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Research Article

CURRENT STATUS OF LYNX LYNX (L. 1758) IN THE OSSOLA VALLEY (WESTERN ITALIAN ALPS)

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ABSTRACT

European Alps are currently inhabited by a meta-population of *Lynx lynx* (L. 1758) well below the optimum level. The aim of the present study was to update and discuss the information available on the species in the study area. Two methods of field research were applied: the naturalistic and the photo-capturing. The naturalistic method was implemented in two sub-periods, 03.2009-03.2011 (58 transects, with 440.1 km walked) and 02.2013-03.2015 (78 transects with 569.9 km walked) with a total sampling effort of 1010 km distributed in a study area of 136.5 km^2. For the photo-trapping method, 4 different cameras and 2014 with a sampling effort of 152 trap-days, both on crossroads or along trails, without the use of any attractant or were placed at two sites in 2013 lure.

Nat-meth produced 18 signs of the presence clusters (each cluster contains the evidences attributable to the same subject); by photo-meth we obtained 7 captures. The data obtained reveal the presence of the two adult males, *concolor* bigger and spotted smaller, in the study area between 2013 and 2015 without any evidence of reproductive activity (presence of adult females and kitten or non-emancipated young). The comparison between the present and previous studies leads to statistically non-significant differences between the relative abundances of the lynx in the study area. However, it is important to emphasize that in the 2009-11 its presence considerably declined while an increase has been recorded in the following sub-period (2013-15). Finally, it is possible to guess that the small deme present in the Ossola Valley is founded by individuals from the south-western Swiss Alps. The hypothesis that there is a flow of individuals between the two areas seems to be confirmed by the considerable numerical oscillation observed in the two sub-periods investigated in this study.

Keywords: Eurasian lynx; Naturalistic method; Photo-trapping method; Long-term status; Ossola Valley

INTRODUCTION

The historical autochthonous population of Eurasian lynx (*Lynx lynx* L. 1758) in the European Alps became extinct between 1830 and the first decades of the 20th century (Lavauden, 1930; Castelli, 1940; Guidali *et al.* 1990; Ragni, 1998). From the 1970s onwards, this species has been reintroduced into Switzerland, Slovenia, Italy and Austria through the release of individuals taken from autochthonous populations in central-eastern Europe (Breitenmoser & Breitenmoser-Wursten, 1990). The European Alps are currently considered to be inhabited by a meta-population, which is still well below the optimum level that may be hypothesized on the basis of the ecological resources available in the region (Molinari-Jobin *et al.,* 2010a). From the end of the 1990s to 2014, the presence, distribution and status of the Eurasian lynx in Europe were described both within the framework of surveys extending to other large carnivores (Kaczensky *et al.,* 2012; Chapron *et al.,* 2014) and in studies focusing on this cat alone (Breitenmoser & Breitenmoser-Wursten 1990; Breitenmoser *et al.,* 2000; Von Arx *et al.,* 2004), allowing precise information on the presence of this feline in the European Alps (Molinari & Molinari-Jobin 2010; Molinari-Jobin 2007; Molinari-Jobin 2010; Molinari-Jobin *et al.,* 2010a; Molinari-Jobin *et al.,* 2010b; Molinari-Jobin *et al.,* 2012). With regard to the Italian Alps, data on the presence, distribution and status of *Lynx lynx* dating from 1980-84 to 2005-09 are to be found in the literature (Ragni *et al.,* 1998; Molinari *et al.,* 2001; Molinari & Genovesi 2006; Molinari & Molinari-Jobin 2010; Molinari *et al.,* 2012).

The portion of the Italian Alps considered in the present research-i.e. the upper portion of the River Toce basin (Verbano-Cusio-Ossola province, Piedmont region) – falls within the above-mentioned papers, but did not receive specific attention. Indeed, except for a degree thesis (Di Lorenzo *et al.,* 1996), the only data available for the study area date back to more than 20 years ago (Di Lorenzo *et al.*, 2000). The aim of the present study was to update and discuss the information available on the Eurasian lynx in the Ossola Valley in the Italian Lepontine Alps.

MATERIALS AND METHODS

The present study was carried out by implementing two

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procedures of zoological field research: the naturalistic method (Ragni, 1998) and the photo-trapping method (Karanth and Nichols, 1998). Only signs of presence that provided photographic documentation and/or material proof were considered, the only exception being one case of vocalizations heard.

Extending over 136.45 km², the study area includes part of the valleys Formazza, Antigorio and Devero orographic system defined by the minimum convex polygon, within which sampling was carried out through the application of the two methods of data collection (Figure 1). The reference area constructed comprises all the types of geographic landscape that fall within it. Among these, the principal components supporting the bio-ecology of the species in the re-colonized areas of European Alps and ecologically connected systems (Matyushkin and Vaisfeld 2003; Ragni 1998; Zimmermann 2004; Zimmermann and Breitenmoser 2007; Zimmermann *et al.,* 2015) are: wood and/or shrub and/or bush vegetation at any altitudes; spontaneous herbaceous areas below the tree-line; all of them 500 meters away of continuously inhabited human settlements. Such lynx-suitable ecological requisites were corresponding to nine Corine Landcover 2012 categories (Pastures, Land principally occupied by agriculture with significant areas of natural vegetation, Broad-leaved forest, Coniferous forest, Mixed forest, Natural grasslands, Moors and heatland, Transitional woodland-shrub, Sparsely vegetated areas). Taken together, these natural and semi-natural landscapes cover 72.9% of the reference area. The three possible areas that are suitable for the Eurasian lynx are therefore of 139, 151 and 163 km².

The naturalistic method consists of collecting and documenting signs of presence of the species under examination (sightings of individuals, vocalizations heard, faecal deposits, footprints and tracks on plastic surfaces, feeding remains, dead individuals, and other traces). To do this the field-collectors walked at a constant speed over a pre-established network of sampling pathways (transects). This method, carried out between March 2009 and March 2015, was implemented on a predetermined network of 136 transects, from a min. of 5.3 to a max. of 9 km, with a transect mean length ± SD of 7.43 ± 0.84 and a total sampling effort of 1010 km.

The collectors walked along the network, without any repetition, only in the coldest period of the year (late autumn-early spring) with snow-covered terrain. Within the above-mentioned overall period, this study has been carried out in two well defined sub-periods:

- 03.2009-03.2011 - 58 transects with 440.1 km, a length range of [6.3,8.8] km, a mean length ± SD of 7.59 ± 0.75 km;
- 02.2013-03.2015 - 78 transects with 569.9 km, a length range of [5.3,9.0] km, a mean length ± SD of 7.3 ± 0.89 km.

The photo-trapping method involves setting up stations for photographic recording (sites) by means of cameras that are automatically activated by the movement of the animals; this enables photo-captures to be made both during the day and at night. This method was enacted by setting up individual sites in places habitually frequented by wildlife in the study area, both on crossroads or along trails, without the use of any attractant or lure.

All photos were examined by expert zoologists who

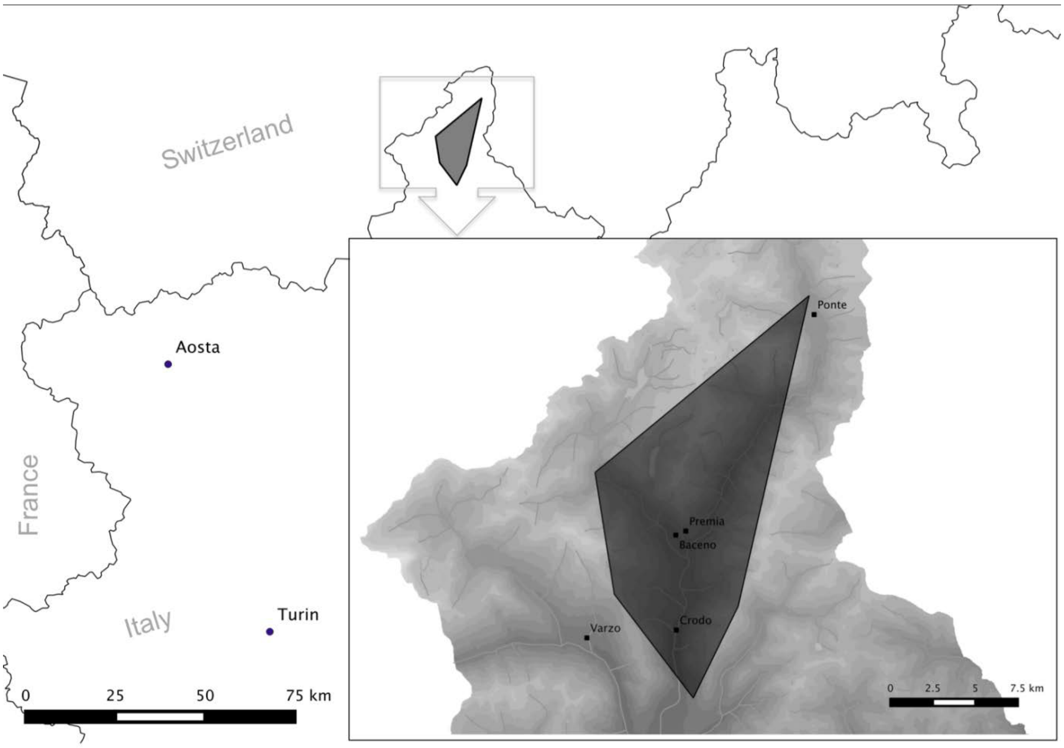

Figure 1: Study area (mcp enclosing the 13645 ha where field data were collected in the study period).

excluded those that did not allow identification of the species (Ragni, 1998, Molinari-Jobin *et al.,* 2012).

For this method, 4 different cameras (1 Bushnell and 3 Ltl Acorn) were placed at 2 sites in 2013 (01.03-08.05; 8°17'07"E, 46°13'59" N and 8°17'03" E, 46°14'09" N) and 2014 (20.03-08-08; 8°17'03" E, 46°14'09" N) for a total sampling effort of 152 trap-days.

In this case, the relative abundance of the species was calculated with Tia: trapping index of abundance = total number of photo-captures/total number of trap days (Ragni, 1998, Bizzarri *et al.,* 2010).

We used the Goodness of fit-χ^2 test (Krebs, 1999) and Jacobs Index (Jacobs, 1974) to compare our results with those obtained by previous studies carried out with same methods.

RESULTS

A total of 43 signs of the presence of *L. lynx* were collected; these were distributed in 18 temporal and spatial clusters (Table 1,Figure 2); each cluster contains

Table 1: *L. lynx* data collected by naturalistic method; Date: YYMMDD; Cluster: a number of signs of presence non-reciprocally independent in time and space.

N	Date	Signs of presence	Locality	X	Y	Cluster
1	090312	Footprint on snow	Alpe Camplero	8°17'06" E	46°14'47" N	1
2	130228	Footprint on snow	Esigo	8°15'57" E	46°17'07" N	2
3						
4						
5	130301	Footprint on snow	Foppiano	8°17'03" E	46°14'11" N	3
6						
7						
8						
9	130301	Feeding remains	Foppiano	8°17'07"E	46°13'59" N	4
10		Footprints on snow				
11	130308	Footprint on snow	Alpe Scengo	8°17'03" E	46°14'13" N	5
12						
13		Trail on snow				
14	130308	Footprints on snow	Scengo-Foppiano	8°17'01" E	46°14'20" N	6
15		Faeces on snow				
16		Trail on snow				
17						
18	130319	Footprints on snow	Scengo	8°16'58" E	46°14'11" N	7
19		Claw tracks on frozen snow				
20	130423	Footprint on snow	Argnai di Varzo	8°16'25"E	46°13'34"N	8
21						
22	140312	Vocalization	Veglio	8.334645°E	46.175872°N	9
23	140401	Picture	Lago di Agaro	8°18'06" E	46°17'29" N	10
24						
25	150301	Footprint on snow	Salera di Aleccio	8°20'52" E	46° 14'59" N	11
26						
27						
28						
29						
30						
31		Urine spraying behavior on rock				
32		Footprints on snow				
33		Footprint on snow				
34	150305	Footprint on snow	Aleccio	8°20'59" E	46°14'45" N	12
35						
36	150305	Footprint on snow	Aleccio	8°20'58" E	46°14'42" N	13
37						
38	150306	Footprint on snow	Aleccio	8°20'57" E	46°14'37" N	14
39	150310	Footprint on snow	Cagiogno di Premia	8°21'04" E	46°16'06" N	15
40	150310	Footprint on snow	Cagiogno di Premia	8°21'10" E	46°15'55" N	16
41	150311	Footprint on snow	Aleccio	8°20'56" E	46° 14'41" N	17
42	150311	Footprint on snow	Aleccio	8°20'58" E	46°14'32" N	18
43						

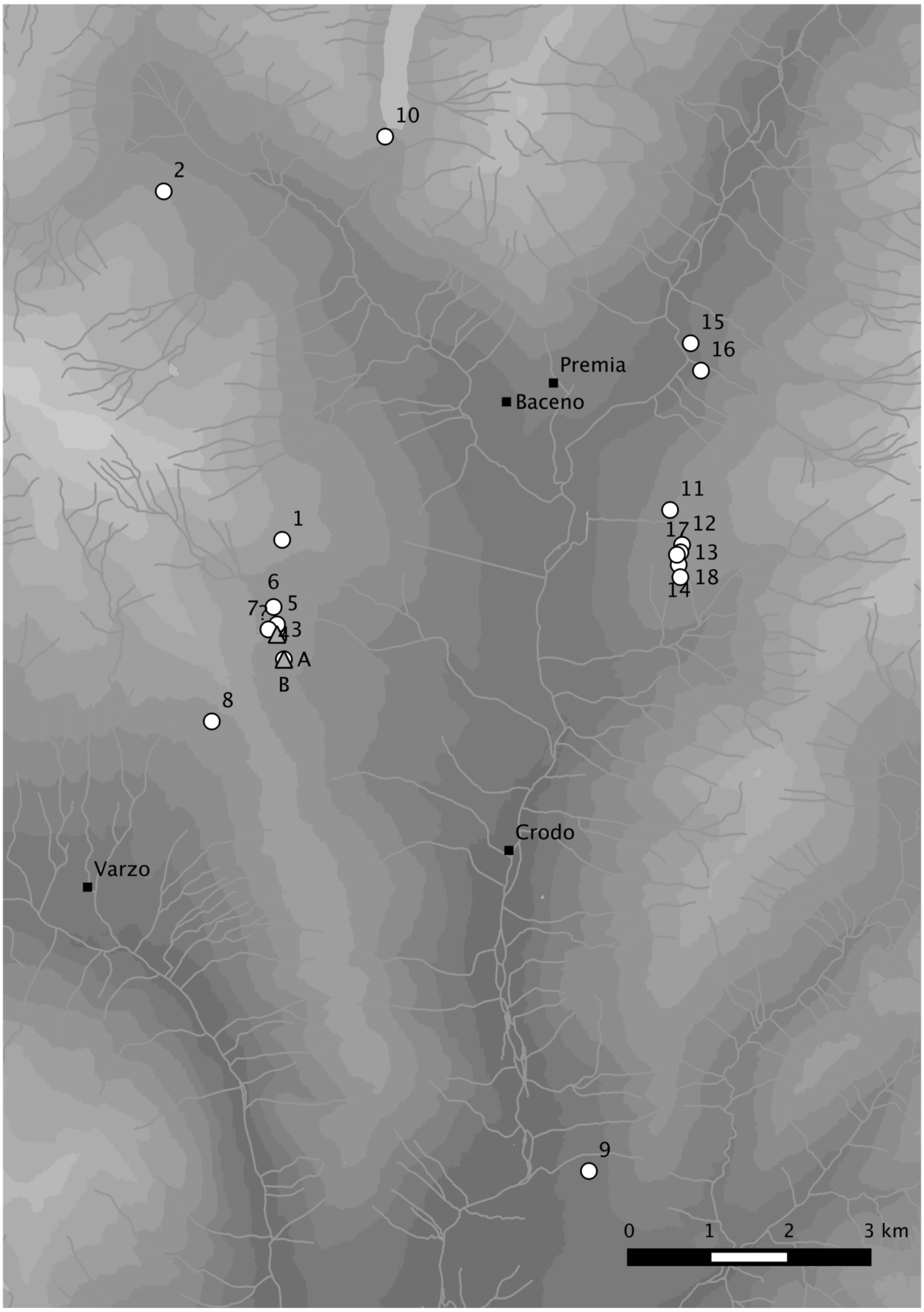

Figure 2: Distribution of *L. lynx* signs of presence (white dots) and photocaptures (triangles); 1-18 and A-? as in Table 1 and 2.

the evidences attributable to the same subject. Different clusters can be collected in the same day and/or in different segments of the same transect (Table 1). All these data were represented by tracks on the snow covered terrain apart from the following cases. On the morning of March 12, 2014, two Provincial Police officers (L. Croppi and P. Tassi pers. comm. 2014) heard a series of vocalizations in the vicinity of Veglio (Table 1,Figure 2). The loud "barking-mewing" sounds continued for at least 20 minutes, suddenly ceasing as the officers approached. Both officers stated that the vocalizations heard in the field were identical to those of an adult specimen of *Lynx lynx* heard in a recording made in controlled conditions (Ragni and Fabrizi, 1998). On the shore of Agaro Lake (Table 1,Figure 2) the morning of April 01, 2014, two workers shot two pictures to a lynx (M. Valeci and A. Scilligo pers. Comm, 2014).

The photo-trapping method shows that the target species, *L. lynx,* was trapped 7 times (Table 2,Figure 2) among other different species (*Corvus corone*, *Garrulus glandarius*, *Lepus europaeus*, *Lepus timidus*, *Sciurus vulgaris*, *Canis lupus familiaris*, *Meles meles*, *Martes* sp., *Cervus elaphus*, *Rupicapra rupicapra*) and human.

With regard to the data gathered by means of the naturalistic method in the study area between March 2009 and April 2014, objective references were not available to establish whether observations concerned different

Table 2: *L. lynx* data collected by phototrapping method; Date: YYMMDD.

Captures	Date	Locality	X	Y	Subject
1	130301	Foppiano	8°17'07"E	46°13'59" N	A
2					
3					B
4					
5	130416	Alpe Scengo	8°17'03" E	46°14'09" N	?
6					
7					

individuals (Table 1,Figure 2). Observations collected in March 2015 in 8 different sites (Figure 2), were attributable to at least two different individuals; indeed, the 18 footprints on the snow were constantly and significantly of different sizes, being compatible with the presence of one "bigger" individual (Clusters 11-13) and one "smaller" individual (Clusters 14-18; Table 1 and Figure 2). In those 12 days of observation, these at least two animals intensively and insistently frequented a restricted area of little more than 1 km² (131 hectares) (Figure 1), though in two different periods of time: the bigger individual from March 1 to 5 and the smaller from March 6 to11 (Table 1).

The two lynxes photo-captured at Foppiano spot (Tables 2A and 2B) were distinguishable from each other in that one was larger and had a *concolor* coat (B), while the other was smaller and had a spotted coat (A). The proportions of the limbs, head and trunk of both individuals were characteristic of the male; in the case of individual "A", however, these proportions were suggestive of a sub-adult specimen. The subject "?" (Table 2) has been photo-captured 1.5 month after the first two in a site 303 m from the previous one (Map 2) and shows a spotted coat, but the three photograms were not clear enough to allow a distinction to be made between the two.

Also the spotted subject "10" (Table 1) accidentally pictured at Lake Agaro presented proportions between limbs, trunk and head that were characteristic of a young adult male. Comparison between patterns of spotted lynxes of Foppiano (A) and Agaro was impossible because the different body side showed by them, for this reason we can't be sure that it is the same individual.

The area in which these animals most probably moved can be estimated by "buffering" the minimum convex polygon (mcp) containing all the locations in our study area where the presence of the Eurasian lynx was ascertained. The most probable depth of this buffer is calculated from the minimum distances between all the points making up the above-mentioned mcp. The minimum number N of the reciprocal distances between these points is $N=(n^2/2)-n/2$, where n is the number of points considered. In this instance, the mean A of the 190 distances among the points yields a reasonable measure of the depth of the buffer to be constructed on the polygon. In our case, with A=4019.45 ± 305.74 m(α=0.05), the total surface area over which the

Table 3: Comparison between naturalistic method studies on *L. lynx*; O: observed signs of presence and clusters; Kia: kilometric index of abundance (O/Sampling effort); J: Jacobs index test.

Study	Sampling effort (km)	O	Kia	J
Di Lorenzo, et al.	215	3	0.014	-0.12
Present (2009-2015)	1010	18	0.018	0.12
Present (2009-2011)	440.1	1	0.002	-0.72
Present (2013-2015)	569.9	17	0.030	0.36

Table 4: Comparison between phototrapping studies on *L. lynx*; O: observed photocaptures; Tia: trapping index of abundance (O/Sampling effort); χ^2: Goodness of fit-chi square test.

Study	Sampling effort (trap days)	O	Tia	χ^2
Bionda, et al.	394	25	0.06	0.06
Present	152	7	0.05	0.16
$\sum\chi^2$ (p=0.86)				0.22

two individuals may have moved in 2013-2015 ranges from 191 to 223 km².

The overall lynx relative abundance did not differ from what reported in previous studies carried out in the same study area (Tables 3 and 4), however, it is very important to emphasize that in the 2009-11 biennium its presence has shown a considerable decline and then an increases in the following sub-period.

DISCUSSION

On August 2015, the Verbania Provincial Police shared with us six photo-captures taken on March 2015 and on September 2015 a technical report (Bionda *et al.,* 2015) showed five photo-captures taken on February-April 2014. Both sets were taken in the study area and show two animals: a smaller size individual with a spotted coat pattern and a larger one with concolor coat patterns. Regarding the individual with spotted coat pattern, a number of detailed markings on the two sides of the trunk prove that it was the same animal photographed in 2013 (A).

Even though a comparison cannot objectively be made between the "our" concolor subject (B) and that caught by others, the most parsimonious approach leads to the conclusion that all photo-captures show the same animal. Indeed we had an important objective confirmation: both lynxes were adult males (scrotus), as clearly shown by the photocaptures made by the VCO Provincial Police. Thus, all these sources confirmed that, between 2013 and 2015, the study area was inhabited by at least two adult male lynxes, without any evidence of reproductive activity (presence of adult females and kitten or non-emancipated young).

The above considerations together with the results of the naturalistic method prompt us to hypothesize that in general the population of *L. lynx* in the upper Ossola Valley has not changed much in the last 20 years, in terms of both local area and number of individuals. This hypothesis is supported by the fact that, in the same study period, the group of field collectors was also engaged in surveillance and data gathering with regard to other species of wildlife in an area within a minimum convex polygon covering 620 km² where they walked near 11000 km transects; this area is contiguous with the present study area and mainly extends over the eastern portion of the lower Ossola Valley, including the Val Grande National Park. Nevertheless, in this area and in the same period, the observers never recorded any sign of presence attributable to *L. lynx*.

An interesting aspect is given by the different coat pattern of the two individuals (A and B). The whole present Alpine meta-population of *L. lynx* is descended from Carpathian stock (Breitenmoser *et al.* 1998), which is characterized by spotted and/or striped genotype-phenotypes in ≥ 75% of cases (Ragni *et al.,* 1993; Thüler, 2002), in accordance with the coat shown by A.

On the contrary, the bigger adult male had a concolor coat (B), without any spots, stripes or other markings, except on the face, distal segment of legs and tail tip. This pattern is determined by a regressive allele at the Tabby locus, and is manifested in the phenotype only when the genotype is in a homozygous state (Ragni *et al.,* 1993). The extinct Alpine population of the Eurasian lynx displayed an allelic frequency of this phenotype-genotype in ≥ 75% of observations (Ragni *et al.,* 1993; Thüler, 2002); this situation, together with other morphometric constants, supported the hypothesis of the existence of an European alpine subspecies named *L. l. alpina* now-extinct (Amori *et al.,* 1999). Therefore, in the tiny Ossola Valley sample, a *concolor* genotype-phenotype characteristic of the extinct *L. l. alpina*, should be observed, even though the probability of this was ≤ 25%. Due to the small size of the sample, it is not possible to draw any reliable conclusion and it is hence mandatory to get new images.

On the basis of what has been discussed above, and in accordance with the hypothesis that at least two lynxes were present in the reference area in the period 2013-2015, the corresponding minimum densities would range from 0.9 to 1.44 individuals/100 km². The north-western Swiss Alps is the sub-region which currently harbors the most abundant lynx population. In this sub-region the population density has been estimated between 1.0-1.5 lynxes/100 km² by a continuous monitoring with radio-tracking and photo-trapping methodologies (Pesenti and Zimmermann, 2013). These data show that *L. lynx* density in Ossola Valley seems consistent with what recorded in the NW Swiss Alps.

As previously hypothesized by Di Lorenzo *et al.*, (2000), the best explanation of the presence of L. lynx in the study area is still based on the biogeographic-ecological source-sink phenomenon (Pulliam and Danielson, 1991), so it is possible to guess that the small deme present in the Ossola Valley is founded by individuals from the south-western Swiss Alps (Molinari-Jobin *et al.*, 2012). The hypothesis that there is a flow of individuals between the two areas, seems to be confirmed by the considerable numerical oscillation observed in the two sub-periods investigated in this study.

As already mentioned, the part of the Italian Lepontine Alps that is able to meet the environmental needs of the Eurasian lynx is much more extensive than the area that has so far proved to be frequented by the species. Indeed, this region is part of one of the most extensive patches of connected lynx habitat in the whole of the European Alps (Zimmermann *et al.*, 2003) and also includes the so-called "most extensive wilderness area in Italy", the Val Grande National Park. Nevertheless, the 20 years that have elapsed between the first and the latest surveys of the presence of the species in this area have evidently not been sufficient for the formation of a permanent local population, however small, given the apparent absence of females. This situation however is not in contrast with the pattern of range expansion of this feline, which is extremely slow and conservative (Molinari-Jobin, 2010; Molinari *et al.*, 2012).

In conclusion, it is possible to recommend that:

1) Regional and national authorities, responsible for the use of the territory, should maintain the area of the Italo- Swiss border and the bottom-valley zones of the River Toce basin in a good state of conservation and ecological continuity;
2) A permanent monitoring implementation related to the presence and distribution of *L. lynx* and the maximum possible extension of the study area, in a similar manner to what is ongoing for the wolf, considering also that the lynx is even more sensitive and vulnerable to the impact of humans (Temple and Terry, 2007).

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