New Zealand Deerstalkers' Association Incorporated

HOW TO AGE A JAWBONE

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Assessing age and condition of deer from jawbones

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Introduction

Age is a critical parameter for studying the dynamics of an animal population. An analysis of the age distribution of harvested animals can provide an insight into a population's demography. In conjunction with estimates of the total number of animals harvested, these data can be used to provide precise estimates of population size (Hayne 1984).

Age-specific rates of reproduction, growth, or survival form parameters of condition, useful as indices of habitat quality, both for comparing populations and for predicting future changes in populations (Mitchell 1967, Challies 1989). Both age and condition parameters form an important basis for the management of wild animal populations (Kie 1988).

For deer species, both age and condition can be assessed from the jawbone. This manual outlines the techniques required for preparing jawbones and measuring these parameters, and is designed to assist managers and researchers of deer populations in New Zealand.

Preparation of jawbones

The jawbones should be boiled for approximately 2 hours. Jawbones that have been in contact with formalin are more difficult to clean and may need to be boiled for 4 - 6 hours.

Before boiling the jawbones, you should make sure that each one is individually tagged. A suitable method is to use numbered aluminium tags attached with a small piece of wire.

After boiling, remove any remaining tissue from the jawbone. You can then extract the incisors and canine (the four anterior teeth), taking care not to break the fine bone structure at the anterior tip of the jawbone. However, if the jawbones are going to be stored for further analyses, these teeth should be left in place to protect the fine bone structure. Jawbone measurements are possible with these teeth intact.

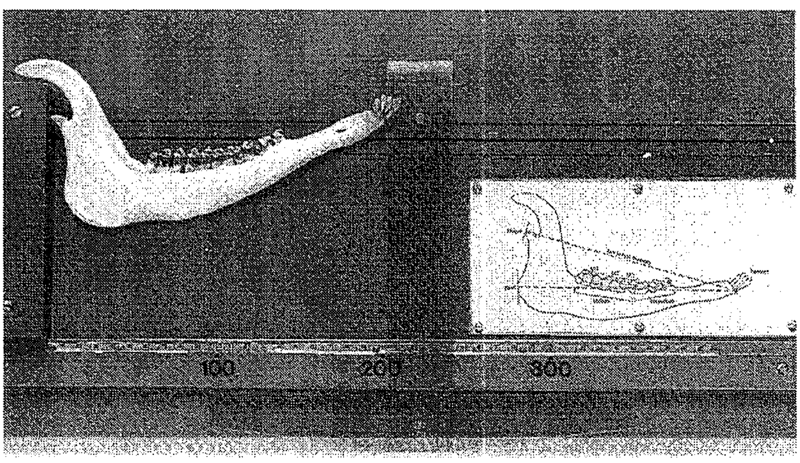


Figure 1 *Jawbone measurement board, Illustrating the correct alignment of the jaw for the heel-to-tip measurement.*

Jawbone measurement

Measure the jawbone length to the nearest millimetre, preferably using a specially designed measuring board (Fig. 1). Take the heel-to-tip measurement (Fig. 2), as this is the most commonly used parameter of jawbone size. It may sometimes be necessary to record the hinge-to-tip measurement as well (see Fig. 2), since this has been used in some previous New Zealand studies. Jawbone measurements should be made before extracting the molars, in case the jawbone is broken during extraction.

Other jawbone measurements can also be taken for specific purposes. For example, Nugent (1989) showed that multivariate analyses based on five jawbone measurements can be used to identify the sex of fallow deer.

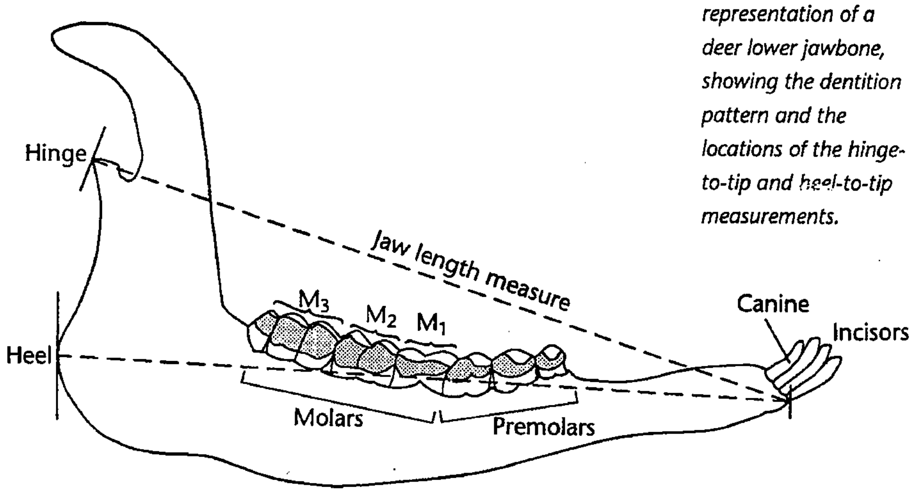


Figure 2
Diagrammatic representation of a deer lower jawbone, showing the dentition pattern and the locations of the hinge-to-tip and heel-to-tip measurements.

Age determination

The age of a deer can be determined from the lower jaw dentition (the current status of the tooth eruption sequence) up to approximately 36 months old. Once full dentition has been attained, age can be assessed by examination of annuli (growth lines) in the cementum layers between the roots of the molars.

These cementum layers are deposited continuously on the external root surface of the teeth (including the incisors) throughout the animal's life. Although the annual increments are relatively constant, seasonal factors cause changes in the rate of deposition throughout the year, which lead to the useful pattern of annuli in this dental tissue.

Ageing from eruption sequence

The lower jaw dentition, together with the date of death, gives an accurate indication of age in young animals. Full dentition for an adult deer consists of three incisors, one canine, three premolars, and three molars on each side of the lower jaw (see Fig. 2). The canine is similar in form and function to the incisors.

At birth, a fawn has only the incisors and the incisiform canine (Table 1). The three premolars erupt within a few days of birth. These teeth are deciduous (temporary or milk teeth) and are completely replaced by permanent teeth by about 2½ years of age. Replacement of the deciduous teeth begins with the 1st incisor at about 12-16 months and progresses sequentially through to the 3rd premolar at about 23-29 months. The permanent 3rd premolar with its two pairs of cusps is easily distinguished from the 3rd deciduous premolar with three pairs of cusps. All other premolars and the 1st and 2nd molars have two pairs of cusps. The 3rd molar has three pairs of cusps, although the posterior pair of cusps may be absent in some animals.

The first permanent molar (M_1) erupts after about 2-5 months, followed by the 2nd molar at about 8-14 months.

Tooth details		Deciduous	Permanent
Incisors:	I_1	present at birth	12-16 months
	I_2	present at birth	15-20 months
	I_3	present at birth	18-26 months
Canine:	C	erupts within a few days of birth	20-27 months
Premolars:	P_1	erupts within a few days of birth	22-28 months
	P_2	erupts within a few days of birth	23-29 months
	P_3	erupts within a few days of birth	23-29 months
Molars:	M_1	not present	2-5 months
	M_2	not present	8-14 months
	M_3	not present	18-24 months

Table 1
Timing and sequence of eruption for the deciduous and permanent mandibular teeth of red deer (adapted from data of Challies 1978).

Note that the correct dentition terminology for the premolars is P_2, P_3, P_4, (see Riney 1951), but for simplicity P_1, P_2, P_3 is used here.

The 3rd molar erupts at about 18-26 months, although the 3rd pair of cusps may not be fully above the gum line until well into the first adult year (30-36 months). When the third pair of cusps is not yet stained by tartar, this indicates that the M3 tooth is still not fully erupted.

Although the timing and sequence of tooth eruption may vary between individuals, an accurate age is easily attained if the date on which the deer was shot is known. For example, an assumed birth date of 9 December for red deer (Caughley 1971) means that an animal shot in September will be 9 months if only the first molar is present (or perhaps the second molar has started erupting), 21 months if both 1st and 2nd molars are fully erupted and the milk teeth are all or partially replaced, and adult if the animal has full dentition.

The median birth date used for ageing sika deer is 13 December (Davidson 1976) and that for fallow deer is 20 December (G. Nugent pers. comm.). There is little quantitative information on median birth dates for other deer species in New Zealand. However, it is generally accepted that most wapiti calves and white-tailed fawns are born in December, and most rusa fawns are born in March and April. There is no clear birth season for sambar deer, since the rut can occur at any time from late May until December and ageing for this species will therefore be only approximate.

Photographs of a selection of deer jawbones from a range of ages may be useful for comparisons when ageing young animals from the eruption sequence (Appendix 1).

If the date of death is not known, such as when jawbones are found incidentally, the age can generally be determined with an accuracy of only ±6 months.

With experience, the age of adult deer (>24 months) can sometimes be estimated from tooth wear with reasonable accuracy (see Lowe 1967, Brown & Chapman 1990). However, this method may be specific to an area, since tooth-wear patterns can vary between habitats, and examination of the annual cementum layers on the 1st molar (M_1) tooth is generally required for ageing deer older than 30 months.

Preparation of molar teeth for cementum analysis

Extract both the M_1 and M_2 teeth. These teeth are most easily extracted immediately after boiling, while the jawbone is still warm.

The molars of red, fallow, and white-tailed deer can usually be extracted using fencing pliers, without damaging the teeth or jawbone. However, the molars of sika deer are more firmly attached. In general, it is necessary to cut between them using a hacksaw and then carefully chisel away the surrounding jawbone to avoid breaking the roots during extraction (see Fig. 3). As the jawbone sometimes gets broken during tooth extraction, jawbone measurements should be taken before the molars are extracted.

This technique also works best while the jawbone is moist. If the M_1 or M_2 teeth are broken, destroying the cementum pad between the roots, extract the M_3 as well.

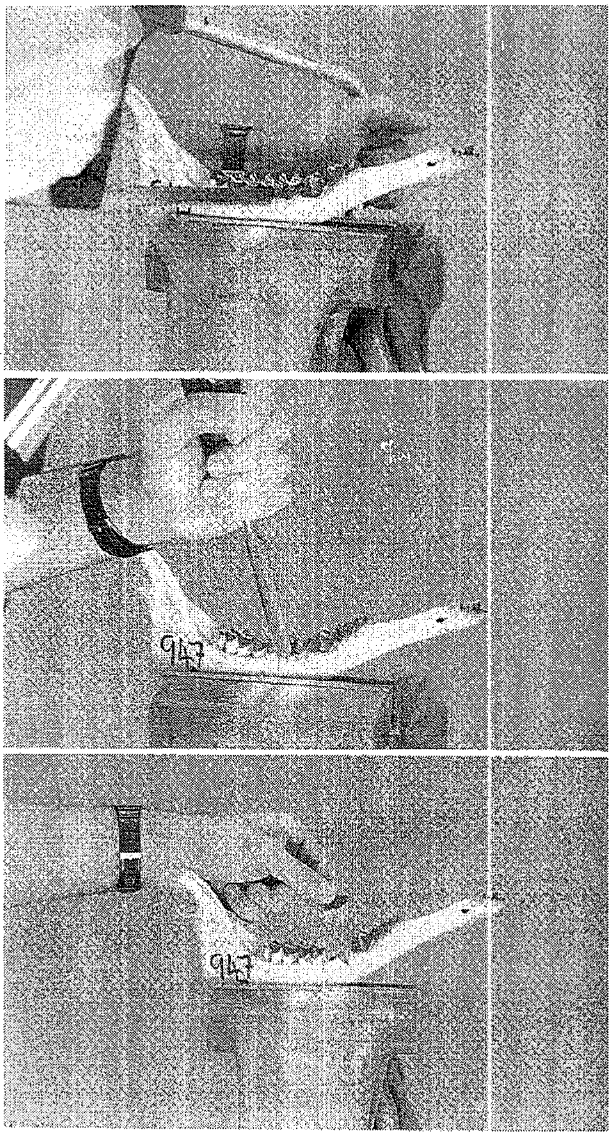


Figure 3
Technique for removing the molar teeth from the jaw- bone if they cannot be removed with fencing pliers.

Cut through both teeth on a diamond-tipped saw, between the two roots immediately adjacent to the thickest part of the cementum pad. The posterior (rear) root of each tooth tends to be angled slightly back, away from the anterior root and the anterior root is usually vertical (Fig. 4). As a result, the cementum pad is usually thickest toward the anterior root, so place the cut behind the centre of the cementum pad. Grind the cut surface with 180-grade carborundum paper on a grinding wheel until the thickest part of the cementum pad is exposed. Polish the tooth with 400-grade carborundum paper. A lapidary unit is the most suitable apparatus for cutting, grinding, and polishing teeth (Fig. 5).

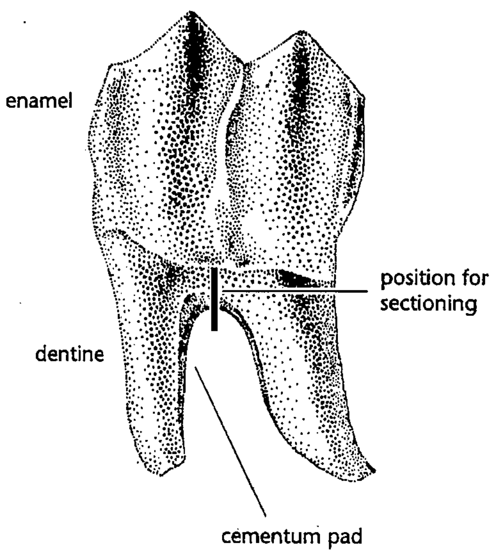


Figure 4
Side view of the first molar (M_1) tooth, showing the cementum pad and the correct position for sectioning the tooth

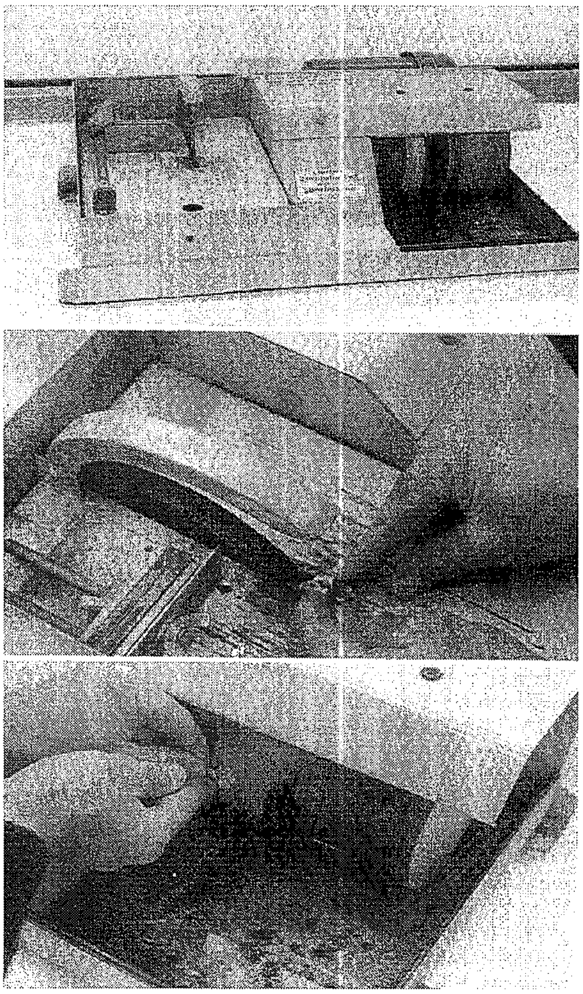


Figure 5
Lapidary unit used for cutting teeth then grinding and polishing the cut surface.

Ageing using cementum layers

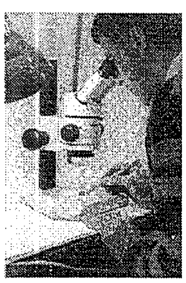
Examining the layers

View the sections under a low-powered binocular microscope using reflected light (Fig. 6). If scratch lines are evident on the surface, more polishing may be needed. Sometimes it may be necessary to brush the sectioned surface with water or glycerine to highlight the layers. You can sometimes improve the clarity by immersing the tooth section in ethanol for 5 minutes before examining it (Godawa 1989).

Changing the angle of the light source can also help. A small piece of putty or plasticine is useful for holding the sectioned tooth steady for viewing under the microscope. Correct orientation of the tooth section and the light source is essential for maximum clarity of the cementum layers. The M_2 tooth can be used as a check, remembering that it should have one less annual layer than the M_2 tooth.

Cementum is generally deposited on the dentine of the roots and under the crown of the tooth from the second summer after eruption onward (i.e., cementum is deposited on the M_1 from approximately 24 months, the $M_2$from 36 months, and the M_3 from 48 months of age).

Figure 6
Viewing the tooth section and counting the cementum layers under a low-powered binocular microscope using reflected light

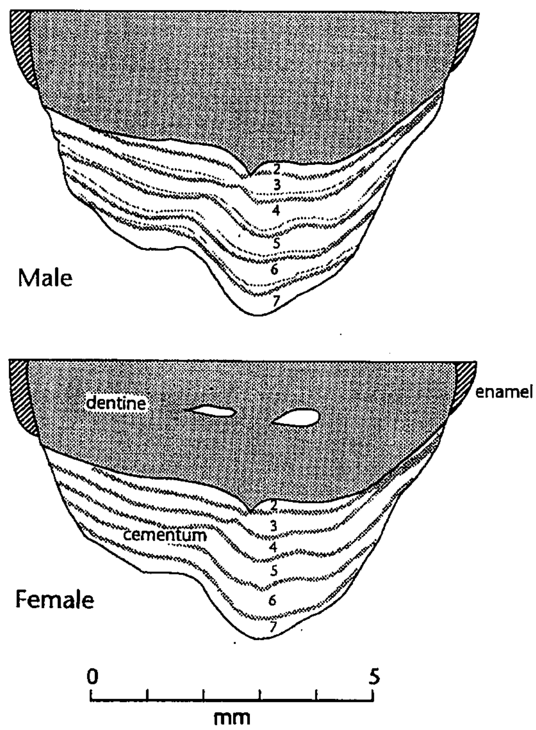


Cementum is deposited as an opaque (whitish) layer throughout the summer and autumn, and as a translucent (darker) layer during winter and spring. The opaque layers are broader and are associated with the annual period of maximum growth. The narrower translucent layers are associated with the annual season of food restriction (Mitchell 1967, Douglas 1970).

The darker bands of winter cementum therefore indicate the completion of successive years' cementum deposits (Fig. 7). For example, an animal shot in December with two complete layers of cementum on the M_1 will be 48 months old. The M_2 from the same animal will have only one complete annual layer. If this animal had been shot 6 months later, the M_1 would show a summer cementum layer outside the two complete annual layers.

The thickest part of the cementum pad is near the middle of the section, and contains the maximum number of layers. The margins of the cementum pad frequently have fewer layers. Counts of layers should therefore be restricted to the central part of the section.

Figure 7
Diagrammatic crosssections of the M_1 cementum pads from male and female deer approximately 7 years old. Note the additional rut lines present in the cementum pad for the male deer.



Occasionally, cementum is laid down on the MI in the yearling year. If present, this layer tends to be thinner and shorter than later layers. Additional narrow layers (a response to the rut in stags, or other causes) are also sometimes found within annual layers. Only those layers of substantial and similar width should therefore be counted as annual cementum deposits. These supplementary layers are typically narrow and sometimes either do not extend completely across the width of the cementum pad or appear broken (see Fig. 7). Storage in formalin does not affect the cementum layers (Mitchell 1967).

Etching and staining for difficult teeth

For those cementum deposits where layers are difficult to see, the tooth should be etched and stained:

- Immerse the tooth section in an etching solution of 15-20% formaldehyde and 90% formic acid (mixed in a ratio 25:5 vol/vol) for 4-5 hours.
- Remove the section from the etching solution and wash in running water for approximately 30 seconds. Rub off any crystals left on the section after etching.
- Immerse the section in 5% ammonia solution for about 5 minutes.
- Stain the section in lukewarm 0. 125% thionine solution for 1-5 minutes.
- Set the stain by brushing with 5% ammonia solution.
- Air-dry the stained section slowly (away from direct sunlight or heat source). Fast drying causes cracking.
- View the stained section under the microscope using reflected light as described above.

Appendix 2 shows photomicrographs of cementum pad sections from a range of deer. Some tooth sections show cementum layers that are whorled, diffuse, or otherwise indistinct, and are therefore difficult to interpret. Omar (1992) found that these patterns were usually continuous throughout the cementum pad, and further preparation of the tooth section failed to improve the resolution.

Histological methods involving fixation, decalcification, sectioning by microtome, and staining (see Low & Cowan 1963, Godawa 1989, Omar 1992) can also be used. However, although they produce sections that are easier to interpret, these techniques are considerably more time-consuming.

Interpretation

Ageing by cementum layers is not foolproof. Interpreting the cementum layers can be difficult, and the production of annual layers does not appear to be consistent in all individuals, with additional or missing layers sometimes observed in samples of known-age animals (see Lowe 1967, Omar 1992). However, Mitchell (1967) found that the cementum annuli method gave agreement with known-age deer in 75% of animals he examined. Since a considerable proportion of the animals harvested from New Zealand deer populations will be young (<4 years old), the number of individuals for which counting the cementum annuli produces an incorrect age will be small. Even for older animals the ageing error is unlikely to be more than 2-3 years, so any age-specific parameters or population age structures calculated from the information are likely to be generally reliable.

Age information for deer populations in New Zealand has two main uses. Firstly, when sex-specific growth curves are available, information on an individual animal's age and size can be used to estimate its condition as outlined above. Secondly, age structure information from populations is useful for examining harvest patterns and trends, as well.

as allowing comparisons between areas (or habitats), over time, and between hunting methods (e.g., aerial vs. ground hunting).

Condition assessment

Jawbone size is a convenient parameter for comparing the physical size characteristics of animals found in different areas or habitats, or for providing comparisons within the same population over a period of time. It is particularly convenient for deer, as jawbones can be obtained from hunters.

It is widely accepted that habitat conditions influence the physical growth of animals (i.e., their size and condition), and that morphological parameters such as jawbone size provide convenient indicators of environmental conditions during the animal's period of growth (the first 4-5 years of life).

Since analyses of jawbone size are often directed towards examining relatively fine geographic or temporal trends, the data should be standardised for age and sex effects which may swamp these smaller differences (Frampton & Nugent 1992).

When sufficient jawbone measurements and ages have been assembled (preferably at least 250 individuals of each sex covering a wide range of ages), sex-specific growth curves can be fitted to the data (Fig. 8).

A number of growth curves may be fitted, but we have found that the Weibull curve generally produces the best fit. The data used should all be from the same area and time period since growth rates and physical size can vary markedly between populations and over time (Challies 1989). Calculation of these growth curves is complex and involves the use of sophisticated computer software. The sex-specific curves can then be used to predict the average (or expected) jawbone lengths for animals of any age.

Once sex-specific growth curves have been fitted, the raw data can be standardised for age and sex simply by expressing the observed value as a proportion of the average size for deer of that age and sex predicted by the curves. This provides an individual "condition score" which can be multiplied by 100 to express it as a percentage, as follows:

$$\text{condition (\%)} = \frac{\text{individual jaw measurement}}{\text{sex-specific population average for age}} \times 100$$

Animals with condition scores less than 100% can be assumed to be smaller than average for the population, and animals with scores over 100% are larger than average. For example, if a particular red deer hind 34 months old has a jawbone measurement of 267 mm, and the local population average for hinds of that age is 257.8 mm, its condition score would be (2671257.8) x 100 = 104%.

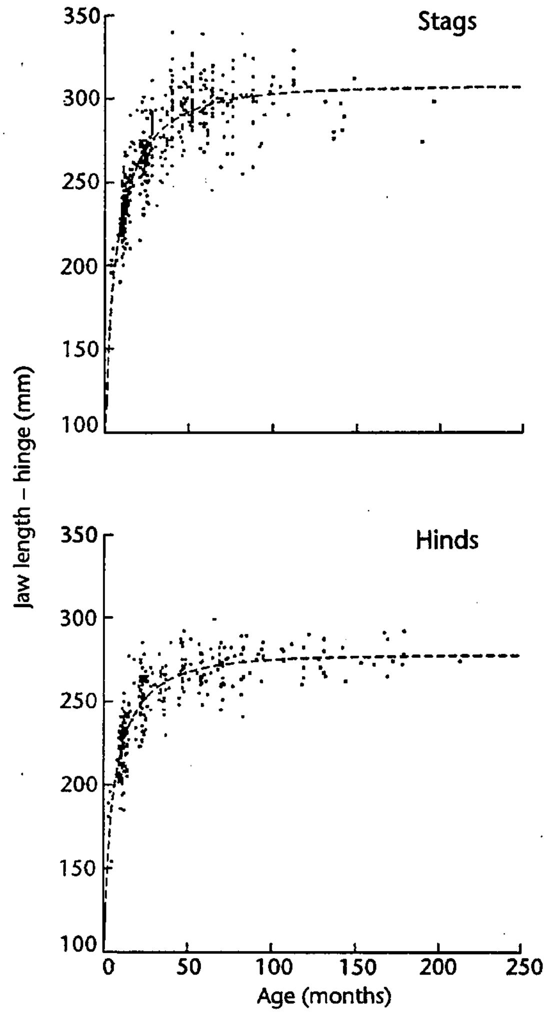


Figure 8
Weibull growth curves for male (n =45 1) and female (n=317) red deer from Pureora Forest Park, 1988- 1992.

Small deviations (±5%) from 100% probably mean little, since measurement and ageing errors must also be taken into account. Ageing error is more critical for younger animals (up to 3~4 years old) since this is when most growth occurs.

As the number of jawbone measurements and ages available increases, confidence limits for the growth curves can be calculated, making it possible to specify the expected condition score range for the population. For example, from Weibull growth curves based on red deer data for 451 stags and 317 hinds from Pureora Forest Park, we know that 90% of deer in that area have condition scores in the range 91-111 %. Individual condition scores failing outside this range would indicate either that an error in ageing had occurred or that the animal was atypical for the population (i.e., considerably smaller or larger than expected).

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We thank Graham Nugent and Joanna Orwin (Landcare Research) for helpful comments on earlier drafts of this manual, and Jan McKenzie and Terry Williams (Zoology Department, University of Canterbury) for taking the photomicrographs of the cementum pad sections.

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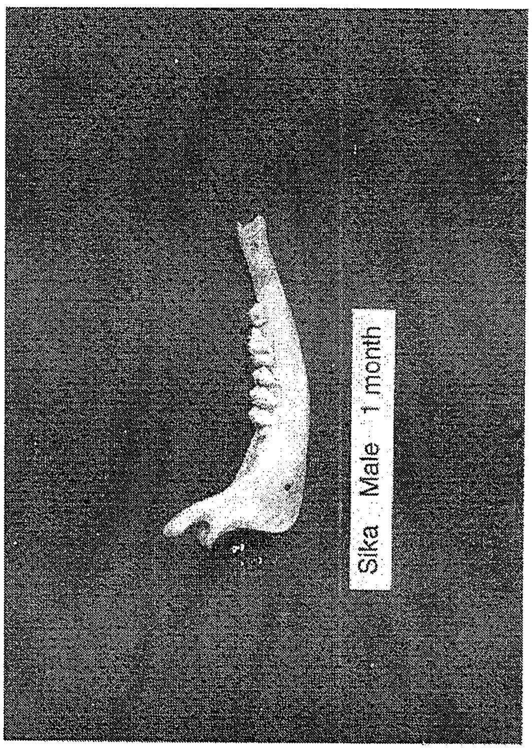
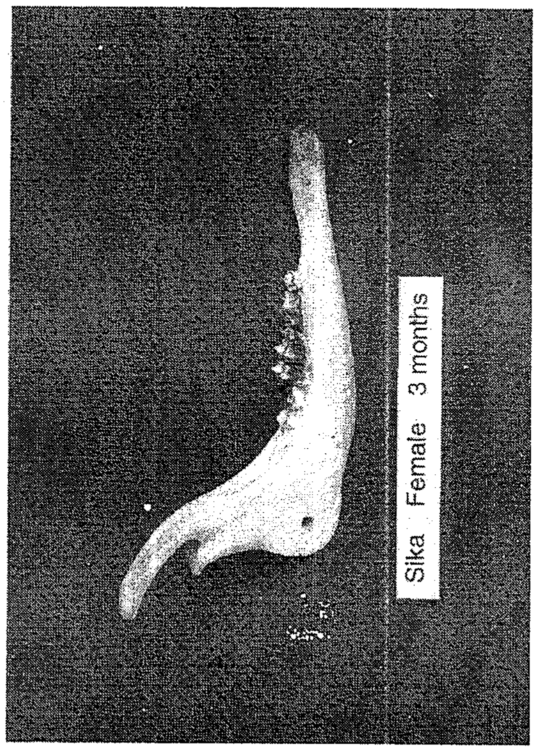
Appendix 1

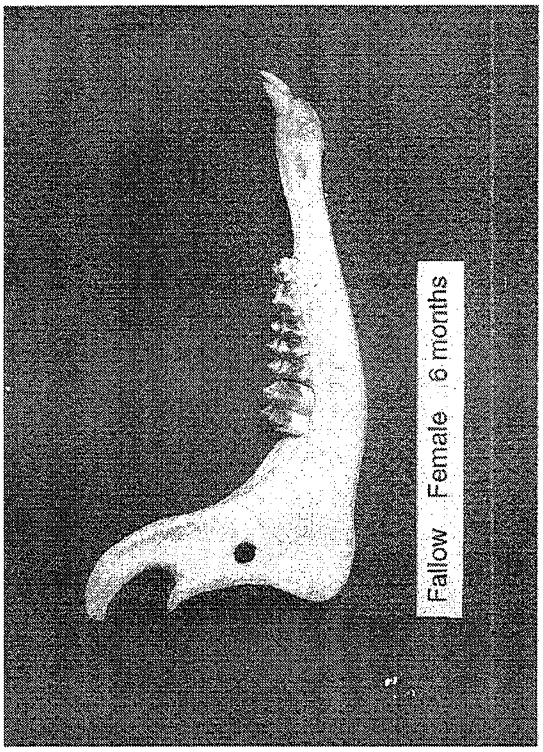
Photographs of lower jawbones from an age sequence of deer.

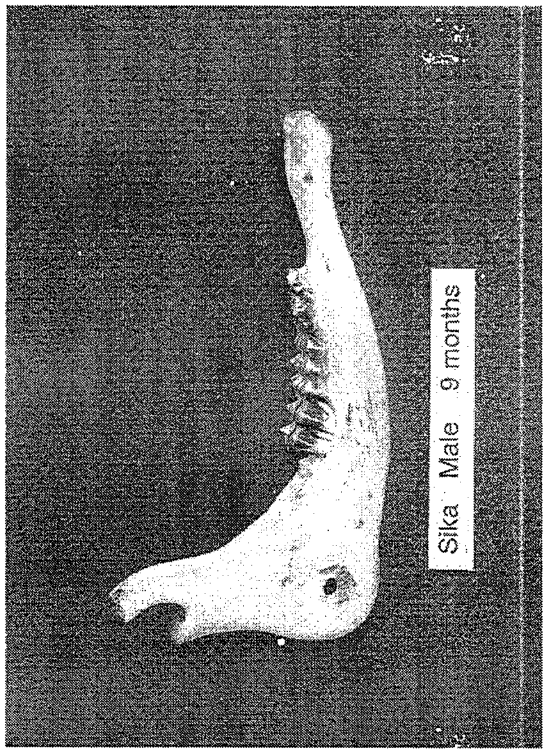
These photographs are of sika and fallow deer jawbones from a range of ages, and illustrate the sequence of tooth eruption.

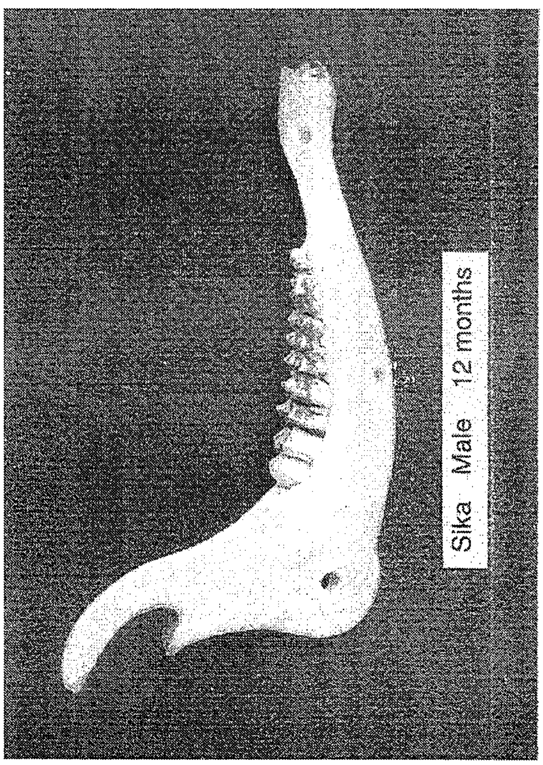
For deer up to about 3 years old, they can be used directly as a reference set to assist with ageing. Older animals should be aged using the cementum annuli technique.

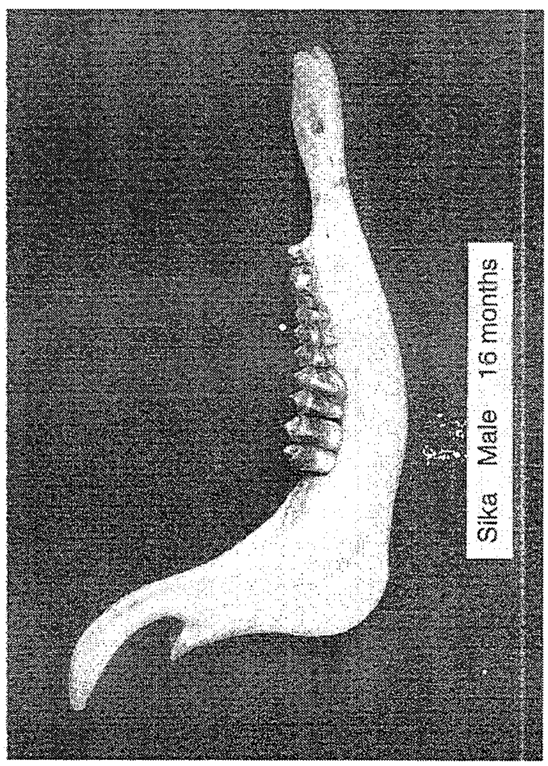


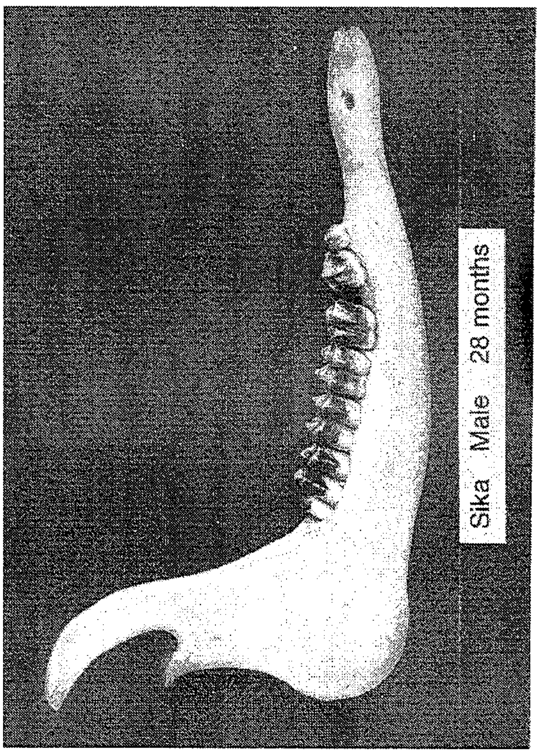


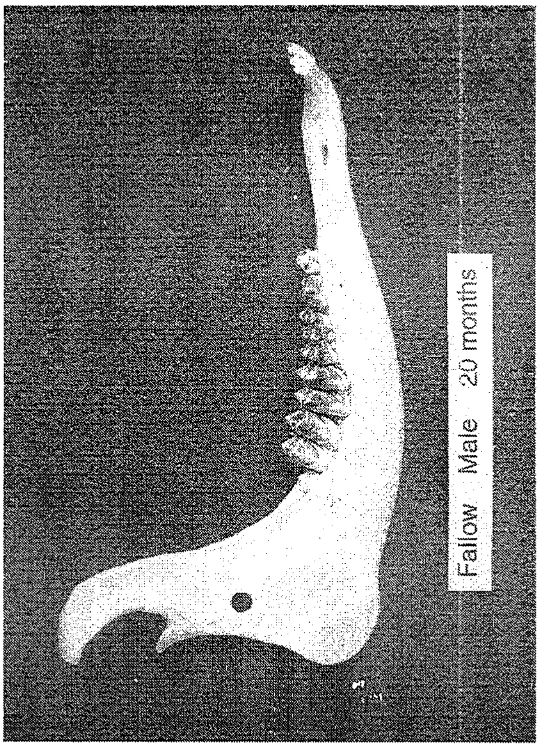

Fallow Female 6 months

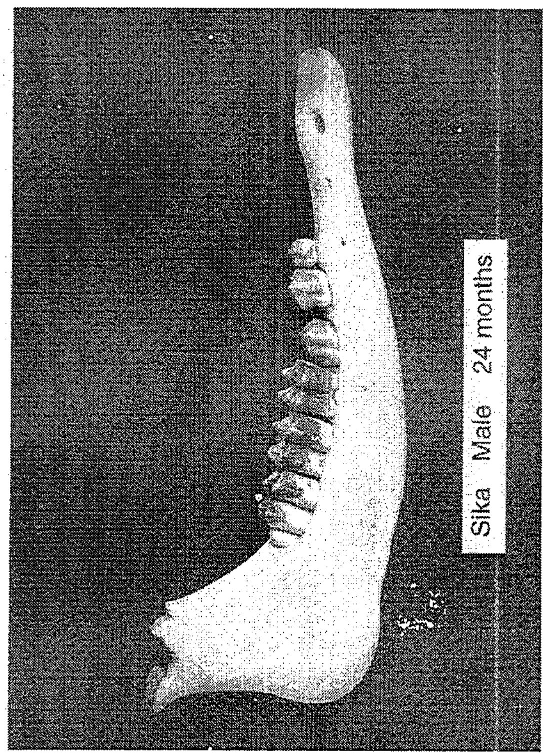

Sika Male 9 months

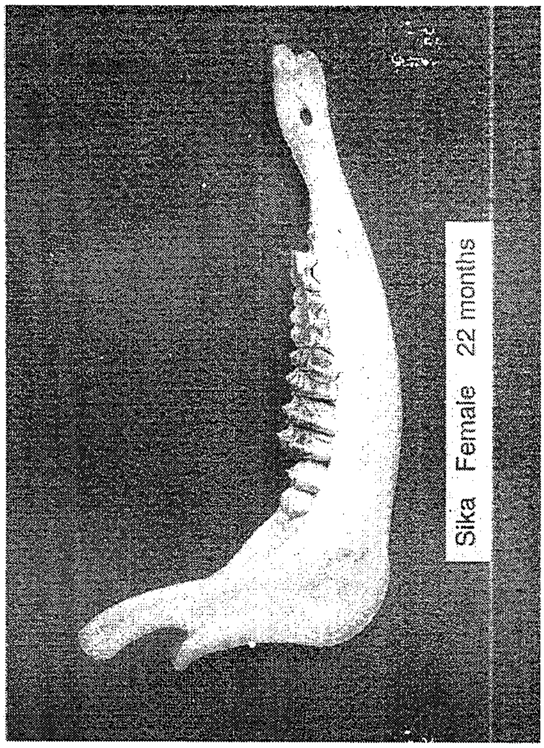

Sika Male 12 months


Sika Male 16 months


Sika Male 28 months

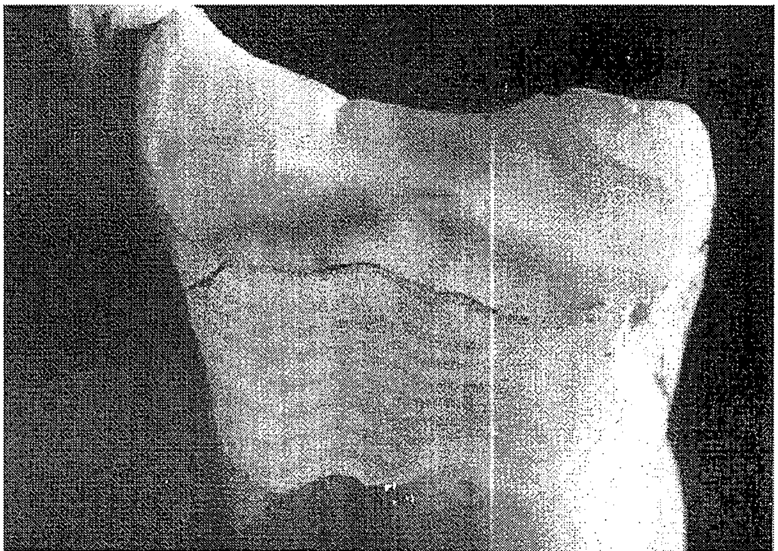

Fallow Male 20 months


Sika Male 24 months

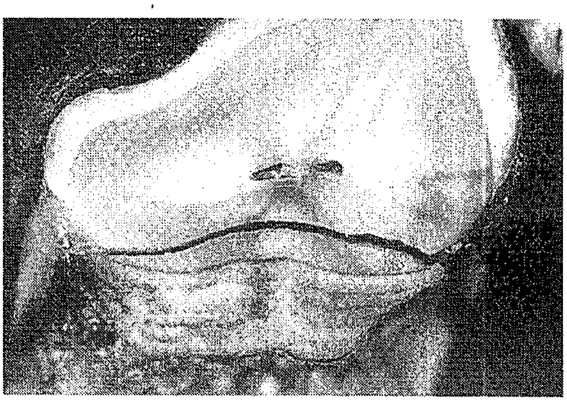

Sika Female 22 months

Appendix 2

Photomicrographs of cementum pad sections from a selection of first (M_I) and second (M_2) molar teeth, from red deer (below) and sika deer (pages 30-32).

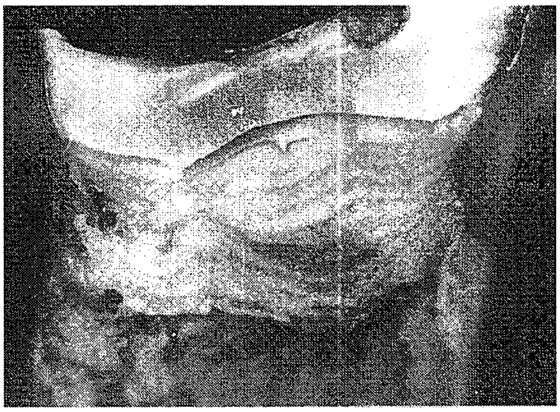


M_I tooth (no animal ID no.), showing eight complete layers (opaque and translucent) and a larger outer opaque layer. The exact month of death unknown, but the 'full' outer opaque layer indicates that the animal was shot towards the end of the summer/autumn period; approximate age 126 months (10½ years). Note the very thin opaque and translucent inner layers immediately adjacent to the dentine, which are likely to be yearling layers.



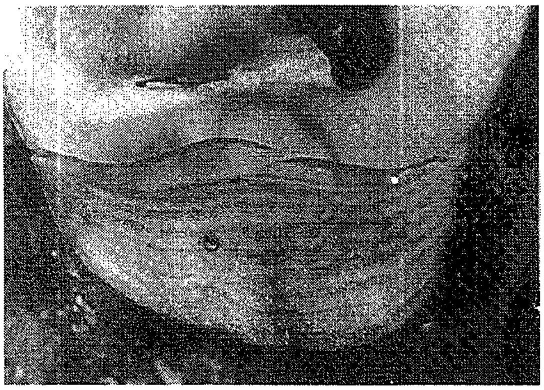
M_1 tooth (animal no. 1042), showing four complete layers with a broad outer opaque layer. Month of death April; age 76 months (4+ years).

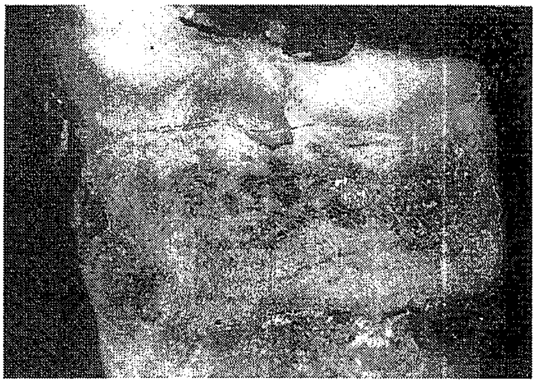
M_2 tooth from the same animal (no. 1042), showing four complete layers with a narrow outer translucent layer.



M_1 tooth animal no. 1047), showing nine complete layers and an outer opaque layer. Month of death April; age 136 months (11 + years).

M_2 tooth from the same animal (no. 1047), showing eight complete layers and an outer opaque layer.





M_2 tooth (animal no. 1026), showing poorly defined cementum layers. This section did not improve with staining.

M_2 tooth from the same animal (no. 1026), showing eight complete layers and an outer opaque layer. Month of death April,. age 736 months (11 + years).