Sex Differences in Dental Caries Rates With the Origin of Agriculture in South Asia
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a small, isolated community of chimpanzees (*P. t. verus*) has been studied intermittently since 1976.

The second session on site reports represented the "next generation" of great-ape field research. None of these sites had been developed at the time of the first conference, and several are sites with sympatric gorillas and chimpanzees. Tutin spoke on Lopé, Gabon, where western lowland gorillas (*G. g. gorilla*) and central western chimpanzees (*P. t. troglodytes*) are being studied; Kuroda discussed Ndoki, Congo, where gorillas (*G. g. gorilla*) and chimpanzees (*P. t. troglodytes*) are also being studied; and Yamagiwa described work at Kahuzi-Biega, Zaïre, which has eastern lowland gorillas (*G. g. graueri*) and eastern chimpanzees (*P. t. schweinfurthii*). Two chimpanzee sites and a bonobo site completed the survey, with Boesch detailing work at Taï, Ivory Coast, on chimpanzees (*P. t. verus*), Wrangham discussing chimpanzee (*P. t. schweinfurthii*) research at Kibale, Uganda, and Kano reporting on the other bonobo (*P. paniscus*) site at Wamba, Zaïre.

During site reports and informal evening meetings, videotapes were shown so that researchers could share the qualitative imagery of field sites and laboratory settings. Video clips illustrated specific behavioral patterns, for example, chimpanzees cracking nuts at Bossou or gorillas foraging in swamp habitat in Ndoki. Video also captured rare but dramatic events such as infanticide by male chimpanzees at Mahale.

A book of 21 chapters by the conference participants with a foreword by Jane Goodall and an afterword by Junichiro Itani is in press with Cambridge University Press, to be published in August 1996. Edited by W. C. McGrew, Linda F. Marchant, and Toshisada Nishida, it is titled *Great Ape Societies*.

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Sex Differences in Dental Caries Rates with the Origin of Agriculture in South Asia[1]

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Questions concerning the impact of agriculture upon the health of prehistoric human populations have played an important role in the design and conduct of research in skeletal biology and dental anthropology over the past decade. While many investigations have focused primarily upon the skeletal and dental health of populations as whole units of study (Cohen and Armelagos 1984, Cohen 1989), attention is now being given to subgroups within populations. Powell's (1988) analysis of status groups in the Moundville chiefdom and Storey's (1992) paleodemography of a low-status residential compound at Teotihuacan are noteworthy examples. Sex differences in health and mortality have long interested biological anthropologists, but discussion of these issues within the context of subsistence transition models is relatively new (Cohen and Bennett 1993; Powell, Bridges, and Mires 1991). An early comparison of pre- and postagricultural populations of the Georgia coast showed that females suffered a greater increase in caries rates than males with the rise of agriculture (Larsen 1983, 1984; Larsen, Shavit, and Griffin 1991). However, studies focusing on the differential consequences of subsistence changes for the health and mortality of males and females are not common. The research on the dental and skeletal health of prehistoric populations of the Indian subcontinent described here, employing an innovative method for reporting pathological dental lesions, permits new insights into sex-based differences in dental disease in South Asia.

The reporting of dental caries prevalence generally employs the observed caries rate or caries index, obtained by dividing the number of teeth with one or more carious lesions by the total number of teeth observed. This index has the important practical limitation that teeth lost during life are not considered. This methodological problem and the potentially significant bias resulting from it have been largely ignored by skeletal biologists and dental anthropologists. Since it is likely that some teeth lost antemortem will have been lost due to extensive caries, the observed caries rate will frequently produce an underestimate of the true caries experience of a group. A method that attempts to rectify this problem is the decayed-and-missing index, in which the sum of all carious teeth and all teeth lost antemortem is divided by the total number of teeth observed

plus those lost antemortem (Kelley, Levesque, and Weidl 1991, Powell 1985). This index assumes, however, that all teeth lost antemortem were lost because of caries. While this assumption may be reasonable for postindustrial agricultural societies and is supported by clinical evidence (Powell 1985:321), it is clearly unjustifiable for many prehistoric skeletal series, especially those in which antemortem loss of teeth has multiple causes (attrition, caries, trauma, cultural treatment, etc.). Several other researchers have advocated correction factors to accommodate or compensate for the loss of teeth before death, but all of these rely upon assumptions that are unrealistic. Some investigators have categorically objected to the use of correction factors on the basis that the etiology of antemortem tooth loss will vary regionally and temporally (Brothwell 1963).

In 1992, in a preliminary report on dental pathology at Harappa, I advocated a new caries correction factor (Lukacs 1992). Tooth loss is often preceded by exposure of the pulp chamber of the tooth, a condition that is rapidly followed by infection. The two primary causes of pulp exposure are caries and severe dental wear. My correction factor relies upon the observation and diagnosis of the etiology of pulp exposure in a skeletal series and determination of what proportion of teeth exhibit pulp exposure due to caries. The number of teeth lost antemortem can then be multiplied by the percentage of teeth with caries-induced pulp exposure to produce an estimate of the number of teeth lost antemortem due to caries. This value can then be converted into a more accurate or corrected dental caries rate by adding the number of teeth observed to have carious lesions and the estimated number of teeth lost antemortem because of caries and then dividing this number by the total number of teeth observed plus all teeth known to have been lost antemortem. This procedure yields a correction factor that obviates the concerns and criticisms leveled at previous formulae for caries correction. A recent restatement of my caries correction factor considers earlier caries correction factors, reiterates computational procedures, and provides examples from prehistoric skeletal series from South Asia and the Arabian Gulf States that demonstrate the value of its use (Lukacs 1995). Application of the caries correction factor is absolutely essential for skeletal series that display high rates of antemortem tooth loss, for example, the series from

the Archaic Period of the Lower Pecos region, Texas (Hartnady and Rose 1991), and those representing the date-eating populations of the circum-Mediterranean region and Gulf states (Højgaard 1980; Littleton and Frohlich 1989, 1994). An illustration of the three different methods for reporting dental caries, using the uncorrected rates for Bronze Age Harappans, is given in table 1.

The impact of applying the caries correction factor to pooled-sex dental samples from prehistoric South Asia is depicted in figure 1. For the Harappan skeletal series, the observed caries rate was approximately half the corrected caries rate. These values were compared with caries rates of pooled-sex samples from Neolithic and Chalcolithic Mehrgarh, and a progressively increasing caries rate was shown to coincide with the intensification of agriculture (Lukacs 1992:147, fig. 7). The observed caries rate increased less dramatically than the more accurate corrected rate. An Iron Age skeletal sample from Oman is included to show the impact of applying the caries correction factor to groups with higher antemortem tooth loss rates than the Harappans (Nelson and Lukacs 1994). The pioneering research of Klatsky and Klatell (1943) revealed the generally parallel relationship between increasing dental caries prevalence and the rise of civilization, but I was the first to demonstrate this biocultural relationship for South Asia (Lukacs 1992, Lukacs and Minderman 1992). The possibility that sex differences in dental caries rates among prehistoric humans might coincide with the adoption and intensification of agriculture was not addressed by Klatsky and Klatell or by other early students of dental pathology (Leigh 1925, 1929).

When the sex differences in dental caries in prehistoric South Asian skeletal series are viewed comparatively using the caries correction factor, an interesting picture emerges (table 2). The two Mesolithic skeletal series from the Ganga Plains, north of Allahabad—Damdama and Mahadaha—show sex-distinctive responses when the caries correction factor is applied (see fig. 2). Male caries rates remain essentially unchanged, while female rates display a substantial increase. Chalcolithic Mehrgarh exhibits a similar pattern; male caries rates remain low while female caries rates show a noticeable increase. For Harappa, both males and females show a dramatic response to application of the caries

TABLE I
Caries Rates at Harappa: Comparison of Reporting Methods

	Observed		Decayed and Missing		Corrected	
	%	(n/Total)	%	(n/Total)	%	(n/Total)
Female	10.1	(29/288)	24.2	(82/339)	17.7	(60/339)
Male	6.4	(18/281)	10.5	(31/294)	10.5	(31/294)
Sexes pooled	6.8	(51/751)	14.7	(121/821)	12.1	(99/821)
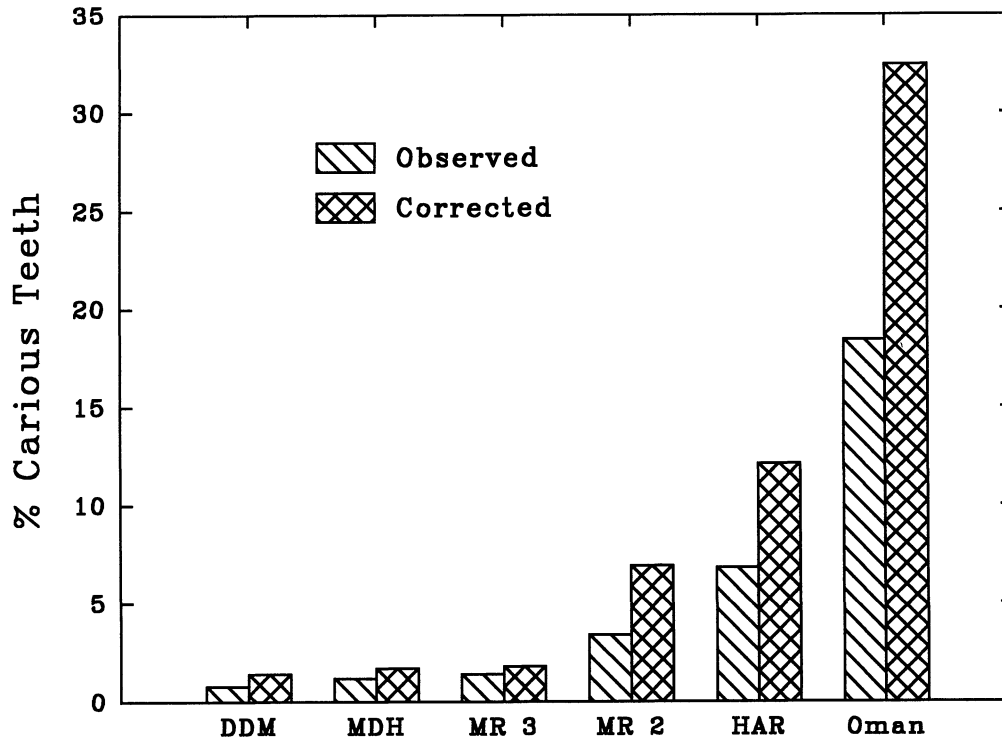
FIG. 1. *Dental caries rates: Sexes combined.* DDM, *Damdama;* MDH, *Mahadaha;* MR 3, *Neolithic Mehrgarh;* MR 2, *Chalcolithic Mehrgarh;* HAR, *Harappa;* Oman, *Samad.*

correction factor, but the effect on females is significantly greater (table 3).

This analysis of caries rates through time for prehistoric peoples of South Asia shows that females suffer from caries more frequently than males and that sex dimorphism in caries rates is accentuated with the adoption and intensification of agriculture. This sex difference is best envisioned by contrasting the corrected caries rates by sex at Harappa with earlier skeletal samples from sites with Mesolithic (Damdama and Mahadaha) and Chalcolithic (Mehrgarh) cultural associations (fig. 3). While the disparity between the sexes is apparent among hunting and foraging Mesolithic peoples, an even more sex-dimorphic pattern is evident among the Bronze Age agriculturalists of Harappa. A recent review of skeletal evidence for sex roles and gender hierarchies in prehistory mentions the utility of dental caries analysis but cites just one case—the Georgia coast (Cohen and Ben-

TABLE 2
Dental Caries Rates by Tooth Count

|	Male				Female				Sexes Pooled			
	Observed		Corrected		Observed		Corrected		Observed		Corrected	
Site	%	(n/Total)	%	(n/Total)	%	(n/Total)	%	(n/Total)	%	(n/Total)	%	(n/Total)
Damdama	0.2	(1/523)	0.2	(1/530)	1.8	(6/359)	4.3	(17/398)	0.8	(7/822)	1.4	(13/928)
Mahadaha	1.0	(2/199)	1.0	(2/199)	1.6	(1/62)	5.9	(5/85)	1.2	(3/216)	1.7	(5/296)
Neolithic Mehrgarh	–		–		–		–		1.4	(18/1,273)	1.8	
Chalcolithic Mehrgarh	1.4	(6/433)	1.8	(8/437)	4.8	(21/433)	6.1	(28/456)	3.4	(29/865)	6.9	
Harappa	6.4	(18/281)	10.5	(31/294)	10.1	(29/288)	17.7	(60/339)	6.8	(51/751)	12.1	(99/821)
Samad	–		–		–		–		18.4	(26/141)	32.4	(59/182)
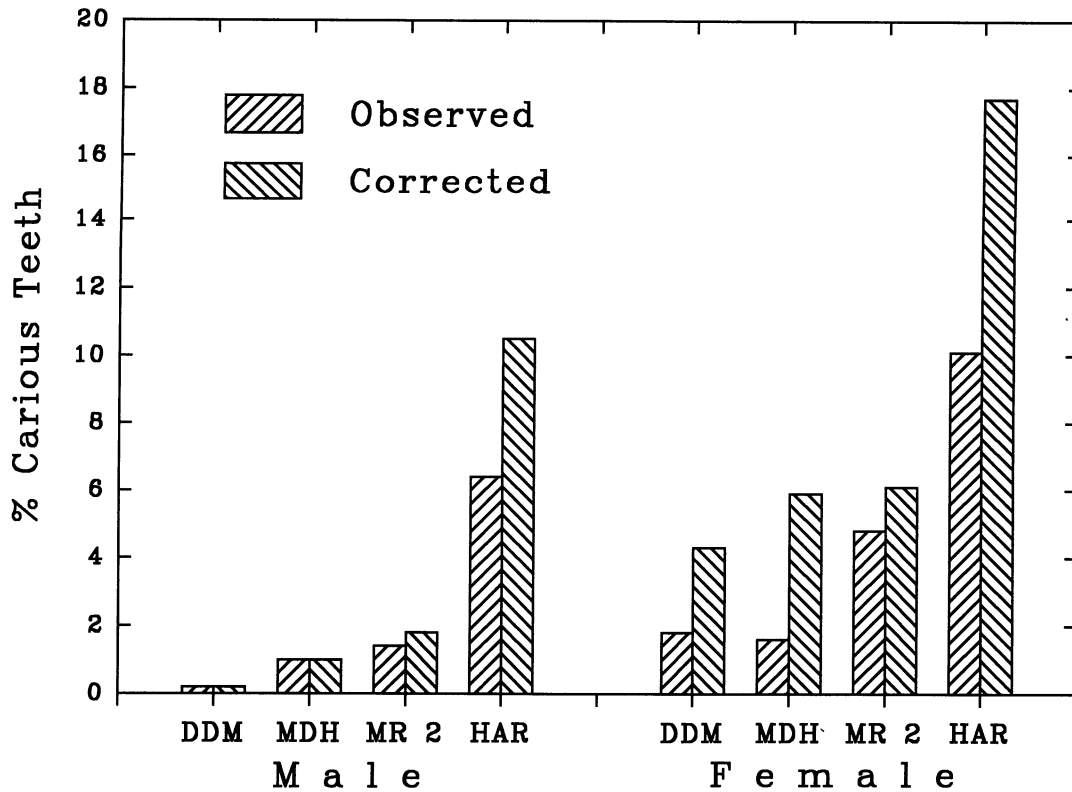
FIG. 2. Observed and corrected caries rates by sex. DDM, Damdama; MDH, Mahadaha; MR 2, Chalcolithic Mehrgarh; HAR, Harappa.

nett 1993:281). In this investigation of dental caries rates before and after the adoption of agriculture, females have been found to suffer from higher caries rates than men (Larsen 1983, 1984). The absence of more extensive reports on sex dimorphism in dental disease during the transition to agriculture increases the significance of the currently available data and should be a stimulus to further research.

The goal of this brief review of sex differences in dental caries is to provide a comparative picture against which the South Asian pattern can be fruitfully assessed. It is important for the comparison to include investigations of dental caries among living as well as pre-

historic skeletal samples, since in many ways they can provide complementary data.

According to Larsen and colleagues (1991:194–95), although many skeletal samples (19 studies are cited) report a higher prevalence of dental caries in females than in males, notable exceptions (5 are cited) suggest that this is not a universal pattern. While sex-dimorphic physiological factors, including earlier eruption of teeth and pregnancy, may be involved in explaining the observed differences in caries rates, these seem to be less important than culturally mediated behavioral differences related to distinctive sex-based activity patterns, especially those connected with the preparation and

TABLE 3
Chi-square Values for Caries Rate Comparisons

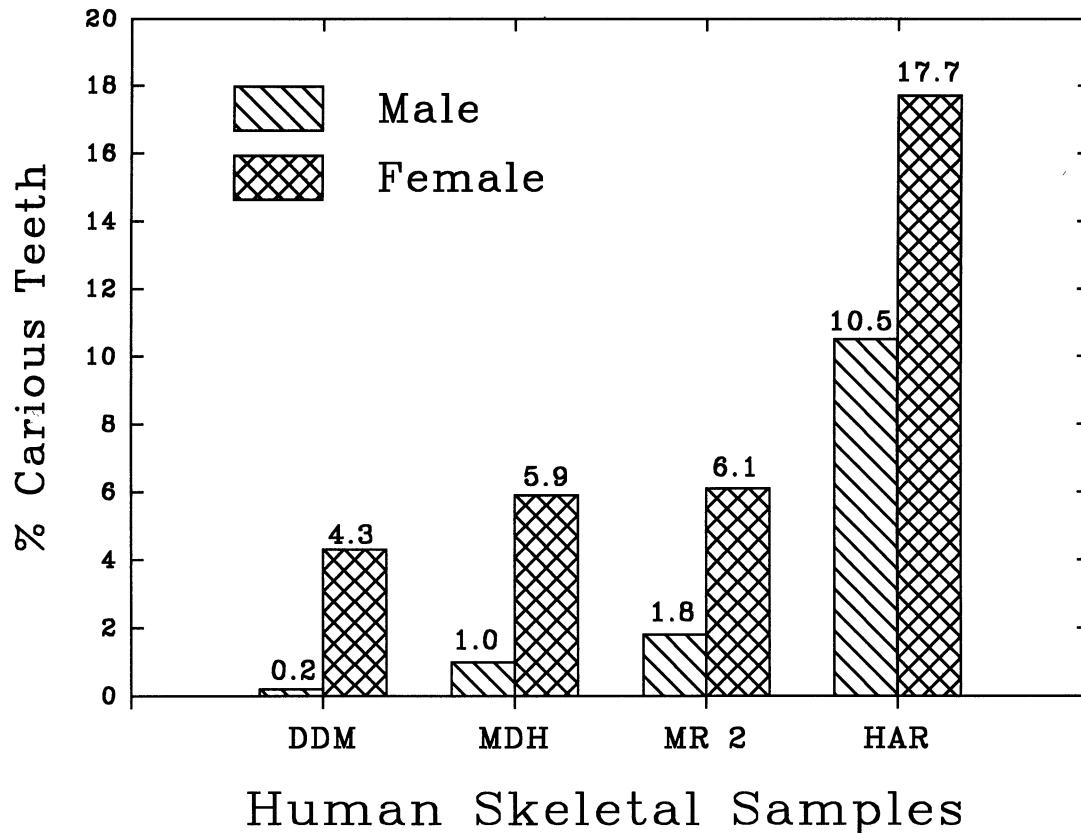| Site	Observed vs. Corrected			Male vs. Female	
	Male	Female	Sexes Pooled	Observed	Corrected
Damdama	0.993	0.037	0.281	0.015	0.000
Mahadaha	1.000	0.196	0.787	0.695	0.015
Mehrgarh (MR 2)	0.602	0.433	—	0.033	0.001
Harappa	0.076	0.006	0.000	0.112	0.011
Samad	—	—	0.005	—	—

FIG. 3. *Corrected caries rates by sex.* DDM, *Damdama;* MDH, *Mahadaha;* MR 2, *Chalcolithic Mehrgarh;* HAR, *Harappa.*

consumption of food. Several investigators, however, report the absence of sex differences in dental caries and missing teeth in prehistoric skeletal samples, including Neolithic and Bronze Age Hungarians (Molnar and Molnar 1985), a Romano-British series from Hertfordshire (Thornton 1991), and prehistoric Native Americans of Oregon (Hall, Morrow, and Clarke 1986). In addition, many otherwise excellent studies of dental caries and subsistence in prehistoric skeletal series and modern populations neither report caries rates or decayed-and-missing indices by sex nor provide adequate descriptions of the cultural content of samples studied (Ganga et al. 1991, Greene 1972, Hall and German 1978, Rahmatulla and Guile 1990).

Human remains from Pontecagnano, Italy, that date to between the 7th and the 4th century B.C. reveal that males display a higher caries prevalence than females (Fornaciari, Brogi, and Balducci 1985–86). However, this difference is not significant statistically and may be explained by the higher average age at death reported for males. When the dental lesion index is controlled for age, Fornaciari and colleagues show that for ten Southern European samples the dental health of females is equal to or worse than that of males. Among Native American skeletal series, Chumash females are reported to have higher caries rates than males (Walker and Erlandson 1986), but Arikara males have a higher caries rate than females (both groups consuming a high-protein diet). The higher mean age at death among Arikara males is more likely responsible for this sex-dimorphic pattern of caries prevalence than dietary differences between the sexes (Hollimon 1992).

Among modern peoples, females have been reported to exhibit higher caries rates (or decayed-and-missing index values) than males among Aka and Mbuti pygmies and their Bantu neighbors (Walker and Hewlett 1990). The opposite situation was found for dental caries prevalence among six dietary groups in Papua New Guinea (Barmes 1968). Among the Muslims of southern Andhra Pradesh a significantly higher percentage of females than males is afflicted with dental caries, yet more teeth are carious among males (Reddy, Vijayalakshmi, and Reddy 1982). The primary teeth of male children from Gulbarga, Karnataka, are significantly more carious than the primary teeth of girls (Reddy 1980). Reports of caries prevalence among other South Indian populations show no strong sex difference among the Madigas (Reddy and Naidu 1980) or the Vysyas (Reddy 1990). A national pathfinder study that included large samples from all four provinces of Pakistan found caries frequency slightly higher in males (60.3%) than in females (57.9%) (Maher 1991).

This comparative review reveals that multiple interacting variables, including the type and consistency of

food, preparation and cooking methods, and sex-based division of labor and activity patterns result in population-specific patterns of dental disease. The unique cultural and ecological context in which human societies develop and function will produce regional differences in the nature and degree of sexual dimorphism in general and in dental disease specifically. Therefore, each region must be investigated individually, and generalizations regarding the direction and significance of sexual dimorphism in dental disease are likely to be misleading or erroneous.

Integrative analyses of prehistoric dietary patterns combining evidence from archaeology (plant and animal remains, coprolites, food refuse, and chemical analysis) with results derived from the anthropological analysis of human skeletal and dental remains (see, e.g., Sobolik 1994) are in their infancy in South Asia. This analysis provides an example of the important lessons that can be learned by adopting a bioarchaeological approach to the distribution of dental diseases, but the significance of these results in isolation is limited. The main conclusions are that women have higher caries rates than men in South Asian prehistory, that sex differences in caries rates vary over time, and that caries is particularly severe in women during the transition to agriculture. When these findings are integrated with the evidence derived from skeletal pathology, stature variation, and archaeological indicators of status their meaning will become clearer.

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The Role of Early Humans in the Accumulation of European Lower and Middle Palaeolithic Bone Assemblages[1]

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As early as the first decades of this century, there were important breakthroughs in taphonomic studies which remain relevant to the interpretation of archaeological faunal inventories today. A classic example of these pioneering studies is Weigelt's (1927), which was translated into English as late as 1989 (see also 1930). Similarly, it was certain of Zapfe's papers describing the morphology of hyaena-modified bones (Zapfe 1939, 1940) which led to a revised view of pieces originally published as bone tools (Franz 1941). On the whole, however, the results of these early investigations met with little reaction (because of the language barrier, especially in non-German-speaking countries), and as a result taphonomic considerations are only exceptionally included in the Pleistocene archaeological literature of the '50s and '60s (see Wetzel 1969, Brain 1967). New research approaches emerged in the '80s with the publication of *Fossils in the Making* (Behrensmeyer and Hill 1980) and *Bones:*

Ancient Men and Modern Myths (Binford 1981), which introduced taphonomic perspectives to an archaeological readership. Since then, a range of innovative methods and models has been employed to describe bone accumulations and to interpret their relevance for the understanding of human behaviour patterns.

Almost 15 years later, at the end of May 1995, the Römisch-Germanisches Zentralmuseum Mainz, in collaboration with the European Science Foundation working group "The Palaeolithic Occupation of Europe," organised a colloquium at Schloss Monrepos, Neuwied (Germany), entitled "The Role of Early Humans in the Accumulation of European Lower and Middle Palaeolithic Bone Assemblages." At earlier meetings on prehistoric faunal analysis (Bonnichsen and Sorg 1989, Patou-Mathis 1994) the emphasis was often on methodological advances; the goal of this meeting was the synthetic discussion of hominid food procurement and exploitation during the Lower and Middle Palaeolithic based on case studies of individual sites. The question was whether we really have a better understanding of hominid subsistence strategies or have merely become more aware of the enormous range of other "natural" processes which affect faunal accumulations. Scientists were invited to respond to this question with papers on some of the most important European Lower and Middle Palaeolithic sites. Two full days were devoted to lectures divided into three sessions: "Bone Assemblages without Human Modification," "Lower Palaeolithic Sites," and "Middle Palaeolithic Sites." All of the sections were chaired by us and included extensive discussion.[2]

In the session on bone assemblages without human modification, papers were presented on bone assemblages recovered in various environments (e.g., fluviatile milieux, open-air sites, and caves). Descriptions of several well-preserved Tertiary and Pleistocene palaeontological sites revealed the canon for natural accumulations of bone. One of the first results of this session was to demonstrate that at many palaeontological sites the superimposition of factors leading to bone accumulation precludes a monocausal interpretation of the assemblage.

Methodological aspects discussed in this session were also of interest. R.-D. Kahlke described features of the Lower Pleistocene site at Untermassfeld, Germany (Kahlke 1991, 1995; Kahlke and Kahlke 1995). The fossil horizon at this site consists of fluviatile sands from the

2. The participants were P. Anconetani (Italy), A. P. Anzidei (Italy), P. Auguste (France), G. Baryshnikov (Russia), G. Bosinski (Germany), B. Bratlund (Germany), J. P. Brugal (France), P. F. Cassoli (Italy), N. Conard (Germany), F. David (France), G. Fabbo (Italy), P. Fosse (France), J.-L Franzen (Germany), C. Gamble (United Kingdom), S. Gaudzinski (Germany), C. Guèrin (France), R.-D. Kahlke (Germany), W. von Koenigswald (Germany), L. Larson (Sweden), U. Mania (Germany), B. Martínez Navarro (Spain), A. M. Moigne (France), M. Mussi (Italy), M. Patou-Mathis (France), N. Praslov (Russia), W. Roebroeks (Netherlands), M. Santonja (Spain), K. Schatz (Germany), K. Scott (United Kingdom), A. Tagliacozzo (Italy), J. F. Tournepiche (France), E. Turner (Germany), and P. Villa (France).