Short-toed Eagle *Circaetus gallicus* population monitoring at the Apuane Alps migration watch-site (Tuscany)

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Abstract – The aim of this study is the monitoring of the Short-toed Eagle population breeding in the Italian Peninsula, through visual counts performed at the Apuane Alps raptor migration watch-site. The "circuitous migration" performed by the species makes it possible to know the source and destination of the migrating eagles. Total migration counts were collected at the site over a six-year period 2008-2013 in March (max 1845, average 1472) and September (max 1934, average 1459). The total spring and autumn counts are compared to validate the reliability of the observations. Data about Short-toed Eagle population trends are analyzed over a ten-year spring sample period 2004-2013, showing the median date (average on 16 March and 21 September) and the peak passage (on 14 March and 21 September). Two samples of 12-day peak periods in spring and autumn over nine years (2005-2013) are compared to validate the trends and the reliability of the counts. Trends of the mean hourly rate over a nine-year period (2005-2013) in spring and autumn are also analysed. Our results allow us to estimate the population size of Short-toed Eagles breeding in Central-Southern Italy (514-872 pairs) and to provide an updated estimate of the entire Italian population (626-1025 pairs). Our data show that Short-toed Eagle population trends have been positive over the last ten years (+102.5%, +10.25% yearly average) and we recommend that the population trend status of the species in Italy be upgraded to "Increasing".

Key-words: Short-toed Eagle, *Circaetus gallicus*, raptor migration, population monitoring, population trends, Apuane Alps.

INTRODUCTION

Information on the population status of raptor species is essential for their conservation. However, surveying and monitoring raptor populations in their breeding areas is challenging, due to large territories, high costs in terms of funds and human resources, and potential disturbance to breeding sites (Bildstein *et al.* 2009).

As raptors often congregate during migration, one effective way of monitoring them is to sample their numbers at "migration bottlenecks" along migration corridors (Bildstein *et al.* 2009). Counts at migration watch-sites are also used to study migration behaviour and ecology, such as flying dynamics, energy management, weather effects, species interactions, roosting and feeding (Bildstein *et al.* 2009).

Despite the difficulty of knowing the origin of migrants, watch-sites are important for monitoring raptor populations and trends (Bednarz *et al.* 1990, Kjellén & Roos 2000, Yosef & Fornasari 2004), and in conjunction with banding and satellite tracking they help delineate the geographic sources and destinations of the migrating raptors (Bildstein *et al.* 2009).

Although yearly counts can vary considerably due to many factors (such as weather condition, skills of observers, protocol used, adherence to the procedures and equipment used), evidence suggests that long-term observations concentrated over the main peak passage period of the species typically reflect their population status and can provide a good assessment of population size (Lewis & Gould 2000, Zalles & Bildstein 2000, Agostini *et al.* 2007, Bildstein *et al.* 2009).

The Apuane Alps is an important raptor migration watch-site due to the behavioral studies carried out there, including: circuitous migration of Short-toed Eagle *Circaetus gallicus* and Booted Eagle *Aquila pennata*, arched migration of Black Kite *Milvus migrans*, and reverse migration of Western Honey Buzzard *Pernis apivorus* (Premuda 2007, Premuda *et al.* 2010b). Due to the fact that the species avoids long sea-crossings (Agostini *et al.* 2002b),

the source and destination of migrating Short-toed Eagles are obvious (the Italian Peninsula) and supported by satellite tracking (Mellone *et al.* 2011a), allowing the monitoring of the Central-Southern Italian population of Short-toed Eagle and its trends from the watch-site (Premuda 2007). In addition, the risk of double counts is extremely low due to the topography of the site: a bottleneck between a coastline (Versilia) and a mountain chain (Apuane Alps) (Premuda 2007, Premuda *et al.* 2010b).

Short-toed Eagle migration has been studied in depth in Italy and its specific "circuitous" migration involving most of the Italian population has been documented, both in spring (Premuda 2004a, 2007, Baghino & Premuda 2005, 2007) and in autumn (Agostini *et al.* 2002a, 2004, 2009, Premuda 2002, 2004b, 2007, Ruggieri *et al.* 2006, Baghino *et al.* 2012). This is probably the result of a conservative strategy (Agostini *et al.* 2002b) and very likely involves a population of western origin (Agostini & Mellone 2008).

Short-toed Eagle migration in Italy has been studied with satellite tracking confirming the circuitous route of some juveniles from Southern Italy (Basilicata) as well (Mellone *et al.* 2011a). Satellite tracking confirmed the hypothesis of summering of some immatures in North Africa (Premuda *et al.* 2010a, Mellone *et al.* 2011b). In addition, evidence of Short-toed Eagle movements towards the Balkans from the Adriatic coast has never been reported (Premuda *et al.* 2004, 2008, 2010a) and the Short-toed Eagle circuitous migration en route to Bosphorus has been observed in Greece at Mount Olympus (Panuccio *et al.* 2012).

The Short-toed Eagle is a fully migratory species (Zalles & Bildstein 2000), in which at least 90% of all individuals leave the breeding range during the non-breeding season (Kerlinger 1989).

In Europe the species is classified as: SPEC 3, Status "Rare" (Criteria < 10000 pairs), 8400-13000 breeding pairs, with the trend "Small decline" (Birdlife International 2004).

In Italy the Status is "VU = Vulnerable" (Peronace *et al.* 2012) and "Stable" (Birdlife International 2004), considering the "Criterion = D1" with a population of less than 1000 adult individuals: 700-800 (350-400 pairs) (Brichetti & Fracasso 2003) and no evidence of immigration from other regions is reported (Peronace *et al.* 2012).

The aim of this study is to highlight the importance of the Apuane Alps watch-site for raptor population monitoring in Italy, provide an estimate of the Short-toed Eagle population of Central-Southern Italy and his trends, and review and update of the estimated breeding population of Short-toed Eagle in Italy.

MATERIALS AND METHODS

Observations took place on the western slopes of the Apuane Alps (Tuscany), as part of the visual counts of raptor migration performed annually at the site since 1998. The main observation point used was Capriglia (Pietrasanta, Lucca), located about 5 km inland of the Tyrrhenian seacoast (43°58'2.6"N - 10°14'22.8"E, 378 m a.s.l.).

Observations were performed daily from about 09:00 to 17:00 (GMT+1); for each observation, time (hh:mm), species, number of individuals, sex and age (whenever possible), flight direction of birds (incoming and outgoing) were recorded. The observations were aided with binoculars and telescopes. Observations were concentrated over the main peak passage period of the adults of the species: March and September (Cramp & Simmons 1980).

Specific identification and ageing characters used are those provided by Clark (1999), Forsman (1999), Premuda (2004c), Premuda *et al.* (2010a). In agreement with Forsman (1999), second and third calendar year birds were considered immatures while older birds, including those in their fourth calendar year, were considered adults.

Data were collected consistently at the same watch-site with a common standard protocol and counting method within and among years (Lewis & Gould 2000, Bildstein *et al.* 2009).

Population estimate

For the population estimate, the total spring counts (1-31 March) of the last six years (2008-2013) are considered. The total autumn counts (1-30 September) are compared (Kruskal-Wallis test) with spring counts to validate the reliability of the spring counts.

As assumption the percentage of non-breeding adults is 4%, considering that in Central-Italy 3.6% of the studied pairs occupy the territories without breeding (six pairs out of 166 in 1988-2007) (Petretti 2008). The total number of adults and immatures is estimated according to the proportions (percentages) recorded in the sample of whose age was estimated.

The formulas used for the estimate of the Short-toed Eagle population in Central-Southern Italy (south of the Apuane Alps) are the following:

- Minimum number of pairs = Minimum spring count * Percentage of adults (mean) - Percentage of non-breeders / 2
- Maximum number of pairs = Maximum spring count * Percentage of adults (on 2013) - Percentage of non-breeders / 2

Population trend

For the population trend in spring over the ten-year period 2004-2013, the sample period of 19 continuous common days (6-24 March) is considered. As this 19-day period data is not fully available in autumn for the whole ten-year period, two samples of 12-day peak period (11-22 March and 15-26 September) over a nine-year period (2005-2013) are compared (Kruskal-Wallis test) to validate the trends and the reliability of the spring and autumn counts.

Trends of the mean hourly rate are also analysed (Kruskal-Wallis test) over a nine-year period (2005-2013) in spring (6-24 March) and autumn (15-26 September).

RESULTS

Population estimate

Over the six-year sample period of counts (2008-2013), 1152.5 hours (over 148 days) and 1160.5 hours (over 135 days) of observations were performed in spring (1-31 March) and autumn (1-30 September) respectively (spring hours/day: x = 7.80, SD = 0.63, CV = 8.07%; autumn hours/day: x = 8.56, SD = 0.45, CV = 5.26%).

During the spring counts (1-31 March) over the six-year sample period (2008-2013), a total of 8832 Short-toed Eagles was observed with a maximum of 1845 (x = 1472, SD = 274.01, CV = 18.63%), while during the autumn counts (1-30 September) a total of 8752 birds with a maximum of 1934 was recorded (x = 1459, SD = 415.63, CV = 28.49% (Tab. 1; Fig. 1).

The Kruskal-Wallis test (non-parametric data) on the spring and the autumn data series gives as result H = 0.

Considering that 98.5% (*N* = 468) of the age estimated birds in March 2013 (*N* = 475) were identified as adults, it is proportionally estimated that 1817 adult and 28 immature Short-toed Eagles passed in March 2013. During March 2010 and 2012, 98.1% (*N* = 709 out of 723 age estimated birds) and 95.0% (*N* = 537 out of 565) of adults were identified respectively. These percentages provide an average of 97.2% for the three consistent and comparable sample periods analyzed (2010, 2012, 2013).

Considering the data collected during the survey (Tab. 1; Fig. 1), it is possible to calculate an estimate of the Short-toed Eagle population of Central-Southern Italy (south of the Apuane Alps) as follows (see methods):

- Minimum number of pairs: 1102 * 0.972 – 4% / 2 = 514 pairs
- Maximum number of pairs: 1845 * 0.985 – 4% / 2 = 872 pairs

Population trend

Over the ten-year spring counts (2004-2013), during the common sample period (6-24 March), 1425 hours (over 178 days) of observations were performed (hours/day:

Table 1. Total counts of spring (March) and autumn (September) over six years (2008-2013).

Years	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	Average
Spring	1228	1102	1549	1451	1657	1845	1472
Autumn	909	1042	1389	1743	1735	1934	1459

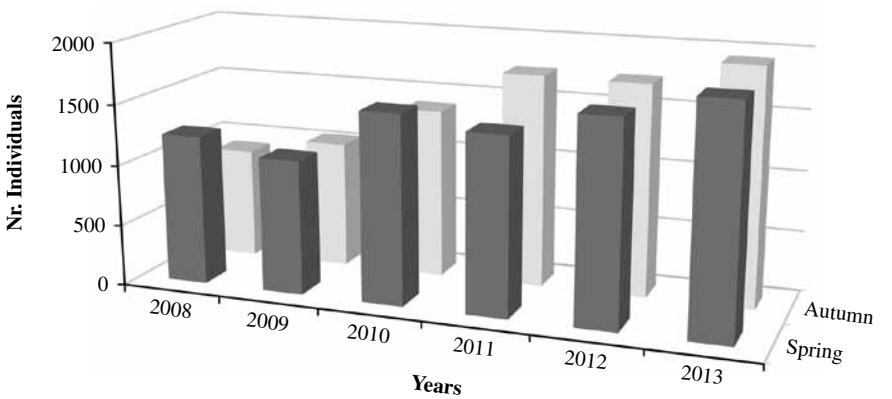

Figure 1. Spring (March) and autumn (September) total counts of migrating Short-toed Eagles at the Apuane Alps watch-site during a six-year sample period (2008-2013).

x = 8.01, SD = 0.63, CV = 7.92%) and a total of 11380 Short-toed Eagles was observed (x = 1138, SD = 338, CV = 29.70%) (Tab. 2; Fig. 2).

Over the nine-year period of counts (2005-2013), during the common sample periods (11-22 March, 15-26 September), 890 hours (over 105 days) and 949 hours (over 107 days) of observations were performed in spring and in autumn respectively (spring hours/day x = 8.49, SD = 0.54, CV = 6.41%; autumn hours/day x = 8.87, SD = 0.29, CV = 3.27%; spring + autumn SD = 0.47, CV = 5.36%). During the 12-day peak period in spring, a total of 9331 Short-toed Eagles was observed in spring (x = 1037, SD = 344.3, CV = 33.21%), while during the 12-day peak period in autumn, a total of 8731 birds was recorded (x = 970, SD = 202.7, CV = 20.90%) (Tab. 3; Fig. 3).

The Kruskal-Wallis test (non-parametric data) on the spring and autumn data series of the 12-day peak period over nine years gives as result H = 0.095.

The mean hourly rate (birds/hr) recorded during the common sample period in spring (6-24 March) and autumn (15-26 September) over nine years (2005-2013) was on average 8.20 and 8.77 respectively, with a minimum of 5.18 in March 2007 and a maximum of 12.93 in September 2013 (Tab. 4).

The Kruskal-Wallis test (non-parametric data) on the spring and autumn data series of the mean hourly rate gives as result H = 0.3820.

The median date of passage recorded in spring 2005-2013 was comprised between 13 and 21 March with average on 16 March, while in autumn it was comprised between 18 and 23 September with average on 21 September (Fig. 5).

Considering the nine-year sample period (2005-2013), the peak passage of the migration flow of Short-toed Eagles at the Apuane Alps was recorded on 14 March in spring (6-24 March) and on 21 September in autumn (15-26 September) (Fig. 6).

DISCUSSION

Population estimate

The Kruskal-Wallis test on the data series, shows that the spring and the autumn counts refer to the same population (H = 0).

The high value of standard deviation and related coefficient of variation both in spring and in autumn counts confirm that the size of the count is not the same year after year (Tab. 1; Fig. 1).

The average percentage of birds identified as adults (*N* = 97.2%) is in line with previous studies performed at the Apuane Alps: 97.5% in 2004-2006 (Baghino & Premuda 2007).

Based on the available published information, the Ital-

Table 2. Records in the common sample period in spring over ten years (2004-2013).

Years	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	Average
Spring (6-24 March)	827	868	809	712	1223	1091	1228	1336	1611	1675	1138

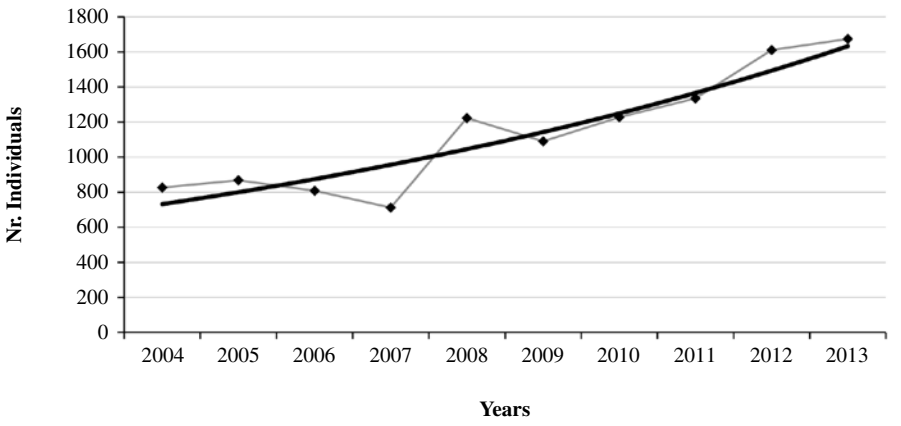

Figure 2. Spring (6-24 March) trend of migrating Short-toed Eagles at the Apuane Alps watch-site on a 19-day common sample period over ten years (2004-2013).

Table 3. Records in the peak sample periods in spring and autumn over nine years (2005-2013).

Years	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	Average
Spring (11-22 March)	839	591	603	1198	1051	1037	964	1434	1614	1037
Autumn (15-26 Sept.)	836	724	792	798	910	1060	1211	1118	1282	970

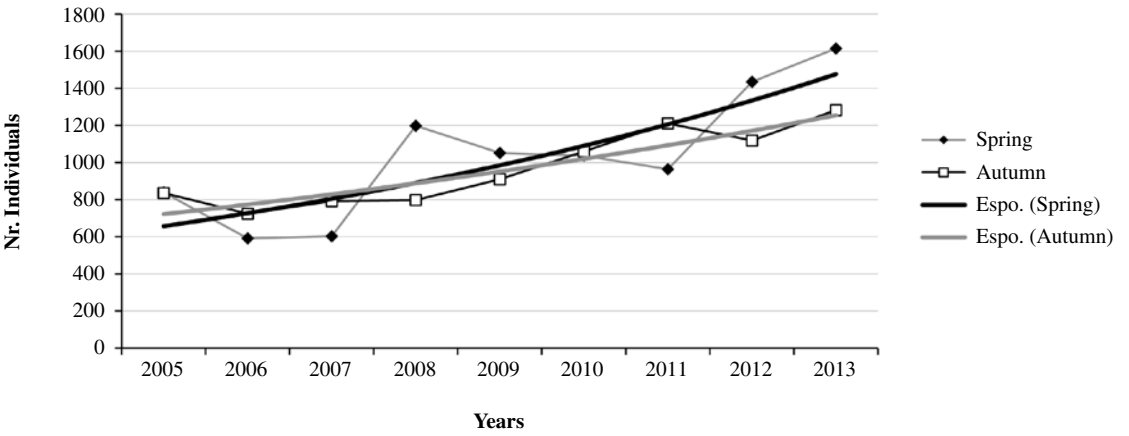

Figure 3. Spring (11-22 March) and autumn (15-26 September) trends of migrating Short-toed Eagles at the Apuane Alps watch-site on a 12-day peak sample period over nine years (2005-2013).

Table 4. Mean hourly rate (birds/hr) during the common sample period in spring (6-24 March) and autumn (15-26 September) over nine years (2005-2013).

Years	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	Average
Spring (6-24 March)	5.9	5.5	5.2	9.7	8.4	8.1	8.5	9.6	12.9	8.2
Autumn (15-26 Sept.)	8.0	6.7	7.3	6.1	6.6	10.1	11.1	10.0	12.9	8.8

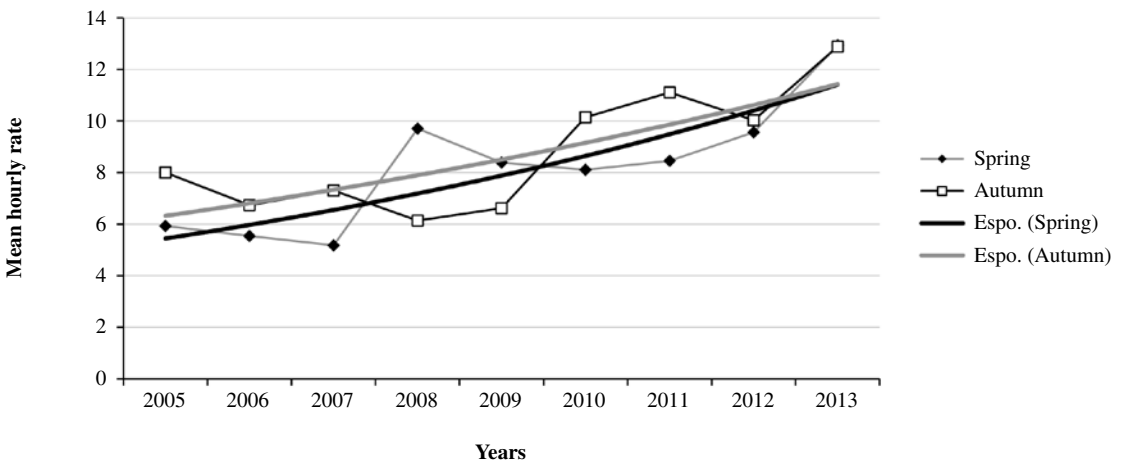

Figure 4. Spring (6-24 March) and autumn (15-26 September) trends of the average hourly rate (birds/hr) of migrating Short-toed Eagles at the Apuane Alps watch-site over a nine-year sample period (2005-2013).

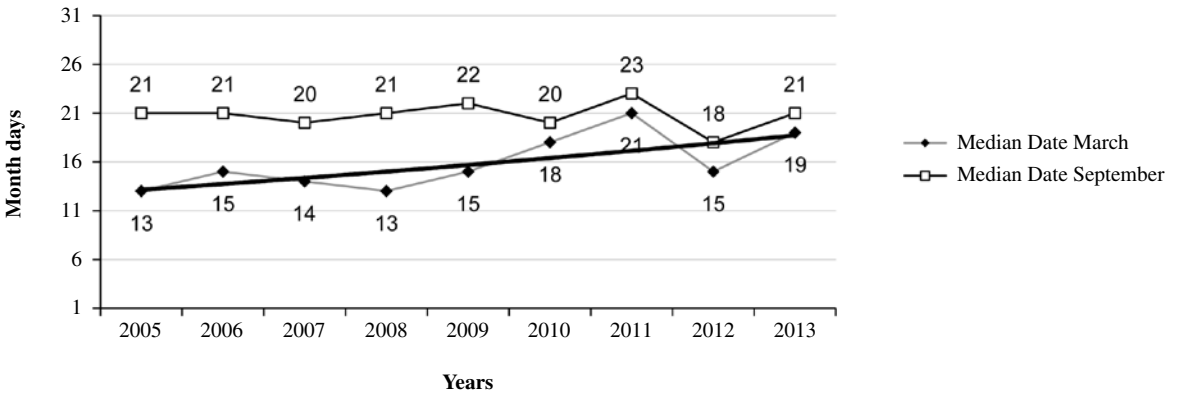

Figure 5. Spring (6-24 March) and autumn (15-26 September) trends of the median date of the migration flow of Short-toed Eagles at the Apuane Alps watch-site over a nine-year sample period (2005-2013).

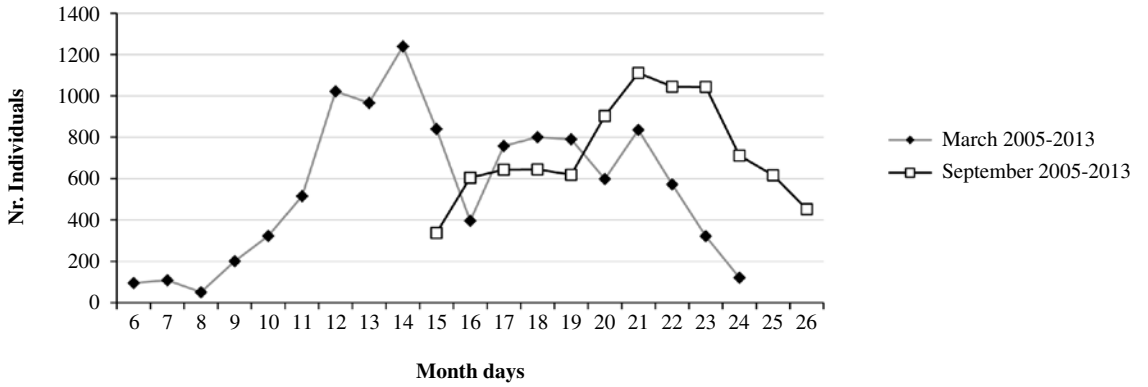

Figure 6. Spring (6-24 March) and autumn (15-26 September) peak passage of the migration flow of Short-toed Eagles at the Apuane Alps watch-site over a nine-year sample period (2005-2013).

ian population north of the Apuane Alps is estimated at 112-153 pairs as follows:

- Italian Western Alps and Pre-Alps: 53-88 pairs (Cattaneo 1998);
- Ligurian Apennines: 50-55 pairs (Campora & Cattaneo 2006);
- Northern Emilian Apennines 9-10 (Battaglia 2002, Ravasini 1996).

The estimated figures north and south of the Apuane Alps provide a total of 626-1025 pairs for the entire Italian population. This estimate should be considered as conservative because during the visual counts on the field it is practically impossible to detect all the migrating raptors.

Despite the most recent estimate published - 350-400 (Brichetti & Fracasso 2003), 480-520 (Baghino & Premuda 2005), 500 (Campora & Cattaneo 2006), 560 (Petretti 2008), 600-700 (Baghino *et al.* 2009) - an update of the official estimate of the entire Italian Short-toed Eagle population is highly recommended (Baghino 2013), considering at least the above-mentioned range of 626-1025 pairs.

Population trend

The recorded spring and autumn peak passages (Fig. 6) are in line with the known peak of the species in Europe (Cramp & Simmons 1980).

Spring median date has clearly shifted later in March in the last years, while in autumn it remained stable (Fig. 5). The shift of the spring median date in the last four years (Fig. 5) could be explained by the occurrence of bad weather and rain fronts that stopped and then released the raptor migration, especially during March 2011 and 2013. The high value of standard deviation and related coefficient of variation both in spring and in autumn ten-year and nine-year counts (see results), confirms that the size of the count is not the same year after year.

Over the ten-year period of counts in spring (2004-2013), considering the counts in 2004 (N = 827) and 2013 (N = 1675) an increase of +102.5% over 10 years occurred (10.25% yearly average) (Tab. 2).

The analyzed data collected at the Apuane Alps watch-site shows a clear positive trend over the ten-year and nine-year periods studied (Tab. 2, 3, 4; Fig. 2, 3, 4).

The Kruskal-Wallis test result on the selected data series over the nine-year period of counts (2005-2013) (H = 0.095), shows that the spring and the autumn counts belongs, with high probability, to the same population. Thus, the trends of the two selected 12-day peak sample periods (11-22 March, 15-26 September) are comparable, confirming the reliability of the counts (Tab. 3; Fig. 3).

During the common sample periods (6-24 March, 15-26 September) over nine years (2005-2013) the spring and autumn positive trends of the mean hourly rate (birds/hr) are comparable (H = 0.3820), confirming the reliability of the counts (Fig. 4). Overall, the number of Short-toed Eagles recorded over the periods (Tab. 2, 3) shows a clear positive trend both in spring (Fig. 2) and in autumn (Fig. 3), thus, as recommendation we suggest to update the population trend status of the species in Italy as "Increasing".

Interestingly, other studies conducted at raptor migration watch-sites showed a similar tendency.

At the Arenzano watch-site (Genova, Liguria), an increasing trend over spring 2000-2008 was reported based on an analysis of the mean hourly rate (birds/hr) (Baghino *et al.* 2009). In addition, an yearly increase of 11.7% and 6.9% is calculated analyzing standardized data from March 1988-2011 and September 2000-2011 respectively (Baghino 2013).

At the Pyrenees raptor watch-sites, an increase of counts of 125% over 25 years (+5% yearly) was recorded in autumn (Urcun 2007) and at the Strait of Gibraltar a strong growth in records occurred during autumn 2007-2009 (Yáñez Vega 2009, De La Cruz *et al.* 2011).

In Italy at Monti della Tolfa (Latium), Petretti (2008) reported an increase of 26% of the breeding pairs during 19 years, from 11 pairs recorded on 1981 to 15 on 2000 (13.7% over ten years) probably reaching the full carrying capacity of the area.

Petretti (1988) estimated 380-415 pairs breeding in Italy. This value was obtained as an extrapolation of the breeding density in sample areas to the whole territory occupied by the species in Italy. After twenty years, Petretti (2008) estimated 560 pairs breeding in Italy (+35%; 17.5% over ten years). This value was obtained by applying the breeding density of a sample area (Monti della Tolfa, Latium; 35.6 km^2/pair) to the whole territory potentially suitable for the species in Italy.

Examples of the recent expansion of the species include: in Tuscany at the Apuane Alps, the first evidence of breeding was collected in 2013 (G. Premuda *pers. obs.*), while in the Elba Island the Short-toed Eagle started to breed about fifteen years ago (G. Paesani *pers. comm.*); in Switzerland the first breeding of the species for the country was recorded on 2012 in Haut-Valais (Maumary *et al*. 2013).

Most probably, the increase of the Short-toed Eagle population in Italy is not linked to only one root cause but to several concurrent factors contributing to the positive trend. Research on the root causes of this population increase is thus warranted.

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