Sorting the mandibular teeth of sheep from goat

The identification of sheep and goat on the basis of Neolithic dental material from eastern Syria.

MSc thesis

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The Front page:
The picture on the front page of this report is a photograph taken of one of the worked bone fragments found during the gathering of the teeth from the bone material of Tell Bouqras. In chapter "Curiosity" more details about this fragment are discussed.

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Abstract

Sheep and goats have been a major source of subsistence in the Middle East since their domestication more than 10,000 years ago in the foothills or mountains of Southwest-Asia. For the deduction of the ecological and cultural relationships of animals and men, the identification of species and age is important.
In this research, the teeth from sheep and goat, excavated in the Neolithic settlement Tell Bouqras are studied. The aim of the study is twofold. On one hand, the efficiencies and deficiencies of the identification methodology are tested. On the other hand, this study tries to reveal the ratio between the numbers of sheep and goat kept and also for what purpose the Neolithic inhabitants of Tell Bouqras kept their sheep and goat.
The determination of the teeth has been done according to the new methodology developed by Helmer (2000) and Halstead *et al.* (in press). On the basis of characteristics described by both researchers, the mandibular premolars P3 and P4 and the molars M1, M2 and M3 are identified as sheep or goat.
The methodology seems to be a good method for separating the mandibular teeth of goat from those of sheep. Deficiencies of this methodology lie in the fact that with ageing, the identification of the teeth becomes less unambiguous. In this study, the ages at which 100% of a tooth type can be identified, and the fading of the characteristics caused by ageing is discussed. The methodology gives better results when applied to complete jaws than on individual teeth.
This research points out that the number of sheep herded in the beginning of the Neolithic period in Tell Bouqras outnumber the amount of goat. The age at which most sheep and goat were slaughtered was approximately 25 months. The kill-off patterns indicate that both species were mainly herded for their meat. The kill-off patterns of sheep as well as the kill-off pattern of goat did not undergo major shifts during the inhabitation period of Tell Bouqras.

Keywords: mandibular premolars and molars, determination characteristics, sheep:goat ratio, herding sheep and goat.

Table of contents

Appendices

Curiosity

The bone material excavated at the Tell Bouqras was used for this study. From this bone material, the mandibular and maxillary teeth from sheep and goat were collected. Apart from the teeth, worked bone material was gathered. Among other things beads, pipes, spatulas and a human figurine, made from solid bone fragment, were found.

Especially the human figure is very remarkable. Human images from the Near East, dated from the Neolithic period, are very rare. The find is even more special considering the good condition and the exceptional detailed design of the human figure worked on the bone material.

The following pictures were taken of the human figure. The face of the figure is elongated. The eyes, ears and nose are distinctly recognisable. Eye-catching is the top headdress.

1. Introduction

1.1 Herding sheep and goat

Sheep and goats have been a major source of subsistence in the Middle East since their domestication more than 10,000 years ago in the foothills or mountains of southwest Asia (Redding 1978). There may have been many reasons why sheep and goat were kept in the Neolithic period. In the beginning of the Neolithic period, the sheep and goat were probably mainly kept for their meat. In later stages, also the milk and wool may have been reasons to herd both species.

The kill-off pattern supplies information about the use of sheep and goat. When animals are kept for their meat, the kill-off pattern will show a high proportion of animals slaughtered at the moment the animals become adult. A few animals are kept for their reproductive value. If milk is the product aimed for, the males will be slaughtered at the age that they become adult. The females will be slaughtered at the age that the milk production permanently stops or the quality of the milk diminishes. The kill-off patterns will show a kill-off of almost 50% just before or at the moment the animals become adult. The other animals, most of the females and a few breeding males, will be slaughtered at high ages. In the last situation, the situation in which the wool production is the reason for herding animals, the kill-off pattern will show a high kill-off proportion at high ages. The animals, the females as well as the males, will be slaughtered when the wool production decreases.

Although sheep and goat are often herded together, these two species exhibit differences in environmental tolerances, feeding preferences, ease of control, reproductive characteristics, carcass quality, and range of secondary products (Payne 1973, Halstead *et al.* in press).

For the deduction of the ecological and cultural relationships of animals and man, the identification of species, age and sex is important. The determination on species level and the establishment of the age at death can sketch the kill-off pattern of ancient populations of sheep and goat. The composition of the herd, the percentage sheep and the percentage goat, can also be deduced from the determination on species level. This may lead to conclusions about the relationship between those animals and man (Wilson 1982).

This study tries to reveal whether the methodology developed by Helmer (2000) and Halstead *et al.* (in press) can be used to accurately identify the mandibular premolars and molars of sheep and goat from ancient bone material to species level. The efficiencies and the deficiencies of this new methodology are tested on ancient bone material.

Besides the testing of the methodology, the teeth from sheep and goat excavated in the Neolithic settlement Tell Bouqras are studied in order to reveal for what purpose the Neolithic inhabitants of Tell Bouqras herded their sheep and goat. The advantage of using teeth for the deduction of the relationship between man and the sheep and goat lies in the fact that the mandibles are the most resilient bones to destruction, particularly the teeth themselves (Maltby 1982).

The kill-off patterns are investigated in order to draw conclusions about the relationship between men and Ovicapra. To establish the age at death, the method developed by Grant (1982) as well as the method developed by Payne (1982) are used. Background information about the excavation site is given for the interpretation of the results.

1.2 Osteological distinction

The distinction between excavated bones of sheep (*Ovis* spec.) and goat (*Capra* spec.) is one of the classical problems in archaeozoology (Loreille 1997). The bones of sheep and goat highly resemble each other. This distinction problem is particularly acute in areas, such as the Mediterranean and the Near East, where sheep and goat have both long been major constituents of livestock populations (Halstead *et al.* in press).

Archaeozoological analyses of mortality patterns for the combined category 'sheep/goat' risk masking differences in the management of these two species or, creating an illusory composite picture which is valid for neither species (Halstead *et al.* in press). Therefore, the distinction on the bone material of the two species is very important for drawing conclusions about the management of sheep and goat separately. Until recently, the distinction between sheep and goat was hard to be made on basis of bones and teeth.

Recently a methodology was developed, which makes a good distinction between goat and sheep mandibular teeth possible. Helmer (2000) published diagnostic criteria for the mandibular permanent premolars, P3 and P4, of sheep and goat. Following Helmer, Halstead *et al.* (in press) developed a methodology in which not only the mandibular permanent premolars P3 and P4, but also the mandibular molars (M1-M3) and part of the mandible can be used as diagnostic criteria for the separation of adult mandibles of these two species. They distinguished diagnostic criteria, which were tested, revised and refined on modern adult mandibles of 43 sheep and 41 goats. To explore further differences between the M1 and M2 in early wear, Halstead *et al.* (in press) examined 20 mandibles of young sheep and 28 mandible of young goats. The diagnostic value and the reliability of the revised criteria were tested on 31 adult and 40 young sheep and 107 adult and 24 young goats.

1.3 Ageing teeth

Research about the age pattern of the hunted and/or slaughtered animals is needed for the deduction of the ecological and cultural relationships of animals and people. From the determination of species and age, conclusions can be derived about kill-off patterns of archaeological populations of sheep and goat. Teeth analysis can be used to determine the age of sheep and goat. Both tooth eruption and tooth wear are indicators of age in cattle and other animals (Grigson 1982). Within a single population individual variation in rates and patterns of tooth wear can be quite high. Consequently, the method is not reliable for ageing specific individuals, but it reasonably well estimates the overall age structure of the population (Stallibrass 1982).

As an animal ages, the appearance of a tooth changes. This is particularly true for sheep and goats, whose high-crowned (hypsodont) teeth are adapted to high rates of tooth-wear. When a tooth erupts, its upper surface is completely covered in enamel. The details of the cusps and cusptips are sharp, but the base of the crown is incomplete, the roots are largely unformed, and much of the crown of the tooth is hidden within the jaw (Payne 1985). As the tooth comes into wear, the enamel of the occlusal, or biting surface, is gradually worn away, revealing the darker coloured dentine below (Grant 1982). The surface detail is abraded and the crown starts to be worn down; at the same time the base of the crown and then the roots are formed, and the tooth-crown gradually emerges from the jaw. With increasing wear, more and more of the crown is worn away. Detail is obscured by the deposition of secondary cement, until, with advanced wear, the crown of the tooth may be completely worn away, leaving nothing but worn root stumps (Payne 1985). The enamel and dentine forms

distinct patterns on the occlusal surface (Grant 1982). The wear of a tooth is normally heaviest on the anterior pillar since it erupts first and consequently comes into wear sooner than the second and third pillar (M3) (Grant 1982).
Tooth measurements may also be affected by wear: the mesio-distal length of the first molar, for instance, decreases with wear because the crown narrows from tip to base (Payne 1985).
In this study the methodology of ageing teeth developed by Grant (1982) has been used to rank the wear stages of the teeth into groups which are assumed to correspond with age. Payne's (1982) methodology has been used to link realistic ages to the mandible wear stages as described by Grant.

1.4 Tell Bouqras

Tell Bouqras is situated in eastern Syria, on the right bank of the Euphrates, circa 35 kilometres southeast of Deir ez-Zor. The Neolithic village was built on a promontory of a plateau overlooking the Euphrates floodplain, just opposite the mouth of the river Khabur (Akkermans 1983). The Bouqras village originates in the second Neolithic period, the Pre-Pottery Neolithic B. This period is characterised by properly built houses and the archaeological findings of cereals. New in this period is the full domestication of animals (Buitenhuis 1988). Tell Bouqras may be representative for the second stage of the domestication period. This second stage happened in the second half of the seventh millennium BC. Man left the area of known earliest domestication (the hills and foothills of the Taurus and Zagros mountains) and migrated with their domesticated animals westward to Anatolia and southern Europe, south to the steppe of the Middle East and northern Africa, and East to Afghanistan and Pakistan (Akkermans 1983).

1.4.1 Geology of Tell Bouqras

The study of environmental conditions within a prehistoric framework may lead to a better understanding of the choice prehistoric man made for certain sites and the use of the environment of a chosen site for subsistence (Boerema 1979).
Two different soil-landscapes must be distinguished: the plateau and the valley floor. Soils of the plateau are aridisols; soils of the valley floor are arid and frequently saline categories of entisols and some aridisols. The location of Tell Bouqras is situated on the border between these two soil-landscapes (see figure 1.1) (Boerema 1979). The actual landscape is built up of two components, corresponding with the soil-landscape. One component is the high, flat and dry plateau, consisting of mainly gypsiferous subsoil on the right bank of the Euphrates valley, and gravelly Euphrates terrace materials of various Pleistocene ages especially on the left bank. The flat plateau is covered with a plant cover of steppe-desert type, very widely spaced as a result of relatively intense (over) grazing.
The second component is the Euphrates valley itself, a floodplain that originated at the end of the Pleistocene. The border between these two components is a steep slope, at some places forming a very steep cliff up to 40 – 50 m high (Boerema 1979).
The location of the site present optimal possibilities for the exploitation of a variety of environments. The steppe offered good grazing and hunting places. The valley with the river, as well as the forest and the frequently inundated lands offered a rich animal life. Close to the mouth of a relative large wadi, moisture is available for the cultivated food plants in the growing season (Akkermans 1981).
Actual mean precipitation is 125 mm per year. This is far too low to practice rainfed agriculture. One will need irrigation systems or groundwater at relatively shallow

depths to be able to practice agriculture. On the plateaux, neither is the case. Since irrigation is not practised on the plateau, its use was restricted to extensive grazing. One exception must be made: the wadi bottoms in the plateau area have a sufficiently high groundwater table. Arable land-use therefore was limited to the valley floor and some wadi bottoms (Akkermans 1983).
Studying the exact location of the site, it is striking that Tell Bouqras is situated on a terrace remnant. These terrace materials are calcareous but non-gypsiferous; a remarkable contrast with the surrounding, mainly consisting of gypsiferous rock. By avoiding the gypsiferous rock, one does not risk the subsidence of houses by the (gradual) dissolution of the relatively soluble gypsum. Therefore, the choice of the site for settlement might have been determined by the presence of the non-gypsiferous subsoil (Boerema 1979&1980).

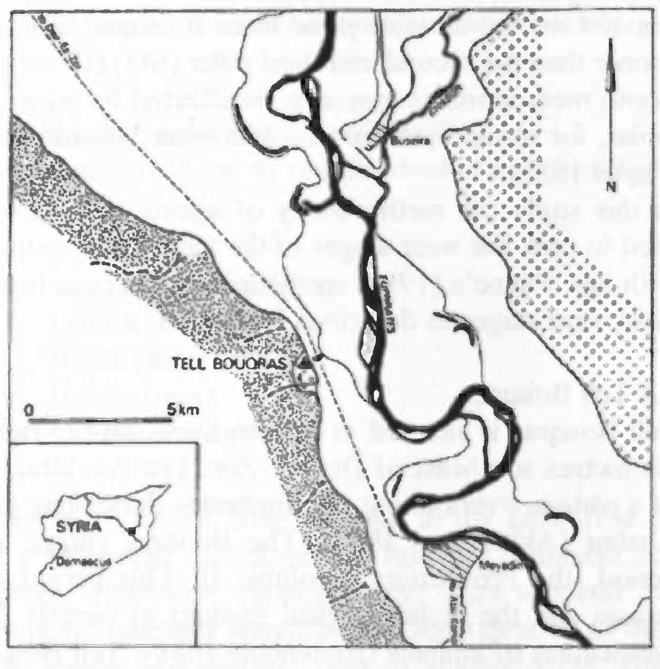

Figure 1.1: Landscape around Bouqras with the Euphrates running in a southern direction, the valley floor (white), the plateau on the right bank (densely grey) and the plateau on the left bank (lighter grey) . [1]

1.4.2 Food supply

Sheep and goat formed from the beginning of this tell the basis of the animal food supply. Shortly after the beginning of the tell, cattle was introduced as an extra food supply. The question whether these animals were domesticated or wild and hunted upon, is essential for the interpretation of the culture of this people.
That most of sheep and goats were probably domesticated animals can be deduced from the low numbers in which gazelle, wild and domesticated cattle and pigs were found. The flat steppe plain, in which Bouqras was situated, seems to be a more likely natural habitat for wild sheep than for wild goat. The complete dependence on goat, sheep and cattle is evidence, that these species were domesticated. The inhabitants of Bouqras must have had knowledge about the broadness of the fauna in their environment. The herding of domesticated *Ovis*, *Capra* and possibly *Bos* must be seen as a conscious choice (Buitenhuis 1988).

[1] Figure 1.1: Akkermans *et al.* (1983)

2. Materials and methods

2.1 The excavation

The Neolithic tell near the present village of Bouqras Fôqani was discovered by the soil scientist W.J. van Liere. Together with H. de Contenson he excavated two test pits in 1965. In 1975 H.T. Waterbolk obtained permission for further excavations. Under the supervision of H.T. Waterbolk and M.N. Loon, a joint team of the universities of Groningen and Amsterdam was formed with J.J. Roodenberg and P.A. Akkermans as field directors (Akkermans 1981). This excavation was executed from 1976 until 1978 (see figure 2.1). A new section down to the terrace surface was made in the two adjacent pits dug by de Contenson and van Liere in 1965. These two pits, 1513 and 1913 were dug up to the natural bottom. Later, also the pits 1613, 1713 and 1813 were dug up to the natural bottom. All the earth dug up during the excavation was sieved with a mesh of 4 * 4 mm (Buitenhuis 1988). This section showed 21 strata of various deposits, corresponding with ten architectural levels with a total thickness of 4.50 meter. It seemed that these ten levels could be grouped into seven major occupation phases. The small rooms in the Northwest sector of the houses from levels 10 and 8 in square 15/13 are about 2.5-3.5 m long and 1.75-2.0 m wide. Radiocarbon dates indicate an uncalibrated age of c. 6400 – 5900 BC (Akkermans 1981).

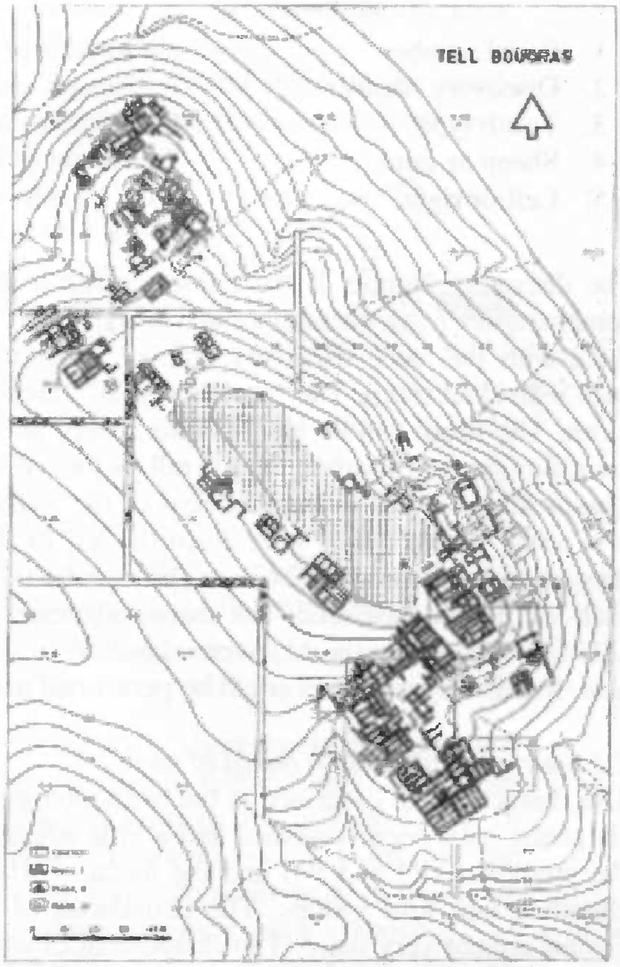

Figure 2.1: Contour map of Tell Bouqras. [1]

The bone material dug up from the pits 1513 -1913 is the only bone material from this site with stratified layers, indicating different time periods. The bone material from these test pits is used in this study because it can possibly reveal information about shifts in the way the inhabitants used their livestock over time. In order to reveal this relationship, the Ovicapra teeth of the lower were collected and identified at species level. Furthermore bones and bone fragments from fish, small mammals as hare, fox and mice were separated out. Also valves, obsidian and worked bone material were gathered.

The bone material excavated was transported to the Netherlands. This bone material is, during the selection of material, in permanent loan at the Archaeological Research and Consultancy in Groningen. The bone material excavated in these squares is as-

[1] Figure 2.1: Akkermans *et al.* (1983)

sumed to be representative for the whole Tell. Conclusions derived from this research on the bone material from pits 1513 to 1913 are expected to apply for the whole site.

2.2 Methods

The following information is, as far as possible, recorded for each tooth:
The length, wide and height measurements are done to reveal possible metric differences between the teeth of sheep and goat.

1. Serial number
2. Discovery number
3. Tooth type
4. Sheep or goat
5. Left or right
6. Maxilla or mandibular
7. Length (mm)
8. Width (mm)
9. Height (mm)
10. Characteristics (1- 6)

The discovery number is the number given to the bone material in the field. It is a combination of the pit number and a sequential find number. There are a number of teeth with the same discovery number. Therefore, serial numbers were ascribed to each individual tooth. The "sheep or goat" category stands for the identification of the tooth. The tooth can be identified as sheep, intermediate, goat or unidentifiable. The identification of a tooth is the overall picture of the tooth, which is the result over the classification as well as the clearness of the characteristics of each tooth. For all teeth it is noted whether they were from the left or the right side of the jaw and whether they were from the mandibula or the maxilla. The length, width and crown height of each tooth were measured. The characteristics of each tooth, three each for the P3, P4, M1, M2 and six for the M3 were classified as sheep, intermediate, goat or unidentifiable. In this way, statistics could be performed on the results.

2.3 Species identification based of teeth

The characteristics described in the methodology of Helmer (2000) and Halstead *et al.* (in press) have been combined and a little adjusted. In order to test the methodology, the premolars (P3 and P4) and the molars (M1-M3) derived from the lower jaw are classified into four groups. The boundaries of the characteristics between this four groups are not very sharp. The characteristics were classified, and therefore teeth were identified to species level on bass of the highest resemblance with one of the four distinctive groups.
The first distinct group is sheep; the second group is called intermediate. Molars and premolars of this group do not have distinctive characteristics and therefore can not be identified as either sheep or goat. The third group exists of premolars and molars identified as goat. The fourth and last group is the group called unidentifiable. Characteristics of teeth from this group are outside the description of the methodology. The fading of characteristics, which is caused by ageing, often leads to the identification of teeth into this group.
Also a few pd3 and P2 are identified on species level. The pd3 resembles the P3; the determination of the pd3 was based on the characteristics of the P3. The P2 was only identified when present in a jaw with other mandibular teeth. The P2 then was assigned to the same group as the other mandibular teeth of the same jaw.
The following characteristics have been developed by Halstead *et al.* (in press).

“ Premolar 3

<u>P3.1</u> A vertical ridge in the middle of the lingual face is more steep in sheep than in goat. As a result, the lingual edge of the occlusal face is usually clearly stepped in sheep and usually forms a more or less straight line, inclining bucally in a posterior-anterior direction, in goat. (Figure 2.2 and 2.3)

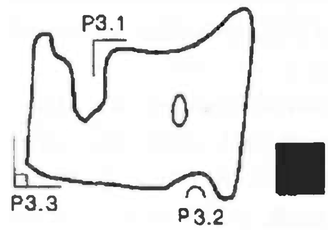

Figure 2.2 : Mandibular P3 sheep [2]

<u>P3.2</u> The vertical ridge on the distal-buccal corner tends to be more pronounced in sheep. As a result, the distal part of the buccal edge forms a relatively distinct and deep hollow in sheep, but a more or less shallow and indistinct hollow in goat.

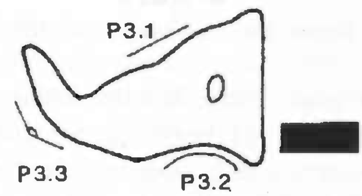

Figure 2.3: Mandibular P3 goat [2]

<u>P3.3</u> The mesial part of the buccal face slopes inwards (lingual) in a posterior-anterior direction more strongly in goat than sheep: the mesial face often slopes anteriorly in a buccal-lingual direction in goat, but is typically perpendicular to the axis of the mandible in sheep. As a result, the mesio-buccal quarter of the tooth tends towards a right angle in sheep, but towards a more open angle in goat. (NB the mesio-buccal corner may be rounded or angled in both species.)

Premolar 4

<u>P4.1</u> A vertical rib, projecting lingually, in sheep typically marks the mesio-lingual corner: this feature is typically weak or absent in goat.

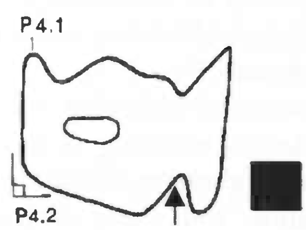

Figure 2.4: P4 sheep [2]

<u>P4.2</u> The mesio-buccal quarter of the tooth forms an open angel in goat, but is closer to a right angle in sheep.

<u>P4.3</u> The third characteristic for the fourth premolar described by Halstead *et al.* has not been used in this study. This characteristic describes the ratio between the length and the width of the tooth (see the block). During the identification this characteristic seemed to be unclear. However, the efficiency of this characteristic could be tested because the length and width were measured. Instead of this characteristic the ridge of the buccal side has been used (see arrow). In sheep this ridge is narrow and steep in goat this edge tends to be more open. (Figure 2.4 and 2.5)

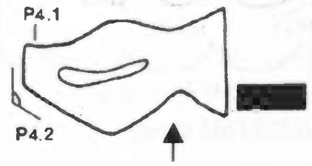

Figure 2.5: P4 goat [2]

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[2] Figure 2.2 – 2.5: Grant (1982)

Molar 1 and Molar 2

M1.1 The mesial part of the buccal edge is typically convex in sheep, but often concave in goat. Note that the mesial part of the buccal edge may be somewhat hollow in unworn M1 and M2 and also in heavily worn M1 and M2. (Figure 2.5 and 2.6)

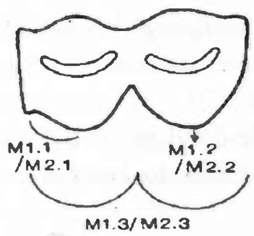

Figure 2.6: Mandibular M1/M2

M1.2 The buccal edge of the disto-buccal cusp of M1 and M2 often points strongly in a posterior direction in goat, while it is typically symmetrical in sheep. A strong posterior orientation is indicative of goat. A slight posterior orientation (or not at all), although more typical of sheep compatible with either sheep or goat. Note that the distal margin of unworn and lightly worn M1 and M2 of both species flares in a posterior direction so that, the buccal edge of the disto-buccal cusp may be symmetrical even in goats.

M1.3 The buccal edge of M1 and M2 overall tends to two pointed 'triangular" appearances in goat and to rounded, 'arcaded' appearances in sheep.

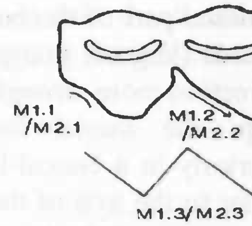

Figure 2.7: Mandibular M1/M2

Molar 3

M3.1 The mesial part of the buccal edge of the mesiobuccal cusp of M3 is typically convex in sheep, but often flat or concave in goat. Note that the mesial part of the buccal edge may be somewhat concave in heavily worn M3 even in sheep. Criterion M3.3 may aid correct identification in such cases. (see figure 2.8 and 2.9)

M3.2 The buccal edge of the centro-buccal cusp of M3 often points strongly in a posterior direction in goat, while it is relatively symmetrical in sheep. A strong posterior orientation is indicative of goat, but a slight or no posterior orientation is compatible with sheep or goat. Note that the distal margin of the centro-buccal cusp of unworn and lightly worn M3 flares in a posterior direction so that, in such cases, the buccal edge of this cusp may be symmetrical even in goats.

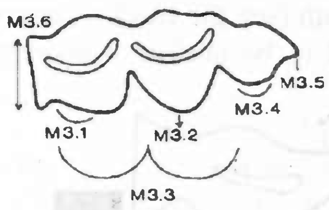

Figure 2.8: M3 sheep [2]

M3.3 The buccal edge of the mesial and central parts of M3 tends to three pointed, 'triangular' appearances in goat and to three rounded 'arcaded' appearances in sheep. A flat and pointed profile is indicative of goat: conversely, a rounded profile is more typical of sheep than of goat, but is of less diagnostic value than the corresponding criteria in M1 and M2.

[2] Figure 2.4 – 2.8: Grant (1982)
[2] Figure 2.9: Grant (1982)

M3.4 The buccal edge of the distal cusp of M3 is often more or less pointed in goat and typically rounded in sheep. A pointed edge is suggestive of goat, but a rounded edge is compatible with sheep or goat.

M3.5 The distal margin of the distal cusp of M3 often has a buccal defined 'flute' in sheep, rarely so in goat. The presence of a flute is strongly suggestive of sheep, while its absence is suggestive of goat. Note that a flute defined only lingually is of no diagnostic value and that a buccally defined flute may be clearer in buccal than in occlusal view.

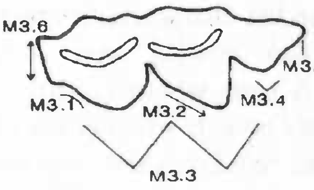

Figure 2.9: M3 goat [2]

M3.6 The flange on the mesial face of M3 tends to be broad in sheep and narrow in goat, but this feature is heavily influenced by, and must be judged relative to, the degree of occlusal wear. A broad flange is suggestive of sheep in a lightly worn M3 and less securely so in an M3 of medium wear, but may be compatible with either species in a heavily worn M3. Conversely, a narrow flange is strongly suggestive of goat in an M3 of medium or heavy wear and less securely so in a lightly worn M3.“

2.4 Ageing teeth

The age-stages of the teeth were determined using the mandible wear stages described by Grant (1982). This methodology is based upon the patterns which originate as a result of the wear of teeth. The shape of the enamel and dentine on the occlusal surface forms distinct patterns (Grant 1982). These distinct patterns caused by the wear of teeth are translated into tooth wear stages. These stages were than interpreted with the methodology of Payne (1982) and Grant (1982). Paynes method indicates real ages, Grants method tooth wear stages. The intervals that occur between the tooth wear stages are illustrated in appendix A. They do not represent equal intervals of time. Some stages last for a relatively short period, while others last much longer. For example, while the tooth wear stage "g" in all the three lower molars of sheep is a very long lasting stage, the early stages of wear in most teeth tend to be relatively short (Grant 1982).

Since the wear of a tooth is a continuous process, some teeth may exhibit wear patterns that lie between two tooth wear stages illustrated. In these instances, the teeth were assigned to the tooth wear stage most closely resembling the observed wear pattern.

2.5 Statistics

To answer the question whether the methodology of Halstead *et al.* (in press) can be used on this bone material and to answer questions about the relationship between man and sheep and goat, the recorded information was edited in EXCEL 97. SPSS was used for the statistical analyses of the results. For the discriminant tests, the groups of teeth identified as sheep and goat were used. With the classification of the characteristics of teeth from these two groups, the canonical discriminant functions were calculated. These functions were used to statistically ascribe all identified teeth into the group sheep or goat. The following tests were performed:

- ✓ The bivariate correlation test was used to investigate the correlation between the different characteristics per tooth. This test indicates whether the distinction between the groups on basis of the characteristics is significant. Furthermore this test gives insight in the consistency of the identification of the teeth to species level based on the characteristics by the researcher.
- ✓ The characteristics were tested with the One-way ANOVA. The One-way ANOVA tests whether groups are distinct, or must be considered as one group. This tests reveals whether the characteristics are equal or not.
- ✓ The data reduction test was used to analyse the significance between the separate characteristics and the defined groups.
- ✓ From the canonical-classified-discriminant analysis a number of tests were used. With the test of the equality of group means, it was tested whether the characteristics are equal or not. The box test reveals whether the characteristics together give equal groups or not. The Eigenvalue reveals the significance of the correlation between the characteristics and the determined groups. The Wilks Lambda tests whether there is one group or more than one.
- ✓ The canonical discriminant function coefficients and the function at group centroids were calculated in order to test whether the teeth were statistically placed into the right groups.

3. Results

3.1.1 Total numbers of teeth

From the bone material excavated in Tell Bouqras, 2137 teeth of Ovicapra were collected and analysed. From this number of teeth, 1058 were from the maxilla and 1079 belonged to the mandibula. From the 1079 mandibular teeth, 968 were identified to species level with the methodology of Halstead *et a*l (in press). The M1 was found in the largest numbers and the M3 in the lowest numbers. Table 3.1 present the amount of premolars and molars from the upper and the lower jaw.

Teeth	Maxillary	Mandibular
P3	162	149
P4	140	147
M1	236	296
M2	182	222
M3	93	97

Table 3.1 Number of teeth from maxilla and mandibula.

3.1.2 Percentage of sheep and goat

The percentage of sheep and goat were determined on basis of the premolars (P3-P4) and the molars (M1-M3) from the lower jaw. The characteristics on basis of which the identification was done are given in chapter 2.3. In table 3.2 the number of teeth from the groups sheep, goat, intermediate and unidentified are presented. The amounts of teeth are split up in teeth from the left and the right side of the jaw.

Group	Left	Right	Total	%
Sheep	300	284	584	60.3
Intermediate	47	50	97	10.0
Goat	106	67	173	17.9
Unidentifiable	49	65	114	11.8

Table 3.2 Determined teeth derived from the left and the right side of the jaw.

Surprisingly, the number of left side teeth identified as goats, is more than 50% higher than the number of the right side teeth. Over 60% of the total amount of identified teeth were identified as sheep. Almost 18 % of this amount were ascribed to goat. The ratio between sheep and goat is 77:23. On basis of the canonical test, the teeth were statistically identified (see Appendix B). Table 3.3 shows the statistical determined amount of teeth from sheep and goat.

Group	Total	%
Sheep	589	67.7
Goat	281	32.3

Table 3.3 Number and percentage of teeth per group based on canonical discriminant test.

The proportion sheep is lower calculated on basis of the canonical discriminant analyses. In table 3.4 an overview is given about the amount and percentage of teeth per group.

	Sheep		Intermediate		Goat		Unidentifiable	
Tooth	Total	%	Total	%	Total	%	Total	%
P3	78	16.8	10	12.0	55	52.4	6	5.8
P4	115	24.8	14	16.9	11	10.5	5	4.9
M1	122	26.3	39	47.0	49	46.7	83	80.6
M2	155	33.5	20	24.1	35	33.3	11	10.7
M3	71	15.3	10	12.0	10	9.5	4	3.9

Table 3.4 Number and percentage of tooth type per determined group.

The M1 is placed in high numbers into the groups intermediate and unidentifiable. The M3s were more often determined as sheep than as goat. For the P3 the opposite can be said.
Table 3.5 gives the numbers of teeth per species based on the canonical discriminant analysis. The sheep:goat ratios are also presented in this table.

Tooth	Sheep (After)	Goat (After)	Ratio sheep:goat (After)	Ratio sheep:goat (Before)
P3	82	66	1.2 : 1	1.4 : 1
P4	119	28	4.3 : 1	10.5 : 1
M1	167	116	1.4 : 1	2.5 : 1
M2	159	60	2.7 : 1	4.4 : 1
M3	62	10	6.2 : 1	7.1 : 1

Table 3.5 Number of tooth type per species based on the canonical discriminant analysis. Ratio's are given before and after the canonical discriminant analysis.

The sheep:goat ratios of the tooth types are more similar after the statistical analysis. The ratio seems to increase with the age each tooth type breaks through the jaw. In this rank, the ratio of the P3 is a bit low and the ratio of the P4 high. This applies especially to the ratios calculated before the canonical discriminant analysis.

3.1.3 Percentage of sheep and goat per level

During the excavation of Tell Bouqras, ten distinct levels were found. Each level belongs to a subsequent other time period. Level 1 is the youngest level, level 10 the oldest. In order to be able to answer questions about the relationship between man and Ovicapra over time, it is important that the whole time-period is represented by more or less equal amounts of teeth. From the levels 2, 4 and 9 low numbers of teeth were found. Therefore, the levels 1and 2, 3 and 4, 9 and 10 were combined. Table 3.6 represents the number of teeth found per (combined) level.

Level	Total
1--2	368
3--4	262
5	334
6	305
7	221
8	292
9--10	353

Table 3.6 Number of teeth per level.

In table 3.7 the number as well as the percentage of teeth identified as sheep, intermediate, goat or unidentified per level are given. Levels 1 and 2, 3 and 4, 9 and 10 are combined.

	Sheep		Intermediate		Goat		Unidentifiable	
Level	Total	%	Total	%	Total	%	Total	%
1--2	72	49.0	16	10.9	38	25.9	21	14.3
3--4	68	60.2	9	8.0	24	21.2	12	10.6
5	106	64.6	9	5.5	19	11.6	30	18.3
6	113	73.9	10	6.5	17	11.1	13	8.5
7	71	59.7	15	12.6	26	21.8	7	5.9
8	66	51.2	15	11.6	29	22.5	19	14.7
9--10	89	61.8	23	16.0	20	13.9	12	8.3

Table 3.7 Number and percentage of teeth per group per level.

The percentage sheep is the highest in level 6 and the lowest in level 1--2. The percentage of goat is the highest in the levels 1--2 and the lowest in the levels 5 and 6.

In figure 3.1 the sheep:goat ratio is plotted against the levels.

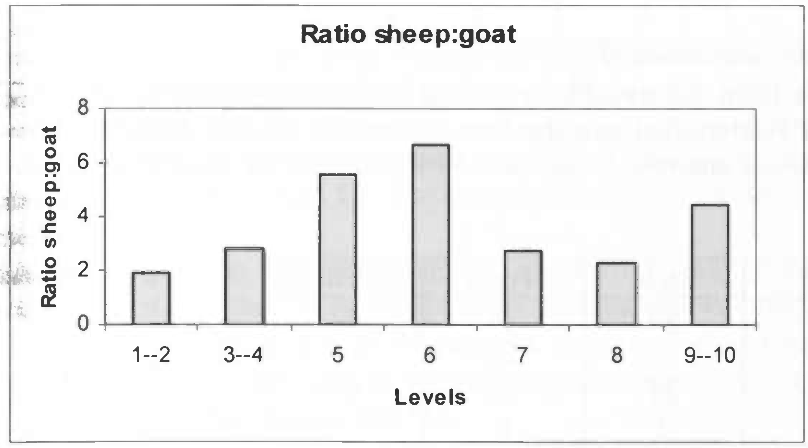

Figure 3.1: Sheep:goat ratio per (combined) level.

The ratio declines from level 10 to level 7. The ratio in level 6 and 5 is very high. From combined level 3--4 to the combined level 1--2, the sheep:goat declines again. The table and figure about the number of teeth per species per level after the canonical discriminant analysis are given in appendix B.

3.1.4 Kill-off pattern

Not only is the sheep:goat ratio important in answering ecological and cultural questions, but also the age structure of the slaughtered sheep and goat must be studied to answer questions about the purpose the animals were kept for. Figure 3.2 presents the overall kill-off pattern of sheep and goat.

The kill-off patterns of sheep and goat resemble each other strongly. The largest numbers of sheep were slaughtered between the mandible wear stages of 30 to 35. This corresponds to an age between 20 and 40 months. Appendix C contains figures presenting the kill-off patterns of sheep and goat per (combined) level. The kill-off patterns over time of sheep as well as the kill-off patterns over time of goat highly each other. Although, in the oldest levels the goat were slaughtered at a bit younger age than in youngest stages. The number of goats slaughtered between the age of 35 to 48 month's increases over time.

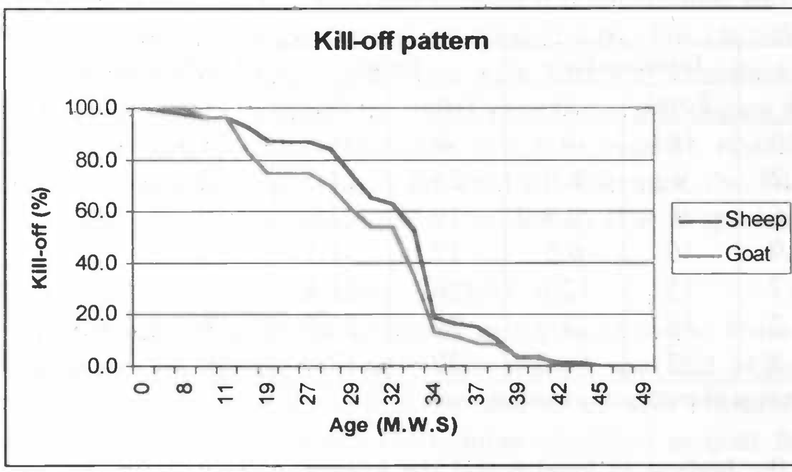

Figure 3.2 Kill-off pattern of sheep and goat, the wear stages are after Grant (1982).

In the following paragraphs the results of the research on separate tooth types will be given. Only those tooth types used for the identification on species level are discussed.

3.2.1. Premolar 3 from the mandibula (P3)

The total amount of P3s from the mandibula studied in this study is 149. Table 3.8 presents the number of P3s identified into the four determined groups, before and after the canonical discriminant analysis. From the 149 P3s found, 78 were identified as sheep and 55 as goat.

Group	Left	Right	Total	Statistical
Sheep	38	40	78	82
Intermediate	7	3	10	
Goat	30	25	55	67
Unidentifiable	4	2	6	

Table 3.8 Number of P3 per group, from the left and right jaw and total numbers before and after the canonical discriminant analysis.

Table 3.8 shows that the numbers of P3 from the left side of the jaw, are nearly equal to the amount from the right side of the jaw. This applies to all the four distinctive groups. The sheep:goat ratio of P3 is 1.4 : 1. Only a few P3s were determined as intermediate or unidentifiable. From the P3s, 82 were statistically determined as sheep and 67 as goat. All the teeth determined as unidentifiable were statistically determined as goat. The sheep:goat ratio shifts from 1.4 : 1 to 1.2 : 1.

The results of the statistical tests of the P3 are presented in appendix D. The correlation test shows that characteristic 3 has the highest correlation with the final determination. Characteristic 1 and 3 are more correlated with each other than with characteristic 2. Characteristic 2 seems to be the least decisive, this applies for sheep as well as for goats. Using the One-way ANOVA, the probability of equality was tested. The probability of equality is 0.000 for all the characteristics. The One-way ANOVA test concludes that the characteristics are distinct groups. The group statistics show that for the P3s determined as sheep characteristic 3 has the value nearest to one. For the P3s determined as goat, characteristic 1 has the nearest value to three. The equality test shows the same results as the One-way ANOVA. The equality test of group means shows that all characteristics are significantly different. The Eigenvalue test shows that the canonical correlation between the characteristics and the distinctive groups is 0.966. The Wilks lambda test shows that, with a significance of 0.000, the sheep and goat are not one group. The classification results show that 100% of the originally grouped cases were correctly classified. This means that teeth were consistently identified. The canonical discriminant analysis was used to test whether the length, width and height, correlated to age can be used as a characteristic for the determination of the P3. The classification results show that 72% of the originally grouped cases were correctly classified.

3.2.2.Premolar 4 from the mandibular (P4)

From the 147 studied P4s 114 were identified as sheep and 11 as goat, based on the methodology described in chapter 2.3. The sheep:goat ratio of the P4 is much higher than the ratio for the other tooth types.

Group	Left	Right	Total	Statistical
Sheep	61	54	115	119
Intermediate	10	4	14	
Goat	7	4	11	28
Unidentifiable	3	2	5	

Table 3.9 Number of P4 per group, from the left and right jaw and total numbers before and after the canonical discriminant analysis.

The canonical discriminant test was used to calculate the statistical identification of individual P4s (Appendix E). The sheep:goat ratio of P4 decreases after this test from 10.45 :1 to 4.25 : 1.

Table 3.10 gives an indication about up to which age all the P4s could be determined. Table 3.10 shows that up to an age of 47 months all P4s could be identified. From the group of P4s with an age of 90 months, still 11 % could be identified. The age at which the P4 becomes hard to identify on species level is for the P4 higher than for the M1and M2 and even for the M3.

Age (months)	Percentage identified to species	Total
28.5	100.0	24.0
30.5	100.0	15.0
36	100.0	27.0
47	100.0	22.0
58	96.4	28.0
75	91.7	12.0
90	72.7	11.0

Table 3.10 Percentage of P4 identified to species level per age, plus amount of P4 per age group.

The results of the statistical test are presented in appendix E. The bivariate correlation test shows that characteristic 1 has the highest correspondence with the identification to species level. The test also shows that the correlation between characteristic 2 and 3 is very low. Characteristic 1 is the first one that fades with the ageing of the P4. The One-way ANOVA test shows that all the characteristics can be seen as distinct groups, with a significance level of 0.000. The group statistics show again that characteristic 1 has the highest correspondence with the identification on species level. The canonical correlation between the classification of characteristics and the identification of the P4 is 0.81. The Wilks lambda test shows that with a significance of 100% the groups sheep and goat are distinctive groups. The classification results show that 96% of the originally grouped cases were correctly classified. The teeth were consistently determined. In appendix E the canonical discriminant function coefficients are given. The canonical discrimination test was used to reveal whether the measured length, width and height could be used to determine the P4. This test showed that these measurements **can not** be used to identify P4s on species level.

3.2.3 Molar 1 from the mandibular (M1)

The total amount of M1s collected from the Bouqras bone material is 293 pieces. From these 293 pieces, 151 were from the left side and 142 were from the right side of the mandibula. Striking is that the number of M1s from the left side of the jaw and identified as goat, outnumber the number identified as goat from the right side of the jaw. Table 3.11 shows the number of M1s per distinctive group, split up in left and right side of the jaw.

Group	Left	Right	Total	Statistical
Sheep	66	56	122	167
Intermediate	16	23	39	
Goat	34	15	49	116
Unidentifiable	35	48	83	

Table 3.11 Number of M1 per group, from the left and right jaw and total numbers before and after the canonical discriminant analysis.

The canonical discrimination test was used to calculate the statistical identification of individual M1. The sheep:goat ratio of the M1 decreases from 2.89 : 1 to 1.44 : 1.
Table 3.12 gives an indication about the percentage of M1s which can be identified per age group, the number of M1s per age group are presented in the last column.

Age (month)	Percentage determined to species	Total
3.2	100.0	1
4.3	100.0	1
5.7	100.0	2
7.6	100.0	2
11.0	100.0	21
14.3	100.0	35
25.0	88.2	144
39.0	22.5	40
42.0	33.3	12
50.0	37.5	16
60.0	0.0	2
75.0	12.5	16
90.0	0.0	1

Table 3.12 Percentage of M1 identified to species level per age, plus number of M1s per age group.

The identified percentage decreases at an age of 25 months. This is sooner than for the other tooth types. After 50 months only 37.5% of the M1s were identified.
Appendix F incorporates the results of the statistical tests done on the results of the M1. The bivariate correlation test shows that characteristic 2 and 3 have the highest correlation with the identification of sheep and goat. Characteristic 1 has the highest degree of unidentifiability. The One-way ANOVA shows that the characteristics are 100% distinctive groups. The group statistics table shows the same results as the bivariate correlation analysis: characteristic 3 is the most discriminative for sheep and characteristic 1 for goat. The Equality test also shows that the characteristics must be seen as distinctive groups. The canonical correlation between the characteristics and the final determination is 0.947. Furthermore the canonical discriminant function coefficients are given. These coefficients are used to calculate identify statistically the individual teeth. The canonical discriminant analysis revealed that the length, width and height, correlated with age **can not** be used as a characteristic for the determination of the M1 into sheep or goat.

3.2.4 Molar 2 from the mandibular (M2)

The total amount of M2s collected from the bone material is 221. From these 221 pieces, 154 were identified as sheep and 34 as goat. Table 3.13 presents the amount of M2 per group, split up in M2s from the left and from the right side of the jaw. Also the number of M2s identified as sheep or goat before and after the canonical discriminant analysis are given

Group	Left	Right	Total	Statistical
Sheep	79	75	154	159
Intermediate	8	12	20	
Goat	23	11	34	60
Unidentifiable	2	9	11	

Table 3.13 Number of M2 per group, from the left and right jaw and total numbers, before and after the canonical discriminant analysis.

The sheep:goat ratio declines after the statistical determination from 4.53 to 2.65. Table 3.14 gives an indication about the percentage of M2s, which can be determined per age group

Age (months)	Percentage identified to species	Total
11.1	100	6
13.8	100	11
16.0	100	2
26.0	100	31
33.0	100	54
50.0	95	100
60.0	78.6	14
82.0	0	2
90.0	0	1

Table 3.14 Percentage of M2 identified to species level per age and total numbers per age.

Table 3.14 shows that at the age of 50 months still 95 % of the M2 could be identified. After 80 months the M2s could not longer be identified.

Appendix G incorporates the outcome of the different statistical analyses done on the results of the M2. The bivariate correlation test shows that characteristic 3 has the highest correlation with the determination of the M2. Characteristic 2 and 3 are more correlated to each other, than to characteristic 1. With a significance of almost 100%, the characteristics are distinctive groups. Characteristic 1 is the characteristic most classified as unidentifiable. The One-way ANOVA as well as the test of equality of group means come to this conclusion. The canonical correlation between the characteristics and the distinctive groups is 0.89. In appendix G also the canonical discriminant function coefficients and the functions at group centroids are presented. The canonical discriminant analysis pointed out that the length, width and height, correlated to age **can not** be used for the determination of the M2 as sheep or goat.

3.2.5. Molar 3 from the mandibular (M3)

From the bone material 95 M3s were collected. From this amount, 71 were identified as sheep and 10 as goat. Table 3.15 shows the numbers per group, split up from the right or the left side of the lower jaw. The total numbers per group before and after the canonical discriminant analysis are given.

Group	Left	Right	Total	Statistical
Sheep	34	37	71	62
Intermediate	5	5	10	
Goat	3	7	10	10
Unidentifiable	1	3	4	

Table 3.15 Number of M3 per group, from the left and right jaw and total numbers before and after the canonical discriminant analysis.

The canonical discriminant test identified 62 M3s as sheep and 10 as goat. The sheep:goat ratio declines from 7.10 : 1 to 6.20 : 1.

Table 3.16 presents the percentages of M2, which could be identified per age group. The youngest M3 found, was from an animals with an age of approximately 31 months. Table 3.16 shows that until the age of 70 months 100 % of the M3s could be identified. Only two M3s with an age of 90 months were found, both could not be identified.

Age (month)	Percentage determined to species	Total
31.5	100	3
37	100	8
39	100	5
44	100	4
48	100	9
52	100	15
70	100	38
80	80	10
90	0	2

Table 3.16 Percentage of M3 determined per age, plus number of M3 per age group.

The results of the statistical analyses are presented in appendix H. The bivariate correlation test shows that characteristics 4 and 5 are less distinctive than the other characteristics Characteristic 1 is the characteristic which is the most often classified as unidentifiable. The One-way ANOVA as well as the equality test of group means show that the characteristics are distinctive groups. The canonical correlation between the characteristics and the determined groups is 0.91. Furthermore, in appendix H the canonical discriminant function coefficients and the functions at group centroids are incorporated. The canonical discriminant analysis pointed out that also for the M3, the length, width and height measurements, correlated with age **can not** be used to sort the M3 of goat from the M3 of sheep.

4. Discussion

4.1 Assumptions

A few assumptions are made in this study. The studied bone material is assumed to be a random sample of the total excavated bone material from Tell Bouqras. The bone material from the pits 1513 to 1913 is assumed to be representative for the whole site and that the samples for the ten distinguished levels are assumed to be representative for the period they represent. Conclusions based on the studied teeth per level, are assumed to apply for all the excavated bone material from that level.

Furthermore, it is assumed that the characteristics described by Helmer (2000) and Halstead *et al.* (in press) are correct. The lack of original data from Halstead *et al.* and Helmer makes it impossible to check this. Their methodologies have been developed on dental material from which the species was known. This study tries to reveal the efficiencies and deficiencies of the use of the characteristics for the identification of species based on teeth.

The methodologies of ageing teeth of sheep and goat have limitations due to factors, which influence the manner and rate of wear. Within a single population individual variation in rates and patterns of tooth wear can be quite high. Consequently the method is not reliable for ageing individuals. The methodologies can be used to estimate the overall age structure of the population (Stallibrass 1982). The variation in patterns of tooth wear can not only be high in a population, but also between populations. Regional differences in climate and environment can be causes for differences between the tooth wear of populations. Differences in the quality of food lead among other things, to differences in nutrient intake and differences in the rate of wear. The ages ascribed to teeth from this site can not, without doubt, be compared to teeth from sheep and goat excavated in other sites.

4.2 The methodology

For the discussion about the efficiencies and the deficiencies of the methodology developed by Helmer (2000) and Halstead *et al.* (in press), the following observations play an important role.

As already noticed by Halstead *et al.* (in press), the methodology can not be unambiguously used on dental bones with a high age. In this study it was established until which age 100% of the mandibular teeth could be identified.

Furthermore the correlation between the classification of the characteristics with the identification of teeth plays an important role. Conclusions can be drawn about which characteristic is the most distinctive and which is least distinctive. Distinctiveness does not say anything about the reliability of the characteristic. Also something can be said about which characteristic fades first with the ageing of teeth.

With the ageing methodologies of Grant (1982) and Payne (1982) the ages of the individual teeth were determined. These methodologies can only be used on the P4, M1, M2 and M3 from the mandibula. As a tooth ages, it comes in wear. The wear stage of a tooth influences the clearness of the characteristics. The M3 is the tooth, which can be determined at species level until the highest age. All M3s with an age of 70 months were identified as either sheep, goat or intermediate. This conclusion is not very remarkable. The M3 is the tooth which erupts last through the jaw, and becomes therefore last into wear. This results in an indistinctive identification until high ages. The M1 is the tooth type, which can be less clearly determined in older teeth. This has consequences for the outcome of this study. The M1 is the tooth type with the highest

number of teeth found. Therefore, a large part of the determined teeth can not be unambiguously determined. This makes conclusions about the sheep:goat ratio, the kill-off patterns for sheep and goat separately and the deduction of the relationship between man and *Ovicapra* less distinct.
In discussing the efficiencies and deficiencies of the characteristics on which the identification of the teeth was based, one can say that for all the determined tooth types the identification was consistently done.
For the M1, M2 and M3 the first characteristic, which describes the mesial part of the buccal edge for sheep as convex and for goat somewhat concave or flat, is the characteristic which fades first when the tooth ages. For the P4 also the first characteristic fades first: the vertical rib which marks the mesio-lingual corner in sheep and is weak or absent in goat, is the least distinctive with the ageing of the P4. For the P3 the characteristic described as a more pronounced vertical ridge on the disto-buccal corner for sheep resulting in a distinct and deep hollow at the distal part of the buccal edge and a more or less shallow and indistinct hollow for goat, fades first with the ageing of the P3.
Halstead *et al.* (in press) noticed that not only very old but also very young teeth were hard to be identified on species level. This can not be examined in this study, because hardly any teeth from young sheep or goat were found.

In testing the methodology developed by Helmer (2000) and Halstead *et al.* (in press) one remark must be made. The methodology was developed and tested on jaws containing several teeth. The bone material excavated in Tel Bouqras was in a high degree fragmentised. Only a few jaws containing a number of teeth were found. The largest part of the examined teeth were found single, not fixed in the jaw. This makes conclusions less certain, there are less characteristics which can be used for the classification.
In this study, the characteristics described by Halstead *et al.* (in press) were used in an adjusted form. The characteristics P3.4 and P4.4 described by Halstead *et al.* were not used for the identification of the P3 and P4. Both characteristics describe the ratio between the length and the width of both dents. During the classification, these characteristics were indistinct and therefore not used. The length, width and height of each tooth were measured. The results of these measurements were used in the canonical discriminant analysis. The canonical discriminant analysis tested whether the length, width and height measurements of the tooth types could be used for the identification on species level. This test turned out that for the P4, M1, M2 and M3 these measurements could not be used for to distinguish between sheep and goat. But for the P3 this test pointed out that the length, width and height measurements correlated with age, could be used to determinate the P3. The rejection of characteristic P3.4 described by Halstead *et al.* (in press) by the researcher was unjust. Measuring the length, width and height must be recommended, because estimating the ratio between the length and width appeared to be difficult. Although the canonical discriminant test pointed out that the length, width and height can not be used for species identification of the P4, there are reasons to assume that this conclusion is unjust. The sheep:goat ratio is much higher for the P4 (10.5 : 1) than for the other tooth types . This ratio is also much higher than the ratios mentioned in other studies about the bone material from Tell Bouqras (Akkermans 1983, Buitenhuis 1988). Therefore, one could assume that the species identification on basis of the characteristics was not very accurate for the P4. The proportion sheep is overestimated. Thus, the assumption that the P4s were determined correctly might be rejected. The incorrect determination of the P4 would

automatically result in a rejection of the characteristic, which describes the ratio between the length and the width of the P4 as distinctive for sheep and goat. The ratio between the length and width as characteristic for sheep and goat was probably unjustly rejected.

If the assumption is true and the P4s were often incorrectly identified, it is indefinite which characteristic might have caused the incorrect determination. Probably characteristic P4.1 and characteristic P4.3 were too often classified as sheep. But characteristic P4.2 was often classified as intermediate and not as goat. It seems that none of the three characteristics, on the basis of which the P4s were identified was very distinctive for the researcher.

4.3 The relationship between man and Ovicapra

From the 2137 studied teeth excavated in Tell Bouqras, 584 were identified as sheep and 173 as goat. The sheep:goat ratio is on average for the ten layers 3:1. The canonical discriminant test based on the classification of the characteristics for individual teeth, calculated that 589 teeth were statistically sheep and 281 were statistically goat. The ratio thus decreases to 2:1. The first ratio corresponds with conclusions drawn in previous studies about the sheep: goat ratio in the bone material from Tell Bouqras (Akkermans 1983, Buitenhuis 1988). Akkermans (1983) found a ratio of 4:1 and Buitenhuis (1988) a ratio of 3:1. The statistical ratio on the other hand, is lower than concluded in those previous studies.

The sheep:goat ratio for the different tooth types, indicates that the sheep were slaughtered at slightly higher age than the goats. The ratio per tooth type, increases with the age the tooth breaks through the jaw. The M3 is the last dental element to break through, the high ratio suggests that most goats do not reach a very high age. The only exception in the rank is the P4, but as said before there are good reasons the assume that the determination of the P4 may have often been incorrect. Not only the sheep:goat ratio of the tooth types, but also the kill-off patterns show that sheep were slaughtered somewhat older than goats. The kill-off patterns over time, made using combined levels, show that the kill-off pattern of goat shifts a little over time. In the lowest and oldest levels the goats were slaughtered younger than in the higher and younger levels. The number of goats slaughtered relatively old, with a mandibular wear stages between 35 to 48 increases over time.

From the kill-off pattern the conclusion can be drawn that the sheep as well as the goat were probably mainly kept for their meat. The mandible wear stage at which most sheep and goat are slaughtered is 34, which corresponds according to Payne's methodology to an age around 25 to 40 months. An explanation for the little shift in the kill-off patterns over time in goat may be that Tell Bouqras is situated in the natural distribution area of sheep but outside the natural distribution area of goat. It may be that the goats needed time to adjust to their new environment. But the slaughter of goat at a younger age than sheep may also be caused by the taste of the meat. The taste of meat from old sheep is not as bad as the taste of old goats.

Striking is that the sheep:goat ratio changes over time. In the levels 5 and 6 the amount of teeth identified as sheep outnumber those identified as goat more than in the other levels. The reason behind this peak compared to the sheep:goat ratio in the other levels is unknown. The kill-off pattern over time does not give any reason to think that a change in management is the cause of the ratio peak.

4.4 Future focus

Important for this study is, that the researcher had little or no experience in identifying sheep and goat on the basis of mandibular teeth. Only an inexperienced researcher could be able to test the methodology. A researcher with experience could, unconsciously, determine the teeth on basis of experience.

But, an inexperienced researcher may cause inconsequences in the study. The characteristics described by Helmer (2000) and Halstead *et al.* (in press) can not be applied to as present or absent. The characteristics of the mandibular teeth from sheep and goat resemble each other. An inexperienced researcher will determine, especially in the beginning of the study, part of the teeth wrongly. The researcher must become sensitive to the boundaries between the characteristics of sheep and goat.

To increase the extent of the correct identification, the inexperienced researcher should determine each tooth twice. But the research would be even more improved when a number of inexperienced researchers would determinate the teeth on basis of these methodologies and than compare the outcome. If the characteristics are really distinctive, the results of the researchers must be similar.

Further research about the identification of sheep and goat teeth is recommended. If not only the mandibular premolars P3, P4 and the molars M1, M2 and M3 can be used for the identification to species level, but also the maxillary teeth, conclusions can be drawn on basis of more studied pieces.

5. Conclusion

The aim of this study is twofold: on the one hand this study was done to reveal the efficiencies and the deficiencies of the methodology recently developed by Helmer (2000) and Halstead *et al.* (in press) for the identification of sheep and goat on the basis of the madibular premolars P3 and P4 and the mandibular molars M1, M2 and M3. On the other hand this study tries to reveal the relationship between man and the *Ovis* and *Capra* in the former Neolithic settlement Tell Bouqras (eastern Syria). By using these new methodologies it was tried to reveal this relationship. The following conclusions can be drawn from the results of this study.

About the methodology:

- ✓ The methodologies of Halstead *et al.* (in press) and Helmer (2000) for the identification of sheep and goat on the basis of the madibular premolars P3 and P4 and the mandibular molars M1, M2 and M3 can be efficiently used on ancient teeth. Although a few exceptions must be made.
- ✓ There are reasons to assume that a sufficient part of the P4s were incorrectly identified. One of the reasons is the very high sheep:goat ratio. It is unsure which characteristic might have caused the incorrect identification. It seems that all characteristics for the P4 were not very distinctive for the researcher. The ageing of the P4 did not cause the incorrect determination, at an age of 90 months, almost 73% of the P4s were identified. If the assumption is true and many P4s were incorrectly identified, the rejection of the characteristic which describes the ratio between the length and the width of the P4 as distinctive for sheep and goat, might have been unjust.
- ✓ The wear of teeth caused by ageing gives restrictions to the use of the methodology. The M1 is the tooth type, which is hardest to identify to species level at high ages because mainly characteristic M1.1 fades. At an age of 39 months only 23% of the M1 were identified. This causes imperfections to this study, because the results of this study are, to a large extent, based on M1s. Remarkable is that the M2, which is identified by the same characteristics as the M1, can be identified to species level at much higher ages. At the age of 60 months almost 80 % of the M2s were identified. For the M2 also characteristic M2.1 fades first with the ageing of the teeth.
- ✓ The M3 is the tooth type which can be identified until the highest ages. The M3 is the tooth which erupts last through the jaw, therefore the M3 comes last into wear.
- ✓ The conclusions drawn in this study about the relationship between man and *Ovicapra,* would have been more precise if the bone material was not fragmented in a high degree. The species identification of a complete row of teeth, is far more precise than the determination of individual tooth.

The relationship between men and Ovicapra:

- ✓ The kill-off patterns of sheep and goat, suggest that the main reason for keeping sheep and goat in the Neolithic settlement Tell Bouqras must have been the meat. It seems, however, that goat were slaughtered at a bit younger age than sheep. It might be that the higher age at which the sheep were slaughtered indicate that milk was one of the aim products to keep sheep.
- ✓ The ratio between the amount of sheep and the amount of goat was probably approximately 70:30. The relative proportions of sheep and goat found in this study corresponds to that of previous studies (Akkermanns 1983, Buitenhuis 1988). The

meat of sheep formed on average, for the ten levels, a larger share of the animal food supply than that of goat.

- ✓ Striking is the relatively high proportion of slaughtered sheep compared to the slaughtered goats in level five and six. The reason for this peak is unknown and can not be found in a change in the management of the animals.

Acknowledgement

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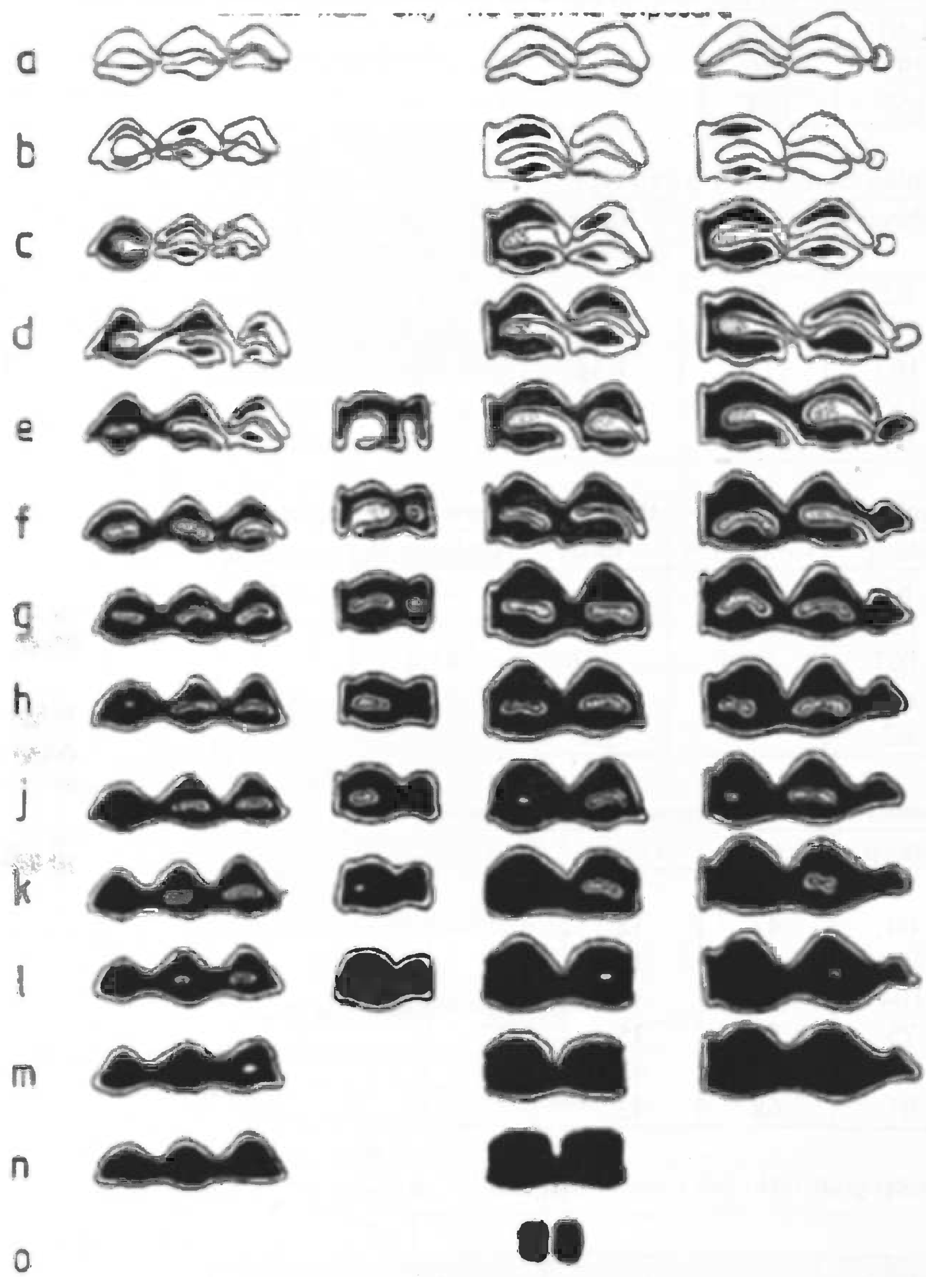
Appendix A

Mandible wear stages according to Grant (1982)

Stage **pd4** **P4** **M1/M2** **M3**



Appendix B

Results of identification of teeth based on the statistical tests. See chapter 2.5 at page 10.

Table B1. Number of teeth per species from the left and the right side of the jaw.

Group	Left	Right
Sheep	293	296
Goat	157	124

Table B2. Number of teeth per tooth type.

Tooth type	Sheep	Goat	Ratio sheep:goat
P3	82	66	1.24
P4	119	28	4.25
M1	167	116	1.44
M2	159	60	2.65
M3	62	10	6.20

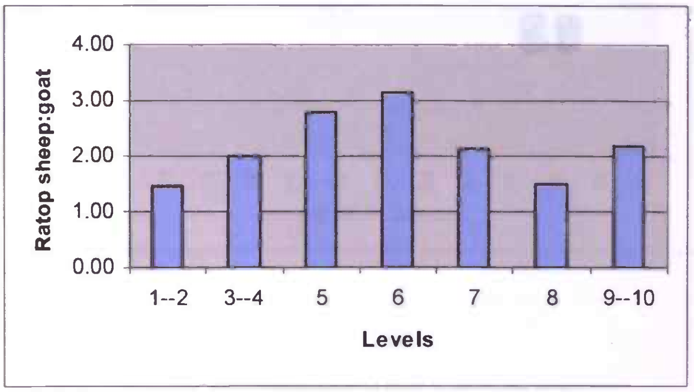
Table B3. Number of teeth per tooth type, plus row percentages.

	Sheep	Column %	Goat	Column %
P3	82	13.9	66	23.6
P4	119	20.2	28	10.0
M1	167	28.4	116	41.4
M2	159	27.0	60	21.4
M3	62	10.5	10	3.6

Table B4. Number and percentages of teeth per level.

Level	Sheep	Row %	Goat	Row %
1--2	77	52	53	36
3--4	64	47	32	23
5	108	98	39	35
6	104	89	33	28
7	75	58	35	27
8	70	73	47	49
9--10	91	68	42	32

Figure B1. Sheep:goat ratio per (combined) level.



Appendix C
Kill-off patterns of sheep and goat per (combined) level. The ages are given as mandible wear stages according to Grant (1982).

Figure C1. Kill-off patterns in combined level 1—2.

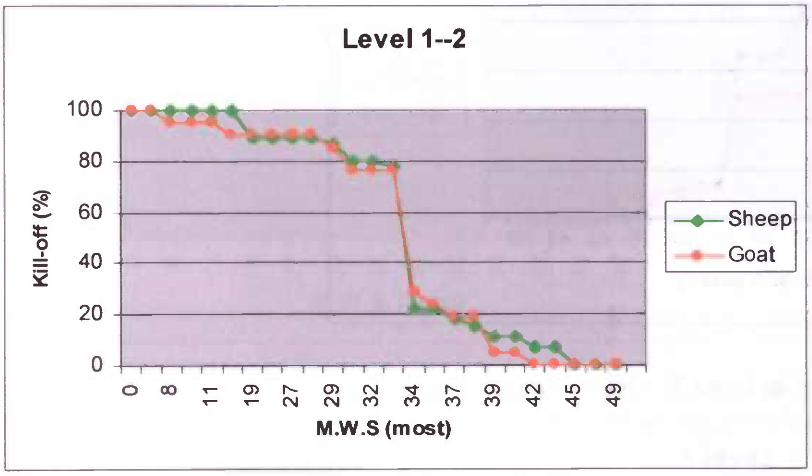


Figure C2. Kill-off pattern in combined level 3—4.

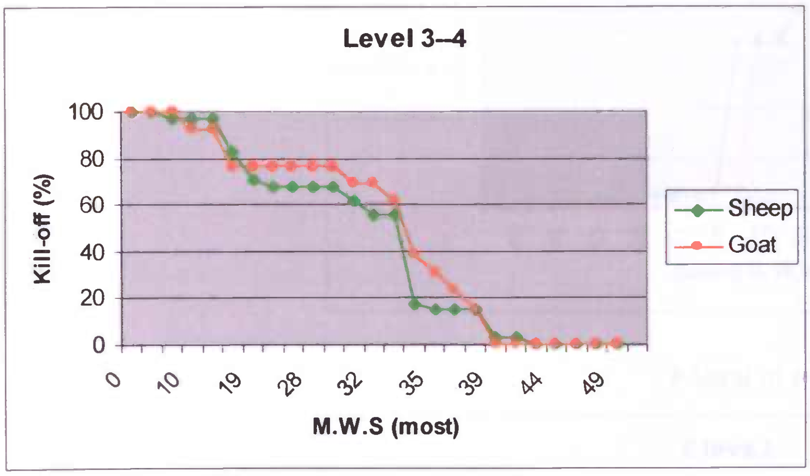


Figure C3. Kill-off pattern in level 5.

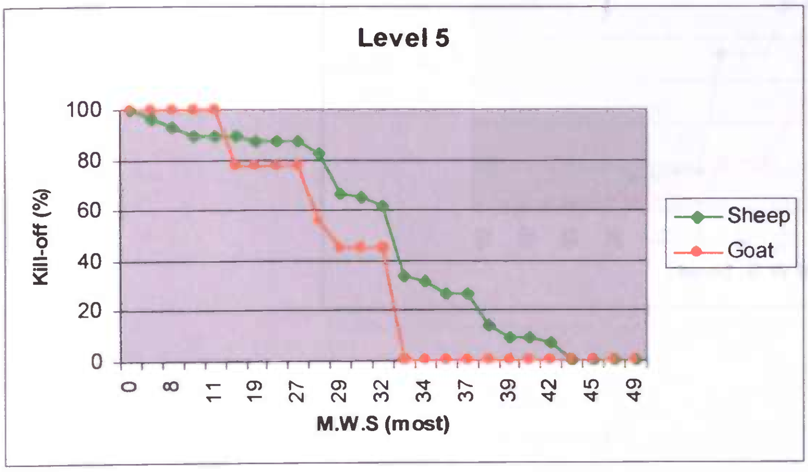


Figure C3. Kill-off pattern in level 6.

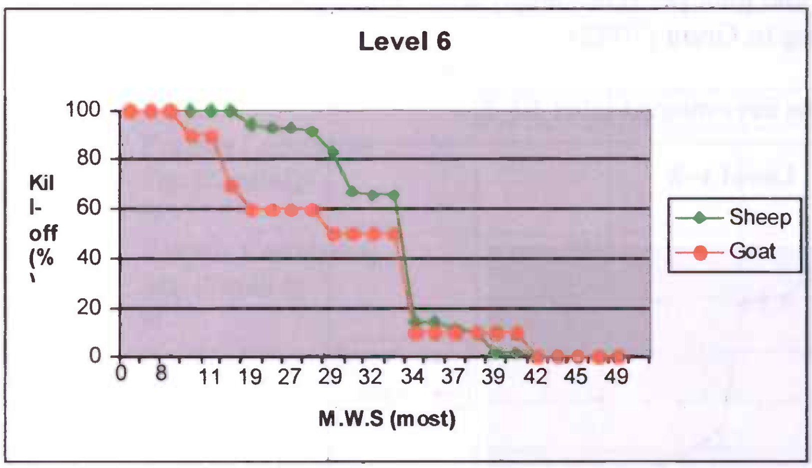


Figure C4. Kill-off pattern in level 7.

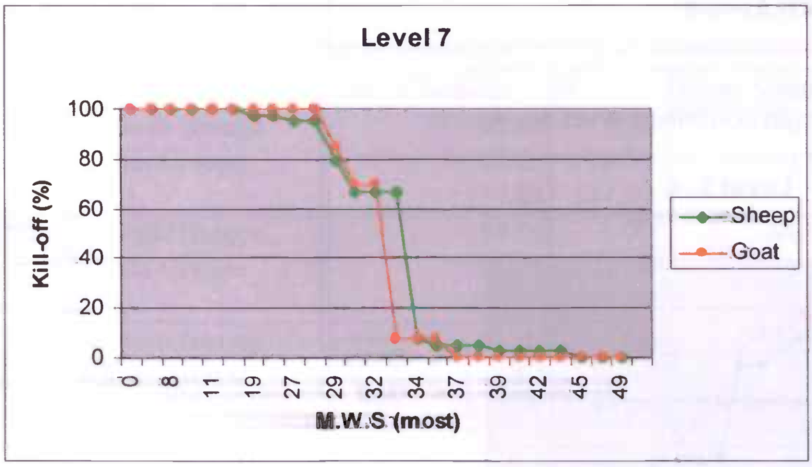


Figure C5. Kill-off pattern in level 8.

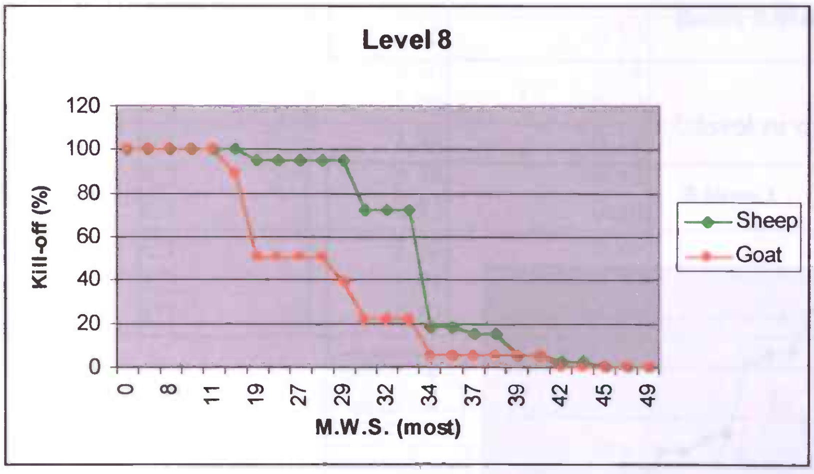
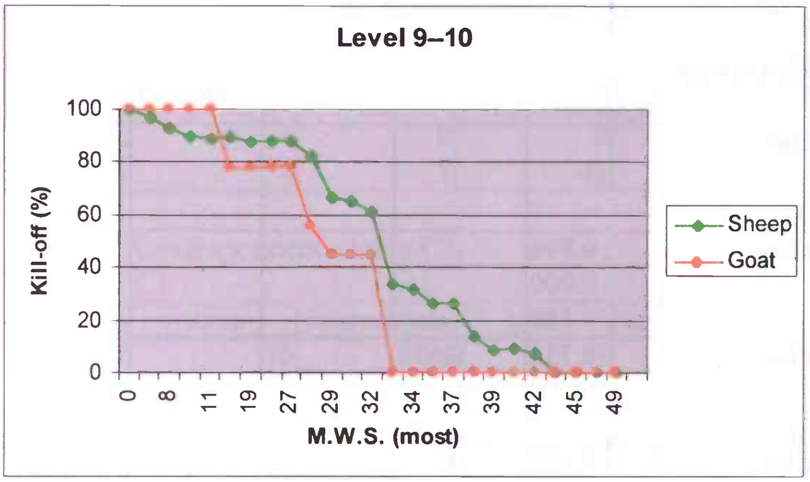


Figure C6. Kill-off pattern in combined level 9—10



Appendix D
Statistical analysis of P3

Table D1. Bivariate correlation test.

		S_G	C1	C2	C3
S_G	Pearson Correlation				
	Sig. (2-tailed)				
	N				
C1	Pearson Correlation	0.896			
	Sig. (2-tailed)	0.000			
	N	130			
C2	Pearson Correlation	0.734	0.626		
	Sig. (2-tailed)	0.000	0.000		
	N	130	144		
C3	Pearson Correlation	0.922	0.791	0.621	
	Sig. (2-tailed)	0.000	0.000	0.000	
	N	131	145	145	

Table D2. One-way ANOVA.

		Sum of Squares	df	Mean Square	F	Sig.
C1	Between Groups	94.64	1.000	94.645	521.474	0.000
	Within Groups	23.23	128.000	0.181		
	Total	117.88	129.000			
C2	Between Groups	64.10	1.000	64.101	149.748	0.000
	Within Groups	54.79	128.000	0.428		
	Total	118.89	129.000			
C3	Between Groups	94.93	1.000	94.934	734.695	0.000
	Within Groups	16.67	129.000	0.129		
	Total	111.60	130.000			

Table D3. Group statistics

S_G		Mean	Std. Deviation	Valid N (listwise) Unweighted	Weighted
Sheep	C1	1.25	0.55	75	75
	C2	1.30	0.68	75	75
	C3	1.09	0.34	75	75
Goat	C1	2.98	0.14	54	54
	C2	2.74	0.62	54	54
	C3	2.83	0.38	54	54
Total	C1	1.98	0.96	129	129
	C2	1.91	0.96	129	129
	C3	1.82	0.93	129	129

Table D4. Correspondence table C1

	C1			
S_G	sheep	intermediate	goat	unidentifiable
1	61	11	4	0
2	0	0	0	0
3	0	1	53	0

Table D5. Correspondence table C2.

	C2			
S_G	sheep	intermediate	goat	unidentifiable
1	58	15	0	3
2	0	0	0	0
3	4	7	42	1

Table D6. Correspondence table C3.

	C3			
S_G	sheep	intermediate	goat	unidentifiable
1	70	6	1	0
2	0	0	0	0
3	0	9	45	0

Table D7. Test of equality of group means.

	Wilks' Lambda	F	df1	df2	Sig.
C1	0.19813651	513.97	1	127	0.000
C2	0.45689213	150.96	1	127	0.000
C3	0.14289249	761.78	1	127	0.000

Table D8. Test results.

Box's M		88.110
F	Approx.	14.294
	df1	6.000
	df2	89416.581
	Sig.	0.000

Table D9. Eigenvalues.

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	13.8026108	100	100	0.965

Table D10. Wilks' lambda.

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1.000	0.068	338.198	3.000	0.000

Table D11. Canonical discriminant functions.

	Function
	1
C1	0.659
C2	0.443
C3	0.778

Table D12. Functions at group centroids.

	Function
S_G	1
1	-3.12790731
3	4.3443157

Table D13. Group statistics.

S_G		Mean	Std. Deviation	Valid N (listwise) Unweighted	Weighted
1	Age (grouped)	5.03	1.73	107	107
	length mm	10.66	1.51	107	107
	width mm	6.70	0.52	107	107
	height mm	15.65	3.99	107	107
3	Age (grouped)	4.89	1.45	9	9
	length mm	11.39	0.95	9	9
	width mm	6.58	0.57	9	9
	height mm	18.11	2.72	9	9
Total	Age (grouped)	5.02	1.70	116	116
	length mm	10.71	1.48	116	116
	width mm	6.69	0.52	116	116
	height mm	15.84	3.95	116	116

Table D14. Test of equality of group means.

	Wilks' Lambda	F	df1	df2	Sig.
Age (grouped)	0.999519	0.054896	1	114	0.815
length mm	0.982479	2.033059	1	114	0.157
width mm	0.99569	0.493447	1	114	0.484
height mm	0.972009	3.282893	1	114	0.073

Table D15. Test results.

Box's M		16.11227
F	Approx.	1.301592
	df1	10
	df2	829.3286
	Sig.	0.224962

Table D16. Eigenvalues.

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	0.041929	100	100	0.200604

Table D17. Wilks'lambda.

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1.000	0.960	4.600	4.000	0.331

Table D18. Canonical discriminant functions.

	Function 1
Age (grouped)	0.312894
length mm	0.211591
width mm	-0.70539
height mm	0.226838
(Constant)	-2.70797

Table D19. Functions of group centroids.

S_G	Function 1
1	-0.05887
3	0.699928

Appendix E
Statistical analysis of P4

Table E1. Bivariate correlation test.

		S_G	C1	C2	C3
S_G	Pearson Correlation				
	Sig. (2-tailed)				
	N				
C1	Pearson Correlation	0.643			
	Sig. (2-tailed)	0.000			
	N	122			
C2	Pearson Correlation	0.621	0.500		
	Sig. (2-tailed)	0.000	0.000		
	N	125	143		
C3	Pearson Correlation	0.515	0.511	0.363	
	Sig. (2-tailed)	0.000	0.000	0.000	
	N	124	141	144	

Table E2. One-way ANOVA.

		Sum of Squares	df	Mean Square	F	Sig.
C1	Between Groups	23.375	1.000	23.375	84.365	0.000
	Within Groups	33.248	120.000	0.277		
	Total	56.623	121.000			
C2	Between Groups	24.358	1.000	24.358	77.070	0.000
	Within Groups	38.874	123.000	0.316		
	Total	63.232	124.000			
C3	Between Groups	11.032	1.000	11.032	43.920	0.000
	Within Groups	30.645	122.000	0.251		
	Total	41.677	123.000			

Table E3. Group statistics.

		Mean	Std. Deviation	Valid N (listwise)	
S_G				Unweighted	Weighted
1	C1	1.11	0.51	110	110
	C2	1.36	0.58	110	110
	C3	1.14	0.48	110	110
3	C1	2.64	0.67	11	11
	C2	2.91	0.30	11	11
	C3	2.18	0.75	11	11
Total	C1	1.25	0.69	121	121
	C2	1.50	0.72	121	121
	C3	1.23	0.59	121	121

Table E4. Correspondence table C1.

	C1			
S_G	sheep	intermediate	goat	unidentifiable
1	105	3	0	3
2	0	0	0	0
3	1	2	8	0

Table E5. Correspondence table C2.

	C2			
S_G	sheep	intermediate	goat	unidentifiable
1	79	31	3	1
2	0	0	0	0
3	0	1	10	0

Table E6. Correspondence table C3.

	C3			
S_G	sheep	intermediate	goat	unidentifiable
1	102	9	0	2
2	0	0	0	0
3	2	5	4	0

Table E7. Test of equality of group means.

	Wilks' Lambda	F	df1	df2	Sig.
C1	0.58761	83.51542	1	119	0.000
C2	0.611776	75.51551	1	119	0.000
C3	0.736764	42.51722	1	119	0.000

Table E8. Test results.

Box's M		15.373
F	Approx.	2.273
	df1	6.000
	df2	1676.627
	Sig.	0.034

Table E9. Eigenvalues.

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	1.845908	100	100	0.805

Table E10. Wilks' lambda.

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1.000	0.351	122.891	3.000	0.000

Table E11. Canonical discriminant functions.

	Function
	1
C1	0.682
C2	0.657
C3	0.441

Table E12. Functions at group centroids.

	Function
S_G	1
1	-0.426075
3	4.260748

Table E13. Group statistics.

S_G		Mean	Std. Deviation	Valid N (listwise) Unweighted	Weighted
Sheep	Age (grouped)	5.03	1.73	107	107
	length mm	10.66	1.51	107	107
	width mm	6.70	0.52	107	107
	height mm	15.65	3.99	107	107
Goat	Age (grouped)	4.89	1.45	9	9
	Length mm	11.39	0.95	9	9
	Width mm	6.58	0.57	9	9
	Height mm	18.11	2.72	9	9
Total	Age (grouped)	5.02	1.70	116	116
	Length mm	10.71	1.48	116	116
	width mm	6.69	0.52	116	116
	height mm	15.84	3.95	116	116

Table E14. Test of equality of group means.

	Wilks' Lambda	F	df1	df2	Sig.
Age (grouped)	0.999519	0.054896	1	114	0.815
length mm	0.982479	2.033059	1	114	0.157
width mm	0.99569	0.493447	1	114	0.484
height mm	0.972009	3.282893	1	114	0.073

Table E15. Test results.

Box's M		16.11227
F	Approx.	1.301592
	df1	10
	df2	829.3286
	Sig.	0.224962

Table E16. Eigenvalues.

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	0.041929	100	100	0.200

Table E17. Wilks'lambda.

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1.000	0.960	4.600	4.000	0.331

Table E18. Canonical discriminant functions.

	Function 1
Age (grouped)	0.312894
length mm	0.211591
width mm	-0.70539
height mm	0.226838
(Constant)	-2.70797

Table E19. Functions of group centroids.

S_G	Function 1
1	-0.05887
3	0.699928

Appendix F
Statistical analysis of M1

Table F1. Bivariate Correlation test.

		s/g	C1	C2	C3
s/g	Pearson Correlation				
	Sig. (2-tailed)				
	N				
C1	Pearson Correlation	0.637			
	Sig. (2-tailed)	0.000			
	N	160			
C2	Pearson Correlation	0.888	0.343		
	Sig. (2-tailed)	0.000	0.000		
	N	168	285	293	
C3	Pearson Correlation	0.898	0.261	0.703	
	Sig. (2-tailed)	0.000	0.000	0.000	.
	N	168	284	292	

Table F2. One-way ANOVA.

		Sum of Squares	df	Mean Square	F	Sig.
C1	Between Groups	65.606	1.000	65.606	107.647	0.000
	Within Groups	96.294	158.000	0.609		
	Total	161.900	159.000			
C2	Between Groups	95.811	1.000	95.811	616.270	0.000
	Within Groups	25.808	166.000	0.155		
	Total	121.619	167.000			
C3	Between Groups	88.747	1.000	88.747	693.161	0.000
	Within Groups	21.253	166.000	0.128		
	Total	110.000	167.000			

Table F3. Group statistics.

s/g		Mean	Std. Deviation	Valid N (listwise) Unweighted	Weighted
1	C1	1.550	0.882	111	111
	C2	1.144	0.378	111	111
	C3	1.036	0.187	111	111
3	C1	2.939	0.475	49	49
	C2	2.796	0.456	49	49
	C3	2.633	0.602	49	49
Total	C1	1.975	1.009	160	160
	C2	1.650	0.863	160	160
	C3	1.525	0.824	160	160

Table F4. Correspondence table C1.

	C1			
s/g	sheep	intermediate	goat	unidentifiable
1	70	30	2	9
2	0	0	0	0
3	1	4	41	3

Table F5. Correspondence table C2.

C2				
s/g	sheep	intermediate	goat	unidentifiable
1	104	14	1	0
2	0	0	0	0
3	1	8	40	0

Table F6. Correspondence table C3.

C3				
s/g	sheep	intermediate	goat	unidentifiable
1	115	4	0	0
2	0	0	0	0
3	3	12	34	0

Table F7. Test of equality of group means.

	Wilks' Lambda	F	df1	df2	Sig.
C1	0.594773342	107.6474	1	158	0.000
C2	0.216662816	571.2437	1	158	0.000
C3	0.1968824	644.5095	1	158	0.000

Table F8. Test results.

Box's M		148.410
F	Approx.	24.100
	df1	6.000
	df2	56748.353
	Sig.	0.000

Table F9. Eigenvalues.

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	8.864936517	100	100	0.948

Table F10. Wilks' lambda.

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1.000	0.101	358.226	3.000	0.000

Table F11. Canonical discriminant functions.

	Function
	1
C1	0.663
C2	1.591
C3	1.797
(Constant)	-6.676

Table F12. Functions at group centroids.

	Function
s/g	1
1	-1.965816236
3	4.453175556

Appendix G
Statistical analysis of M2

Table G1. Bivariate correlation test.

		S_G	C1	C2	C3
S_G	Pearson Correlation				
	Sig. (2-tailed)				
	N				
C1	Pearson Correlation	0.788			
	Sig. (2-tailed)	0.000			
	N	187.000			
C2	Pearson Correlation	0.761	0.465		
	Sig. (2-tailed)	0.000	0.000		
	N	186.000	216.000		
C3	Pearson Correlation	0.825	0.410	0.767	
	Sig. (2-tailed)	0.000	0.000	0.000	
	N	187.000	217.000	216.000	

Table G2. One-way ANOVA.

		Sum of Squares	df	Mean Square	F	Sig.
C1	Between Groups	63.962	1.000	63.962	302.244	0.000
	Within Groups	39.150	185.000	0.212		
	Total	103.112	186.000			
C2	Between Groups	71.978	1.000	71.978	253.435	0.000
	Within Groups	52.258	184.000	0.284		
	Total	124.237	185.000			
C3	Between Groups	70.171	1.000	70.171	394.086	0.000
	Within Groups	32.941	185.000	0.178		
	Total	103.112	186.000			

Table G3. Group statistics.

S_G		Mean	Std. Deviation	Valid N (listwise) Unweighted	Weighted
Sheep	C1	1.132	0.376	152	152
	C2	1.243	0.552	152	152
	C3	1.118	0.398	152	152
Goat	C1	2.647	0.734	34	34
	C2	2.853	0.436	34	34
	C3	2.706	0.524	34	34
Total	C1	1.409	0.746	186	186
	C2	1.538	0.819	186	186
	C3	1.409	0.746	186	186

Table G4. Correspondence table C1.

	C1			
S_G	sheep	intermediate	goat	unidentifiable
1	135	16	2	0
2	0	0	0	0
3	4	5	24	1

Table G5. Correspondence table C2.

	C2			
S_G	sheep	intermediate	goat	unidentifiable
1	122	25	3	2
2	0	0	0	0
3	1	3	30	0

Table G6. Correspondence table C3.

	C3			
S_G	sheep	intermediate	goat	unidentifiable
1	138	13	1	1
2	0	0	0	0
3	1	8	25	0

Table F7. Test of equality of group means.

	Wilks' Lambda	F	df1	df2	Sig.
C1	0.38	300.04	1	184	0.000
C2	0.42	253.43	1	184	0.000
C3	0.32	391.27	1	184	0.000

Table F8. Test results.

Box's M		43.314
F	Approx.	6.971
	df1	6
	df2	20487.011
	Sig.	0.000

Table F9. Eigenvalues.

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	3.797114	100	100	0.890

Table F10. Wilks' lambda.

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1.000	0.208	286.163	3.000	0.000

Table F11.Canonical discriminant functions.

	Function
	1
C1	1.334
C2	0.650
C3	1.226
(Constant)	-4.606

Table F12. Functions at group centroids.

	Function
S_G	1
1	-0.91664
3	4.097902

Appendix H
Statistical analysis of M3

Table H1. Bivariate correlation test.

		S_G	C1	C2	C3	C4	C5	C6
S_G	Pearson Correlation	1	0.706	0.749	0.771	0.569	0.539	0.820
	Sig. (2-tailed)	.	0.000	0.000	0.000	0.000	0.000	0.000
	N	81	80	81	81	64	66	77
C1	Pearson Correlation	0.706	1.000	0.415	0.422	0.525	0.625	0.620
	Sig. (2-tailed)	0.000	.	0.000	0.000	0.000	0.000	0.000
	N	80	96	96	96	76	79	91
C2	Pearson Correlation	0.749	0.415	1.000	0.711	0.396	0.459	0.536
	Sig. (2-tailed)	0.000	0.000	.	0.000	0.000	0.000	0.000
	N	81	96	97	97	77	80	92
C3	Pearson Correlation	0.771	0.422	0.711	1	0.413	0.408	0.652
	Sig. (2-tailed)	0.000	0.000	0.000	.	0.000	0.000	0.000
	N	81	96	97	97	77	80	92
C4	Pearson Correlation	0.569	0.525	0.396	0.413	1	0.480	0.514
	Sig. (2-tailed)	0.000	0.000	0.000	0.000		0.000	0.000
	N	64	76	77	77	77	73	77
C5	Pearson Correlation	0.539	0.625	0.459	0.408	0.480	1.000	0.417
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	.	0.000
	N	66	79	80	80	73	80	79
C6	Pearson Correlation	0.820	0.620	0.536	0.652	0.514	0.417	1
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	.
	N	77	91	92	92	77	79	92

Table H2. One-way ANOVA.

		Sum of Squares	df	Mean Square	F	Sig.
C1	Between Groups	24.015	1.000	24.015	77.454	0.000
	Within Groups	24.185	78.000	0.310		
	Total	48.200	79.000			
C2	Between Groups	21.308	1.000	21.308	100.851	0.000
	Within Groups	16.692	79.000	0.211		
	Total	38.000	80.000			
C3	Between Groups	17.563	1.000	17.563	115.688	0.000
	Within Groups	11.993	79.000	0.152		
	Total	29.556	80.000			
C4	Between Groups	18.080	1.000	18.080	29.611	0.000
	Within Groups	37.857	62.000	0.611		
	Total	55.938	63.000			
C5	Between Groups	18.108	1.000	18.108	26.213	0.000
	Within Groups	44.211	64.000	0.691		
	Total	62.318	65.000			
C6	Between Groups	22.688	1.000	22.688	154.325	0.000
	Within Groups	11.026	75.000	0.147		
	Total	33.714	76.000			

Table H3. Group statistics.

S_G		Mean	Std. Deviation	Valid N (listwise)	
				Unweighted	Weighted
Sheep	C1	1.173	0.617	52	52
	C2	1.135	0.397	52	52
	C3	1.077	0.334	52	52
	C4	1.288	0.800	52	52
	C5	1.519	0.896	52	52
	C6	1.077	0.269	52	52
Goat	C1	2.857	0.690	7	7
	C2	2.714	0.755	7	7
	C3	2.857	0.378	7	7
	C4	2.857	0.900	7	7
	C5	3	0.577	7	7
	C6	2.714	0.951	7	7
Total	C1	1.373	0.828	59	59
	C2	1.322	0.680	59	59
	C3	1.288	0.671	59	59
	C4	1.475	0.953	59	59
	C5	1.695	0.987	59	59
	C6	1.271	0.665	59	59

Table H4. Correspondence table C1.

	C1			
S_G	sheep	intermediate	goat	unidentifiable
1	64	5	0	2
2	0	0	0	0
3	0	2	6	1

Table H5. Correspondence table C2.

	C2			
S_G	sheep	intermediate	goat	unidentifiable
1	63	6	2	0
2	0	0	0	0
3	1	1	8	0

Table H6. Correspondence table C3.

	C3			
S_G	sheep	intermediate	goat	unidentifiable
1	66	4	1	0
2	0	0	0	0
3	1	3	6	0

Table H7. Correspondence table C4.

	C4			
S_G	sheep	intermediate	goat	unidentifiable
1	49	2	2	3
2	0	0	0	0
3	1	0	6	1

Table H8. Correspondence table C5.

	C5			
S_G	sheep	intermediate	goat	unidentifiable
1	41	8	5	3
2	0	0	0	0
3	0	1	7	1

Table H9. Correspondence table C6.

	C1			
S_G	sheep	intermediate	goat	unidentifiable
1	135	16	2	0
2	0	0	0	0
3	4	5	24	1

Table H10. Test of equality of means.

	Wilks' Lambda	F	dfl	df2	Sig.
C1	0.560	44.725	1	57	0.000
C2	0.427	76.397	1	57	0.000
C3	0.251	170.164	1	57	0.000
C4	0.712	23.058	1	57	0.000
C5	0.761	17.940	1	57	0.000
C6	0.355	103.366	1	57	0.000

Table H11. Eigenvalues.

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	4.760597	100	100	0.909

Table H12. Wilks' lambda.

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1	0.173593	94.55622	6	0.000

Table H13. Canonical discriminant functions.

	Function
	1
C1	0.425347
C2	0.565774
C3	2.070638
C4	0.346262
C5	0.257468
C6	0.251208
(Constant)	-5.265494

Table H14. Functions at group centroids.

	Function
S_G	1
1	-0.786846
3	5.845138