Trend and status of the Golden Eagle *Aquila chrysaetos* breeding population in the northern Apennines: Results from 20-years of monitoring

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The historical occurrence of the Golden Eagle *Aquila chrysaetos* in the Northern Apennines is supported by many documentary evidences, and confirmed by several toponyms that include the Italian term "*aquila*" referred to mountainous locations near nesting sites or where this raptor was frequently observed. This raptor was probably more widespread in the past and faced a strong demographic decline due to centuries of human persecution until 1977, when the killing of raptors was definitively banned in Italy. Nevertheless, a number of breeding pairs survived in the wildest locations of the Apennines, most of which were gradually included inside protected areas.

Studies on the status of the Northern Apennines's breeding population date back to the 1980s (Fasce & Fasce 1984) when a total of 8-10 breeding pairs was reported. Updated reports were published some years later by Chiavetta (1994), Chiavetta (2001) and Fasce & Fasce (2003). An improved collection of standardized data from the late 1990s, achieved through the coordination of volunteers from different regions of the study area (Liguria, Tuscany, Emilia-Romagna) resulted in two more recent reports (Magrini & Perna 2007, Schiassi *et al.*, 2013). Currently the monitoring of the breeding population is supported by over 20 observers through regular controls of known pairs and home ranges, according to a standardized field protocol.

This paper aims to update the data collected in Schiassi *et al.* (2013) by reporting on the last four breeding seasons, and to better assess the trend of the Golden Eagle's breeding population and distribution across a period of 20 years (1997-2016). In order to put in evidence the effects due to population increase in time, we compared the breeding performance of the known oldest home ranges during the first decade of monitoring to the ones recorded during the last decade. Our aim was to test the occurrence of variations in breeding performances in time and space associated to increased intra-specific interactions among territorial pairs.

Finally we briefly list further extrinsic factors that may affect demographic variations of the breeding population, including anthropogenic pressures and threats.

The Northern Apennines extend for over 400 km along the WNW-ESE direction, dividing the Po river basin from the Tyrrhenian valleys. This chain is limited to west by the Pass of Cadibona and to east by the Bocca Trabaria Pass; the highest mountain is M. Cimone (2165 m a.s.l). The study area (Fig. 1) was covered through a 5x5 km^2 grid, obtained by partitioning the ETRS89-LAEA 10 x10 km grid. To better define the study area, we applied the criterion of including all the cells with ridges above 800 m, so that the resulting total surface (511 cells, 12,775 km^2) is larger than the one estimated by Schiassi *et al.* 2013 (10,000 km^2). We divided the study area into four sub-regions (west to east: Ligurian Apennines Tuscan-Emilian Apennines, Apuan Alps, Tuscan-Romagnolo Apennines) according to their relative homogeneity in physical and environmental features.

Among the study area cells, 125 (24.6%) comprise ridges above 1400 m, and 23 (4.5%) above 1800 m. The majority of tops exceeding 1800 m a.s.l. are located in the central portion of the chain (Tuscan-Emilian Apennines, Apuan Alps), while few ridges exceeding 1400 m. in the western (Ligurian Apennines) and eastern portion (Tuscan-Romagnolo Apennines). Woodland dominates the landscape. Traditional farmlands and pastures are wide-
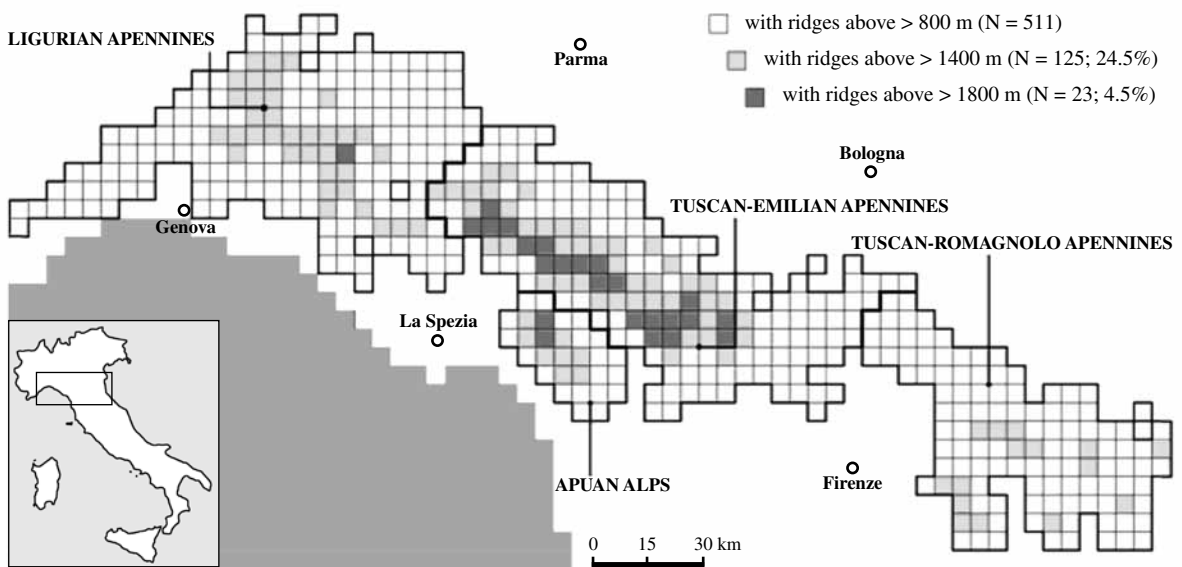
Figure 1. Study area, defined by means of a 5x5 km grid. The cells have been classified according to three classes of altitude a.s.l.

spread in the less steeper slopes, especially in the north side of the study area, while meadows are restricted to ridges over 1500 m. Rocky areas and cliffs mostly occur at medium altitudes along valley sides.

The monitoring protocol of known home ranges required a minimum of 3 visits/pair between late winter and fledging, according to the methods by Fasce (1988) and Eaton *et al.* (2007). Unsuccessful visits with uncertain data were usually repeated. Beyond the breeding period, investigations on new territorial pairs were carried out by exploring suitable sites for the species or cliffs presumably used in the past for breeding, by finding nests on cliff or tall trees, or by reporting stable occurrence of adults. Discovery of new breeding pairs close to known home ranges is usually coupled by simultaneous checks in order to confirm the occurrence of distinct pairs. Visits to potentially-suitable breeding sites were more frequent in the last 15 years as new volunteers were involved in the monitoring efforts.

The annual breeding parameters included: productivity, breeding success and mean number of fledged young/pair, as defined by Fasce (1988) and Andreotti & Leonardi (2007). Data on clutch size was not collected. Individual ages were determined according to moult patterns of the flight feathers into three categories (adult, sub-adult, young). Home ranges of adults that have never bred or attempted to breed with certainty were excluded from the analyses.

Due to missing data on home range boundaries, the breeding distribution was roughly estimated by including the cells where any breeding site was located, plus the 8 cells around. This method employs the theoretical home range model proposed by McLeod *et al.* (2002). Time variation in the breeding distribution has been calculated as percent variation of occupied cells. Density refers to the number of home ranges per 1000 km². The mean nearest neighbour distance (NND) was employed to obtain the maximum theoretical density (Watson 1997).

Means of the breeding parameters for each home range were calculated for the first (1997-2006) and second (2007-2016) decade of monitoring. The home ranges were estimated and then classified as "old" if settled before December 1997, or "new" if settled after. Grouped and paired data were compared using a non parametric test (Wilcoxon Test).

Monitoring datasets collected between 1997 and 2006 are summarized in Fig. 2. The number of detected home ranges gradually increased from 17 in 1997 to 32 in 2016 (+88.2%; mean yearly increase: +3,38%). One breeding home range has never been detected since 2014.

The distribution, computed in terms of number of occupied cells, amounts to 212 units with a percentage increase of 63% from the beginning of the monitoring. Current values compared to those collected during the 1980's result in a remarkable increase in distribution, estimable in about +220-300% of population increase and +140-200% of occupied land. Home ranges of the breeding population are spaced throughout the whole northern Apennines (G Test = 0.84): 13 are located in the Ligurian Apennines, 11 in the Tuscan-Emilian Apennines, 5 in the Apuan Alps,
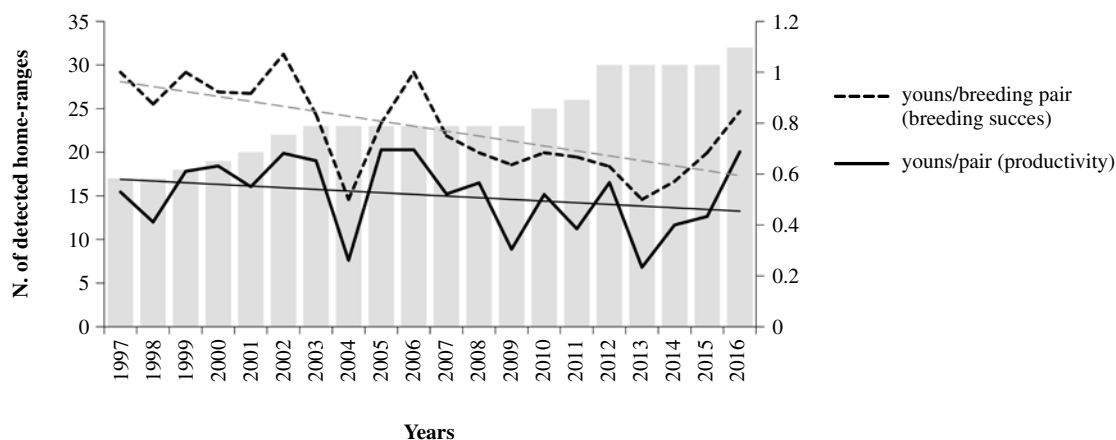
Figure 2. Trends in the number of home ranges, productivity and breeding success of the breeding population monitored between 1997 and 2016.

and 3 in the Tuscan-Romagnolo Apennines; 14 are situated south of the main watershed, 18 north of it (Tab. 1). Home range density, mean NND and maximum theoretical density were 2.51 home ranges/1000 km^2, 11.4 km and 8.9 pairs/1000 km^2 respectively. We noticed a higher increase in number and density of home ranges in the Ligurian Apennines (+10 pairs, from 0.64 to 2.78 home ranges/100 km^2) and Apuan Alps (+2 pairs, from 4.0 to 6.67 home ranges/100 km^2). In the former sub-region the increase is likely to be partly related to a better inspection of suitable sites for breeding.

Cells with ridges exceeding 1400 m occupied by the Golden Eagle account for a higher percent (32.8%) than the total study area (24.5%). In addition, a higher local mean density was recorded in cells having elevated altitude (0.41 home ranges/100 km^2, >1400 m) compared to cells with lower altitude (0.23 home ranges/100 km^2, <1400 m), thus indicating the tendency to select the home ranges mostly close to the main ridges of the Apennines. Relatively-clumped home range zones in the study area gave a local mean density of 0.7-0.8 home ranges/100 km^2, particularly in the Apuan Alps, the Ligurian Apennines and the Tuscan-Emilian Apennines. Conversely, we observed wide zones where home ranges were apparently lacking, such as the western Emilian Apennines, the eastern Tuscan-Emilian Apennines and the eastern Tuscany.

In twenty years of monitoring, 320 detected pairs out of 474 were breeding, 231 of which successfully, producing a total of 244 young (0.76 young/pair/year). Nests with two-nestlings were observed 13 times (3 in 2016). All the known pairs built their nests on cliffs, with the exception of one pair breeding regularly on a very old silver fir *Abies*

alba, while another pair built its nest on a turkey oak tree *Quercus cerris* instead of the usual sites on rock-faces (Schiassi *pers. comm.*, first report of breeding on deciduous tree in the study area, Fig. 3).

Mean productivity was 0.52 young/pair, ranging between 0.23 and 0.70, recorded in 2013 and 2005-2006 respectively. Comparing our observations with that of a previous report (Schiassi *et al.* 2013), we likewise also found no evidence of an increase in yearly mean productivity and negative trend in yearly breeding success. Breeding success resulted positively correlated to the yearly mean NND (Spearman, p <0.008). Productivity of old home ranges significantly decreased from the period 1997-2006 (0.63 young/pair, S.D. = 0.25) to the period 2007-2016 (0.46, S.D. = 0.20; p <0.023, Wilcoxon Test, N = 17). Similarly, the breeding success significantly decreased from 0.90 young per breeding pair (S.D. = 0.29) to 0.70 (S.D. = 0.22) (p <0.016, Wilcoxon Test, N = 17). Among these old home ranges, stronger significant decreases in productivity from the first (0.73, S.D. = 0.21) to the second decade (0.40, S.D. = 0.19, p <0.027; Wilcoxon Test, N = 6) of monitoring were recorded in 6 home range that reduced their NND due to the settlement of new neighbouring home ranges.

The Golden Eagle population of the Northern Apennines experienced a significant increase like in other Italian regions located south of our study area (Magrini & Perna 2007, Magrini *et al.* 2013). Similarly, the monitored population is supported by a mean productivity very close to the value recorded in a breeding population present in central Italy (Magrini *et al.* 2013). A gradual spread on land and the settlement of new home ranges suggest a return to previously occupied locations that were later aban-

Table 1. Breeding parameters, number of home ranges and density in four sub-regions and whole study area.

	decade	Ligurian Apennines	Apuan Alps	Tusco-Emilian Apennines	Tusco-Rom. Apennines	TOTAL Northern Apennines
No. of monitored breeding pairs	*1997-2006*	49	30	98	27	204
	2007-2016	93	40	105	32	270
	1997-2016	142	70	203	59	**474**
Breeding pairs (laying)	*1997-2006*	31	23	60	19	133
	2007-2016	58	30	78	21	187
	1997-2016	89	53	138	40	**320**
No. of young	*1997-2006*	25	20	53	20	118
	2007-2016	45	19	48	14	126
	1997-2016	70	39	101	34	**244**
Productivity (young/pair)	*1997-2006*	0.51	0.67	0.54	0.74	0.58
	2007-2016	0.48	0.48	0.46	0.44	0.47
	1997-2016	0.49	0.56	0.50	0.58	**0.51**
Breeding success (young/breeding pair)	*1997-2006*	0.81	0.87	0.88	1.05	0.89
	2007-2016	0.78	0.63	0.62	0.67	0.67
	1997-2016	0.79	0.74	0.73	0.85	**0.76**
No. of fledged (young/successful breeding pair)	*1997-2006*	1.04	1.00	1.02	1.25	1.05
	2007-2016	1.07	1.00	1.07	1.08	1.06
	1997-2016	1.06	1.00	1.04	1.17	**1.06**
Area (km²)		4675	750	4350	3000	12775
%		36.7%	5.9%	34.1%	(23.3%)	
No. of home ranges in 1997		3	3	9	2	17
New home ranges (1998-2016)		10	2	2	1	15
Current N. of home ranges (2016)		**13**	**5**	**11**	**3**	**32**
No. of home ranges/1000 km²		2.78	6.67	2.53	1.00	**2.50**

doned as a consequence of human persecution. Our results lead to believe that the population trend reflects a true increase, although partly biased by a greater survey effort in certain zone of the study area (in particular, the Ligurian Apennines). The detected trend is likely to be outdated compared to the actual trend, as new pairs were usually discovered a few years after their settlement.

The relatively homogeneous distribution of home ranges is coherent with a regular morphological development of Apennines, since this raptor can find a number of suitable sites for breeding in both sides of the mountain chain, especially on slopes located at average altitudes in the more harsh and deep valleys. Nevertheless, higher local densities were detected in some portion of the study area, likely due to the occurrence of particularly suitable sites for breeding (e.g., high availability of cliffs) as well as the abundance or prey availability.

The breeding performances of the first decade of monitoring in formerly-settled home ranges compared to the breeding performances of the second decade suggest that a marked decrease in productivity and breeding suc-

cess of the oldest home ranges is matched to the settlement of new neighboring home ranges. Territorial interference among neighboring breeding pairs can reduce breeding success (Haller 1982). In our study, this kind of intraspecific interactions induced by newly-settled home ranges could locally affect the breeding parameters of pairs that were settled formerly, but the mechanisms and behaviors involved are still unknown. Furthermore, the age of old adult birds could have direct or indirect negative effects on their breeding performance. In at least two cases we noticed an improvement in breeding performance following the change of one of two partners, but at present we cannot support this explanation due to the unknown age of the bird and to an excessively scarce sample.

At a larger scale, competition is unlikely to be the determinantal factor of variations in breeding parameters, as suggested by the detected low density in home ranges, and lower-than-expected density-dependent effects compared to other monitored regions where high density can affect breeding performance (Fasce *et al.* 2011). In addition, we believe that the local population has not yet achieved its

Figure 3. Peculiar nest built up on a turkey oak growing on a very steep slope (Tuscan-Emilian Apennines). The flying adult has just been replaced by mate during incubation (courtesy of Giorgio Nini).

carrying capacity, in consideration of the increasing number of new home ranges during the last decade, the appearance of new breeding new pairs still incapable of breeding, and the occurrence of potentially suitable sites for breeding.

The implementation of the Birds Directive played a key-role in the conservation of the Golden Eagle. The legal protection of raptors in Italy, coupled with the creation of parks and protected areas, supported the local population thanks to the introduction, protection and increase of prey species. Moreover prey species benefited from natural dynamics following the human abandonment of the Apennine during the last century. In light of our monitoring results, the current status of the Golden Eagle in the northern Apennines can be classified as favorable. Possible threats to the species' conservation in the study area are as follows: illegal killings (shooting, poisoned baits), ingestion of intoxicated prey (e.g. remains or carrion of ungulates killed by lead shot), collision with cables or wind turbines, human disturbance near the breeding sites and habitat modification induced by the abandonment of traditional pastures. Although killing of raptors does not occur as often as in the past, a possible relapse could be caused by the

dramatic reduction of officials employed to deter illegal actions against wildlife, mainly due to recent rearrangement of the local administrations.

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