NOTE TECHNIQUE

FIELD AGE DETERMINATION IN THE EUROPEAN BADGER

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Fundamental to any critical population studies, including those of reproductive ecology and the epidemiology of diseases such as rabies or bovine tuberculosis of concern to man, is a valid ageing technique — this being stressed recently as one of four key research needs outstanding for the Eurasian Badger (*Meles meles* L.) (Anderson & Trewhella, 1985).

Among existing ageing methods, counting annual incremental lines in sections — usually in canine tooth cementum — is the primary technique, and the only absolute index for all ages, but of course inapposite ethically for live population studies. Furthermore, owing to faint or irregular lines, this method has variously been shown to be unsuitable for up to 20 % of the material studied (Britain : Fargher & Morris, 1975 ; Hancox, 1973 ; Kruuk, *pers. comm. ;* MAFF, 1985 ; Denmark : Grue & Jensen, 1979 ; France and Holland : Bree *et al.,* 1974 ; Sweden : Ahnlund, 1976 ; Switzerland : Graf & Wandeler, 1982 ; USSR : Klevezal *et al.,* 1981). Annual rings in dentine may be as reliable as those in cement (Ahnlund, 1976 ; Driscoll & Jones, 1985) ; and incisors or perhaps the single rooted second premolars (Kolb, *pers. comm.*) may be easier to soften and section than canines ; while pilot sectioning studies of growth rings in alternative material include mandible and limb bones (Klebanova & Klevezal, 1966) and the eye lens (unreliable : Klevezal & Kleinenberg, 1967).

Amongst other accepted methods, few are practical in the field ; and most serve only to separate juvenile from adult, whilst retaining tooth sectioning for older categories. The three principal such criteria are limb bone epiphysis closure by circa 18 months of age (Ahnlund, 1976 ; Hancox, 1973 ; see below ; MAFF, 1985), and occlusion of the pulp cavity (Graf & Wandeler, 1982 ; Jenks *et al.,* 1984) : both of which might be achieved by X-rays (Sullivan & Haugen, 1956), possibly even under semi-field conditions ; and, thirdly, the conformation/weight/length of the baculum (Ahnlund, 1976 ; Fargher & Morris, 1975 ; Hancox, 1973 & 1988 *in press ;* Graf & Wandeler, 1982 ; Stubbe, 1970). Some other criteria which have likewise been noted as of only limited value include : uterine placental scar counts, eye lens weight, thymus weight, and a brown blaze on the paw in adulthood (Ahnlund, 1976 ; Hancox, 1973 ; Klevezal & Kleinenberg, 1967).

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METHODS

During the course of a general ecological study from 1969-1973, of the dozen clans of badgers on the 1,080 hectare University Wytham Estate near Oxford, skeletal material was collected from spoil heaps outside sett entrances from some 60 individuals ; and from a further 80 badgers (including some road deaths) from elsewhere in southern England. General skeletal variation was studied in over 1,100 badgers altogether, notably in the museums of Copenhagen, Geneva, London, Oxford and Stockholm, and including some known age material. Potential age criteria alternative to tooth sectioning were evaluated to permit study of live badgers or of the spoil heap material which represents a considerable proportion of « natural » mortality, but in which all of the single rooted teeth usually used for sectioning are normally missing (although molars are almost always retained, and show clear patterns of wear).

RESULTS AND CONCLUSIONS

The reliability of tooth wear age determination in different mammalian groups has been variously estimated as 40-80 % accurate (eg. for Raccoon, Grau *et al.,* 1970). Patterns of molar wear in the European Badger were discussed by Heran (1971), and used in ageing a single population by Stubbe (1965), as well as in limited material from diverse Dutch — French sources with a suggested 59 % accuracy by Bree *et al.* (1974). Clear stages in molar wear differentiated four age classes in the present material (Fig. 1), and were a valuable alternative to tooth sectioning, for all ages and sources of material ; particularly for reasonably large samples from specific populations, as in Kruuk's current Scottish studies. Incisors if present, were particularly useful in the 1-3 year stage before much molar wear had occurred. Genetic or dietary deficiency factors in wear appeared to be of limited significance — only one case of rickets — although wear was slight in captive material not surprisingly, and also varied in accordance with edaphic/geographic factors. Two calcium-rich areas thus showed different degrees of wear probably linked to the abrasiveness of the soil clinging to/or contained in the main earthworm food of the badger (over 50 % of the annual diet) : the Wytham population living on coral rag limestone - grit sandstone contrasting with the relatively low wear in badgers on clayey chalk downland near Winchester.

A mortality of nearly 50 % in the first year of life was noted in the present material, only some 35 % achieving ages over three years, and under 10 % living beyond ten years of age ; only two captives have exceeded 15, the longevity record being 19 (Hancox, 1987). Reliable criteria for the adolescent phase of active growth were particularly important : tooth wear then being nil (or slight). Ontogenetically, cubs eyes open at 5-6 weeks of age ; the milk - permanent dentition transition occurring from 6-16 weeks, and usually coinciding for the last few weeks with weaning, although in dry poor earthworm years cubs' growth may be stunted and sows may still be lactating even in late July. Puberty is typically at the yearling stage (c. 14 months) although a few sows in particular, may mature at circa 9 months (30 % in the American Badger), whereas a minority of boars may mature in their second autumn or even later (Neal, 1986).

TABLE I

Age classes based on skeletal criteria.

Age	Teeth	Sagittal crest	Sutures	Epiphyses /Symphyses	Comments
2-6 wk	Milk dentition	Absent	All open	All open	Cub eyes open 5-6 wks
6-16 wk	Milk-permanent transition	Temporal lines apparent			6—8 wk First above ground. 12-15 wk weaning.
5-7 mnth	Adult denti-tion	20-25 mm gap between lines		Ischio-pubic fusion	
8-9 mnth	Wear nil	10-15 mm gap	Closure of inter-frontal inter-parietal	Iliac fusion hence 2 half pelvises, distal humerus epip. fusing	Glenoid flange recurves part locks' jaw-skull
10-12 mnth		Single median crest	Fronto-parietal open		Mandible coronoid process smooth bone now
1-2 yr	Wear nil-slight, canine sharp ant-post edges still	Crest height 2-9 mm, of spongy-rough bone	Fronto-parietal closed, closing : nasals, zygoma squamoso-partl, pre-basisphenoid-basioccipital	Closing of long bone epiphyses ; distal tibia, radius, ulna by 18 mnth (M.A.F.F.)	Puberty ♂ & ♀, baculum adult length & flaring of tip
2-3 yr	Wear nil-slight	6-10 mm, sides become rugose	Trace nasal, zygoma, squamoso-parietal	Closure & obliteration last long bone epips. & pelvic epiphyses	Growth effec-tively ceases
3-5 yr	Wear slight-moderate	7-13 mm, thickens, posterior over-hang develo-ping		Inter-pubis symp. & proxi-mal scapular epip. close	Inter-mandibular symphysis often fused
5-10 yr	Wear moderate-marked	8-15 mm		Pelvis one unit	Baculum roun-ding & thicke-ning apically
10-15 yr	Wear very marked				

A peak cub mortality occurs within setts ; before first emergence above ground at 6-8 weeks (Neal, 1986) ; a second peak, also of circa 20 %, coincides with the adult dentition — immediate post-weaning stage of 5-9 months of age before some cubs have mastered independant foraging. This stage is represented

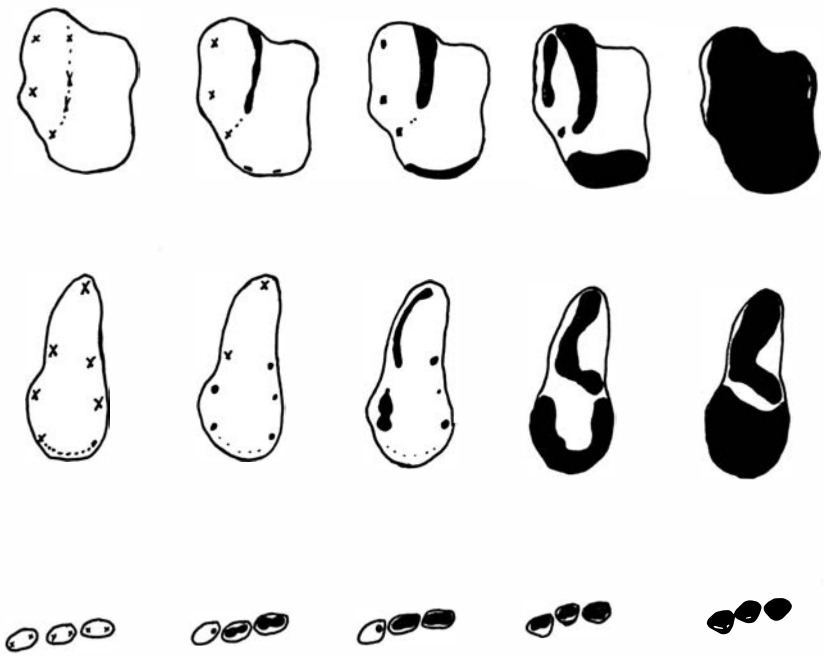

Figure 1. — Stages in tooth wear (right upper molar, left lower first molar, left lower incisors).

by the very characteristic and common spoil heap material comprising just the posterior cranial casket, with distinctive squared auditory bullae as compared to the ovoid bullae of comparable fox material also encountered on spoil heaps, but lacking the entire nasal/maxillary region owing to incomplete suture closure : all sutures and epiphyses remain open until circa 8 months of age. The two lateral temporal line muscular attachment ridges have a 20-25 mm separation at this age, but coalesce to form a single median sagittal crest at 10-12 months of age ; which has a very characteristic spongy surface indicative of rapid growth in height to 2-9 mm by circa 2 years old. The crest may ultimately attain 15 mm in height, but this development is partly sex-linked ; much of the growth being by slow accretion, smoothing the bone surface initially, then increasing the rugosity and thickening the crest.

A third mortality peak in the adolescent yearling stage (1-2 years), coinciding with the first winter and attempt to become established within the community, has skulls with this characteristic spongy low crest ; canines which still have distinctive sharp antero-posterior edges ; and the fronto-parietal and other skull sutures closed, although traces of the nasal and zygoma (jugo-squamosal) sutures persist as a diagnostic faint line even into the third year.

The morphological features of advanced age are well described by Heran (1984) and by Schufeldt (1922), although his « remarkable » skull photograph is clearly *Meles* (as labelled : Smithsonian Institution *pers. comm.*), and not *Taxidea* as he believed !

Spoil heap material other than skulls was of limited value for age determination, but nevertheless ageable for population studies : long bone epiphyses fused in a sequence related to their involvement in articulations, the distal humerus at circa 8-9 months, the remaining epiphyses — notably the distal tibia/radius/ulna — usually by 18 months of age (Ahnlund, 1976 ; Hancox, 1973 *in* Neal, 1986 ; MAFF, 1985) ; although this was clearly dependant on cub nutrition and rate of growth according to season, with the obliteration of the long bone/pelvic/scapular epiphyses not being completed until 3 years old or so. The ischiopubic fusion by 5-7 months, and subsequent incorporation of the ilia resulted in two half pelvic units by 8-9 months — although the eventual fusion of these two halves to form a single pelvis, as well as the fusion of the symphysis between the two mandibular rami at circa 3-5 years of age was subject to much individual variation and very unreliable for age determination.

In summation ; tooth wear was an alternative, and probably as accurate a technique as tooth sectioning, for the age classes of 3-15 years old limited adult elements of populations in the fields ; whereas changes in the dentition and morphology of the skull and post-cranial elements provided some more precise and practical additional criteria for assessing the adolescents which constitute over sixty percent of wild badger population material.

There is some limited evidence that the numerical stability of badger populations may on occasion be regulated by density dependent constraints on fecundity (Hancox, 1973 ; Anderson & Trewhella, 1985 ; Neal, 1986). However, there is little evidence of migration between clans at high density showing maximal territoriality, eg. of dispersing sub-yearlings (MAFF, 1985) ; and the present study could suggest that the annual recruitment of 20-5 cubs to the minimum estimated population of 45-55 only just allowed for the modest increase in numbers during the study period following earlier culling : the bulk of the recruitment being lost to the heavy natural cub mortality. There is evidence that territoriality is less rigorous at lower density (Kruuk & Parish, 1987) or in atypical discontinuous urban conditions (Harris, 1984), and culling with a view to rabies or tuberculosis disease control programmes is hence likely to be counter-productive, actually encouraging the spread of badger vector individuals — a factor taken into account in the recent changes of Ministry of Agriculture policy in Britain (Dunnet *et al.*, 1986).

RÉSUMÉ

Les critères utilisés antérieurement pour établir l'âge des blaireaux sont évalués pour les études pratiques d'écologie ou d'épidémiologie. L'usure des dents d'adultes vivants et les critères de développement du crâne et des os de membres adolescents (crête sagittale, et fermeture des sutures et des épiphyses) sont des caractères utiles dans certaines populations.

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