits, as they are now present in much greater numbers than in the before the beginning of the project.- Also satellite locations show their preference for the site. Griffon vultures moving to and from Croatia change in part their traditional routes, at the border between Friuli Venezia Giulia and Slovenia, and move through the hilly areas and foothills, to use the shortest way to and from the feeding point area. Movements are regularly observed between the mountains of Friuli and the Slovenian Alps in spring and summer; this is an area historically frequented by the vultures, where there is still some food supply linked to grazing sheep (Genero, 1985; 2009). Movements to and from Austria, in summer, originate and end almost always in the area of the Natural Reserve. Movements to the West are very rare, as griffon vultures normally do not cross the Arzino Valley, despite the presence of favorable areas.
In the last years the period of stay in Friuli has also changed. In the past griffon vultures were traditionally present from May to October. Currently, summer visitors stay for longer periods. Some birds stay for years or even breed in the colony (Genero, 2009).
It is known that juveniles tend to wander in vast areas and to be attracted at regular feeding points (Bose et al., 2012; Duriez et al., 2012). The reason why immature vultures continue to move between different areas, even if food is abundant at the feeding point, can be related with the high intraspecific competition suffered in the heavy feeding points where adults are dominant (Duriez et al., 2012). As birds reach

sexual maturity, at least part of them, tend to move less and to go back to the native areas (Zuberogoitia et al., 2012). In Friuli, however, a high number of Croatian adults (about 1/3 of the total) is observed in summer (Genero, *unpubl.*). Probably these are non-breeders, but adults who make long trips to bring food to the young, as data from a Croatian bird equipped with GPS indicate (Sušic, *pers. Com.*).
In any case vultures seem able to alternate successfully strategies based on social information (unpredictable resources like in Croatia and Austria) and personal information (predictable resources like the heavy feeding point in Italy) (Deygout *et al.*, 2010).

11.6 Interpretation of results

The different parameters considered in the study have been analyzed, in relation to the behavior of vultures in the different areas and seasons. The seasonal ranging behavior of 11 griffon vultures in 3 different areas is presented, according to Kernel and MPC home-range analysis. Regarding the areas frequented by the birds, data show that Home Range, Core Area and MCP are greater in Croatia than in Italy and Austria, the latter two being relatively similar to each other. The reason why these values are bigger in Croatia could be related with the sea surfaces found between the islands and the mainland. These surfaces are in fact not used to forage and are avoided. Griffon vultures are forced to cross them as part of their movement and this factor increases the values of spatial indices (areas and distances). Removing from the values the calculated marine surfaces (approximately 35-45% of the values), similar results to other areas are obtained. In literature there are no similar situations, as other island populations inhabit large islands from which they rarely move. A suitable example is Sardinia (Schenk, 1976; Schenk *et al.*, 2008) and Creta (Xirouchakis & Andreou, 2009).
The home range minus the sea areas, appear to differ between Croatia ($HR_{95=}$188 km^2 e HR_{50} 28 km^2) and Italy (HR_{95} 215 km^2 e HR_{50} 42 km^2) compared to Austria (HR_{95} 49 km^2 e HR_{50} 19 km^{22}), where it is lower.
The fig. 11.1 also shows that movements outside the coast line are rare and the birds move between islands crossing the sea where the distances are smaller. Also the comparison between Italy and Austria is interesting. Higher values for Italy seem to indicate that the feeding point does not affect movements and the areas explored by the birds. The comparison in the seasons, shows no significant differences in the Core Area, since griffon vultures tend to concentrate their activities in areas rich in food, while they are higher in Home Ranges and MCP. Such differences are lower in winter and higher in other seasons, especially in spring and autumn. Winter presents unfavorable flight weather conditions and the birds move with difficulty. In summer they tend to stay in areas rich in food, while spring and autumn are intermediate periods when birds are moving searching the most suitable areas. Also in other studies (in the Grand Causses (F) (Monsarrat et al., 2013) and Abruzzo (Altea *et al.*, 2013) a high diversity in the foraging area was found during spring-summer and autumn-winter.



KDE 50% and 95 % countour and influence of land and sea surface

	KDE 50%	KDE 95%
Total area	175,72	1523,51
Land area	116,67	879,30
% land area	66,39%	57,72%

Fig. 11.1 – Influence of the sea surface on KDE calculations in Croatia.

Values obtained are within the main foraging radius considered for griffon vultures: 9,7-14,90 km from the colonies or roosting places (Gil *et al*., 2009; Xirouchakis *et al*., 2009; Garcia-Ripolles*et al*., 2011; Spiegel *et al.,* 2013). Adult griffon vultures are typical central-place foragers being obliged to return to their breeding colony and ranging through a relatively small foraging area (Rosenberg & Mc Kelvey, 1999; Zuberogoitia *et al*., 2012). On the other hand non-breeders and immature birds tend to have a similar behavior once identified an area with good food supply or being strongly bound with roosts and feeding points. Zuberogoitia *et al*. (2012) demonstrated that subadult vultures are also related to breeding areas and their home ranges are largely restricted to zones close to breeding sites. In the study in the Grand Causses no differences between adults and immatures in home ranges were found (Monsarrat *et al*., 2013).

Considering both areas and seasons, the effect of the feeding point and the severe alpine climatic conditions are more evident in winter than in summer, when the griffon vultures, even with a feeding point constantly replenished, explore large territories. In Croatia, the higher surfaces values are recorded in fall and to a lesser extent in spring, the two seasons with the greatest availability of food (Sušic, 2009). Such trend is explained by the greater competition that occurs in these times for the births of the lambs in spring and the high number of vultures coming back from other areas in autumn. In Austria the values are similar to Italy, but highest in spring, when there is still snow on the Hohe Tauern and a few grazing animals and griffon vultures have to make large movements to locate available food sources. The data for Austria in spring are related to a single bird whose KDE 95% and MPC high values are related to movements from the Hohe Tauern to the Salzburg area.

The ratio KDE 50% /% KDE 95 highlights that, despite the different trophic situations, in all three areas griffon vultures tend to concentrate their activities in areas rich in food and of size equal to about one fifth of the Home Range. This ratio shows the lowest values in spring (HR 6 times more than the core area, CA), when CA is nearly constant but HM increases a lot. The data of the distances are similar to those of the areas, being correlated.
As for the frequency of movements and stay in the three main areas, there is a tendency to linger for longer periods in Friuli, and shorter periods in Croatia, while Austria has intermediate values. The value for Italy can be explained by the constancy of the food resource, while in Croatia griffon vultures are obliged to move more searching for food. The intermediate values of Austria, where food supply is based on cattle grazing, are probably related to the fact that griffon vultures reach the area when food resources are abundant and therefore tend to stop for relatively long periods.
The presence in different seasons is affected by the limited movements in winter, with values of total days per month and duration of monthly periods particularly high. In spring-summer griffon vultures often visit Croatia for short periods, moving frequently to the Alps, where they stay longer periods. Visits are frequent also in Friuli in summer, when the birds use this area also for their movements between Croatia and Austria.

12. Conclusions

Vultures are large obligate scavengers that rely on thermal and orographic uplift for their soaring flight that enables them to cover long distances in search of food (Ruxton & Huston, 2004). In our study griffon vultures move between 3 different areas, in relation with seasons and food availability. This allows vultures to concentrate in the more favorable areas with abundant food resources, related to pastoralism (Croatia and Austria and partially FVG and Slovenia) or to a feeding point (FVG). In this study a great importance of some spots (feeding point, roosting places, areas with good food resources) connected by direct and fast flights, with seasonal differences was identified. The feeding point in Friuli provides the whole year food *ad libitum* for the vultures.

This is the first time that this population is studied in detail, showing modalities and frequency of movements and use of foraging areas and roosting places, and via GPS telemetry methodology. This research shows a great individual variation of movement patterns and behavioral flexibility with travel distances till over 300 km/day.

The average time spent seasonally by the birds in the different areas shows a clear tendency to winter in one place and to visit different areas in spring and to a lesser extent in summer and autumn. In spring and summer, periods are particularly short in Croatia, as birds prefer to move in the Italian and Austrian Alps. In Austria griffon vultures are present only in summer and stay for longer periods and move less (searching for abundant concentrate food resources - mostly cows). There is probably a great importance of seasonal weather conditions, particularly important in the high mountains. In Croatia they stay for shorter periods and move more (small carcasses scattered on the islands).

The Core area has small variations between seasons. The Home Range and MCP have maximum values in spring and autumn due to favorable flight conditions and dispersion of food resources. Results show that Core Areas, Home Ranges and MCP are bigger in Croatia. This can be related with more distributed trophic resources (Sušic, 1983; IvankovicI *et al*., 2012) but also with the influence of the see surface between the islands and the coast, included in the KDE and MPC calculations but obviously irrelevant for foraging activity. If we don't consider the see surface, there are no significant differences between the area with heavy feeding point (Friuli), and Croatia (traditional sheep pastoralism) and the Hohe Tauern (summer pastoralism with different species). Apparently in those different situations griffon vultures are able to find patches with high amount of food (Croatia) or periods with accidental high mortality events in the Hohe Tauern (A) (Genero & Knollseisen, 2013).

Although not significant, there are remarkable differences between Austria and Friuli, where a heavy feeding point is active. The presence of the heavy feeding point doesn't restrict the foraging area, at least in comparison with the two other locations, even if movements of the birds appear more repetitive and less random. Although vultures preferred predictable resources, the preference showed for open grassland suggests that they also forage in Friuli on randomly distributed resources.

GPS tracking technology can be used effectively to provide detailed information about vulture movements and land use selection, and as a tool to inform the planning of vulture conservation strategies.

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