Monitoring and distribution of the lynx *Lynx lynx* in the Swiss Jura Mountains

Simon Capt

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Lynx were reintroduced to the Jura Mountains in the mid-1970s. A first retrospective update of the situation in France and Switzerland was undertaken 10 years later. Since then, real-time collection of occasional observations has been going on in both countries. The monitoring methods have been standardised since the beginning of the 1990s using, among other methods, a network of observers. During 1972-2001, 862 observations were collected in Switzerland and in this paper, these are used to describe the colonisation of the Swiss Jura Mountains and the present distribution of lynx. A comparison with the results of French researchers shows that during the first years of recolonisation, most of the observations were collected in the Swiss part of the Jura Mountains. Today, the French territory has become the core area of the population and includes about ⅔ of the population. The population has recovered after a period of reduced presence at the beginning of the 1990s. The range occupied permanently by lynx in the Swiss Jura Mountains is estimated to be 2,100 km^2, representing a potential population of 17-23 resident individuals. The range occupied permanently by lynx in the Jura Mountains on both sides of the border is estimated to be 7,100 km^2. Depending on the degree of saturation in the population, this represents a potential population of 56-78 resident individuals. Compared to existing habitat suitability models, most of the suitable habitat has already been occupied. In the future more importance will be given to the exchange of information across the international border and the participation of local people in the survey. I recommend that active monitoring using camera-traps be carried out periodically as a supplement to the ongoing passive surveillance system.

Key words: distribution, Jura Mountains, Lynx lynx, monitoring, population size

Simon Capt, KORA, Thunstrasse 31, Muri b. Bern, Switzerland - e-mail: simon.capt@unine.ch*

**Present address: Centre Suisse de Cartographie de la Faune, Terreaux 14, CH-2000 Neuchâtel, Switzerland*

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Mentioned as common in the 16th century, the lynx *Lynx lynx* were eradicated from the Jura Mountains in the 18th and 19th centuries due to direct persecution and human-caused habitat deterioration. For a more detailed description see Breitenmoser et al. 2007). Overviews of the reintroduction of lynx in the Swiss Jura Mountains undertaken in the middle of the 1970s have been published by Breitenmoser & Baettig (1992) and Herrenschmidt & Leger (1987). Authorised releases of a total of four individuals (two males and two females) originating from Slovakia took place in 1974 and 1975 in the Swiss Jura Mountains. Most evidently, other animals were also introduced without authorisation during the same decade, resulting in a maximum founder population of 8-10 individuals (Breitenmoser et al. 1998). As no follow-up study of the released animals was undertaken, there is a lack of information about the development of the lynx population during the initial period after the reintroduction. Nevertheless, a first overview at the end of the 1980s showed the existence of two, more or less separated, nuclei of lynx distribution, a southern one in the French department of Ain and the adjacent Swiss cantons of Vaud and Neuchâtel and a northern one in the Swiss cantons of Bern, Jura and Solothurn (Breitenmoser et al. 1992). Furthermore, no evidence of contact with the adjacent, reintroduced Alpine population was found. This first review revealed the necessity of establishing a long-term surveillance programme for the lynx population in order to document the ongoing development of the lynx population and to allow constant re-evaluation of the status of the population. In 2002, a second overview of the situation of the species in the Swiss Jura mountains was published (Breitenmoser et al. 2002).

To assess the distribution and information about the viability of the reintroduced population, a systematic survey covering the whole potential range of the population, independent of national boundaries, is basically necessary. Preference is given to the term 'surveillance', when speaking about passive monitoring of the lynx population's distribution as described and analysed further in this paper. The term 'monitoring' is reserved for active census methods undertaken in the field. The surveillance contributes to an accurate knowledge of the past and present distribution of the lynx population and may allow a rough estimate of population size and trend, spatial development and identification of potential contact zones between adjacent populations (Capt et al. 1998). Furthermore, this information is needed for the management of the lynx population. In the following sections, a more detailed description of the actual method used is given. I describe the development and the present distribution of the lynx population in the Swiss Jura Mountains. For the discussion, a comparison with some of the results obtained by French researchers and a general estimation of lynx distribution and population size for the entire Jura Mountains is undertaken. In France, a standardised method of collecting information on lynx presence based on a network of observers has been put into practice (Vandel et al. 1994, Vandel 2001) since 1990 using qualification and classification of collected observations comparable to those applied in Switzerland.

Method

Area of investigation

The investigated area comprises the chain of the Jura Mountains, a secondary limestone mountain range, reaching from the Savoie in France in the south to the Black Forest Mountains in Germany in the north. The chain is nearly 400 km long and 70 km wide, covers about 14,000 km^2 and summits at 1,718 m a.s.l. (Blant 2001). Two thirds of the chain is situated on French territory (departments of Ain, Jura, Doubs, Haut-Rhin and Territoire de Belfort) and the other third in Switzerland (cantons of Vaud, Neuchâtel, Jura, Berne, Solothurn, Basel-Landschaft, Aargau and Schaffhausen). For a more detailed description about demographic statistics see Breitenmoser et al. (2007).

Survey of the lynx population distribution in the Swiss Jura Mountains

Information about the presence of lynx was scarce during the first decade after the lynx had been reintroduced in the Alps and the Jura Mountains of Switzerland at the beginning of the 1970s. None of the released lynx were tagged, and no systematic collection of observations took place. Until the beginning of the 1990s, the survey was characterised by the non-standardised collection of occasional observations, first consisting of retrospective updates of past observations, and then on real-time collection of observations. Data covering the period until 1987 was validated and published by Breitenmoser & Baettig (1992). During 1988-1992, post-validation of occasional observations has been undertaken by the researchers engaged in the lynx study in the Swiss Jura Mountains (Breitenmoser et al. 1993). Standardised real-time collection of signs of lynx presence based on a network of collectors of observations and potential observers was established in Switzerland in 1992. Principal elements of this network were the state game wardens, who already played a main role as collectors and providers of occasional lynx observations in the 1980s.

Swiss lynx survey

Today, the basic survey of the lynx populations in Switzerland consists of collecting occasional signs of presence, and an annual inquiry among state game wardens by means of a questionnaire for a more systematic survey. Training courses conducted by zoologists and veterinarians to identify lynx signs, especially kills and tracks, were offered to state game wardens starting from 1989 and repeated every five years. Game wardens play an essential role in the survey by the fact that owners of killed domestic animals need to have the kill examined by a warden to get reimbursed by the state, and that wild animals found hurt or dead have to be reported to them. The trained game wardens, who have participated in at least one national training course, form a stable, reliable and competent network of collectors of observations and potential observers covering most of the Swiss Jura Mountains. The aim of the annual inquiry is to obtain a summary of the number of observations, and the status and trend of the lynx population compiled from an assessment in each individual game warden's district. The absence of signs of presence for a given report year in a district, permitting the separation between 'no observation' and 'no report', has to be reported, too. The assessment made by the game warden is based on his own observations and occasional signs of presence reported to him by any third party, which in most cases represent the majority of the data collected by a game warden throughout a year. Results of this inquiry are presented through annual reports delivered to cantonal and federal authorities.

To survey lynx populations, the following types of observation are taken into account: occasional signs of presence, such as animals found dead, captured or killed, photographs, sightings, findings of tracks, killed prey, scats, hair and vocalisation. In order to evaluate the reliability and validity of the information, observations are classified in three categories: 1) reliable, 2) probable and 3) doubtful. Observations, which cannot be assigned to one of the three categories because of incoherent or missing data, are not entered into the database, but are kept in archives. For an observation to be considered for evaluation, observers need to produce written and signed information about the exact location of the observation, date, hour of the day, general habitat, type of observation, lynx behaviour and duration of the observation in case of sightings, circumstances, full address and if possible names of other observers. Incompletely described observations are entered into category 3. If complete and plausible, unverifiable observations like sightings are classified as reliable, if not plausible in some points as probable and in absence of any plausibility as doubtful. Verifiable signs of presence like kills or tracks need to be validated in the field by the game warden or expert naturalists to be accepted as reliable observations. In the case of incomplete information, these observations are entered into category 2 or category 3 in the absence of any description. Facts like lynx found dead or captured and verified photographs of lynx are automatically considered as reliable observation. Excrements and hairs are only accepted as reliable, if validated by specialists. For the subsequent spatial analyses, only the first two categories, reliable and probable, are considered.

To be in concordance with the criteria for reliability for the SCALP programme (Status and Conservation of the Alpine Lynx Population; Molinari-Jobin et al. 2001), each observation is additionally assigned to one of the three SCALP reliability levels. Lynx found dead or captured and verified photographs enter quality 1 (Q1) level, reliable data on kills and tracks are classified as quality 2 (Q2), all other reliable or probable observations are classified as quality 3 (Q3).

For reasons of practical use and interpretation, the collected data are managed through four separate databases:

1) a database on lynx found dead, killed or captured,
2) a database containing occasional observations,
3) a database on livestock killed by lynx, and
4) a database containing the information about the standardised questionnaires sent annually to state game wardens since 1992.

All databases are centrally managed. Special attention is given to obtaining geographic coordinates for all observation sites for optimal use in a geographic information system (GIS). Results of the survey are made available to game wardens and the interested public through websites maintained by the institutions in charge of the data management.

Results

Distribution, development and present status of the lynx population

The Swiss survey produced 862 reliable or probable signs of presence collected during 1972-2001. These data included a total of 171 (19.8%) domestic animals killed by lynx, all confirmed by trained state wardens and reimbursed by the state. Another 29 (3.4%) lynx were found dead or removed from the population (see also Breitenmoser-Würsten et al. 2007). Additionally, 292 (33.9%) cases were reported as sightings, 147 (17.0%) as tracks, 142 (16.5%) as kills, 64 (7.4%) were data originating from the Swiss mammal atlas inventory (Hausser 1995) and 17 (2.0%) were other signs, such as vocalisation, captures and photographs. With < 30 cases, the number of doubtful or rejected observations was low. This was probably due to the fact that game wardens, collecting a large part of the information, transmitted only reliable observations and that, after 20 years of lynx presence, people probably tend to be more experienced or critical in judging lynx signs. Damage to livestock was rare, irregular in time, and restricted mainly to one area in the Swiss Jura Mountains (see also Molinari-Jobin et al. 2007). Compared to France, attacks on livestock are of minor importance in the Swiss Jura Mountains (Stahl et al. 2001).

The development in the number of grid cells (5 × 5 km) occupied by lynx in the Swiss Jura mountains per 3-year period during 1972-2001 is shown in Figure 1, and the development of the lynx distribution in the Swiss Jura Mountains in the same period is shown in Figure 2. Until the mid-1980s, the increase rate with ≥ 20 newly occupied grid cells per 3-year period as well as the increase in distribution was higher than afterwards. Only during the last 3-year period (1999-2001), did we again notice an increase in the number of newly occupied grid cells. Evidence for the colonisation of new territory appeared in the second 3-year period (1978-1983; see Fig. 2B-C). This period was also characterised by a spatial segregation of the lynx population in two subareas separated close to Neuchâtel. A temporary decrease in occupancy of the area by lynx appeared in the beginning of the 1990s. Afterwards, the number of occupied grid cells increases steadily, not primarily because of an extended expansion of range, but as a consequence of the occupation of previously empty grid cells within the range (see Fig. 2D-E). Figure 2F summarises all grid units ever occupied during the whole period (N = 139), which represent 78% of the 178 grid cell units (5 × 5 km) attributed to the Swiss Jura Mountains (without including the cantons of Aargau and Schaffhausen).

A more realistic map of the now permanently inhabited range is shown in Figure 3, summarising the period 1990-2001 using 10 × 10 km grid cells. The resulting surface of 100 km^2 per unit represents about ⅔ of the home-range area of adult lynx in the Swiss Jura mountains (Breitenmoser et al. 1993). Grid cells with dots (N = 21) represent the core area of lynx distribution, irregularly occupied units (N = 28) appear as circles. Dots represent cells counting more than two 3-year periods during which lynx presence has been documented, circles show a lower frequency. Attributing 100 km^2 (grid unit of 10 × 10 km) to each dot, the range occupied permanent-

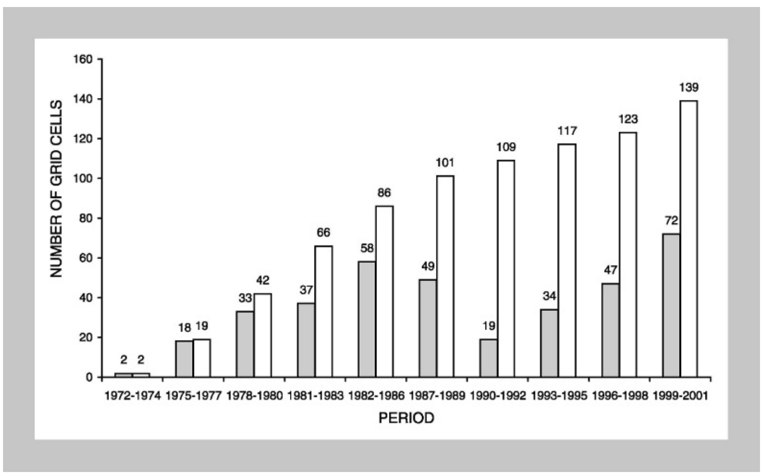

Figure 1. Number of 5 × 5 km grid cells with lynx observations in the Swiss Jura Mountains with indications of the number of grids cells occupied per period (■) and the cumulative number of grids cells occupied (□).

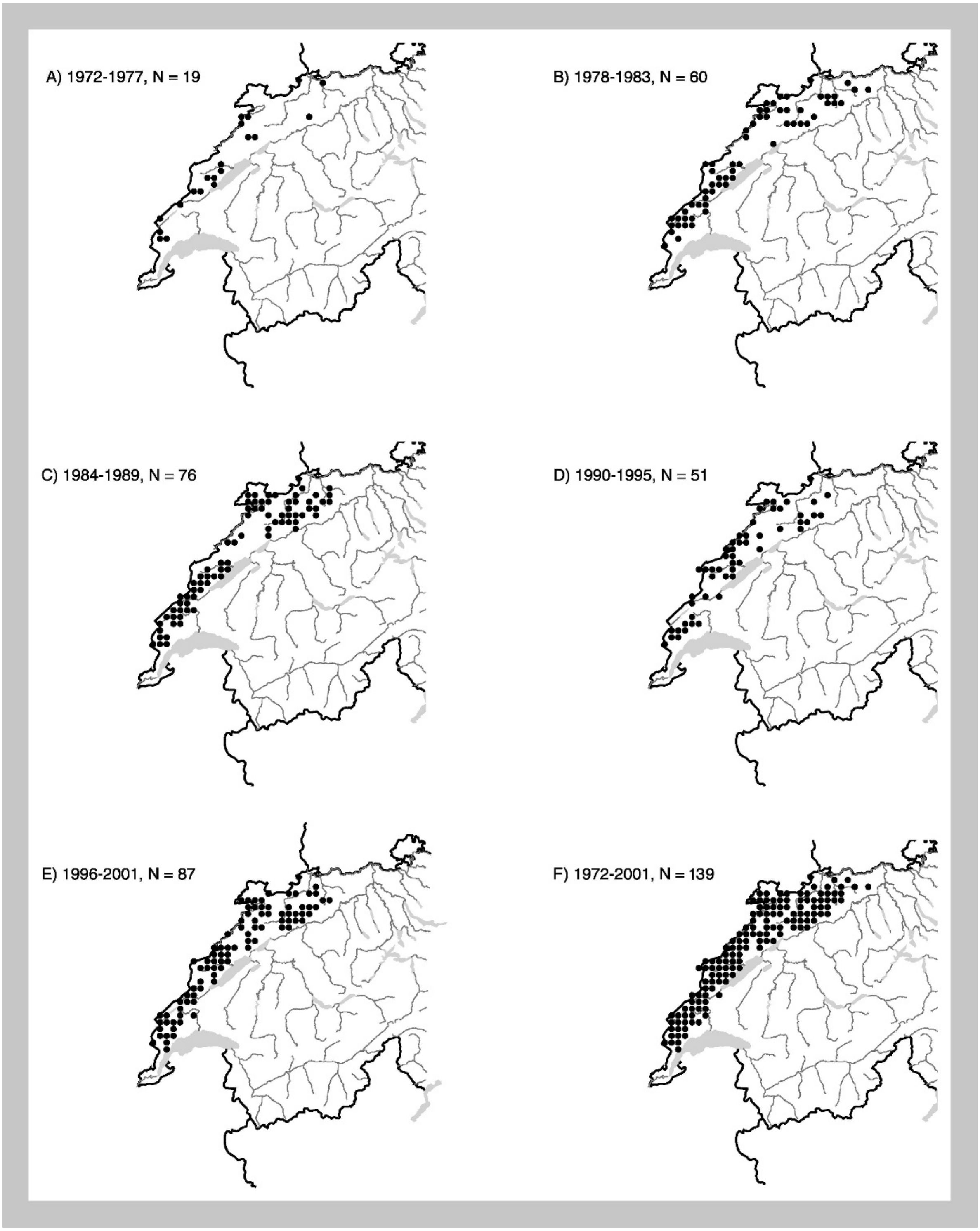

Figure 2. Distribution of lynx in the Swiss Jura Mountains per 6-year period from 1972 to 2001 shown using a 5 × 5 km grid. Dots indicate that at least one confirmed or probable observation was recorded inside the grid cell.

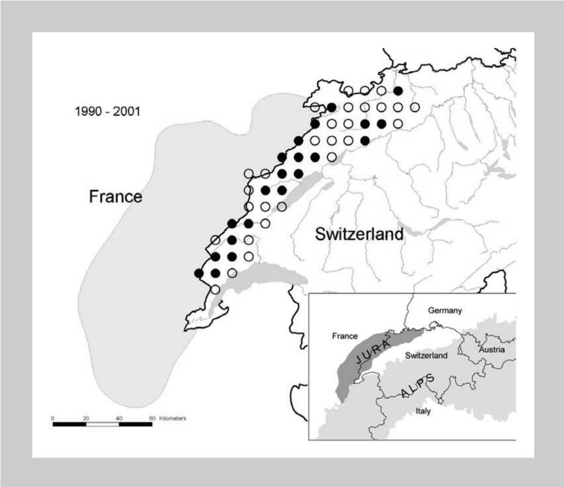

Figure 3. Distribution of lynx in the Jura Mountains shown for 3-year periods during 1990-2001 in a 10 × 10 km grid. The black dots (●) show grid cells (N = 21) occupied during 3-4 periods, open circles (○; N = 28) show cells occupied during 1-2 periods. The distribution range shown in grey indicates the presence of lynx in the French part of the Jura Mountains as described by Vandel (2001).

ly by lynx in the Swiss Jura Mountains is roughly estimated to be 2,100 km^2, representing a potential population of 17 resident individuals when considering a conservative density of 0.8 individuals/100 km^2, or 23 individuals for a more optimistic density of 1.1 individuals/100 km^2 (Zimmermann & Breitenmoser 2007).

Discussion

Development of the lynx population in the Jura Mountains

The passive surveillance data show that the expansion of the lynx population in the Swiss Jura Mountains has continued until the present. However, within the settled area, some cells were not continuously occupied. In the early 1990s, the number of grid cells with lynx presence temporarily decreased. These years correspond to the years of reduced presence of resident males in the study area in the Swiss Jura Mountains (Breitenmoser-Würsten et al. 2007). As shown by Vandel (2001), colonisation of the French Jura mountains took place later than in the Swiss part; lynx range on French territory increased significantly only starting from the second half of the 1980s. This supports the assumption that all releases took place on or near Swiss territory. The spatial segregation observed in the second period (1978-1983) has already been described by Breitenmoser & Baettig (1992), who attributed this phenomenon to the chronology of the reintroduction and to reduced habitat suitability in the central part of the Jura Mountains. A rather optimistic picture of lynx distribution in the Swiss Jura Mountains is drawn by Figure 2F, showing that 78% the grid cells had been occupied during at least one observation period. This result also takes into account grid cells irregularly inhabited by lynx and is therefore not identical to the range permanently occupied by lynx.

Vandel (2001) estimates the area continuously occupied by lynx since the beginning of the 1990s in the French Jura Mountains to be about 5,000 km^2. This part of the Jura Mountains now constitutes the core area of the lynx population with ⅔ of the range lying in France and only 2,100 km^2 of permanently occupied range lying on Swiss territory (see Fig. 3). The range occupied permanently by lynx in the entire Jura Mountains can therefore be roughly estimated at 7,100 km^2, representing a potential population of 56 resident individuals based on a conservative density estimate of 0.8 individuals/100 km^2, or 78 individuals based on a more optimistic density estimate of 1.1 individuals/100 km^2. The density numbers represent edge values of fluctuating saturation levels as observed during long-term field studies on lynx by Zimmermann & Breitenmoser (2007). These authors predict an estimated potential of 80 individuals for the studied area. A comparison with the potential expansion predicted by the same authors, who mention a maximum of about 8,400 km^2 to be good potential lynx habitat when considering also discontinuous areas, shows that most of the suitable habitat has already been occupied. Consequently, the expansion of the Jura lynx population is not expected to increase significantly in the future, and in the long term, a population of about one hundred individuals will have to be conserved and managed. The few additional regions that could be colonised by lynx are situated in the northeastern part of the Jura Mountains, especially in the cantons of Solothurn, Basel-Landschaft and partially Aargau for Switzerland, and the lower western valleys of the French Jura. Lynx inhabit almost all suitable habitat in the southern Jura Mountains. According to Stahl & Vandel (2001) this has already led to the colonisation or reinforcement of the lynx population of the French Alps (the region of the Chartreuse; see Zimmermann & Breitenmoser 2007).

Although lynx are secretive and few in numbers, there is a good chance that the species' presence is detected in regularly occupied areas and even in recently colonised areas with occasional findings of indirect signs of presence, such as tracks and kills. Lynx readily use the network of forestry roads in winter, which results in many observations of tracks. Systematic collection of basic survey data often allows the early detection of new spatial developments. This information becomes even more pertinent when calibrated through local studies on spatial and social behaviour. A species' absence, on the other hand, cannot be proved. However, the repeated lack of observation in the annual surveys indicates a real absence of lynx. This is especially true when a trained network of observers covers the whole potential distribution range of lynx.

Long-term surveillance by means of passive data

To guarantee the sustained assessment of the status of the lynx population in the Jura Mountains, survey and coordination across national borders must be maintained or reinforced at different geographical levels. At the large scale, methods already in use should be continued in order to get basic information on the overall distribution and the spatial trend (e.g. colonisation and occupation). When calibrated through local studies on spatial organisation and social structure, information gathered by the basic survey allows a rough estimation of the relative density and abundance of the population. All survey methods mentioned earlier, such as the collection of occasional signs of presence, recording lynx found dead, killed or captured, and statistics of a killed domestic or wild prey should be continued. These data can be collected independently of special investment in fieldwork and are efficient in determining lynx population trends over large areas.

In order to reinforce the lynx survey in the Swiss Jura Mountains, and to implement the new Swiss lynx policy as outlined in the 'Swiss Lynx Concept' (see also Breitenmoser et al. 2007.), a 'lynx group' including game wardens, hunters, naturalists and scientists was established in 2002 in the northern part of the Swiss Jura Mountains with the intention of expanding it to cover all of the Swiss Jura Mountains. Several persons engaged in this group were already participating in the survey before the group was formed. Based on the idea of the 'Réseau lynx' in France (Vandel & Stahl 1998), the organisation of locals into a network of observers and correspondents aims to improve the survey and will allow for a better comparison with the data from the French Jura Mountains. The lynx group receive logistic, methodological and technical help from the game biologists in charge of lynx monitoring in Switzerland. One function of the members of this group is to produce more confirmed data, by improving the quality of their own occasional observations through proper documentation. Another important function of the group is to act as regional contacts and to improve the registration of observations by local people. Locals are more willing to report to local residents than to regional or national authorities.

Besides these practical tasks of the group, confidence-building effects between local people and scientists, and between different interest groups at the regional level is of high importance (see discussion in Breitenmoser et al. 2007). All too often local people do not trust in lynx numbers produced by scientists. An estimation of lynx abundance resulting from joint fieldwork by biologists, wildlife managers, local hunters and naturalists will hopefully be more easily accepted.

As a control sample (and to bridge the time until lynx groups will be established throughout the lynx range), the annual investigation by state game wardens remains important. It summarises the situation for each warden's district and serves as a 'negative control' because the lack of any signs of presence must be reported, too. Furthermore, it is often the only information available from newly colonised regions.

Active field monitoring

While surveillance by collecting passive data is successful in determining the distribution of lynx populations at large scales, it is less suited to obtain information about density and lynx population size at a regional level. Such information is needed to implement the 'Swiss Lynx Concept'. The lynx group established in the Swiss Jura Mountains will participate in active monitoring in the future, using methods such as camera traps or snow-tracking. The use of camera traps, based on capture-mark-recapture models, can produce quantitative data in medium to high population density situations (Laass 2002). Results are less confident for low densities. Costs in material and labour are relatively high for this method, and its application is therefore limited to specific situations and to reference areas. For the long-term monitoring of the lynx population in the Jura Mountains, intensive camera-trapping sessions will have to be carried out periodically. To improve the efficiency of the method, extensive camera trapping has already been established with the help of the lynx group. Cameras were placed near fresh lynx kills or at passages, allowing 'pre-marking' of individual lynx for later resightings. To make the active monitoring work, appropriate training was given to all members of the lynx group, and all participants are regularly informed at meetings, through circulars and via the internet.

Conclusions

The great challenge for the future is to gain the acceptance of lynx by local people. Good and widely accepted monitoring data allowing accurate estimation of lynx abundance is crucial to gain the public's confidence. For Switzerland, such information is needed to implement the 'Swiss Lynx Concept', a federal management plan which allows translocation or limited culling of lynx if the predator's impact on local prey populations is too strong. In this context, great hope is given to estimations produced by regional lynx monitoring groups who unite local hunters, environmentalists, game wardens and scientists.

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