



European lagomorphs

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Last update

17.12.2015

Brief description of the species/group of species: basic ecology and its relevance from an epidemiological perspective

Three main genuses in Europe: the genus Lepus with six species in Europe (*L. castroviejoi, L. granatensis, L. europaeus, L. corsicanus, L. timidus* and *L. capensis*), the genus Oryctolagus with only one (*O. cuniculus*) and the genus *Sylvilagus* (allochtonous, introduced in 1966) with one species (*S. floridanus*). They are keystone species as prey for a number of predators (Delibes-Mateos et al. 2007; see also Lees and Bell 2008). As game species, they are managed in most of their ranges and due to their high socio-ecological relevance they are included in monitoring programs (e.g. Gortázar et al. 2007; Delibes-Mateos et al. 2008a). From an epidemiological perspective, rabbits and hares are important regarding zoonotic viral infections such as Hepatitis E and Crimean-Congo Haemorrhagic Disease, and regarding Calicivirus diseases that can have huge effects on lagomorph populations (Rabbit Haemorrhagic Disease, RHD; and European Brown Hare Syndrome, EBHS). Myxomatosis is still an important factor limiting rabbit populations. Hares are also relevant as victims or indicators of bacterial infections including Francisella tularensis and Yersinia preudotuberculosis, among others. Lagomorph host a large number of nematodes and cestodes parasites, some of them can have huge effects on host fitness and population dynamic (e.g., Tizzani et al. 2011)

Recommended method(s) for most accurate population estimation

The gold standard method to estimate lagomorph population density is the line transect and the application of Distance Sampling procedure (see Thomas et al. 2010). It was successfully applied on hares and rabbits in both Mediterranean and Atlantic environments (e.g. Langbein et al. 1999; Barrio et al. 2010b). A key characteristic working with this group of species is that the activity patterns of the target population should be determined prior to the counts in order to synchronize surveys with the hours of maximum activity of the population (Barrio et al. 2010b; Fernández-de-Simón et al. 2011).

Mini-review of methods applied in Europe

General reviews

Several methods have been used to estimate population abundance of hares and rabbits in different environments. To the best of our knowledge, a complete review of the methods used with lagomorphs to estimate the population abundance does not exist. The study by Langbein et al. (1999) that is focused on the European brown hare (*L. europaeus*), can be considered as a general guide for this group of species since direct and indirect methods able to be applied on *L. europaeus* populations are likely also suitable for other hare species, too; and also – to a lower extent – for rabbits.

Direct methods (i.e. based on the direct observation of animals)

As previously stated, as a general rule the direct methods require of the previous determination of the activity pattern in the target population, which is mainly relevant working on rabbits since they remain undetectable during most of their inactivity period; inactive hares, in contrast, could be surveyed by direct methods (see Langbein et al. 1999). Indices of both population abundance (e.g. kilometric abundance index-KAI; Gortázar et al. 2007; Williams et al. 2007) and density (Barrio et al. 2010b; Strauß et al. 2008; Parrot et al. 2012) can be easily obtained. At this respect, working with wild rabbit Barrio et al. (2010b) compared the performance of KAI and distance sampling at two times of day

(dusk and night) and concluded that KAI and distance sampling abundance indices are highly correlated and that night counts provided better and more precise estimates than did dusk counts (see also Fernández-de-Simón et al. 2011). Other direct methods used to estimate densities are based on live trapping, mostly by means of capture–recapture (e.g. Marchandeau et al. 2006; but see Bisi et al. 2011), the minimum number of individuals known to be alive (Wood 1988), and the road casualty indices (George et al. 2011).

Indirect methods (i.e. based on the detection of presence signs, but not animals)

When due to the sampling requirements/limitations direct methods cannot be used, indirect methods are the alternative. In relation to indirect methods, even stronger controversies emerge as compared to direct methods. Dung pellet counts are accepted to estimate hare and rabbit abundance (Langbein et al. 1999) – particularly plots (Fernández-de-Simón et al. 2011; Perry and Robertson 2012). However, rabbit latrine counts are not always indicative of population abundance, which is likely related to their role in the social communication of the species. Nevertheless, latrine counts are sometimes successfully used at large spatial scales (e.g. Calvete et al. 2004). Counts of warrens are widely used (Palomares et al. 2001; Price and Rachlow 2011) and other signs, such as scrapes and tracks, are rarely used to obtain indices of abundance (but see Twigg et al. 2001).

APHAEA protocol (for harmonization at large scale)

Line transects, possibly using Distance Sampling analytical framework if the number of detected individuals allows it, are the proposed protocol for population monitoring of European lagomorphs. If the number of individuals detected is below 20 per locality, a kilometric index of abundance can still be calculated, and might allow good comparisons in time and rough (categoric) comparisons between sites.

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Tables

Characteristic	Observations
Distribution	Wide distribution in Europe, present in almost all countries (Mitchell-Jones et al. 1999). Three species are endemic to Europe: <i>L. castroviejoi</i> , <i>L. granatensis</i> and <i>L. corsicanus</i> .
Population trends	No general trend exists for this group of species. Iberian hare (<i>L. granatensis</i>), for example, is increasing in range in some areas (Gortázar et al. 2007), whereas <i>L. timidus</i> declines in most of its range (Thulin 2003). Although most rabbit populations are still declining in the Iberian Peninsula due to habitat loss and the arrival of myxomatosis and RHD, a few seem to have recovered (e.g. Delibes-Mateos et al. 2008a). Rabbits are locally considered as pests in places where they cause crop damage (Barrio et al. 2010a; see also Lees and Bell 2008). <i>S. floridanus</i> is present in Italy with naturalized population that are increasing in number and distribution (Silvano et al. 2000).
Introduction-Releases	Yes, and translocations are usually carried out by both hunters and conservationists (e.g. Angelici et al. 2000; Delibes-Mateos et al. 2008b). Annual rabbit translocations in Spain can reach 500,000 animals, but introduction of <i>S. floridanus</i> is strictly forbidden as allochthonous species.
Activity rhythms	Hares and rabbits are crepuscular-nocturnal but with seasonal changes related to the mating period and anti-predatory strategies (e.g. Villafuerte et al. 1993).
Detectability	High in periods of maximum activity (Barrio et al. 2010b).

Table 1. Peculiarities of the species that modulate the methods to be used.

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Table 2. Classification of the different methods (all cited in this species' review, incl. the recommended method(s) for most accurate results) based on desirable characteristics for monitoring populations from an epidemiological perspective (1- very low, 5-very high).

Method	Distance Sampling	Capture- Recapture	Kilometric abundance index	Pellet counts (plots)	Latrine counts
Abundance / Density	D	D	А	A/D	А
Temporal / Spatial trends	T/S	T/S	Т	T/S	T/S
Info on population structure (Y/N)	Y	Y	Y	Ν	Ν
Precision	5	5	4	4	3
Seasonal independence	2	5	2	4	3
Visibility independence	4	4	2	5	5
Effort effectiveness	3	2	5	5	5
Budget effectiveness	2	1	4	4	4
Ease of learning	3	2	5	5	5
Applicable at large scales	4	2	5	4	5
Useful at very low density	3	3	4	5	4
Useful at very high density	5	5	4	4	3

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