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Research Article

Surveying wolves without snow: a critical review of the methods used in Spain

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Abstract

Wolves (*Canis lupus*) are difficult to survey, and in most countries, snow is used for identifying the species, counting individuals, recording movements and determining social position. However, in the Iberian peninsula and other southern regions of its gobal range, snow is very scarce in winter, so wolves must be surveyed without snow. In Spain and Portugal, wolves are surveyed through estimating number of wolf packs in summer by means of locating litters of pups when they are at rendezvous sites. Packs are confirmed when pups are observed or respond to simulated howling. We make a critical review of this method, exploring the sources of error when estimating number of packs, the constraints of the simulated howling method, the sources of uncertainty caused by variations in effort, in observer experience and in other variables. We stress the difficulty of assessing average pack size and percentage of wolves not included in packs (pairs and solitary wolves), which can exceed 30% of the population. These restrictions make this method unaccurate and unable to detect moderate or even large population size variations. At the same time, indices based on abundance of wolf tracks and scats is hampered by the lack of snow and the problem to distinguish them from those of dogs. We conclude that accepting the limitations of these wolf surveys and highlighting the uncertainty of the figures they provide is more realistic and will encourage a more prudent approach to wolf management.

When faced with uncertainty about a species, the first question administrators and the public ask is "How many are there?". This appears to be an entirely reasonable inquiry, but is usually the wrong question. The crucial questions are: "Is the population increasing or decreasing?" and "Which parameters are responsible for the observed trend?" (Eberhardt and Knight, 1996). How many grizzlies in Yellowstone?

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Introduction

Many bird species, like storks and vultures, are conspicuous, breed in very visible nests and are easy to count. In recent decades, reasonable complete censuses of these species have been carried out, and results including number of breeding pairs, its annual change and other informative data such as productivity are regularly published (Birdlife International, 2004). Because of this, many managers and the public think that wolves (*Canis lupus*) can be monitored in the same way. Nevertheless, wolves, as other large carnivores, are elusive, mainly nocturnal, wonder over long distances, and live at low densities. As Linnell et al. (1998) have stated, "estimating the density, and monitoring

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the trend, of large carnivore populations is not easy – in fact, it must be one of the most difficult tasks that a wildlife biologist or manager can undertake!".

In addition, snow seems to be crutial for surveying wolves. Except when surveys are based mainly on genetic methods, almost all wolf estimates are based on estimating the number of reproductive units (i.e. wolf packs). In North America, the most common method to estimate wolf populations during the last 30 years has combined estimates of occupied range, average territory, and winter pack size as computed by ongoing telemetry studies, with estimates of interstitial spaces between packs and the percentage of lone wolves in the population. Estimates of occupied range and pack size are carried out in winter when snow is present, since the snow tends to unify members of the pack (Fuller, 1991), and allows researchers to track and count them from aircrafts, especially when there is at least one radio-collared wolf in a pack (Fuller et al., 1992; Mech, 1986; Wydeven et al., 2009).

In Europe, in recent years, similar methods also have been used. For example, in Scandinavia, the area where research and monitoring on wolves has reached the highest level in Europe, a combination of snow tracking and faecal genotyping has been used to establish number of packs, pairs, and solitary wolves (Wabakken et al., 2001). Over the last decade, data provided by radio-collared wolves have added more information on wolf territory, group size, and reproductive success. These parameters are estimated from combined data of 1) pre- and post- reproduction intensive monitoring in snow, 2) movement patterns of adult GPS-collared wolves during the parturition period, 3) summer field-work by trained research personnel and 4) data on age-specific dispersal (Sand et al., 2008). In Poland, wolf numbers have been estimated with data from winter snow tracking collected by services of the state forests and national parks (Jedrzejewski et al., 2002). In the Alps, a mixture of snow tracking and genetic analysis has been used for the annual monitoring of its population (Marucco et al. 2009; Marucco et al. 2012, this issue).

In all these countries, snow is crucial to estimate wolf populations. As has been stated by Wabakken et al. (2001) in Scandinavia, "snow was a pre-requisite for identifying species, counting individuals, recording movements and delimiting territories, determination of sex, and determining social position (i.e., distinguishing scent-marking residents from solitary non-residents)". Even in the small Italian Alpine population, where wolf surveys are mainly based on faecal genotyping, snow is needed to track wolves and collect their scats (Lucchini et al., 2002; Marucco et al., 2009).

Nevertheless, in the southern parts of the global wolf range, snow is absent during winter, thus making the population estimates more difficult. In Spain and Portugal, number of wolf packs are estimated in summer by means of locating the litters of pups when they are at rendezvous sites (Blanco et al., 1992; Llaneza et al., 2005; Pimenta et al., 2005). The objective of this review is to make a critical description of the methods used to survey wolves in Spain, where snow is absent in winter from most of the regions. The lessons learned from this review can be helpful to researchers working in the southern regions of the wolf range, where snow is very scarce in winter. This area includes most of southern Europe, a large region in southern Asia, and part of the southern Unites States.

A principal purpose of this review is to discredit the idea that it is possible to obtain accurate wolf numbers using this method. We will explore its sources of error and levels of inaccuracy due to: the difficulty in estimating number of packs, the problems of determining average pack size, and the impossibility of knowing the percentage of wolves living outside packs without undertaking intensive radiotracking. Because of these inaccuracies, this method can fail to detect large variations in number of wolves over time. We emphasize the need to highlight the uncertainty of these wolf surveys, rather than hiding it, is important to carry out wise management of the population.

Spain: a large area to survey in a decentralized country

All the methods to survey wolves must be adapted to the geographic and habitat conditions, to the political and social circumstances of the area and to resource availability (Linnell et al., 1998). In Spain there is a large wolf population (few hundred packs), distributed over more than 100,000 km^2 in different habitats, from relatively well preserved mountain regions to agricultural and densely populated areas. The Spanish population is contiguous with the Portuguese one (around 63 packs: Pimenta et al. 2005), and both form the large Iberian wolf population (Linnell et al., 2007). In most of these wolf areas snow is completely absent in winter; the ground is covered by snow during a few weeks in winter only above 1500 m of the Cantabrian Mountains.

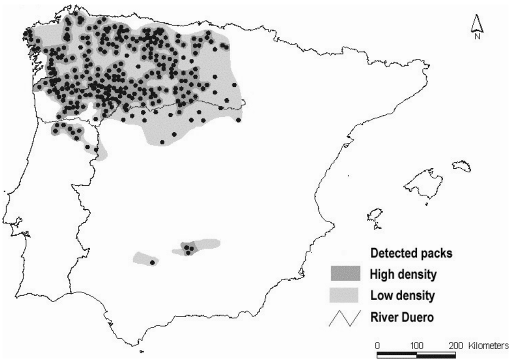

Figure 1 – Detected wolf packs in Spain and Portugal. The figure shows the river Duero. From Álvares et al. 2005.

Spain is a decentralized country, where wildlife management is under the jurisdiction of each autonomous region. The Ministry of Environment has the task of coordinating the autonomous regions; however, its influence has been recently decreasing. There are 17 autonomous regions in Spain, and wolves breed in 8 to 9 of them. The autonomous regions decide if survey the wolf population, the amounts of funds invested, whether to hire scientists for this purpose or use their own staff, the interval between consecutive surveys, etc. Most of the Spanish wolves live north of the river Duero, so they are included in the Annex V of the Habitats Directive and can be hunted with quotas established by the autonomous regions. South of the river Duero the wolves are protected under the Annexes II and IV of the Habitats Directive, and can only be culled under the conditions of article 16 (Fig. 1).

Apart from the first wolf survey carried out in 1987 and 1988 (Blanco et al., 1992), no other national survey has been undertaken. Nowadays, all the surveys are carried out at a regional level. There are big differences in regions characteristics and size (from Castilla y León, 94000 km^2, to La Rioja, 5000 km^2). The wolf population estimate in Spain is the sum of the most recent surveys carried out in every autonomous region.

Methods used for wolf surveys in Spain

The method currently used for wolf surveys has been described and discussed several times in Spain (Blanco, 2008; Blanco and Cortés, 2002; Blanco et al., 1992; Fernández-Gil et al., 2010; Llaneza and Blanco, 2005; Llaneza et al., 2005). The method has two parts: a) collecting and analyzing the known information in published and unpublished reports, and b) field work. The ultimate objective of the field work is to find rendezvous sites and confirm pups presence in summer or early autumn to document wolf packs, assuming that every pack produces just one litter every year.

The field work consists of three main activities: 1) Personal (face-to-face) interviews with shepherds, wardens, hunters, biologists, and naturalists, to obtain local data on wolf presence: number of wolves seen together, evidence of breeding (presence of pups, females with visible nipples, dens), wolves killed, damage to livestock, and other data. The main objective is to detect rendezvous sites or areas of high wolf activity; 2) Transects travelled on foot or by driving along forest roads to detect wolf signs (scats, tracks, scratches, etc.); the assumption is that areas heavily used and marked with scats in late spring and summer can point to possible locations of dens or rendezvous site. Special searches of dens and rendezvous sites are then carried out in areas where many signs have been collected, and with low human activity, dense vegetation and water availability (Ausband et al., 2010). 3) Confirmation of pup presence mainly from August to October during sit-and-wait sessions from vantage points and transects using elicited howling (Fuller and Sampson, 1988; Harrington and Mech, 1982a) to see or hear pups.

Two types of packs are defined: confirmed and probable packs. In the first case presence of pups is confirmed by direct observation, when pups respond to simulated howling or when pup tracks are found in areas of high activity of adult wolves. The packs are generally considered as probable when there is evidence of stable presence of several wolves in summer – sightings, livestock damage, signs, etc. – at least 8

Table 1 – Number of packs detected in the Autonomous Regions of Spain and in Portugal.

Region		Packs detected	Authors	Survey year
Galicia		68	Llaneza et al.[1]	1999-2003
Asturias		36	Llaneza et al.[1]	2004
Cantabria		5	Blanco ans Cortés[1]	1997
Basque Country		1	Arberas[1]	2010
Castilla y León		149	Llaneza and Blanco (2005)	2000-2001
Castilla - La Mancha		1	Blanco[1]	2010
Andalousia		2	Carrasco[1]	2010
Total	Spain	262		
	Portugal	63		

[1] personal communication

km away from the next nearest pack (considering average pack territories of 200 km^2: Cortés 2001), but the presence of pups has not been confirmed.

For example, in the 2000 and 2001 wolf survey in Castilla y León Region (total area: 94000 km^2), 9 biologists carried out the field work during 557 man-days. During this time, 2778 personal interviews with local people were conducted, 7787 km of forest roads were scouted for wolf signs, and 209 sit-and-wait sessions and 879 simulated howling sessions carried out. In addition, data on 11 radio-collared wolves were used. In total, 149 packs were located, 107 of which were considered confirmed and 42 probable over an area of about 75200 km^2 (80% of the region) (Llaneza and Blanco, 2005).

In total, 265 packs have been detected in 8 regions of Spain over an area of 120000 km^2; documented with data collected from 1997 (in Cantabria) to 2010 (in Asturias). In Portugal, 63 packs (51 of them confirmed and 12 probable) were documented over 16000 km^2 in 2003-2004 (Table 1).

Interpreting the survey data and assessment of the reliability of the method

In order to assess if the described method of surveying packs in summer produces plausible results, Blanco et al. (1992) compared the results obtained by different regional teams within Spain, and additionally compared them to those of other authors using different methods. Tellería and Sáez-Royuela (1989) calculated the wolf population in an 8000 km^2 area in Castilla y León by using hunting statistics. They related the number of wolves shot (n = 34) with the number seen (n = 179) during 52 hunting drives. Applying this percentage to the number of wolves shot in drives during one year over their complete study area, they calculated a minimum density of 2 wolves/100 km^2 during the winter hunting season. Blanco et al. (1992) estimated a density for the whole Spanish range of 1.5-2.0 wolves/100 km^2 (1470-2058 wolves in 100000 km^2). Furthermore, Purroy et al. (1988) using the same method as Tellería and Sáez-Royuela (1989) calculated the number of wolves (17.5) in the Riaño Hunting Reserve (715 km^2) in the León mountains during the hunting season. In spite of the small size of their study area, the result (2.44 wolves/100 km^2) agrees with those found by Blanco et al. (1992) for the whole mountain area of León and for the bordering region of the Asturias province. Hence, assuming an homogeneous density of wolves over the area, the agreement of these estimates indicate that the results of these surveys are roughly plausible, but does not give any measure of accuracy and precision. In Portugal, the number of wolves has not been estimated, but the density of packs (Tab. 2) is higher than in Spain, despite a more disturbed habitat. In Minnesota, the density of packs is much higher than those estimated in the Iberian peninsula (Tab. 2), but in Minnesota a pack is defined as a group of >1 wolf, while in Spain and Portugal a pack is defined as a group of wolves with pups (otherwise they cannot be detected by simulated howling). In Spain, the recent estimates focus only on the number of packs, whereas number of wolves has not been estimated. Blanco et al. (1992) estimated 1500-2000 wolves, but some NGOs claim that the figures are much lower. Considering this last es-

Table 2 – Packs and wolf densities estimated in the Iberian peninsula and in Minnesota.

Region/ Year	Packs[1] detected	Area (km^2)	Packs/ 1000 km^2	Number of wolves	Wolves/ 100 km^2	Method	Reference
Spain 1987-88	293	100000	2.9	1500-2000	1.5-2.0	Surveys of packs[2]	Blanco et al. 1992
Spain 2010	262	120000	2.2			Survey of packs[2]	several authors
Portugal 2002-03	63	16000	3.9			Survey of packs[2]	Pimenta et al. 2005
Agricultural area of Castilla y León (Spain) 2001	6	2000	3		3.0	Radiotelemetry	Blanco and Cortés 2002
Bragança (Portugal) 1995	17-20	4900	4			Radiotelemetry and survey of packs	Moreira et al. 1997
Minnesota 1988-89	233	53100	4.4	1521	2.9	Mainly radiotelemetry[2]	Erb and DonCarlos 2009
Minnesota 1997-98	385	73920	5.2	2445	3.4	Mainly radiotelemetry[2]	Erb and DonCarlos 2009
Minnesota 2003-04	485	67852	7.1	3020	4.5	Mainly radiotelemetry[2]	Erb and DonCarlos 2009

[1] In Spain and Portugal, a pack is a group of wolves with pups. In Minnesota, a pack is group with ≥ 2 wolves.
[2] Described in the text.

timate (2000 wolves in 120000 km^2), the average density of wolves in Spain would be 1.6 wolves/100 km^2; this figure is plausible for a large area, is lower than the density estimated by Tellería and Sáez-Royuela (1989) in Castilla y León using a different method (2 wolves/100 km^2), and is lower than that recorded in radio-tracking studies carried out in Spain and in wolf surveys in Minnesota (Tab. 2).

The results produced by the method used in Spain and Portugal seem to be plausible. Wolf densities estimates are similar using different methods in the same area, and fit roughly with densities calculated in areas of similar latitude. Nevertheless, although this method can produce good general information, it has several disadvantages. The level of precision cannot be measured in terms of confidence intervals (CI) around the estimate, and the method has small power to detect moderate changes in the wolf population.

In theory, the estimate of the total number of wolves in an area is given by $[(A \times B) + C]$, where A is the number of packs, B is the average pack size (i.e., the average number of wolves living in each pack) and C is the percentage of wolves living out of the packs (solitary and pairs). This formula to census a wolf population is very simple; however, it is extremely difficult to accurately obtain a value for each variable of the formula and sometimes impossible. In the following sections, we will explore the uncertainties and challenges we face when estimating each of these variables in Spain.

Sources of error in estimating the number of packs

The main source of error is failing to detect some packs, mainly in large study areas where the search effort is low. Hence, this method obviously produces approximate results. In a recovering population where adjacent packs are sometimes many kilometres apart, it is easy to discriminate one pack from the nearest one. But in saturated populations, where the packs are contiguous and share a portion of their home ranges, identifying every packs is an hard task, especially considering that packs are very dynamic and unstable. In Denali National Park (Alaska) where the human influence is almost nonexistent, Meier et al. (1995) and Mech et al. (1998) have demonstrated that packs are constantly changing their territory limits and disintegrating, splitting, and budding. Sometimes packs produce multiple litters, and sometimes wolves have multiple pack affiliation. In our experience, even with several radio-collared wolves in one pack, sometimes it is difficult to assess where a pack finishes and where the next one starts. Hence, in a high wolf density area, it is necessary to include an extensive radio-collaring program to unravel the complex social system of a wolf population.

Constraints of the simulated howling method

The simulated howling technique has been widely described by Harrington and Mech (1982a). Crête and Messier (1987) tested this method in the field for the first time and obtained a reply rate of 3%. They considered that this low rate poses statistical problems of precision and demands high levels of fieldwork and concluded: "We are inclined not to recommend this technique. At best it can provide an index of wolf abundance, but requiring a considerable amount of work and expense".

Fuller and Sampson (1988) made an excellent evaluation of the method in the field. They used 6 contiguous packs with radio-collared wolves in a 1400 km^2 area. The surveys were carried out by the second author, who did not know the wolves' locations. They concluded that the logistical and statistical constraints probably prevent the use of this technique for surveys over large areas, where the aim is to monitor population changes. However, they located 5 of the 6 packs living in the study area, confirming that wolf howling is a good technique to locate wolf packs on a relatively small study area. Other authors have reviewed this method (Ballard et al., 1995; Ciucci and Boitani, 1998, 2000; Kunkel et al., 2005; Linnell et al., 1998), and they agreed that it demands a lot of work when used in large areas, but provided that enough effort and manpower is employed, it can give reasonable minimum pack numbers.

The surveys carried out in Spain produce a percentage of packs which are probable or unconfirmed (i.e. the presence of pups has not been confirmed). While the criteria to consider a pack as confirmed is objective (i.e. documented presence of pups), the criteria to consider a pack as probable have a wide margin of interpretation and subjectivity. In general, the percentage of probable packs is directly proportional to the surface of the study area, and inversely proportional to the effort (person-days/area surveyed). For instance, in 2000-2001 survey of the Castilla y León region (wolf area: 75000 km^2) the effort was low (0.7 person-days/100 km^2, although considering just the best wolf areas, the effort can rise to 1 person-day/100 km^2 or even higher). Nevertheless, in the 2002-2003 survey of Portugal (wolf area: 16000 km^2), the survey effort was 3.5 person-days/100 km^2, 5 times higher than in the Castilla y León survey. This could have influenced the results of pack density: 3.9 and 2.0 packs/1000 km^2 were detected in Portugal and Castilla y León respectively (Llaneza and Blanco, 2005; Pimenta et al., 2005). Therefore, with small rates of search effort (field days/area), the opportunities for confirming all or most of the packs decrease, so it is necessary to be more flexible when applying the criteria to consider probable packs. For instance, in Portugal 81% of the packs were confirmed, whereas is Castilla y León just 72% were confirmed. Nevertheless, when the survey is done in smaller area (e.g. Los Picos de Europa National Park, 750 km^2), the probable packs category is not used; we documented only confirmed packs. Therefore, the major constraint to consider and evaluate is the difference in search effort between areas and years, which is dependent on funds availability.

The observer experience

Searching for the aggregations of wolf tracks and scats that usually reveal the presence of rendezvous sites, and carrying out simulated howling trials at night, demands a lot of experience and motivation. Hence, the experience of the field technicians may influence the results of the surveys. Several studies have tested the influence of personal skills in the results of wildlife surveys. For instance, in the surveys of desert tortoises (*Gopherus agassizii*) in California, which do not demand particular skills, the previous experience of the observer apparently does not affect their ability to find tortoises (Freilich and LaRue, 1998). In contrast, there were large differences in the ability of professional biologists and volunteers to find moufflons (*Ovis* sp.) during a day census in France (Garel et al., 2005). In large mammal surveys, several studies have shown that most of the parameters variation is due to differences among observers capability (Kindberg et al., 2009). In Spain, there is a real case showing the strong influence of the observer skills on the results of a wolf survey. In the Asturias region (with wolves living in a 6000 km^2 area), the number of packs has been surveyed annually or every second year since the late 1980s. In 1995, two survey teams working independently on the same area reported 12 and 17 wolf packs, respectively, showing the big difference of the results collected by people with different skills (Blanco and Cortés, 2002; Llaneza, 1997).

Sources of error in estimating pack sizes

Estimating pack sizes (i.e. the average number of wolves per pack) is a great challenge. Although wolves preying on large ungulates have shown the largest pack size, a few studies consistently show a negative relationship between pack size and food acquisition per wolf, thus rejecting the hypothesis that the reason wolves live in packs is to facilitate their predation on large prey (Schmidt and Mech, 1997). These authors believe that wolves live in packs primarily because adult pairs can then efficiently share with their offspring the surplus of the food available. This study explains why wolves feeding on carcasses can live in packs of ten wolves or more, as happens in the agricultural areas of Spain (Blanco and Cortés, 2002). In the past, we used data from the literature (e.g. Blanco et al. 1992), but nowadays, managers and the public demand more accurate data on average pack size obtained from data collected in the field. However, it is very hard to collect accurate data on pack size because members of packs search for food alone or in small groups, and it is very unusual to observe all or most of the pack members together (Mech and Boitani, 2003). The main factors assembling the members of the pack are snow and large prey species in winter (Fuller, 1991), and the presence of pups during summer around dens and rendezvous sites (Ausband et al., 2010). However, in Spain, because of the lack of snow, wolves in winter travel alone or in small groups, just like in summer.

Estimating pack size in summer

In Spain, Barrientos (2000) estimated the minimum pack size in summer by watching uncollared wolves at rendezvous sites in agricultural areas of the Castilla y León region, where wolves mainly fed on carrion (Cortés, 2001). Barrientos (2000) observed 26 packs with an average of 4.73 pups and 3.58 subadult/adult wolves. The main factor affecting pack size estimation was the number of times the packs were observed, suggesting that observations produced incomplete counts. In packs observed three or more times (n = 15), 5.47 pups (range 3-10) and 3.86 >1 year old wolves (range 3-6) were counted, for a total of 9.33 pack members. In packs observed once or twice (n = 11), just 3.73 pups (range: 3-8) and 3.18 >1 year old wolves (range 2-4) were detected, for a total of 6.91 pack members.

The restrictions posed by dense vegetation, the mainly nocturnal activity of wolves living in disturbed areas (Vilà et al., 1995), and the characteristics of the rendezvous site attendance patterns by wolves make it difficult to count all wolves in the pack together. Rendezvous site attendance is very variable and unpredictable, as has been documented by several authors (Ballard et al., 1991; Demma and Mech, 2009; Harrington and Mech, 1982b; Jedrzejewski et al., 2001; Potvin et al., 2004). For this reason, the available pack size estimations in summer must be considered as minimum numbers.

Estimating pack size in winter

In much of the wolf distribution area, wolf numbers are estimated in winter because the snow cover allows to follow wolf tracks during high levels of pack cohesion (Marucco et al. 2012, this volume). In addition, the wolf population size in winter, when many pups have died, is lower than in late spring or summer, just after the births. In North America, winter time, when all or many of the pack members travel and hunt together, facilitate the location and counting of wolves from aircraft if there is a radio-collared wolf in the pack (Fuller et al., 1992; Mech, 1986). Fuller (1991) gave some quantitative details on the effects of the snow depth on wolf activity and prey selection in Minnesota. When the mean weekly snow depth in Grand Rapids was 22 cm, just 49% of the radio-marked pack members were located together; when the snow depth increased to 44 cm, 81% of the radio-collared wolves in the same pack were together. Fuller (1991) stated that when hunting becomes more difficult due to shallow snow, pack cohesion may also be reduced. Wolves usually hunt alone or in smaller groups in summer when prey are dispersed, but increase pack cohesion in winter as prey concentrate in wintering areas and snow depth increases. When snow is shallow and deer are more dispersed, wolves spend less time hunting together and revert to more summer-like hunting behaviour. Hunting in smaller groups, even alone (Mech 1970, p. 227), may increase overall encounter and capture rates of deer and thus increase mean per capita food acquisition. However, deep snow probably encourages individuals to travel together, follow in the tracks of others, and reduce energetic demands.

Conditions of deep snow and concentration of ungulates in winter ranges rarely happen in Spain. One of the main issues about the size of the wolf population in Spain is with the estimation of winter pack size. Barrientos and Fernández (2002) stated that the average group size (the number of wolves travelling together) observed in winter in agricultural areas was 3.78, and the average group in the Cantabrian Mountains (deduced from snow-tracking) was 3.60 wolves. Some authors have claimed that all pack members travel and hunt together in winter in Spain, even with no snow at all. Consequently, they assumed that the size of the groups seen travelling together correspond to the pack size, so the total number of wolves in winter can be calculated by multiplying the number of packs by 3.60-3.78. Therefore, the total population in Spain would be 937-1188 wolves (Echegaray et al., 2008). This wrong assumption can produce a huge underestimation of the wolf population size (Blanco, 2008).

Llaneza et al. (2009) applied the snow-tracking method to determine winter pack size, and showed that the members of the packs split in groups to travel and hunt even in winter. During winter 2006-2007, they carried out 9 simultaneous transects on snow to estimate pack size for two packs in Los Ancares natural park (Cantabrian Mountains in the Galicia region). In December 2006, the 11-12 wolves of the first pack divided into three groups of 4, 2-3 and 5 wolves; the 7 members of the second pack were divided in groups of 4, 1 and 2 wolves. In March 2007, the first pack of 11 wolves was divided in two groups of 2 and 9 wolves; the second pack of 5 wolves, in two groups of 2 and 3 wolves. Interestingly, the average size of the wolf groups which were travelling together was 3.7, but the average winter pack size (the mean of December and March) was 8.6 wolves. Unfortunately, these more accurate estimates are carried out high wolf density areas, and cannot be extrapolated to the rest of the wolf range.

Natural and human-induced variation in pack size

One of the problems in obtaining pack size estimates over the years is that wolf packs are changing over time, both in pack and territory sizes. Even in protected wolf populations, pack size can change every year. For instance, the same pack in the High Arctic studied during 8 years by Mech (1995, 1997) had 7, 7, 4, 8, 3, 3, 2 and 5 adult/subadult wolves from 1986 to 1993. Another pack monitored for 8 years in Minnesota had 2, 6, 2, 7, 6, 6, 11 and 6 wolves in winter from 1973 to 1981 (Mech and Hertel, 1983). Considering a larger sample, in Denali National Park (Alaska), the average pack size of 30 packs monitored during 9 years changed from 4.3 to 13.3 wolves/pack as a consequence of the variation of the prey vulnerability due to changes in winter severity (Mech et al. 1998, p.

41). In these three cases, there was no human-caused mortality.

In most wolf surveys carried out in Spain, we assume that if the number of packs remains stable, then the total wolf population remains stable too. But the variation in wolf number does not always correspond in a variation in number of packs. For example, in Denali National Park over a 4 year period with a natural increase in food availability, the wolf numbers increased by 2.5x, but the number of packs only increased by 1.7x and the pack size increased by 1.5x (Mech et al., 1998). In Yukon, after severe culling, the wolf numbers were reduced to 52% (from 124 wolves in 1985 to 65 in 1986), but the number of packs remained stable (18 packs) and the pack size decreased from 6.9 to 3.6 wolves per pack. In the recovery process, between 1986 and 1988, the wolf numbers almost doubled (from 65 to 112 wolves) but the number of packs increased just 10% (from 18 to 20) (Hayes and Harestad, 2000; Hayes et al., 1991). These examples show that the average pack size can suffer large variations as a consequence of changes in food availability, hunting pressure, because of the natural increase of recently established populations, or the recovery of the population after heavy human-caused mortality. These changes may be very difficult to detect using the techniques described above adopted in Spain.

Sources of error in estimating wolves not included in packs

In addition to the wolves living in packs, an important percentage of the population can live in pairs or be solitary (i.e. dispersers or peripheral wolves). These loners can be considered a buffer for the population, making it less vulnerable to exploitation as they are adult individuals that can quickly replace breeders when they die (Fuller et al., 2003). In addition, loners are undetectable without intensive radiotracking, and they form a shadow part of the population (Rohner, 1997), which is almost impossible to estimate using the population surveys adopted in Spain and Portugal.

Fuller et al. (2003), in an extensive review, concluded that the average percentage of loners in North American studies was 12% (range: 7–20%). But in agricultural habitats of the Castilla y León region in Spain, during an intensive study carried out mainly with radiotracking, we documented higher percentages. In total, we found that the 14 wolves radio-collared during 40.6 wolf-years spent 28% of the radio-days living out of the packs, alone or in pairs (Blanco and Cortés, 2007). The three wolves radio-collared in the low wolf density study area, south of the river Duero, were documented as loners (dispersers plus peripheral wolves) for 1.6% of the observations (13.3 wolf-years monitoring), and the rest of the time as territorial wolves living in packs or in pairs. In contrast, the 11 wolves radio-collared in the apparently saturated population north of the Duero were documented as loners during 33.5% of the observations (27.3 wolf-years monitoring). The reasons for the high percentage of loners north of the river Duero likely are the semi-permeable river Duero barrier, which can limit the dispersal (Blanco et al., 2005), the presence of food surplus provided by livestock carrion, which delays dispersal, and the poor vegetation cover, which may limit breeding possibilities and formation of new packs
(Blanco and Cortés, 2007).

Other survey methods and indices to monitor population trends in Spain

In addition to the method described in this article, other survey and monitoring methods have been used or can be used in Spain to assess wolf numbers, but all of them have severe logistical or economic constraints. In the 80's, the absolute density of wolves was estimated in some Spanish areas using hunting statistics (Tellería and Sáez-Royuela, 1986, 1989). But the establishment of hunting quotas made this method unsuitable. Genetic analyses on faeces has been used just once in Spain, in the Basque Country, to identify the minimum number of individuals (n = 16) in a small area between the Burgos and Álava provinces (Echegaray and Vilà, 2010). The primary disadvantages of genetic sampling over larger areas are: (1) the high cost,

(2) the significant field effort needed, and (3) the presence of genotyping errors that require expensive methods to be reduced (Kunkel et al., 2005; Marucco et al., 2011). The cost of DNA analyses applied over the whole Spanish range is the limiting constraint and further research is needed to assess sampling designs and optimization of the method. Accurate estimates of population size based on CMR genetic methods have high standards in sampling design, which increase the field work required. This technique has only been tested over relatively small areas, mainly in the Alps (Lucchini et al. 2002; Marucco et al. 2009; Marucco et al. 2012, this volume), where scats have been collected in winter by snow-tracking wolves. The lack of snow in most of the Iberian wolf range increases the problems of proper sample collection. Lucchini et al. (2002) recommended that scats be collected in winter so the samples are better preserved for analysis. In addition, scats collected in summer, primarily from roads and trails, were largely only from dominant pack members. Marucco et al. (2009, 2011), who collected wolf scats in the Italian Alps in winter following their tracks in the snow, estimated that they would have missed 27.7% of young wolves if they had simply sampled on roads or human trails, and highlight the requirements of this technique to avoid errors. Echegaray and Vilà (2010), working in the north-eastern border of the Spanish wolf range, could not estimate the wolf population size because their scat sampling method did not accomplish the requirements of the rarefaction curves.

The use of indirect indices can help to monitor wolf populations, especially when wolf numbers are unknown. However, the statistics of attacks on livestock can be misleading, since wolf damage directly depends on habitat characteristics and livestock management (Blanco et al., 1992; Swenson and Andrén, 2005). Hunting statistics are not applicable because of the hunting quotas, which depend on political criteria. Kunkel et al. (2005), in estimating the annual wolf population trend in Idaho, recommended using a combination of 3 different index methods to detect a 30-40% population change with 80% power at the 90% CI level: (1) hunter questionnaire, (2) winter track survey, and (3) summer scat survey. However, the inability to verify authenticity of reports and resulting unknown bias precludes the use of hunter surveys as a primary method (Kunkel et al., 2005). In Spain and Portugal, methods 2 and 3 are impracticable because of the lack of snow and the abundance of free-ranging dogs, which makes the recognition of wolf scats difficult. For instance, Echegaray and Vilà (2010), in the Basque Country, collected faeces preliminarily identified as belonging to wolves, but the subsequent genetic analyses showed that, of 86 scats, just 31 actually corresponded to wolf (53 corresponded to dog and 2 to red fox, *Vulpes vulpes*).

Crête and Messier (1987), after assessing indices of wolf density in Quebec, concluded that "there is no inexpensive way to evaluate the absolute wolf density over large forested areas". We come to the same conclusion, but in Spain the lack of snow makes things worse. In the same way, Boitani and Ciucci (1993), after reviewing the wolf population estimates in Italy have concluded: "The current estimates and those published in the past must be interpreted as orders of magnitude of the populations and their trends, rather than as figures able to support statistical comparisons". The monitoring of the area occupied by wolves seems to be the easiest indicator of the population trend. An increase or decrease of the range usually reflects the increase or decrease of the population. Nevertheless, the population can suffer important variations, while distribution area remains stable. In addition, an assessment of the combination of several indices, such as livestock attack statistics, records of dead wolves, pack surveys in selected areas (mainly on the borders of the wolf range), may give an insight into wolf population trends. All the ecological and demographic data that can be collected in simultaneously carried on intensive radio-tracking studies, can be helpful to interpret the information produced by the surveys.

Accepting uncertainty and the impossibility to detect small variations

Using the methods described above in Spain and Portugal, and given the scarce information available on pack size and solitary wolves and pairs in different regions and under different circumstances, it is not possible to obtain an accurate figure of wolf numbers. In addition, accurate knowledge on the number of packs is very difficult, and is perhaps restricted to limited areas (national parks or provinces with a few wolf packs), where it is possible to apply a high search effort and obtain detailed knowledge of the area. The results of these surveys are likely more inaccurate as the area's size, and hence the wolf population, increase. The wolf pack surveys are probably far more accurate in areas with expanding (low density) wolf populations in the borders of the wolf range, where packs are apparently well separated; estimates are more difficult in saturated areas where the radiotracking studies have shown a large overlap among pack home ranges (Authors, unpublished data), and the presence of floaters and pairs settled in the interstices of packs' territories in some cases obscure the pack delimitation. Therefore, at low wolf population levels (for instance, the Sierra Morena population or the Portuguese segment south of the river Duero) monitoring techniques will need to intensify. Methods should be used that provide greater precision and higher levels of resolution needed to detect small and immediate changes in population status to avoid population extinction. At higher population levels (the large north-western Iberian population), monitoring precision and resolution can be relaxed as larger long-term trends or changes in population levels are of more interest (Kunkel et al., 2005).

Even if the number of packs does not change, the variation in the pack size and in the percentage of floaters can have a huge influence on the total number of wolves (Blanco and Cortés, 2007). Nevertheless, in order to detect these parameters without snow, intensive ecological studies with radiotracking and/or genetic analyses are needed, and these kinds of studies are very scarce in Spain. When wolves are hunted (as is the case in much of Spain north of the river Duero) the impact of the wolf removal is very different in populations with large packs and a lot of floaters ready to replace the missing pack members, than in populations with small packs and a lack of adult solitary wolves. Using the method described in this paper for Spain, it is very difficult to assess wolf population changes derived from changes in food resources or an increase of wolf hunting. For instance, after the outbreak of the Bovine Spongiform Encephalopathy (BSE) in Spain in the year 2000, the carrion pits have been gradually removed from the field. In addition, the laws banning leaving livestock carcasses in the field, that were traditionally ignored, are now strictly enforced. Nowadays, the dead livestock is officially collected and burned both from the small and the big farms, and hence, the availability of livestock carrion in the field has apparently dropped in agricultural and semi-natural areas. These livestock carcasses abandoned in the field represented a huge amount of biomass available to wolves (Tellería and Sáez-Royuela, 1989), and were a staple food for wolves in agricultural areas, forming 75% of their diet biomass before BSE (Cortés, 2001).

In theory, this food decrease can change the population parameters resulting in fewer loners, smaller pack sizes and a general reduction in the wolf population (Blanco and Cortés, 2007). Since we have not updated surveys in much of the Spanish wolf range (the last survey in Castilla y León region, which holds more than 50% of the Spanish wolf population, was carried out in 2000 and 2001) and because of the low power of the survey method described above to detect small or moderate variations in wolf numbers, there are no data on wolf trends. Nevertheless, for the first time in 40 years, a small but clear reduction of the wolf distribution has been recorded, as has been shown in the Atlas of the Spanish Mammals published by the Mammal Society (SECEM) in 2003 and 2007 (Blanco et al., 2002, 2007). The distribution area reduction is compatible with the theoretical population changes predicted, but so far it has been impossible to obtain robust data on pack size and the percentages of loners and pairs to confirm our hypothesis, because of the political constraints on wolf research in some parts of Spain.

As happens with other surveys of large carnivores, there is a degree of uncertainty surrounding surveys in Spain and Portugal. Uncertainty, in this context should not be confused with ignorance. As Garshelis (2002) has stated in relation to the situation of several bear species, "in the interest of both science and conservation, biologists should emphasize the uncertainties of population assessments and thus the necessity of more rigorous research". Nevertheless, to acknowledge this uncertainty can be difficult from a political perspective, because, "in most human societies, knowledge empowers, whereas uncertainty signifies fallibility, timidity and weakness". In addition, managers and public are used to have more accurate figures of bird censuses and do not accept the uncertainties surrounding the wolf surveys. We think that accepting the limitations of the wolf surveys and highlighting the uncertainty of the produced estimates is more realistic and will encourage a more prudent approach to wolf management.

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