

Diagnostic parameter selection for species identification of bite marks on chewcards

Milestone 4 & 5, chewcard bite identification tool (DOC 3033864)

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Background

The Department of Conservation has contracted Manaaki Whenua – Landcare Research to produce diagnostic keys and guides for the identification of animals interacting with chewcards (baited sheets of plastic coreboard that preserve the tooth impressions of animals that bite them, which are used for indexing vertebrate pest species abundance). Identifying and quantifying the characteristics of bite marks that are peculiar to each species (diagnostic parameters) and are consistent in occurrence and appearance is crucial to producing a robust species identification guide.

This document describes and quantifies a set of diagnostic parameters for the bite marks of a range of small mammal pest species, and demonstrates their advantages over other parameters. It primarily aims to describe how the diagnostic parameters used in subsequent tools were selected and the data used to quantify them. It is not, by itself, a diagnostic tool or user guide for chewcard bite identification.

Methods

Mammals are equipped with a range of incisor, canine, premolar and molar teeth in varying combinations and relative sizes. The presentation of a broad, flat, rigid device (a chewcard 90 × 90 mm) firmly fixed to a tree or similar support means that generally only teeth at the front of the mouth of interacting animals come into contact with the chewcard. This restricts the selection of diagnostic parameters to incisors (broad, shallow-depth teeth at the front end of jaws) and canine teeth (long, pointed teeth immediately adjacent to incisors, if present). Incisors are large and broad in herbivores and rodents, while canines are most developed in carnivores, in which incisors are reduced or absent (Figures 1–4). It is clear from these photos that bite marks on chewcards will be dominated by incisor teeth in herbivores and rodents, and by canine teeth in carnivores. Hedgehog bite marks are likely to be made by a range of teeth.

A range of canine and incisor tooth impressions on chewcards were measured to quantify potential diagnostic parameters for species comparisons, and to qualitatively assess their ease of measurement. Impressions from wild animals were measured for mice, ship rats¹, possums, hedgehogs, and some lagomorphs (hares and rabbits), as these species or groups could be confidently identified from approximate tooth dimensions, shape and biting patterns (Sakata 2011; Sweetapple and Nugent 2011). Where sample sizes were small (cats, weasels) or individual species could not be easily separated by qualitative means (lagomorphs, mustelids and cats), samples were augmented or solely gathered by simulating bite marks (pressing skulls and mandibles firmly onto

¹ Wild ship rat measurements may include a few measurements of Norway rats.

unmarked chewcards) and measuring the impressions. Measurements were taken from impressions with a clearly defined start and end for incisors, and of inter-canine distances (centre to centre) and maximum canine diameters for predators (Figure 5).

In most species there are differences in the size and shape of the upper (skull) and lower (mandible) impressions. Therefore, separating upper and lower jaw measurements is likely to result in more robust diagnostics. This was done by taking upper jaws as the impressions more distant from the card margin for incisors, and the longest inter-canine distances for canines, when clear upper and lower impression sets were identifiable. (Note that upper canines are exterior to [outside] the lower canines in predators; e.g. the stoat in Figure 4.)

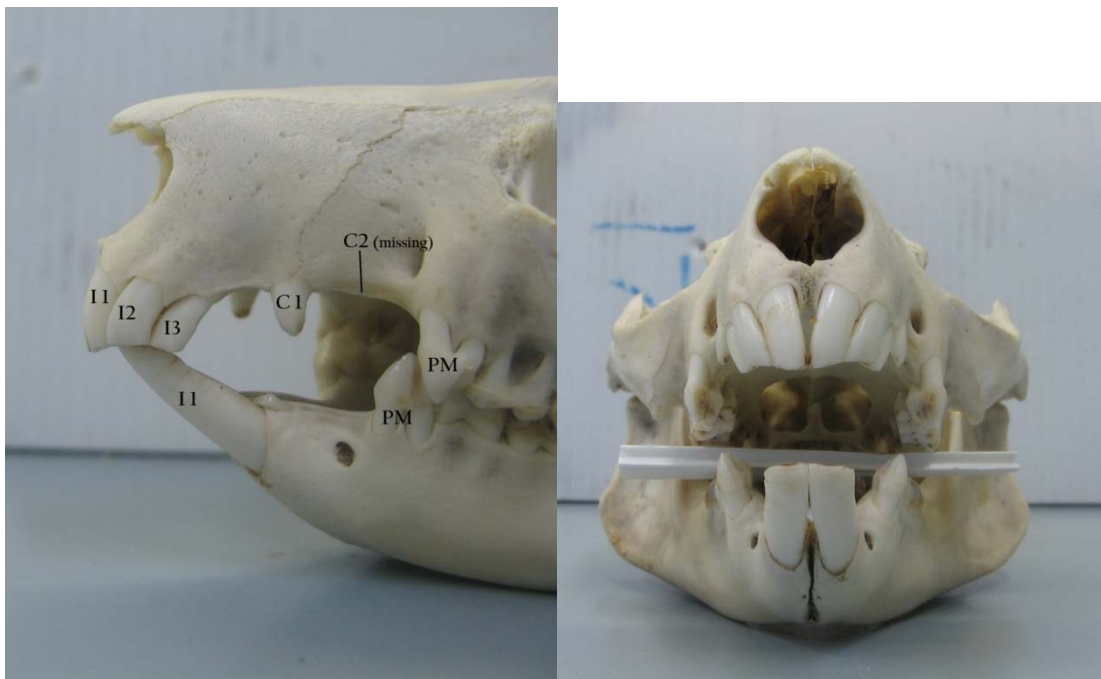


Figure 1. Possum skulls showing incisor (I1–I3), canine (C1) and premolar (PM) teeth.



Figure 2. Rat skulls showing the large incisor teeth typical of rodents (four large teeth at the front of

the skull) separated by a large diastema (gap) from rows of molar teeth at the back of the mouth. Canines and premolars are absent.



Figure 3. The upper (left) and lower (right) incisors of a hare. Note the medial groove along the length of the upper incisors.



Figure 4. A stoat skull (left) showing the small incisors and large, widely spaced canines typical of carnivores, and a hedgehog skull (right), showing moderate-sized canines at the front of the upper jaw and two peg-like incisors at the front of the lower jaw.

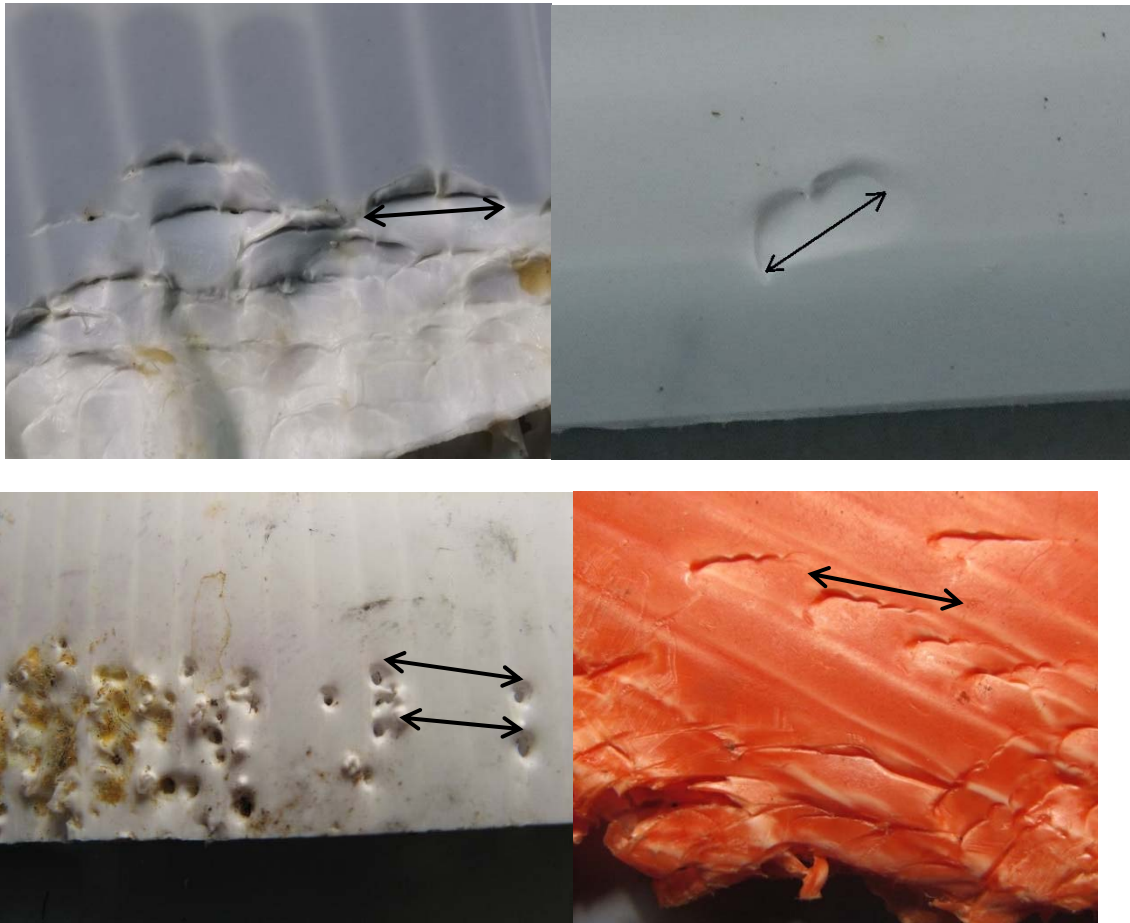


Figure 5. Examples of bite-mark measurement. The top row shows possum (left) and rat (right) incisor-pair impressions. The lower left shows inter-canine distances for the upper and lower jaw of a stoat, and the lower right is an upper incisor-pair measurement for a lagomorph.

Selecting and testing potential diagnostic parameters

Possums, lagomorphs and rodents

There are just two incisors in both the lower and upper jaws in rodents and lagomorphs (Figures 2 and 3) and the lower jaw (mandible) of possums (Figure 1), so that bite marks made by these jaws are mainly represented by wide but thin (in depth) incisor-pair impressions (Figure 5) or holes. Similar incisor-pair impressions are made by the upper jaw of possums, because the I1 teeth extend further than the adjacent incisors (Figures 1 and 5). The remaining teeth, premolars/molars (and small canines in possums) are positioned well back on the jaws and skulls, separated from the incisors by a large diastema (gap), so that they are not usually engaged while biting chewcards. This means that lower and upper incisors or incisor-pair impressions are the only practicable candidates for diagnostic parameters in rodents, possums and lagomorphs. Incisor-pairs, as opposed to individual teeth, were chosen because full pair impressions are only made when the jaw is held parallel to the card surface, which minimises distortion of the impression.

Tooth shape and arrangement are very similar in all New Zealand rodent species, so they can only be separated using incisor-pair size. Although no wild-caught Norway rats were available for measurement, ship and Norway rats are unlikely to be separated by tooth impression size because there is considerable overlap of body size in wild-caught rats from extensively forested sites (ship rats: 52–210 g, Norway rats 103–328 g; King 1990).

Upper jaw incisor impressions were more, or as, frequently identified and measured on chewcards than lower incisor impressions for cards with measurable mouse, rat, possum or lagomorph incisor-pair impressions (Figure 6). For chewcards with at least one measurable rodent or possum incisor-pair impression, upper and lower incisor-pair impressions were identified on 94–98% and 56–63% of those chewcards, respectively.

Mice, rats and possums can all be confidently separated by incisor-pair measurement, for both upper and lower impressions, as there is no overlap in measurements between these species (Figure 7). Upper incisor measurements of kiore were available for 11 skulls from Chatham Island, and these showed some overlap with the extreme lower range of European rat measurements, but the majority of kiore measurements (82%) did not overlap with either mice or rats (Figure 7). It is unlikely there are any kiore among the 'rat' measurements, as most of those chewcards came from Karamea, Marlborough and the North Island. There is no way to tell if the rat measurements include any Norway rats, but if present their numbers will be small as they always comprise no more than a small proportion of rats in forested mainland habitats.

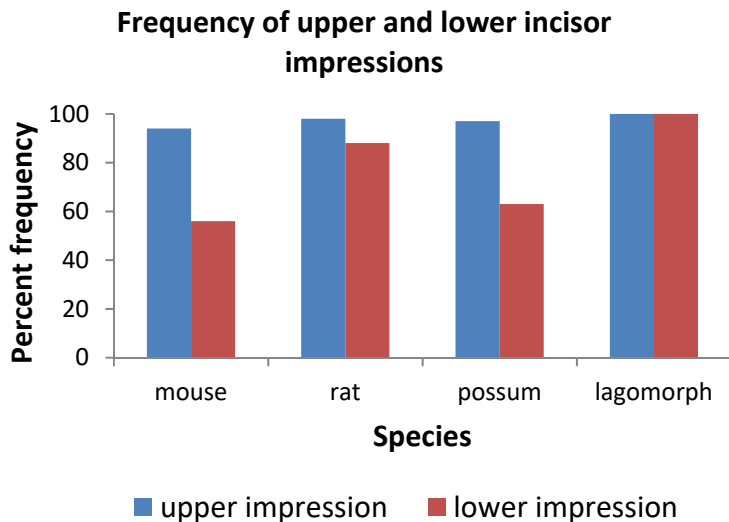


Figure 6. Frequency of occurrence of measurable incisor-pair impressions for four species on chewcards where they were positively identified.

Clear species distinctions based on incisor-pair impression measurement and the superior frequency of measurable upper incisor impressions point to the width of upper incisor-pair impressions being the best candidate for a diagnostic parameter to identify mice, rats and possums on chewcards. Qualitative differences in the patterns of bite marks exist between mice, rats and possums, and can also, with experience, be used to identify these species. Qualitative parameters should always be confirmed using impression-width measurements, when available.

Rabbits and hares are not separable from incisor-pair measurements (Figure 8), and combined lagomorphs are not separable from possums, with upper jaw measurements for lagomorphs lying entirely within the range of those for possums (Figure 9). Possums and lagomorphs must, therefore, be separated using qualitative criteria. Fortunately, the upper incisors of lagomorphs have a prominent longitudinal groove on their anterior surface, which produces distinctive notches in the middle of impressions of each upper incisor. These, together with a similar-sized notch that separates the left- and right-side incisors, produce impressions with the appearance of four adjacent similarly sized incisors in a straight line (Figure 5). That pattern is not matched by any other candidate species, and is further confirmed as produced by a lagomorph by the presence of just one notch (the medial notch) in the lower incisor-pair impressions, which otherwise are of similar size and straightness to the upper impressions. The upper incisor-pair impression width and shape, therefore, are diagnostic for lagomorphs.

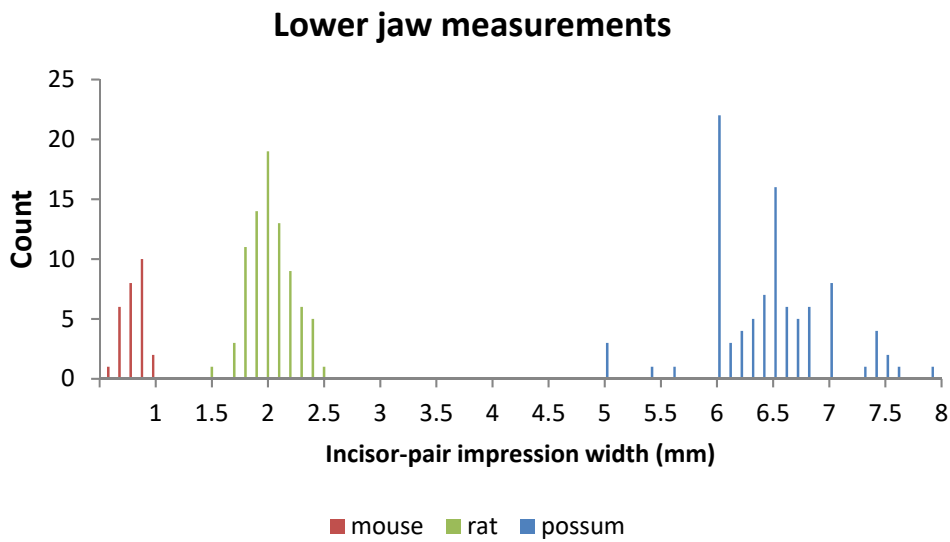
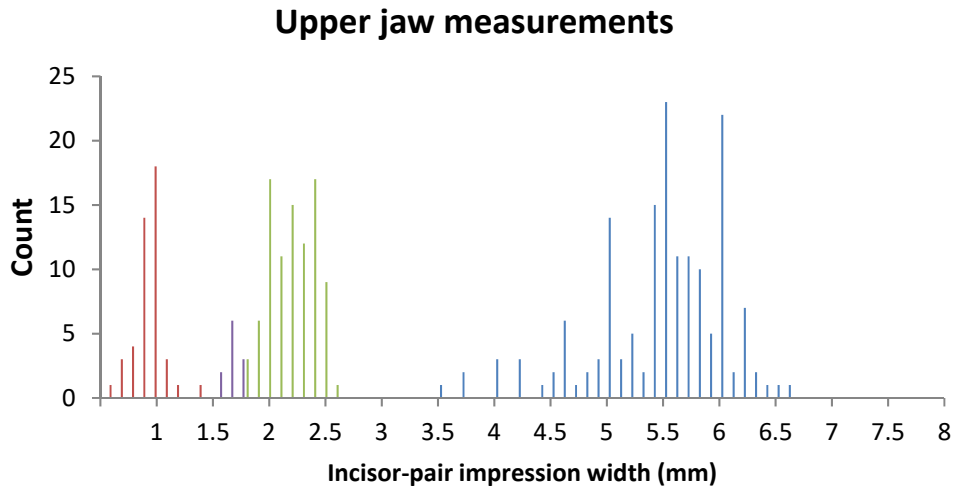
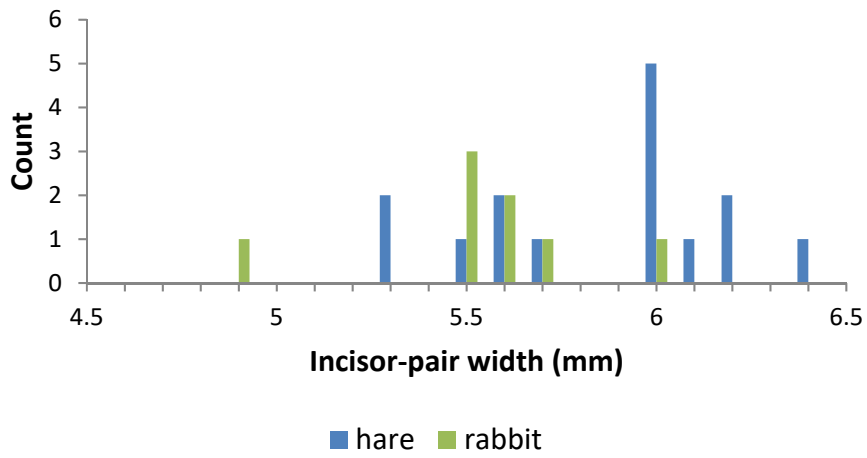


Figure 7. Incisor-pair impression measurements from chewcards with positive identifications of kiore, mice, rats or possums (11 kiore, 48 mice, 93 rats and 164 possums). Kiore were from Chatham Island and identified from carcass morphology before their skulls were used to make simulated impressions. All other measurements are from cards bitten by live animals, with species identified by biting patterns. Shaded regions indicate zones of overlapping bite measurements between rodent species.

Lagomorphs: skull



Lagomorphs: mandible

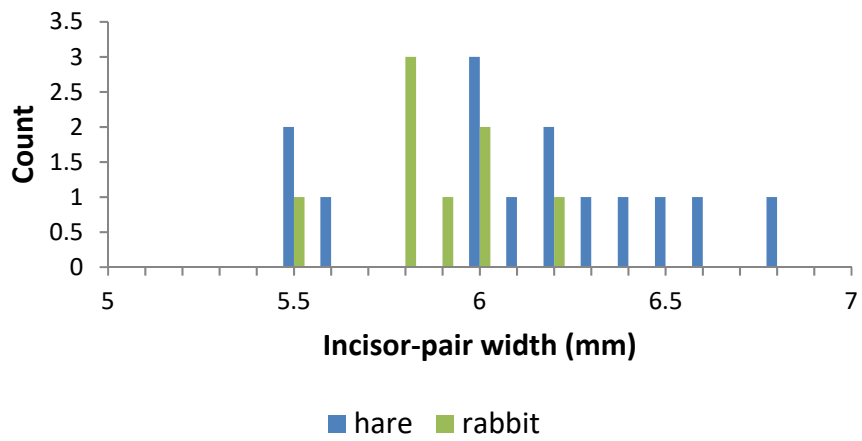


Figure 8. Measurements of simulated (on chewcards) inter-canine distances (upper jaws) and incisor-pair impression widths (lower jaws) for 16 hares and 8 rabbits.

Possums & Lagomorphs

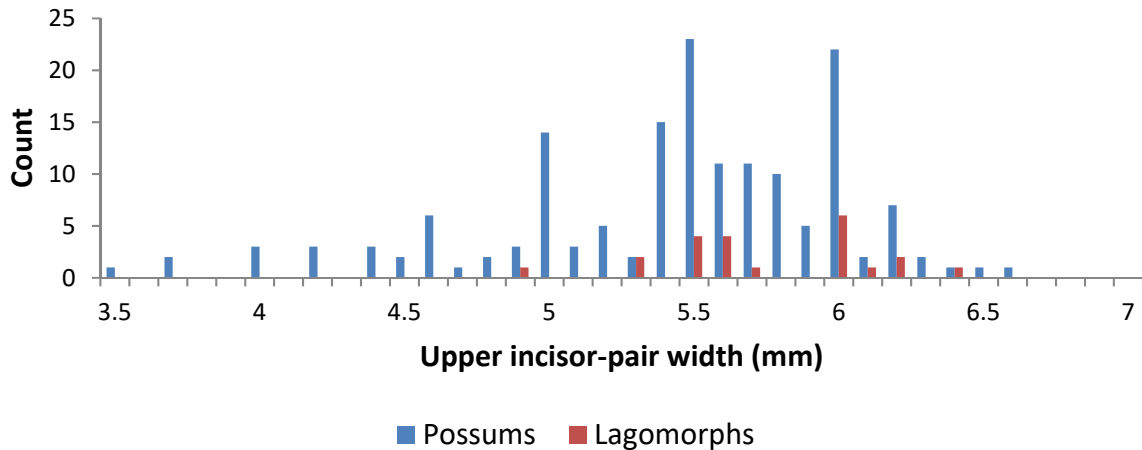


Figure 9. Upper incisor-pair width measurements from chewcards for 159 possums and 22 lagomorphs.

Mustelids and cats

Canine impressions and puncture holes predominate on chewcards bitten by all mustelids and cats (e.g. Figure 5). Measurement of these bite marks revealed that although there was a general trend towards larger-diameter puncture holes being made by larger-bodied species, the diameter of those holes could not be consistently measured because they were frequently distorted due to splaying of the teeth, their margins were indistinct, and the puncture walls tended to partially close.

The resulting uncertainties regarding bite-mark dimensions were minimised by using centre-to-centre measurements of inter-canine distances, which are presented in Figure 10. Errors were further minimised by measuring upper-canine pair widths on the lower card surface when these incisors had extended through to the lower card surface. Each species has a discrete peak of inter-canine distances (cats excepted due to the small sample size), but there is some overlap in measurement extremes with adjacent species, principally between the lower measurements for cats and the upper measurements for ferrets (Figure 10). Upper canine measurements have a smaller range of overlap than do lower canines; for ferrets, 14.5% of upper canine measurements fall within the range for cats. The proportion of cats with measurements within the ferret range cannot be accurately determined at present due to an inadequate sample of cats (their measurements do not conform to a normal, bell-shaped, distribution; Figure 10).

We can estimate the probability that a measurement within the zones of overlap is from one species by adjusting sample sizes upwards for each size class of the less frequently measured species, so that total observations equal those of the most frequently measured species (e.g. ferrets), then calculating the proportion of total adjusted observations that were of the species and size class of interest (Table 1).

Hedgehogs

Hedgehogs differ from other species in that the relevant teeth in the upper jaw differ from those in the lower jaw. Upper- and lower-jaw bite marks are represented by canine and incisor teeth, respectively (Figure 4). The upper jaw inter-canine distances overlap with those for weasels at the upper end of their range (c. 6 mm), but can be separated from them based on impression shape: hedgehogs have oval-shaped canines that usually do not perforate the chewcard, as opposed to the sharp, circular canines in predators. Also, the presence of blunt, peg-like incisors in the lower jaws of hedgehogs produces a unique combination of marks (small canine marks on one surface and blunt marks or crushed areas on the opposite surface of chewcards). Therefore, hedgehogs can be separated from other species by this unique combination of qualitative criteria.

Ruminants (goats, deer and domestic stock)

Ruminants have four incisors on both the left and right lower jaw, with no teeth opposing them in the upper jaw. The two inside incisors (I1 and I2) are always broad and thin, with the I3 and I4s sometimes narrow. This combination of teeth produces a distinctive pattern of an arc of incisor impressions, ranging from c. 20 mm (sika deer fawn) to 80 mm (cattle) wide, with no impressions, or an indistinct ridge, on the opposite card surface to the incisor impressions.

Within ruminants, species are difficult to separate, but their bite marks occur infrequently in forests, and the identity of ruminant bite marks on farmland can usually be ascertained from the stock present or the landowner. Extensive motion-camera databases indicate that deer rarely if ever bite chewcards, and are more likely to be spooked by them.

Pigs

Pigs have a full range of teeth on both the jaw and in the skull so do not exhibit the missing upper incisor impressions of ruminants. Their teeth are robust, with generally rounded or flat grinding surfaces, although recently erupted incisors and premolars do have points and ridges. The mouths of adult pigs are large enough to envelope the entire chewcard. As a result, pigs can produce extensive, but usually non-indistinctive, chew marks and crushing across both surfaces of the chewcard that do not lend themselves to quantifiable diagnostic description. Where individual tooth impressions are evident, they are usually of the peg-like incisor teeth, either in an arc of four rounded impressions, each about c. 5 mm diameter (jaw), or a larger pair of oval tooth impressions each c. 8 mm wide (skull). Extensive motion-camera databases indicate that pigs take little interest in chewcards, and the rare records of interactions have not included biting. Therefore, pig bites on chewcards are rarely encountered.

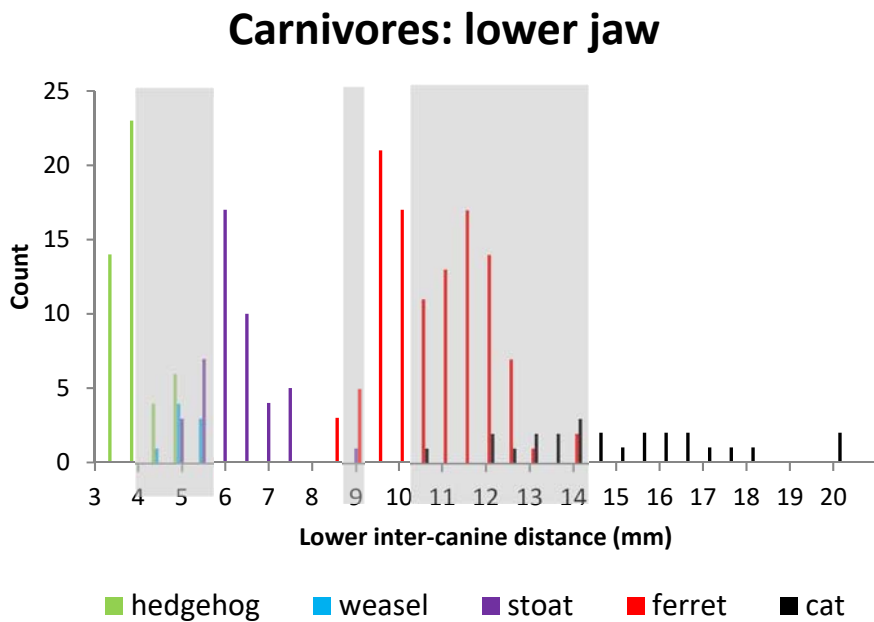
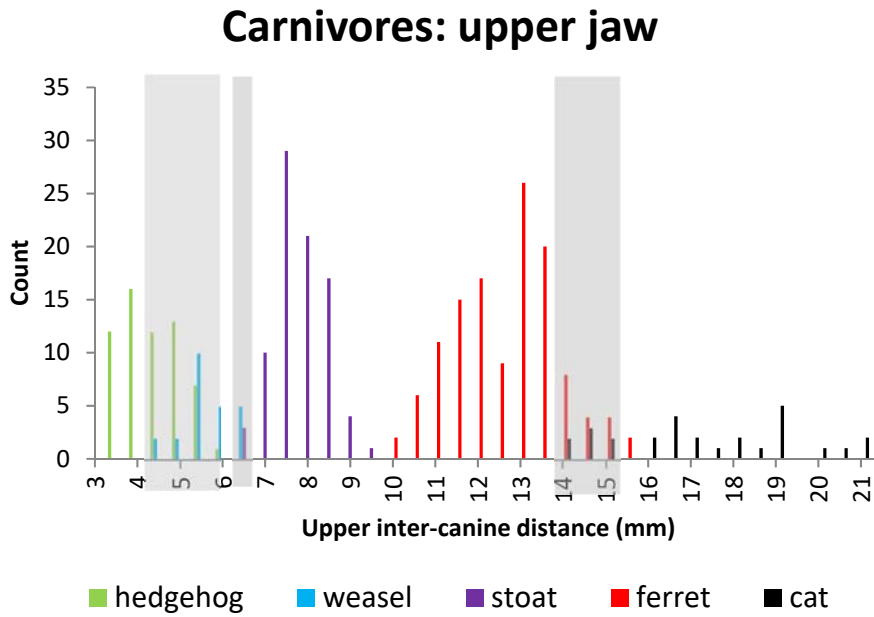


Figure 10. Inter-canine distances for mustelids, cats and hedgehogs. Shaded regions indicate zones of overlapping bite measurements between predator species.

Table 1. Number of upper inter-canine distances measured from chewcards for four predator species, and the probability (Prob.) of the measurements belonging to one of the four species. Where probabilities are <1, assume that both species are equally abundant. Measurements were taken from simulated bites from skulls of wild-caught animals. All captures, including juveniles, were included.

Inter-canine distance (mm)	Weasel		Stoat		Ferret		Cat	
	No.	Prob.	No.	Prob.	No.	Prob.	No.	Prob.
4.5	2	1						
5.0	2	1						
5.5	10	1						
6.0	5	1						
6.5	5	0.855	3	0.145				
7.0			10	1				
7.5			29	1				
8.0			21	1				
8.5			17	1				
9.0			4	1				
9.5			1	1				
10.0					2	1		
10.5					6	1		
11.0					11	1		
11.5					15	1		
12.0					17	1		
12.5					19	1		
13.0					26	1		
13.5					20	1		
14.0					8	0.509	2	0.491
14.5					4	0.244	3	0.756
15.0					4	0.326	2	0.674
15.5					2		0	
16.0							2	1
16.5							4	1
17.0							2	1
17.5							1	1
18.0							2	1
18.5							1	1
19.0							5	1
19.5							0	1
20.0							1	1
20+							5	1
Totals	24		85		124		30	

Selected diagnostic parameters

The findings from bite mark measurements and analysis are summarised in Table 2. This provides the basis for the diagnostic keys in the accompanying documents (keys, descriptions and PowerPoint). Ship rat measurements may include some Norway rats. Measurements were rounded to the nearest 0.5 mm before collating.

Table 2. Diagnostic parameters and supporting qualitative characteristics for chewcard bite mark identification

Species	Sample size (animals/cards)	Quantitative parameters	Qualitative characteristics
Invertebrate	20 field cards	Circular impressions ≤ 0.3 mm diameter	Fine rough tears on margins and/or between card channels on one surface.
Mouse	45 field cards	Upper incisor pair width 0.5–1.2 mm	Small cuts on margins and/or material removed from between channels on one surface, with narrow (c. 1mm) heavily chewed band around smooth cut edges. Lower incisor pair strongly curved.
Kiore	11 skulls	Upper incisor pair width 1.6–1.8 mm	NA
Ship rat	91 field cards	Upper incisor pair width 1.8–2.5 mm	Small to large portion of (usually) both surfaces removed, leaving jagged edges, but usually without a chewed band. Lower incisor pair strongly curved.
Possum	161 field cards	Upper incisor pair width 3.5–6.6 mm.	Card surfaces \pm extensively crushed within about 5–20 mm of card edge, \pm including whole or partial incisor-pair impressions. Lower incisor pair more strongly curved than the upper pair.
Lagomorph	24 skulls	Upper incisor pair width 5.0–6.5 mm, comprising 4 humps (3 notches) in a straight line.	\pm large portions of card removed leaving cleanly cut edges buffered by a band of extensive incisor impressions. Lower incisor-pair impression c. 6 mm,

			straight with 1 medial notch.
Weasel	24 (3 field cards and 21 skulls)	Upper inter-canine distance 4.5–6.5 mm	Circular canines, puncture holes about 0.5–1.0 mm diameter.
Stoat	56 (7 field cards and 49 skulls)	Upper inter-canine distance 7.0–9.5 mm	Circular canines, puncture holes about 0.5–1.5 mm diameter.
Ferret	124 skulls	Upper inter-canine distance 10.0–14.0 mm	Circular canines, puncture holes about 1–2.5 mm diameter.
Cat	27 skulls	Upper inter-canine distance 14.5–22.0 mm	Circular canines, puncture holes about 1.5–3 mm diameter. Chewed card corners often missing.
Hedgehog	66 (33 field cards, 33 skulls)	Upper inter-canine distance 3.0–6.0 mm	Oval canines, puncture holes or depressions generally <1 mm (short) diameter. Blunt incisor impressions/crushing on lower card surface.
Ruminant (chamois and deer)	35 jaws	Single I1 tooth width 5.0–11.0 mm	Lower incisor arc about 20–60 mm wide and with no opposing incisor impressions.
Pig	6 skulls and two chewcards inspected	NA	Extensive biting and crushing by blunt peg-like teeth ± across the entire chewcard surface

References

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