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DENSITY, PRODUCTIVITY, DIET, AND HUMAN PERSECUTION OF GOLDEN EAGLES (*AQUILA CHRYSAETOS*) IN THE CENTRAL-EASTERN ITALIAN ALPS

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ABSTRACT.—A Golden Eagle (*Aquila chrysaetos*) population of 46 pairs was regularly censused between 1982–92 in a 7800-km^2 study plot in the central-eastern Italian Alps. Density was stable at 5.9 territorial pairs per 1000 km^2. Mean nearest-neighbor distance was 8.7 km (N = 46), and nest areas were regularly dispersed. Sixteen percent of 70 pairs consisted of an adult and a nonadult individual. Mean laying date was 23 March (N = 27). The percentage of successful territorial pairs was 55% (N = 109). Mean number of fledged young was 0.61 per territorial pair (N = 109) and 1.10 per successful pair (N = 56). Diet was dominated by mammals (64%) belonging to the orders Artiodactyla, Rodentia, Lagomorpha, and Carnivora, and by birds (32%) belonging to the order Galliformes (N = 247 prey items). Productivity was affected by age of territory holders and the extent of woodland or grassland within the potential foraging range. Illegal shooting accounted for the deaths of 15 individuals between 1980–89. Compared to other alpine populations, the study population showed a low density, average nearest-neighbor distance and productivity, and a typical frequency of nonadult territory holders. We suggest that the future long-term population trends of alpine Golden Eagles will be determined by the interactions among increasing food supply, declining availability of foraging habitat, decreasing human persecution, and increasing human disturbance.

KEY WORDS: Aquila chrysaetos; *Golden Eagle*; *breeding success*; *density*; *diet*; *Italian Alps*; *land use changes*.

Densidad, productividad, dieta y persecucion humana de aguilas doradas (*Aquila chrysaetos*) en los alpes centro orientales

RESUMEN.—Una población de águilas doradas (*Aquila chrysaetos*) de 46 pares fue censada regularmente entre 1982–92, en una parcela de 7800 km en el centro—oriente de Los Alpes. La densidad fue estable en 5.9 pares territoriales por 1000 km. La distancia media al vecino mas próximo fue de 8.7 km (N = 46), las distancias de los nidos fueron regularmente dispersadas. Diez y seis por ciento de las 70 parejas consistieron de un adulto y un individuo subadulto. La media de la fecha de postura fue el 23 de marzo (N = 27). El porcentaje de parejas exitosas fue del 55% (N = 109). La media de pichones emplumados fue de 0.61 por pareja territorial (N = 109) y 1.10 por pareja exitosa (N = 56). La dieta estuvo representada por mamíferos en un 64% de los órdenes Artiodactila, Rodentia, Lagomorfa y Carnívora y por aves en un 32% pertenecientes al orden Galliformes (N = 247 presas). La productividad fue afectada por la distancia del vecino más próximo, edad de los poseedores del territorio y por el tamaño de los bosques y pasturas dentro del área de forrajeo. La caza ilegal fue la causa de la muerte de 15 individuos entre 1980–89. Comparado con otras poblaciones alpinas, la población estudiada mostró una baja de densidad, un promedio de distancia entre el vecino más proximo, y una frecuencia tipica de los poseedores del territorio no adultos. Sugerimos que la tendencia poblacional a largo plazo de las águilas doradas alpinas puede estar determinada por las interacciones entre el incremento de alimento, la declinación de la disponibilidad del habitat de forrajeo, la disminución de la persecución humana y el incremento de la perturbación humana.

[Traducción de César Márquez]

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In Europe, populations of Golden Eagles (*Aquila chrysaetos*) are generally stable or increasing, but declines have been reported for Spain, Portugal, Albania, Romania, Greece, Belarus, and Ukraine (Watson 1994, Haller and Sackl 1997). In the Alps, Golden Eagles usually nest near tree line and hunt in alpine areas at higher elevations (Haller 1996). Alpine populations have recently recovered from a long history of human persecution and are currently considered to be stable or slightly increasing (Fasce and Fasce 1992, Haller and Sackl 1997). Land abandonment in remote mountain valleys, however, is causing widespread woodland expansion (Potter 1997, Tucker and Dixon 1997, Pedrini and Sergio 2001), mainly at the expense of alpine pastures, which are the main foraging habitats of Golden Eagles in the Alps (Haller 1996). Land abandonment and afforestation are predicted to have a high impact on Golden Eagle populations in European mountainous areas, with declines of more than 20% of the overall population over the next 20 yr if these trends continue (Tucker and Dixon 1997). Such habitat loss emphasizes the need for quantitative monitoring of the density and productivity of these eagle populations. Despite the intensive studies conducted on this species in the western-central Alps (Huboux 1985, Fasce and Fasce 1992, Haller 1996), very little data are available for the eastern portion of the alpine chain (Tormen and Cimbien 1995).

Here, we report the results of an 11-yr study on a Golden Eagle population in the central-eastern Italian Alps. We provide quantitative data on the density, diet, and productivity of the population, compare them with estimates from other alpine populations, and examine some of the factors potentially affecting reproductive success.

STUDY AREA

Golden Eagles were surveyed within a 7800 km^2 study area in the central-eastern Italian Alps and pre-Alps, within the administrative provinces of Trento, Vicenza, Brescia, and Belluno (45°N,11°E). Elevation of the study area ranged from 65–3764 m and 31% of the land was <1000 m (Tomasi 1962); these areas were rarely used by Golden Eagles for hunting. Twenty-eight percent of the area was between 1000–1500 m, 22% between 1500–2000 m, 13% between 2000–2500 m, and 6% was >2500 m (Tomasi 1962). The natural tree line is at 1800–1900 m, but was often lower because of human activities and sheep grazing (Piussi 1992). The landscape is characterized by cultivated valley floors, mountain slopes covered by forests interspersed with sparse pastures, and by montane grassland, rocky outcrops, and permanently snow-covered ground above tree line. In particular, 52% of the area was covered by woodland, 18% by montane grassland and pastures, 6% by agricultural crops (mainly vineyards and apple groves), and 3% by human development. Forest composition varied from deciduous to coniferous depending on elevation, slope orientation, and local microclimate. With increasing elevation, woodland tended to be dominated by *Quercus pubescens*, *Quercus-Tilia-Acer* spp., *Fagus-Abies* spp., *Picea* spp., and *Larix-Cembra* spp., respectively (P.A.T. 1995). Eighty-two percent of the woodland area was managed for wood production; 73% of this woodland was managed as mature forest and 27% by stool shoots regeneration (P.A.T. 1995). Woodland extent is currently increasing at a rate of 1.0% every three years, mainly at the expense of alpine and subalpine grassland (P.A.T. 1995).

METHODS

The Golden Eagle population was censused annually from 1982–92 inclusive, and intensively monitored between 1984–89. A nest area was defined as an area where more than one nest was found in the same or in different years, but where only one pair nested each year (e.g., Newton 1979, Sergio and Bogliani 1999, Sergio and Boto 1999). Each Golden Eagle pair occupied a traditional nest area, containing 1–9 alternate nests. Nest-area occupancy was checked each year during the two months before the average laying date (23 March, $N = 27$). Territorial and courtship displays, copulations, nest material transfers, or presence of at least one freshly refurbished nest were considered as minimum evidence of nest-area occupation. The center of each nest area was defined as the arithmetic center of the locations of all alternative nests within the nest area. Nearest-neighbor distance (NND) was calculated as the distance from the center of the nest area of a pair to the center of the nest area of the nearest pair (Tjernberg 1985). Nest-area dispersion was examined by means of the *G*-statistic (Brown 1975), calculated as the ratio between the geometric and the arithmetic mean of the squared NNDs; the *G*-statistic ranges from 0–1 and values >0.65 indicate a regular dispersion of nest areas (Brown 1975). Statistical significance of the deviation from randomness towards regularity was tested according to Clark and Evans (1954), with the modification applied by Donnelly (1978). Details of the mathematical procedure can be found in Krebs (1989).

Individual eagles within territorial pairs were aged on the basis of plumage characteristics, following Jollie (1947), Mathieu (1986), and Tjernberg (1988). Immature and subadult eagles were both classified as nonadults, following Mathieu (1986), and Tjernberg (1988)

Nest contents were checked at least three times during the breeding cycle: during incubation to assess whether egg laying had taken place, just after hatching to record hatching date, and when the nestlings were >60-d old to record fledging success (nestlings usually fledge at 70–80 d old, Cramp and Simmons 1980). To minimize disturbance, nest contents were checked from a distance >800 m with a 20–60x telescope. Hatching dates were estimated from feather development, following Cramp and Simmons (1980) and Mathieu (1985). Laying dates were estimated by subtracting 44 d, the median incubation period (Cramp and Simmons 1980), from hatching dates.

To analyze the factors potentially affecting breeding output, we first calculated a mean estimate of productivity for each nest area within the study period. This measurement of nest area productivity was expressed as the percentage of nesting attempts which were successful (≥1 young raised until fledging), and as the mean number of fledged young per nesting attempt. Only nest areas where productivity had been checked for at least three years between 1984–89 were used for such analyses. To examine the effect of land use on productivity, we measured the percentage extent of woodland and grassland habitats within 5 km of the nest-area center of 22 pairs. The measure of 5 km was slightly higher than half the average NND of the study population, and the area within 5 km of the nest-area center was assumed to be an estimate of the potential hunting range of the resident pair (Watson 1992, Pedrini and Sergio 2001).

To minimize disturbance, collection of prey remains was carried out at all accessible nests 7–15 d after the first flight of the young (Watson 1997). Prey remains were identified to genus or species level by comparison to a reference collection of the Trento Museum of Natural History. Prey weights were calculated using Mathieu and Choisy (1982), Haller (1996), and Macdonald and Barrett (1993). Because capture roe deer (*Capreolus capreolus*) were mainly juveniles, they were assigned a weight of 3700 g, following Haller (1996).

A reproductive pair was one which laid eggs, a successful pair was one which raised at least one young until fledging, and breeding success was the percentage of territorial pairs which were successful (Steenhof 1987).

To meet the assumptions of normality of parametric tests, variables were logarithmically, square root, or arcsin-square root transformed as necessary (Sokal and Rohlf 1981). All proportions of land-use types were arcsin-square root transformed. Differences in mean productivity values between or among groups were tested by means of *t*-tests, or ANOVA; differences in frequency of successful territorial pairs or in frequency of successful pairs raising two young to fledging were tested by means of χ^2-tests (Sokal and Rohlf 1981). The effect of laying date, NND, and habitat composition within the potential hunting range on productivity was assessed by means of parametric and nonparametric correlations, and by partial correlation analysis (Sokal and Rohlf 1981). Means are given ±1SE. All tests were two-tailed and statistical significance was set at $P \leq 0.05$.

RESULTS

Density and Nest Dispersion. Between 1982–92, the study area supported a stable population of 46 territorial pairs of eagles. This corresponded to a density of 5.9 pairs per 1000 km^2. NND ranged from 4–15 km, averaging 8.7 ± 0.4 km (N = 46). The *G*-statistic value of 0.82 indicated a regular dispersion of nest areas. The pattern of nest dispersion deviated significantly from randomness towards regularity (z = 17.26, P < 0.0001, Krebs 1989).

Nest Sites. The number of alternate nests within a nest area ranged from 1–9, averaging 2.7 ± 0.3 (N = 46). All but one of 123 censused nests were positioned on cliffs. The only tree nest was in a spruce fir (*Picea excelsa*). Mean nest elevation was 1445 ± 32 m (range = 750–2280 m, N = 108). Eighty-six percent of the nests (N = 108) were between 1000–2000 m.

Age of Territory Holders, Breeding Season, and Productivity. We classified both partners of 70 pairs as adult or nonadult: 59 pairs (84.3%) were composed of adult individuals, 6 pairs (8.6%) of one adult male and one nonadult female, and 5 pairs (7.1%) of one adult female and one nonadult male. Mean laying date was 23 ± 1.5 March (range = 1 March–7 April, N = 27). Between 1984–89, there were no significant differences among years in mean number of young fledged per territorial pair ($F_{5,84}$ = 0.74, P = 0.59, Table 1), mean number of young fledged per successful pair ($F_{5,43}$ = 0.49, P = 0.78), or percentage of nesting attempts which were successful (χ^2_5 = 2.48, P = 0.79).

Factors Affecting Breeding Output. The number of fledged young was not related to laying date (r_S = −0.26, N = 27, P = 0.19). Breeding success was not correlated with NND (square root transformed) (r = 0.289, N = 25, P = 0.161). The mean number of fledged young was not correlated with percentage woodland extent within the potential hunting range (Pedrini and Sergio 2001). When controlling for NND through partial correlation, the relationship between mean number of fledged young per territory was not related to percentage woodland extent within the potential hunting range (r = −0.41, N = 19, P = 0.063), or to percentage amount of grassland habitats within the potential hunting range (r = 0.40, N = 19, P = 0.075), though both results neared significance. Mean number of fledged young was higher for pairs composed by two adults (0.71 ± 0.1, N = 55) than for pairs composed by one adult and one nonadult individual (0.11 ± 0.1, N = 9) (t_{62} = 4.28, P = 0.0001).

Diet. Diet was dominated by mammals and birds which accounted for 64% and 32% of 247 prey items collected between 1984–89 (Table 2). The importance of mammalian prey was even higher in the analysis by fresh weight, with mammals accounting for 85% of consumed food. In particular, diet was mainly composed by species belonging to the order Artiodactyla (20% by number and 40% by fresh weight), Rodentia (29% and 25%), Lago-

Table 1. Mean (±SE) productivity estimates of a Golden Eagle population in the central-eastern Italian Alps between 1982–92.

VARIABLE	1984	1985	1986	1987	1988	1989	1982–92
Number of checked pairs	9	14	12	16	22	17	109
Percentage successful pairs	44	64	50	56	45	65	55
Mean no. of young fledged per territorial pair	0.44 ± 0.2	0.71 ± 0.2	0.58 ± 0.2	0.63 ± 0.2	0.45 ± 0.1	0.76 ± 0.2	0.61 ± 0.1
Mean no. of young fledged per successful pair	1.00 ± 0.0	1.11 ± 0.3	1.17 ± 0.4	1.11 ± 0.3	1.00 ± 0.0	1.18 ± 0.1	1.10 ± 0.0

Table 2. Diet of breeding Golden Eagles in the central-eastern Italian Alps (1984–89), as estimated by food remains collected in nests.

PREY CATEGORY	NUMBER OF ITEMS (%)	% FRESH WEIGHT
Mammals	157 (64)	84.6
Roe deer (*Capreolus capreolus*)	38 (15)	30.6
Alpine marmot (*Marmota marmota*)	26 (11)	22.6
Edible dormouse (*Glis glis*)	25 (10)	0.7
Hares (*Lepus* sp.)	19 (8)	11.6
Red squirrel (*Sciurus vulgaris*)	13 (5)	1.0
Red fox (*Vulpes vulpes*)	9 (4)	5.9
Chamois (*Rupicapra rupicapra*)	11 (4)	8.9
Other mammals[a]	16 (6)	3.3
Birds	80 (32)	15.0
Black Grouse (*Tetrao tetrix*)	31 (13)	7.1
Hazel Grouse (*Bonasa bonasia*)	9 (4)	0.6
Rock Ptarmigan (*Lagopus mutus*)	9 (4)	0.8
Other birds[b]	31 (13)	6.4
Reptiles[c]	10 (4)	0.4
Total	247	—

[a] Includes: common dormouse (*Muscardinus avellanarius, N* = 4), pine marten (*Martes martes, N* = 3), beech marten (*Martes foina, N* = 1), domestic cat (*Felis silvestris, N* = 1), brown rat (*Rattus norvegicus, N* = 1), *Mustela* spp. (N = 3), *Apodemus* spp. (*N* = 1), unidentified rodents (*N* = 2).

[b] Includes: domestic fowl (*Gallus* spp., *N* = 7), Capercaillie (*Tetrao urogallus, N* = 3), Rock Partridge (*Alectoris graeca, N* = 3), Eurasian Jay (*Garrulus glandarius, N* = 3), Eurasian Kestrel (*Falco tinnunculus, N* = 2), Alpine Chough (*Pyrrocorax graculus, N* = 2), Ring Ouzel (*Turdus torquatus, N* = 2), Ring-neck Pheasant (*Phasianus colchicus, N* = 1), Common Cuckoo (*Cuculus canorus, N* = 1), Mistle Thrush (*Turdus viscivorus, N* = 1), Hooded Crow (*Corvus corone cornix, N* = 1), unidentified Galliform (*N* = 5).

[c] Includes: Aesculapian snake (*Elaphe longissima, N* = 4), western whip snake (*Coluber viridiflavus, N* = 1), *Vipera* spp. (*N* = 1), unidentified Colubridae (*N* = 4).

morpha (8% and 12%), Carnivora (7% and 9%), and Galliformes (28% and 15%). Main prey species by number were roe deer, alpine marmot (*Marmota marmota*), Black Grouse (*Tetrao tetrix*), and edible dormouse (*Glis glis*). Main prey species by weight were roe deer, alpine marmot, hares (*Lepus* spp.), and chamois (*Rupicapra rupicapra*).

Comparison of Breeding Parameters with Other Alpine Populations. We obtained estimates of density, mean NND, and productivity of Golden Eagles in other alpine areas (Table 3). It was possible to compare mean NND in our study area with one in the western Italian Alps (Fasce and Fasce 1984) and in the French pre-Alps (Mathieu and Choisy 1982). Mean NND did not vary significantly among

Table 3. Estimates of density, mean (±SE) nearest-neighbor distance (NND), and productivity for 13 Golden Eagle populations in the alpine chain (1978–94).

Area	Year[a]	Density (*N*)[b]	Mean NND (*N*)[c]	Breeding Success[d] (*N*)	Mean No. of Fledged Young per Territorial Pair[e]	Percentage Successful Pairs Raising Two Young (*N*)	Source
France:							
Southern Alps	1978–80	—	10 (19)	29 (51)	0.29 ± 0.1	0.0 (15)	Mathieu and Choisy 1982
South-western Alps	1982–92	13.7	—	64 (105)	0.82 ± 0.1	39.6 (67)	Couloumy 1996
Southern Alps A	1980–84	—	7 (31)	36 (107)	0.44 ± 0.1	26.7 (38)	Huboux 1984
Southern Alps B	1980–84	—	8.8 (26)	31 (93)	0.35 ± 0.1	16.0 (29)	Huboux 1984
Haute-Savoie	1980–84	9.3 (28)	—	38 (95)	0.38 ± 0.1	0.0 (36)	Estève and Matérac 1987
Switzerland:							
Grisons	1984–89	13 (61)	6.1 (61)	80 (74)	0.95 ± 0.1	22.9 (59)	Haller 1996
Berne	1987–89	11.9 (33)	—	35 (105)	0.38 ± 0.1	8.8 (37)	Jenny 1992
Pre-Alps	1980–84	11.3 (18)	—	42 (60)	0.47 ± 0.1	13.6 (25)	Henninger et al. 1986
Pre-Alps	1983–94	—	—	55 (33)	0.55 ± 0.1	0.0 (18)	Haller 1996
Italy:							
Western Alps	1980–83	—	8.6 (80)	65 (153)	0.76 ± 0.1	2.2 (99)	Fasce and Fasce 1984
Western Alps	1972–87	9.5 (31)	6.8 (31)	68 (168)	0.79 ± 0.0	2.0 (114)	Bocca 1989
Eastern Alps	1989–92	—	9.9 (27)	36 (67)	0.36 ± 0.1	0.0 (24)	Tormen and Cimbien 1995
Central-eastern Alps	1982–92	5.9 (46)	8.7 (46)	55 (109)	0.61 ± 0.1	11.1 (60)	This study

[a] The study period indicated refers to the years in which productivity was checked. Whenever possible, data were employed for periods coinciding as much as possible with the study period of our systematic survey (1984–89).

[b] Number of territorial pairs per 1000 km^2.

[c] Measured in km.

[d] Percentage successful pairs.

[e] Sample size is the same as for breeding success.

areas ($F_{2, 142}$ = 1.17, P = 0.31). Mean number of fledged young per territorial pair varied significantly among populations ($F_{12, 1207}$ = 12.22, $P <$ 0.0001). In particular, mean number of fledged young in our study population was lower than recorded in the western Italian Alps (Fasce and Fasce 1984, Bocca 1989), southwestern French Alps (Coulumy 1996), and Swiss Grisons (Haller 1996) and it was higher than recorded in the French pre-Alps (Mathieu and Choisy 1982, Huboux 1984), Haute Savoie (Estève and Matérac 1987), Canton of Berne (Jenny 1992), and eastern Italian Alps (Tormen and Cimbien 1995) (Duncan's multiple range test, $P <$ 0.05). The percentage of successful pairs raising two young to fledging also varied significantly among populations (χ^2_{12} = 43.7, P = 0.0001): in our study area it was higher than in Haute Savoie (Estève and Matérac 1987) (χ^2_1 = 5.8, P = 0.015), but lower than in the southwestern French Alps (Couloumy 1996) (χ^2_1 = 7.1, P = 0.008). The proportion of pairs composed of one adult and one nonadult individual was 35% (N = 26) in the French pre-Alps in 1979–80 (Mathieu and Choisy 1982), 4% (N = 132) in the western Italian Alps between 1980–83 (Fasce and Fasce 1984), 10% (N = 31) in the western Italian Alps in 1987 (Bocca 1989), 21% in the eastern Italian Alps (Tormen and Cimbien 1995), and 16% in this study. The estimate from our population was similar to both the western Italian Alps in 1987 (χ^2_1 = 0.69, P = 0.40) and the eastern Italian Alps in 1989–94 (χ^2_1 = 0.62, P = 0.43), higher than in the western Italian Alps in 1980–83 (χ^2_1 = 8.41, P = 0.004), and lower than in the French pre-Alps in 1979–80 (χ^2_1 = 3.83, P = 0.05).

Human Persecution and Electrocution. Between 1970–89, 18 deaths were caused by illegal shooting and reported to local authorities, or directly to the authors. Fifteen of the deaths occurred between 1980–89. Electrocution caused the death of three individuals in the same time period.

DISCUSSION

In our study area, Golden Eagles occupied traditional nest areas and showed remarkable population stability over a period of 6–11 yr. Density was the lowest published for the Alps, but mean nest spacing was comparable and not different from those reported for other alpine populations. Productivity was lower than reported in the Swiss Grisons, southwestern French Alps, and in the western Italian Alps, but similar or higher than all other nine estimates for eastern, central, and western populations. Finally, diet was dominated by roe deer, marmots, hares and chamois, as observed elsewhere within the alpine chain (Huboux 1984, Henninger et al. 1986, Haller 1996).

Golden Eagle population density and productivity are affected by food availability (Watson et al. 1989, Watson et al. 1992, Steenhof et al. 1997), land use changes (Marquiss et al. 1985), human persecution and unintentional disturbance (Jenny 1992, Watson 1994, McGrady 1997), and intraspecific interference competition (Jenny 1992, Haller 1996). In our study area, populations of all main prey species are currently increasing (Perco 1990, P.A.T. 1995), mainly due to better management of hunting activities, more effective wildlife legislation, and marmot reintroduction programs. As an example, between 1982–94, the local roe deer and chamois populations increased by 12% and 101%, respectively (P.A.T. 1995). While food supply was increasing, land abandonment and consequent forest expansion were causing an increasing loss of alpine pastures (P.A.T. 1995, Pedrini and Sergio 2001), the main Golden Eagle foraging habitat in the Alps (Haller 1996). This trend is common throughout the alpine chain and is causing considerable concern over its long-term impact on local eagle populations (Mathieu and Choisy 1982, Huboux 1984, Estève and Matérac 1987, Fasce and Fasce 1992). The negative long-term effects of afforestation on Golden Eagle reproduction have been demonstrated in Scotland by Marquiss et al. (1985) and Watson (1992). In our study, the amount of woodland and grassland habitats within 5 km of the nest-area center appeared to be almost significantly related to productivity, after removing the effects of density, which may be important in explaining variations in productivity in some alpine populations (Jenny 1992, Haller 1996). We suggest that further woodland expansion could cause significant long-term declines in productivity. Watson (1992) showed how afforestation can affect Golden Eagle breeding success with a time lag of up to 10 yr.

Persecution accounted for the death of 15 individuals between 1980–89. In the province of Trento, Golden Eagles were given legal protection in 1970. Since then, illegal shooting and trapping have declined markedly. However, our data suggest a level of persecution higher than estimates from the Italian Alps (Bocca and Maffei 1984, Fasce and Fasce 1984) and similar to reports from the Appennines, where Golden Eagles are reported to be kept at low densities mostly by human persecution (Ragni et al. 1986). Also, the 15 deaths from persecution were probably a minimum estimate, as killings are illegal and thus likely to go usually unrecorded. Thus, the real level of persecution may be much higher. The high percentage of pairs with nonadult partners further testified to elevated levels of persecution (Steenhof et al. 1983, Watson et al. 1989), though it may have also been associated with a possible population increase, suggested by data collected in the late 1990s (Pedrini unpubl. data). More public education on the well-demonstrated insignificant impact of Golden Eagles on domestic or game species (Clouet 1981, Mathieu and Choisy 1982, Haller 1996) could be beneficial in decreasing the level of illegal shooting.

If the trend in direct human persecution is slowly declining within the alpine chain, unintentional disturbance seems to be a steadily increasing threat. Road construction has allowed easy access to once remote areas. The rapid expansion of "green" tourism is leading to considerable human presence in remote mountain valleys. Off-site skiing is expanding human presence in areas far away from ski runs during the winter and early spring period, both of which are sensitive stages during the breeding cycle. Various recreational activities have been widely reported to cause breeding failures or prevent usage of hunting grounds by alpine Golden Eagles. These include climbing, para-gliding, hang gliding, hiking, heli-skiing, snowmobile and helicopter activities, and nature photography (Mathieu and Choisy 1982, Bocca 1989, Jenny 1992, Beaud and Beaud 1995, McGrady 1997). In Switzerland, 27% of known breeding failures were caused by unintentional disturbance near occupied nests (Jenny 1992). Problems are aggravated by the high sensitivity of Golden Eagles to human presence around nest areas and by the fascination of this raptor to photographers (Jenny 1992). We know of one case of premature fledging caused by disturbance by photographers in our study area. In the province of Trento, disturbance connected with nature photography has been increasing so rapidly in the last decade that a mass media campaign against photography at the nest has been undertaken and, in 1998, led to a new law against disturbance to wildlife.

Finally, breeding success in our study area was not related to NND, a difference from the density-dependent reproductive output reported for the Swiss Alps (Jenny 1992, Haller 1996). In these studies, productivity was negatively affected by intraspecific interference competition early in the breeding season and, particularly so, by territorial disputes between resident pairs and intruding floaters.

In conclusion, alpine populations of Golden Eagles have been reported to be locally increasing to almost carrying capacity (Haller and Sackl 1997). Despite this, we suggest that the future long-term population trends of Golden Eagles in the Alps will be determined by the interaction among increasing food supply, declining availability of suitable foraging habitat, decreasing human persecution, and increasing unintentional human disturbance. We also warn that the local density dependency of productivity and the potential time lags in the effects of land-use changes on productivity could be masking the long-term effects of habitat loss on alpine populations. As a result, we strongly recommend the continuous monitoring of Golden Eagle density and productivity within the alpine chain. Current threats to alpine Golden Eagles could be decreased by: (1) increasing subsidies of the Common Agricultural Policy for extensive agro-pastoral practices; (2) educating hunters, farmers, foresters, development planners, and local communities on the ecological role of top predators within alpine ecosystems; (3) informing organizations and institutions related to the growing industry of tourism and recreational outdoor activities on ways to minimize unintentional disturbance to nesting pairs; and (4) increasing the current knowledge of factors affecting the selection of nesting and foraging habitat by territorial and nonterritorial eagles in the Alps.

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