Errors in Age Determination of Mouflon in the Field

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Abstract

*In mouflon (*Ovis gmelini musimon × Ovis *sp.) populations, most age-related ecological studies have used morphological characteristics to determine age categories in the field although the validity of this approach remains largely untested. We estimated error rates in age determination from observations of known-age mouflon in southern France. Based on repeated observations of 163 animals, we estimated the sex-, age- and time-variations in error rates. We showed that the age-related pattern of error was the same for both sexes and was not time dependent. Male (7.4% [6.7; 11.1] $_{CI95\%}$) and female (6.7% [3.2; 12.9] $_{CI95\%}$) lambs had a low and similar probability (*P *= 0.61) of error, whereas older mouflon, and more females (53.2% [43.2; 62.5] $_{CI95\%}$) than males (27.1% [19.2; 34.5] $_{CI95\%}$,* P *≤ 0.001), had a high probability to be misclassified. Over and above the skill of the observers, the morphological criteria used to discriminate age categories probably account for these high and sex-specific error rates. To correct these errors, we recommend that: 1) criteria used in the field be tested on a sample of known-age animals from the studied population; or 2) field aging be restricted to well-defined age categories such as lambs, ewes, and rams.*
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Key words

age determination, Caroux-Espinouse massif, France, mouflon, observer error, Ovis gmelini musimon × Ovis *sp.*

Variation in life history traits such as survival or reproduction of most vertebrates is closely related to age (Stearns 1992). Age structure is, therefore, key to understanding population dynamics (Gaillard et al. 2000, Coulson et al. 2001) and executing management programs (Bender et al. 1994, Jensen 1996, Van Deelen et al. 2000, Sæther et al. 2001). When studying ecological or ethological patterns of unmarked free-ranging animals, wildlife researchers have to classify animals into age categories (e.g., Gray and Simpson 1980, Bleich 1998). In ungulate populations several criteria based upon physical or behavioral characteristics have been developed (e.g., head and horn size of Barbary sheep, *Ammotragus lervia* [Gray and Simpson 1980] and mountain goats, *Oreamnos americanus* [Smith 1988*a*]). However, the first step for using such criteria is to validate them with a sample of known-age animals (Bender et al. 1994). The subsequent step involves developing field application methods and testing observers' abilities (Smith 1988*b*, Garel et al. 2005*b*).

In mouflon (*Ovis gmelini musimon* × *Ovis* sp.), criteria used to discriminate between age categories in the field have been developed in hunted populations of Central Europe (Türcke and Schmincke 1965, Tomiczek 1989, Ludwig and Peukert 1992) and extended to other populations (e.g., Pfeffer 1967, Chauvière 1978). In these studies, age categories were principally discriminated using length and development of horns for males and the size of the white facial mask for females. Many field studies have subsequently used these criteria to discriminate among age categories when analyzing age-related behavioral and ecological characteristics (e.g., Le Pendu et al. 1995, Ciucci et al. 1998, Cransac et al. 1998, Réale et al. 1999). The reliability of such techniques remains, however, largely untested. Moreover, recent studies (Boussès and Réale 1994, Garel et al. 2005*c*) have reported that the high variability among animals in horn and facial mask length limit their utility for determining the age of animals.

We tested and quantified errors of field-based age-category determination of 163 known-aged mouflon in the Caroux-Espinouse population, France. We first assessed the general pattern of error in relation to the age categories used in the field for both males and females. We then modelled age- and sex-dependent variation in error rates. Horn length of males has been reported to be a better age criterion than the facial mask length used for females (Garel et al. 2005*c*). The error rate should, thus, be higher in females compared to males. Further, because age criteria are growth functions, we also accounted for time-dependent variation in error probability. We finally propose recommendations to assess age of unmarked free-ranging mouflon.

Study Area

Our study site was located on the southern border of the Massif Central in southern France. Mouflon inhabited the Caroux-Espinouse massif (43°38′N, 2°58′E, c.a. 17,000 ha). Elevation ranged from 300–1,124 m. Climate was a mixture of mediterranean, oceanic, and mountain influences (Thiebaut 1971, Garel et al. 2004), providing an irregular mosaic of forest (beech [*Fagus sylvatica*], chestnut [*Castanea sativa*], evergreen oak [*Quercus ilex*]), broom moorlands (*Cytisus purgans*, *C. scorparius*), heather moorlands (*Erica cinerea*, *Calluna vulgaris*), meadows (*Festuca panicula*, *Agrostis capillaris*) and steep rocky slopes.

The mouflon of this population were introduced and originated from both native Corsican mouflon (*Ovis gmelini musimon*, var. *corsicana*) and continental mouflon (French and Czechoslovakia) which had ancestors crossbred with other wild or domestic sheep (Cugnasse 1994, Petit et al. 1997, Garel et al. 2005*a*). Therefore, our population had uncertain and possibly mixed origin,

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Table 1. Error rate (CI 95%) in age category determination of mouflon in the field, southern France, 1994–2004.

Age categories[a]	Males ($n = 85$)	Females ($n = 78$)	Bootstrap comparison
Lambs	7.4% [6.7; 11.1]	6.7% [3.2; 12.9]	$P = 0.61$
1 year	29.2% [17.4; 41.7]	56.3% [35.7; 75.0]	$P = 0.04$
2–3 years	31.6% [18.8; 46.7]	50.0% [33.3; 71.4]	$P = 0.09$
4–6 years	20.0% [6.7; 33.3]	30.0% [10.0; 53.9]	$P = 0.39$
7+ years	0.0% [0.0; 33.3]	77.8% [60.0; 90.9]	[b]

[a] For sample size within each age and sex category see Fig. 1.
[b] Because of the low sample size for males ($n = 3$, see Fig. 1), we did not compare male and female estimates for this age category.

considered to be *Ovis gmelini musimon* × *Ovis* sp. by Cugnasse (1994).

Methods

Collection of Known-Age Animals

These mouflon have been monitored by the National Game and Wildlife Service (O.N.C.F.S.—French ministry of environment) since 1974. Males and females were trapped during spring and individually marked with colored collars (Cugnasse et al. 2001). Mouflon captures were done with ministerial authorization (French Environment and Regional Planning Ministry no. 99/392/AUT, 3 Mar 1999). Collared animals were visually monitored year-round. For our study, we considered only animals that had been marked as lambs, which enabled us to compare an exact true age with observations in the field (78 females and 85 males).

Estimation of Age in the Field

We systematically recorded estimated age categories of collared animals from 1994–1995 and from 2000–2004. We made observations with 8 × 42-mm binoculars and 20–40–60 × 77-mm spotting scopes. We assigned observed mouflon to age–sex classes in line with schema relating morphological criteria to the age of the animal (see e.g., Türcke and Schmincke 1965, Pfeffer 1967, Chauvière 1978).

We principally estimated the age of males from horn size and horn development. We characterized age categories by position of the horn tip relative to the base of the neck and eyes (Türcke and Schmincke 1965, Pfeffer 1967, Chauvière 1978, Tomiczek 1989). Most often, we used the size of the white facial mask as the criterion for age category estimation of ewes (Türcke and Schmincke 1965, Pfeffer 1967, Tomiczek 1989, Boussès and Réale 1994). The facial mask corresponds to a whitening of the skin of the face, which progresses with age from the nostril toward the face (Tomiczek 1989). Discrimination of age categories also was complemented by studying combinations of physical characteristics, such as age-related variation in body size and morphological configuration (e.g., head shape; Chauvière 1978 and Tomiczek 1989), and behavioral characteristics, such as mother–lamb relationships (Türcke and Schmincke 1965, Pfeffer 1967, Tomiczek 1989).

Age categories used in field studies (e.g., Le Pendu et al. 1995, Ciucci et al. 1998, Cransac et al. 1998, Réale et al. 1999) generally distinguish between lambs, yearlings (1 year), and older animals. Age category estimation is less precise for old mouflon compared to young because annual variations of criteria (e.g., horn length; Hoefs 1982) are less distinct in older animals. Therefore, wider age categories generally are used to classify older mouflon. Based on the combination of schema (see Türcke and Schmincke 1965, Pfeffer 1967, Chauvière 1978) describing horn tip position and facial mask length with age, the following classes were used for both sexes in Caroux-Espinouse: lambs, yearlings (1 year), 2–3 years, 4–6 years, and 7+ years. Although it was not always possible to distinguish male and female lambs in the field (e.g., during the first 2 months when males have small horns), we separated these 2 sex-categories during the analysis based on sex identification of the animal when it was trapped and marked. We considered change of age category to occur on 1 April (Bon et al. 1993).

Statistical Analysis

Data in the total data set (309 observations for females and 266 for males) were partly non-independent due to the repeated observation of some animals. Indeed, we observed most mouflon (107 out of 163 animals) more than once (mean number of observations = 4.9). We thus built a subsample of the data set including only independent observations by randomly drawing 1 observation for each animal observed more than once. We then bootstrapped this procedure 1,000 times to obtain, for each age and sex class, the distribution of error rates (Table 1) as well as the distribution of the number of animals which were correctly or incorrectly assigned to their age category (Fig. 1). We used the quantiles 2.5%, 50% and 97.5% as unbiased descriptive statistics of such distributions (Efron and Tibshirani 1993). To compare error rates between sexes, we computed from the 1,000 samples the vector of differences between male and female parameters. We then compared this distribution with zero to assess the significance of the difference (Table 1).

We also computed the probability of error (0 or 1) by age and sex class for each subsample. We then used a logistic regression model with a binomial link function to investigate sex-, age- and time-dependent variation in error rate in each subsample. We used the 5 age categories used in the field (see "Estimation of age in the field") as the full-age model. To test alternative age structures for the error, we used all different potential combinations resulting from the reduction of the full age model (e.g., lambs, 1 year, 2–6 years, 7+ years). Because males and females were not aged with the same age criteria, we included an age × sex interaction term. Furthermore, age estimation is based on growth parameters. We, thus, included the effect of date of observation in the model, either as a linear effect (month or day of observation) or as a factor, by considering the seasons of growth in age criteria. We used 4 seasons: 1) 15 June–31 August and 1 November–31 March when growth is expected to be limited by climatic constraints (drought and winter periods; Auvray 1983, Garel et al. 2004); and 2) 1 April–14 June and 1 September–31 October during vegetation

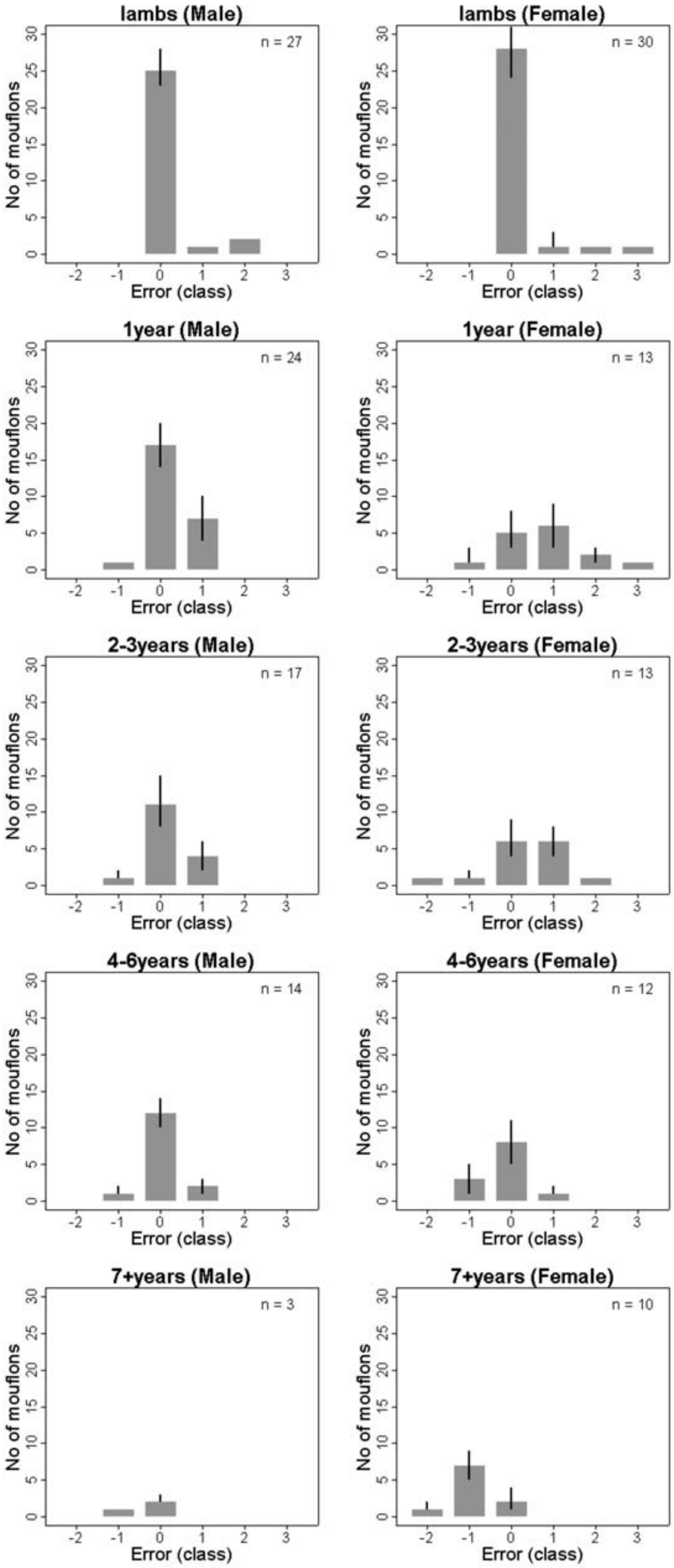

Figure 1. Mean number (CI 95%) of mouflon correctly or incorrectly classified in relation to the age categories used in the field, southern France, 1994–2004. Error class corresponds to the range of error calculated as the number of classes of difference between the known age category and the estimated age category.

growth (Auvray 1983). These periods also account for changes in females' coat (from winter to summer coat, Pfeffer 1967) which might influence assessment of facial mask length. We also took into account a possible interaction between sex and time in the model. Indeed, the annual growth of the white facial mask probably is less related to the availability of food than horn growth and is, thus, more unpredictable (Pfeffer 1967, Boussès and Réale 1994, Garel et al. 2005*c*). We excluded other and higher-order interactions because of the low sample size for some age categories (see Fig. 1).

We were not able to look for an observer effect because of the high number of observers (31), the variation in the number of observations per observer (from 1–25), and the absence of an observer identifier in some cases. Moreover, we had no reliable way to classify observers in relation to their ability. James et al. (1996) showed that the bias associated with differences among observers may be offset by the gains in precision obtained by ignoring observer effects.

Model selection was based on the Akaike Information Criterion (AIC) with second-order adjustment (AICc) to correct for small-sample bias (Burnham and Anderson 1998). The most parsimonious model (i.e., lowest AICc) was selected for each of 1,000 subsamples as the best model. The strength of evidence in favor of a given model is, thus, estimated by the number of times that model occurred as the best model among the 1,000 subsamples. We performed all analyses and bootstrapping using R 1.9.0 (R Development Core Team 2004).

Results

On average, the error rate in age determination estimated from the 1,000 subsamples of the data set was lower in males (21.2% $[15.3; 25.9]_{CI95\%}$) than in females (35.1% $[28.6; 41.6]_{CI95\%}$, $P \leq 0.001$). Relative to male and female lambs which had the same and low probability to be misclassified (Table 1), average error rates were greater for ≥1-year-old animals (Male: 27.1% $[19.2; 34.5]_{CI95\%}$, Female: 53.2% $[43.2; 62.5]_{CI95\%}$) and still lower in males than in females ($P \leq 0.001$). Females tend, thus, to be misclassified more often than males for all age categories >lambs (Table 1). For both males and females, observers overestimated the age of mouflon in the intermediate age categories (1 year and 2–3 years), whereas for the 4–6-years category there was no pattern to systematically underestimate or overestimate age (Fig. 1).

Five models were strongly supported by the data given that they occurred in 646 samples ($n = 1{,}000$) as the best models (Fig. 2). Among them, none included time-dependent effects, suggesting that the age-related pattern of error was constant over the year for both sexes. Model 12 appeared to be the best model from the set of candidate models (Fig. 2): it was 1.8 times as likely ($n = 261$) as the second-best model, 21 ($n = 146$). Both these 2 models suggested that the pattern of error across age categories is the same for both sexes. Under model 12, the probability of error should be the same for 1-year-old and for 2–3-year-old animals (Females 1–3 years old: 54.0% $[39.1; 66.7]_{CI95\%}$; Males 1–3 years old: 30.7% $[21.2; 39.0]_{CI95\%}$, difference between sexes: $P = 0.003$). Over and above such similarities of error rate among the young age categories, we concluded, as suggested by the second-best model,

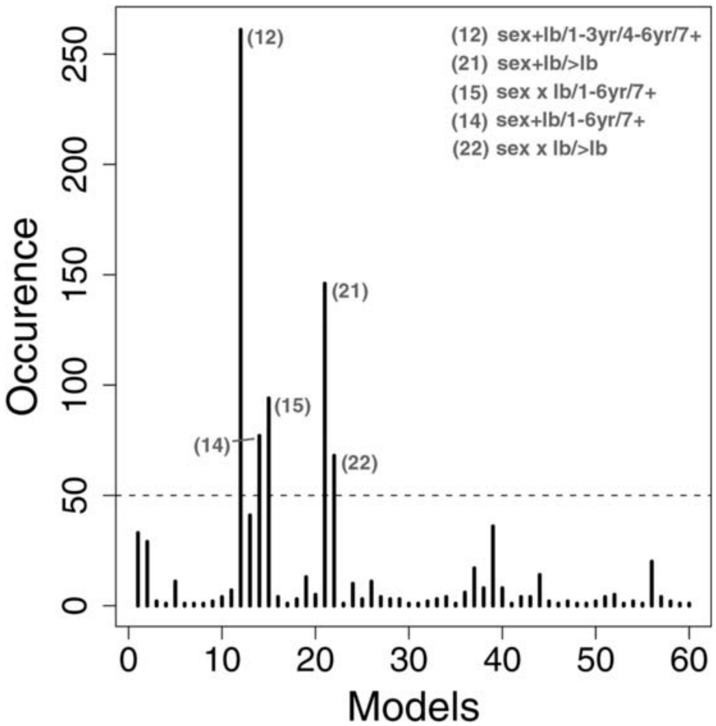

Figure 2. Occurrence of the 60 best models selected from 1,000 sub-samples of the data set obtained after randomly drawing 1 observation for each animal observed repeatedly, southern France, 1994–2004. Only the symbolic notation of the most frequent models ($n > 50$) is provided according to their model number. "+" indicates additive effects and "×" interactions between factors.

that error rate was higher for adults than lambs (see estimations above), and that such a pattern was consistent among sexes and was not time-dependent (Figs. 1, 2; Table 1).

Discussion

Previous studies have reported a high inter-individual variability in horn length (Garel et al. 2005*c*) and facial mask length (Boussés and Réale 1994, Garel et al. 2005*c*) which limit the utility of such criteria to age mouflon. In agreement, we found a high error rate during field observations, both for males and females, even when age category is determined in the field with the help of other morphological characteristics such as age-related variation in body mass or head shape as well as the comparison with other easily aged animals (lambs, for instance). Further, inter-individual variability in age criteria has been reported to be higher in facial mask length than horn length (Garel et al. 2005*c*) and was, thus, consistent with the higher error rate for females reported here (Table 1).

Occurrence of observer effects also could explain the age determination error reported in our study. Observer effects correspond to individual variability among observers due to motivation, experience, animal perception, and conditions during the time of observation. For example, differences in the way that horn length or facial mask length are viewed subjectively may contribute to the incorrect age category classification. Climatic conditions (e.g., wind, fog), distance between observer and animal, and animal behavior also may contribute to variation in perception of morphological characteristics used in age category determination in the field. However observer effects were probably minor in our study because 1) most groups were observed in open areas and for several minutes before age was determined; 2) most observers were experienced; 3) the effect of observer experience during observations decreased rapidly with training (after 2 days; Garel et al. 2005*b*) and 4) previous studies have shown that both inexperienced and fully experienced observers may misclassify animals (Bleich 1998 in mountain sheep, *Ovis canadensis*; Smith 1988*b* in mountain goats). We cannot exclude, however, that observer effects partly explain the difference in error rates among sexes given that such effects are greater for coloration patterns than for horn size (Tomiczek 1989).

Despite the difference in age criteria used and the differences in their growth propriety, the age-related pattern of error was not time dependent and was similar between sexes, with higher error rate for animals older than lambs (Fig. 1; Table 1). For lambs, behavioral characteristics such as mother–lamb interaction provide additional information which may help in age determination. Moreover, at this stage the inter-individual variability in horn length is low, improving reliability of age estimation of males (Garel et al. 2005*c*). For older animals, in addition to the high error rate, we showed that observers tend to systematically over-estimate the age of animals of 1 and 2–3 years old (Fig. 1). Although for females it is difficult to suggest an explanation, such a pattern for males may result from the fact that the horn-growth scheme used to discriminate age categories was established in northern European populations (Türcke and Schmincke 1965, Tomiczek 1989, Ludwig and Peukert 1992). Rams from southern populations (e.g., present study) invest more in horn growth during their first year of life compared to rams from northern populations (Pfeffer 1967, Hoefs 1982, Hoefs and Hadjisterkotis 1998, Garel et al. 2005*c*), and this could explain the overestimation of age for males in our population.

Management Implications

In continental Europe, mouflon originating from native Corsican and Sardinian populations (Uloth 1972, Bon et al. 1991) were introduced in several habitat types (e.g., Alpine, Coastal, Forest, Park; see Pfeffer 1967, Weller 2001), which were sometimes much different from their original biotope. During such introductions inter-mating occurred between domestic and wild sheep (Türcke and Schmincke 1965, Ultoh 1972, Cugnasse 1994). As a result, both environmental and genetic variation within and between mouflon populations are high, resulting in wide variation in life history traits (e.g., Garel et al. 2005*a*). As such, managers should be cautious when assigning age categories using horn length or facial mask length (see e.g., Frisina 2002). In such a context, our results can only describe a general pattern of the error rate of age estimation in mouflon populations.

However, the real problem remains that misclassified animals may contribute to wrong estimates of population composition (Bleich 1998) or trend (Rubin et al. 1998) and can bias analysis of population dynamics (Link and Sauer 1997) and management programs (Jensen 1996, Sæther et al. 2001). The most reliable alternative is to mark free-ranging animals of known age (e.g., Gaillard et al. 1997, Bonenfant et al. 2002). However, in most

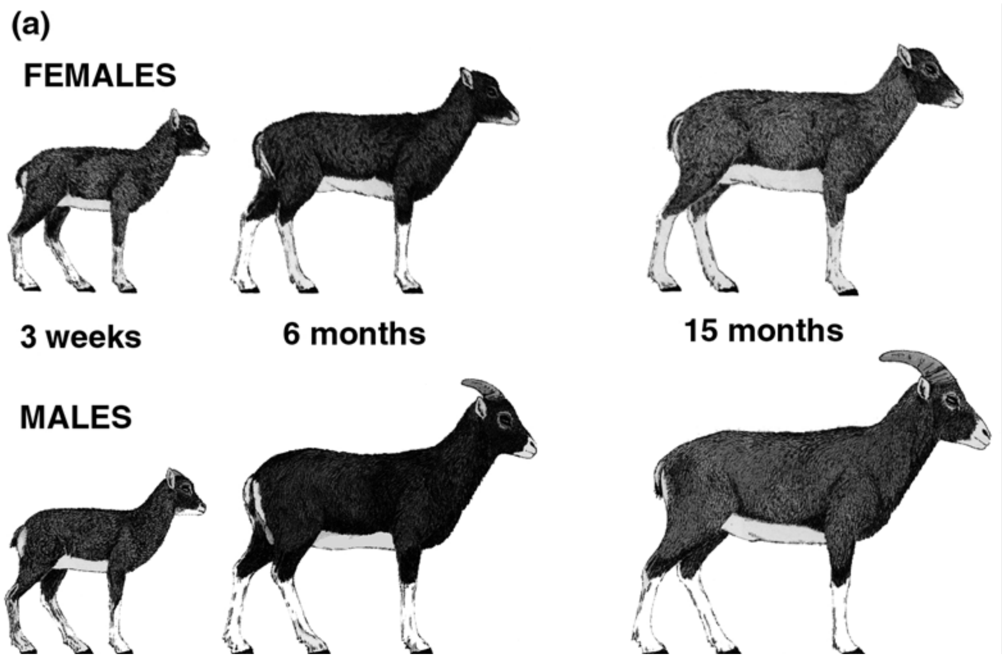

Figure 3. Schematic representation of (a) age-related variation in body size, horn length, rib cage size, and (b) muzzles shape in mouflon (adapted from Corti et al. 1994).

cases, mark–recapture or mark–resighting methods are both costly and time consuming (Link and Sauer 1997).

When working with unmarked animals, we, thus, suggest the following: 1) use only criteria validated on a sample of known-age animals from the studied population to account for inter-population variability in environmental condition, genetic origin, and growth pattern (see e.g., previous paragraph); or, 2) use a restricted number of age categories: lambs ($<$1 year), ewes and rams ($\geq$1 year). Our results showed that little error was made in age determination of lambs and few animals of $\geq$1 year old were misclassified as lambs.

To distinguish lambs from other mouflon, we, thus, recommend the use of behavioral criteria during the first 3 months of life such as suckling behavior, and, subsequently, the age-related variation in horn length for males ($<$30 cm, Garel et al. 2005c), in body size and morphological configuration (Figs. 3a,b). For instance, lambs have a shallower rib cage (Fig. 3a) than adults and narrow and triangular muzzles (Fig. 3b; see also Chauvières 1978, Tomickezk 1989). In this context, we believe that age-category determination in the field of unmarked mouflon should be used only for assessing simple ecological characteristics of the population (e.g., an index of reproduction), as commonly used in North American deer populations for ground and aerial surveys (Williams et al. 2002, Bender et al. 2003).

Group mixture of adult mouflon with two males, on the left and on the right, and three females (horned) in the middle. Variations of facial mask length can be seen in females and males, and variations of horn shape can be seen between males. (Photo by D. Maillard, Office National de la Chasse et de la Faune Sauvage.)

Group mixture with four females (two horned on the front) and one male. One female is marked with a collar (horizontal black sign). This female was not marked as a lamb, and therefore it is not possible to know her exact age. (Photo by D. Maillard, Office National de la Chasse et de la Faune Sauvage.)

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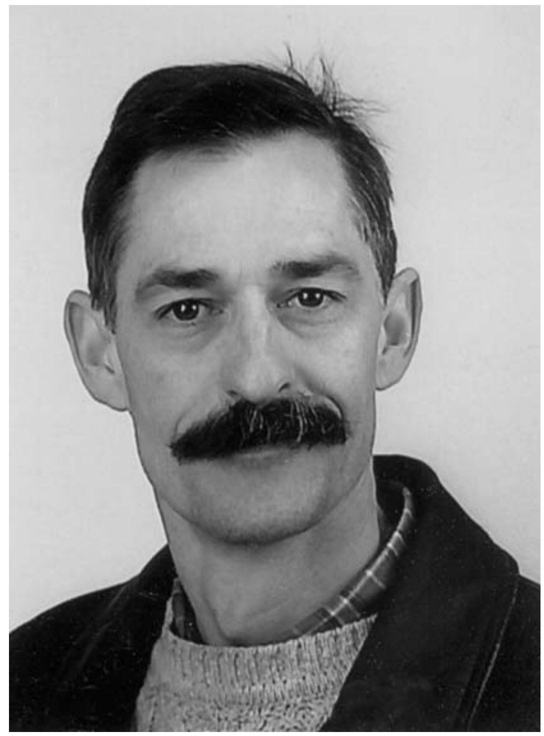

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