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Estimate of breeding pair's distribution and seasonal abundance patterns of floating Golden Eagle *Aquila chrysaetos* population in the Italian Central Alps through field surveys and contemporary censuses

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The Golden Eagle *Aquila chrysaetos* in Lombardy occupies a wide range of the whole mountainous sector where it is present with highest densities in the northern areas of Valtellina, Val Chiavenna and Val Camonica. Slightly lower densities occur in the Orobie Pre-Alps chain. At the regional scale the species usually frequents environments from 1200 m up to 3500 m a.s.l.

In the peripheral sectors of the western and eastern Pre-Alps it presents a more fragmented distribution associated to larger territories characterized by less trophic resources and suitable breeding habitats. The Golden Eagle is also present south of the Po plain in the Apennines chain (Oltrepo, Pavia province).

At the end of 1980s, regional estimates were 25-30 territorial pairs (Tosi & Pinoli in Brichetti & Fasola 1990) increasing to 61-75 pairs in 2010 in a recent survey that combined information available in literature with data collected by local ornithologists (Brambilla *et al*. 2012).

More recently (2016) more new pairs have been found, thus the estimated total number reached 76-89 territories with an increase of 197-204% over the last 27 years (1990-2016, Tab. 1).

In order to explain this remarkable increase compared to the past, it is necessary to consider the combination of several hypotheses, one of which is prey abundance-dependence, which may also be the main positive factor affecting productivity and quantity of parental cares by both sexes in the Central Alpine and Pre-Alpine nucleus, especially within the core area where the population density is high and increasing (Bassi *et al*. 2017).

Other main factors that could explain this increase are the larger extent of regional protected areas, the better knowledge about the territory distribution through a more accurate field research and the substantial reduction of illegal kills.

Despite that, eight poaching acts were recorded in Bergamo, Brescia and Lecco provinces in the 1998-2014 period; illegal shooting represents 50% of the total causes of recovery in 16 cases (Bassi *et al*. 2015; data from Lecco Province).

However, increasing food supply and decreasing human persecution could disguise current effects of habitat loss caused by land abandonment and afforestation, with consequent decrease of Alpine pastures, i.e. the main foraging habitat for Golden Eagles (Pedrini & Sergio 2001). As well as the number of territories, even their mean surface areas cannot be entirely estimated in the Lombardy region.

The regional estimate area is about 9,500 km^2 in the Alps and pre-Alps, where the species breeds on cliffs and, very rarely, on trees. This area includes all kinds of habitats comprised from 900 to 4,000 m a.s.l. with the exception of glacier surfaces (data updated to 2001 from the Servizio Glaciologico Lombardo).

Basing on the estimate of 76-89 territories and by means of a coarse partition of the regional mountainous sector, each Golden Eagle home range would have approximately a mean size of 116 km^2 (min 107 km^2, max 125 km^2). In order to assess the accuracy of this estimate, it resulted useful to compare it with the most recent literature about data on densities and pair distributions from some regional protected areas.

Programmes of intensive monitoring in Lombardy were mostly carried out only within the Stelvio National

Table 1. Estimate of the distribution of territories in the Lombardy region (updated to 2016).

N. of territories (min-max)	**Regional sectors**	**Source**
6	Orobie valtellinesi Regional Park (Sondrio province) and Concarena (Brescia province)	Bassi & Chemollo in Brambilla *et al.* 2012
17-18	Orobie Bergamasche Regional Park	Chemollo 2010; Chemollo, Zambelli & Ferrari (*unpublished*)
10	upper Val Camonica (Stelvio National Park, Adamello Regional Park and Parco Alto Garda Bresciano	Leo & Micheli 2002; Borgo 2005, Bassi & Trotti 2015
10-16 (estimation)	Sondrio province (not included in protected areas)	Hunting Office Sondrio Province (Ferloni *pers. comm.*) and Bassi (*unpublished*)
4-7 (estimation)	Brescia province (not included in protected areas)	Bertoli, Brichetti & Micheli (*pers. comm.*)
16	upper Valtellina from Mazzo di Valtellina to Livigno (Stelvio National Park and external area in the Sondrio province)	Bassi 2011, Bassi *et al*. 2017
5-6	Lecco province	Hunting Office Lecco Province (Facoetti and Bonvicini, *pers. comm.*)
7-8	Como province	Bonvicini (*pers. comm.*)
1-2	Varese province	Saporetti (*pers. comm.*)
1990: 25-30	**Lombardy**	**Tosi & Pinoli in Brichetti & Fasola 1990**
2016: 76-89		**Present study**

Park (620 km^2), Adamello (510 km^2) and Orobie Bergamasche Regional Parks (700 km^2) totalling 1,830 km^2, i.e. 19,2% of the regional mountainous surface. In these three areas, the mean size of territory amounted to 67 km^2 ± 25.4 (min 34, max 126) (Stelvio, Bassi *et al*. 2017, N = 17), 106.9 km^2 ± 15 (min 85, max 119) (N = 5, Adamello, Bassi & Trotti 2015) and 99 km^2 ± 28.04 (N = 12, Pre-Alps, Chemollo 2010) respectively, in agreement with the mean regional estimate shown in the present study (Tab. 2).

In particular, the mean home range, referred to Orobie Bergamasche and Adamello Regional Park and covering a total area of 1,210 km^2, are comparable, albeit higher, to those unknown for the remaining part of the regional mountain sector not included in protected areas. Differently from the Stelvio National Park, which is one of the most ancient protected areas in Western Europe, hunting activity is allowed here, and this is reflecting in the remarkable difference of trophic resources abundance in the form of live prey and carrion (mostly ungulates).

In fact, in the Stelvio NP marmots *Marmota marmota* occurred at high densities (6.9 burrows or 56-62 individuals/km^2, Bassi *et al*. 2017) and a rich wild ungulate community is present: 6.7 Alpine Chamois *Rupicapra rupicapra*/km^2, 15 Alpine Ibex *Capra ibex*/km^2 and 5-25 Red Deer *Cervus elaphus*/km^2 (Carro & Pedrotti 2010). Within the Stelvio NP, especially for this reason and also for the wide availability of suitable nesting cliffs, the Golden Eagle's territories show a mean size notably lower than for the entire

Table 2. Comparison of density and nest spacing of the Golden Eagle's territories in three areas of central Italian Pre-Alps and Alps in Lombardy. *n.c.* = not calculated.

Area	**Province**	**N. of territories**	**NND** (km)	**Mean extent** (sq. km)	**S.D.**	**min-max**	**Source**
Orobie Bergamasche RP	Bergamo	12	7.2	99	*n.c.*	*n.c.*	Chemollo 2010
Adamello RP	Brescia	5	8.9 ± 2.3	106.9	15	85-119	Bassi & Trotti 2015
Stelvio NP	Sondrio and Brescia	17	5.34 ± 2.3	67	25.4	34-126	Bassi *et al.* 2017
Lombardy	Varese, Como, Lecco, Bergamo, Brescia and Sondrio	76-89	*n.c.*	116	*n.c.*	107-125	present study

regional mountain area, where also poaching versus wild ungulates and other species is more frequent.

Furthermore it was confirmed that, besides scavengers like Raven *Corvus corax* and vultures, prey and carrion abundance can attract an elevated number of floating Golden Eagles as observed in Switzerland by Jenny (1992) and in the Stelvio NP.

As the population size, divided by age classes could not be estimated directly by single ornithologists, enlisting the assistance of 122 observers on average (min 54, max 190), two contemporary censuses per year (autumn and winter) between 2004 and 2017 were carried out in Lombardy and in the Trentino Stelvio NP including the park`s surroundings (mean covered area: 1,076 km^2). Each survey lasted for 5.5 hours from 9.00 A.M. to 14.30 P.M. The aim of this census was to monitor along a time and space dimensions the total number of territorial birds, and to quantify the floaters that are not associated with a defined territory. Floaters consisted predominantly of juvenile, immature and sub-adult birds.

All flight trajectories of the observed Golden Eagles (and Bearded Vultures *Gypaetus barbatus*) were registered, and individuals were identified on the basis of their age and sex. Based on this, the minimal number of individuals in each age class was determined. Overall, a mean index of 1.5 floaters/100 km^2 (S.D. 0.7) has been record-

Table 3. Golden Eagle's population counted during 26 contemporary censuses carried out in the Stelvio NP (Lombardy and Trentino sectors) during the 2004-2017 period.

Lombardy Trentino Stelvio NP	N. censused individuals	Censused adults	Expected adults	N. floaters	% censused adults/expected adults	% floaters/ tot. indiv.	% floaters/ n. expected adults	% floaters/ n. censused adults
2004-05	30	19	28	7	67.9	23.3	25.0	36.8
2004-05	45	28	36	8	77.8	17.8	22.2	28.6
2005-06	33.5	21	34	7	61.8	20.9	20.6	33.3
2005-06	34.5	21	44	7.5	47.7	21.7	17.0	35.7
2006-07	21	13	22	3	59.1	14.3	N.C.	N.C.
2006-07	59.5	32	46	15	69.6	25.2	32.6	46.9
2007-08	28	16	20	5	80.0	17.9	25.0	31.3
2007-08	61	30	38	14	78.9	23.0	36.8	46.7
2008-09	51.5	32.5	40	14	81.3	27.2	35.0	43.1
2008-09	63.5	38.5	54	13	71.3	20.5	24.1	33.8
2009-10	56	30	52	16	57.7	28.6	30.8	53.3
2009-10	46.5	28	44	11.5	63.6	24.7	26.1	41.1
2010-11	68	48	52	12	92.3	17.6	23.1	25.0
2010-11	69	43	52	20	82.7	29.0	38.5	46.5
2011-12	47	31	45	10	68.9	21.3	22.2	32.3
2011-12	79	47	52	26	90.4	32.9	50.0	55.3
2012-13	83	49	54	27	90.7	32.5	50.0	55.1
2012-13	75	47	48	22	97.9	29.3	45.8	46.8
2013-14	63	40.5	48	12.5	84.4	19.8	26.0	30.9
2013-14	84	48	51	31	94.1	36.9	60.8	64.6
2014-15	51.5	35	50	10.5	70.0	20.4	21.0	30.0
2014-15	66	43	53	17	81.1	25.8	32.1	39.5
2015-16	63	46	51	11	90.2	17.5	21.6	23.9
2015-16	82	58	55	23	105.5	28.0	41.8	39.7
2016-17	43	28	34	8	82.4	18.6	23.5	28.6
2016-17	75	55	59	18	93	24	31	33
Mean in Autumn	**49.1**	**31.5**	**40.8**	**11.0**	**75.9**	**21.5**	**27.0**	**35.3**
S.D. in Autumn	**17.9**	**12.1**	**12.0**	**6.0**	**12.3**	**5.1**	**8.4**	**10.2**
Mean in Winter	**64.6**	**39.9**	**48.6**	**17.4**	**81.1**	**26.1**	**35.3**	**42.9**
S.D. in Winter	**15.2**	**11.3**	**6.8**	**6.9**	**15.7**	**5.2**	**12.2**	**9.8**

ed during 13 contemporary censuses carried out in March from 2005 to 2017 over a total surface area of 1,134 km^2, which differs from the mean index of 1.1 floaters/100 km^2 (S.D. 0.5) recorded during 13 contemporary censuses carried out in October over a total surface of 1,000 km^2 from 2004 to 2017. The amount of non-territorial floaters counted during concerted surveys in the Stelvio NP ranged from 7 to 31 (mean 17.3; S.D. 7.2) in winter and from 3 to 27 (mean 11; S.D. 6) in autumn (Tab. 3).

It was possible to calculate an effective density index of Golden Eagles standardized to 100 km^2 by adding the number of censused floaters to the number of expected territorial birds: this index ranged from 6.1 (S.D. 1.7) in fall to 6.3 Golden Eagles (S.D. 0.9) in winter over an average surface area of 1,076 km^2 (S.D. 226.6).

In brief, the number of Golden Eagles floaters has remarkably increased during the censuses despite the high territorial eagle density already known for the Stelvio's area (15.75 pairs/1000 km^2, Bassi *et al.* 2013).

It has been proved that in Switzerland, juvenile and immature floaters interfere with paired adult birds, and can negatively affect reproductive success of sedentary pairs (Haller 1996, Jenny 1992). Also within the Stelvio NP high frequencies of floaters may affect the breeding performance of the territorial pairs, especially during late winter as this coincides with the beginning of the breeding season. In March, the mean percentage of floaters with respect to the expected adults is 42.4% (S.D. 13.1) versus 26.6% (S.D. 11.1) recorded in autumn.

Thus, taking into account the uncertainty, the available data for Golden Eagles are somewhat equivocal, with count data for territorial birds suggesting a stable population but with demographic data (that includes also the floaters proportion) indicating a progressive increase over time.

The winter median number of non-territorial floaters observed in the two periods (2005-2010 *vs* 2011-2016) during the concerted surveys in the Stelvio NP increased significantly (Mann-Whitney test, U =2, p = 0.0047).

However, it should be pointed out that the high-density values of eagles recorded in March in the Stelvio NP cannot be representative of the situation of the whole regional mountain extent, because the high frequencies of floaters can be heavily influenced by the high availability of ungulate carcasses that weren't found elsewhere, at least not in the abundance present in the Stelvio NP.

Similarly these considerations are valid also for the number of territorial pairs hypothesized at regional scale, but the mean estimate of 116 km^2 for each territory seems realistic even if it does not take into account the differences between protected areas, more favourable to the conservation of this species, and the external areas characterized by less availability of prey and potentially by more human disturbance such as lead poisoning, hunting, poaching and outdoor activities like free climbing, photography and paragliding. In particular, recent studies (Bassi *et al.* 2014, Jenny *et al*. 2015, Madry *et al*. 2015) have demonstrated that lead poisoning within the Alps is not linked to exceptional events, but more likely it represents the 'tip of the iceberg' of a substantial proportion of the Golden Eagle's populations affected by sub-lethal levels of lead, thus indicating the need and urgency to replace lead bullets with other not-toxic metals (most preferably, copper).

In fact, sub-lethal chronic lead assimilation may result in higher mortality or reduced reproduction, potentially affecting a much higher proportion of the population than evidenced from individuals found with symptoms of acute lead poisoning (Bassi *et al*. 2016).

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