A new project to monitor forest raptors in Catalonia

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Raptors have attracted great interest due to the strong population declines suffered over the 20th century in Europe. In the Mediterranean basin, however, forest species have often been poorly monitored so far. The lack of a standardized monitoring methodology for this group of species poses problems in official communications on the state of populations, such as the Article 12 reporting of the Birds Directive and the reporting of the species status in Natura 2000 sites by EU member states. In Catalonia (NE Spain), in contrast to scarce cliff-nesting raptors, data on forest raptors have been collected using a variety of different methods and have remained largely decentralized up until now. After a series of discussions, a new standardized long-term monitoring scheme — the SEGRE project (general raptor monitoring in specially protected areas, in Catalan: SEguiment General de Rapinyaires en Espais naturals protegits) — was launched in 2019, based on previous experiences from both Catalonia and other European countries. The project coordinates the collection of precise information on territories of raptors in protected areas. SEGRE aims to accurately inform on the status and trends of forest raptors and represents a basis for the assessment of the impact of management, particularly within each protected area. Its protocol consists of four 3-hour morning surveys from a fixed viewpoint with good visibility within a reference 2.5 × 2.5 km square grid. The visits cover the whole breeding season of a target species between March and July. Each observation is geo-located together with a behavioural code that facilitates determining the breeding status, to enable mapping of territories. The first results of the project after the three-year pilot period in 12 protected areas seem to be promising, since the project substantially increased the amount and standardisation of data for this group of species.

Over the 20th century, raptor populations suffered a massive decline in Europe, not just because they were intensively persecuted and killed due to the interactions with human activities (Newton 1979, Donázar et al. 2016), but also because of their sensitivity to habitat degradation and to toxic chemicals (Newton 1979, Sergio et al. 2008, Zuberogoitia et al. 2011). Luckily, the establishment of new law regulations to protect all raptor populations by the end of the century led to the recovery of many species in several countries (Donázar et al. 2016), although the situation varies depending on the particular species and region within Europe (Keller et al. 2020).

Historically, raptors have attracted a lot of interest, because of their appealing visual appearance, their fascinating predatory life-style, as well as their rarity and conservation status (Donázar et al. 2016). There are several reasons that highlight the importance of raptors in ecosystems. First, they are considered indicator species (Sergio et al. 2008). This means that, in many cases, they can indicate the state of the ecosystems they live in, because their high trophic level and slow demographic rates make them particularly sensitive to disturbances. Moreover, raptors can be ecosystem-structuring agents in some biological systems, as it has been demonstrated that their presence is positively related with the richness and abundance of other species groups at the local scale (Sergio et al. 2008, Burgas et al. 2014). Finally, many raptors have been treated as flagship species to reach conservation goals, due to the public interest that they raise. By targeting those species in conservation projects, other species and habitats that fall within the territories of raptors may benefit as well (Sergio et al. 2008).

In general, raptors are more endangered than other bird groups, with 52% of the world species in decline, and 18% threatened with extinction (McClure et al. 2018). In addition, accurate and current information on the conservation status and population trends of most raptor species is still lacking (Palomino and Valls 2014). In Catalonia (NE Spain), the first data available on raptor conservation status from the 20th century showed restricted distributions for many species (Muntaner et al. 1984), but recent publications document a recovery for most raptor populations in this area (Alcaraz et al. 2020, Franch et al. 2021). Here, we focus on forest raptors, considering those species that rely on forest habitats for breeding and feeding (Zuberogoitia et al. 2011, Palomino and Valls 2014).

The often secret behaviour of raptors, together with their low densities, make them species that are difficult to detect (Newton 1979, Fuller and Mosher 1981). As Common Breeding Bird Monitoring programs often fail to survey these species properly (Franch et al. 2021, PECBMS 2021), specific standardised monitoring schemes are needed to understand their trends. In addition, several conservation programs are in place in specially protected areas (SPA) to conserve raptors, but in general forest raptors are excluded from region-wide monitoring strategies (Generalitat de Catalunya 2021). Likewise, the monitoring of these species in Catalonia lacks a common protocol that would allow to compare the results among SPAs. Accordingly, a new general monitoring scheme to survey forest species in Catalonia, the SEGRE project (general raptor monitoring in specially protected areas, in Catalan: SEguiment General de Rapinyaires en Espais naturals protegits), was planned and established in 2019. The goals of the project are (1) to develop a standardised monitoring scheme to fill a knowledge gap in Catalonia, and in doing so, (2) to obtain long-term trends and to detect population changes over time, and (3) to establish abundance patterns comparable among SPAs and at the regional level.

1. Materials and methods

1.1. Study area

The SEGRE project is a region-wide monitoring scheme to survey diurnal forest raptors in Catalonia (Fig. 1), NE Spain, in the long term. Catalonia has a surface of 31 990 km², of which 63.8% is currently forest (Institut d'Estadística de Catalunya 2022), ranging from 0 to about 2400 m a.s.l. Nevertheless, only some specially protected areas (SPA) have been surveyed by game wardens until 2021. These SPA represent around a 31.9% of the area in Catalonia (Institut d'Estadística de Catalunya 2021). From 2022, the project will be progressively offered to experienced volunteers (i.e., «citizen scientists»), to better cover the whole region of interest and to obtain data for the entire study region, also comprising forests outside of SPAs.

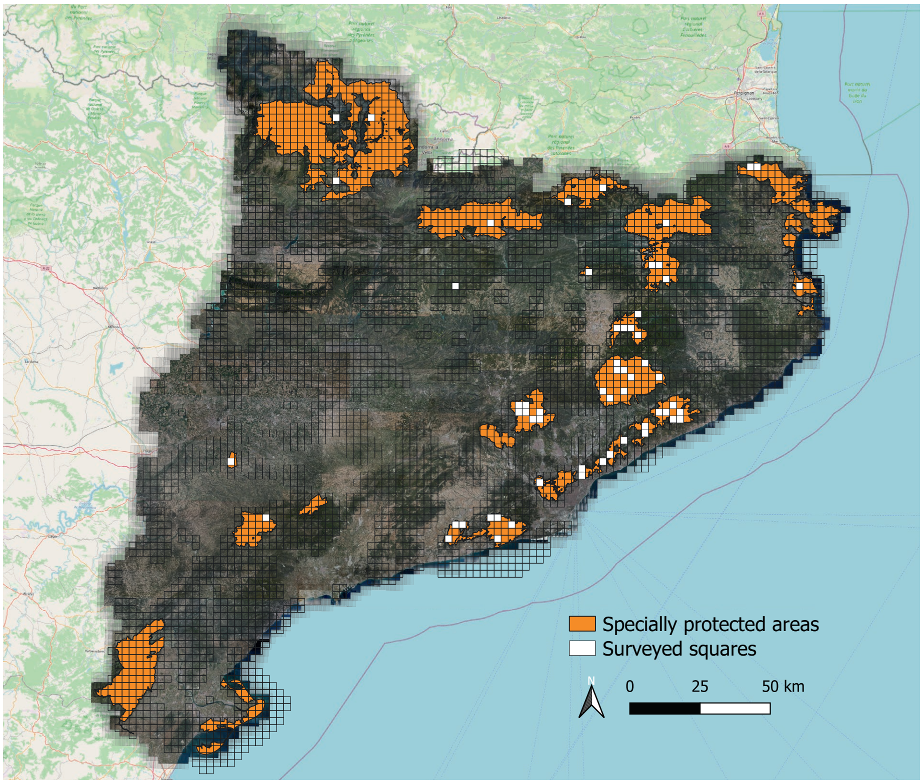

Figure 1. Map of the specially protected areas of Catalonia, with the 2.5 × 2.5 km grid and the surveyed plots between 2019 and 2021.
Karte der europäischen Vogelschutzgebiete in Katalonien mit einem Raster von 2,5 × 2,5 km und den zwischen 2019 und 2021 untersuchten Flächen.

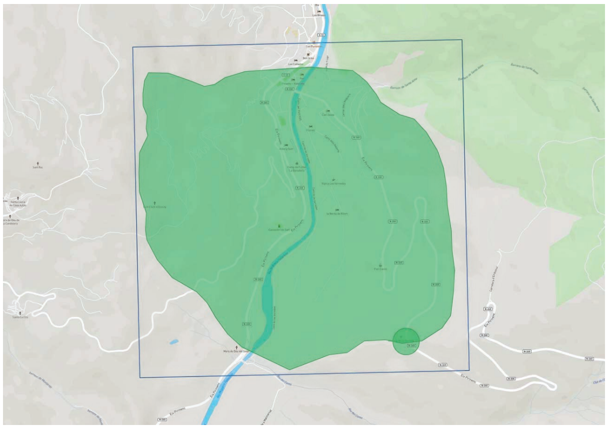

Figure 2. Example of a surveyed 2.5 × 2.5 km square, with the observation point marked as a green dot, and the visibility area shown as a polygon. Although in this case, the visibility area falls completely within the square, this is not always the case, and the visibility area might cover a part of the external area as well.
Beispiel für ein untersuchtes Quadrat von 2,5 × 2,5 km, wobei der Beobachtungspunkt als grüner Punkt und das vom Beobachtungspunkt sichtbare Gebiet als Polygon dargestellt ist. Obwohl in diesem Fall der sichtbare Bereich vollständig innerhalb des Quadrats liegt, ist dies nicht immer der Fall, und er kann auch einen Teil ausserhalb des Quadrats umfassen.

Figure 3. Habitat and visibility from an active observation point.
Lebensraum und Sichtbarkeit von einem aktiven Beobachtungspunkt aus.

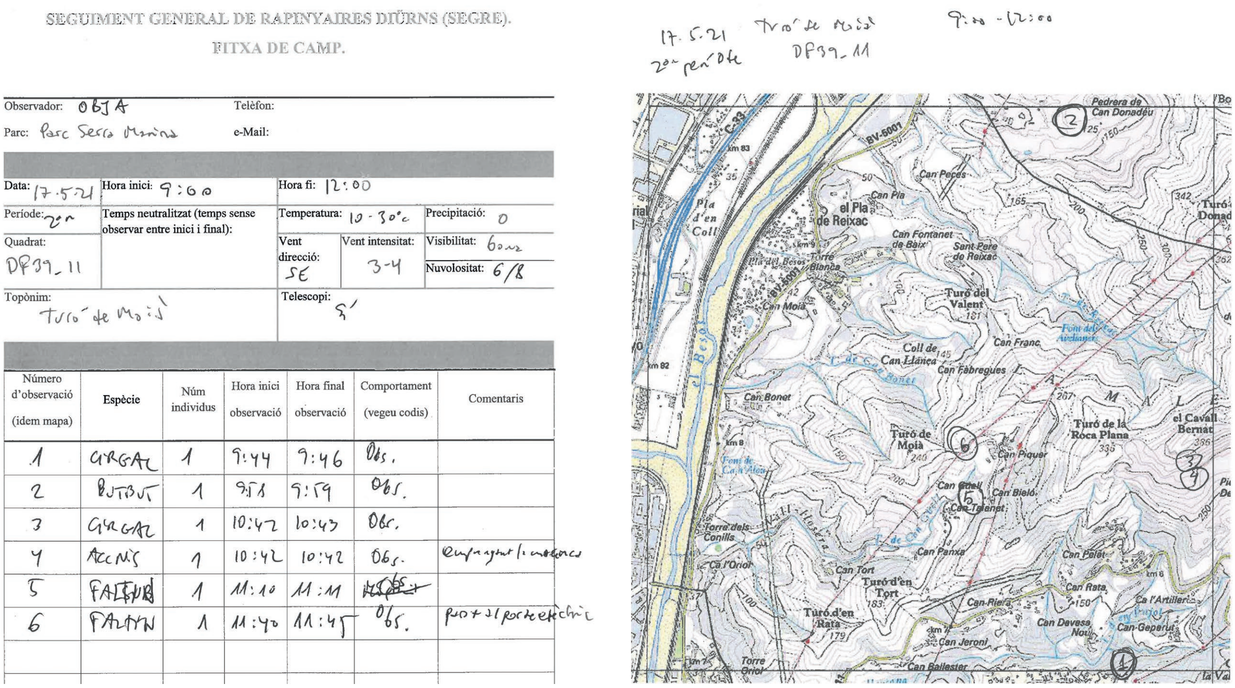

Figure 4. Field sheet (a) and field map (b) given to every observer, to be filled in once per survey and square.
Feldblatt (a) und Feldkarte (b), die den Beobachterinnen und Beobachtern ausgehändigt wurden. Sie waren einmal pro Erhebung und Quadrat auszufüllen.

Table 1. List of raptor species recorded in the SEGRE project.
Liste der im SEGRE-Projekt erfassten Greifvogelarten.

Species	
European Honey-buzzard	*Pernis apivorus*
Egyptian Vulture	*Neophron percnopterus*
Short-toed Snake-eagle	*Circaetus gallicus*
Griffon Vulture	*Gyps fulvus*
Cinereous Vulture	*Aegypius monachus*
Golden Eagle	*Aquila chrysaetos*
Bonelli's Eagle	*Aquila fasciata*
Booted Eagle	*Hieraaetus pennatus*
Western Marsh-harrier	*Circus aeruginosus*
Montagu's Harrier	*Circus pygargus*
Eurasian Sparrowhawk	*Accipiter nisus*
Northern Goshawk	*Accipiter gentilis*
Red Kite	*Milvus milvus*
Black Kite	*Milvus migrans*
Eurasian Buzzard	*Buteo buteo*
Lesser Kestrel	*Falco naumanni*
Common Kestrel	*Falco tinnunculus*
Eurasian Hobby	*Falco subbuteo*
Peregrine Falcon	*Falco peregrinus*
Common Raven	*Corvus corax*
Carrion Crow	*Corvus corone*

1.2. The grid

The whole region was divided into a grid of 2.5 × 2.5 km squares, from which the surveyed squares (hereafter referred to as plots) were chosen and monitored yearly. In SPAs, the decision on how many plots to survey was based on the budget and previous breeding evidence in the area. For every surveyed plot, an observation point was carefully and purposefully chosen (Fig. 2 and 3). To do so, not only the topography was considered, but also the background type (sky vs. forest), and knowledge of the area was taken into account to maximise the visibility and the chances to detect forest raptors. For each observation point, a visibility analysis was done in QGIS (QGIS Development Team 2019), to estimate the actually surveyed area based on lines of sight from the survey point, and to obtain accurate abundance estimates that refer to a well-defined area.

1.3. Target species

All breeding forest raptors in Catalonia were included in the monitoring scheme: European Honey-buzzard *Pernis apivorus*, Short-toed Snake-eagle *Circaetus gallicus*, Cinereous Vulture *Aegypius monachus*, Booted Eagle *Hieraaetus pennatus*, Eurasian Sparrowhawk *Accipiter nisus*, Northern Goshawk *A. gentilis*, Red Kite *Milvus milvus*, Black Kite *M. migrans*, Eurasian Buzzard *Buteo buteo*, and Eurasian Hobby *Falco subbuteo*. Nevertheless, other non-explicit forest raptors (Table 1) found in Catalonia were also incorporated in case of detection of a breeding pair from the observation points, such as the Common Kestrel *Falco tinnunculus*.

1.4. Study period and field methodology

The methodological principle on which the SEGRE project was based is territory mapping (Bibby et al. 2000), and our project followed the active monitoring protocol from Finland (Saurola 2008), though it was adjusted to fit the regional goals and requirements. The SEGRE project is an annual scheme with four surveys per plot and year to cover the whole breeding season of all target species from March to July: 1 March – 15 April, 15 April – 15 May, 15 May – 15 June, 15 June – 15 July. Successive surveys should be separated by at least 15 days.

Each survey was carried out by one or several observers between 9:00 (about 3 hours after sunrise) and 12:00 (noon), with a duration of 3 hours. As many authors have noted, the behaviour and detection of most species changes in the course of the day (Fuller and Mosher 1981). The observation period was chosen to avoid early morning hours, when most individuals are still perched waiting for the warm thermals to appear. No survey should be carried out in bad weather, as it reduces the activity of raptor species.

Throughout each survey, a field sheet was filled in (Fig. 4a) to characterise the survey conditions, also when no observations were made. Furthermore, all observations, even those made outside of the 2.5 × 2.5 km square, were recorded, and an observation code was used to relate the geolocation of each observation in a field map (Fig. 4b) to the description of the observation in the field sheet. Finally, a breeding code (Table 2) was given to each observation, to define possible, probable, or confirmed breeding territories.

Table 2. Breeding codes.
Verwendete Brutzeitcodes.

Code	Description
Obs.	Species observed in breeding season in possible nesting habitat
Territ.	Territorial behaviour, courtship and display
AdCrits.	Breeding calls heard during the pre-breeding phase
Còpula.	Breeding
ConstNiu.	Nest material transport and/or nest building
AdNiu.	Adults in the nest site
PolNiu.	Nest with young birds seen or heard
Poll.	Fledgelings or young birds calling or seen
AdPres.	Adults carrying food for the young
Migrant.	Migrant or dispersing individual; non-breeding individual

Table 3. Values used to define the final area covered by a home range initially estimated with a minimum convex polygon (mcp). Values defined after a thorough literature research and using expert criteria.
Werte, die zur Festlegung der endgültigen Fläche eines ursprünglich mit einem konvexen Minimalpolygon (mcp) geschätzten Aktionsraums verwendet wurden. Die Werte wurden nach einer gründlichen Literaturrecherche und Expertenkriterien festgelegt.

Species		Max. distance between observations (m)	Buffer size around the mcp (m)	Maximum home range size (km^2)
European Honey-buzzard	*Pernis apivorus*	1000	780	6
Short-toed Snake-eagle	*Circaetus gallicus*	750	780	6
Booted Eagle	*Hieraaetus pennatus*	1000	780	6
Eurasian Sparrowhawk	*Accipiter nisus*	500	320	1
Northern Goshawk	*Accipiter gentilis*	500	380	1.5
Red Kite	*Milvus milvus*	750	550	3
Black Kite	*Milvus migrans*	750	550	3
Eurasian Buzzard	*Buteo buteo*	750	550	3
Common Kestrel	*Falco tinnunculus*	750	640	4
Eurasian Hobby	*Falco subbuteo*	1000	780	6

1.5. Population abundance estimates

The study unit of the SEGRE project was the breeding home range, which is expected to provide an estimate of the species' abundance and population trends over the years. The home range was defined as the area used by a breeding pair and includes areas that are not necessarily defended; thus it was not strictly identical to a territory, which is traditionally understood as the area that is defended (Burt 1943, Maher and Lott 1995). We defined home ranges (hereafter also referred to as territory) as the area where several observations of the same individuals were collected, thus approximating the area used by a breeding pair. The number of territories within a surveyed plot was considered an index of abundance and was used to determine temporal and distribution trends.

The home range was defined as the 100% Minimum Convex Polygon (MCP) resulting from the cluster of observations obtained for each pair (QGIS Development Team 2019). All observations situated closer than a minimum predefined distance (Table 3) were assumed to belong to the same territory. Once the MCP was defined, a buffer of a predefined size (Table 3) was added to the polygon to model the real area used by each breeding pair, because we expect that the real size of the territories cannot be correctly modelled with only four visits per plot. Finally, if the final size of the poly-

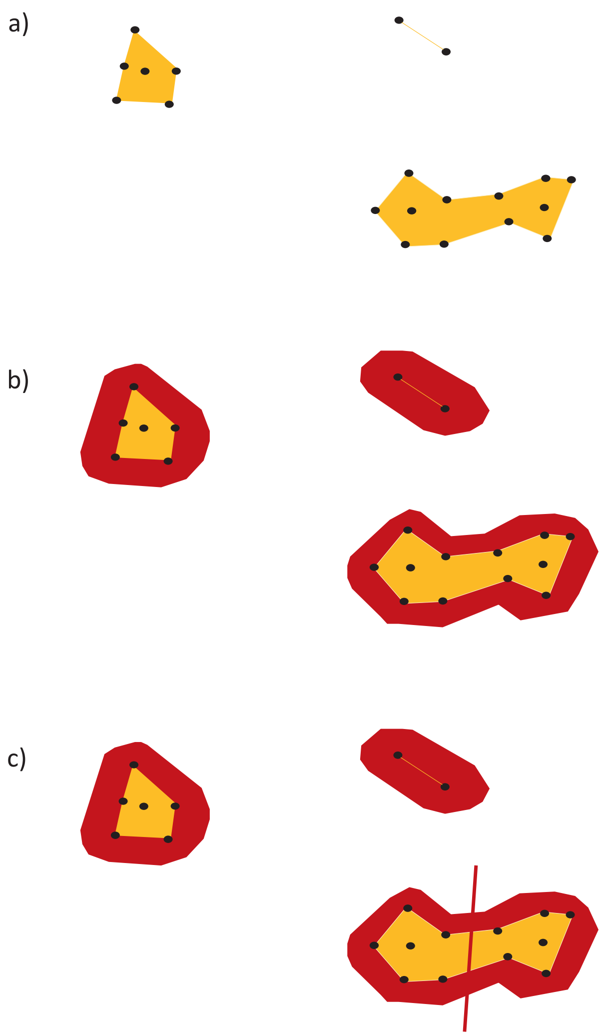

Figure 5. Preliminary home range determination process in QGIS: (a) The minimum convex polygon for each group of observations is calculated; (b) an extra buffer area is added according to a predefined radius for each species; (c) when the home range is bigger than a certain size, it is assumed that two different pairs occupy the area.
Vorläufiger Prozess zur Bestimmung des Verbreitungsgebiets in QGIS: (a) Das minimale konvexe Polygon für jede Gruppe von Beobachtungen wird berechnet; (b) für jede Art wird ein zusätzlicher Pufferbereich mit einem vordefinierten Radius hinzugefügt; (c) wenn das Homerange eine bestimmte Grösse überschreitet, wird angenommen, dass zwei verschiedene Paare das Gebiet besetzen.

gon was bigger than a predefined area (Table 3), it was divided into two different territories (Fig. 5). All predefined sizes were exclusive for each species and were determined according to results from a thorough literature research (e.g., Poirazidis et al. 2011), with a further size correction using expert criteria. Nevertheless, we acknowledge limitations that the current method probably has, and further research to improve the protocol is currently being carried out.

1.6. Statistical analyses

To meet our goal of obtaining long-term population trends, we analysed the data with the R package rtrim (Bogaart et al. 2020). Furthermore, once the geographic distribution of the data allows it, we would like to account for detection probability to establish abundance patterns in protected areas and/or throughout Catalonia. It still needs to be decided which model to use, according to the available data, as there are many possibilities like occupancy models, N-mixture models, or distance sampling. These models not only account for detection probability but can include variables that might drive the results over the surveyed area (e.g., forest cover; Royle 2004, Kéry and Schmidt 2008, Schmidt et al. 2013).

2. Initial results of the project

Over the three initial years from 2019 to 2021, a total of 49 plots in 15 specially protected areas were surveyed (SPA; Fig 1). A total of 3541 field observations were collected for 14 raptor species over these three field seasons. The Eurasian Buzzard was the most common species with 1099 observations, followed by the Short-toed Snake-eagle with 583 observations, and the Eurasian Sparrowhawk with 318 observations. The number of species detected per surveyed plot (2.5 × 2.5 km squares) in 2019 (42 plots), 2020 (41 plots), and 2021 (47 plots) was 2.6 ± 1.6 (mean ± SD), 2.5 ± 1.8, and 2.9 ± 1.8 species (see Table 4 for more details on each target species).

Between 2019 and 2021, a total of 49 plots in 15 SPAs were surveyed. Nevertheless, not every square was surveyed over the four sessions as defined in the protocol, with a range of surveys per plot between one and four. In 2019, six plots reported missing surveys, nine in 2020, and five in 2021. Despite that, the median number of surveys carried out per plot and year was 4, and the mean number of surveys per plot was well above 3 (2019: 3.70 surveys, 2020: 3.56, 2021: 3.81).

In the initial study period of three years, we observed short-term increases in the number of territories detected across SPAs for some species, such as Booted Eagle (+114%), Short-toed Snake-eagle (+47%), and Eurasian Sparrowhawk (+152%; Fig. 6), although this could well be due to start-up effects (Link and Sauer 1999, Sauer et al. 2019).

Table 4. Descriptive statistics on the detection of each forest species between 2019 and 2021.
Deskriptive Statistiken über die Entdeckung der einzelnen Waldarten zwischen 2019 und 2021.

Species		% of squares where the species had a territory	Total number of squares where the species established a territory	Number of years that a territory was detected (mean of all squares ± SD)
European Honey-buzzard	*Pernis apivorus*	0	0	0
Short-toed Snake-eagle	*Circaetus gallicus*	77.6	38	1.6 ± 0.7
Cinereous Vulture	*Aegypius monachus*	0	0	0
Booted Eagle	*Hieraaetus pennatus*	40.8	20	1.6 ± 0.8
Eurasian Sparrowhawk	*Accipiter nisus*	59.2	29	1.7 ± 0.8
Northern Goshawk	*Accipiter gentilis*	65.3	32	1.7 ± 0.8
Red Kite	*Milvus milvus*	4.1	2	2.0 ± 1.4
Black Kite	*Milvus migrans*	6.1	3	1.7 ± 1.2
Eurasian Buzzard	*Buteo buteo*	89.8	44	2.0 ± 0.9
Common Kestrel	*Falco tinnunculus*	42.9	21	1.5 ± 0.7
Eurasian Hobby	*Falco subbuteo*	30.6	15	1.9 ± 0.7

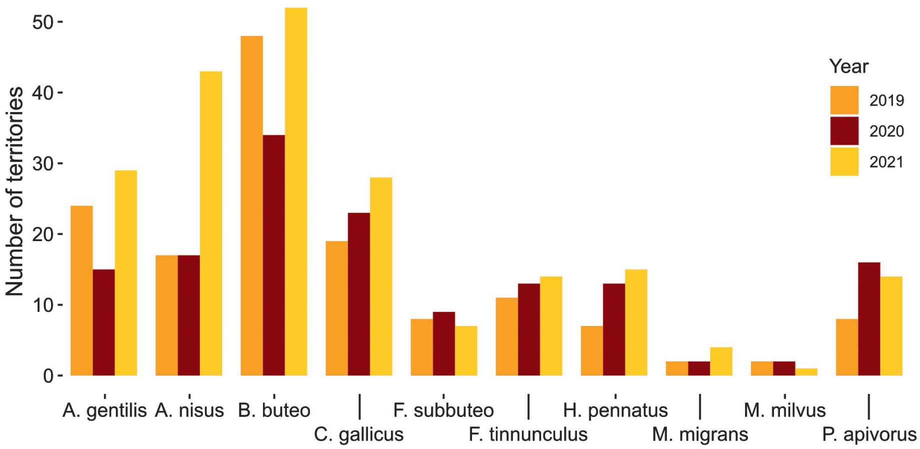

Figure 6. Number of territories per forest raptor species and survey. The number of plots (2.5 × 2.5 km squares) surveyed in 2019, 2020, and 2021 are 42, 41 and 47, respectively.
Anzahl der Reviere pro Waldgreifvogelart und Erhebung. Die Anzahl der in den Jahren 2019, 2020 und 2021 untersuchten Flächen (2,5 × 2,5 km grosse Quadrate) beträgt 42, 41 bzw. 47.

3. Future perspectives

The SEGRE project was designed as a monitoring scheme to survey diurnal forest raptors for obtaining long-term trends and estimating the abundances of species. Although our first results seem to meet our goals, the temporal sequence of the data is of course still far from being long enough to draw clear conclusions on the effectiveness of the project, and especially to obtain meaningful estimates of population trends. However, the SEGRE project seems to be an accurate method to survey the same territories yearly, at least for the ten forest raptors and some other non-strict forest species.

Nonetheless, several caveats should be considered as follows. The first year, 2019, was planned as a pilot year, and as such, some methodological adjustments were made in the following seasons that should be considered when analysing the results further. In 2019, the surveys lasted 3 hours and were between 8:00 and 13:00. After an analysis of the detectability of species over different time periods, the survey time was restricted to 9:00 to 12:00, to better fit the behaviour of the species (Fuller and Mosher 1981), which led to slight inconsistencies in the survey methods over the three years. Also, the effect of missing surveys on the detection probability of certain species should be evaluated. In 2019 and 2020, missing surveys might especially affect the detection of early-breeding raptors, which, for example, could explain the increase in the number of territories detected in 2021 for the Eurasian Sparrowhawk.

Further, we plan to further study the maximum home range size assumed for each species for our study area and to contrast the results with the existing literature, to estimate the sizes of territories as accurately as possible. For example, we believe that the increase in the number of territories detected for the Booted Eagle could partly be due to a real increase in the number of pairs present in the area (which would be consistent with the overall trend for that species in Catalonia; see Franch et al. 2021), but the increase might also partly be the result of the method to estimate home range sizes up to 2021 that might not be accurate enough for our study area. Until 2021, we assumed that the real home range size for the Booted Eagle is 6 km^2, but several studies conducted on the Iberian Peninsula using 100% minimum convex polygons in fact estimated that the real home range size could be larger than 28 km^2 (Díaz-Ruiz and Cebollada-Baratas 2011, López-López et al. 2016). Another improvement would be to include simultaneous observations with confirmed breeding territories into the home range classification. Finally, more appropriate statistical analysis techniques to obtain long-term trends should be used to account for the continuous increase in sampling effort over the years, as well as for the possible increase in raptor detection probability of the observers. To avoid biases, the preferential sampling in specially protected areas should also be accounted for in the analyses. Failing to do so could reduce the reliability of the obtained estimates of abundance (Conn et al. 2017).

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Zusammenfassung

Peris-Morente E, Anton M, Burgas D, Herrando S (2022) Ein neues Projekt zur Überwachung von Waldgreifvögeln in Katalonien. Ornithologischer Beobachter 119: 390–399.

Greifvögel ziehen seit geraumer Zeit grosses Interesse auf sich, da die Populationen in Europa im Laufe des 20. Jahrhunderts stark zurückgingen. Im Mittelmeerraum wurden die Waldgreifvogelarten jedoch bisher oft nur unzureichend überwacht. Das Fehlen einer standardisierten Überwachungsmethode für diese Artengruppe wirft Probleme bei offiziellen Mitteilungen über den Zustand der Populationen auf, z.B. bei der Berichterstattung nach Artikel 12 der Vogelschutzrichtlinie und bei der Berichterstattung über den Zustand der Arten in Natura-2000-Gebieten durch die EU-Mitgliedstaaten. In Katalonien (Nordostspanien) wurden die Daten bei Waldgreifvögeln – anders als bei den seltenen felsenbrütenden Greifvögeln – mit einer Vielzahl unterschiedlicher Methoden erhoben und bis heute meist nicht zusammengeführt. Nach einer Reihe von Diskussionsrunden wurde 2019 ein neues standardisiertes Langzeitmonitoring – das SEGRE-Projekt (Greifvogelmonitoring in besonders geschützten Gebieten, auf Katalanisch: SEguiment General de Rapinyaires en Espais naturals protegits) – ins Leben gerufen, das auf den bisherigen Erfahrungen sowohl in Katalonien als auch in anderen europäischen Ländern basiert. Das SEGRE-Projekt koordiniert die Sammlung präziser Informationen über Brutgebiete von Greifvögeln in Schutzgebieten. Zu den Zielen von SEGRE gehört, genaue Informationen über den Status und die Trends von Waldgreifvögeln zur Verfügung zu stellen. Diese bilden die Grundlage für die Bewertung der Auswirkungen des Managements, insbesondere innerhalb der einzelnen Schutzgebiete. Das Protokoll besteht aus vier dreistündigen morgendlichen Erhebungen von einem festen Aussichtspunkt mit guter Sicht innerhalb eines quadratischen Referenzrasters von 2,5 × 2,5 km. Die Besuche decken die gesamte Brutsaison einer Zielart zwischen März und Juli ab. Jede Greifvogelbeobachtung wird zusammen mit einem Verhaltenscode, der die Bestimmung des Brutstatus erleichtert, geografisch verortet, um eine Kartierung der Reviere zu ermöglichen. Die ersten Ergebnisse des Projekts nach der dreijährigen Pilotphase in 12 Schutzgebieten sind vielversprechend, da durch das Projekt die Menge und die Standardisierung der Daten für diese Artengruppe erheblich gesteigert werden konnten.

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