Patterns of Prehistoric Economic Exploitation on the Alpine Foreland

A Statistical Analysis of Faunal Remains in the Zoological Museum of Zürich University

By

C. F. W. HIGHAM

Department of Anthropology, University of Otago

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Introduction

The Zoological Museum of the University of Zürich houses one of the richest and best documented collections of faunal remains in Europe, sites from the Neolithic to the later stages of the Iron Age being represented. Moreover, the advanced stage of prehistoric research in Switzerland has resulted in the isolation of a remarkably complete succession of prehistoric cultures (VOGT, 1961, DRACK, 1959). One of the particularly attractive features of research into Switzerland's prehistory is the unique state of preservation of artifactual, faunal and floral material, which together permit the evaluation of an unusually detailed picture of prehistoric activity.

The analysis of faunal remains from the point of view of assessing the economic aims and methods of successive prehistoric societies calls for statistical methods of study. Moreover, the interpretation of the metrical attributes of prehistoric bone samples requires modern samples derived from animals of known age, sex, breed and plane of nutrition. Such modern samples of bovine and caprovine bones reveal that sexual dimorphism is a feature of the size and shape of certain limb bones in bovines, sheep and goats (HIGHAM, 1968, 1968b). Moreover, since sample variance increases significantly with both sex and breed admixture, marked variation may indicate heterogeneity from either source, a situation not easily resolved.

Three aspects of the faunal samples are considered particularly relevant: the relative numerical importance of different species, the sex ratio for certain anatomical bones, and the relationship between age and death. Since only certain anatomical bones reveal sexual dimorphism, however, detailed statistical analyses may be restricted to key dimensions from those bones,

The following analytical procedure has been adopted: In a sample of bones large enough for statistical analysis, the estimate of variance has first been calculated and compared with the corresponding estimate in modern sexually homogeneous samples, in order to assess the likelihood of sample heterogeneity (vide Appendix 2). The distribution of the bones has then been plotted in a scatter diagram. If grouping is visually apparent, the statistical validity of the presumed groups has been checked by calculating the major and minor axes of 95% equiprobability ellipses from relevant sample mean vectors and covariances (JACKSON, 1956), and the existence of a within-group normal or Gaussian distribution curve. Any specimens falling within the region of overlap between the two ellipses circumscribing groups with a normal distribution have been randomly assigned to either group. The number of possible interpretations for the occurrence of a bi- or trimodality have subsequently been ordered in terms of plausibility in the light of modern comparative material.

Mortality frequencies have been constructed on the basis of the known sequence of tooth eruption and replacement (SILVER, 1963). Since the pattern of death among domestic species might be expected to reflect, in part at least, herd policy, it has been considered necessary to check the statistical validity of any observed rise or fall in the frequency of death. The mortality frequencies from different sites, as well as the actual and mean number of species per immature age stage in any given sample, have therefore been compared by means of the Kolmogorov-Smirnov test (SIEGEL, 1956).

The relative importance of species within a faunal spectrum may be calculated either through the total number of species-identified bone fragments, or through the number of individual animals represented. As has been shown, the latter method is the more valid (HIGHAM, 1968a).

The Sequence of Swiss Prehistoric Farmer Cultures

The sites which are represented in the Zürich Zoological Museum are listed in Appendix I. In the following brief review of the sequence of Swiss prehistoric farmer cultures most, but not all, the relevant faunal samples are housed in Zürich.

The late hunting cultures of Switzerland are best represented at Birsmatten (BANDI, 1964). The faunal remains from this cave site have been described by SCHMID (1964), who noted that in the Late Tardenoisian level, radiocarbon dated to 3390 ± 120 B.C., there were no bones from domesticated animals. The bones of red deer, wild swine and beaver predominated. The avifauna, mammalian microfauna and pollen all attest the immediate proximity of forest during the Tardenoisian occupation at Birsmatten.

Farmers of the Younger Danubian culture penetrated the Alpine Foreland at Gächlingen (Kt. Schaffhausen), a settlement situated on an isolated pocket of loess (GUYAN, 1953). No fauna has survived however, due to the damaging effect of loess upon bones.

Egolzwil 3 is the earliest known Swiss Neolithic site with substantial associated faunal remains, the average radiocarbon date for its occupation phase being 2940 ± 90 B.C. Formerly thought by VOGT (1951) to belong to the older phase of the Cortaillod culture, it is now considered to be the eponymous site of the Egolzwil culture. A few sherds of South German type have been held to indicate the site's contemporaneity with the Rössen culture (VOGT, op. cit.).

The Older Cortaillod culture settlements concentrate in the western part of the Swiss Alpine Foreland, but the younger phase of the same culture saw an easterly extension to Nussbaumerhorn on the edge of the Bodensee. Radiocarbon dates for the Younger Cortaillod culture occupation at Seeberg Burgäschisee-Sud range from 2992 ± 90 to 2592 ± 100 B.C. Cortaillod culture settlements concentrate on lake margins, and most are situated under the 500 metre contour. The Younger Cortaillod culture of Western Switzerland was contemporary with a southward extension of the Michelsberg culture, the best documented site of the latter being Thayngen-Weier, the occupation phase of which has been radiocarbon dated to 2732 ± 180 B.C. Settlements of the Michelsberg culture have also been found at Zürich Breitingerstrasse (DRACK, 1960), and at Eschner Lutzengüetle in Liechtenstein (HARTMANN-FRICK, 1960), in both cases in association with domestic animal bones. The distribution of this culture in Switzerland however, is largely restricted to Cantons Schaffhausen, Thurgau and Zürich (BAER, 1956).

The Late Neolithic Horgen culture is stratified above the Michelsberg culture occupation levels at Zürich Breitingerstrasse and Eschner Lutzengüetle. There are many Horgen culture settlements on the shores of the Bodensee as well as in the uplands at, for example, Cazis Petrushügel (Kt. Graubünden). At Zürich Utoquai, the Horgen settlement was succeeded by the Corded Ware culture, in the occupation levels of which some copper artifacts were found. The settlements of the Corded Ware culture within Switzerland were restricted to the north east.

As WYSS (1959) noted, the Swiss Early Bronze Age, which succeeded the Corded Ware culture, may be subdivided into two phases, which are equivalent to periods A 1 and A 2 of REINECKE's South German Bronze Age sequence. Two important settlement sites of the later phase in the Swiss Lowlands are found at Arbon Bleiche on the Bodensee, and Baldegg on the lake of the same name.

During the Middle Bronze Age, settlement around the small piedmont lakes ceased. Sites are known in the alpine region at Crestaulta and Cazis however, and Middle

Bronze Age occupation remains have been located in some Jura caves. VOGT (1959) views the Middle Bronze Age in Switzerland as a chronological rather than as a cultural concept.

The Late Bronze Age on the Swiss Plateau was permeated with Urnfield culture influence, while a further current of influence from the South Tyrol led to the Melaun culture occupation at Mottata-Ramosch in the Engadine, and Montlingerberg in the Lowlands (WÜRGLER, 1962). The Urnfield culture itself has been found at lakeside settlements (Zug-Sumpf and Zürich Alpenquai), fortified posts (Bonistein) and in the alpine region at Cazis.

The principal technological advances observed during this remarkably complete culture sequence are seen first in the Early Neolithic, where the polished stone axes and wooden hafts formed such an important feature of the Egolzwil culture, and secondly during the Late Bronze Age, when bronze became widely available. Seen in its West European context however, the sequence started late. Danubian culture farmers were settling the loess regions to the north over 1,000 years before the occupation of Egolzwil 3. Nevertheless, the Swiss prehistoric sequence is important for the great variety of cultures found within a similar environment.

The Metrical Attributes of Certain Prehistoric Bone Samples

The Cortaillod Culture Bovines

Initially, the bovine remains from Egolzwil 2 will be analysed, prior to a comparison being made with those from other Cortaillod culture settlements. The bones studied are exactly the same as those published by HESCHELER and RÜEGER (1939, 1942). In that study, they concluded that the bovine sample contained a large proportion of *Bos primigenius*, a number of domestic bovines, and a group of bones intermediate in size which they could ascribe neither to the wild, nor to the domestic, group. On morphological grounds however, they were able to distinguish between the bones of *Bos primigenius* and the bison.

The Bovine Mortality Frequencies

The maximum cumulative percentage difference between the actual number of mandibles per immature age stage and those predicted on the basis of a random uniform distribution of mandibles between the age stages (23.6%) is significant at the 1% level. The rise in mortality during age stage 5 (Table 1), which accounts for almost a quarter of all mandibles, is particularly notable. The Egolzwil 2 bovine mortality frequencies have been compared with those from other prehistoric settlements (Table 2). It is noted that the mortality frequencies of Egolzwil 2 and those of other Cortaillod sites are statistically identical ($P = 0.01$).

The animals ascribed to age stage 6 at Egolzwil 2 were probably killed between June and February, with September to November as the most likely months. Just as the key to the Troldebjerg bovine economy lay in the status of animals killed during stages 20 and 21 (HIGHAM and MESSAGE, 1968), it appears likely that from

Table 1. The bovine mortality frequencies from some Swiss prehistoric settlement sites. (Percentage of mandibles per age stage)

Stage of dentition development	Approximate age (months)	St. Aubin	Egolzwil 2	Egolzwil 4	Seematte-Gelfingen	Arbon Bleiche	Zürich Alpenquai
1	Foetal	0.0	0.0	0.0	5.2	0.0	0.0
2	Birth-3 weeks	2.5	2.5	2.0	1.7	0.0	0.0
3	1—4	3.3	3.1	4.0	6.9	0.0	0.8
4	5—6	16.4	0.62	6.0	12.0	3.1	2.3
5	6—7	6.6	21.8	28.0	12.0	3.1	5.5
6	7—9	5.7	0.0	12.0	1.7	0.5	0.8
7	8—13	2.5	2.5	0.0	1.7	0.5	4.7
8	15—16	7.4	6.8	6.0	13.8	4.7	5.5
9	16—17	0.8	4.4	2.0	8.6	4.7	3.9
10	17—18	0.8	0.0	0.0	0.0	6.75	2.3
11	18—24	3.3	0.62	0.0	0.0	6.75	3.1
12	24	4.1	0.0	4.0	3.5	0.0	3.1
13	24—30	1.6	1.2	0.0	0.6	5.2	0.8
14	30	0.8	0.0	0.0	0.6	3.7	6.3
15	30—31	1.6	6.8	2.0	2.3	3.7	2.3
16	31—32	1.6	0.62	2.0	0.0	2.1	2.3
17	32—33	4.9	0.62	2.0	0.0	2.1	2.3
18	36	1.6	1.2	1.0	0.0	9.9	3.1
19	38	2.5	1.9	2.0	0.0	9.9	0.8
20	40	2.5	3.1	1.0	1.7	6.3	1.6
21	40—50	5.7	6.2	0.0	5.2	8.3	9.4
22	50	18.9	29.2	16.0	19.0	8.3	16.4
23	over 50	4.9	6.8	10.0	3.5	10.4	22.7
N		122	161	45	50	96	128

Table 2. The maximum cumulative percentage differences between some prehistoric bovine mortality frequencies

Site						
1. Egolzwil 2	—	15.9	25.4**	19.4**	24.7**	23.9*
2. St. Aubin		—	32.5**	24.1**	18.4	17.5
3. Arbon Bleiche			—	21.5*	47.0**	46.1**
4. Zürich Alpenquai				—	40.1**	42.6**
5. Seematte Gelfingen					—	13.8
6. Egolzwil 4						—

* Significant (P = 0.05)
** Significant (P = 0.01)

an economic standpoint, the most important concentration of mortality at Egolzwil 2 occurred among animals ascribed to stage 5. The status of the bovines dying when under 12 months of age cannot be ascertained however, without reference to the limb bones.

The Limb Bones: Basic Metrical Attributes

In studying the bovine limb bones from Egolzwil 2, particular attention will be paid to the first-fore phalanx, the metatarsal, the metacarpal and the radius. All

Table 3. A comparison between the variability of certain bovine bones from Egolzwil 2 and modern breeds

Sample	Dimension	N	s	V	F Ratio on comparing with Egolzwil 2
Egolzwil 2	Metacarpal: Distal Width	52	11.42 ±1.20	18.33	
Red Danish ♀	Metacarpal: Distal Width	32	1.97 ±0.27	3.33	33.4**
Aberdeen Angus ♀	Metacarpal: Distal Width	40	2.05 ±0.23	4.10	30.9**
Aberdeen Angus, steer	Metacarpal: Distal Width	40	2.22 ±0.25	3.28	26.5**
Egolzwil 2	Radius: Distal Width	93	16.39 ±1.36	20.02	
Red Danish ♀	Radius: Distal Width	32	3.54 ±0.44	4.17	21.5**
Egolzwil 2	Fore Phalanx I: Width of P.A.S. +	69	5.86 ±0.49	18.54	
Red Danish ♀	Fore Phalanx I: Width of P.A.S. +	32	0.85 ±0.15	4.47	47.6**
Aberdeen Angus ♀	Fore Phalanx I: Width of P.A.S. +	40	1.04 ±0.15	3.75	31.7**
Aberdeen Angus, steer	Fore Phalanx I: Width of P.A.S. +	40	1.10 ±0.12	3.51	28.3**

** Significant ($P = 0.01$)
+ = Proximal articulating surface

estimates of variability for these bones are significantly greater, at the 1% level at least, than for modern sexed bovines (Table 3).

The distribution of the proximal width and proximal articulating surface width of the first fore phalanges appears visually to fall into three groups (Fig. 1). The major and minor axes of the 95% equiprobability ellipses have been calculated for each presumptive group: as may be seen, but one specimen falls within the region of overlap between large and medium sized groups. The variances of the proximal width for each group are statistically identical with the corresponding estimates for modern sexed bovines (Table 4).

The distribution of the distal transverse and distal anterior-posterior widths of the metatarsal also appears, visually at least, to fall into three groups (Fig. 2). Again, the major and minor axes of the 95% equal probability ellipses have been calculated: but one specimen falls within the region of overlap between the medium and large sized groups. The variabilities of the distal width of the bones comprising the larger two groups are statistically identical with those for modern sexed bovines, while the variability for the small group is significantly greater, at the 1% level, than for Aberdeen Angus cows, and at the 5% level than those for Aberdeen Angus steers and Red Danish cows (Table 5).

Table 4. The value of the F-Ratio on comparing the estimates of variability for Egolzwil 2 and modern sexed bovine first fore phalanges (maximum proximal width)

	N	$\bar{X}$	s	F Ratio 1.	2.	3.	4.	5.	6.	7.
1. Egolzwil 2 "Robust"	24	43.2 ±0.27	1.35 ±0.19	—	1.28	1.30	1.39	1.13	1.13	27.55**
2. Egolzwil 2 "Medium"	13	37.3 ±0.42	1.53 ±0.30		—	1.01	1.07	1.45	1.45	21.41**
3. Egolzwil 2 "Small"	32	27.7 ±0.27	1.54 ±0.19			—	1.06	1.47	1.47	21.15**
4. Red Danish ♀	32	35.7 ±0.26	1.59 ±0.18				—	1.57	1.57	19.18**
5. Aberdeen Angus ♀	40	32.1 ±0.20	1.27 ±0.14					—	0.00	31.13**
6. Aberdeen Angus, steer	40	36.2 ±0.20	1.27 ±0.14						—	31.13**
7. Egolzwil 2 "Pooled"	69	34.9 ±0.84	7.08 ±0.60							—

** Significant (P = 0.01)

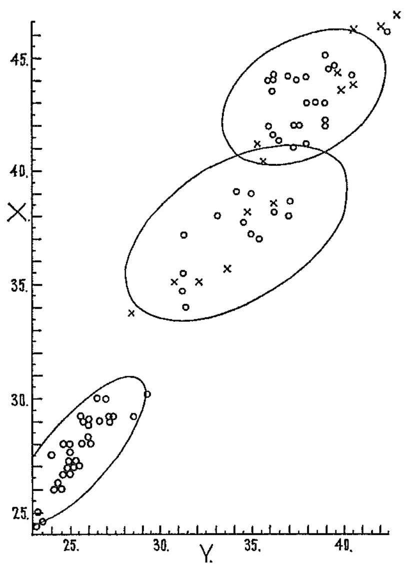

Fig. 1. Egolzwil 2: Scatter diagram of bovine first fore phalanges. X-axis, maximum proximal width, Y-axis, maximum width of proximal articulating surface. Crosses depict specimens of Danish *Bos primigenius.*

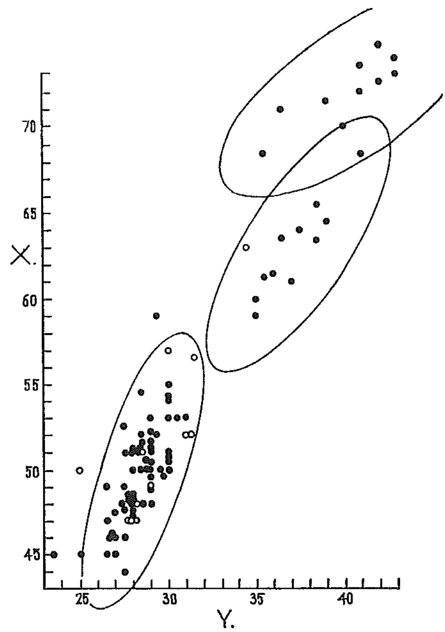

Fig. 2. Egolzwil 2: Scatter diagram of bovine metatarsals. X-axis, maximum distal width, Y-axis, maximum distal anterior-posterior width. Hollow circles depict complete specimens.

Table 5. The values of the F-Ratio on comparing the estimates of variability for the distal width of Egolzwil 2 and modern sexed bovine metatarsals (maximum distal width)

	N	$\bar{X}$	s	1.	2.	3.	4.	5.	6.
1. Egolzwil 2 Large Group	10	72.7 ±0.55	1.56 ±0.39	—	2.74	4.11*	1.51	2.01	1.50
2. Egolzwil 2 Medium Group	12	62.8 ±0.74	2.58 ±0.53		—	1.50	1.80	1.36	1.82
3. Egolzwil 2 Small Group	71	50.0 ±0.37	3.17 ±0.26			—	2.71**	2.05*	2.44*
4. Aberdeen Angus ♀	40	56.1 ±0.30	1.92 ±0.21				—	1.36	1.01
5. Aberdeen Angus, steer	40	62.5 ±0.35	2.21 ±0.25					—	1.34
6. Red Danish ♀	32	61.4 ±0.40	1.91 ±0.29						—

* Significant (P = 0.05)
** Significant (P = 0.01)

Table 6. The values of the F-Ratio on comparing the estimates of variability for Egolzwil 2 and modern sexed radii (maximum distal width)

				F Ratio			
Sample	N	$\bar{X}$	s	1.	2.	3.	4.
1. Egolzwil 2 Large Group	27	102.8 ±1.14	5.91 ±0.80	—	3.53**	2.31*	2.79**
2. Egolzwil 2 Medium Group	19	86.4 ±0.71	3.13 ±0.52		—	1.54	1.27
3. Egolzwil 2 Small Group	47	66.1 ±0.56	3.88 ±0.40			—	1.20
4. Red Danish, Female	32	84.8 ±0.62	3.54 ±0.44				—

* Significant (P = 0.05)
** Significant (P = 0.01)

The distribution of the bovine radii also reveals, visually, the presence of three groups (Fig. 3), no specimen falling within either region of overlap circumscribed on the basis of 95% equiprobability ellipses. Although the estimate of the variability for specimens comprising the largest group (on the basis of the maximum distal transverse width) is significantly greater, at the 1% level, than that for Red Danish cows, the values of the coefficient of variation are similar (5.7 against 4.2). The variability of the maximum distal width for the remaining two groups however, is in each case statistically identical with that for Red Danish cows (Table 6).

In the scatter diagram of the maximum distal transverse and maximum distal anterior-posterior width of the metacarpal, there appear to be two concentrations of bones, with distal widths between 49 to 59 mm, and 73 to 86 mm, respectively.

Specimens with distal widths of between 59 and 73 mm are on visual grounds, not as clearly nucleated as those comprising the two presumptive groups (Fig. 4). A discussion of this scatter diagram is therefore deferred pending consideration of the possible reasons for the presence of three groups of radii, metatarsals and phalanges.

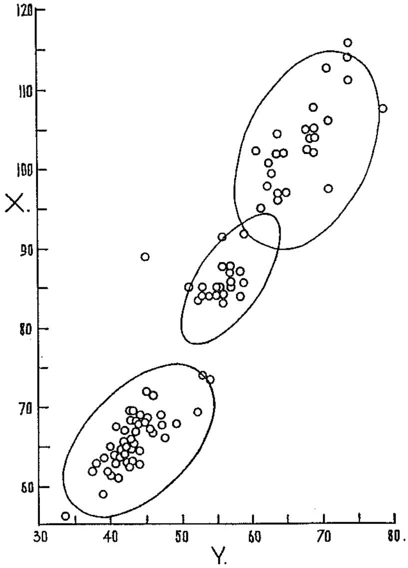

Fig. 3. Egolzwil 2: Scatter diagram of bovine radii. X-axis, maximum distal width, Y-axis, maximum distal anterior-posterior width.

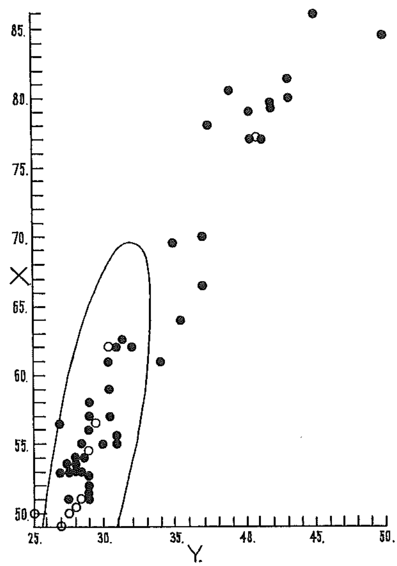

Fig. 4. Egolzwil 2: Scatter diagram of bovine metacarpals: X-axis, maximum distal width, Y-axis, maximum distal anterior-posterior width. Hollow circles depict complete specimens.

Discussion

In interpreting the distribution of the metatarsals, radii and phalanges, it should be remembered that a high degree of correlation exists between the distal widths of the metatarsal and radius, and the proximal width of the first fore phalanges in modern comparative material (Table 7), a finding which permits confirmation of the assumption that the bones comprising the large group of metatarsals, radii and phalanges come from the same animals. Moreover, bones comprising the medium and small groups would come from two further, distinct categories of bovine. As may be seen from Table 8, the relationships between the mean dimensions of metatarsals, radii and phalanges in the three groups confirm this assumption. Any conclusions regarding the status of bovines in any of the three groups will therefore apply equally to the bovines comprising the equivalent group, but based on either of the other anatomical bones.

In discussing potential reasons for the presence of three groups of bovine bones, it must be remembered that mandibles from nearly all juvenile age stages have been found at Egolzwil 2. This situation, in indicating that cattle breeding probably took

Table 7. The values of r from certain limb bone dimensions of sexually homogeneous samples of Aberdeen Angus and Red Danish bovines

A. Aberdeen Angus Steers (N=29)

	1.	2.	3.	4.
1. Metacarpal: Max. Distal Width	—	0.84	0.79	0.48
2. Metatarsal: Max. Distal Width		—	0.67	0.57
3. Fore Phalanx I: Max. Proximal Width			—	0.45
4. Calcaneum: Max. Width of Proximal Tuberosity				—

B. Aberdeen Angus Cows (N=40)

	1.	2.	3.	4.
1.	—	0.49	0.87	0.06
2.		—	0.53	0.01
3.			—	0.15
4.				—

C. Red Danish Cows (N=32)

	1.	2.	3.	4.	5.
1.	—	0.79	0.75	0.55	0.58
2.		—	0.66	0.59	0.71
3.			—	0.48	0.51
4.				—	0.45
5. Radius: Distal Width					—

place at that site, raises the possibility that the observed grouping results from the admixture of bovines of two, or three, breeds. In the former case, the medium sized group of bones would comprise a mixture of male specimens from one breed, and females from another, while in the latter situation, each group would correspond to distinct breeds, with of course, the necessary corollary that the inhabitants bred only within, and not between, breeds.

Given, for the moment at least, that more than one breed of cattle was maintained, then it is highly likely that animals of both sexes of each breed were maintained, and in the subsequent analysis of the preceeding "genetic" interpretation of the presence of three groups, this view will be adopted.

Metapodials and phalanges from modern, sexed adult bovines of the same breed reveal quantitative sexual dimorphism both in size and in shape. Furthermore, metapodials from *Bos primigenius* also display sexual dimorphism (HOWARD, 1962). It would seem possible therefore, to accept analogous characteristics for prehistoric domestic bovines, a view which will be adopted in the subsequent analysis of the potential reasons for the presence of three groups of bovine bones at Egolzwil 2. The smallest, medium and largest sized groups of metatarsals, radii and phalanges will be referred to as the small, medium and large groups.

Table 8. The estimates of the mean derived from three dimensions of sexed Aberdeen Angus bones and corresponding dimensions from the three groups of bovine bones of Egolzwil 2

	1. Max. D.W.* Metatarsal	2. Max. P.W. Fore Phalanx I	$\frac{2}{1}\times 100$	3. Max. D.W. Radius	$\frac{1}{3}\times 100$
Aberdeen Angus steers	62.5	36.3	58.1	—	—
Aberdeen Angus cows	56.1	32.3	57.6	—	—
Egolzwil 2 "large"+	72.1	43.2	59.9	102.8	71.1
Egolzwil 2 "medium"+	63.1	36.4	57.6	86.4	74.2
Egolzwil 2 "small"+	50.0	27.7	55.4	66.1	75.6
Red Danish cows	61.4	35.7	58.1	84.8	72.4

* Distal Width
\+ "large" implies presumptive male specimens of *Bos primigenius*
"medium" implies presumptive female specimens of *Bos primigenius*
"small" implies presumptive female specimens of domestic bovines

Table 9. Egolzwil 2: The value of Student's t on comparing the mean proximal width to length ratios of the first fore bovine phalanges

Sample	N	$\bar{X}$	s	Student's t 1.	2.	3.
1. Egolzwil 2: Small Group	32	45.9 ±0.36	2.04 ±0.25	—	1.04	4.29**
2. Egolzwil 2: Medium Group	13	46.6 ±0.56	2.11 ±0.40		—	2.45*
3. Egolzwil 2: Robust Group	24	48.5 ±0.47	2.29 ±0.33			—

* Significant (P = 0.05)
** Significant (P = 0.01)

Given that the nature of the source material precludes a final interpretation, the availability of extensive modern comparative material permits possible interpretations to be ranked in order of plausibility. Thus, the presence of bones from both sexes of three breeds of bovines at Egolzwil 2 is unlikely, due to the observation that the dimensions under consideration are highly sexually dimorphic.

A further potential reason for the presence of three groups of bones is that the medium group comprises a mixture of male and female bones, with the bones of corresponding sex in the small and large groups respectively. It has been shown however, that the breadth to length ratio in male bovine phalanges is significantly greater than in female bovines of the same breed. The breadth of the proximal articulating surface to length ratio for the medium group is statistically identical with that for the small group, but significantly smaller, at the 5% level, than that for the large group (Table 9). Thus, while the medium group of phalanges could comprise female specimens corresponding to the males in the large group, the low magnitude of its mean proximal articulating surface width to length ratio rules out the alternative possibility.

Potentially, the small group could comprise a mixture of females from two distinct breeds, corresponding to the males in the medium and large groups. It has been demonstrated however, that the mean proximal articulating surface width to length ratio for the phalanges in the medium group, being statistically identical with that for the small group, renders such an interpretation extremely unlikely. Moreover, the magnitude of the coefficient of difference for the proximal widths of the phalanges in the large and small groups (5.36, against 1.62 in the Aberdeen Angus) also renders the possibility that these two groups represent males and females of the same breed unlikely.

The small group could comprise females, and the medium and large groups the corresponding males of the same breed, but differentiated by the effects of castration. No modern comparative material permits an estimation of the effect of castration on the shape of phalanges. ZALKIN (1962) however, has shown that the mean distal metatarsal width for steers and bulls of the Kalmyk breed are statistically identical. The estimate of the mean distal width for the metatarsals comprising the large group is significantly greater, at the 1% level at least, than for the medium group, a situation rendering the interpretation that the medium and large groups comprise males of the same breed, but differentiated by castration, unlikely.

It is possible that either bulls or cows of the same breed were raised on different planes of nutrition. On the one hand, the medium and small groups would comprise females of the same breed, but raised on different planes of nutrition, while on the other hand the medium and large groups would comprise male bovines differentiated by two distinct nutritional regimes. Again however, the extremely high coefficients of difference between the linear dimensions of the large and small groups argue against such an interpretation. Moreover, all adult domestic bovines at Egolzwil 2 would have been maintained on collected fodder during the winter, thus equalising the effect of differential summer feeding.

HESCHELER and RÜEGER (1939, 1942) distinguished the bones of bison from the majority of the bovine bones at Egolzwil 2. A further possible interpretation of the three groups of bones however, is that the large and medium groups represent male and female *Bos primigenius* respectively, while the small group derives from domesticated animals. Clearly, the lower size limit of the dimensions of presumptive female *Bos primigenius* bones is a crucial factor in considering such a possibility. The presence of auroch bones at a site of the Younger Cortaillod Culture would not be unexpected: STAMPFLI (1963) noted the presence of such bones at Seeberg Burgäschisee-Sud.

The agreement over the question of this lower limit is notable. Thus BÖKÖNYI (1962) has suggested that the difference between the sexes of Hungarian *Bos primigenius*, on the basis of the distal width of the radius, is 91—92 mm, and that the lower limit for this dimension in the female is 81 mm. LEHMANN (1949) estimates this

Table 10. Some dimensions from presumptive female European *Bos primigenius* bones

Egolzwil 2, Medium Group Dimension	O.R.	$\bar{X}$	s	Minimum corresponding dimension in female *Bos primigenius* according to: BÖKÖNYI Hungary	STAMPFLI Switzerland	REQUATE Germany	HIGHAM (Danish Material)
Metatarsal:							
Max. distal width	59.0—68.5	62.8 ±0.74	2.58 ±0.53	62.5	57.0	63.0	61.6
Radius:							
Max. distal width	83.0—91.5	86.4 ±0.71	3.13 ±0.52	81.0	79.0	80.0	—
Metacarpal:							
Max. distal width	—	—	—	68.5	62.0	69.6	65.0

Table 11. Egolzwil 2: A comparison between the estimates of the mean for certain bovine bone dimensions and the corresponding means for presumptive *Bos primigenius*

Sample	N	$\bar{X}$	s	Student's t 2.	3.	4.
1. Hungarian male *Bos primigenius* Radius M.D.W.+	24	99.6 ±0.80	3.94 ±0.57	13.53**	1.33	10.98**
2. Hungarian female *Bos primigenius* Radius M.D.W.+	16	84.4 ±0.65	2.61 ±0.46	—	—	2.03
3. Egolzwil 2 Large group Radius M.D.W.+	27	102.8 ±1.14	5.91 ±0.80		—	—
4. Egolzwil 2 Medium group Radius M.D.W.+	19	86.4 ±0.71	3.13 ±0.52			—
				6.	7.	8.
5. Hungarian male*** Metatarsal M.D.W.+	29	73.1 ±0.36	1.93 ±0.25	9.82	0.86	13.99**
6. Hungarian female*** Metatarsal M.D.W.+	6	64.4 ±0.88	2.15 ±0.62	—	8.84**	1.81*
7. Egolzwil 2 Large, Metatarsal M.D.W.+	10	72.7 ±0.55	1.56 ±0.39		—	9.61**
8. Egolzwil 2 Medium, Metatarsal M.D.W.+	12	62.8 ±0.74	2.58 ±0.53			—

\+ Maximum distal width
* Significant at the 5% P.L.
** Significant at the 1% P.L. at least
*** Presumptive *Bos primigenius*

lower limit at 85 mm, STAMPFLI (1963) at 79 mm, and REQUATE (1957) at 80 mm (vide Table 10).

The smallest radius in the medium group of Egolzwil 2 has a distal width of 83 mm, while the suggested discontinuity between the distal widths of the medium and large groups (92 mm) corresponds to that between female and male *Bos primigenius* (cf. BÖKÖNYI, op. cit.). The mean distal widths of the radii in the medium and large groups and the corresponding means for presumptive female and male Hungarian *Bos primigenius* specimens are statistically identical (Table 11).

BÖKÖNYI (op. cit.) suggested that the lower limit of the distal width of female Hungarian *Bos primigenius* metatarsals is 62.5 mm. STAMPFLI'S suggestion that the smallest auroch metatarsal at Seeberg Burgäschisee-Sud has a distal width of 57.0 mm is based on a fragmentary specimen, and without the complete bone, the assertion that it comes from a wild bovine is open to doubt. The smallest presumptive female *Bos primigenius* metatarsal from Denmark (the Bonnerup specimen) has a distal width of 61.6 mm. It will be noted that the smallest specimen within the 95% equi-probability ellipse for the medium group in Fig. 2 has a distal width of 58.5 mm.

The means of the medium and large groups of metatarsals at Egolzwil 2 have been compared with those from presumptively sexed Hungarian *Bos primigenius* specimens. In neither case is the resultant value of t significant at the 1% level.

The lower limit of the proximal width of fore phalanges from the auroch was not discussed in BÖKÖNYI'S (op. cit.) paper. The proximal width and proximal articulating surface width of presumptive *Bos primigenius* first fore phalanges from Svaedborg, Holmegaard, Terp Mose and Ullerslev have however, been included in Fig. 1. As may be seen, their distribution coincides with the medium and large groups from Egolzwil 2.

It is possible therefore, that the medium and large groups comprise female and male *Bos primigenius* bones respectively. This assertion however, poses the problem that, since it has been assumed that domestic bovines were raised at Egolzwil 2, the bones of male and female animals should be present. Yet the phalanges, metatarsals and radii evidence but three groups of bones, of which two represent male and female *Bos primigenius*. This paradox however, should be related to the extremely high proportion of domestic bovine mandibles from animals dying when under a year of age.

Now the variability of a sexually homogeneous sample of female Aberdeen Angus metacarpals is statistically identical with that for a sample comprising up to 10% of male specimens (HIGHAM, 1968b). Were selective mortality of animals at Egolzwil 2 confined to either males of females, then the mature limb bones need display a degree of variance similar to that of a sexually homogeneous sample. On the basis of present knowledge, it is only possible to determine the predominant sex on the basis of complete bones which reveal marked sexual dimorphism in shape.

IMHOF (1964) has asserted that the distal width of male bovine metacarpals from Cortaillod settlements on the Bielersee ranges from 60 to 70 mm. The estimates of the lower limit for female *Bos primigenius* specimens vary from 62.0 to 69.6 mm (Table 10). Clearly, therefore, an overlap between the distal width in male Cortaillod culture domestic bovine metacarpals and female *Bos primigenius* specimens is in

Table 12. The dimensions of some complete metapodials from prehistoric Swiss settlements

A. Metacarpals

Site	1 Length	2 Max. proximal width	3 Min. diaphysial width	4 Max. distal width	$\frac{4}{1}\times 100$	$\frac{3}{1}\times 100$
Egolzwil 2						
1.	176.5	48.0	27.6	49.0	27.7	14.2
2.	186.5	50.0	31.0	50.5	27.0	13.9
3.	193.5	57.0	35.5	62.0	32.0	16.0
4.	189.5	44.0	25.5	50.0	26.5	13.8
5.	188.5	51.5	31.0	51.0	27.0	12.8
6.	182.4	53.0	30.0	54.5	29.8	15.7
7.	175.0	44.5	27.0	—	—	14.0
8.	202.0	60.6	34.0	—	—	18.7
9.	198.0	52.0	32.7	56.5	28.6	16.5
10.	247.5	81.2	48.9	77.0	31.0	19.0
11.	182.0	48.0	31.5	50.0	27.5	17.5
St. Aubin						
12.	191.0	53.0	28.5	52.0	27.2	14.8
13.	179.0	50.3	26.5	51.2	28.6	14.8
14.	194.2	56.2	30.2	58.2	30.0	15.5
15.	197.0	54.0	27.0	54.0	27.5	13.7
16.	189.0	58.0	34.2	60.1	32.0	18.1
17.	191.5	52.0	28.2	53.0	27.7	14.7
18.	186.0	53.2	24.1	53.0	28.5	13.0
19.	184.2	51.5	29.0	53.0	28.6	15.7
20.	188.7	50.0	26.0	51.0	27.0	13.8
21.	187.0	54.2	31.0	59.0	31.5	16.6
22.	184.0	56.5	29.0	62.0	33.7	15.8
23.	187.0	52.2	34.0	—	—	18.2
24.	196.5	58.0	31.0	57.0	29.0	15.8
Arbon Bleiche						
25.	194.9	61.0	33.0	66.1	34.0	16.9
26.	196.8	62.7	33.0	63.0	32.0	16.8
27.	163.2	42.5	24.1	44.5	27.4	14.8
28.	177.7	52.9	27.6	54.5	30.8	15.6
29.	195.0	—	33.5	—	—	17.2
30.	192.3	60.6	32.0	59.1	30.7	16.6

B. Metatarsals

Site	1	2	3	4	$\frac{4}{1}\times 100$	$\frac{3}{1}\times 100$
Egolzwil 2						
1.	218.5	42.4	21.1	47.0	9.6	21.6
2.	227.7	47.9	25.0	52.0	11.0	23.0
3.	223.4	42.0	22.0	48.0	9.9	21.5
4.	225.0	46.2	25.9	52.0	11.0	22.1
5.	225.5	44.0	21.0	49.1	8.9	20.8
6.	210.0	41.0	20.0	47.0	9.5	22.4
7.	207.0	43.5	23.5	51.0	11.4	24.6
8.	200.0	40.0	21.0	47.0	10.5	23.5
9.	217.0	47.0	23.5	56.6	14.0	26.2
10.	217.9	48.0	25.0	57.0	11.9	26.3
11.	254.0	55.5	30.5	63.0	12.0	24.9

question. Without complete metacarpals, in which female *Bos primigenius* may be expected to reveal the lower breadth to length ratios, the distinction between large male domestic and small female wild metacarpals is not at present possible.

Fortunately, a handful of complete metapodials from Egolzwil 2 survive (Table 12, Nos. 1—11). Complete metacarpals are depicted as hollow circles in Fig. 4. The great distal width to length ratio, and marked length of no. 10 suggests the presence of male *Bos primigenius*. The correspondingly low breadth to length ratios and relative shortness suggest strongly that nos. 1—2, 4—7, 9 and 11 are derived from domestic female bovines. Nos. 3 and 8 are longer and more robust than the putative domestic female metacarpals, and their high breadth to length ratios indicate masculinity. Yet these two specimens are too short to be considered wild. The distal width of no. 3 is identical with the lower limit for this dimension in female *Bos primigenius* metacarpals as proposed by STAMPFLI (1963), while the distal width of no. 8 although fragmentary, probably lies between 60 to 65 mm. The robustness of these two specimens suggests that male, in addition to female, domestic bovine metacarpals are present.

Of the complete metatarsals (Table 12), nos. 1—8 appear likely to derive from cows, on account of their low distal width to length ratios and relative shortness. Nos. 9 and 10 however, are more likely to be male domestic specimens, since their distal width to length ratios are considerably higher than in nos. 1—8 while neither approaches the length of presumptive female *Bos primigenius* specimens. No. 1 appears likely to come from a female *Bos primigenius*, on account of its great length, yet low width to length ratios. In the light of the foregoing consideration of the complete metatarsals, the small group in Fig. 2 appears likely to comprise female domestic bovines, but with at least the two specimens with distal widths of 57 mm being derived from domesticated males. The shape of no. 11 suggests that its analogous in the medium group derive from female aurochs, with, of course, the necessary corollary that the large group derived from male aurochs.

Conclusions (A)

The most plausible interpretation of the presence of three groups of bovine bones at Egolzwil 2 is that the small group comprises female domestic bovines, the medium group female *Bos primigenius* and the large group, male *Bos primigenius*. The scarcity of male domestic bovine bones is explained by the high and selective killing of such animals when under a year of age.

Cortaillod Culture Bovine Bones Compared

The domestic bovine mortality frequencies of St. Aubin IV, Egolzwil 2, Egolzwil 4 and Seematte Gelfingen are statistically identical at the 1% level (Table 1). The differences between Egolzwil 2 on the one hand, and Egolzwil 4 and Seematte Gelfingen on the other however, are significant at the 5% level. Consideration of these mortality frequencies suggests that the difference lies in the greater proportion of bovines dying at Egolzwil 4 and Seematte Gelfingen during stages 3—6. The rise in mortality during these stages however, is common to all sites, the relevant percentages being 25.6% of the total mandible sample at Egolzwil 2, 34.3% at Seematte Gelfingen and 50% at Egolzwil 4.

It will be noted that the distribution of bovine metacarpals from St. Aubin IV (Fig. 5) does not reveal the same pattern as at Egolzwil 2 (cf. Fig. 4). As at Egolzwil 2, the complete metacarpals (marked as hollow circles in Fig. 5) permit a detailed interpretation of the scatter diagram. Nos. 12—15, 17—20, and 24 in Table 12 appear, on the basis of their shortness and low width to length ratios, to be derived from domestic cows. No. 16 has the robust characteristics of a domestic bull, while nos. 22 and 23 have the marked breadth of presumptive male specimens, although their epiphyses are in the process of closure. No. 23 is unfortunately incomplete, but its great diaphysial width classes it a male specimen. The three complete presumptive male specimens thus have distal widths varying from 59 to 62 mm.

It will be noted that no metacarpal from St. Aubin IV has the characteristic length of female *Bos primigenius* specimens. The absence of hunting at St. Aubin IV could, therefore, account for the differences between the distributions of the metacarpals from this site and Egolzwil 2.

IMHOF'S (1964) suggestion that the maximum distal width of bull's metacarpals from Cortaillod settlements on the Bielersee ranged from approximately 60 to 70 mm, and that for cow's from 48 to 58 mm, finds confirmation in the corresponding specimens from St. Aubin and Egolzwil 4. Moreover, the distal width of Cortaillod culture steer's metacarpals is practically identical with that for bull's (60.5 to 70 mm). The available material thus suggests that a distal width of 59 mm is the approximate divi-

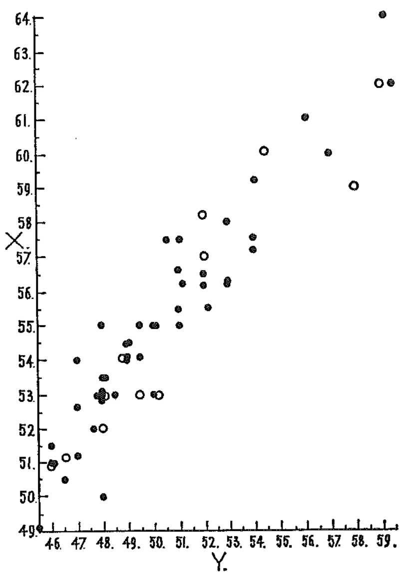

Fig. 5. St. Aubin: Scatter diagram of bovine metacarpals. X-axis, maximum distal width, Y-axis, maximum distal diaphysial width. Hollow circles depict complete specimens.

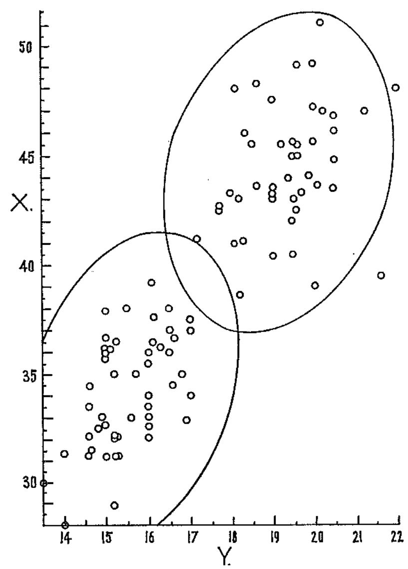

Fig. 6. Egolzwil 2: Scatter diagram of suid lower third molars. X-axis, maximum length, Y-axis, maximum breadth.

sion between the male and female metacarpals. If this is accepted, then at St. Aubin IV, as at Egolzwil 2, the ratio of male to female metacarpals was low.

Conclusions (B)

The bovine mortality frequencies from Egolzwil 2, Egolzwil 4, Seematte Gelfingen and St. Aubin IV reveal a similar pattern. Moreover, both at Egolzwil 2 and St. Aubin, the only two sites with sufficient limb bones for detailed analyses, a substantial number of male bovines appear to have been killed for consumption when under a year of age.

The Swine Bones from Cortaillod Culture Settlements

Introduction

The environment of Swiss Cortaillod culture settlements, in which oak and beech trees formed a substantial part, would have favoured swine rearing, but could also have supported wild swine. Indeed wild swine are still to be found in remote areas of Switzerland. The potential admixture of wild and domesticated swine bones in a prehistoric sample poses the problem that it is not at present possible to distinguish between their immature limb bones. Since the dimensions of the permanent molars remain substantially unchanged from the time of eruption however, they should provide evidence for the age structure of both wild and domestic mandible samples, as well as the relative number of mandibles from wild or domesticated animals. Much attention will therefore be paid to the Egolzwil 2 suid mandibles.

The Suid Dentition

The lengths and breadths of the lower third molars from Egolzwil 2 have been plotted on a scatter diagram. Visually, two groups are apparent, the larger corresponding in size to specimens assumed by BOESSNECK (1963) to be from wild swine (Fig. 6). The axes of the 95% equal probability ellipses have been calculated from the sample mean vectors and covariances of the two presumptive groups. As may be seen, no specimen falls within the region of overlap between the two ellipses.

An examination of the canines in the mandibles of the group with larger molars suggests that boars and sows are present. There are few complete canines from mandibles belonging to the smaller group, so it cannot be decided whether or not two sexes are present in that group also. Nevertheless the presence of males and females in the larger group is held to indicate that the two groups seen in Fig. 6 are not derived from male and female swine of the same species. In view of the similarity between the size of the molars comprising the large group and those from known specimens of wild swine, it is concluded that the larger group comprises wild swine and the smaller group, domestic swine.

In an attempt to distinguish between the immature mandibles of wild and domestic swine, the following method has been used. The first lower molar erupts approximately four months after birth. Fig. 7 is a plot of the length of the third against the length of the first molar taken from mandibles in which both teeth are present. There appear to be two groups separated at 15 mm on the Y axis. The major and minor axes of the 95% equal probability ellipses have been calculated from the sample mean vectors and covariances: the two ellipses do not overlap. The coefficient of difference between the mean length of the lower first molar of the specimens comprising the two groups (2.41), demonstrates a degree of overlap of less than 1%.

Because some of the first lower molars are either unerupted or missing, the length of the deciduous premolar row (PM 2–4) is also considered. Fig. 8 is a plot of the length of the deciduous premolar row against the length of the lower first molar. Again there appear to be two groups separated at the 36 : 15.5 co-ordinate. No specimen falls within the region of overlap between the two relevant 95% equal probability ellipses. The coefficient of difference between the length of the deciduous premolar row for the small and large groups (2.22) reveals a 2% degree of overlap between the two groups. The lengths of the first lower molar and deciduous premolar row are therefore held to distinguish between the mandibles of wild and domestic swine at Egolzwil 2.

The mortality frequencies of the wild and domestic swine from Egolzwil 2 are given in Table 13. They differ in a number of respects. The high proportion of mandibles belonging to stages 4 to 6 in the wild sample is absent in the domestic, and furthermore only 7% of the wild specimens belong to stages 10 to 13, while the corresponding domestic figure is 29.6%. The number of mature animals represented

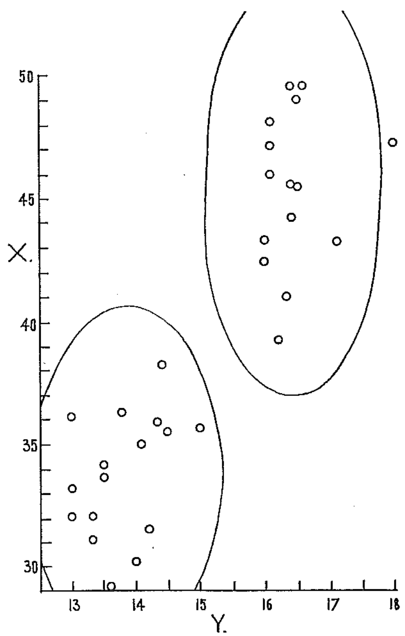

Fig. 7. Egolzwil 2: Scatter diagram of suid lower third and first molars from Egolzwil 2. X-axis, maximum length of lower third molar, Y-axis, maximum length of lower first molar.

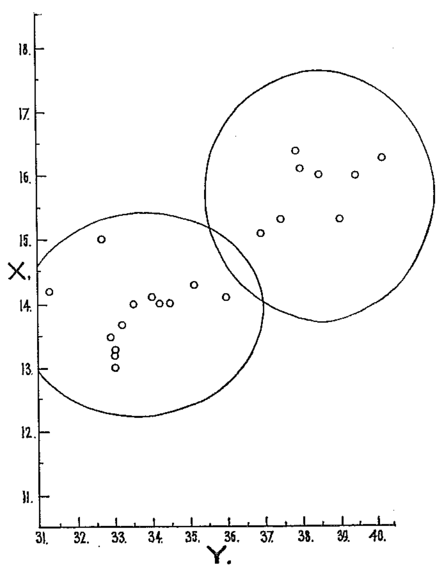

Fig. 8. Egolzwil 2: Scatter diagram of suid lower first molars and deciduous premolar row. X-axis, length of lower first molar, Y-axis, length of deciduous (PM 2—4) premolar row.

however, is similar in both groups. The mortality frequencies of the wild and domestic samples from Egolzwil 2 have been compared by means of the Kolmogorov-Smirnov test. The maximum cumulative percentage difference is 19.1 and the corresponding 5% probability level is 20.4. Therefore the observed differences between the wild and domestic mortality frequencies have no statistical significance. While there are no differences significant at the 1% level between the domestic swine mortality frequencies of Egolzwil 2 and those from other Younger Cortaillod culture domestic swine samples, the Egolzwil 2 wild swine mortality frequencies are significantly different at the 1% level from the domestic swine mortality frequencies of Egolzwil 4 and at the 5% level from those of Seematte Gelfingen.

All the three Cortaillod culture domestic swine mortality frequencies have dying peaks centred on stage 11 (Table 13). A further slightly larger rise in mortality characterises stages 17 to 20. The maximum cumulative percentage differences between the mean numbers of mandibles per age stage and the numbers of mandibles predicted on the basis of a random uniform distribution of mandibles per age stage have been compared by means of the Kolmogorov-Smirnov test, the maximum

Table 13. The suid mortality frequencies from some Swiss prehistoric settlement sites. (Percentage of mandibles per age stage)

Stage of dentition development	Approximate age (months)	Egolzwil 2 (domestic)	Egolzwil 2 (wild)	Seematte-Gelfingen	Arbon Bleiche	Zürich Alpenquai	Egolzwil 4
1	Foetal	0.0	0.0	0.0	0.0	0.0	0.0
2	Birth —1 week	0.0	0.8	0.0	0.0	0.0	0.0
3	1—4 weeks	0.0	0.8	0.0	0.0	0.0	0.9
4	4—7 weeks	0.0	2.5	0.0	0.0	0.0	0.9
5	2—4	0.0	6.6	4.8	0.0	1.5	5.6
6	4—5	0.0	4.9	0.0	0.0	2.2	5.6
7	5—6	1.4	1.6	0.0	0.0	0.7	0.0
8	6—7	0.0	0.0	0.0	0.0	2.2	0.0
9	7—8	0.0	1.6	6.5	0.0	1.8	6.0
10	8—9	12.7	1.6	9.7	1.5	1.8	5.1
11	9—10	9.9	1.6	17.8	3.1	4.4	11.1
12	10—11	4.2	2.5	4.8	0.0	2.9	1.8
13	11—12	2.8	0.8	1.6	1.5	1.5	0.0
14	12—14	0.0	0.0	1.6	1.0	8.7	0.0
15	14—15	1.4	2.5	1.6	1.0	0.7	3.7
16	15—16	1.4	9.0	4.8	2.5	0.0	0.0
17	16—17	12.7	10.6	9.7	1.5	7.2	5.6
18	17—18	5.6	8.2	9.7	13.9	6.5	9.3
19	19—21	0.0	4.9	3.2	38.5	6.5	5.6
20	21—23	16.9	1.6	8.1	7.7	12.3	7.4
21	23—25	0.0	0.8	0.0	1.5	6.5	1.8
22	25—27	1.4	1.6	0.0	4.6	6.5	9.3
23	27—29	1.4	2.5	3.2	6.3	5.8	0.0
24	30+	5.6	13.1	9.7	7.7	10.8	7.4
25	Adult	14.1	10.6	1.6	3.1	5.1	9.3
26	Late maturity	7.0	4.9	1.6	3.1	4.4	3.7
27	Senile	1.4	4.1	0.0	1.5	0.0	0.0
N		71	122	62	65	138	54

cumulative percentage differences for Egolzwil 2 and Seematte Gelfingen (34.9% and 25.9% respectively) being significant at the 1% level. The maximum cumulative percentage difference for Egolzwil 4 however (18%) is not significant at the 5% level. The similarities noted between the Egolzwil 2 and 4 and Seematte Gelfingen domestic swine mortality frequencies are held to demonstrate a uniformity in the approach to swine rearing in these sites of the Younger Cortaillod culture.

Conclusions

It has been possible to distinguish between both the mature and the immature mandibles of domestic and wild swine at Egolzwil 2. An analysis of the mandibles from the domesticated swine of all three Younger Cortaillod settlements reveals two recurrent rises in mortality among animals of 9 to 10, and 16 to 22 months of age.

The Caprovine Bones from Cortaillod Culture Settlements

Introduction

The analysis of the caprovine bones from Cortaillod culture settlements concentrates upon those from St. Aubin IV and Egolzwil 2. The former have been described by REVERDIN (1921) and the latter by HESCHELER and RÜEGER (1939). Exactly the same bones have been studied as were available to those three workers. Reference will also be made to two smaller samples from Seematte Gelfingen (HESCHELER and RÜEGER, op. cit.) and Egolzwil 4 (unpublished material). The essential preliminaries to a reconsideration of the caprovine bones from these settlements are to study the bones with the possible admixture of ibex or chamois in mind, and obtain an estimate of the ratio of sheep to goats.

The Basic Metrical Attributes

The lengths of the ibex bones from the Grotte de L'Observatoire (BOULE and VILLENEUVE, 1927) exceed the corresponding lengths in all Egolzwil 2 specimens with the exception of the metapodials (Table 14). The magnitude of the minimum diaphysial width of the metapodials from Egolzwil 2 rules out the presence of ibex at that site. None of the horn cores from the four Cortaillod culture sites derives from either the ibex or the chamois.

Table 14. The observed ranges of certain Pleistocene *Ibex*, and caprovine bone dimensions from Egolzwil 2

Bone length	*Ibex*	n	Egolzwil 2	n
Radius	190—253	77	141.4—152.0	6
Femur	220—281	34	178.0	1
Metacarpal	123—166	164	105.0—137.0	6
Metatarsal	138—178	162	111.0—131.1	2

As has been discussed, sheep may be distinguished from goats on the basis of the shape of the metacarpal and configuration of certain skull sutures (HIGHAM, 1968). The estimate of variability of the St. Aubin IV metacarpals on the basis of the ratio

Table 15. The value of the F-Ratio on comparing the estimates of variance for the St. Aubin and modern caprid metacarpals

Sample	N	$\overline{X}$	s	F Ratio
Capra hircus ♀	19	66.1 ±0.82	3.61 ±0.58	6.82**
St. Aubin pooled	39	72.8 ±1.50	9.42 ±1.07	

** Significant (P = 0.01)

of minimum anterior-posterior to minimum transverse diaphysial width is significantly greater than that for female goats (Table 15). This finding is held to suggest that the sample from St. Aubin may comprise the metacarpals of both sheep and goats: indeed visually there appear to be two groups of specimens in Fig. 9 which should on the basis of modern comparative material, reveal differences between sheep and goats. The major axes of the 95% equal probability ellipses have been calculated from the mean vectors and covariances of the two presumptive groups. No specimen falls within the region of overlap between the two ellipses, and it is concluded that the proportion of sheep to goats at that site is in the region of 1 : 1. This conclusion is supported by the morphology of the distal ends of the bones themselves.

All six measureable metacarpals from Egolzwil 2 appear to be derived from ovines, but on the basis of the skull fragments and horn cores, an uncommonly high number of which survive, the proportion of sheep to goats is 33 : 27. The population structures of sheep and goats at Egolzwil 2 and St. Aubin IV are statistically identical.

The high caprid fraction at these two sites poses the problem that different eruption dates for the second and fourth deciduous premolars and the first molar in modern sheep and goats have been demonstrated (SILVER, 1963). Because it is not at present possible to distinguish between sheep and goats on the basis of fragmentary mandibles and teeth, this situation rules out precise comparisons between the mortality frequencies from sites with a sizeable caprid admixture. Furthermore, the mortality frequencies of the Egolzwil 4 and Seematte Gelfingen caprovines are too small to permit the application of the large-sampled two-tailed Kolmogorov Smirnov test.

Nevertheless the high incidence of sheep or goats dying when under a year of age (at least 47.6% against 16.7% at Egolzwil 2 — Table 17) is noted. Over one fifth of the entire St. Aubin mandible sample is ascribed to stage 4, which is equivalent to approximately three months of age in sheep and six months of age in goats. It could be that the environmental conditions at St. Aubin were unfavourable for the survival of young caprovines irrespective of their sex. In this situation it would follow that the sex ratio of mature animals should be 1 : 1.

The modern comparative caprovine collection reveals a considerable degree of sexual dimorphism in the pelvis. Now the variability of the St. Aubin IV caprovine pelvis on the basis of the minimum width of the acetabular wall is statistically identical with that for pooled male and female goats (Table 16). It is significantly greater however, at the 1% level at least, than that for female goats. The same situa-

Table 17. The caprovine mortality frequencies from some Swiss prehistoric settlement sites. (Percentage of mandibles per age stage)

Stage of dentition development	Approximate age (months)	Egolzwil 2	Egolzwil 4	Seematte-Gelfingen	Arbon Bleiche	Zürich Alpenquai	St. Aubin	Zug Sumpf
1	Newly born	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	Birth-6 weeks	0.0	4.4	0.0	0.0	1.1	3.4	0.0
3	1½—3	1.1	0.0	7.4	0.9	0.0	3.4	0.0
4	3	7.8	6.7	11.1	2.0	2.2	21.1	7.8
5	4	1.1	8.9	7.4	1.2	1.1	8.8	0.0
6	5	1.1	4.4	3.7	1.2	2.9	3.4	0.0
7	5—7	5.6	3.7	0.0	1.2	4.0	7.5	0.0
8	7—9	13.4	3.0	3.7	0.9	4.0	7.5	0.0
9	9—10	4.5	8.9	0.0	3.9	9.7	2.7	11.6
10	10—11	4.5	0.0	0.0	1.2	2.9	2.7	0.0
11	11—12	1.1	2.2	0.0	3.0	3.4	0.7	0.0
12	12—21	6.7	8.9	3.7	5.3	16.0	6.1	19.2
13	21—24	12.2	2.2	18.5	35.3	11.5	9.6	11.4
14	25—26	3.3	8.9	11.1	8.8	2.9	0.7	11.6
15	26—28	1.1	8.9	5.7	21.0	7.4	2.7	0.0
16	Mature	5.6	20.0	7.4	8.8	16.0	0.7	23.0
17	Adult	22.0	4.4	11.1	5.3	14.3	17.0	15.4
18	Old	7.8	4.4	11.1	0.0	0.6	2.0	0.0
N		90	35	27	57	175	147	26

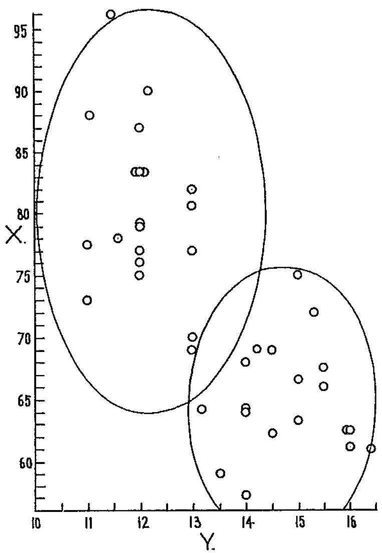

Fig. 9. St. Aubin: Scatter diagram of caprovine metacarpals. X-axis, ratio of minimum anterior-posterior to minimum transverse diaphysial width, Y-axis, minimum transverse diaphysial width.

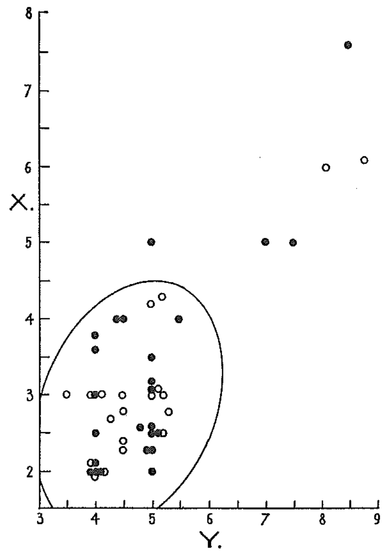

Fig. 10. St. Aubin and Egolzwil 2: Scatter diagram of caprovine pelvis. X-axis, minimum width of acetabular wall, Y-axis, minimum width of eminentia iliopectinea. Filled circles, St. Aubin, hollow circles, Egolzwil 2.

tion obtains for the variance of Egolzwil 2 caprovine pelvis. Visually, there appear to be two groups of pelvis at both St. Aubin and Egolzwil 2 (Fig. 10). In each case, the group with smaller sized bones comprises considerably more specimens than are to be found in the presumptive groups with larger sized bones. In the following discussion the "small group" will denote the smaller sized bones. The major axes of the 95% equal probability ellipse for the small group of St. Aubin pelvis include nearly all the specimens of the small group of Egolzwil 2 pelvis. Bones comprising the large groups however, fall outside the boundaries of that ellipse.

The small groups could comprise sheep and the large groups, goats. Yet it is known that the ratio of adult sheep to goats at both sites is in the region of 1 : 1, which is at variance with the ratios of approximately 1 : 10 for the two groups of adult pelvis. If the dimensions under consideration are sexually dimorphic, why are there not four groups of pelvis, representing male sheep, female sheep, male goats and female goats? On the basis of the available evidence it is admitted that this question cannot be answered unless it is assumed that sheep and goat pelvis of a given sex were similar in size, and that the two groups represent male sheep and goats and female sheep and goats respectively.

If this conclusion is accepted, the proportion of male to female pelvis at St. Aubin is 3 : 22, and at Egolzwil 2, 2: 18. If fragmentary pelvis with only one of the measurements used in Fig. 10 are included within the computation, the sex ratio at St. Aubin is 3: 29 (9.4% male), and at Egolzwil 2, 2: 21 (8.7% male). Since there are marked differences between the caprovine mortality frequencies of St. Aubin and Egolzwil 2 (Table 17), it is suggested that the mortality among young males, concentrated in stage 4 of the St. Aubin sample, was more evenly spread at Egolzwil 2. This same spreading of mortality appears to have been the case at Egolzwil 4 also.

Conclusions

Both at St. Aubin IV and Egolzwil 2, the ratio of sheep to goats was in the region of 1 : 1. Moreover the adult pelvis from both settlements indicate that the ratio of male to female specimens was approximately 1 : 10. The raising of young male sheep and goats for consumption when under 2 years of age is thus attested for both phases of the Cortaillod culture.

Michelsberg, Horgen and Corded Ware Bone Samples

The samples available for the Michelsberg, Horgen and Corded Ware cultures are too small for detailed statistical analysis. Recent excavations at Zürich (Ut.)* have yielded two Horgen and one Corded Ware culture level, while Zürich (Br.) comprises Michelsberg and Horgen occupation phases. In order to view the faunal remains from those two settlements in their wider perspective, samples from St. Aubin 111 (Horgen culture), Sipplingen (Horgen culture) and Eschner Lutzengüetle (Michelsberg and Horgen culture), although not part of the Zürich collections, will also be referred to.

* For a key to abbreviations for the Zürich sites, see Appendix 1, page 89.

Bovines predominated at Zürich (Br.) during the Michelsberg occupation. Numerically, swine were second in importance, while caprovines were extremely rare (Table 23). During the Michelsberg occupation phase at Eschner Lutzengüetle however, the relative importance of the domestic species was exactly reversed.

The faunal compositions of Sipplingen, Zürich (Ut.) and St. Aubin 111 are statistically identical, swine being predominant, followed by cattle, with sheep and goats only sporadically represented. Again however, the faunal spectrum of Eschner Lutzengüetle (Horgen) is the reverse of the other three sites.

Bovines again returned to dominance at Zürich (Ut.) during the Corded Ware occupation, and as at the Michelsberg settlement of the Zürich region, swine exceeded sheep and goats in numerical importance.

The Faunal Remains from Arbon Bleiche

Introduction

The fauna from Arbon Bleiche has been studied by KUHN and GÜLLER (1946). A re-examination, however, of the mandibles and teeth actually used in that study suggests that the number of animals represented is greater than that estimated by KUHN and GÜLLER (Table 18).

Table 18. Arbon Bleiche: Two estimates of the relative importance of each species represented by bone fragments

Species	% after KUHN and GÜLLER (1946)	% after HIGHAM
Bos taurus (domestic) L.	34.0 ±7.3	40.5 ±6.3
Sus scrofa (domestic) L.	26.5 ±6.8	27.5 ±5.7
Ovis aries or *Capra hircus* L.	15.2 ±5.3	24.0 ±5.4
Equus caballus L.	2.0	1.7
Canis familiaris L.	3.5	3.0
Cervus elaphus L.	1.5	1.3
Capreolus capreolus L.	0.5	0.4
Sus scrofa ferus L.	0.5	0.4
Ursus arctos L.	0.5	0.4
Castor fiber L.	0.5	0.4
Phalacrocorax carbo L.	0.5	0.4
Total number of individuals	173	237

The Bovines

The difference between the mean lengths of the Arbon Bleiche and presumptive Danish *Bos primigenius* lower third molars is significant at the 1% level at least, a finding which suggests that admixture of *Bos primigenius* in the bovine sample under consideration is unlikely. The limb bone sample is too small to allow accurate estimation of the sex ratio. There are however, sufficient mandibles and teeth to permit a study of the mortality frequencies. The differences between the observed number of mandibles per juvenile age stage and that predicted on the basis of a random uniform distribution of mandibles between age stages are significant at the 1% level at least; the greatest concentration of mortality at Arbon Bleiche being during age stages 18 to 21 inclusive (Table 1). The Arbon Bleiche mortality frequencies have also been compared with those from other sites (Table 2), and as may be seen, the greatest differences are those with samples from the Cortaillod culture; all being significant at the 1% level at least. On comparing the mortality frequencies of the Danish TRB culture sites with those of Arbon Bleiche however, none of the differences is significant. Thus whereas in the Cortaillod culture bovine economy a large proportion of animals died before they were a year of age, in the TRB culture bovine economy a large number of steers were maintained until they were at least three years of age (HIGHAM and MESSAGE, 1968). Clearly the similarity between the mortality frequencies of Arbon Bleiche and Troldebjerg suggests very strongly that male bovines were maintained until adulthood at the former site also.

If this view is accepted, then metacarpals no. 27 and 28 in Table 12, on account of their shortness and low distal width to length ratios, probably come from cows, while nos. 25, 26, 29 and 30 with their greater lengths and distal width to length ratios, are presumptively from steers. Furthermore, none of the F ratios derived from comparing the variabilities of the Arbon Bleiche bovine radius (distal width) and first fore phalanx (proximal width) with those of the corresponding dimensions of the Troldebjerg sample are significant.

It is concluded therefore, that despite the small sample size it is possible to demonstrate, on the basis of the mortality frequencies, that the Arbon Bleiche bovine economy represents a distinct break from that of the Younger Cortaillod culture. Furthermore, on the basis of the mortality frequencies and the variabilities of certain limb bone dimensions, the Arbon Bleiche bovine economy appears to have been similar to that of Troldebjerg. It is important, in the context of European Prehistory, to compare the Troldebjerg and Arbon Bleiche economies with that of the Corded Ware culture: this must await the collection of larger samples.

The Caprovines

There are insufficient limb bones to permit a reliable estimation of the ratio of sheep to goats.

The high caprovine mortality during age stages 13 to 15 is notable (Table 17), and on comparing the mortality frequencies with those from other prehistoric sites, it is apparent that, as with the bovines, the caprovine mortality frequencies are far more akin to those of the Danish TRB rather than to those of the Younger Cortaillod culture. Thus in both the Arbon Bleiche and Troldebjerg samples there is low mortality in the younger age groups and a concentration of deaths when the animals were close to, or had reached, maturity.

Due to the uncertainty of the species ratio at this site, no further conclusions have been drawn from the mortality frequencies except to emphasize the significant differences between those from Arbon Bleiche and those from sites of the Younger Cortaillod culture.

The Suids

As with the Egolzwil 2 suid sample the length and breadth of the lower third molars have been considered in an attempt to ascertain whether or not admixture with wild swine is in question. It is clear from Fig. 11 that at Arbon Bleiche the third lower molars fall into one group only and that no individual specimen approaches the size of lower third molars from wild swine.

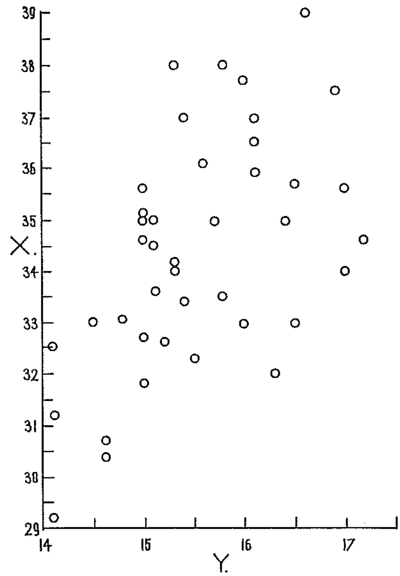

Fig. 11. Arbon Bleiche: Scatter diagram of suid lower third molars. X-axis, maximum length. Y-axis, maximum width.

The maximum cumulative difference between the observed number of mandibles per juvenile age stage and that predicted on the basis of a random uniform distribution of mandibles between the age stages (59.5%) is significant at the 1% level at least. The Arbon Bleiche suid mortality frequencies reveal a low mortality during stages 1 to 17, followed by a striking increase; indeed at Arbon Bleiche four out of every ten mandibles are ascribable to stage 19.

Conclusions

Although the bone sample from Arbon Bleiche is relatively small, the bovine economy has been shown to be distinctly different from that of the Cortaillod culture, in that a significant rise in mortality took place among animals of approximately three years of age. There is no apparent admixture of wild swine teeth at Arbon Bleiche, the majority of domesticated swine being killed when between 17 and 23 months of age.

The Domestic Animal Bones from Late Bronze Age Settlements

Introduction

The present study of the domestic animal bones from Zürich Alpenquai is based on exactly the same material as was analysed by WETTSTEIN (1924). The interpretation of these bones, particularly those from the bovines, is most difficult: indeed, Wettstein himself was able to draw only the most general of conclusions. The bones from Zug Sumpf comprise those found during the second excavation at this site (SPECK, 1954); the excavation produced but a small faunal sample, which will be referred to wherever feasible in the following analyses.

The Bovines: Basic Metrical Attributes

The bovine sample from Zürich Alpenquai includes both complete (n = 48), and incomplete (n = 44) specimens. With the exception of the Kalmyk steers and bulls, the variance of the maximum distal width of the pooled (i. e. n = 92) metacarpals is significantly greater, at the 1% level, than the corresponding estimates for modern, sexed bovine metacarpals from three distinct breeds (Aberdeen Angus, Kalmyk and Red Danish: vide Table 19). Despite this significantly greater variability, there appears to be no grouping of the material from Zürich Alpenquai on the basis of either the distal width or the distal diaphysial width of the pooled complete and incomplete metacarpals (Fig. 12), findings which are at variance with the situation in modern sexed bovines of Aberdeen Angus and Kalmyk breeds. The ratios of distal width to length and minimum diaphysial width to length for each of the complete metacarpals however, have also been considered. When plotted, the relationships between the maximum distal width and length and minimum diaphysial width and length seem to show that the 48 complete metacarpals fall into at least two, and possibly into three, distinct groups (Fig. 13).

Now, as can be seen from Fig. 13, one of those putative groups consists of but one specimen. Clearly, it might be argued that this particular bone is actually an outlier from the group of bones with distal width to length ratios of between 30 and 35 (subsequently named the large group). Yet this one specimen is significantly broader relative to its length than is any of the specimens comprising the large group. Moreover, its minimum diaphysial width to length ratio is significantly greater, at the 1% level at least, than that for any of the bones within the large group, and it falls outside both the 95% and the 99% equal probability ellipses calculated from the sample mean vectors and covariances of the large group (Fig. 13).

Consequently, this bone will be treated as comprising a separate group which will be referred to henceforth as the "robust" group.

It will be noted from Fig. 13 that there is no overlap between the 95% equiprobability ellipses calculated from the sample mean vectors and covariances for the large group and that with distal width to length ratios of under 30, henceforth these will be termed the large and the small groups respectively.

At the 1% level, the mean distal width of the metacarpals in the large group is significantly greater than that for the small group. The coefficient of difference between these means is 1.21, compared with values of 1.77 (Aberdeen Angus cows

Table 19. The values of the F-Ratio on comparing the estimates of variance of pooled Zürich Alpenquai and modern bovine metacarpals (maximum distal width)

Sample	N	$\bar{X}$	s	F Ratio on comparing with Zürich Alpenquai (pooled)
1. Zürich Alpenquai	92	53.3 ±0.50	4.87 ±0.36	—
2. Red Danish ♀	32	65.0 ±0.37	1.97 ±0.27	6.24**
3. Aberdeen Angus ♀	40	60.0 ±0.32	2.05 ±0.23	5.64**
4. Aberdeen Angus, steer	40	67.7 ±0.35	2.22 ±0.25	4.87**
5. Kalmyk ♀	59	59.7 ±0.38	2.99 ±0.27	2.66**
6. Kalmyk, steer	13	70.5 ±0.86	3.10 ±0.61	2.36
7. Kalmyk ♂	10	74.6 ±1.44	4.55 ±1.02	1.14

Significant (P = 0.01)

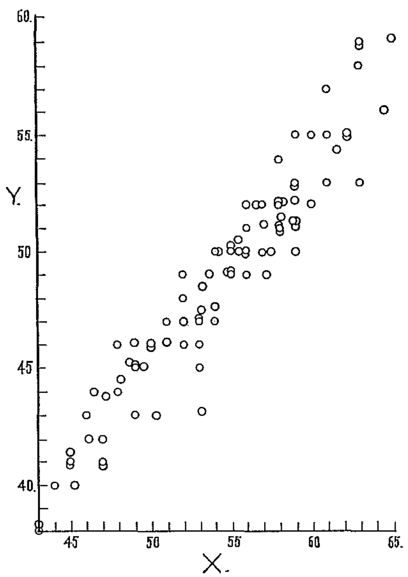

Fig. 12. Zürich Alpenquai: Scatter diagram of bovine metacarpals: Y-axis, maximum distal diaphysial width, X-axis, maximum distal width.

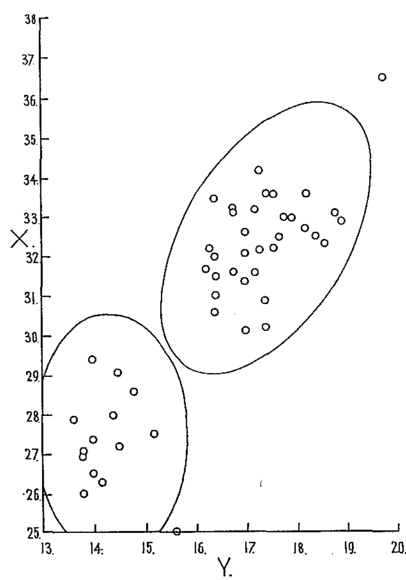

Fig. 13. Zürich Alpenquai: Scatter diagram of bovine metacarpals: X-axis, ratio of maximum distal width to length, Y-axis, ratio of minimum diaphysial width to length.

Table 20. Zürich Alpenquai: A comparison between the metrical attributes of two groups of bovine metacarpals

Dimension	Group	N	$\bar{X}$	s	Student's t	C.D.+	Corresponding for Kalmyk ♀/steer	C.D.+ ♀/♂
Maximum distal width	Large	32	56.9 ±0.69	3.96 ±0.49	7.46**	1.21	1.77	1.71
	Small	15	48.2 ±0.84	3.24 ±0.59				
Minimum diaphysial width	Large	32	30.5 ±0.38	2.18 ±0.27	9.09**	1.76	1.44	4.01
	Small	15	24.9 ±0.41	1.57 ±0.29				
Length	Large	32	176.1 ±1.52	7.27 ±1.07	0.57	0.09	0.77	0.05
	Small	15	177.6 ±2.19	8.18 ±1.53				
Ratio of maximum distal width: Length ×100	Large	32	32.0 ±0.18	1.04 ±0.13	12.78**	2.30	1.19	1.94
	Small	15	27.4 ±0.24	0.96 ±0.15				
Ratio of minimum diaphysial width: Length ×100	Large	32	17.2 ±0.12	0.67 ±0.08	12.62**	2.54	0.65	2.08
	Small	15	14.1 ±0.14	0.55 ±0.10				

+ = Coefficient of difference ** Significant (P = 0.01)

and steers) and 1.71 (Kalmyk cows and bulls) in modern, sexed bovines (Table 20).

The estimated variance of the distal width of the metacarpals comprising the large group is significantly greater, at the 1% level, than that of the corresponding measurements of the metacarpal in both Aberdeen Angus cows and steers. However, this variance is statistically identical with those for Kalmyk cows, steers and bulls. No estimate of the variance of the maximum distal width of the metacarpals from modern, sexed bovines is significantly different, at the 1% level, from that of the small group from Zürich Alpenquai (Table 19).

The mean minimum diaphysial width of the metacarpals in the large group is significantly greater, at the 1% level, than the corresponding mean for the small group, while the coefficient of difference between these means reveals a 5% degree of overlap (Table 20).

The variabilities of the minimum diaphysial width of the metacarpals comprising the large and the small groups are statistically identical and furthermore, that of the small group is statistically identical with those from Kalmyk bulls, cows and steers, and Red Danish cows. The variability of the minimum diaphysial width of Kalmyk bulls' and cows' metacarpals, however, is significantly greater, at the 1% level, than the corresponding variability for the large group from Zürich Alpenquai (Table 2).

The mean lengths of the metacarpals comprising the large and small groups at

Table 21. The values of the F-Ratio on comparing the estimates of variance for Zürich Alpenquai and modern bovine metacarpals

Sample	1.	2.	3.	4.	5.	6.	
1. Zürich Alpenquai large	—	1.93	4.42**	1.87	2.23**	1.60	
2. Zürich Alpenquai small	1.26	—	2.27	1.06	1.15	1.20	Upper right: minimum diaphysial width
3. Kalmyk ♂	1.74	1.36	—	2.34	1.89	2.74	Bottom left: maximum length
4. Kalmyk, steer	1.82	1.59	1.15	—	1.19	1.39	
5. Kalmyk ♀	1.38	1.09	1.26	1.46	—	1.39	
6. Red Danish ♀	1.29	1.64	2.23	2.61	1.78	—	

Sample	1.	2.	3.	4.	5.	6.	
1. Zürich Alpenquai large	—	1.50	1.42	2.57**	4.44**	4.35**	
2. Zürich Alpenquai small		—	2.13	3.86*	6.66**	4.66**	Ratio of minimum diaphysial width to length ×100
3. Red Danish ♀			—	1.83	3.16*	3.06**	
4. Kalmyk ♀				—	1.73	1.61	
5. Kalmyk, steer					—	1.02	
6. Kalmyk ♂						—	

Sample	1.	2.	3.	4.	5.	6.	7.	8.
1. Zürich Alpenquai large	—	1.49	4.04**	3.73**	3.18**	1.75	1.32	1.11
2. Zürich Alpenquai small	1.17	—	2.70*	2.50*	2.13	1.17	1.97	1.34
3. Red Danish ♀	1.17	1.13	—	1.08	1.27	2.31**	4.33**	3.63**
4. Aberdeen Angus ♀	N.A.	N.A.	N.A.	—	1.17	2.13**	4.93**	3.38**
5. Aberdeen Angus ♂	N.A.	N.A.	N.A.	N.A.	—	1.81	4.19**	2.86*
6. Kalmyk ♀	1.39	1.63	1.77	N.A.	N.A.	—	2.31*	1.57
7. Kalmyk ♂	3.00*	3.52*	3.81**	N.A.	N.A.	2.14	—	1.46
8. Kalmyk, steer	1.56	1.83	1.98	N.A.	N.A.	1.12	1.92	—

Lower left: Ratio of maximum distal width to length X 100
Upper right: maximum distal width

N.A. = not applicable * = Significant (P = 0.05) ** = Significant (P = 0.01)

Zürich Alpenquai are statistically identical. Moreover, the estimated variability of the lengths of the metacarpals in both large and small groups are not only statistically identical with each other, but also with the corresponding estimates derived from modern, sexually homogeneous material (Table 21).

As may be seen from Table 20, the mean ratios of distal width to length derived from the large and small groups are significantly different at the 1% level, the resultant coefficient of difference being 2.30, compared with 1.94 for Kalmyk cows and bulls. The variances of the distal width to length ratios of the large and small groups are either statistically identical with, or significantly smaller at the 5% level, than the corresponding variability for sexually homogeneous modern material.

The difference between the mean values for the minimum diaphysial width to length ratio of the large and the small groups of metacarpals is significant at the 1% level, while the coefficient of difference is 2.54, compared with 2.08 for Kalmyk cows and bulls. The estimate of the variability of this index in the small group from Zürich Alpenquai differs at the 5% level, from that for Kalmyk cows' metacarpals, while its variability for the large group is smaller at the 1% level than in Kalmyk bulls and steers, and Red Danish cows (Table 21).

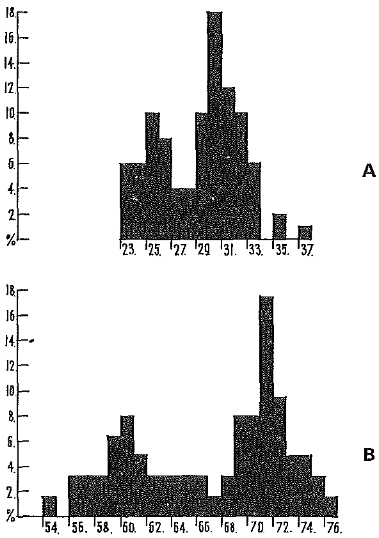

Fig. 14. Zürich Alpenquai: Histograms of bovine radii and metacarpals: A, minimum diaphysial width of metacarpal, B maximum distal width of radius. Dimensions in millimetres.

Fig. 14 shows a histogram of the minimum diaphysial width of the complete bovine metacarpals from Zürich Alpenquai. Its appearance is compatible with the presence of two groups of bones, but with a certain degree of overlap between groups.

The appearance of the frequency histogram of the distal width of the Zürich Alpenquai bovine radii (Fig. 14) is also held to indicate that two groups of bones are present. Clearly, in a histogram of this nature, it is impossible to obtain an accurate estimate of the variability of the two presumptive groups. If however, the two peaks at 59 mm and 70 mm represent the means for the two groups, and the ranges 54 to 59 mm and 70 to 76 mm are taken as approximately half the actual ranges of these groups, then by assigning specimens in the region of overlap at random to one or other group, a fair approximation to variabilities of the two groups may be obtained. The estimates derived in this way do not differ from that for Red Danish cows. The ratio of large to small radii which results from that procedure is very similar to the ratio of large to small metacarpals (11 : 6 against 11 : 5). The evidence from the radii therefore, is compatible with the interpretation that the bovine remains from Zürich Alpenquai fall into at least two groups.

The bovine mortality frequencies from this site indicate that approximately 70% of the bovines represented were at least 24 months old at death (Table 1). This figure accords with the finding that 78% of the metacarpals from Zürich Alpenquai possess fully fused distal epiphyses. By analogy with the modern bovine, it appears fair to assume that animals over two years of age played an important role in the bovine economy at Zürich Alpenquai. However, any evaluation of that role will turn on the reasons for the existence of three groups of metacarpals.

Discussion

Manifestly the presence of three groups of bovine bones at Zürich Alpenquai might be explained in terms of sex, breed and plane of nutrition, or any combination of these factors. Although the nature of the material at hand precludes any definite conclusion, the availability of extensive modern comparative material does permit possible explanations for the presence there of these groups to be placed in order of plausibility.

In the discussion of the Egolzwil 2 bovines it was pointed out that a breed of large bovines inhabited the Alpine Foreland during the sub-boreal period, and there is unanimous agreement that the bovine in question was *Bos primigenius*. A priori some, at least, of the larger bovine bones from Zürich Alpenquai might be derived from this species. The ranges of the four dimensions measured on the Zürich Alpenquai bovine metacarpals show no overlap with the observed ranges of the corresponding dimensions from Danish, presumptive female *Bos primigenius* (Table 12). Moreover, the value of Student's t on comparing the mean length of the lower third molars of the Zürich Alpenquai bovines and those from Danish *Bos primigenius* is highly significant ($t = 28.67$, $n = 110$). Thus the presence of three groups of bovine bones at Zürich Alpenquai is extremely unlikely to be the result of the admixture of the bones of domesticated bovines and *Bos primigenius*.

The possibility that the observed grouping of the metacarpals results from the admixture of two breeds of domesticated bovines, is underlined by the discovery of bovine mandibles from nearly all juvenile age groups; a finding held to indicate that cattle raising did take place at Zürich Alpenquai. Moreover, if there were two breeds of bovines present at that site, then it is reasonable to assume that males and females of both breeds were maintained.

It has been demonstrated that the breadth dimensions and breadth to length ratios of metacarpals in the modern bovine are sexually dimorphic. HOWARD (1962) has claimed similar characteristics for *Bos primigenius* metacarpals, the bones with the smaller breadth dimensions and the lower breadth to length ratios belonging to the female and, conversely, those with the greater breadth dimensions and the higher breadth to length ratios belonging to the male. It would seem highly probable therefore, that prehistoric domestic bovine metacarpals were also sexually dimorphic; in the following discussion this view will be adopted.

Since metacarpals from male and female bovines of the same breed should fall into two distinct groups, the admixture of male and female metacarpals from two breeds of different sizes should result in there being four groups of bones if the two breeds were markedly different in size, and three groups if there was a high degree of overlap in size between the males of one breed and the females of the other. In considering the Zürich Alpenquai metacarpals with the presence of two breeds in mind therefore, most attention will be directed towards the large group, where such an overlap might exist.

Now if the bones in the small group represent female bovines corresponding to males in the large group, the relationship between certain statistical characteristics for both groups are, in the light of modern control samples, predictable. For example, the mean distal widths and minimum diaphysial widths for the two groups should be significantly different from each other, and since the mean lengths for each group should be statistically identical, the mean distal width to length and minimum diaphysial width to length ratios should also be significantly different. Furthermore, the variance of each dimensional ratio should be statistically identical with the corresponding estimate for the other group, and the coefficients of difference between certain dimensions should be similar with those for corresponding dimensions in the modern bovine.

As may be seen in Tables 20 and 21 each of these situations obtains for the large and small groups of metacarpals at Zürich Alpenquai. Thus the metrical attributes of metacarpals comprising the large and small groups convincingly support the hypothesis that they are derived from male and female bovines respectively. What, however, of the origin of the metacarpal comprising the robust group?

A possible answer to that question is that the robust metacarpal comes from the male of a second breed of domestic bovines with the equivalent females "hidden" in the so-called "large group". Now both the mean distal width to length and minimum diaphysial width to length ratios for the metacarpals comprising the large group are significantly smaller, at the 1% level, than the corresponding ratios for the robust specimen. This supports the preceding hypothesis. Nevertheless, the mean minimum distal width of the specimens in the large group is statistically identical with the distal width of the robust specimen: yet this dimension reveals considerable sexual dimorphism in both Kalmyk and Aberdeen Angus bovines. Furthermore, the mean distal width to length ratio from the large group metacarpals is consistently higher than any corresponding mean in modern female metacarpal samples (Table 22), and the frequency distributions of the specimens comprising the large group, on the basis of not only linear dimensions but also breadth to length ratios, are not significantly different from normal, or Gaussian, distributions.

It is improbable therefore, that the robust specimen and the large group metacarpals, in whole or in part, represent males and females of the same breed, respectively. In subsequent discussions, this view will be adopted.

So far this discussion has not taken into account ZALKIN'S (1962) assertion that

Table 22. Zürich Alpenquai: A comparison between the metrical attributes of certain bovine metacarpals

Dimension	Group	N	$\bar{X}$	s	Student's t
Maximum distal width	Large	32	56.9 ±0.69	3.96 ±0.49	1.86
	Robust	1	65.0	—	
Minimum diaphysial width	Large	32	30.5 ±0.38	2.18 ±0.27	2.15*
	Robust	1	35.3	—	
Ratio of maximum distal width: length ×100	Large	32	32.0 ±0.18	1.04 ±0.13	4.24**
	Robust	1	36.5	—	
Ratio of minimum diaphysial width: length ×100	Large	32	17.2 ±0.12	0.67 ±0.08	4.10**
	Robust	1	19.8	—	

* = Significant (P = 0.05) ** = Significant (P = 0.01)

castration affects the shape of bovine metacarpals. In the Kalmyk sample, the mean length for steer's metacarpals is significantly greater than for bull's, with the result that the breadth to length ratio for Kalmyk steer's metacarpals is significantly smaller than for Kalmyk bull's.

Whereas the mean length of the metacarpal in Kalmyk steers is significantly greater than it is in Kalmyk cows, the mean lengths for cows and bulls are statistically identical. According to ZALKIN (1962) the greater length of steer's metacarpals results from the delaying of epiphysial closure by castration. If it is assumed, for the moment at least, that the large group represents male bovines of the same breed as the female metacarpals in the small group, it should be possible to decide whether or not bovines at Zürich Alpenquai were castrated, and if they were, whether this took place before or after the age at which metacarpal epiphyses close. Thus, if by analogy with modern bovines, castration were to be delayed until just before, during or after epiphysial closure (i. e. circa 24 months after birth), then the mean length of steer's metacarpals would be indistinguishable from those of either bulls or cows of the same breed. It is clear from Table 20 that the mean lengths of both large and small group metacarpals are statistically identical. One interpretation of this result is that the large group comprises either bulls and/or late castrated males, while the small group comprises cows alone. This interpretation would, of course, still leave the robust specimen uninterpreted.

SILVER (p. c.) however, has suggested that late (i. e. post 24 month) castration would result in not only the breadth of the articulating surfaces of steer's and bull's metacarpals being similar, but also in the minimum diaphysial width of steer's metacarpals being absolutely slimmer than in bull's. As may be seen from Table 22, the minimum diaphysial width of the robust specimen is significantly broader, at the 5% level, than the corresponding mean for the large group, while the maximum distal widths of the robust specimen and the large group are statistically identical. It is asserted therefore, that the large and small groups at Zürich Alpenquai could represent steers and cows respectively, while the robust specimen could be derived from a bull of the same breed.

Another explanation which might be advocated to account for the presence of three groups of bovine metacarpals at Zürich Alpenquai is that the animals there were raised on different planes of nutrition. Thus, the robust specimen could represent a bull, with the large and small groups representing cows of the same breed, but raised on differing nutritional regimes.

By analogy with the situation today (GUTERSOHN, 1958), at least three contemporary micro-environments would have existed within the immediate vicinity of Zürich Alpenquai: lakeshore reed swamp, airy mixed oak forest with a well developed herbaceous undergrowth, and dense beech and silver fir forest on slopes over 600 metres above sea level. To these must be added pastureland established where natural tree cover had been cleared. Selected bovines might have been raised in open grassy glades within the mixed oak forest, while others were maintained exclusively on the more nutritious pastureland.

Alternatively, transhumance to the high alps with selected animals might have occurred. Yet the closest areas for potential alpine grazing are on the Kaiserstock, which is 120 km distant via the Sihl-Lauerzersee-Altdorf route, or the Gufelstock and Vordere Glärnisch flanking Glarus, which is the further from Zürich, but of easier access via the Linth and Zürichsee. Clearly, the practice of such transhumance cannot be ruled out on any known a priori grounds, but the distances to those areas above the tree line, and the hazardous terrain to be crossed, are held to render this possibility unlikely.

Moreover, were either transhumance to the Alps, or the raising of selected bovines on preferable pastureland undertaken, the necessary period of winter feeding would have tended to equalise the differential effect of summer feeding. Therefore, the presence of animals raised on different planes of nutrition at Zürich Alpenquai is considered to be unlikely.

The Bovines: Conclusions

Of the potential reasons for the presence of three groups of bovine metacarpals at Zürich Alpenquai, the bones themselves present metrical features consistent with the view that they represent cows, steers and bulls. In this case the ratio of cows to steers becomes 15 : 32; this ratio differs at the 5% level, from the expected ratio of 1 : 1.

The Caprovines: Basic Metrical Attributes

A consideration of modern sheep and goats revealed a 6% degree of overlap between the two species on the basis of the ratio of the minimum anterior- posterior to minimum transverse diaphysial width* of the metacarpals. Nevertheless, if the bones falling within the potential region of overlap between sheep and goat metacarpals have complete distal ends, their morphology permits one to determine the species origin of individual bones with a high degree of probability of being correct.

* Hereafter abbreviated as MAP/MTW.

Figure 15, which is a plot of the ratio of MAP/MTW against the minimum transverse width of caprovine metacarpals from Zürich Alpenquai, reveals a marked concentration of specimens between 70.0 and 80.0 on the X (ratio) axis, and two specimens with values of under 65.0 for the ratio in question.

Now twenty of the Zürich Alpenquai metacarpals in Fig. 15 possess complete or almost complete distal ends, of which only the specimen with a MAP/MTW ratio of 60.0 appears, morphologically, to be caprid in origin. The remainder, in terms of both the ratio in question and the shape of the distal end, appear more likely to be ovine. The major and minor axes of 95% and 99% equiprobability ellipses have been calculated for the 19 presumptive ovine specimens; from Fig. 15, it is clear that the great majority of specimens lie within the 95% ellipse. Moreover, with the exception of the bone on the 86 : 14 co-ordinate, which appears to be from an ovine on the basis of its MAP/MTW ratio, only the known caprid specimen falls outside the boundary of the 99% ellipse. There remain four specimens (A, B, C and D in Fig. 15) which lie between the 95% and 99% ellipses. On the basis of not only the MAP/MTW ratio, but also the morphology of the distal end, complete specimen A is undoubtedly ovine in origin, while incomplete specimen B also appears to be

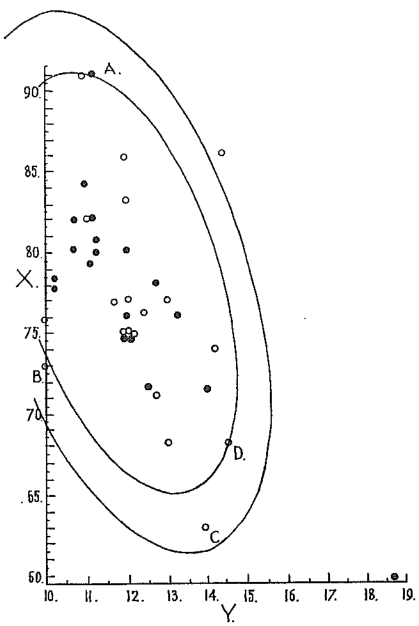

Fig. 15. Zürich Alpenquai: Scatter diagram of caprovine metacarpals. X-axis, ratio of minimum anterior-posterior to minimum transverse diaphysial width, Y-axis, minimum transverse diaphysial width. Filled circles, fragments with complete distal ends, hollow circles, diaphysial fragments without distal ends attached.

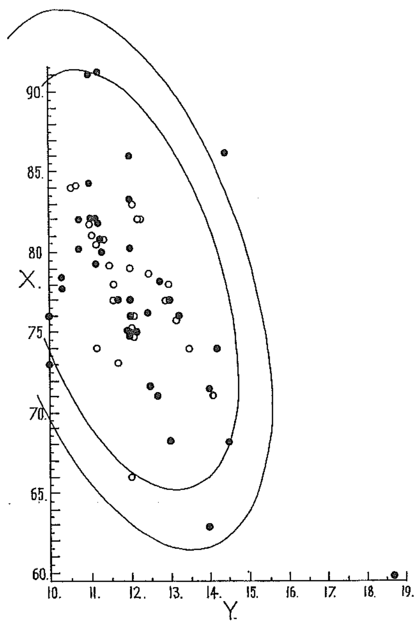

Fig. 16. Zürich Alpenquai and Zug Sumpf: Scatter diagram of caprovine metacarpals. X-axis, ratio of minimum anterior-posterior to minimum transverse diaphysial width. Y-axis, minimum transverse diaphysial width. Filled circles, Zürich Alpenquai, hollow circles, Zug Sumpf.

ovine, because of the high value of its MAP/MTW ratio. The remaining two specimens (C and D), both of which are fragmentary, cannot be ascribed with certainty either to a caprid or to an ovine origin. Nevertheless, even if both were assumed to be caprid, the ratio of sheep to goat metacarpals from Zürich Alpenquai would still be at least 11 : 1.

In Fig. 16, caprovine metacarpals from Zug Sumpf and Zürich Alpenquai are combined. As may be seen from that figure, all but one specimen from Zug Sumpf lie within the 95% equal probability ellipse calculated for the 19 complete and presumptively ovine specimens from Zürich Alpenquai. The six specimens with complete distal ends from Zug Sumpf all appear to be ovine in origin, but the fragmentary bone with a MAP/MTW ratio of 66.0 could be derived either from a sheep or a goat. Nevertheless, even if it is assumed to be caprid, the ratio of sheep to goats would still be as high as 20 : 1.

When one studies the caprovine pelvis, one is faced not only with the problem of species, but also that of sexual dimorphism. If breeding of sheep and goats took place at Zürich Alpenquai, then there should be at least four types of pelvis, viz. male and female sheep and male and female goats.

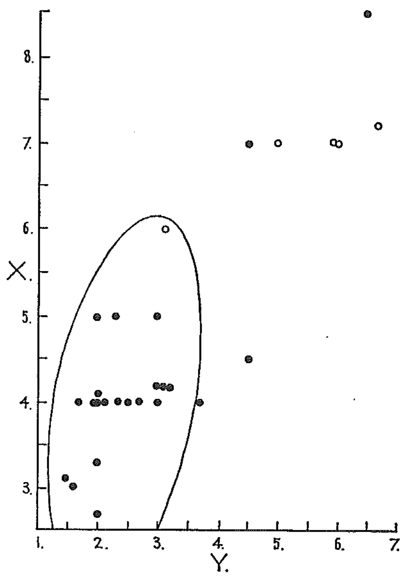

Fig. 17. Zürich Alpenquai: Scatter diagram of caprovine pelvis. X-axis, minimum width of eminentia iliopectinea, Y-axis, minimum width of acetabular wall. Hollow circles depict specimens in the process of epiphysial fusion.

The variance of the minimum width of the acetabular wall for the pooled Zürich Alpenquai caprovine pelvis is significantly greater, at the 1% level at least, than that for modern female caprids (Table 16). Moreover visually, the distributions of the minimum width of the eminentia iliopectinea and of the acetabular wall taken from the Zürich Alpenquai specimens appear to be bi-modal (Fig. 17), the two presumptive groups hereafter being called "large" (i. e. the larger bones) and "small". There are insufficient specimens in the former putative group to warrant the calculation of control ellipses. Nevertheless, those specimens fall outside the boundary of the 95% ellipse calculated for the small group.

The measurements under consideration reveal considerable quantitative sexual dimorphism in both modern sheep and modern goats. It might therefore be argued that the large group represents male, and the small group female, caprovines, But at least three, possibly four, groups of pelvis may be expected. In the former situation it would be assumed that female pelvis of one species overlapped in size the male pelvis of the other species, and in the latter, that the dimensions in question reveal absolute sexual and specific dimorphism.

Clearly in considering the caprovine pelvis of Zürich Alpenquai, either there was no sexual, or no specific, dimorphism. As LEMPPENAU (1964) has shown, however, sexual dimorphism in the region of the acetabular wall is a recurrent feature in the pelvis of ibex, roedeer, chamois and other small ruminants, while such dimorphism has also been noted in the modern sheep and goat. It would appear therefore, that the absence of any such dimorphism at Zürich Alpenquai is most unlikely. Such a finding of course, has the necessary corollary that either there was no species dimorphism at Zürich Alpenquai, or the pelvis of one species were considerably more numerous than the pelvis of the other. It is not at present possible to distinguish sheep from goats on the basis of the morphology of the acetabulum. Nevertheless, the extremely high ratio of sheep to goat metacarpals (11 : 1 at least) suggests that admixture of caprid pelvis in Fig. 17 is slight, and that the two groups reflect the presence of male and female sheep.

In over half the presumptive male pelvis, the iliac, pubic and ischial bones have not fully closed; the corresponding figure for female specimens being only 5%. While a third of all caprovine mandibles from Zürich Alpenquai are from mature animals, 31% come from animals under a year old at death, and 28% from animals between one and two years of age at death. Thus there appears to have been steady mortality among immature animals most of which, on the basis of the pelvis, were males.

The Suids

The observed range of the length of lower third suid molars does not overlap that for presumptively wild suid lower third molars from Holmegaard. The difference between the observed number of mandibles per age stage and that predicted on the basis of a random uniform distribution of mandibles between the age stages is significant at the 1% level. It is notable that only the mortality frequencies of Seematte Gelfingen differ significantly at the 1% level from those under discussion (Table 13). Thus at Zürich Alpenquai as at most sites, there appears to have been low mortality during immaturity, with a concentration of dying between stages 19 and adulthood.

The Faunal Spectra of Prehistoric Swiss Settlements

Much of the interpretation of prehistoric stock rearing attitudes turns upon the evaluation of the relative frequencies with which each of the domesticated species occurred at a given prehistoric settlement (Table 23). In order to decide whether or not any given species was particularly favoured, the number of individuals for each species has been compared with that expected on the basis of a uniform distribution of all individuals among the four main domestic species.

CLARK (1947) suggested that there was a progressive increase in the relative numerical importance of sheep at the expense of swine during the prehistoric period in Switzerland. The validity of this assertion has been further assessed in the light of the present material, the basis for comparison being the X^2 test.

Egolzwil 3 has provided the earliest Neolithic faunal sample from Switzerland, and indeed the only faunal sample yet available for the Egolzwil culture. The predominance of caprovines and extreme rarity of domestic bovines at that site contrasts sharply with the situation at the Older Cortaillod settlement of St. Aubin, where cattle, sheep, swine and goats occur in statistically identical numbers (HIGHAM, 1967d).

A decline in the frequency of sheep and goats relative to swine and cattle had taken place by the Younger Cortaillod culture's occupation of Egolzwil 2: the value of X^2 obtained on comparing the actual and mean numbers of individuals per species being significant ($P = 0.01$). Caprovines accounted for 45% of all domestic animals (excluding the dog) at St. Aubin, but for only 20% to 30% at the Younger Cortaillod settlements which have been examined. Domestic cattle predominated at Egolzwil 2, Seematte Gelfingen and Burgäschisee Süd-West, while at Egolzwil 4, the predominant domestic animal was the pig. The decline in the relative importance of sheep from Older to Younger Cortaillod settlements should not however be stressed: sheep remained as numerous as swine at both St. Aubin and Egolzwil 2.

It has not been possible to estimate the ratio of sheep to goats at the Early Bronze Age site of Arbon Bleiche. Cattle, swine and caprovines however, were present in statistically identical numbers.

Whereas the number of individual sheep, cattle and swine evidenced by the Zürich Alpenquai bone sample are statistically identical, sheep are significantly more abundant than swine or cattle at the culturally related site of Zug Sumpf: the goat is rare in both samples. It has been possible to estimate the ratio of sheep to swine in the samples from St. Aubin, Egolzwil 2, Zürich Alpenquai and Zug Sumpf. These species occur in statistically identical proportions in all samples except Zug Sumpf, where there was a significant predominance of sheep.

On the basis of the four species under consideration, the population structure of St. Aubin is significantly different from those of Egolzwil 2, Zürich Alpenquai and Zug Sumpf. The difference between St. Aubin and Egolzwil 2 may be ascribed to the decline in the frequencies of both the sheep and the goat at the latter site, while the difference between St. Aubin and the Late Bronze Age settlements results from the decline in the frequency of goats and the rise in the importance of sheep at the later sites. The structure of the population of sheep and swine at St. Aubin is statistically identical with those for Egolzwil 2 and Zürich Alpenquai. On comparing the numbers of sheep and swine from Egolzwil 2 and Zürich Alpenquai however, the value of X^2 is significant ($P = 0.05$). There are significantly more sheep than swine at Zug Sumpf than at Egolzwil 2, St. Aubin or Zürich Alpenquai.

Although the four major species are represented at all sites under review, their relative frequencies indicate that with considerable justification, the peasants of the

Egolzwil culture may be viewed as being primarily concerned with caprovines, of the Horgen culture with swine, and of the Michelsberg and Corded Ware cultures with cattle husbandry. Nevertheless, despite these culture-specific attitudes, some prehistoric cultures of the Alpine Foreland, notably the Cortaillod, the Hallstatt at Zürich Alpenquai, and the Early Bronze Age at Arbon Bleiche, showed no predilection for the husbandry of any one of the four major domestic species.

Discussion

During the Sub-Boreal period, the Western Alpine Foreland was occupied by seven successive prehistoric cultures, each being defined by distinctive artifact assemblages, and exhibiting a trend towards greater technological ability. As part of their total settlement pattern however, each of those cultures occupied what was, in all essentials, an identical physical and vegetational environment. Consequently, it is possible to consider changes in both agriculture and stock rearing during the prehistoric period, without the need to invoke environmental change as a formative influence.

The environmental diversity of the Alpine Foreland only serves to emphasize the choice of one particular micro-environment for settlement by all seven prehistoric cultures under consideration. As GUTERSOHN (1958) has shown, the natural vegetation on the Alpine Foreland relates to altitude and aspect. On southward facing slopes, the mixed oak forest flourishes up to 600 metres above sea level, where it gives way to beech. Silver Fir intrudes into beech woods in increasing quantities above the 900 metre contour, while pine and spruce dominate above 1200 metres. Even those trees become stunted with altitude, and the highest parts of the Jura are above the tree line. On northward facing slopes, native vegetation zones are located at considerably lower altitudes, and Mixed Oak Forest may be absent.

Now TROELS-SMITH (1960) has demonstrated that the Sub-Boreal climate was no colder than at present. On the basis of the relevant pollen spectra therefore, it is reasonable to assert that similar vegetation zones existed during the occupation periods of the settlements under review.

In settling southward facing margins of lowland piedmont lakes, the prehistoric farmers in question were better able to exploit the most beneficial characteristics of the region as a whole. The local soils of lacustrine origin were fertile and easily worked. The ameliorating effect of large bodies of water upon the climate, and the relatively low altitude of the settlements would have lengthened the growing season for crops. Mixed oak forest, which in distinction to the higher beach and fir forests, supports a luxuriant herbaceous undergrowth, would have provided fodder necessary for the over-wintering of domestic stock, while the water plants and rushes of the immediate border of the lake would have supplied vital sources of additional fodder during the early spring. The lake shore too, would then as now have attracted wildlife, and encouraged fishing and fowling.

Although the same natural vegetation cover existed at all sites, the effect exercised on the environment by different cultures differed markedly. The Egolzwil, Cortaillod and Michelsberg culture farmers cleared forest by means of the flint axe and fire, and established small cereal fields (WELTEN 1954, TROELS-SMITH 1954). They did not however, create open pasture land. The Early and Late Bronze Age cultures on the other hand, not only cleared an increased area of forest, but also established progressively greater areas of pasture (LÜDI, 1954). The varying intensity of forest clearance is basic to a consideration of the stock rearing of the seven societies under consideration, for forest imposes serious limiting factors on the amount of stock which may be maintained.

As HIGGS (1967) has noted, bovines prefer grassland to sylvan conditions. Although surviving in the forested environment of post glacial Europe, *Bos primigenius*, the wild progenitor of domestic cattle, declined in size (LEHMANN, 1949). Moreover DEGERBØL (pers. comm.) has suggested that wild herds disappeared from the heavily wooded islands of Denmark early in the post-glacial period, but survived in the more open conditions of Jutland.

The principal obstacle to rearing bovines during the prehistoric period on the Alpine Foreland would have been the all-pervading forest. During the winter "hungry gap", bovines would have found little natural fodder even in the Mixed Oak Forest, and consequently the collection of plants, leaves and wasteland hay would have been necessary during the summer months. That practice persists in marginal forested areas of Finland (MEAD, 1953), while the importance of sown grasses to keep cattle through the winter in Switzerland today reflects the relative harshness of winters on the elevated Alpine Foreland. In the prehistoric period, therefore, the head of cattle maintained in summer would have been directly related to the number which could be overwintered.

Sheep, being a smaller species than cattle and needing less winter fodder, do not present the same over-wintering problems. Flocks survive winter with little trouble on the Alpine Foreland today, and are even known to dig through snow to gain access to herbage beneath. Yet the sheep by nature is a grazer, and an exotic to forest. Between 2 to 5 acres of pastureland are necessary to support one sheep in the Scottish Hills. Therefore dense woodland, in offering only minimal grazing, would have severely limited flock size. The goat, although a browser, would also have been poorly adapted to a low-lying forested habitat. While exposed and rocky slopes behind Swiss settlements may have been browsed by goats, any increase in the area under pasture rather than forest would have encouraged the proliferation of sheep.

Of all four major domestic species, swine were, and remain, most at home in the natural woodland environment of the Alpine Foreland. Both the acorns of the mixed oak forest and beechmast of the higher hillslopes were most beneficial to swine rearing. Indeed, the scale of human demand, in addition to disease and other natural losses, may well have been a factor in determining the limits on the number of swine maintained.

While all animals would have supplied meat and hides, each species had particular economic attributes. Cattle would have also provided milk and potential traction. Sheep could have been reared for wool and milk. Goats are normally better milkers than sheep, while the particular qualities of swine lie in a high birth rate and rapid fattening qualities. Consequently swine herds could have been much reduced in times of unexpected death without prejudicing subsequent herd regeneration. Because swine, sheep and cattle do not compete for grazing land, the proliferation of one species need not be accompanied by a decline in another. Sheep and goats however, are often herded together, and although the latter eats a wider range of plants as well as young trees, competition for food between the species would occur in marginal areas. Therefore a selection in favour of either one could well be accompanied by a decline in the other.

Clearly, a detailed consideration of a particular culture's economy can only be undertaken when both pollen spectra and large samples of animal bones are available. These conditions are fulfilled only for the Cortaillod, Early and Late Bronze Age cultures. In other cases, only limited conclusions are permitted.

In contrast to the Egolzwil culture, the relative importance of the four domestic species at Cortaillod sites varied only slightly. Cattle dominated at Egolzwil 2 and Seematte Gelfingen, while swine were numerically ascendant at Egolzwil 4. At St. Aubin IV, all four species were represented in statistically identical frequencies. The characteristics of Cortaillod culture domestic animal husbandry reveal that male bovines and caprovines were raised for meat and killed long before their maximum body size was attained. Several interpretations are compatible with this finding. The size of the summer cattle herd might have been greater than that which could have been overwintered, resulting in the autumn killing of young males surplus to herd maintenance. Death among animals under a year of age may have resulted from natural causes. The selective killing of young males when in good condition following a summer's grazing might have been deemed the most profitable method of producing meat in the prevailing environmental conditions. Certainly as GOUIN and ANDOUARD (1910) have shown, as much hay is required to raise seven bovines to two years as three bovines to three and a half years, the former method providing a 40% meat gain.

In considering these possibilities, it should be noted that natural mortality is unlikely in view of the marked preponderance of mortality among males. Certainly the forced killing of stock during the autumn may have occurred. It is salutary to remember however, that the autumn slaughter of stock in Medieval England is a myth; only in times of a catastrophic failure of normal fodder supplies was there such seasonal killing (THIRSK, 1967). It is possible that the Cortaillod labour force was not large enough to collect the necessary quantities of wasteland hay. On balance however, it seems unnecessary to invoke a winter fodder shortage to account for a pattern of mortality which reflects sound economic reasoning. The breeding of working oxen would have found no place in an economy based on Brandwirtschaft, in which the ashy topsoil was tilled with hoes rather than turned by the plough.

The high incidence of mortality among immature caprovines at Egolzwil 2 and St. Aubin, as well as the high ratio of goats to sheep, suggest strongly that the latter were not valued for their wool. This assertion is based on the fact that rams or wethers produce a considerably larger fleece than do ewes (HIGGS, 1962), and finds confirmation in the survival of linen rather than wool weaving equipment at Cortaillod settlements. The mixed flocks of sheep and goats may have fed in grassy

Table 23. The faunal spectra from some Swiss prehistoric settlements

Species	Egolzwil 2	Egolzwil 4	Egolzwil 3	Seeberg Süd	Burgäschisee: Süd West
Bos taurus (domestic) L.	13.5 ±3.4	20.5 ±5.1	2.2 ± 4.5	1.9 ±1.3	22.8 ±5.9
Sus scrofa (domestic) L.	8.4 ±2.6	22.2 ±5.4	14.1 ±10.0	5.5 ±2.4	15.8 ±4.9
Ovis aries L. / *Capra hircus* L.	9.3 ±2.8	18.4 ±4.9	30.5 ±15.0	4.8 ±2.0	10.7 ±4.2
Bos primigenius L.	5.7	3.7	0.0	4.3	6.4
Sus scrofa ferus L.	7.1	3.7	14.1	14.7	7.5
Cervus elaphus L.	27.4	10.3	6.4	28.5	15.8
Capreolus capreolus L.	8.6	2.9	8.7	9.5	7.0
Castor fiber L.	3.5	2.9	4.3	6.9	2.3
Ursus arctos L.	2.4	1.2	2.2	1.6	2.3
Meles meles L.	3.0	5.7	0.0	5.0	1.9
Martes sp. L.	0.1	1.6	0.0	1.9	0.0
Putorius putorius L.	0.0	0.0	0.0	1.4	0.0
Lutra lutra L.	0.5	0.8	2.2	1.4	0.0
Canis lupus L.	0.3	0.0	0.0	0.9	0.5
Vulpes vulpes L.	0.8	0.0	0.0	3.5	0.9
Felis sylvestris S.	0.5	1.2	0.0	1.9	0.0
Lynx lynx L.	0.3	0.0	2.2	0.0	0.0
Alces alces L.	4.2	0.8	2.2	0.0	1.9
Bison bonasus L.	1.3	0.0	0.0	1.2	0.0
Canis familiaris L.	3.0	3.7	0.0	3.1	4.2
Erinaceus europaeus L.	0.1	0.0	2.2	1.2	0.0
Sciurus vulgaris L.	0.0	0.4	8.7	0.5	0.0
Lepus europaeus Pall.	0.0	0.0	0.0	0.2	0.0
Equus caballus L.	0.0	0.0	0.0	0.0	0.0
Rupicapra rupicapra L.	0.0	0.0	0.0	0.0	0.0
Capra ibex L.	0.0	0.0	0.0	0.0	0.0
Sample size (Individuals/Fragments)	391 Inds.	244 Inds.	46 Inds.	421 Inds.	214 Inds.

glades within the mixed oak forest. It is hard to conceive that they could have thrived in higher vegetation belts, or even along swampy lake margins.

Two distinct peaks of mortality are evident for Cortaillod culture suids, one among animals of approximately one year of age, and the second among animals of between 2 and 3 years of age. While animals of the latter age group would probably have attained adult body size by feeding in the oak and beech woods, the former category of animals could have been brought into good condition with the assistance of supplementary food, such as skimmed milk or grain surplus.

Wild animals are commonly represented at Cortaillod settlements (Table 23). While this may reflect the failure on the part of domestic animal husbandry to provide sufficient food for the village community, alternative factors may be in question. One cannot for example, rule out the pleasures of the chase, or the need to protect small cereal plots from the depredations of wild animals. Cortaillod artifacts reveal the presence of a mature hunting tradition (VON GONZENBACH 1949). Indeed, the origins of the culture itself among the native Central European hunter fishers is not unlikely.

Zürich Utoquai: (Horgen)	(Corded Ware)	Zürich Breitingerstr. (Michelsberg)	Zürich Alpenquai	Seematte Gelfingen	Arbon Bleiche	Zug Sumpf
17.6 ±13.0	51.0 ±6.8	54.0 ±5.2	28.5 ±1.3	21.8 ±4.2	40.6 ±6.3	19.0 ±6.7
27.5 ±14.2	21.8 ±5.0	17.4 ±3.7	23.0 ±1.6	14.2 ±3.6	27.5 ±5.8	13.4 ±5.7
12.4 ±10.2	8.5 ±3.4	1.3 ±1.0	29.6 ±1.3	9.1 ±2.8	24.0 ±5.6	38.9 ±8.2
2.5	2.2	0.4	1.9	5.2	0.0	0.0
2.5	1.1	2.4	1.6	4.7	0.4	4.2
25.0	8.5	22.6	5.5	28.2	1.3	5.6
5.0	4.7	1.1	0.07	4.1	0.4	0.0
0.0	1.1	0.0	0.05	2.6	0.4	0.0
2.5	0.0	0.0	0.4	1.0	0.4	2.1
0.0	0.0	0.0	0.0	1.0	0.0	0.0
0.0	0.0	0.0	0.0	0.5	0.0	0.0
0.0	0.0	0.0	0.0	0.3	0.0	0.0
0.0	0.0	0.0	0.0	0.3	0.0	1.4
0.0	0.0	0.0	0.0	0.3	0.0	0.0
2.5	0.0	0.0	0.0	0.5	0.0	0.0
0.0	0.0	0.0	0.0	0.5	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.8	0.0	0.0
0.0	0.0	0.0	0.04	0.0	0.0	0.0
2.5	1.1	3.1	4.6	4.7	3.0	9.8
0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	1.4
0.0	0.0	0.0	3.6	0.0	1.7	4.2
0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0
40 Inds.	257 Frags.	384 Frags.	5432 Frags.	385 Inds.	237 Inds.	142 Inds.

The Michelsberg culture peasants occupied the lake shores and river banks on North-East Switzerland contemporaneously with the Cortaillod culture further west. Both practiced Brandwirtschaft in small forest clearings, and both disposed of a basically similar technology. Some Michelsberg sites however, were situated on dry uplands, where the faunal spectra reveal marked changes compared with the lowland sites. At least three interpretations are possible. In the first place, it may well have been that transhumance took place between the lowland lakeside settlements to such upland areas as Eschner Lutzengüetle. Alternatively, such sites as Eschner Lutzengüetle may represent shielings, to which certain animals were taken during the summer to take advantage of local grazing, and conserve the reservoir of plants round the permanent settlement for winter. Finally, both types of site could have been permanently occupied by different economic facies of the same culture.

As has been argued, Michelsberg occupation of the Eschnerberg and its potential analogues could have been permanent or seasonal (HIGHAM, 1967). One conclusion to be drawn from either alternative however, is that a settlement away from the lakeside and only 100 metres higher than most shore settlements called into question an entirely different micro-environment, and that people of the same culture, in the sense that culture has been defined by CHILDE (1956), conditioned their economy to benefit from the environment surrounding their chosen settlement. In the case of the Michelsberg culture, the dry and sunny slopes of the Eschnerberg would have been better suited to sheep rearing than the lake edge at Zürich.

As was the case for the Michelsberg culture, the Horgen culture also settled lake-side and upland sites, the pottery from which is uniformly badly fired and lacking in imaginative design. The economy of the Horgen culture however, should not be interpreted as retrogressive on the basis of the material available. Thus, one cannot rule out the possibility that the actual head of cattle, relative to the size of the human population, was similar to the corresponding figure for the Cortaillod or Michelsberg cultures, and that by increasing the size of the herds of swine, the Horgen peasants exploited their environment more effectively than did their predecessors.

It is possible that the Horgen culture peasants practiced transhumance, although the existing settlement pattern could equally well represent two economic facies of the same culture. Further evaluation of the Horgen economy however, must await the results of the pollen analysis for Zürich (Ut.), and the collection of larger faunal samples.

The Corded Ware settlement of Zürich (Ut.) lacks a pollen spectrum. The faunal sample from this site reveals that the relative importance of each domestic animal was very similar to that of the Michelsberg occupation at Zürich (Br.). Thus, during a relatively short time span, three successive and distinct societies occupied what was effectively an identical physical environment. Two of those societies maintained a relative abundance of cattle, and the other a relative abundance of swine.

A discussion of those differences turns upon the former existence of three distinct vegetation-zones within reach of the settlements; the immediate shorebelt, the mixed oak forest, and the beech forest. Thus, the Horgen culture peasants could have allowed their swine to run in the oak and beech woods. Conversely, the Michelsberg peasants could have established shielings on favourable slopes between 500 and 700 metres above sea level, where cattle grazed during the summer months prior to a period of winter stall feeding. The Corded Ware culture, by analogy with the situation in Holland and Denmark (WATERBOLK, 1956; KJAERUM, 1954) would have intensified forest clearance, established pasture land and increased economic productivity by means of the ox-drawn ard.

Through creating pastureland, the Early Bronze Age farmers exploited their environment more intensively than was hitherto the case. The limitations on the number of cattle and caprovines kept would have been reduced without prejudicing swine husbandry, since plentiful woodland persisted. Where pastures reserved for winter use, considerably more cattle could have been overwintered with the same amount of supplementary collected fodder than was necessary for the Neolithic herds. In that pastureland encouraged the overwintering of an increased proportion of cattle and caprovines than was the case for the Cortaillod culture, more meat was obtained with the same expenditure of effort. Manifestly, the Early Bronze Age economy was the more productive.

Trends apparent at Arbon Bleiche intensified during the Late Bronze Age occupation of Zürich (Al.) and Zug Sumpf. The pollen spectrum for Zug Sumpf suggests a further extension in forest clearance and the consequent establishment of pastureland (LÜDI, 1955), features of significance to a discussion of Late Bronze Age bovine and caprovine husbandry.

There are three principal characteristics of bovine husbandry at Zürich (Al.). Draught oxen were maintained, heifers rather than steers or bulls were killed when under 2 to 2½ years of age, and more animals represented attained adulthood than at any other settlement examined. Clearly, the open pastures could have provided summer grazing. It would have been reasonable however, to preserve them for late autumn to spring feeding, a practice which would undoubtedly have enabled more bovines to be overwintered than under a regime in which every item of winter fodder had to be collected by hand. The deliberate preservation of pastures for the winter feeding of livestock is to be found in Switzerland and Sweden today (FRÖDIN, 1952), and was the basis of the foggage system of winter feeding in Medieval England.

The greater degree of forest clearance at Zug Sumpf than at Neolithic or Early Bronze Age sites thus implies that more bovines could be fed in winter with less expenditure of effort. GOUIN and ANDOUARD'S (1910) observation that as much fodder is required to raise seven bovines to two years of age as to raise 3 bovines to 3½ years of age, the former method realising 40% more meat, is relevant to this discussion. With the fodder supply limited by a lack of open pastureland, as was the case for the Cortaillod and Michelsberg cultures, the former alternative is preferable. But where forest clearance resulted in the major limiting factor on the size of cattle herds being relaxed, the raising of male bovines to over three years of age, though demanding more food per unit weight of meat produced, would in the long term supply more meat per animal. Furthermore, if the economic system involved the intermediate utilisation of the oxen's tractive power, the advantages of maintaining oxen to maturity would have been correspondingly increased. CLARK (1952) has shown that the plough was widespread in Europe by the Late Bronze Age. The mortality frequencies and the sex ratios of the Zürich Alpenquai bovines are thus held to reflect the presence of working oxen and a substantial supply of meat.

The availability of special pastureland during winter bears the implication that more bovines could have been overwintered at Zürich Alpenquai than during the preceding periods, with less expenditure of effort. By maintaining male bovines to a greater age, therefore, the Late Bronze Age community would have produced more meat from the same number of cows than would the Younger Cortaillod community. While the selective killing of cows when under two years of age might at first sight appear surprising therefore, it should be remembered that relatively more meat was obtained from the same number of males than was the case for the Cortaillod culture. Moreover, the killing of immature cows, in that it points to the existence of a high birth and survival rate, indicates a successful bovine economy.

Increased forest clearance is reflected not only in the greater relative importance of caprovines, but also in the high ratio of sheep to goats. Approximately a third of all mandibles come from animals too young to have supplied more than one fleece. The remaining juvenile mandibles at Zürich (Al.), on the basis of modern comparative material (SILVER, 1963), appear to have been raised to between 12 and 28 months of age. Those animals may well have been raised for their wool and subsequently fattened for consumption. That wool-weaving was practiced by this time is clear from the surviving artifactual evidence.

Combined studies of pollen and faunal spectra from a given site suggest that agriculture and stock rearing integrated to comprise distinct patterns of economic exploitation of the region under discussion. The enclosed woodland environment of the Cortaillod peasants was compatible with a high ratio of goats to sheep, and the raising of male bovines for early consumption. On the other hand, the open landscape of the Late Bronze Age encouraged the proliferation of sheep and the increase in agricultural productivity through the use of the ox-drawn plough.

The technological evolution which characterised the sequence of prehistoric cultures during the Sub-Boreal period in Switzerland was accompanied by human interference on the natural environment. Increasingly wider areas were brought under pasture, while the qualities of domestic stock were more intensively utilized. These three lines of advance however, should not be viewed in isolation: indeed, the relationship between an increasingly sophisticated technology and the means whereby both environment and domestic stock were exploited should be viewed as essentially symbiotic.

Appendix 1

Schedule of Sites Mentioned in the Text

Arbon Bleiche: Kt. Thurgau. Early Bronze Age. Situated on a slight eminence of quaternary moraine overlooking the Salweise, 500 metres from the modern shore of Lake Constance. Since the fringes of the site during the occupation period were clearly inundated, the prehistoric settlement probably lay on a promontary within a small bay. The Salbach and Aach flow into the Salweise, on either side of the prehistoric site. Wyss (1959) has assigned the occupation to the second phase of the Swiss Early Bronze Age. Meyer, Keller-Tarnuzzer and Gesner (1945) have described the excavations and Kuhn and Güller (1946) the faunal remains. Lüdi has published the site's pollen spectrum. The material is housed in Zürich.

Seeberg Burgäschisee Süd-West: Kts. Bern and Solothurn. Younger Cortaillod culture. Three culturally related sites have been located on the shores of the Burgäschisee. The lake is small, and the level fluctuated considerably during the postglacial period. It is currently surrounded by peat deposits, and in turn by Würm moraines. A number of hills rise 600 to 700 metres above sea level within 10 miles of the site, but to the north, no land rises above 600 metres for over 30 kilometres. The faunal remains have been published by Josien (1956), and the pollen samples discussed by Welten (1955) and Troels-Smith (1954). The material is housed in the Naturhistorisches Museum, Bern.

Egolzwil: Kt. Lucerne. Egolzwil 2 and 4 belong to the Younger Cortaillod culture, and Egolzwil 3 to the Egolzwil culture. All sites fringe the northern margin of the former Wauwil Lake, which is ringed by hills rising to between 600 and 700 metres above sea level. Vide Vogt (1951), Hescheler and Rüeger (1939, 1942), Troels-Smith (1954). The material from all sites is housed in Zürich.

Seematte Gelfingen: Kt. Lucerne. Younger Cortaillod culture. The site lies between the Baldegg and Hallwil Lakes, on a flat stretch of lacustrine alluvium. The Lindenberg to the east of Seematten-Gelfingen rises to 850 metres above sea level. Vide Hescheler and Rüeger (op. cit.). The material is housed in Zürich.

St. Aubin, Kt. Neuchâtel: St. Aubin has yielded a lower Older Cortaillod, and an upper Horgen, culture level. The site lies on the northern margin of Lake Neuchâtel, in an area famed for the richness of its soil. Hills rise steeply behind the settlement, the Bandes Bourgat and Cret Teni being 1450 metres above sea level, although a bare 5 kilometres from St. Aubin as the crow flies. Vide REVERDIN (1921), VON GONZENBACH (1949). The material is housed in the Musée de L'Histoire Naturelle, Geneva.

Sipplingen, Bavaria: Horgen culture. Situated on the northern edge of Lake Constance, vide VOGEL (1933). There is no record of the location of the faunal sample.

Eschner Lutzengüetle: Principality of Liechtenstein. Schussenreid, Michelsberg, Horgen, Early and Late Bronze Ages. The prehistoric settlements are situated on the Eschnerberg, a low hill projecting into the eastern edge of the Rhine Valley. The hill itself, skirted by the Rhine Glacier, comprises outcrops of chalk with loess deposition. The settlement is 600 metres above sea level. Vide HARTMANN-FRICK (1960), BECK (1944). The material is housed in Vaduz.

Zug Sumpf: Kt. Zug. Late Bronze Age Hallstatt B culture. The prehistoric site lies on the northern edge of Lake Zug. Most of the lake is hemmed in by steeply shelving moraines covering conglomerate and sandy carbonaceous sediments. The northern edge however, comprises alluvial sediments over a wide flat area. There have been two major phases of excavation. The fauna from the first has been published by REVERDIN (1927) and the present location of the specimens is unknown. The second excavations have also provided a faunal sample, housed in Zürich (SPECK, 1954). The pollen sample has been studied by LÜDI (1954).

The Zürich sites: Kt. Zürich. Three sites are in question. Zürich Utoquai has provided Horgen and Corded Ware culture samples (RUOFF, pers. comm.). Zürich Breitingerstrasse has provided Michelsberg and Horgen levels (DRACK, 1960), and Zürich Alpenquai is a Late Bronze Age site (WETTSTEIN, 1924). All lie within the environs of Zürich, and border the edge of the lake itself. The Adlisberg behind Zürich Utoquai rises to 700 metres, while three or four kilometres to the west of Breitingerstrasse, the Uetliberg rises to 870 metres above sea level. The material from all three sites is housed in Zürich.

Within the text, Zürich Breitingerstrasse is abbreviated as Zürich (Br.), Utoquai as (Ut.) and Alpenquai as (Al.).

Appendix 2

Statistical Techniques Employed

1. Student's t test: This test is used in comparing sample means. The 5% level is regarded as inferring an interesting possibility of difference, and the 1% level, as indicating a significant difference. In all cases the two samples under comparison have been compared initially to check that their variances are similar. No t test has been undertaken unless the distribution of each sample is normal.
2. The X^2 test: This is employed in testing for significant differences between the observed numbers of specimens in variates from two or more samples, or between the observed and mean numbers of specimens in variates from the same site.
3. The Kolmogorov-Smirnov test: This test is used in comparing mortality frequencies of domestic animals from site to site, for comparing the observed and mean numbers of mandibles per age stage, and for testing for normal distribution prior to the application of the Student's t test (vide SIEGEL, 1956).
4. The Coefficient of Difference: This coefficient is employed for assessing the degree of sexual dimorphism between bone dimensions in modern and prehistoric collections.
5. The Coefficient of Variation: This is calculated to obtain an estimate of the variability in modern and prehistoric bone samples.

6. Sex Ratios: These have been tested for significance by means of KURTÉN's (1955) method.
7. The F ratio: This is used to test for the significance of the difference between two sample variabilities.
8. Equiprobability Ellipses: The major and minor axes of such ellipses have been calculated following JACKSON's (1956) method.

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