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## Chapter 4

### Mortality models and the interpretation of horse population structure

Marsha A. Levine

Assemblages of prehistoric horse teeth are aged to reveal the structure of the animal populations from which they were derived. The material is from French and German Pleistocene deposits, some natural and some archaeological in origin. Two systems of relative ageing are employed here: eruption–wear sequences and crown–height curves. The age patterns derived from the various assemblages are compared with one another and with various mortality models. The results of this study suggest that the horses from the archaeological deposits examined here were probably not domesticated.

#### Introduction

Assemblages of prehistoric horse teeth have been aged in order to reveal the structures of the carcass populations from which they have been derived. An assemblage might never have been representative of any living animal population, but it should be representative of the individuals whose carcasses comprised it. If that is true, it should be possible to suggest from its age structure how the assemblage might have been formed. In the case of material from an archaeological deposit it should be possible to learn something about the subsistence patterns of the people who created it. The material used in this study is from 13 Pleistocene deposits; 9 are archaeological in origin and 4 are natural (table 4.1). All but one (a German site) are French.

Two interlocking and internally coherent tooth ageing systems have been employed in the analyses carried out here: eruption–wear sequences and crown–height wear curves

(Levine 1979). They are relative ageing techniques, but used together they constitute an ageing system of considerable precision and one which is easily applicable to a wide range of material. The age patterns thus derived are compared with one another and with various mortality models. Cluster analysis techniques are used in an attempt to discover patterns not otherwise apparent.

Although sophisticated methods of demographic analysis have been developed for studies of both men and animals, they are not strictly applicable here because of the inadequacy of the fossil data. However, generalizations based upon analyses of modern comparative data can help to explain some of the fossil patterns observed below.

#### Mortality patterns

Palaeontologists frequently classify fossil assemblages according to two basic mortality types: catastrophic and attritional (Craig and Oertel 1966; Hallam 1972). Voorhies writes: 'it may be said that catastrophic mortality furnishes a sample of the standing crop of the vertebrate community while attritional mortality mainly reflects the rate of turnover of biomass within the community' (1969: 23).

*Natural catastrophes* include floods, droughts and volcanic eruptions. An equivalent *archaeological catastrophe* is the herd drive in the course of which a large number of animals are frightened over a precipice or into an enclosure

Table 4.1. *Assemblage unit list and tooth: bone ratios*

Site and assemblage unit	Level or square	Geological period	Industry and C14 date (if any)	Teeth	Bones	Bone fragments		Bones, excluding fragments	Teeth:bone-fragments
						no.	%		
<i>Combe Grenal</i>									
CG10	10	Würm II	Typical Mousterian	7	2	1	50.0	1	7.0:1.0
CG11	11	Würm II	Denticulate Mousterian	135	3	1	33.3	2	67.5:1.0
CG12	12	Würm II	Denticulate Mousterian (39 000 ± 1500 b.p., GRN-4304 or 30 300 ± 350 b.p., GRN-4311)	20	2	1	50.0	1	20.0:1.0
CG14	14	Würm II	Denticulate Mousterian	435	14	11	78.6	3	145.0:1.0
CG15	15	Würm II	Denticulate Mousterian	56	2	0	0.0	2	28.0:1.0
CG20	20	Würm II	Denticulate Mousterian (non-Levallois)	25	5	3	60.0	2	12.5:1.0
CG21	21	Würm II	Quina Mousterian	55	2	0	0.0	2	27.5:1.0
CG22	22	Würm II	Quina Mousterian	200	49	15	30.6	34	5.9:1.0
CG23	23	Würm II	Quina Mousterian	173	30	13	43.3	17	10.2:1.0
CG24	24	Würm II	Quina Mousterian	40	5	0	0.0	5	8.0:1.0
CG25	25	Würm II	Quina Mousterian	42	4	1	25.0	3	14.0:1.0
CG27	27	Würm II	Ferrassie-type Mousterian	34	0	0	0.0	0	–
CG28	28	Würm II	Typical Mousterian	6	0	0	0.0	0	–
CG29	29	Würm II	Typical Mousterian	10	0	0	0.0	0	–
CG31	31	Würm II	Typical Mousterian	10	0	0	0.0	0	–
CG70	I	Würm II	Quina Mousterian?	65	14	3	21.4	11	5.9:1.0
CG33	33	Würm II	Ferrassie-type Mousterian	6	0	0	0.0	0	–
CG34	34	Würm II	Ferrassie-type Mousterian	4	0	0	0.0	0	–
CG35	35	Würm II	Ferrassie-type Mousterian	36	9	1	11.1	8	4.5:1.0
CG36	36	Würm II	Typical Mousterian	5	2	1	50.0	1	5.0:1.0
CG37	37	Würm II	Typical Mousterian	22	1	0	0.0	1	22.0:1.0
CG38	38	Würm I	Denticulate Mousterian	12	0	0	0.0	0	–
CG40	40	Würm I	Typical Mousterian	16	2	1	50.0	1	16.0:1.0
CG47	47	Würm I	Mousterian (type uncertain)	13	1	0	0.0	1	13.0:1.0
CG49	49	Würm I	Mousterian (type uncertain)	7	0	0	0.0	0	–
CG50	50	Würm I	Typical Mousterian	94	3	1	33.3	2	47.0:1.0
CG98	50A	Würm I	Typical Mousterian	31	2	0	0.0	2	15.5:1.0
CG51	51	Würm I	Typical Mousterian	13	1	1	100.0	0	–
CG52	52	Würm I	Typical Mousterian	54	2	1	50.0	1	54.0:1.0
CG55	55	Würm I	Typical Mousterian	4	0	0	0.0	0	–
CG56	56	Riss III	Upper Acheulian	6	0	0	0.0	0	–
CG57	57	Riss III	Upper Acheulian	6	0	0	0.0	0	–

*Le Morin*

MO01	AI	Late Würm	Magdalenian VI	57	20	2	10.0	18	3.2:1.0
MO03	AIII	Late Würm	Magdalenian VI	106	26	1	3.8	25	4.2:1.0
MO04	AIV	Late Würm	Magdalenian VI	98	37	2	5.4	35	2.8:1.0
MO05	BI	Late Würm	Magdalenian V	39	20	4	20.0	16	2.4:1.0
MO12	AI/AII	Late Würm	Magdalenian VI	72	24	3	12.5	21	3.4:1.0

*Pech de l'Aze*

PA01	1	surface		11	0	0	0.0	0	—
PA21	2G or 2G1	Würm I	Ferrassie-type Mousterian	4	0	0	0.0	0	—
PA03	3	Würm I	Typical Mousterian	4	0	0	0.0	0	—
PA04	4	Würm I	probably Typical Mousterian	8	1	0	0.0	1	8.0:1.0
PA41	4A2	Würm I	Typical Mousterian	4	0	0	0.0	0	—
PA42	4B	Würm I	Denticulate Mousterian	36	0	0	0.0	0	—
PA43	4C2	Würm I	Typical Mousterian	26	1	0	0.0	1	26.0:1.0
PA05	5	Würm I	almost sterile	15	1	0	0.0	1	15.0:1.0
PA51	5R	Würm I ?	almost sterile	7	1	1	100.0	0	—
PA06	6	Riss II	Acheulian	85	21	1	4.8	20	4.3:1.0
PA67	6/7	Riss II	Acheulian	5	2	0	0.0	2	2.5:1.0
PA69	6/7B	Riss II	Acheulian	5	5	0	0.0	5	1.0:1.0
PA07	7	Riss II	Acheulian	55	20	1	5.0	19	2.9:1.0
PA08	8	Riss I	Acheulian	73	22	7	31.8	15	4.9:1.0
PA09	9	Riss I	Acheulian	91	32	7	21.9	25	3.6:1.0

*Chatillon-St-Jean*

CSJ0		probably Riss	natural	15	115	4	3.5	111	0.14:1.0
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*La Fage-Aven I*

F123	2/3	Riss	natural	18	13	2	15.4	11	1.6:1.0
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*La Fage-Aven II*

F201	1	probably Upper Pleistocene	natural	18	56	29	51.8	27	0.7:1.0
F202	2	probably Upper Pleistocene	natural	78	343	182	53.1	161	0.5:1.0
F203	3	probably Upper Pleistocene	natural	8	85	26	30.6	59	0.1:1.0

*Jaurens*

JA01		Würm II, III or II/III	natural (29 300 ± 1400 b.p., Ly-359)	593	970	47	4.8	923	0.6:1.0
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Table 4.1. continued.

Site and assemblage unit	Level or square	Geological period	Industry and C14 date (if any)	Teeth	Bones	Bone fragments		Bones, excluding fragments	Teeth:bone-fragments
						no.	%		
<i>Roc de Marsal</i>									
RM02	II	Early to Middle Würm	Denticulate Mousterian	4	0	0	0.0	0	—
RM03	III	Early to Middle Würm	Denticulate Mousterian	11	0	0	0.0	0	—
RM04	IV	Early to Middle Würm	Typical Mousterian	26	2	0	0.0	2	13.0:1.0
RM05	V	Early to Middle Würm	Typical Mousterian	46	0	0	0.0	0	—
RM06	VI	Early to Middle Würm	Typical Mousterian	65	1	1	100.0	0	—
RM07	VII	Early to Middle Würm	Typical Mousterian	54	0	0	0.0	0	—
RM09	IX	Early to Middle Würm	Quina Mousterian	69	0	0	0.0	0	—
RM19	IXA	Early to Middle Würm	Quina Mousterian	20	0	0	0.0	0	—
RM29	IXB	Early to Middle Würm	Quina Mousterian	54	0	0	0.0	0	—
RM10	X	Early to Middle Würm	Quina Mousterian	42	0	0	0.0	0	—
RM11	XI	Early to Middle Würm	Quina Mousterian	68	1	1	100.0	0	—
RM21	XIA	Early to Middle Würm	Quina Mousterian	18	0	0	0.0	0	—
RM12	XII	Early to Middle Würm	Quina Mousterian	21	0	0	0.0	0	—
<i>Gönnersdorf</i>									
FG15		pre-Allerod, Late Glacial	Late Magdalenian (10 500 b.c., Ly-768)	220	440	165	37.5	275	0.8:1.0
<i>Blot</i>									
BL22	22	Late Würm	Proto-Magdalenian	13	0	0	0.0	0	—
BL23	23	Late Würm	Proto-Magdalenian	137	43	24	55.8	19	7.2:1.0
BL26	26	Late Würm	Proto-Magdalenian	7	0	0	0.0	0	—
BL27	27	Late Würm	Proto-Magdalenian	62	8	7	87.5	1	62.0:1.0
BL28	28	Late Würm	Proto-Magdalenian	4	0	0	0.0	0	—

BL30	30	Late Würm	Proto-Magdalenian?	15	0	0	0.0	0	—
BL34	34	Late Würm	Proto-Magdalenian	4	0	0	0.0	0	—
BL99	HA			4	0	0	0.0	0	—
<i>Arlay</i>									
ARO1	1	Late Würm	Magdalenian	150	54	2	3.7	52	2.9:1.0
<i>Gigny</i>									
GI15	XV	Würm II	Ferrassie-type Mousterian	12	0	0	0.0	0	—
GI18	XVIII	Würm I	Typical Mousterian?	8	0	0	0.0	0	—
GI19	XIX	Würm I	Typical Mousterian	10	11	1	9.1	10	1.0:1.0
GI29	XIXA	Würm I	Typical Mousterian	9	0	0	0.0	0	—
GI39	XIXB	Würm I	Typical Mousterian	14	0	0	0.0	0	—
GI49	XIXC	Würm I	Typical Mousterian	54	0	0	0.0	0	—
GI20	XX	Würm I	Typical Mousterian (about 31 500 b.p., Ly-804)	21	2	0	0.0	2	10.5:1.0
GI21	XXIA	Würm I or II	possibly Acheulian	8	0	0	0.0	0	—
<i>Solutré</i>									
SO1M	Sq. M12	Würm III	Lower Aurignacian	65	270	82	30.4	188	0.3:1.0
SO2L	Sq. L13	Würm III	Upper Perigordian	275	548	74	13.5	474	0.6:1.0
SO3P	Sq. P16	Würm IV	Final Magdalenian (12 580 ± 250, Ly-393)	422	898	249	27.7	649	0.7:1.0
SO3N	Sq. N16	Würm IV	Final Magdalenian	53	55	15	27.3	40	1.3:1.0
Total				5238	4303	996	23.1	3308	1.6:1.0
Total in archaeological units				4508	2717	703	25.9	2015	2.2:1.0

*Note:* this table includes all the teeth from all the assemblage units studied here, even those not appropriate for ageing. A horse skeleton includes 205 bones and 36 permanent teeth (but a total of 60 teeth if deciduous ones are included). Therefore the ratio of teeth to bones is from 36:205 (0.18:1.00) to 60:205 (0.29:1.00).

and slaughtered *en masse*. Examples of *natural attritional mortality* are disease, malnutrition, senescence, predation and the accidents that affect individuals rather than populations. Those most affected are usually the very young and the very old (Kurtén 1964; Caughley 1966; Voorhies 1969; Mech 1970). A pattern of *archaeological attritional mortality* develops out of those kinds of man-animal interactions in which animals are withdrawn from the living population more or less individually. Either hunting or pastoralism may generate attritional patterns. The shape of the archaeological attritional distribution is not as uniform as that of the natural one. It will depend upon the particular hunting or slaughtering techniques employed and, in the case of some species, the season of the kill.

*Coursing* (chasing on foot) and *scavenging* dead or unfit individuals should produce the same pattern as natural attrition. A *trapping* pattern will depend upon the kind of traps used, but in most cases it should look random: age classes will probably be taken from the living population in the proportions in which they were represented in that population. However in the archaeological situation most samples of trapped ungulates will probably be too small to show any systematic structure. *Stalking* is an attritional hunting technique, which may produce a non-random, non-representative distribution. A good hunter can often choose his prey. Amongst the Bisa and the Hadza of eastern Africa the preferred prey is a large, fat, healthy male (Woodburn, pers. comm.; Marks 1976). However, when hungry, people will eat whatever they can get. Caughley attests to the utility of such an opportunistic strategy in his discussion of ungulate management: 'there is usually little or nothing to be gained from harvesting age classes at different rates. The optimum strategy turns out to be the unselective harvest' (Caughley 1977: 189). In contrast to natural attrition, scavenging and coursing, this strategy takes a low proportion of juveniles and a high proportion of prime adults. Moreover, 'Should mortality be excessively high at the adult stage but juvenile mortality is at a normal level for the species this is *prima facie* evidence that the decline is caused by excessive hunting. Most other agents of mortality act more heavily on juveniles' (Caughley 1977: 171).

When, as with a species like the horse, a number of social units occupy overlapping home ranges, slaughter of whole social units is probably the most efficient hunting strategy: 'Disturbance is minimized thereby and food and other resources made available by the removal of a group are open to utilization by other groups' (Caughley 1977: 187). Driving individual family groups or bachelor groups into enclosures, water or deep snow could achieve this end. It is, in effect, a small-scale catastrophe, affecting all age classes in proportion to their representation in the relevant type of social group.

The only quantitative structural model of *pastoral nomadism* available to me was that devised by Dahl and Hjort with reference to East African cattle husbandry. A short discussion of this model brings up several points probably

Table 4.2. A life table based upon Dahl and Hjort's 'base-line herd model' for cattle

Age (in years)	Mortality rate (%)	Survival		Mortality	
		Frequency	%	Frequency	%
0-1	20.0	1000.0	13.7	200.0	20.0
1-2	7.0	800.0	11.0	56.0	5.6
2-3	7.0	744.0	10.2	52.2	5.2
3-4	7.0	691.0	9.5	48.4	4.8
4-5	5.0	643.5	8.8	32.2	3.2
5-6	5.0	611.3	8.4	30.6	3.1
6-7	5.0	580.7	8.0	29.0	2.9
7-8	10.0	551.7	7.6	55.2	5.5
8-9	10.0	496.5	6.8	49.7	5.0
9-10	20.0	446.9	6.1	89.4	8.9
10-11	33.0	357.5	4.9	118.0	11.8
11-12	49.0	239.5	3.3	117.4	11.7
12-13	90.0	122.2	1.7	109.9	11.0
13-14	100.0	12.2	0.2	12.2	1.2

Note: this model presumes a life expectancy of 9-14 years.

The first column of the table shows the age span during which the deaths are occurring. The second column shows the mortality rate for each age span. The third and fourth columns show respectively the number and proportion of individuals alive at the beginning of each age span. The fifth and sixth columns show respectively the number and proportion of individuals dead by the end of each age span.

Source: Dahl and Hjort 1976: 45-6.

relevant to all kinds of large ungulate husbandry. Dahl and Hjort's 'base-line herd model' has been constructed from a number of sources and represents a stable population with a static age structure. According to the model, cows first produce young at 2 to 4 years of age and continue breeding until approximately their twelfth year. They have a life expectancy of 9 to 14 years (Dahl and Hjort 1976). If we follow a cohort (in demographic terms, a group of animals born simultaneously) of cattle from birth, when they numbered 1000, to the death of the last individual, employing the suggested mortality rates, the age structure of the 'population' can be presented in the form of a simplified life table (see table 4.2 and figs. 4.1 and 4.2). When the mortality frequency is plotted, the age distribution resembles that predicted for natural attrition (see table 4.2 and fig. 4.3).

It cannot be assumed that prehistoric horse husbandry would necessarily have produced the same kind of age distribution as East African cattle husbandry. The physiological differences between the two species more or less ensure that they will play somewhat different roles in human subsistence. The little information available concerning horse nomadism (for example, among the Kazaks of Central Asia) indicates that milk production of horses is markedly inferior to that of cattle. Kazak horses can produce about two quarts of milk a day

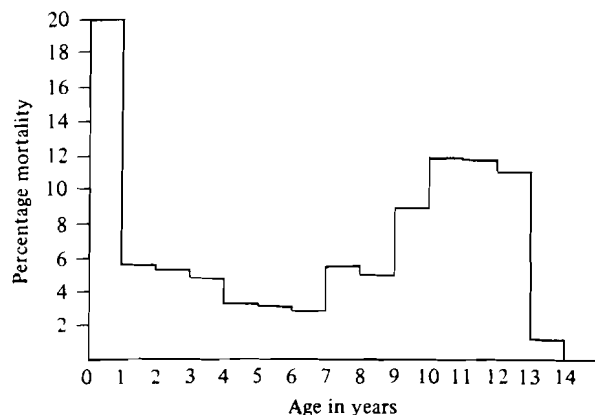


Fig. 4.1. Cattle mortality based on Dahl and Hjort's 'base-line herd model' (see table 4.2).

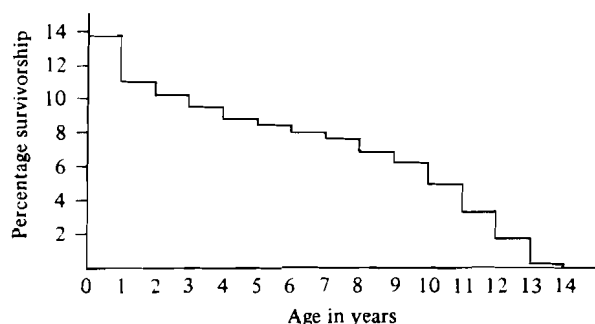


Fig. 4.2. Cattle survival based on Dahl and Hjort's 'base-line herd model'.

during 4 months of the year for human consumption (Forde 1934). East African cattle produce, on average, 1.5 kg or 1.7 quarts a day during 7 to 9 months of the year for human consumption in marginal dry lands (Dahl and Hjort 1976). Cow's milk is a staple, while mare's milk is a luxury. The sheep herds of the Kazak are larger than their horse herds and represent their major food resource. The greatest importance of the horse lies in the mobility it provides. Poor Kazak families with few horses do not milk their mares at all, 'but reserve their strength for use as riding and baggage animals' (Forde 1934: 339).

East African cattle are primarily milk producers. Meat is of secondary importance, consumed or traded for other products in times of need or when the animals are old or even dying. Dahl and Hjort (1976) have estimated that in the case of a cattle herd with a normal growth rate, 8% of the animals could be slaughtered each year without prejudicing the growth of the herd (that is, roughly between 4 and 12 animals per family per year). Usually most of the animals killed are young bullocks (4 to 5 years old and fully grown), while the rest are usually old and unproductive cows and bulls. Apparently horse meat is sometimes consumed by the Kazak, but information concerning the quantity and age distribution of those animals is unavailable (Forde 1934). However, since horses reach sexual maturity relatively late and since a mare produces on average only one offspring every two years, it may be suggested

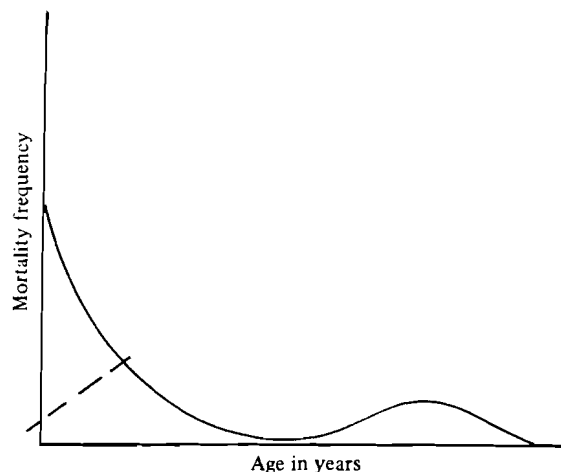


Fig. 4.3. The attritional death model.

that the horse would be an inefficient meat producer by comparison with sheep, goats and possibly even cattle (Dahl and Hjort 1976).

Although the data are inadequate and the role of the horse is likely to differ somewhat from that of cattle, it is not unreasonable to suggest that horse herding would produce an age structure similar to that of cattle herding. Infant mortality in both cases should be high; mortality during the productive years, relatively low. Mares bear their first offspring at about 3 years, approximately one year later than cows, and may continue breeding past their twentieth year (Tyler 1969; Mohr 1971). Horses on average appear to have a longer life span than cattle. This should be reflected in the mortality curve by an extended period of low mortality.

#### Mortality models

The behavioural patterns discussed above can be used to define a series of formal models representing various patterns of mortality.

##### *The attritional assemblage model*

The mortality distributions for natural attrition, scavenging, coursing and pastoral nomadism are all similar to figure 4.3. This curve is sometimes described as 'U-shaped' or 'fish-hook shaped'. Mortality is low for adults during their reproductive years, and high for juveniles and senescent adults (Caughley 1966).

##### *The carnivorous husbandry model*

As explained above, neither horses nor cattle are productive enough to be raised primarily for meat in a non-industrial society. However a mortality curve somewhat like that in figure 4.4 might be generated if a pattern of slaughter at maturity of all surplus males were superimposed upon the usual pastoral pattern of attritional mortality. Only isolated segments of the model might be archaeologically visible if the killing (or scavenging) of the various age and sex classes were separated by time or space.

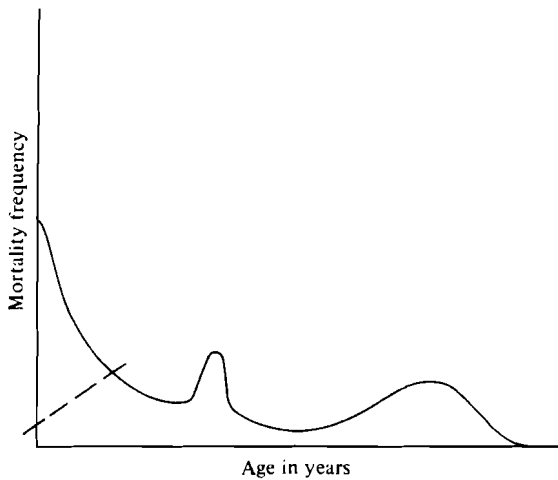


Fig. 4.4. The carnivorous husbandry model.

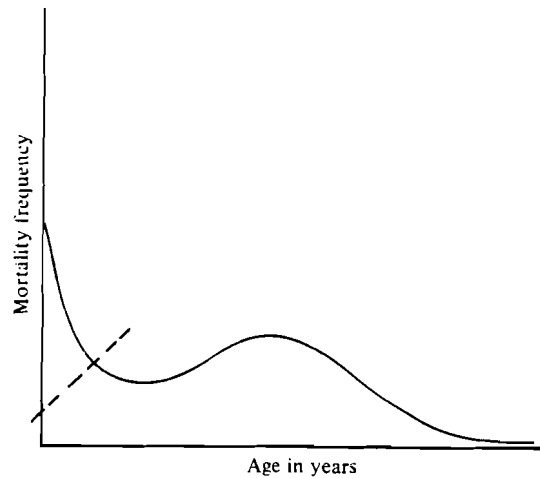


Fig. 4.6. The family group model.

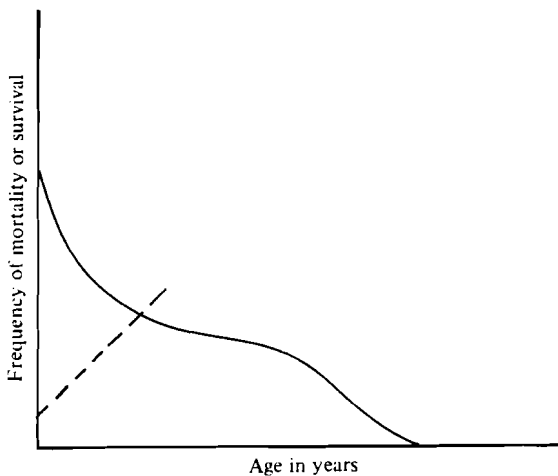


Fig. 4.5. The life assemblage or catastrophe model.

#### *The life assemblage or catastrophe model*

The obverse of the U-shaped curve is the 'sigmoidal' or 'S-shaped curve', characteristically 'concave in early life, reflecting high but gradually diminishing juvenile mortality; approaching the straight diagonal in middle life, and convex when senescence sets in and mortality rates again build up' (Kurtén 1964; 101-3) (fig. 4.5). This curve is representative either of a living population (when it is referred to as a survivorship curve), a catastrophe assemblage, or an assemblage in which all age classes are represented as they would be in the living population because of completely random (and therefore representative) sampling.

#### *Social group models (variants of the life assemblage model)*

The hunting of whole social groups might produce a variety of patterns. The structure of an assemblage, composed of one or several social units, may be dependent upon the degree of heterogeneity manifested by the various types of social groups characterized by a particular species. For

example, the horse has two types of social unit: the family group and the bachelor group. The family group is composed of one mature male over 5 or 6 years old, a number of adult mares (on average, two to three) and their young (on average, two to three). From the ages of 2 years to 4½ years the male young leave the family group to join bachelor groups (Levine 1979). A number of different group types in one deposit may result in a pattern indistinguishable from that of the life assemblage model, especially if the stratigraphy of that deposit is not well understood.

#### *The family group model*

The family group assemblage should, when enough data are considered, have an age distribution very similar to that of the total species population. The main difference should be the relatively low proportion of adolescents marking the absence of bachelor males. The actual effect of bachelor mobility on the age structure has not been established for a living population. It may, however, be suggested that the proportion of individuals 3 to 6 years old will be relatively low (fig. 4.6).

#### *The bachelor group model*

There is little quantitative data about horse social structure and almost none concerning the age structure of bachelor groups. However it has been observed among both zebra and horse that bachelor groups are often segregated from family groups. This segregation is probably at least partly ecological in nature (Klingel 1965; Rubenstein 1978). The most obvious difference in the age structures of the two types of social groups is the absence of individuals less than about 2 years old from bachelor groups. From the age of 5 or 6 years some males leave the bachelor groups to build up their own family groups. However it is likely that some males remain in bachelor groups or solitary throughout their lives (Rubenstein, pers. comm.). A hypothetical bachelor-group age distribution is suggested in figure 4.7.

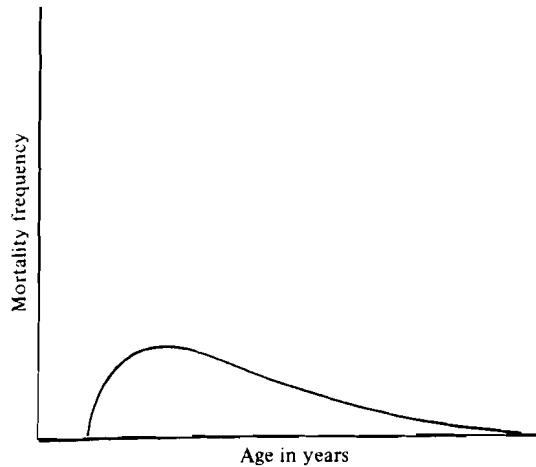


Fig. 4.7. The bachelor group model.

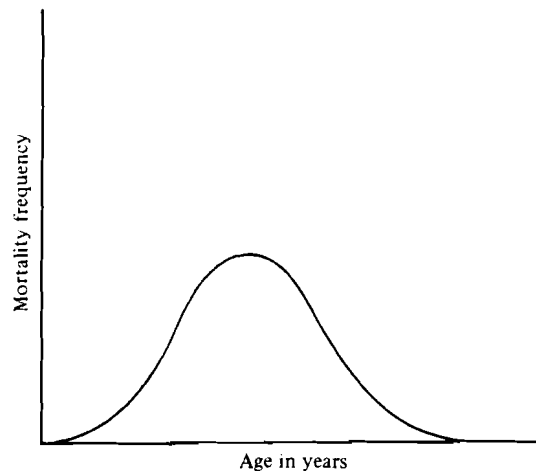


Fig. 4.8. The stalking model.

#### *The stalking model*

Hunting mainly prime adults should produce a distribution approximating a bell-shaped curve (fig. 4.8). Identification of the stalking assemblage will probably be handicapped by the intrinsically small sample produced by such a hunting strategy. Stalking may produce a pattern archaeologically indistinguishable from bachelor-group hunting.

#### **Problems related to mortality-type interpretation**

There are three kinds of problems involved in mortality-type interpretation: (1) problems of data interpretation (fitting the ageing data to a population structure); (2) problems of pattern interpretation (fitting the population structure to a mortality model); (3) problems of statistical analysis.

#### *Problems of data interpretation*

Immature teeth are probably not as poorly preserved in a fossil deposit as immature bone. However, it is likely that the incomplete mineralization of jaw bones and teeth will result in the under-representation of juvenile teeth. This may distort assemblage age distributions as indicated by the broken lines

in figures 4.3 to 4.6. That is, the area above the line may not be represented in the fossil assemblage. This is a critical problem, because it means that material representing a random sample of the living population, or resulting from a catastrophe or family-group hunting, could produce a pattern resembling a stalking or bachelor-group distribution. Special consideration is therefore given here to estimating a hypothetical adjustment factor to compensate for the probable under-representation of immature teeth.

Despite the absence of quantitative measurements of differential preservation of teeth at various ages, it is obvious that immature teeth are much less sturdy than mature teeth. Moreover, each tooth type (e.g. Upper P<sub>3</sub>, Upper P<sub>4</sub>, Lower M<sub>1</sub> and so on) develops – mineralizes, erupts and wears – according to its own schedule. A model has been constructed, setting an average (hypothetical but not unreasonable) value for the development of all tooth types for each of the years from 0 to 5. Such a model can be useful without any pretensions to accuracy.

The little information available concerning unmanaged, feral horses suggests that 13% to 19% of a living population may be 0 to 1 year old (Rubenstein 1978). Estimates for other age classes cannot be used, as the criteria for membership within them are not compatible with the needs of the model proposed here; that is, they are behavioural rather than chronological criteria. However if 13% to 19% is accepted as the approximate membership for the first year, the adjustment model can be devised so that on average it recreates a population structure which is not too different from that of living horse populations.

For the purposes of this model it is assumed that throughout the first five years of life tooth preservation increases linearly (see fig. 4.9, curve A). The actual shape of the curve is probably convex, with an initial high rate of increase in preservation that tapers off as maturity is reached at about 4 or 5 years, after which it remains constant (see fig. 4.9, curve B). The real situation is complicated by the fact that the total number of teeth per individual varies throughout the first five years of the horse's life, as demonstrated in table 4.3. In the case of a fossil assemblage, the number in the third column is probably more meaningful than that in the second column. Each tooth in each row is at a different point in its development. Since the relative durability of each individual tooth type at each point cannot (at this time) be measured, the actual probability that any tooth at any point will be represented in a fossil assemblage cannot be determined. From 2 to 3 or 4 years of age the over-representation of tooth types probably compensates somewhat for poor tooth preservation (fig. 4.9, curve C). Therefore a convex adjustment model would probably over-adjust for those teeth aged 2 to 4 years. A linear model decreases the preservation rate where adjustment could be most distorted by the large number of teeth in each jaw. Therefore it is the linear model that will probably best illustrate how differential preservation can affect the shape of a fossil age distribution.

Table 4.3. Change in the number of teeth in a horse throughout its first 5 years of life (approximate values)

Age	Total number of teeth	Number of well-developed teeth
Birth	16	16
2 months	28	20
9 months	32	26
10 months	32	28
1 1/4 years	36	32
1 1/2 years	48	32
1 3/4 years	56	46
2 1/2 years	60	54
3 years	50	44
4-4 1/2 years	36	36

Source: Küpfer 1937: 149, 160-73.

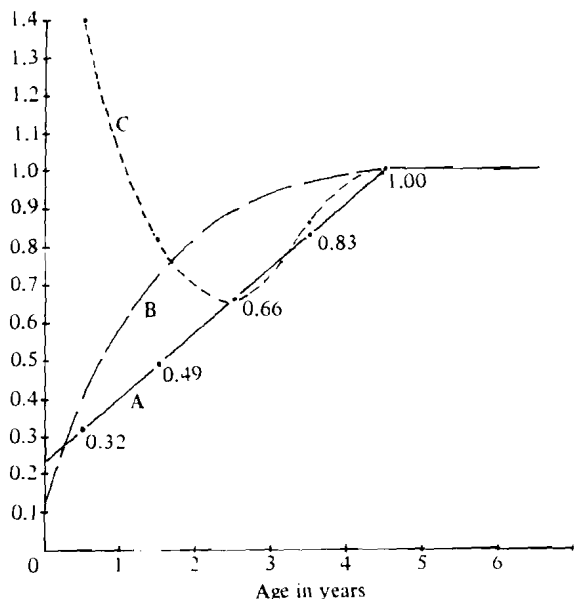


Fig. 4.9. The adjustment factor used in tooth age distribution histograms (fig. 4.10 to 4.23, and 4.25 to 4.30), to account for differential preservation of immature teeth. Curve A is used to adjust the age distribution histograms to account for the differential preservation of immature teeth. The values given are the average values for each whole year (e.g. 0-1, 1-2, 2-3 etc.). The formula for the line is  $y = 0.23 + 0.17 \times \text{age}$ . At 5 years old the teeth are completely mineralized. Curve B shows the probable shape of the actual preservation curve.

$$\text{Curve C} = \frac{\text{The number of teeth in an adult}}{\text{The number of teeth at a given age}}$$

Curve A is approximately equal to Curve B  $\times$  Curve C.

It is assumed that all teeth are completely mineralized and have ceased growing by the age of 5 years and that thereafter teeth from all age classes have an approximately equal chance of being preserved. In the case of extremely old animals that may not be true. However, such individuals are

rare in any population and doubtless of negligible importance here.

The formula for the preservation curve is:  $y = 0.23 + 0.17 (\text{age})$ . When this equation is plotted on a graph, 0.23 equals the  $y$  intercept; 0.17 is the slope of the line; and 'age', the average age for each age class (e.g. the 0 to 1 age range is equal to 0.5) (fig. 4.9). What this means is that approximately 32% of the teeth from a horse up to one year old would be preserved; at 1 to 2 years 49% would be preserved and so on. Multiplying the frequency of teeth in each age class from 0 to 5 years by  $1/[0.23 + 0.17 (\text{age})]$  gives the average adjusted frequency for each age class. The adjusted frequencies can then be converted into percentages and plotted as histograms.

The adjustment formula used here raises the proportion of teeth up to one year old in the pooled assemblages from approximately 4% to 12%, which is close to the lower limit for living equid populations (fig. 4.10). It is also comparable with Dahl and Hjort's mortality estimate for the 'base-line herd model' (figs. 4.1 and 4.2). If anything, in most cases it probably underestimates the bias against immature teeth.

For deposits where preservation is bad, the value of the slope could probably be set lower than where it is good - except that the method of adjustment employed here is probably too crude for such manipulations to be worthwhile. A further guide is the comparative preservation of bones and teeth. To my knowledge there have been no quantitative studies but it is not improbable that the relationship between the two is roughly linear. If that is true, the bone preservation state should provide some idea of how well immature teeth will be preserved in a particular assemblage (Levine 1979). Moreover if a linear model is at all suitable, the tooth:bone ratio will provide a further indication of differential preservation. That is, there are approximately four times more bones than teeth in a horse skeleton. Therefore the deviation of the actual ratio in each assemblage from the ideal ratio

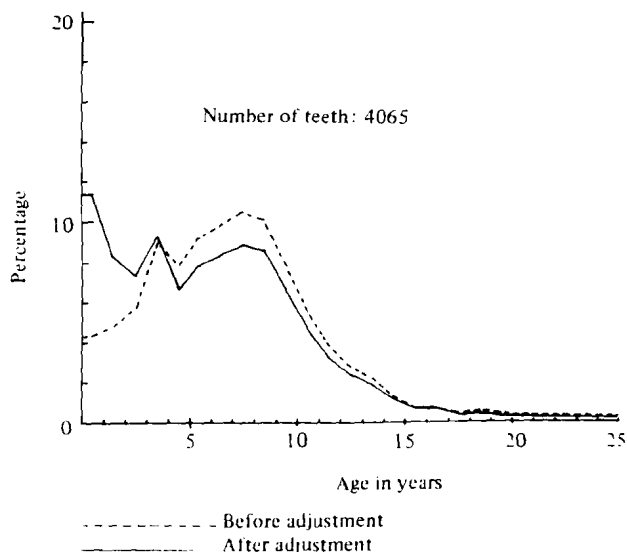


Fig. 4.10. Tooth age distribution - all assemblage units pooled.

could provide a rough assessment of the preservation conditions in that deposit (table 4.1). If two deposits are compared – for example, Gönnersdorf with a tooth:bone ratio of 0.8:1.0 and Jaurens with a ratio of 0.6:1.0 – it may be suggested that preservation is better at Jaurens than at Gönnersdorf. These results are comparable with those from bone preservation studies carried out on the same sites (Levine 1979).

Another type of interpretation problem is the possible absence of skulls from a site. The structure of an archaeological deposit is more complicated than that of a natural deposit. Taphonomic processes may affect both similarly, but human decisions will have an important impact on archaeological fossil distributions (Levine 1979). If the carcass of a large animal must be carried far, the skull may be left at the kill site. However if the skull has some special importance aside from its food value, its size may not bias its representation. Because bone preservation is generally much poorer than tooth preservation in archaeological deposits, the only reliable evidence for skull abandonment would be the virtual absence of teeth from a large bone assemblage. No such pattern has been observed in this study.

Poplin has observed that the skull bones and teeth of horse are under-represented at Gönnersdorf (evidently an open-air habitation site) by comparison with those of smaller animals such as fox, hare and reindeer. His tentative interpretation of this pattern is that small game would have been brought back whole to the habitation site; while large game, such as the horse, would have been butchered at the kill site and only the meat-bearing bones brought back (Poplin 1976). However, small teeth are probably more likely to be preserved than large ones in an environment in which trampling is an important agent of destruction – as it should be at a habitation site. Also, an experimental study in the South Dakota Badlands has indicated, with regard to teeth, that 'body size is an important criterion in understanding differential damage to species, particularly the relative tooth volume to enamel thickness. In most small mammals there seems to be no dehydration cracking of the teeth. . . Large teeth splinter very quickly' (Hill 1975: 158). Poplin's estimate for the bone MNI is 13; mine is 12 (Poplin 1976). My estimate for the tooth MNI is 10. The MNI estimates for teeth and bones are not significantly different (using Poplin's estimate  $z = 0.63$ ,  $p > 0.05$ ). Neither the bone preservation state, nor the tooth:bone ratio, nor the tooth age distribution suggest that the skulls were abandoned. However if skull abandonment were a pattern characteristic of small deposits, the samples might be too small for analysis. No evidence has been uncovered for special cultural functions of horse teeth or skulls. This may be because of poor preservation or it may be that the relevant information has not been available to me. In any case it seems likely that the deposits studied here were, like those at Gönnersdorf, at or near kill sites (Levine 1979).

For several reasons the proportion of male horses in a fossil assemblage cannot be determined directly from the teeth

in a deposit. The cheek teeth and incisors do not show sexual dimorphism. And although only males have well-developed permanent canines, these teeth do not even begin to grow until the animal is about  $2\frac{1}{2}$  years old. They erupt between the ages of 4 and  $5\frac{1}{2}$  years. Nothing further can be said with any precision about the age of loose canines, once in wear. Moreover, because of their odd shape and relative fragility, canines will probably be under-represented in fossil deposits (Levine 1979). Therefore inferences about the sex structure of a fossil population must be made through an interpretation of its age structure or through some other kind of analysis of sexual dimorphism.

#### *Problems of pattern interpretation*

A series of patterns has been distinguished thus far according to the various agents of mortality. However, the archaeologist can never be certain that he has not uncovered a palimpsest of patterns rather than a single event. What is taken to be a homogeneous assemblage may have been deposited in a series of hunting episodes, for example, each employing a different hunting strategy and each recovering a different segment of the prey population structure. Moreover in the archaeological situation an attritional pattern may look like a catastrophe pattern if populations are sampled in a random fashion. If it is certain that only a small number of animals had been killed, there is no problem; since a small accumulation by definition cannot constitute the type of catastrophe discussed above. If the deposit is large but carefully excavated, it should be possible to disentangle the various patterns according to the context of the assemblage and the depositional sequence. However, collection of the necessary data is often neglected. Small assemblages cannot usually be assigned confidently to any of the models. If more than one agent of accumulation is responsible for the deposit, interpretation of the distribution may be impossible. Moreover, if the proportion of males in a population is very much lower than the proportion of females, a representative sample may produce a pattern resembling the family group model rather than the life assemblage model.

Poor preservation is not the only bias against the representation of immature animals in the tooth/bone assemblage. They will also be under-represented when agents of mortality other than those which have caused the death assemblage have already removed them from the living population. Such agents include predation, malnutrition, disease, floods and drought – all of which hit juveniles more heavily than healthy adults. When that happens a catastrophe, family-group or random distribution may resemble a stalking or bachelor-group distribution.

#### *Problems of statistical analysis*

The fossil data studied here have two important drawbacks ruling out statistical analysis based upon significance testing: non-independence of observations and overlapping age spans.

The fatal deficiency of the data is the non-independence of observations. Obviously there was a time when each tooth was embedded in a jaw. In the fossil situation and particularly in the archaeological situation most jaws are broken up, and in most cases only a small number of them can be reconstructed. All or some of the teeth from a particular jaw may remain in a deposit and be recovered in excavation. It may reasonably be assumed that once a tooth is fully developed, the probability that it will be preserved remains equal to that of any other fully developed tooth of that type in that deposit and is not dependent upon its exact age. Therefore ageing individual teeth rather than individual animals should not distort the general shape of an age distribution. However this does mean that the true sample size, the number of carcasses, is smaller than the apparent sample size, the number of teeth. As the true sample size cannot be determined, no level of statistical significance can be established. Therefore significance tests comparing the age distributions of the various assemblages cannot be carried out.

The second serious fault in the data is overlapping age classes. Some teeth can be assigned an age span of one year (e.g. 1 to 2, 2 to 3, 3 to 4 years old). In other cases the age determinations are broader and often overlapping (e.g. 2 to 4, 3 to 6 years old). That occurs when teeth are aged by eruption and wear sequences, when they are broken, or when the exact tooth type cannot be determined (e.g.  $P_3$  or  $P_4$ ,  $M_1$  or  $M_2$ ) (Levine 1979). Teeth with age spans of ten years or more are excluded from the age distribution histograms.

There are two reasons for the inclusion of teeth with age spans greater than one year in the age distribution histograms. One is that exclusion of those cases would reduce the size of the already barely adequate samples available for study. The second and more important reason is that omission of this data would bias the distributions by under-representing adult cheek teeth when they are at their maximum length. That is, teeth at their maximum length are, by reason of their long, thin shape, more likely to be broken than older stubbier teeth. The broken cheek teeth can be assigned a minimum age by virtue of their wear state and a maximum age by virtue of their length. Because age determination becomes increasingly inaccurate beyond 15 years, very old teeth must be assigned relatively broad age spans.

Incisors are not as well represented in the age distributions as cheek teeth because they cannot be as closely aged and because their representation in fossil deposits is relatively poor; that is, they are small, fragile and loosely held in the jaw. Canines are completely excluded from the age distribution study, as they are rare, difficult to age and sex-linked.

When a tooth is assigned an age span greater than one year, it is divided between as many columns of the histogram as necessary. In this way a tooth aged 2 to 4 years will add 0.5 to the column for 2 to 3 years, and 0.5 to the column for 3 to 4 years. Thus the values for each column are not true frequencies, but the area covered by the histogram is correct.

Despite the limitations of the data discussed above, it is believed that the age distributions as presented by the histograms are representative of the age distributions of the fossil assemblages under consideration.

#### Analyses of age distribution histograms

This study includes 95 assemblage units, each containing at least 10 teeth. Of these, 72 units have enough data to be used in a cluster analysis. Eight are of sufficient interest to be discussed individually and in some detail. Pooling assemblage units is useful here for two reasons. One, it increases the functional sample size by allowing inclusion of data from units otherwise too small for consideration. Two, classes of data (for example, natural deposits and archaeological deposits) can be compared with one another and with individual assemblage units in order better to understand the nature of the variability.

#### Natural assemblages

It is useful to look at natural assemblage units first, in order to have examples of age distributions presumably unaffected by man, to which archaeological assemblage units can be compared.

The pooled natural assemblage unit includes one very rich unit, Jaurens, and five small units from La Fage and Chatillon-Saint-Jean. Out of 610 ageable teeth 498 are from Jaurens. This unit obviously dominates the age distribution of the pooled natural data (figs. 4.11–4.13). However when the natural assemblage units are pooled excluding Jaurens, the age distribution remains similar, although it no longer resembles a smooth curve (fig. 4.13). It is not possible to make useful generalizations about the small samples from Chantillon-Saint-Jean and La Fage.

An extensive bone deposit, dated by C14 to  $29\,300 \pm$

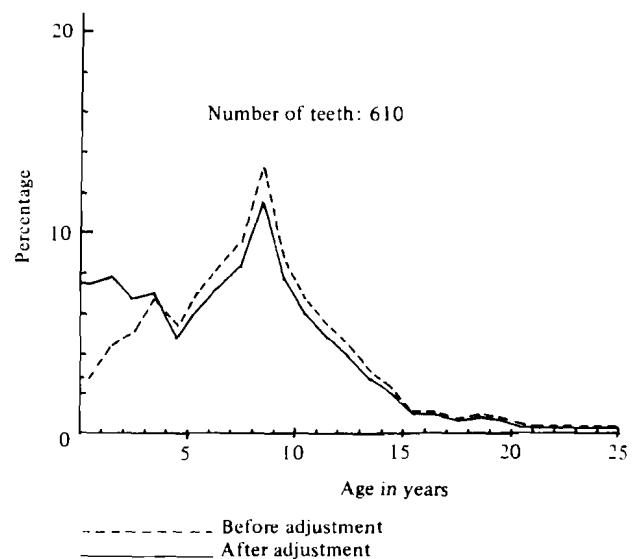


Fig. 4.11. Tooth age distribution – all natural assemblage units pooled.

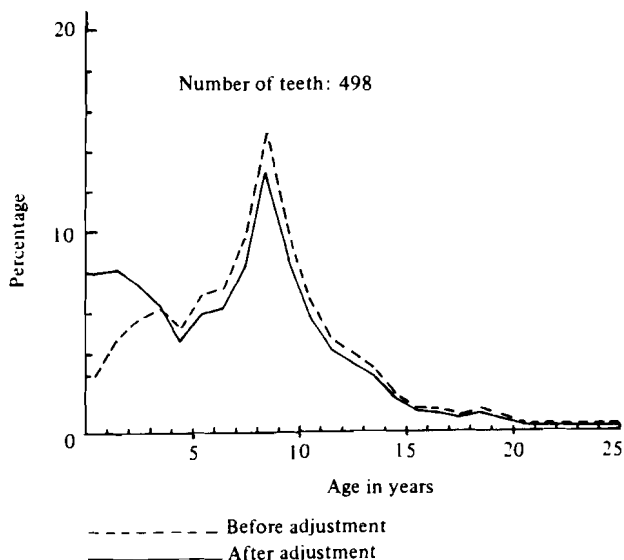


Fig. 4.12. Tooth age distribution – Jaurens.

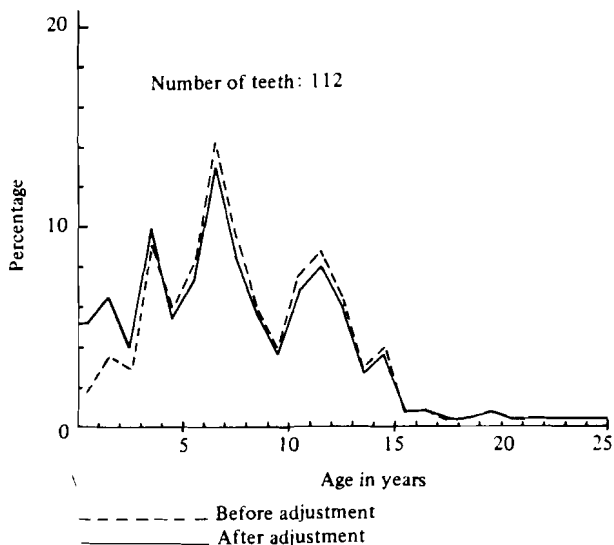


Fig. 4.13. Tooth age distribution – natural assemblage units pooled excluding Jaurens.

1400 years b.p. (Ly-359), was found in Jaurens, a cave site (fig. 4.12). The deposit was probably formed when a flood swept the carcasses of a large number of animals of various species into the cave (Guerin 1969, 1970; Levine 1979). The preservation state of the skeleton material from this site is excellent (table 4.1; Levine 1979).

The adjusted age distribution histogram for Jaurens most closely fits the family group assemblage model except that, even when adjusted, the percentage of teeth up to one year old is low. A bone cluster analysis (employing the Ward's Method dendrogram and a principal components analysis from the *Clustan* computer package) carried out on the astragali, metacarpal II, metatarsal III and anterior phalange II suggests that Jaurens represents a number of family groups with an average stallion:mare:juvenile ratio of 1.0:2.2:3.0 (Levine 1979). This interpretation is strongly dependent upon the

assumption that the separation of the clusters associated with mares and juveniles has been created by the absence of bachelor males. An examination of the age distribution of the teeth from Jaurens confirms this hypothesis. If it is assumed that the horse carcasses from Jaurens had been derived from a stable living population, the low representation of teeth 4 to 7 years old may be explained as follows. If males leave their family groups when they are 2 to 4 years old, during the year 4–5 there may be no adolescent males at all in those groups. Males leave the bachelor groups to acquire their own families from 5 years old at the earliest. But for most this will probably happen several years later or not at all. If most stallions are 7 to 9 years old when they begin collecting mares, that would perhaps explain the high proportion of teeth 8 to 9 years old at Jaurens.

The adult:juvenile ratio (stallions + mares:juveniles) suggested by the bone cluster analysis is 1.0:0.7. If the tooth frequency trough at 4 to 7 years is identified with the break between the bone clusters representing adults and juveniles, the focal point of the break is probably located at the centre of the trough at about 5 to 6 years. If juveniles, then, are roughly equated with individuals 6 years or younger, the adult:juvenile tooth ratio is 1.0:0.5, unadjusted, or 1.0:0.7, adjusted. Comparable data for the plains zebra yields an adult:juvenile ratio of 1.0:0.8 (Klingel 1969). The close agreement of these results lends support to the hypothesis that this assemblage unit comprises a number of family groups.

The family-group structure does not explain the low proportion of teeth 0 to 1 year old. Both the bone-preservation state and the tooth:bone ratio, 0.6:1.0, indicate that preservation conditions at Jaurens were excellent (table 4.1). This suggests that, although the adjusted proportion of teeth in the first year is only 8%, it is more likely to overestimate than to underestimate the true percentage for that year. Therefore the low proportion of teeth 0 to 1 year old is likely to reflect the under-representation of this age class in the population of carcasses swept into the cave. There are at least three plausible explanations for this pattern. One, the catastrophe, which was probably a flood, occurred, as floods often do, in the early spring before the horses' main breeding season. Two, infant mortality for that year was unusually high before the catastrophe (or the birth rate unusually low). Three, since the hydraulic behaviour of foal carcasses is probably different from that of adults, they may have been deposited elsewhere.

The results of the Jaurens tooth analysis support the hypothesis which holds that this assemblage unit was composed of a number of family groups killed in a flood from which most or all bachelors were excluded, possibly because of the ecological separation of the two types of social groups.

#### *Archaeological assemblages*

The shape of the age distribution for the pooled archaeological assemblage unit, when adjusted, resembles the sigmoidal curve of the life assemblage model (figs. 4.5 and

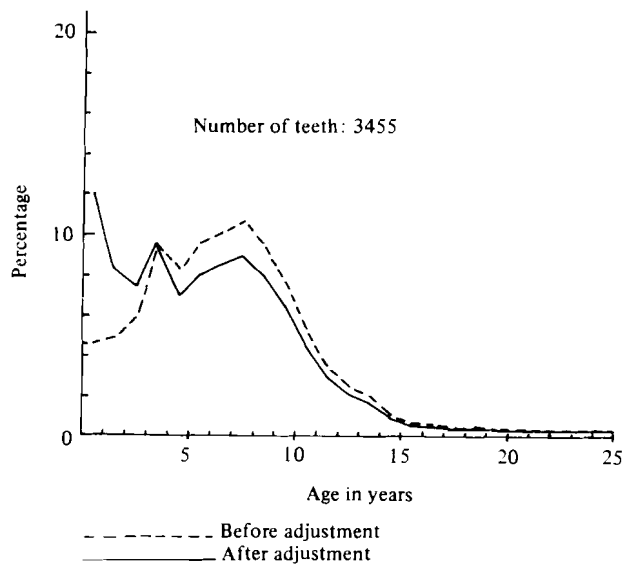


Fig. 4.14. Tooth age distribution – all archaeological assemblage units pooled.

4.14). The adjusted percentage of teeth 0 to 1 year old, 12%, is close to the lower limit suggested by the comparative data for feral horses. Although this age distribution is broadly representative of a living, stable population of horses, it also has its anomalies. The somewhat low proportion of teeth 4 to 7 years old is reminiscent of (though not as extreme as) the pattern at Jaurens, associated there with the absence of bachelor males. However, the data from the pooled archaeological assemblage unit are an amalgam of many different units. There is therefore a strong possibility that they reflect an amalgam of strategies. An emphasis on family-group hunting, possibly with some preference for prime individuals might account for the apparent bias.

The second anomaly in the age distribution of the pooled archaeological data is the high proportion of teeth 3 to 4 years old. One possible explanation is selective mortality. By the age of 3 to 4 years most juveniles have left their natal family groups. This may be the period when they are most mobile and therefore least protected. Moreover it is the year when females first bear young, which makes them all the more vulnerable (Tyler 1969; Mohr 1971; Bureau of Land Management 1973). An alternative explanation is differential preservation. That is, at this stage in the horse's tooth growth a relatively large number of teeth are well developed and may therefore be preserved (table 4.3). If the adjustment factor used is not quite right, the shape of the age distribution might be somewhat biased. If this hypothesis were correct a similar anomaly might be expected in the Jaurens age distribution. In fact there is a slight mortality peak at 3 to 4 years in that assemblage, but it disappears when the data are adjusted (figs. 4.11 and 4.12). The absence of the anomaly in Jaurens is not conclusive, however, since it might be caused by two factors peculiar to natural assemblages. For one thing, if, as the evidence suggests, Jaurens really is a catastrophe site, the relative vulnerability of horses 3 to 4 years old should be low

or even manifested as a deficiency rather than as an excess of individuals. That is, a proportion of individuals from this age class should already have succumbed to other, more selective, agents of mortality than the catastrophe. Moreover, the preservation state of material from natural deposits is usually better than that from archaeological deposits (table 4.1). It may be that the superior conditions of preservation at Jaurens have resulted in a superior representation of teeth 1 to 3 years old, contrasting with the archaeological over-representation of teeth 3 to 4 years old.

The anomalies of the pooled archaeological assemblage unit do not prejudice its identification with the life assemblage model. Such an age distribution is best accounted for by a generally opportunistic adaptation. That is, the problem of the prehistoric people concerned was not so much to select a particular age class or sex from the animal population as it was to select a strategy or series of strategies – for example, stalking, trapping, scavenging and herd driving – that would provide most efficiently for their immediate needs. This is the tactic of the hunter, not the pastoralist.

#### *Large archaeological assemblage units*

Each assemblage unit containing a total of 150 or more teeth is discussed individually. This is, of course, an arbitrary limit; it means in effect that a relatively large sample has been excavated. The larger the sample the more likely that it will be representative of the age distribution of the animals interred in the deposit.

*Combe Grenal—level 14 (CG14)* (fig. 4.15). This site has the greatest total number of teeth of any archaeological assemblage unit studied here. Yet it contains only 14 pieces of bone, of which 11 are fragments of shaft or articulation; two are metapodials and one is a second phalange. Bone preservation here is very poor indeed. The tooth:bone ratio at CG14 is perhaps rather extreme, 145:1, which may mean that the adjustment factor under-compensates here for

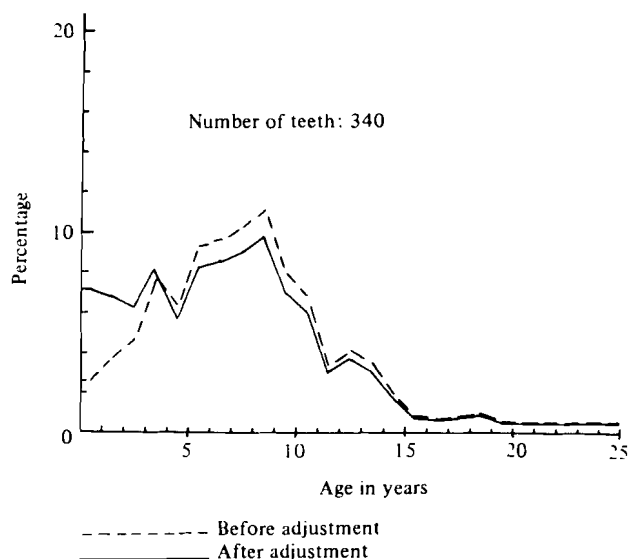


Fig. 4.15. Tooth age distribution – Combe Grenal, level 14.

differential representation of immature teeth. If that is so, the relatively low proportion of teeth 0 to 1 year old in the adjusted distribution, 7.1%, may not adequately reflect their original representation in this assemblage unit. The proportion of teeth 3 to 4 years old is somewhat high, indicating either adolescent vulnerability or, particularly in this unit, the inadequacy of the adjustment factor. The percentage of teeth 4 to 5 years old is somewhat low, perhaps indicating a low proportion of bachelor males. From 5 to 9 years the mortality rate is at its highest and it remains relatively high until 11 years.

Combe Grenal—level 14, like Jaurens, most closely fits the family group model. That the absence of teeth 4 to 6 years old is not as marked here as it is at Jaurens might suggest that the exclusion of bachelor males is not as systematic. There is practically no information available about the context and disposition of the bones and teeth within CG14. The MNI is 18, but the true number of horses is almost certainly much greater. The population structure and the quantity and density of material within the deposit suggest that the hunting technique most often employed here might have been herd driving.

Combe Grenal—level 22 (CG22) (fig. 4.16). There are 200 teeth in Combe Grenal—level 22, 152 of which are ageable. The tooth:bone ratio is 5.9:1.0, significantly lower than that of Combe Grenal—level 14 ( $\chi^2 = 51.5$ ,  $p < 0.001$ ). The difference between the two ratios suggests that preservation is better at CG22 than at CG14. The mean age of the teeth in CG22 is lower than that in CG14. The adjusted percentage of teeth 0 to 1 year old, 16.7%, fits well within the limits suggested by the comparative data for feral horses. However the proportion of teeth 2 to 4 years old is rather higher than expected and the drop in mortality at 4 years rather abrupt. From 4 to 10 years the percentage of teeth in each age class remains more or less constant.

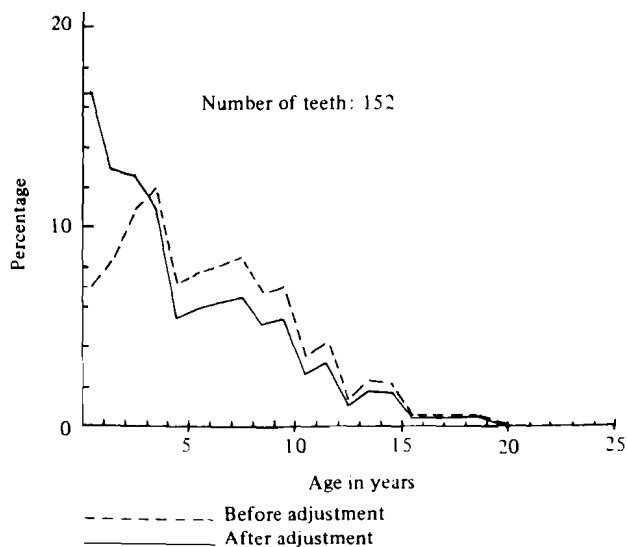


Fig. 4.16. Tooth age distribution – Combe Grenal, level 22.

This assemblage unit is not a very large one. Therefore although the data are undoubtedly useful, it is not certain that they are completely representative of the animals originally deposited in level 22. For example, the high proportion of teeth 2 to 4 years old might be interpreted most plausibly in three ways. One, it might be a chance distortion, arising from the inadequate sample size. Two, it might be truly representative of the age distribution and accounted for by the killing of inexperienced adolescents. Three, it could be the result of an unstable age structure; for example, caused by increased resources (e.g. grazing) or decreased predation from the years 0 to 4. In the absence of contextual information (as in the case of CG14), it is not possible to give any of these alternatives precedence over the others. Even so, the shape of the adjusted age distribution is, on the whole, most similar to that of the sigmoidal life assemblage model. With an MNI of 10, the horses of CG22 could have been killed in a herd drive, in several group drives, in random stalks and scavenging, or any combination of these.

Combe Grenal—level 23 (CG23) (fig. 4.17). Combe Grenal—level 23 is similar to the pooled archaeological assemblage unit in its size, general shape and preservation state. It contains however a higher proportion of teeth 0 to 1 year old than either the pooled archaeological assemblage unit or any of the other large archaeological or natural units. When adjusted, the proportion, 22.4%, for that year surpasses the limits suggested by the comparative feral horse data. Yet, since preservation in this unit is relatively poor and the tooth:bone ratio rather high, it is unlikely that the adjustment factor over-compensates for juvenile under-representation. As in the case of the pooled archaeological assemblage unit, the proportion of teeth 4 to 6 years old is relatively low.

The shape of the CG23 age distribution resembles that

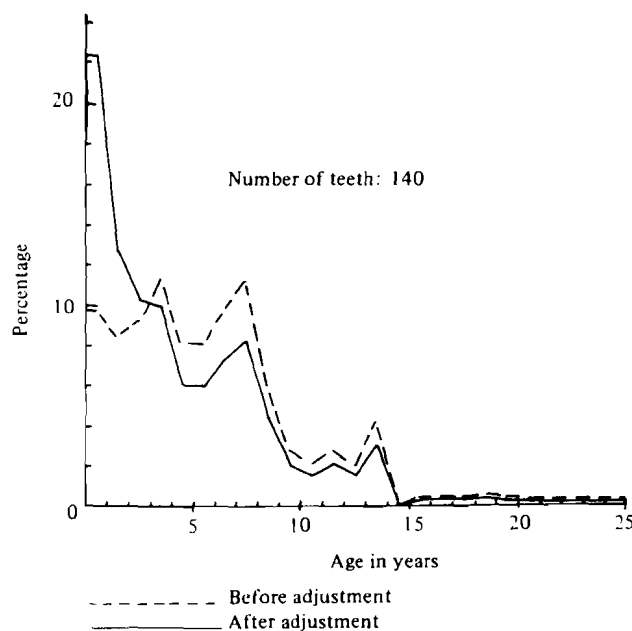


Fig. 4.17. Tooth age distribution – Combe Grenal, level 23.

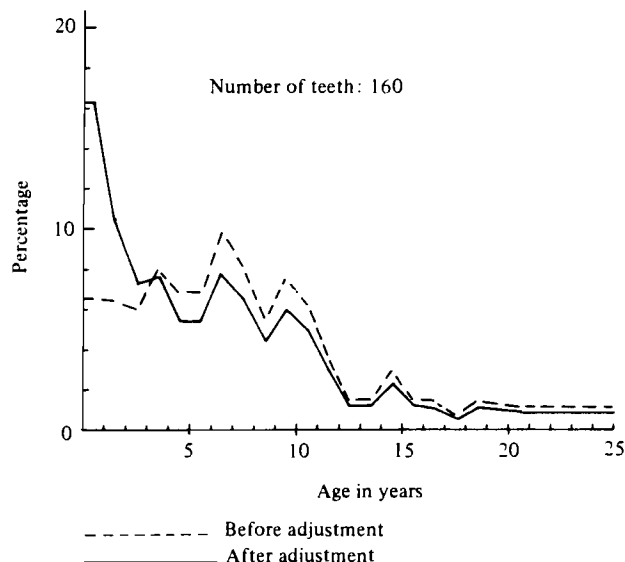


Fig. 4.18. Tooth age distribution – Gönnersdorf.

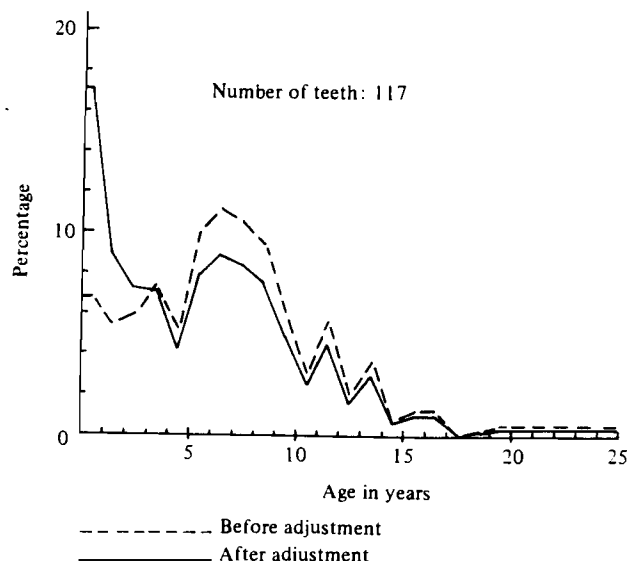


Fig. 4.19. Tooth age distribution – Arlay, level 1.

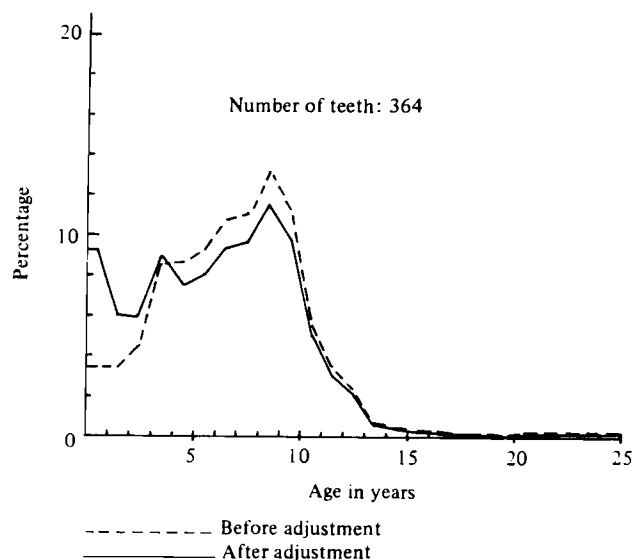


Fig. 4.20. Tooth age distribution – Solutré, square P 16.

of the life assemblage model, but the sample is too small to distinguish between two similar patterns: the one including, the other excluding, bachelor males. The high proportion of teeth 0 to 1 year old suggests that the animals had been killed in an unusually productive year, perhaps during the main breeding season. However the sample is also small enough that chance might explain both that and the low proportion of teeth over 8 or 9 years old. Stalking, trapping and scavenging or driving could explain the age distribution manifested here.

*Gönnersdorf (FG15)* (fig. 4.18). The age distribution at Gönnersdorf is similar to those of the archaeological units already discussed. The proportion of teeth 0 to 1 year old, 16.3%, fits within the limits suggested by the comparative data. But since the tooth:bone ratio, 0.8:1.0, is significantly lower in FG15 than in the pooled archaeological assemblage unit ( $\chi^2 = 125.06, p < 0.001$ ), it is quite possible that the adjustment factor over-compensates here for the hypothetical under-representation of immature teeth.

As with several of the other assemblage units already discussed, the sample at FG15 is not large enough to define unambiguously the shape of the distribution. However the general pattern is that of the life assemblage model – possibly somewhat deficient in bachelor males. Considering the context and environment of this assemblage unit, it is likely that the horses were killed over a relatively short period of time (Poplin 1976). I would also suggest that whole social groups were hunted and that, most probably, driving techniques were employed.

*Arlay-level 1 (AR01)* (fig. 4.19). Arlay-level 1 is the smallest of the large assemblage units. The relative inadequacy of the sample is reflected by the irregularity of the distribution. However the overall pattern is not very different from those of the archaeological units discussed. The adjusted proportion of teeth 0 to 1 year old, 17.1%, fits within the limits of the comparative data. There is a low percentage of teeth 4 to 5

years old. The tooth:bone ratio, 2.9:1.00, is close to the average ratio for all assemblages combined (see table 4.1, last line). This suggests that the degree of preservation at Arlay is similar to that at the other deposits studied here and hence that the adjustment factor used to compensate for the under-representation of immature teeth is applicable here.

The pattern is apparently again that of the life assemblage model, possibly deficient in bachelor males. The distribution is best explained by a hunting strategy of group or herd driving. However information concerning the formation of this deposit is so sparse that random (and ultimately, representative) stalking, trapping and scavenging cannot be ruled out.

*Solutré-square P16 (SO3P)* (fig. 4.20). As regards teeth, SO3P is the second largest archaeological assemblage unit examined here. Both the tooth:bone ratio, 0.7:1.0, and a

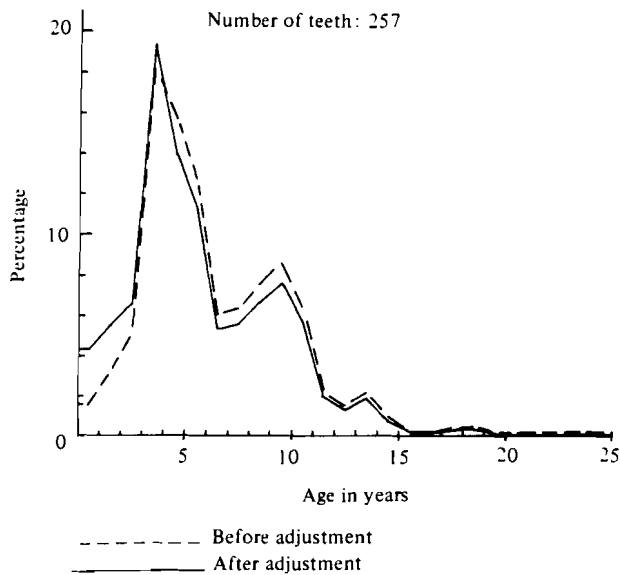


Fig. 4.21. Tooth age distribution – Solutré, square L 13.

differential bone representation study indicate that preservation in this assemblage unit is excellent, though perhaps inferior to that at Jaurens and Solutré–square L13 (Levine 1979). Aside from the rather low proportion of teeth 0 to 3 years old, SO3P looks very much like the pooled archaeological assemblage unit. The low proportion of juveniles might reflect a chance sampling bias, the inadequacy of the adjustment factor, a relatively high proportion of bachelor males, an unstable age distribution – for example, reflecting a gradually deteriorating environment – or any combination of these factors. The rather high, but relatively unimportant, representation of teeth 3 to 4 years old might be explained by a high proportion of young dams and bachelor males, a sampling bias, or an ageing bias. That the proportion of teeth in each age class increases from 4 to 9 years might indicate an unstable age distribution, the return of bachelor males as stallions to family groups or again merely a sampling bias. The SO3P age distribution most closely resembles the life assemblage model. It was probably composed of the butchering refuse from a hunters' herd drive (Levine 1979).

*Solutré–square L13 (SO2L)* (fig. 4.21). Solutré–square L13, from the Upper Perigordian breccia level, is an important assemblage unit from an important site. With 275 teeth, of which 257 are ageable, it is the third largest archaeological assemblage unit studied here. Like Jaurens it has a very low tooth:bone ratio, 0.6:1.0. The SO2L bone preservation state is not as good as that of Jaurens, but better than that of any other archaeological assemblage unit (Levine 1979).

Site SO2L has an age distribution rather different from that of any other unit or model described in this study. The percentage of teeth 0 to 3 years old is unusually low even when adjusted. The preservation state, if anything, indicates that adjustment probably over-compensates for differential preservation of immature teeth. The percentage of teeth 3 to 6

years old is extremely high. The decrease at 6 years is very steep and the proportion of teeth 6 to 9 years old somewhat low. Three hypotheses will be discussed to account for these anomalies: (1) pastoralism; (2) an emphasis on hunting bachelor males; (3) hunting an unstable population.

Because archaeologists habitually use domestication to explain unusual age distributions, that possibility will be discussed first. If this were a pastoralists' slaughter site, it would appear that few horses 0 to 3 years old were killed, but many 3 to 6 years old. From 6 to 11 years slaughter would be moderate, and thereafter, extremely rare. This pattern is very different from the model based upon the Dahl and Hjort data (table 4.2, figs. 4.1 and 4.2). The low representation of teeth 0 to 3 years old and especially 0 to 1 year old might be accounted for if natural mortality took those individuals while at pasture, and if they were rarely killed at the slaughter site. Despite the almost complete absence of comparative data, this hypothesis seems plausible. The slaughter rate at SO2L then would be highest during the horses' early reproductive years. That would make sense only if young males, almost exclusively, were killed.

As noted earlier, there are no data available concerning the age structure of horse herds belonging to pastoral nomads. However the shape of the age distribution for the living domesticated cattle population synthesized by Dahl and Hjort is a sigmoidal curve. If that general structure were also characteristic of domesticated horse herds (as is not unlikely), then according to Dahl and Hjort's data, 26.7% of the living population would be 3 to 6 years old (or taking into account the fact that cattle may begin breeding one year earlier than horses, 28.5%) (Dahl and Hjort 1976). Probably only half of those individuals, 13–14%, would be males. If an age and sex class containing only 13–14% of the postulated living population had contributed 46.5% (the percentage of teeth 3 to 6 years old recovered from SO2L) to the archaeological assemblage, then it is clear that individuals could not have been butchered in proportion to their representation in the living population. No accurate size estimate can be provided for the 'magma' or breccia level, but it certainly comprised hundreds and probably thousands of horses (Levine 1979). Moreover the disposition of the bones and associated artefacts (as yet unpublished) suggests to me that the material had probably been deposited within a relatively short period of time. If half of those hundreds or thousands of horses consisted of 3 to 6 year old males, as hypothesized above, then the living herds from which the slaughtered animals were drawn must have been at least three times greater than the total number of slaughtered animals. If this were so, the living herds must have been vast; much larger than the herds of most pastoral nomads and particularly most domesticated horse herds (Levine 1979).

Approximately 81.6% of the teeth at SO2L were from horses slaughtered between the ages of 3 and 10 years. That is the most important reproductive period of the horse. Such a slaughter pattern would be most unusual for pastoral nomads

(unfortunately data have not been available for comparison with meat producers like the Chukchi). That such a large quantity of animals should have been killed in one place, within a relatively short period of time, is itself uncharacteristic of pastoralist behaviour. Also, the large quantity of whole bones and bones in connection suggests butchering techniques too wasteful to be attributed to pastoralists.

That adults in their prime reproductive years were the main victims of the kill suggests some kind of hunting strategy for SO2L. The high proportion of teeth 3 to 4 years old could be the result of an emphasis on bachelor-group hunting. But a rather different kind of explanation is also possible. That is, until now it has been assumed that survivorship and the rate of increase in the population from which SO2L was derived remained constant over a relatively long period of time. However, that is not necessarily the case. Changes in either of those two variables could have induced the pattern observed at SO2L. Caughley states that: 'A positive rate of increase is . . . generated by lowering density, thereby increasing the resources available to the survivors' (Caughley 1977: 175). For example, if survivorship had been low in the first years of life for the cohorts now 6 to 8 years old, then when conditions had improved, the rate of increase would rise because of the increased resources per head. That increase might perhaps be reflected in the high proportion of teeth 3 to 6 years old. The low proportion of teeth 0 to 3 years old could result from low fertility in age classes older than 6 years or from the return of unfavourable living conditions. Natural conditions, such as disease or drought, could generate such oscillations in the age structure. Alternatively, man could also effect such changes. Heavy predation of the cohorts over 6 years old during some stage in their development may have reduced population density to a level at which hunting was no longer practical. The ensuing low predation of the cohorts in the age classes 3 to 6 years and the increased resources available to them could have brought about the exceptionally high growth rate for those years.

It is not possible to prove that horses were not domesticated at SO2L (or any other prehistoric site for that matter); however, the data fit a hunting strategy far more satisfactorily. The general context of the deposit suggests that the main technique employed was herd driving – possibly into an enclosure against the cliff face (Levine 1979).

#### *Comparing large and small assemblage units*

Small assemblage units do not have the same value as large ones because the role of chance is so much greater where small samples are concerned. However it has been demonstrated that pooling assemblage units, including small ones, will often provide useful insights into the general structure of the data. Figures 4.22 and 4.23 show the unadjusted and adjusted age distributions for all large assemblage units pooled (those with 150 or more teeth), and for all small assemblage units pooled (those with fewer than 150 teeth).

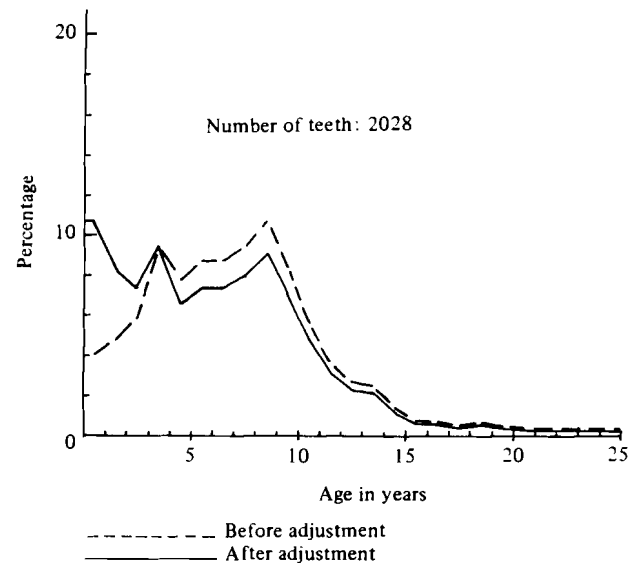


Fig. 4.22. Tooth age distribution – large assemblage units pooled (those with 150 or more teeth).

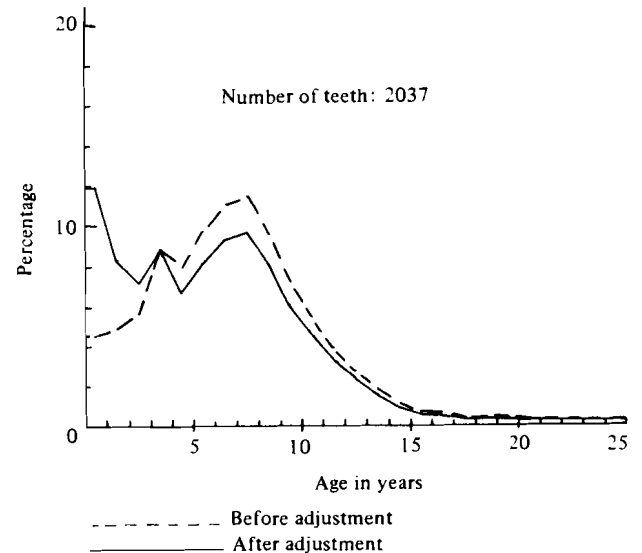


Fig. 4.23. Tooth age distribution – small assemblage units pooled (those with fewer than 150 teeth).

The distributions for the large pooled assemblage unit and the small pooled assemblage unit are remarkably similar to one another and to the life assemblage model. That is, on average, both large and small units seem to withdraw a representative sample from the living population.

#### *The clustering of assemblage units*

A cluster analysis is used here to show variability among units of all sizes. The variables employed are the descriptive statistics: the mean, standard deviation, skewness and kurtosis. These four statistics taken together define most of the shape of the age distribution. They are the most convenient variables because they can be used to describe any assemblage unit containing ageable teeth, even when the sample is very small. The cluster analysis techniques used here are the Ward's

Table 4.4. Cluster unit size and chronology

Cluster unit	Assemblage unit	Geological period	Industry	Number of ageable teeth	Mean number of ageable teeth		
IA	1	CG11	Würm II	Denticulate Mousterian	91		
	13	CG29	Würm II	Typical Mousterian	9		
	5	CG20	Würm II	Denticulate Mousterian	19		
	31	PA01	surface		8		
				Total	127	31.8	
IB	27	MO03	Late Würm	Magdalenian VI	84		
	28	MO04	Late Würm	Magdalenian VI	73		
	58	FG15	Late Glacial	Late Magdalenian	160		
	62	AR01	Late Würm	Magdalenian	117		
	44	JA01	Würm II, III or II/III		498		
	67	GI39	Middle Würm	Typical Mousterian	10		
	68	GI49	Middle Würm	Typical Mousterian	43		
	3	CG14	Würm II	Denticulate Mousterian	340		
	24	CG70	Würm II	Quina Mousterian	40		
	15	CG37	Würm II	Typical Mousterian	8		
	18	CG50	Würm I	Typical Mousterian	65		
	37	PA42	Würm I	Denticulate Mousterian	24		
	42	F202	Upper Pleistocene		52		
	40	CSJ0	Riss		14		
					Total	1528	109.1
	IC	72	SO3P	Würm IV	Final Magdalenian	364	
30		MO12	Late Würm	Magdalenian VI	66		
70		SO2L	Würm III	Upper Perigordian	257		
4		CG15	Würm II	Denticulate Mousterian	45		
6		CG21	Würm II	Quina Mousterian	39		
8		CG23	Würm II	Quina Mousterian	140		
49		RM06	Early to Middle Würm	Typical Mousterian	47		
20		CG52	Würm I	Typical Mousterian	38		
34		PA07	Riss	Acheulian	41		
					Total	1037	115.2
IIA	29	MO05	Late Würm	Magdalenian V	35		
	59	BL23	Late Würm	Proto-Magdalenian	84		
	2	CG12	Würm II	Denticulate Mousterian	11		
	7	CG22	Würm II	Quina Mousterian	152		
	11	CG27	Würm II	Ferrassie-type Mousterian	26		
	56	RM21	Early to Middle Würm	Quina Mousterian	16		
	53	RM11	Early to Middle Würm	Quina Mousterian	52		
	50	RM07	Early to Middle Würm	Typical Mousterian	48		
	48	RM05	Early to Middle Würm	Typical Mousterian	40		
	45	RM02	Early to Middle Würm	Denticulate Mousterian	3		
	16	CG40	Würm I	Typical Mousterian	9		
	35	PA08	Riss I	Acheulian	51		
36	PA09	Riss I	Acheulian	46			
				Total	573	44.1	

Table 4.4. continued.

Cluster unit	Assemblage unit	Geological period	Industry	Number of ageable teeth	Mean number of ageable teeth
IIB	71	SO3N	Würm IV	Final Magdalenian	43
	60	BL27	Late Würm	Proto-Magdalenian	35
	61	BL30	Late Würm	Proto-Magdalenian	7
	69	SO1M	Würm III	Lower Aurignacian	57
	9	CG24	Würm II	Quina Mousterian	30
	12	CG28	Würm II	Typical Mousterian	6
	14	CG35	Würm II	Ferrassie-type Mousterian	32
	65	GI20	Middle Würm	Typical Mousterian	16
	55	RM19	Early to Middle Würm	Quina Mousterian	15
	57	RM29	Early to Middle Würm	Quina Mousterian	47
	54	RM12	Early to Middle Würm	Quina Mousterian	14
	51	RM09	Early to Middle Würm	Quina Mousterian	59
	47	RM04	Early to Middle Würm	Typical Mousterian	25
	32	PA04	Würm I	Typical Mousterian	4
					Total
					27.9
IIC	26	MO01	Late Würm	Magdalenian VI	54
	10	CG25	Würm II	Quina Mousterian	33
	52	RM10	Early to Middle Würm	Quina Mousterian	30
	46	RM03	Early to Middle Würm	Denticulate Mousterian	10
	17	CG47	Würm I	Mousterian	9
	25	CG98	Würm I	Typical Mousterian	20
	19	CG51	Würm I	Typical Mousterian	7
	22	CG56	Riss III	Upper Acheulian	6
	66	GI29	Würm I	Typical Mousterian	8
	63	GI18	Würm I	Typical Mousterian	8
	64	GI19	Würm I	Typical Mousterian	9
	38	PA43	Würm I	Typical Mousterian	13
	39	PA51	Würm I ?	almost sterile	2
	33	PA06	Riss II	Acheulian	51
	41	F123	Riss		18
43	F203	probably Upper Pleistocene		7	
				Total	285
					17.0

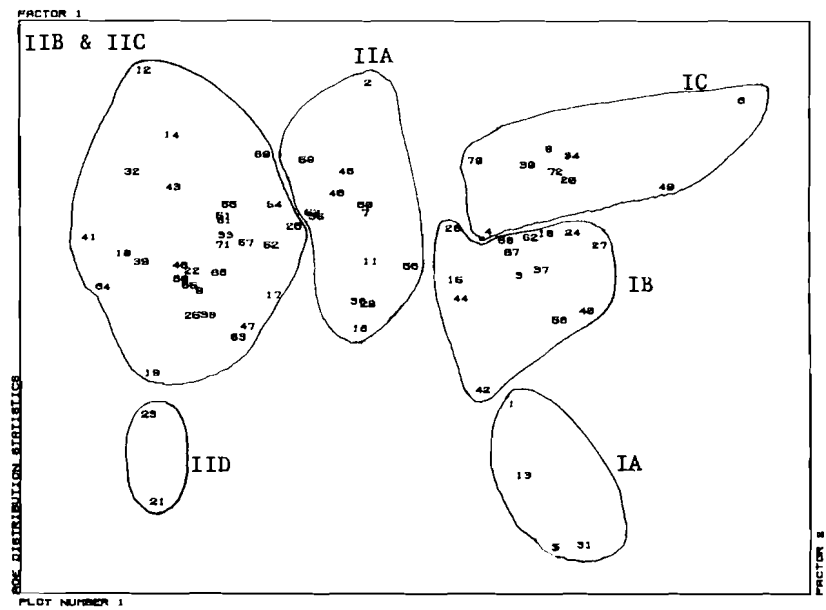
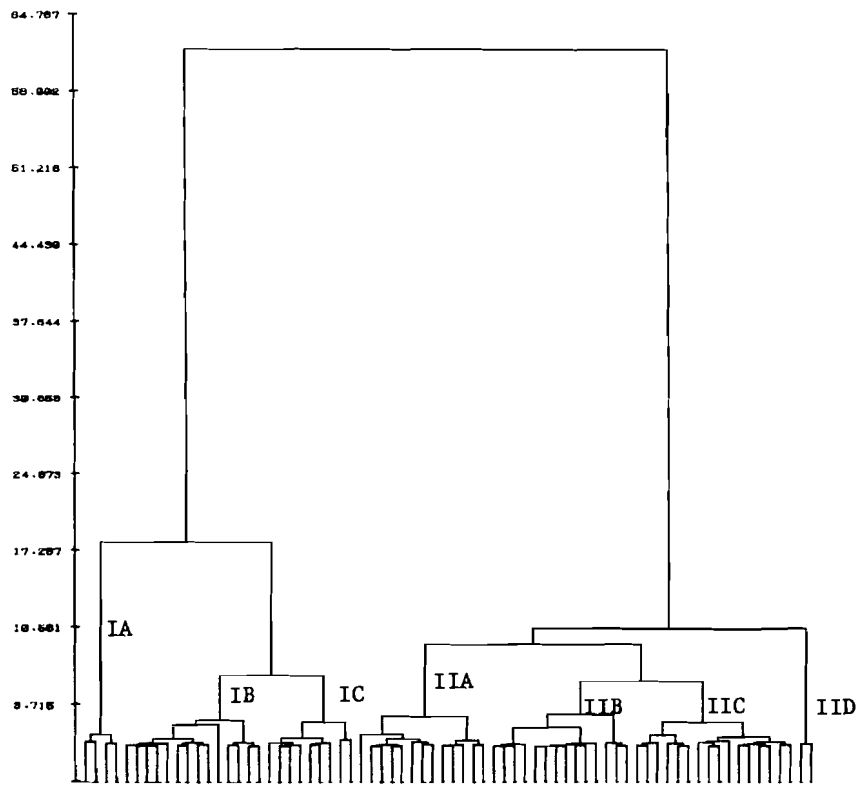


Fig. 4.24. Cluster analysis of tooth age distribution statistics (data in table 4.4).

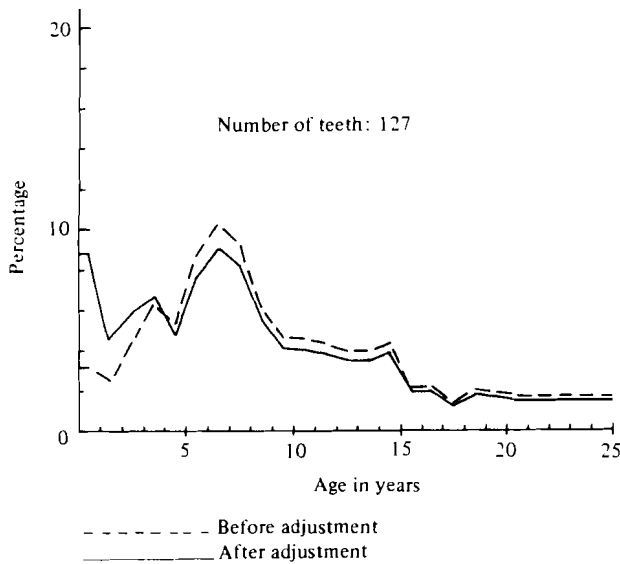


Fig. 4.25. Tooth age distribution – cluster unit IA.

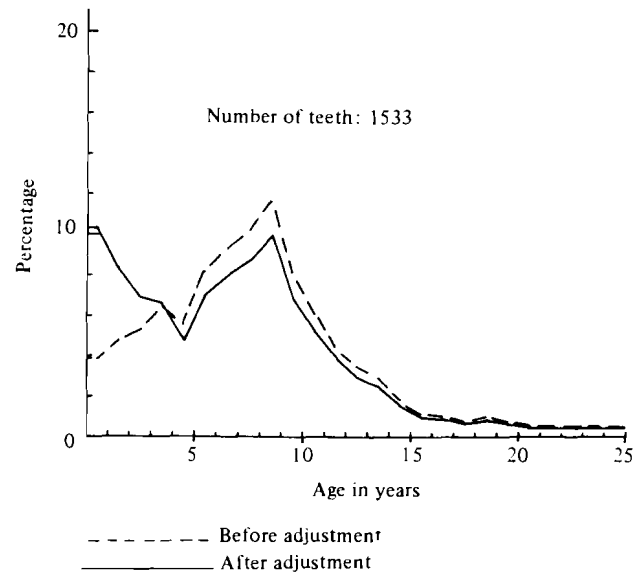


Fig. 4.26. Tooth age distribution – cluster unit IB.

Method dendrogram and a scatter diagram based upon a principal components analysis (Ward 1963; Wishart 1975; Levine 1979; fig. 4.24).

Assemblage units with data occupying fewer than ten columns (ten is an arbitrary, but plausible number) of the histogram are excluded from the cluster analysis. In that case the probability would have been high that all the teeth in that unit would have come from only a very few animals. If that were so, the statistics would be measuring the accuracy of the ageing technique rather than the shape of the age distribution. Of the 23 assemblage units thus excluded from the cluster analysis, 17 have an MNI of 1 and the rest of 2 or 3. Seventy-two assemblage units are suitable for inclusion in the cluster analysis in table 4.4.

According to the scatter diagram, not even the two main clusters identified by Ward's Method are discretely separate from one another. This suggests that the units do not easily fall into types. However, when the data from the 'clustered' units are pooled and histograms from that data plotted, some interesting distributions are generated.

*Cluster IA* (fig. 4.25). Cluster IA, with 127 ageable teeth, is the smallest of the clusters discussed here. It comprises only four assemblage units (IID contains only 8 ageable teeth and is therefore not discussed at all). Only one unit has more than 100 teeth; it accounts for 91 (or 72%) of the ageable teeth. The age distribution for IA is relatively flat – especially when the data are adjusted. The proportion of senescent teeth is unusually high. The percentage of teeth 0 to 3 years old is low by comparison with the pooled archaeological assemblage unit. However the preservation state of all these deposits is relatively poor. Such a small sample allows only for provisional interpretation. However it can be said that this age distribution resembles a somewhat flattened life assemblage model. It might reflect the hunting of rather aged family groups, random

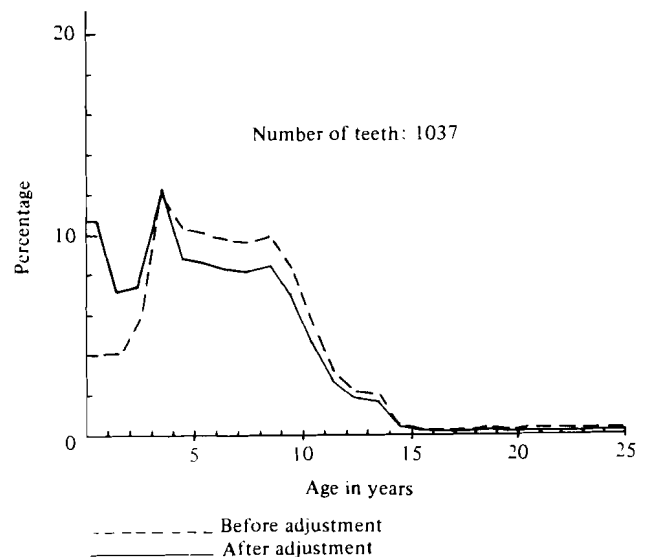


Fig. 4.27. Tooth age distribution – cluster unit IC.

stalking with an emphasis upon adults, trapping (some traps only capture adults), or stalking and scavenging.

*Cluster IB* (fig. 4.26). With 1533 ageable teeth, cluster IB is much larger than IA. The relevant units are relatively large. Four have over 100 ageable teeth; six have 40 to 100; and only four have less than 40. The overall pattern for this cluster is that of an almost ideal aggregate of family groups.

*Cluster IC* (fig. 4.27). Cluster IC is composed of 1037 ageable teeth. None of the assemblage units included here is very small. Three have over 100 ageable teeth, and the rest contain 38 or more each. Aside from the low proportion of teeth 0 to 3 years old and the rather high proportion 3 to 4

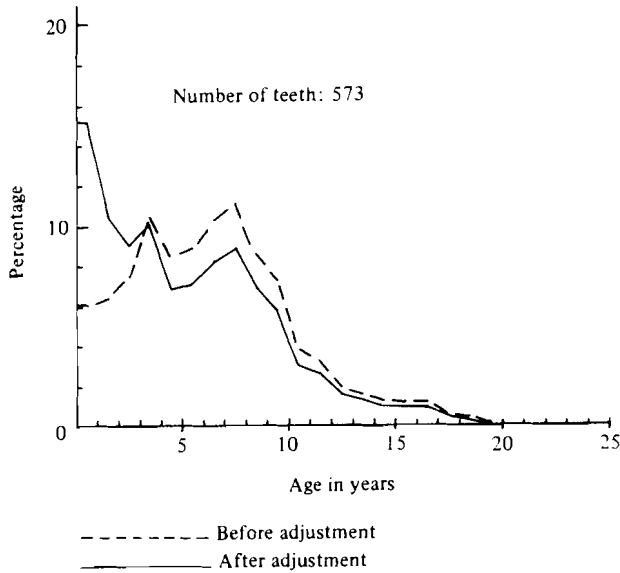


Fig. 4.28. Tooth age distribution – cluster unit IIA.

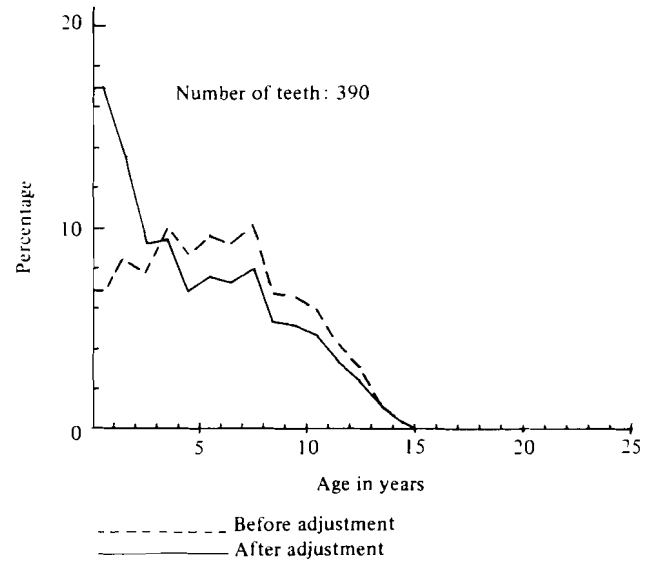


Fig. 4.29. Tooth age distribution – cluster unit IIB.

years old, the adjusted age distribution for this cluster is consistent with the life assemblage model.

*Cluster IIA* (fig. 4.28). The constituent assemblage units of clusters IIA–C are, on average, smaller than those of IA–C. Moreover the average size of the units comprising each cluster decreases from IIA to IIC.

Cluster IIA is composed of a relatively large number of medium to small assemblage units. Only one of these units contains more than 100 ageable teeth. Six contain 40 to 100, and six contain less than 40 each. IIA is then a cluster of medium-size assemblage units. The histogram for this cluster closely resembles the life assemblage model, although teeth 3 to 4 years old are somewhat over-represented and teeth 4 to 6 years old somewhat under-represented as in the pooled archaeological assemblage unit.

*Cluster IIB* (fig. 4.29). Cluster IIB comprises more assemblage units, but fewer teeth than IIA and it resembles the life assemblage model perhaps even more closely than does IIA. Apparently all age classes are sampled according to their representation in the whole population (rather than just the family group). The individuals comprising these assemblage units may have accumulated through any agency operating randomly or representatively on the whole population. Opportunistic stalking, trapping or driving could have produced the manifested pattern.

*Cluster IIC* (fig. 4.30). Cluster IIC is composed of a relatively large number of small and very small assemblage units. The age distribution as regards the archaeological units in this cluster is particularly interesting, because it so markedly fits the stalking model (fig. 4.8). That is, it contains a low proportion of teeth less than 3 years old and greater than 10 years old, but a high proportion between 3 and 10 years old. It looks very much as if the hunters responsible for these tooth deposits were choosing large, prime adults.

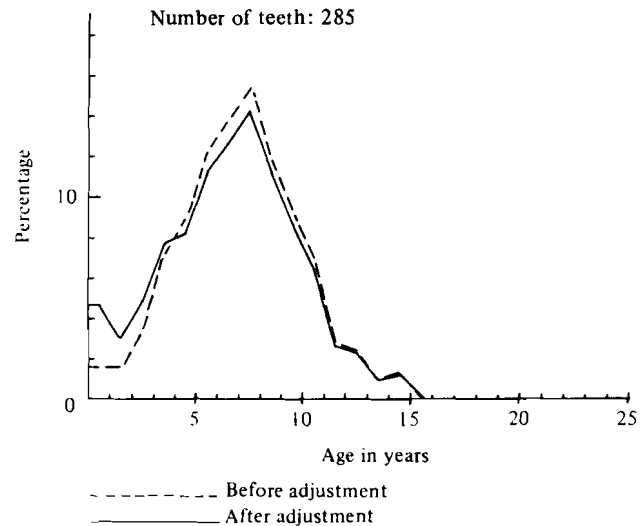


Fig. 4.30. Tooth age distribution – cluster unit IIC.

#### *Age distribution and chronology*

On the whole it appears that the type of age distribution manifested by a particular assemblage unit is not linked to its chronology (table 4.4). This is not surprising, since all the hunting techniques needed should have been well within human capabilities throughout all the time periods relevant here. That various strata within one site seem to have similar age distributions – for example, belong to the same cluster – could probably be explained by the site's ecology and the traditions of the human groups reoccupying it repeatedly over time. There may be some significance in the fact that cluster IIC includes a rather large proportion of Würm I assemblage units. However, such a temporal clustering may be chance (the site sample in reality being very small); or it may

be that the units cluster together because the tooth samples for those units are small, rather than because of the particular type of hunting strategy employed.

### Conclusion

The results of this age-distribution study are of particular interest because they deal with one of the major problems of Pleistocene archaeology – the question of the subsistence level of Palaeolithic man. Throughout the development of the discipline workers have taken various and often conflicting points of view in their interpretations of Pleistocene man—animal relationships (Perkins 1964, 1969; Higgs 1972; Sturdy 1972; Bahn 1978a; Levine 1979).

Comparison of fossil material with data from living populations shows that the age classes best represented in the archaeological assemblages studied here have been those of mature animals. This pattern is most similar to that of the life assemblage model in which each age class is represented as it would be in a living population or as it would be if an opportunistic hunting strategy were employed. This pattern is in marked contrast to the attritional type of mortality pattern predicted for a population of large domesticated ungulates. These results have been repeated for individual assemblage units whenever the samples have been large enough to be compared with the models. Thus it may be concluded that the age distribution patterns for the sites studied here are characteristic of hunting, not pastoralism. This makes sense, especially as the horse is not particularly suitable as a milk or meat domesticate. It matures slowly and produces on average only one offspring every two years. Historically its most important function has been to provide transport; that is a role in which individuals are almost never intentionally killed during their prime reproductive years.

We must, then, ask why in some situations animals are domesticated, while in others they are not. It cannot be assumed that there was any more reason for Palaeolithic man to have domesticated the horse than there has been for the Hadza to domesticate the zebra. Since there can be no first-hand knowledge of the earliest domestication of animals, we cannot judge how, in the absence of prior knowledge about

domestication, such a concept would have evolved amongst more or less isolated human groups. However, information about contemporary and historical pastoralist groups indicates that pastoralism is largely restricted to regions too marginal for either cultivation or hunting. That is, animal domestication would apparently have been necessary for those regions to have been inhabited (Beardsley 1953). However, the Pleistocene low latitude tundra and steppe, with its allegedly tremendous carrying capacity, would not have been a marginal environment for Palaeolithic hunters (Butzer 1971a). Hunting would probably have been the most efficient strategy (in terms of energy expenditure) by which to exploit such an environment. There is little information available about the relative energy inputs into the various subsistence strategies, however. Paine states that 'what should be stressed is the multiplicity of husbandry tasks, whereby the herd is handled as a complex aggregation of assets. . . the principle of least effort has no place in the pastoral adaptation. . . this is an underlying difference between the herder and hunter' (Paine 1971: 161). This, of course, does not rule out the possibility that Palaeolithic pastoralist adaptations were of a completely different form from contemporary and historical ones. However there is no evidence to support such a hypothesis.

### Acknowledgements

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