The Apennine brown bear: A critical review of its status and conservation problems

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Abstract: The small and isolated population of brown bears (*Ursus arctos marsicanus*) in the Central Apennines, Italy, has been protected since the establishment of the National Park of Abruzzo, Lazio and Molise in 1923, but little active management has been implemented during the past decades to ensure effective conservation of this population. Being almost exclusively distributed within the National Park and its immediate surrounding mountains, the Apennine brown bear population suffered high human-caused mortality in the last 3 decades, but no reliable estimates of its size, trends, and vital statistics have ever been produced. Given the paucity of information available at the international level, we have critically reviewed the status of the Apennine brown bear population and have summarized data and information concerning past management. By describing the threats that appear to be the most immediate (lack of reliable knowledge, small population size, persistent illegal killing, administrative fragmentation across the bear range), we comment on what might and might not have worked in previous conservation assessments of this population. Our final aim is to substantiate more effective conservation efforts in the immediate future. The challenge of saving the Apennine brown bear calls for a renewed effort based on sound, applied research, addressing issues from basic ecology to the human dimension.

Key words: Abruzzo National Park, Apennines, brown bear, conservation status, Italy, *Ursus arctos marsicanus*

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In light of the persistent small size of the Apennine brown bear (*Ursus arctos marsicanus*) population, and its high human-caused mortality rates reported during the past decades (Zunino and Herrero 1972, Boscagli 1987, Posillico et al. 2002, Lorenzini et al. 2004b), a renewed effort for conservation of this population is critically and urgently needed. Recovery of small brown bear populations is a major conservation priority in Europe (Habitat Directive 92/43/CEE). Long-term isolation of the Apennine population from other brown bear populations also makes it a unique evolutionary and conservation unit, based on genetic (Randi et al. 1994, Lorenzini et al. 2004a), morphological (Bologna and Vigna Taglianti 1992, Vigna Taglianti 2003, Loy et al. 2008), and perhaps behavioral (Zunino 1976, 1981; Boscagli 1999) traits.

Although the 500 km^2 National Park of Abruzzo Lazio and Molise (PNALM), where most of the Apennine brown bears still survive, has been — and still is — instrumental for the conservation of this sole, remnant bear population, no conservation strategy based on a single protected area will ensure the long-term maintenance of a viable bear population. Furthermore, current lack of reliable data for the Apennine brown bear population sharply contrasts with the need to develop a sound, effective, and outreaching conservation strategy. Due to the lack of any formal approach to population estimation, the assessment of population trends and threats has been traditionally limited to expert opinions. Accordingly, the absence of any monitoring program, whether addressed to the population and its resources, or to the implementation of conservation measures, has made it impossible to adapt management policies and interventions. As a result, the Apennine brown bear population appears to be declining or stable at best, despite the 85 years of protection within the PNALM and many conservation projects launched to facilitate its expansion, both in range and numbers.

Given the limited published information concerning the Apennine brown bear at the international level, we hereby provide a critical review of the

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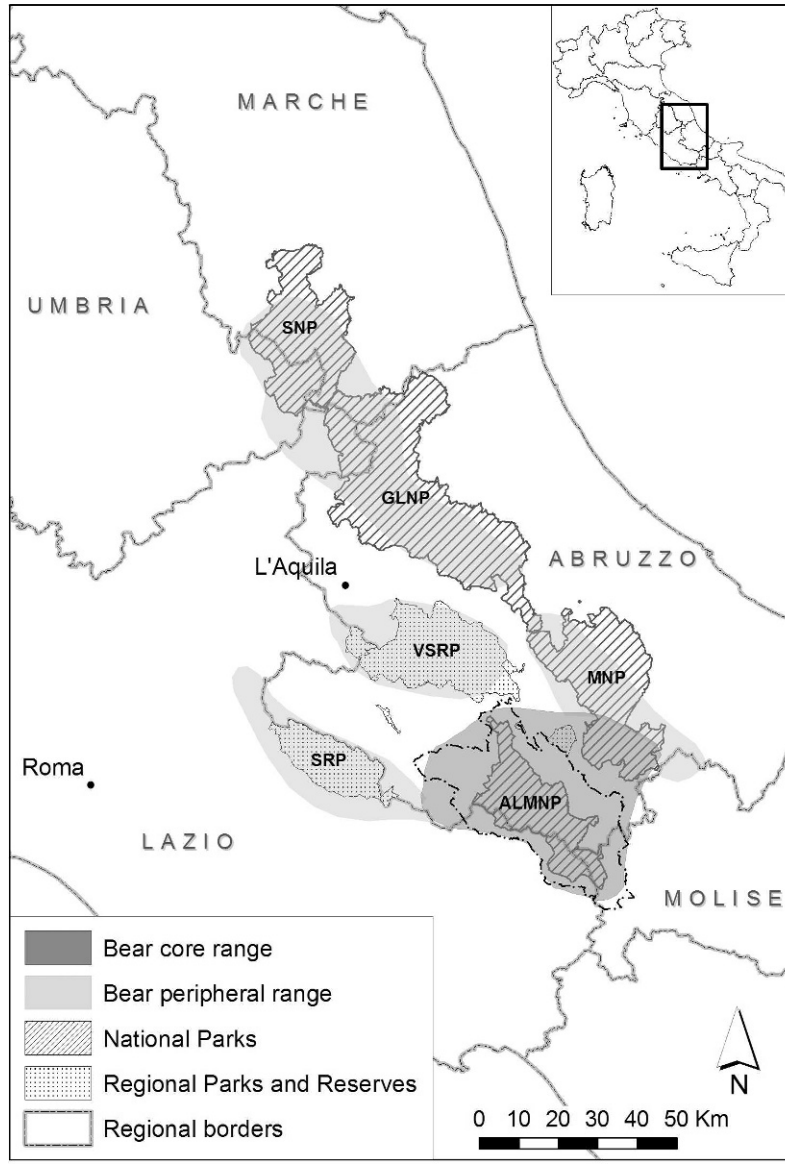

Fig. 1. Approximate range of the Apennine brown bear and distribution of the main protected areas in the central Apennines (SNP: Sibillini National Park; GLNP: Gran Sasso–Laga National Park; MNP: Majella National Park; ALMNP: Abruzzo Lazio and Molise National Park; VSRP: Velino–Sirente National Park; SRP: Simbruini Regional Park). Dashed line around ALMNP represents its external buffer area (modified from Boscagli et al. 1995, Posillico et al. 2004, Falcucci 2007).

status, current knowledge, and past management of this bear population. Although we present no original data, we build upon population status reports (e.g., Boscagli 1999, Swenson et al. 2000, Zedrosser et al. 2001) and other literature to summarize published data and evaluate the effectiveness of management policies and interventions.

History and status

A small population of the Apennine brown bear (*Ursus arctos marsicanus*; Altobello 1921) is still present in the Apennine mountains in Central Italy, about 100 km east of Rome (Fig. 1). However, it has been separated from the Alpine population for at least 400–600 years (Randi et al. 1994, Lorenzini et

al. 2004a). Following random drift and extinction of maternal lineages since isolation, the original genetic diversity of this small brown bear population has been severely depleted (Lorenzini et al. 2004a) and it now possesses a unique mtDNA haplotype (Randi et al. 1994). In addition, recent multivariate skull analyses clearly separated the Apennine from other Alpine and Pyrenean brown bear populations, suggesting that its differentiation from other bear populations could be older than an assumed post-glacial isolation model (Vigna Taglianti 2003, Loy et al. 2008). The Apennine brown bear is protected by law (National Laws 157/92 and 150/92) and European directives (Habitat Directive 92/43/CEE), and it is included as a fully protected species in the Bern Convention (1979) and in the European rule (1986) on the implementation of the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES). A description of the study area can be found in Zunino and Herrero (1972), Posillico et al. (2004), and Falcucci et al. (2008).

Historic and recent distribution

Historically spanning most of the Apennine range (Zunino and Herrero 1972, Carpaneto and Boitani 2003), the Apennine bear distribution has progressively been reduced since the 17th century (Boscagli 1990, 1999; Febbo and Pellegrini 1990, Boscagli et al. 1995). Consistent range reduction has particularly occurred over the past 200 years, mostly due to human persecution (Febbo and Pellegrini 1990). In 1923, the PNALM was formally established, and by the 1970s the remnant bear population survived almost exclusively in the Park and its immediate surrounding mountains (Zunino and Herrero 1972).

Historical and recent data on bear presence in the Apennines is available (Febbo and Pellegrini 1990, Boscagli et al. 1995, Posillico et al. 2004), but no method has been applied to formally assess its range. Based on occasional signs of presence recorded more or less regularly in the Central Apennines, the current extent of occurrence of the population appears to be differentiated into one core and some peripheral areas (Fig. 1; Posillico et al. 2002, 2004). The core of the Apennine bear population range comprises the PNALM ecosystem (the Park and its contiguous areas, for about 1,500–2,500 km^2), whereas the peripheral area includes a limited number of bears, possibly occasional dispersers, irregularly detected at much lower densities in more peripheral areas northwest, northeast, and east of the PNALM. This marginal population is partly included within a larger network of protected areas in the Central Apennines (Fig. 1), embedded in a matrix of more than 10,000 km^2 of estimated suitable bear habitat (Posillico et al. 2004, Falcucci 2007, Falcucci et al. 2007). This larger area encompasses 5 regional (Abruzzo, Lazio, Molise, Umbria, and Marche) and 12 provincial administrations that have a direct or indirect impact on bear conservation through land use regulations. Inconsistency of the species occurrence in this peripheral range suggests that these bears were and still are of limited significance for the dynamics and conservation of the population (Fabbri et al. 1983, Boscagli et al. 1995, Boscagli 1999, Posillico et al. 2004). However, they may indicate that some connectivity occurs with the core population in the PNALM (Boscagli 1999), although this assumption needs to be validated. The furthest bear presence from the PNALM was recorded 110 km north as recently as 2007 in Sibillini National Park (Fig. 1), where an adult male was repeatedly detected by means of camera traps and hair-snagging (P. Forconi, Sibillini National Park, Visso, Italy, personal communication, 2007), and remotely genotyped (E. Randi, Italian Institute for Wildlife Conservation, Ozzano Emilia, Italy, personal communication, 2008).

However, no significant extension characterized the historical bear range in a southward direction from the PNALM (Febbo and Pellegrini 1990). In this area, higher levels of human activity might provide excessive disturbance to bears (Boscagli et al. 1995), creating a significant gap in connectivity between suitable habitat patches (Posillico et al. 2004). Marginal efforts, however, have been historically devoted to monitor bear presence in this area.

The nature and frequency of bear monitoring in these peripheral areas (Majella–Morrone and Gran Sasso–Laga national parks; Febbo and Pellegrini 1990, Boscagli et al. 1995) has made it impossible to accurately assess the dynamics of the bear range outside the PNALM over the last 30 years (but see Zunino 1981, 1990; Boscagli et al. 1995). Accordingly, no fine-scale dynamics of the range of the core PNALM population can be quantitatively evaluated for the same period. However, miscellaneous signs of bear presence as well as movements of radiocollared bears in recent years (H.U. Roth, PNALM, Pescasseroli, Italy, unpublished data; Ciucci et al. unpub-

Table 1. Historical and recent estimates of the Apennine brown bear population size in the National Park of Abruzzo Lazio and Molise and the Central Apennines, Italy, 1928–2004.

Year	Bear population	Study area location (size, km^2)	Methods	Reference
1928–68	60–180	park and vicinity (none)	educated guess[a]	Various (listed in Zunino 1976:682)[b]
1930s	<100	park and vicinity (none)	guess	Zunino and Herrero 1972
1970	70–100	park and vicinity (360 + 160[c])	cumulative count of signs of presence[d]	Zunino and Herrero 1972; Zunino 1976
1974	66	park and vicinity (520)	cumulative count of signs of presence[d]	Zunino 1976:679, 1990
1972–82	45–80[e]	park and vicinity (none)	cumulative count of signs of presence[d]	Fabbri et al. 1983
1985[f]	48–49[g] (70–80)	park and vicinity (600)	snow-tracking survey	Boscagli 1990 (Boscagli 1991, 1999)
1995	30–40	park and vicinity (none)	educated guess[h]	H.U. Roth, personal communication
1997–98	40–80	Central Apennines (~5,000)	expert opinion	Zedrosser et al. 2001
2000–03	40[i]	park and buffer zone (698–1,564)	remote genetic sampling	Lorenzini et al. 2004a, Potena et al. 2004
2004	43 (35–67)[j]	park and buffer zone (1,462)	DNA-based CMR modelling	Gervasi et al. 2008

[a]Includes 2 (1928, 1931) snow-tracking survey attempts (Zunino 1976)
[b]Interviews, internal documents, correspondence, and technical reports
[c]Bear density estimated in a 360 km^2-core and extrapolated to additional 160 km^2 of 'usual bear presence'; additional 405 km^2 in the surrounding mountains may have been inhabited by other bears (Zunino & Herrero 1972)
[d]Criteria of Zunino & Herrero (1972) contemplated (1) monthly mapping the cumulative signs of bear presence in a core area; (2) clustering them according to individual (unduplicated) bears, assuming their restricted movements; (3) summing the number of bears detected in the month with the highest count to the number of additional bears detected in other months to produce an annual estimate, and (4) extrapolating bear density in the core area to the entire area with stable bear presence.
[e]An approximate figure (Fabbri et al. 1983); the authors believed the real figure was "several tens" higher to include bears living "outside the study area and those living in secluded, rarely patrolled Park valleys" (Fabbri et al. 1983:164).
[f]A second snow-tracking survey was attempted in 1988, but lack of snow did not allow the application of the technique on the entire study area (Boscagli 1991).
[g]Described as the "absolute minimum number" (Boscagli 1990); higher estimate includes bears indirectly estimated in more peripheral ranges of the Central Apennines (Boscagli 1991)
[h]Subjectively based on live-capture frequency and rate of sightings and detection of tracks
[i]45% of which (n = 18) captured only once (DNA analyses based on 9 microsatellite loci)
[j]95% confidence interval

lished data) suggest no significant range modifications have occurred in the core population since the 1970s (Zunino and Herrero 1972).

Population size and trends

Although the Apennine brown bear population represents one of the most endangered mammal species in one of the oldest Italian National Parks, no reliable estimate of the Apennine brown bear population size has ever been produced. However, bear population estimates have been irregularly attempted using approaches from guesses to uncorrected counts of tracks in the snow, producing results that vary 3-fold (Table 1). The diversity and often subjective nature of the methods, including sampling approaches, definition of the study area, or inference criteria, severely limited the interpretability and comparability of these estimates.

The first attempt to make a formal assessment of the bear population abundance within the PNALM and neighbouring areas was carried out in 1970, with 70–100 bears estimated in 520 km^2 (about the size of today's PNALM). This figure was quoted for years by the Park as a reliable estimate of the bear population size (Tassi 1990), even though it likely was an overestimate (S. Herrero, quoted in Wilson and Castellucci 2006). However, other sources of error could have affected the reliability of this estimate, as the method implied a subjective assignment of signs of presence (sightings, scats, tracks, diggings, rolled stones, feeding remains, claw marks, hair samples, dens and resting places, depredations to crops and livestock) to individual bears (Zunino

and Herrero 1972, Zunino 1976). Emphasizing the inherent uncertainty of this approach, Zunino (1976:679), by applying the same method in 1974, reported a 30% decrease in population, which was interpreted in terms of expected variation in bear detectability and wardens' reporting effort. In the years 1974–82, other authors used the same method, reconstructing a minimum population size of 45–80 bears in the PNALM and reporting inter-annual variations of up to 21% (Fabbri et al. 1983). These were interpreted as natural fluctuations, and no sampling error was taken into account, even though it might have shadowed any population trend in those years. In 1985, based on an unreplicated, late-fall snow-tracking count, Boscagli (1990) counted an absolute minimum of 48–49 bears over an area of 600 km^2, comprising 400 km^2 in the PNALM and 200 km^2 of its buffer area. The same figure was later adjusted to 70–80 bears, including additional bears that had been indirectly estimated in the surrounding mountains of the Central Apennines (Majella massif, Ernici-Simbruini and Velino-Sirente mountains; Boscagli 1991, 1999).

In the mid-1990s, based on frequency of live-captures and detection of tracks and sightings as part of a radiotelemetry bear research, about 30–40 bears were believed to be living in the Park (H.U. Roth, PNALM, Pescasseroli, Italy, personal communication, 2002). More recently, the Forest Service detected a minimum of 40 bear genotypes in the Central Apennines bear range over a period of 5 years (1999–2003) using remote (hair-snag) genetic sampling (Lorenzini et al. 2004a, Potena et al. 2004, E. Randi, Italian Institute for Wildlife Conservation, Ozzano Emilia, Italy, personal communication, 2005), but the sampling design did not allow any formal estimate of bear population size (Potena et al. 2004). Finally, a first step in this direction was recently attempted by applying capture–mark–recapture modeling to DNA data collected in 2004 according to a systematic sampling design (Woods et al. 1999), and this produced a population estimate of 43 bears (95% CI: 35–67) in the PNALM (Gervasi et al. 2008). A similar approach, using refined field techniques to increase capture probability, was designed through a pilot study in 2007; its application was implemented in the spring 2008.

Given the nature of the data (Table 1), we believe that quantitative assessments of population trends over the last 30 years (Posillico et al. 2002, Wilson and Castellucci 2006) are questionable. Based on indirect evidence, however, many experts believe that the Apennine brown bear population has decreased in recent years (Zunino 1990, Posillico 1996, Zedrosser et al. 2001, Posillico et al. 2002, Lorenzini et al. 2004b, Wilson and Castellucci 2006). This opinion is based on high human-caused mortality sustained by the bear population during 1980–85 (see below); the 84% decrease in bear depredations reported for the Abruzzo Region during 1980–88 (Fico et al. 1993); and the alleged lower rate of bear sightings by PNALM wardens in these past years, including females with cubs (Posillico et al. 2002, C. Sulli, PNALM Scientific Service, Pescasseroli, Italy, personal communication, 2005). Despite the protected status of the bear in the PNALM for many years, no evidence of population increase has been reported in the last 4 decades. This condition contrasts with recent population projections (Boscagli et al. 1995, Boscagli 1999) of expanded the bear range across the network of protected areas in the Central Apennines, and the more formal habitat analyses depicting adequate bear habitat suitability and connectivity at a landscape scale (Posillico et al. 2004, Falcucci 2007, Falcucci et al. 2008).

Mortality

In past decades, several authors have compiled cases of human-caused bear mortality (Zunino 1976, Boscagli 1987, Posillico et al. 2002, Wilson and Catellucci 2006). However, the fundamental uncertainty in bear population size and trends, and the unknown ratio between reported and true mortality, makes it impossible to assess the effect of this mortality on the bear population. Nevertheless, mortality figures clearly indicate that protection of the bears has not been as effective as is desirable for such a small bear population. Between the establishment of the park (1923) and 1974, at least 99 bears were killed or removed, with a higher rate of known bear mortality (2.4 bears/year) during the last decade of this period (Zunino 1976). Higher rates (3 bears killed/year) were reported in the following decade, when bears killed by poaching and vehicle collision accounted for 60% of known mortalities (Boscagli 1987). The highest human-caused bear mortality recorded since establishment of the Park was during 1980–85, when a minimum of 32 bears were illegally or accidentally killed (5.3 bears/year; Posillico et al. 2002). In 1982 alone, 16 bears were known to have been killed (Zunino 1990), possibly representing over a third of the Park population (Boscagli 1990). An

increase in poaching was reported within and outside the PNALM area in those years (Boscagli 1987), and most probably it was a consequence of the increasing wild boar (*Sus scrofa*) population with a corresponding higher level of hunting (and poaching) pressure and efficiency (Boscagli 1987, Zunino 1990). Human-caused mortality in those years most likely caused the largest demographic reduction of the PNALM bear population over the past decades. During 1991–2002, known bear mortality in the PNALM averaged 2.5 bears killed/year, with half of these being females (L. Gentile, PNALM Veterinary Service quoted in Lorenzini et al. 2004b). In more recent years, minimum known mortality has comprised an adult female and a yearling male, both poisoned in 2003, and 3 more bears, including an adult female, an adult male (radiocollared), and a subadult male, killed in a poisoning event. This event, in which 5 wolves (*Canis lupus*) and 18 wild boars were also killed, occurred in the very core of the PNALM as late as November 2007, and it was probably motivated by conflicts over livestock depredations (Ciucci et al. unpublished data).

Of reported bear mortalities, 84% have been from illegal or accidental killing by humans (Posillico et al. 2002). Deliberate poaching (mostly shooting) has been among the main causes of reported bear fatalities (Boscagli 1987, Posillico et al. 2002), but intentional killing of bears can also be a demonstration against Park authority or a reaction to livestock depredation (Boscagli 1987, 1999). Bears have also been lost unintentionally to human activities, including vehicle and train accidents (Boscagli et al. 1995), accidental shooting during wild boar hunts, and mortality from snares or poison baits illegally set for other animals (dogs, wolves, foxes [*Vulpes vulpes*]) (Boscagli 1987, 1999, Wilson and Catellucci 2006).

Reproduction

Unfortunately, no data on the productivity of the Apennine brown bear population is available. Although there have been direct observations of females with cubs-of-the-year (F_{cub}) by Park wardens, these resulted from opportunistic sampling schemes, and no specific criteria were reported to aid their interpretation (for example, to ensure unduplicated counts or to distinguish cubs from yearlings). Nevertheless, F_{cub} have been observed more or less regularly since the 1970s, although some of the Park wardens believe that the sighting rate of F_{cub} has decreased in recent years (C. Sulli, personal communication, 2005).

Sightings of reproducing females by Park wardens were tallied for 1960–70, resulting in an annual estimated 0–11 females with cubs or yearlings in the PNALM (Zunino and Herrero 1972, Zunino 1976). In the early 1970s, these authors believed that bear productivity was high, and they conservatively counted a minimum of 4 (1974) to 6 (1970) F_{cub} on an annual basis (Zunino and Herrero 1972, Zunino 1976). These figures, however, were possibly biased by error (such as double counts, no distinction between cubs and yearlings; Zunino and Herrero 1972:266), including the undetected proportion of F_{cub} (Keating et al. 2002, Schwartz et al. 2008) and unclear criteria to distinguish family groups (Knight et al. 1995, Ordiz et al. 2007, Schwartz et al. 2008).

No data has been collected regarding the reproductive cycle of adult females in the Apennine brown bear, and no information is available concerning the age at first and last reproduction of adult females, nor the weaning age of the yearlings.

Threats to the population

With the exception of the reported bear mortalities, little is known about the demographic and ecological status of the Apennine bear population. Contrary to opinions by experts, managers, administrators, and the public on what ought to be done to save the bears in Abruzzo, there are no reliable data to support any objective assessment of threats. In this section, we discuss threats perceived as affecting the Apennine brown bear, emphasizing, when feasible, a historical perspective regarding management indications and conservation interventions (Zunino and Herrero 1972; Zunino 1976; Boscagli 1990, 1999).

Human-caused mortality

Since the early 1970s, several authors have reported that high human-caused bear mortality is a serious threat to the small Apennine bear population, as total mortality (unknown) could have easily exceeded recruitment or affected reproductive potential (Zunino and Herrero 1972; Boscagli 1987, 1999; Zunino 1990; Lorenzini et al. 2004b; Wilson and Castellucci 2006). Although the effect of human-caused mortality is unknown, the high number of bears killed in the early 1980s, the persistence of illegal killing throughout past decades, and the

specific causes of human-related mortality are all important indicators.

Throughout past decades, little has been done to prevent the killing and arrest the criminals and, more than 35 years after these concerns were first raised (Zunino and Herrero 1972), poisoning is still taking its toll in the very core of the PNALM. If not yet definitive, especially in the core bear population in the PNALM, illegal killing still appears to be the single, most immediate threat to the population. Given the small size and the minimal remaining allelic diversity (Lorenzini et al. 2004a), each bear lost to the population at this stage is expected to decrease the already limited chances of persistence of this bear population (Chapron et al. 2003, Wilson and Castellucci 2006).

In the PNALM area, risks of human-caused mortality can be exacerbated in the fall, when hyperphagic bears may move long distances to reach key autumn food sources (such as acorns, *Quercus* spp.), which are generally located at lower altitudes and outside Park borders. Not only is human density in these areas higher than in the rest of the Park, but risks of bear mortality locally increase from late fall to early winter when large parties of wild boar hunters and dogs are out (Boscagli 1987, 1999).

Illegal killing adds to indirect, more subtle forms of human-related mortality (Boscagli et al. 1995, Boscagli 1999, Posillico et al. 2002). For instance, Apennine brown bears have tested positive for canine parvovirus and canine distemper (Marsilio et al. 1997), which can cause mortality in carnivores. They can also contract *Brucella* (Colli et al. 2000), which can depress reproduction. Both pathogens are hosted and probably transmitted to bears from the many dogs and free-ranging livestock in bear range. In addition, free-ranging dogs, frequently encountered in the PNALM where they have been observed chasing wildlife (Ciucci et al. unpublished data), may represent an additional threat to bears. Based on anecdotal information, free-ranging dogs are suspected to kill cubs or young bears (Sipari 1926, quoted in Zunino and Herrero 1972:270) and contribute to livestock depredations (e.g., Ciucci and Boitani 1998), generating high levels of conflict and therefore adoption of illegal control measures (such as poisoning) by farmers.

Viability of the small bear population

The Apennine brown bear population is unquestionably small, perhaps too small to be viable in the long-term. Sæther et al. (1998) estimated a minimum of 6–8 adult female bears, in 2 Scandinavian populations, are required to maintain a population below a 10% probability of extinction in 100 years. These estimates are conservative (Sæther et al. 1998:410), based on protected Scandinavian populations with large, positive growth rates ($r \geq 0.13$, modeled with no density dependence), and survival and reproduction rates which were much higher than those reported for North American grizzly bears (Hovey and McLellan 1996). Therefore, a much less conservative estimate is probably applicable to the Apenine bear population, for which no positive growth rate was reported. However, even if the Sæther et al. (1998) indications were applicable to the Apennine population, the number of adult females in the population may nevertheless be below the minimum threshold. For an effective:censused population ratio (N_e/N_o) of 0.2–0.3 and a sex ratio of 1:1 (Harris and Allendorf 1989), the estimate of 35–67 bears in the core PNALM population (Gervasi et al. 2008) may correspond to an effective population of 4–10 adult females. In addition, Sæther et al.'s (1998) analysis was entirely based on a demographic diffusion model and did not consider any genetic stochastic process which could be much more relevant in the already genetically depleted Apennine bear population (Randi et al. 1994, Lorenzini et al. 2004a). However, Lorenzini et al. (2004a) gave no indication of inbreeding among 30 individually genotyped bears, including captive individuals, collected during 1991–2002. At present, there is no way to empirically confirm the viability of the Apennine brown bear population and, unfortunately, the full weight of this threat may be difficult to assess until it is too late to apply any form of appropriate action. In addition, the translocation of bears form other source populations is an undesirable management option in this case, based on recent evidence that the Apennine brown bear is distinct from other European populations (Randi et al. 1994, Vigna Taglianti 2003, Lorenzini et al. 2004a, Loy et al. 2008). It should be recognized, however, that whatever the extinction risks for the population, these could be reduced by an immediate and effective prevention of human-caused mortality in the core population, as well as by facilitating an increase in population size and range in the near future. Although small, remnant bear populations have responded positively to increased protection in Sweden since 1930. Others have become extinct in

Norway due to persistent eradication efforts (Swenson et al. 1995).

Depredation and conflict with humans

Bear damage to livestock, crops, and beehives have been an issue since the late 1960s (Zunino and Herrero 1972). In the PNALM, a compensation program originated by WWF-Italy in 1967 has been maintained by the Park Authority since 1969, then by Regional Governments since 1973 (Abruzzo) and 1975 (Lazio, Molise), and then again by the Park authority from 1991 (National Law 394/91). The compensation program was originally established to ensure ''the goodwill of the farmers and pastoralists'' (Zunino and Herrero 1972:270), even though in the early 1970s depredations in the PNALM were limited (about 0.3% of the sheep stock; Zunino 1976). No data on bear depredations in the PNALM are available for successive years (Zunino 1990), although depredations on livestock and crops are believed to be sporadic and are normally covered by the compensation program (Boscagli 1999). Based on depredation statistics during 1998–2003, the PNALM administration verified 87% of the claims of bear damages, reimbursing full market value to farmers for an average of $89,130/year (converted at 1.5 euros/$; Latini et al. 2005). Verified losses to bears involved livestock (51%), domestic poultry (18%), beehives (16%), and crops and fruit trees (15%). Bear livestock depredations were deemed to be of low productive and economic importance to local communities (compensation costs of $43,050/year; Latini et al. 2005). However, the recent penetration of some small villages by a few food-conditioned bears that destroyed some poultry and domestic rabbits was more socially upsetting (Latini et al. 2005). Despite the long-term compensation policy adopted by the Park, illegal toll on wolves and bears did not appear to decrease (L. Gentile, quoted in Latini et al. 2005), an indication that the social conflict remains unsolved.

Livestock within the PNALM comprises sheep, goats, cattle, and horses. Sheep traditionally graze from June to October; they are guarded by the shepherd and dogs throughout the day and herded into corrals at night. In recent years, however, an increasing number of cattle and horses have been left free-ranging throughout the year without any surveillance (Latini et al. 2005). In these conditions, compensation alone will never be effective in preventing depredations and mitigating conflicts.

Damage to wild game is also not an issue, and aggressiveness toward people has never been a concern in Central Italy (Zunino 1990). Despite the long, close coexistence between bears and humans in Abruzzo, there is no memory of bear attacks on humans (Boscagli 1999). However, since 1993, a few individual bears have been feeding on garbage and other food in small mountain villages, where they easily enter orchards, chicken yards, and stables (Latini et al. 2005). The PNALM authority casually tried aversive conditioning to discourage these bears from coming close to villages, but the long-term effects were marginal. One of these bears was most probably illegally shot, and another 2 were caught and put in captivity. Although the damage caused by these bears was of little economic importance, these situations may eventually modify the generally positive attitude of local people toward the bear or, as a last resort, result in the removal of individual bears.

Tourism in the PNALM has been described as a threat to the bear population (Zunino and Herrero 1972, Zunino 1976), and increased tourism pressure in the PNALM was feared to be the proximate cause of a trend toward bears emigrating outside Park boundaries (Zunino 1981, 1990; Wilson and Castellucci 2006). However, no reliable data support this hypothesis, and alternative interpretations were also offered to explain bear presence outside the Park (Febbo and Pellegrini 1990, Boscagli et al. 1995, Boscagli 1999). No further data has been collected to address this potentially relevant problem.

Food

Based on a scat-analysis study in 1970, and a comparison with food-habits grossly estimated for the available Park records from 1925 to 1969, Zunino and Herrero (1972) concluded that the Apennine brown bear lived on a natural diet, supplemented by widely available crops and livestock. Although these authors did not ascertain how much the bear population depended on anthropogenic foods (Zunino and Herrero 1972:226), Zunino (1976) feared that the regression of agriculture and livestock practices might progressively force bears to adapt solely to a natural diet, which might not be sufficient. The hypothesis was supported years later, when it was noted that in the past 40 years more than 50% of cultivated areas in the PNALM area had been abandoned, and this possibly affected bear survival by limiting late-summer and early autumn

foods of anthropogenic origin (Boscagli 1999). No nutritional studies addressed this problem further, but the PNALM authority and WWF-Italy deemed it desirable to establish a long-term program of artificial food supplementation, using permanent plantations of corn, carrots, and fruit trees within and outside the park (Zunino 1976, 1990; Boscagli 1999; Latini et al. 2005). This program ran for several years and was complemented by financial support to traditional agriculture practices, with an aim to make these crops available to bears (Zunino 1976, Latini et al. 2005). In addition, in 1993, the PNALM authority and WWF-Italy launched an educational campaign named ''Plant an apple tree: you can save the bear'' and similar projects targeted at schools and the general public in other protected areas of the Central Apennines (Boscagli 1999).

In addition, in the mid-1980s the PNALM established permanent feeding sites for bears in the core of the PNALM loaded with remains of livestock and wild prey (Zunino 1990:79, Russo 1990). As early as the 1970s, however, it was noted that the proportion of meat in bear diets due to livestock was probably unnaturally high as a consequence of the recent historical increase in domestic stock abundance (Zunino 1976). At that time, reintroduction programs of roe (*Capreolus capreolus*) and red deer (*Cervus elaphus*) to replenish the wild prey in the PNALM had been already successful. Therefore, the feeding site campaign was probably motivated by the high number of bears poached in those years, especially outside Park borders (see Mortality), and probably had the unstated aim of keeping bears inside the Park. Although carrion feeding sites were heavily used by bears (C. Sulli, personal communication, 2005), absence of monitoring in those years prevents assessing the effect of the supplemental feeding campaign on the population. It should be noted, however, that this strategy might also have increased the likelihood of food-conditioning and habituation by some bears.

Currently, no other evidence supports the hypothesis that food limits the bear population in the PNALM. Distribution, availability, and quality of key food resources used by bears have been never assessed throughout the Park, and no estimate of theoretical carrying capacity has been produced. Anecdotal information (body condition of captured bears, litter size of reproducing females, habitat evaluation) and telemetry data currently collected on the bear population in the PNALM do not seem to indicate that the population is food-stressed. The same idea was already advanced in the early 1970s, when Zunino (1976) regarded the PNALM as a highly productive ecosystem for bears and noted that key food resources (e.g., wild fruits ripening during the hyperphagic phase such as *Rhamnus*, wild rose, wild apples and pears) were not exhaustively used by bears (Zunino 1976:618). Supplemental feeding was nevertheless initiated and maintained for the following 3 decades, and we believe additional reasons explain why the food-limiting hypothesis had driven management interventions. For instance, the lack of data concerning bear ecology and bear-habitat relationships could have played a critical role, as this knowledge is necessary to formulate alternative and more complex hypotheses and management scenarios.

Habitat

Habitat degradation is often considered the most important threat to bears in Europe (Swenson et al. 2000). Although the issue is clearly critical also for the Apennine brown bear population, it is perhaps secondary to human-caused mortality (Zunino and Herrero 1972, Boscagli 1999, Zedrosser et al. 2001). Consistent with the recent structure of the Apennine brown bear range (Febbo and Pellegrini 1990, Boscagli et al. 1995), habitat effects on bear conservation are best assessed at 2 two scales: the core bear range and a wider area in the Central Apennines where the population could expand in the near future.

The PNALM itself was established to preserve the remnant bear population and its habitat, but a substantial part of bear habitat was not included in the Park (Zunino and Herrero 1972, Zunino 1976, Fabbri et al. 1983). Although important areas were added in the mid-1920s (Table 2), critical feeding and refuge habitat were still outside its borders, and further enlargement saved habitat from development and extraction activities (Zunino and Herrero 1972, Zunino 1976). After three important expansions (Table 2), the most critical sites for bears (Zunino and Herrero 1972:268) were included within the Park or its buffer area. The latter, an 800-km^2 area around the Park, was established in 1970 to allow more flexible management of human activities to mitigate effects on the bear and its habitat. Accordingly, since the 1970s, PNALM authorities have restricted further ski resort development in the Park (Boscagli 1999).

Table 2. Expansion of the Abruzzo Lazio and Molise National Park since its establishment, Italy, 1922–present.

Year	Park area (ha)		Notes
	Added	Park total (Buffer)	
1922		500 (0)	Park establishment (private initiative)
1923	17,500	18,000 (0)	PNALM institutionally established (11 Sep 1923)
1925–26	12,000	30,000 (0)	Meta Mountains added
1970	80,000	30,000 (80,000)	Buffer zone added around park
1977	10,000	40,000 (80,000)	Mt. Marsicano area added
1990	4,000	44,000 (80,000)	Mainarde Mountains added
1999	6,000	50,000 (80,000)	Giovenco Valley added

Even if included within the Park borders, bear habitat could still face degradation due to land management practices, from forestry to road construction (Zunino and Herrero 1972). In the early 1970s, further road development was believed to represent a potential threat (Zunino and Herrero 1972) and, by the mid-1970s, the Park authority closed about 80 km of dirt and gravel roads to vehicles (Zunino 1976). Since the early 1970s, most of the forested areas of the Park have been owned by townships and managed for timber and firewood extraction, potentially depriving bears of critical habitats (Zunino and Herrero 1972). To reduce habitat degradation due to forestry practices, in the mid-1970s the Park authority began a rental policy with about 800 ha of forested land from private owners. Today, the Park rents about 20,000 ha of forest to prevent wood and other resource extraction from private citizens, compensating townships for income loss with costs of $525,000–540,000/year (C. Sulli, personal communication, 2007). However, if deforestation increases bear mortality risks and habitat loss, limited timber and firewood extraction may increase forest productivity by encouraging shade-intolerant, fruit-bearing plants. Nevertheless, in the absence of fine-scale, reliable data regarding bear habitat and resource use, no habitat intervention and forest management in the PNALM has been designed to maintain or increase habitat suitability and productivity for bears (Nielsen et al. 2004a,b).

On a larger scale, the area of the Central Apennines once inhabited by bears has been transformed by an increase of human presence and infrastructures that has seriously fragmented forests (Febbo and Pellegrini 1990, Boscagli et al. 1995). More recently, however, bear range reduction appeared to be related more to direct persecution by humans than to a decrease in habitat suitability (Febbo and Pellegrini 1990, Posillico et al. 2004). In past decades, expanded protected areas in the Central Apennines (National Law 394/91) represented an important step toward large-scale conservation of the Apennine brown bear habitat (Boscagli 1999, Posillico et al. 2004), even though more effective bear-oriented conservation actions need to be implemented in these areas. Accordingly, recent large-scale modelling of land-cover suitability for bears suggests that overall suitability and connectivity in the Central Apennines increased markedly from the 1960s to the 1990s (Falcucci et al. 2008). Favorable land-cover changes have resulted from a marked decrease in human population and land use since the 1960s, and the expansion of forests over less suitable land-cover. Today, >38% of the Central Apennines area once inhabited by bears is protected (National and Regional Parks, Natura 2000 network), and their connectivity with the PNALM seems adequate to allow natural recolonization and to host a larger brown bear metapopulation (Falcucci et al. 2007). However, restrictive policies concerning development are necessary to ensure future connectivity over the Central Apennines, and several habitat suitability and bear occurrence models have been recently proposed as planning tools for the process (Posillico et al. 2004, Falcucci 2007, Falcucci et al 2008).

Lack of reliable knowledge on bear ecology

Excluding the 1-year ecological study in 1970 (Zunino and Herrero 1972, Zunino 1976), no other study of bear ecology has been launched. Limited efforts have produced a preliminary serological assessment (Marsilio et al. 1997, Colli et al. 2000), a few taxonomic and phylogeographic investigations (Randi et al. 1994, Loy et al. 2008), and a preliminary remote genetic application (Lorenzini et al. 2004a), but no other reliable data have been available to develop an effective conservation strategy. From our review of 19 studies on the Apennine brown bear published in international journals since

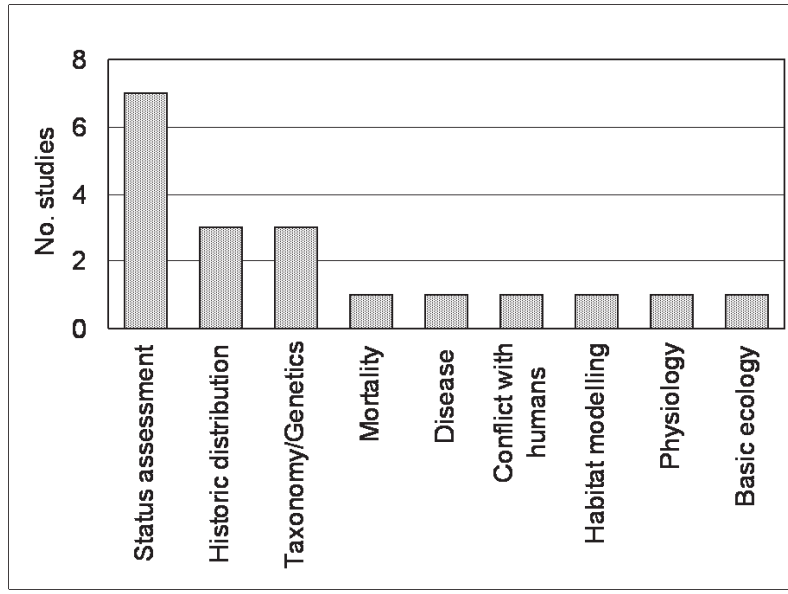

Fig. 2. Studies on the Apennine brown bear (n = 19) in international journals, according to their main topic (1972–2007).

the early 1970s, only one has dealt with basic ecology (Zunino and Herrero 1972). The others assessed population status (36.8%), reconstructed historical bear range (15.8%), or were taxonomic and genetics applications (15.8%; Fig. 2). As early as the 1980s, the lack of incentives for applied research to support bear conservation was regarded as a problem (Zunino 1990), and a long-term research program on bear ecology was recommended among the most relevant conservation actions (Boscagli 1999). Since then, a radiotelemetry research program was carried out by the PNALM in the 1990s (C. Sulli, personal communication, 2005; H. Roth, unpublished data), but no data have been made available to design and implement conservation actions. Conversely, some bear advocates argue that further research on the Apennine brown bear is not needed, and funds should be exclusively devoted to conservation. We reject this view. Nonetheless, it has adversely affected the financial, administrative, and political support for applied research.

Conservation and recovery actions

Establishment of the PNALM in 1923, its progressive enlargement to include more critical bear habitat, and nationwide legal protection since 1939 represent the most important conservation interventions on behalf of the Apennine brown bear. It is not just by chance, then, that bears in the Central Apennines area outside the PNALM have survived at much lower densities or have not survived at all (Boscagli 1999). Furthermore, since the 1960s, the bear conservation policy of the PNALM was designed for general, proactive interventions regarding habitat, the bear population, and potential threats. These interventions include: (1) measures to prevent habitat deterioration (closure of public access to gravel roads, prevention of development plans, reduction of timber harvest by renting privately-owned forests; Zunino 1976, Boscagli 1999); (2) interventions to supplement bear foods (reintroduction of red and roe deer populations, establishment of permanent plantations and feeding sites, promotion of feeding campaigns; Zunino 1976, 1990; Russo 1990), and (3) policies to reduce bear–human conflicts (establishment of compensation programs, management of problematic bears, promotion of preventive measures, and educational campaigns; Zunino 1976, Boscagli 1999, Latini et al. 2005).

Although not all bear conservation prescriptions have been followed (Boscagli 1999), and some have been inconsistently supported due to administrative and financial instability, most were implemented under the assumption they were appropriate and effective, although no data were available for their assessment. In fact, the absence of data concerning the Apennine bear population makes it

Table 3. European Commission projects (Life-Nature program) which directly or indirectly targeted the Apennine brown bear or its habitat, 1992–2007. Projects were co-funded by the European Commission (2007).

Area	Beneficiary	Years	Project life code	Total budget ($)
Abruzzo, Lazio and Molise National Park	Park administration	1992–97	LIFE92 NAT/IT/013001	1,556,000
		1992–97	LIFE94 NAT/IT/000607	790,874
Sirente-Velino Regional Park	Park administration	1995–97	LIFE94 NAT/IT/001140	600,000
		1998–2001	LIFE98 NAT/IT/005114	528,537
		2003–07	LIFE03 NAT/IT/000151	1,297,200
"Zompo Lo Schioppo" Natural Reserve	Reserve administration	1997–2001	LIFE97 NAT/IT/004115	237,264
		2003–07	LIFE03 NAT/IT/000160	1,419,183
Sibillini Mountains Gran Sasso–Laga, and Maiella–Morrone National Parks (Central Apennines)	Legambiente	1998–2001	LIFE97 NAT/IT/004141	1,228,938
Central Apennines and Eastern Alps	WWF-Italy	1992–97	LIFE92 NAT/IT/013002	742,000
		1992–97	LIFE94 NAT/IT/000575	420,003
		1993–97	LIFE95 NAT/IT/004801	563,497
	Forest Service (Ministry of Agriculture)	1992–97	LIFE92 NAT/IT/013000	902,500
		1992–97	LIFE94 NAT/IT/001077	433,623
Central Apennines	Forest Service (Ministry of Agriculture)	1999–2003	LIFE99 NAT/IT/006244	1,316,966

difficult to evaluate management programs implemented at the local and regional levels. Nevertheless, 2 arguments highlight how past management policies might have not supported bear recovery as was originally expected. First, the known number of illegally killed bears, compared to rough population estimates (Table 1), suggests that antipoaching campaigns were not effective and that total mortality might have been too high to allow population recovery. Second, the recent dynamics in bear range and number of bears does not provide, even with the most optimistic view, any clear indication of its recovery: both indicate that the Apennine brown bear might have persisted at dangerously small numbers in the past 4 decades or that the population might have experienced negative trends, especially during the 1980s (Zunino 1990, Posillico et al. 2002, Lorenzini et al. 2004a). In contrast, with effective habitat protection within the PNALM, the stationary or decreasing status of the small bear population underscores how, at small bear population size, illegal or accidental human-caused mortality may negatively affect long-term conservation.

On a larger scale, several localized projects have been implemented to assist, directly or indirectly, bear conservation in protected areas of the Central Apennines. Among these, 17 projects have been funded by the European Commission (Life-Nature program) since 1992, and 14 of these involved conservation of the Apennine brown bear and its habitat, for a total of $12,036,600 over 17 years (Table 3). Some projects have promoted habitat quality and restoration as well as public awareness, and habitat interventions should not be expected to generate immediate population responses on a large scale. However, both the core and the peripheral bear populations in the Central Apennines have shown no tendency to increase or expand their range to date (Febbo and Pellegrini 1990, Boscagli et al. 1995, Posillico et al. 2004).

We believe that several problems might undermine the outreach and effectiveness of these projects. First, there was no coordination on a larger scale, nor were management priorities for the bear and its habitat set and evaluated. Second, in the absence of any effective campaign to prevent and persecute illegal killing, even a single killing of a bear by humans may spoil costly habitat management interventions. Third, the lack of hard data concerning population size and structure, as well as vital statistics and bear–habitat relationships, makes it impossible to assess the effectiveness of management interventions or to evaluate their adequacy a priori. Finally, administrative fragmentation of the bear conservation policy framework makes it extremely difficult to effectively and permanently include bear conservation strategies in land-use planning and policy, especially outside protected areas.

Lessons from the past; recommendations for the future

Since its establishment, the PNALM has played a critical, instrumental role in supporting Apennine brown bear conservation. However, more recently the often-fierce confrontation between Park administration and the Regional Government and other authorities (e.g., Forest Service, hunters' organizations) has isolated the Park from the support that a coordinated management plan could have provided. For years, by using the 1970s population estimate (70–100 bears; Zunino and Herrero 1972), PNALM officials implied that bears were safe under Park protection (Tassi 1983, 1990), even though evidence indicated otherwise (Zunino 1981, 1990; Fabbri et al. 1983; Boscagli 1990). In addition, past Park administrations contributed to a generalized absence of involvement of external research and conservation groups, and conservation-oriented movements did not have the opportunity, until very recently, to regard the Apennine brown bear as an operational priority. Accordingly, no local, regional, or national campaigns have been launched to highlight the critical status of the brown bear in Abruzzo to administrators and the general public and, with the exception of the study by Zunino and Herrero (1972), no new data have been produced or considered relevant to support bear conservation.

Both at local (PNALM and buffer area) and regional level, fragmentation of management authority has probably been the single most important problem limiting the adoption of large-scale, coordinated land-use and bear conservation policies. Many recent attempts to get stakeholders (authorities, group of interests, scientists) at the same table have failed. Especially outside protected areas, support from administrators, politicians, and lawmakers is difficult to obtain in the absence of regional and national laws that specifically facilitate the design, implementation and monitoring of conservation strategies for endangered species.

The conservation status of the Apennine brown bear is alarming, and options to save it are decreasing rapidly. Three fundamental actions are urgently needed: (1) development of a new strategic approach to overcome the traditional division among authorities and to coordinate all conservation efforts; (2) a renewed effort to control illegal killing within and outside the PNALM; and (3) research aimed at collecting basic information concerning population size and trends, vital statistics, spatial patterns, and basic ecology.

Efforts to control illegal killing and reduce the potential impacts of human activities (hunting, timber harvest, tourism, road and other infrastructure construction) are currently among the most urgent and critical conservation measures needed not only in the PNALM but on a larger, Central Apennines scale. However, they are bound to fail unless bear conservation becomes a priority for all administrations where bears live or may expand in the near future. About 4 decades ago, Zunino and Herrero (1972) recognized that the only viable conservation strategy for the Apennine brown bear was to prevent every human-caused bear mortality and to maintain habitat connectivity on a larger scale to ensure unrestricted movement and genetic exchange through an expanding population. Today, after almost 40 years, little progress has been made toward the first goal, even though habitat suitability and connectivity for bears on a large scale seems adequate. Bears are still being illegally killed, and the population has not expanded as expected based on the network of protected areas (Boscagli 1999; Posillico et al. 2004, Falcucci et al. 2008).

As of May 2008, positive changes were occurring in the directions outlined above. A 5-year research and conservation project was launched in 2006 funded by the Wildlife Conservation Society through a private US donor, and it is being carried out as a cooperative effort between the University of Rome, the PNALM, the Forestry Service, and other research and management institutions. In addition, under the initiative of the Abruzzo Region and the Italian Ministry for the Environment, an interagency commitment (PATOM, Action Plan for the Conservation of the Apennine Brown Bear) was established in 2005, and it has been signed by 24 administrations, including all national, regional and provincial administrations and non-governmental organizations involved in Apennine brown bear conservation. The PATOM is expected to overcome administrative fragmentation by facilitating adoption of ad hoc laws and regulations and by promoting coordinated land-use planning and management interventions for the conservation of the brown bear on a large scale. Through the work of technical groups dedicated to a specific issue (hunting regulations, anti-poaching campaigns, human dimension, livestock conflicts), PATOM is developing management and land-use

planning guidelines which are compatible with bear survival and facilitating their adoption by local and regional administrations in the bear range. The PATOM initiative is still in its infancy and undoubtedly challenged with fundamental tasks and responsibilities. However, large scale, long-term recovery of the Apennine brown bear, especially in the human-dominated landscapes of Central Italy, depends on the success of innovative solutions to overcome administrative fragmentation.

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