# APPENDICES

## APPENDIX A1

### Jackal Capture Methods

Darting of jackals was moderately successful, while trapping with foot-hold traps was highly successful, as reported in Chapter 3. The following is an abbreviated account of the demise of the other methods that were tried. If the foot-hold traps had been unsuccessful, the only option remaining was a helicopter with a netgun!

<u>Method 1: Cage Trap.</u>

Cage trap with vertical sliding trapdoor (200x50x40 cm). Baited with remains of impala carcases.

Results: No jackals captured after 40 trap nights. One lioness captured on 41st trap-night.

Shortcomings: The trap was inspected by jackals, but they did not enter the trap despite thorough camouflage with vegetation.

<u>Method 2: Noose trap.</u>

Modification of a noose trap described by Ferguson (1980) as being the most successful method. Instead of a fishing rod, elastic rubber strips were used which were attached to a suitable tree.

Results: Four jackals captured - all juveniles.

Drawbacks: Adults not captured.

Method 3: Pitfall trap.

Holes 1 x 1 x 1,2 m deep were dug in flat alluvial soil. A square metal frame was constructed from 25 x 25 mm square tubing, and placed on the rim of the hole. Four 800 x 800 x 12mm Bison Board boards were placed so as to meet at the centre of the frame and so cover the hole. The boards were attached to the frame and joined with cotton thread at the centre. The boards were covered with a 20 mm layer of soil. All other soil was removed from the site. Bait (meat, rumen contents, blood, jackal urine) was placed at the centre of the covered boards.

Results: No jackals captured. Some of the traps were set off by unidentified animals which were not captured.

Drawbacks: To much activity required. Jackals alerted to human activity by disturbed soil.

Method 4: Drop trap.

A 3 m diameter covered weldmesh drop trap with remote mechanical release was constructed. This was suspended from a central pole over a wildebeest carcase.

Results: No jackals captured. They would not approach the carcase while the trap was in position.

Drawbacks: Too much activity. Too visible. Noisy, movement of the suspended trap in windy weather.

Method 5: Driving into drop net.

Two 4x1,5 m nets of 1 mm dacron with 70x70 mm openings were made by hand. These nets were suspended from poles by clothes pegs. A 70 m funnel constructed of a 400 mm wide strip of woven plastic led to the nets. Jackals were attracted to the mouth of the funnel with an impala carcase. They were then driven towards the funnel with vehicles, with the intention being that they would run into the nets.

Results: No jackals captured.

Drawbacks: Jackals would turn and run past the vehicles, and would not approach the plastic walls or the nets.

Method 6: Driving into boma.

From Method 5 it was apparent that jackals would avoid unnatural objects even at the risk of running towards an approaching vehicle. It was thus surmised that an artificial barrier could be used to direct jackals into a large pen. A 10 m diameter pen with a 400 mm side opening was constructed from weldmesh. A woven-plastic and barrier tape funnel was constructed for Method. Each arm of the funnel was 1 km long. Fourteen helpers drove jackals into mouth of funnel and towards pen.

Results: No jackals captured.

Drawbacks: Too much activity in setting up pen. Jackals ran over or under barrier tape before reaching pen.

Method 7: Drugged bait.

Eight mg of phencyclidine hydrochloride (Syclan, Centaur, Johanesburg, South Africa) were injected into each of two separate small pieces of meat. This dose was based on an approximate dose of 1-2 mg $kg^{-2}$ and the fact that phencyclidine is rapidly absorbed by the oral route (Harthoorn 1975). The pieces of drugged meat were placed on the ground next to the edge of a road in the centre of the study area. Approximately five litres of a mixture of impala blood and rumen contents were spread over an area approximately 10 m in diameter centred on the bait. This was in order to keep jackals at the bait for as long as possible to allow the drug to take effect. Extra meat was not provided as this would have slowed absorbtion of the drug from the stomach. An open, short-grass area with a visibility of 100 m in all directions was chosen to facilitate finding drugged jackals.

Results: No jackals captured. Bait was eaten after one hour and the site abandoned after further fruitless search for more meat.

Drawbacks: Jackals did not remain at bait area long enough for drug to take effect. Use of higher doses was considered unethical due to the prolonged recovery period.

# APPENDIX A2

## Radio collars

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Legend for Figure A2.

A Standard collar

B Activity collar

- a Machine belting collar.
- b Size 'C' Lithium battery.
- c VHF transmitter.
- d Whip antenna.
- e Mercury switch.
- f 2 ohm resistor.
- g Pop rivets.

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Construction

Radio collars for jackals were constructed as shown in Fig. A2.

Materials:

1 VHF radio transmitter with 25 cm antenna (G. van Urk, Potchefstroom University for Christian Higher Education, Potchefstroom, South Africa).

1 size C Tadiran (Israel Electronics Industries, Tel Aviv, Israel) lithium battery.

800 x 30 x 1 mm reinforced machine belting (Interbelt, Kramerville, South Africa)

Araldite epoxy casting (CW1312GB & HY1300GB, Ciba Geigy Plastics, Cambridge, UK).

2 mercury switches (Kopp Electronics, Johannesburg, South Africa).

1 2 ohm resistor.

Manufacture:

Standard collars The machine belting was scored and bent to form a hanging compartment of 55 x 38 cm between two layers of belting. The two layers of belting were temporarily joined with cyanoacrylate glue (Bostik, Fernex Industries (Pty) Ltd., Johannesburg, South Africa). One side of the framework was then glued to a smooth cardboard surface using contact adhesive (Genkem, General Chemical Corporation Ltd., Johannesburg, RSA). The radio transmitter was then connected to the battery. The battery and transmitter were placed in the compartment as shown in Fig. A2a, with the antenna between the two layers of belting, and the compartment was filled with epoxy.

Activity collars It was found that if the transmitter was connected for activity detection (ie. rapid pulse rate for active mode), a continuous transmission resulted when the collar was placed on an animal. This was avoided by housing the transmitter in a separate compartment as depicted in Fig. A2b. The battery and mercury switches were housed in the main compartment. Potting procedure was the same as for standard collars.

Ends of the compartments were secured with twin pop rivets. A further two rivets were placed at the most dorsal side of the collar, with the antenna between the two rivets.

Completed collars weighed between 152 and 191 g.

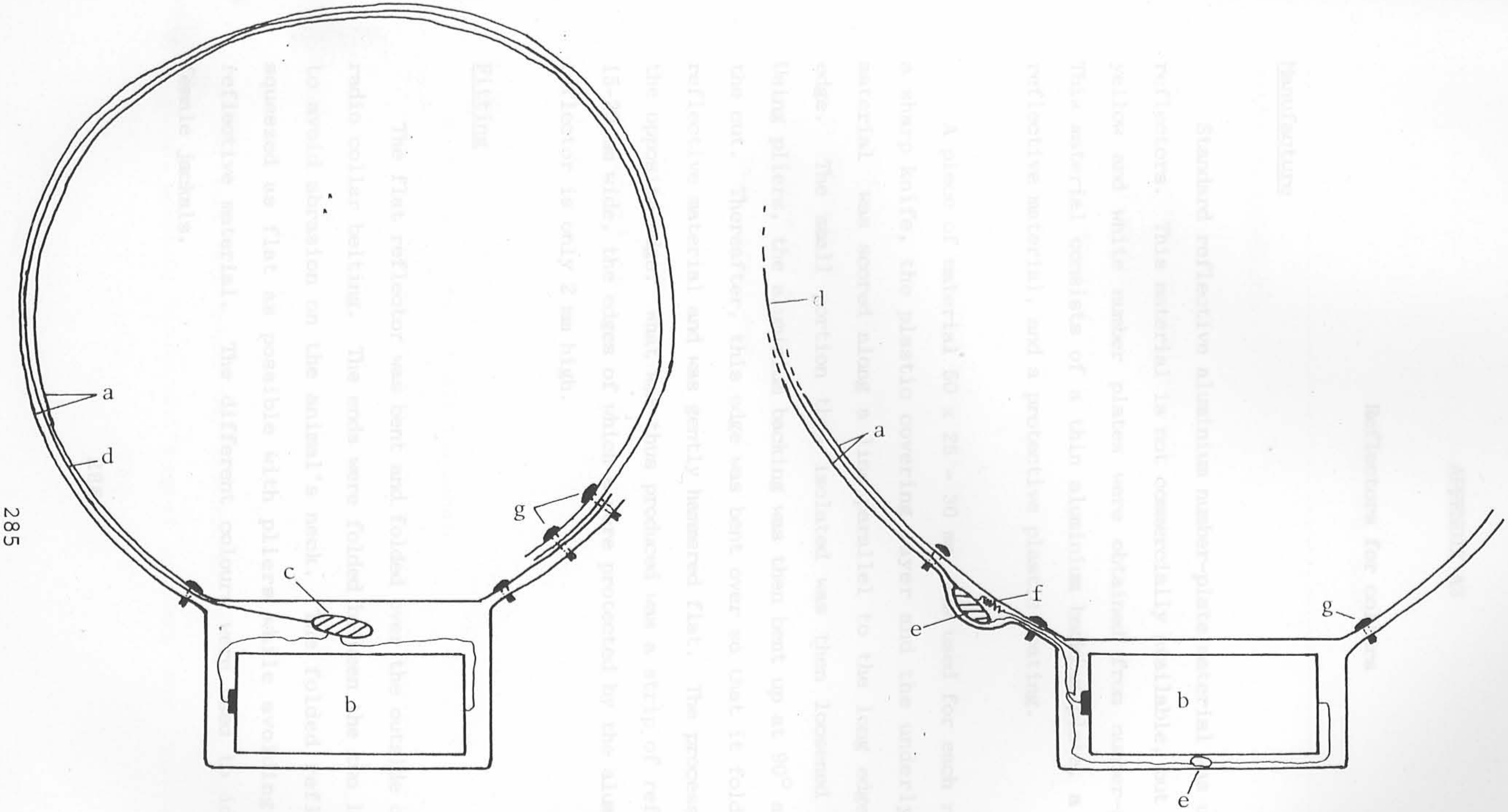


Figure A2. Radio collars. See text for legend.

# APPENDIX A3

## Reflectors for collars

### Manufacture

Standard reflective aluminium number-plate material was used to construct reflectors. This material is not commercially available, but pieces of reject yellow and white number plates were obtained from number-plate suppliers. This material consists of a thin aluminium backing plate, a layer of highly reflective material, and a protective plastic coating.

A piece of material 50 x 25 - 30 mm was used for each reflector. Using a sharp knife, the plastic covering layer and the underlying reflective material was scored along a line parallel to the long edge, 3 mm from the edge. The small portion thus isolated was then loosened and peeled off. Using pliers, the aluminium backing was then bent up at 90$^{\circ}$ along the line of the cut. Thereafter, this edge was bent over so that it folded on top of the reflective material and was gently hammered flat. The process was repeated on the opposite edge. What was thus produced was a strip of reflective material 15-20 mm wide, the edges of which a were protected by the aluminium fold. The reflector is only 2 mm high.

### Fitting

The flat reflector was bent and folded over the outside of the 30 mm wide radio collar belting. The ends were folded between the two layers of belting to avoid abrasion on the animal's neck. The folded reflector was then squeezed as flat as possible with pliers while avoiding damage to the reflective material. The different colours were used to identify male and female jackals.

# APPENDIX A4

## Yagi Roof Mount

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Legend for Figure A4.

A Front-to-back vertical section.

- a Seal retainer.
- b Upper mounting block.
- b' Lower mounting block.
- c Support platform.
- d Support platform retaining bolt and wing nut.
- e Handle.
- f Roof.
- g Nylon bush.
- h Rubber 'O' ring.
- i Yagi support mast

B Support platform.

- a Lateral view.
- b Frontal view.

C Ventral view

- a Recess to receive sliding handle.

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Construction

The Yagi roof mount was constructed as shown in Fig. A4. The seal retainer, mounting blocks and support platform were constructed from wood.

The support mast was constructed from 20 mm chromed round tubing, the support bracket from 20 mm cold rolled mild steel angle iron, and the handle from 6 mm mild steel rod.

Operation

In the position shown, the Yagi can be swung in an arc of $250^{\circ}$. If, when in the forward position, the handle is pushed backwards, the slot accepts the handle and stabilizes the antenna in the forward direction. Direction of the animal can then be ascertained by swinging the vehicle through an arc while the Yagi in is this fixed position.

By loosening the butterfly nut and swinging the support platform to the side, the support and handle can be pulled downwards to avoid damage eg. by low branches.

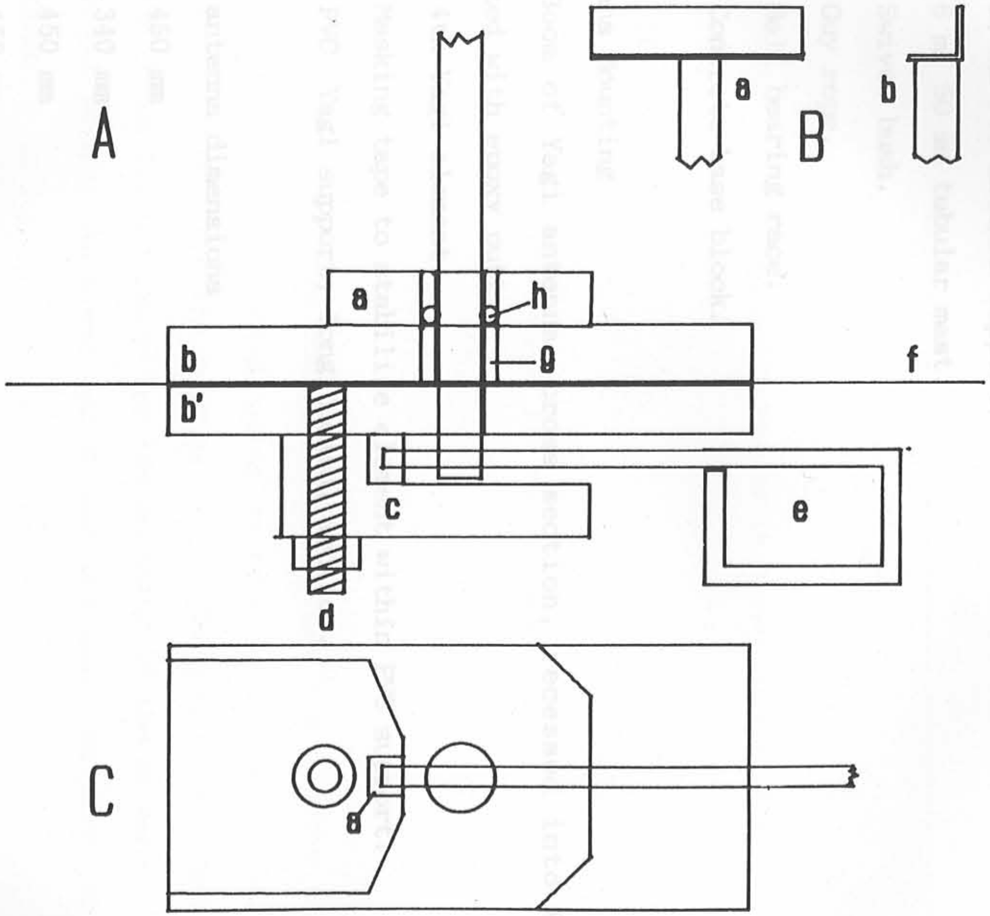


Figure A4. Yagi roof mount. See text for legend.

# APPENDIX A5

## Telemetry Stations

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Legend for Figure A5

A Telemetry Mast

a 2 m, 5 element Yagi antenna.

b 30 mm PVC antenna support.

c 6 m, 50 mm tubular mast.

d Swivel bush.

e Guy rope.

f Ball bearing race.

g Concrete base block.

B Antenna Mounting

a Boom of Yagi antenna, cross section, recessed into PVC support. Stabilized with epoxy putty.

b 4th Yagi element.

c Masking tape to stabilize element within PVC support.

d PVC Yagi support, longitudinal section.

C Yagi antenna dimensions

a 450 mm

b 340 mm

c 450 mm

d 450 mm

e 1000 mm

f 950 mm

g 870 mm

h 860 mm

Legend for Fig. A5 (cont.): C Yagi antenna dimensions

i 860 mm

j 130 mm (gamma match)

D Wiring diagram

a Yagi antenna.

b VHF Booster, upper component.

c Booster, lower component.

d VHF receiver.

e Earphones.

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<u>Construction</u>

The design of the telemetry towers is shown in Fig. A5A.

<u>Co-axial cables</u>

RT58U coaxial cable, length 7,5 m, was used.

<u>Masts</u>

Masts (Fig. A5A) were constructed from two 3 m lengths of 50 mm water pipe. Bases were constructed using reinforced concrete, and incorporated handles and a recess for the bearing race. The top of the mast was extended by 1m with 30 mm PVC waterpipe for the mounting of the antenna. This was done as any metal within the array can affect the gain and directionality of the Yagi antenna.

Compass bearings were marked onto 400x400x4 mm masonite boards such that two halves could be joined to surround the base of the pipe which stood on the bearing race. A pointer was bolted to the base of the mast to facilitate accurate reading of bearings from the compass rose.

Masts were mounted with three guy ropes attached to a swivel bush above the socket connecting the two lengths of water pipe.

Antennas

Two metre, five-element Yagi antennas were constructed from 10 mm aluminium tubing as shown in Fig A5C. This design was obtained from H. de Beer (Omega Communications, Johannesburg, South Africa) (pers. comm.).

Mounting of antenna

A recess was cut into the top of the PVC pipe to accommodate the centre beam of the Yagi antenna (Fig. A5B). Masking tape at the tip of the 4th element ensured a snug fit within the PVC pipe. Pratley's Quickset Putty (Pratley Manufacturing & Engineering Co. (Pty) Ltd., Krugersdorp, RSA) was used to stabilize the antenna in the pipe.

Boosters

12v VHF boosters (Ellies Electronics, Johannesburg, RSA) were connected as shown (Fig. A5D)

Erection and lowering

Once the three anchor points had been established and the tower erected, the tower could be raised and lowered by one person. The compass rose is removed, and the mast is lifted and placed alongside the concrete block. One of the anchors is then loosened. While holding the rope the mast is stabilized and then gradually lowered to the ground, with the bottom of the mast stabilized against the concrete base. The reverse procedure is used to erect the mast again. Single-handed raising and lowering is important in areas where lightning can damage the tower, and where there are not always two people to undertake the procedure.

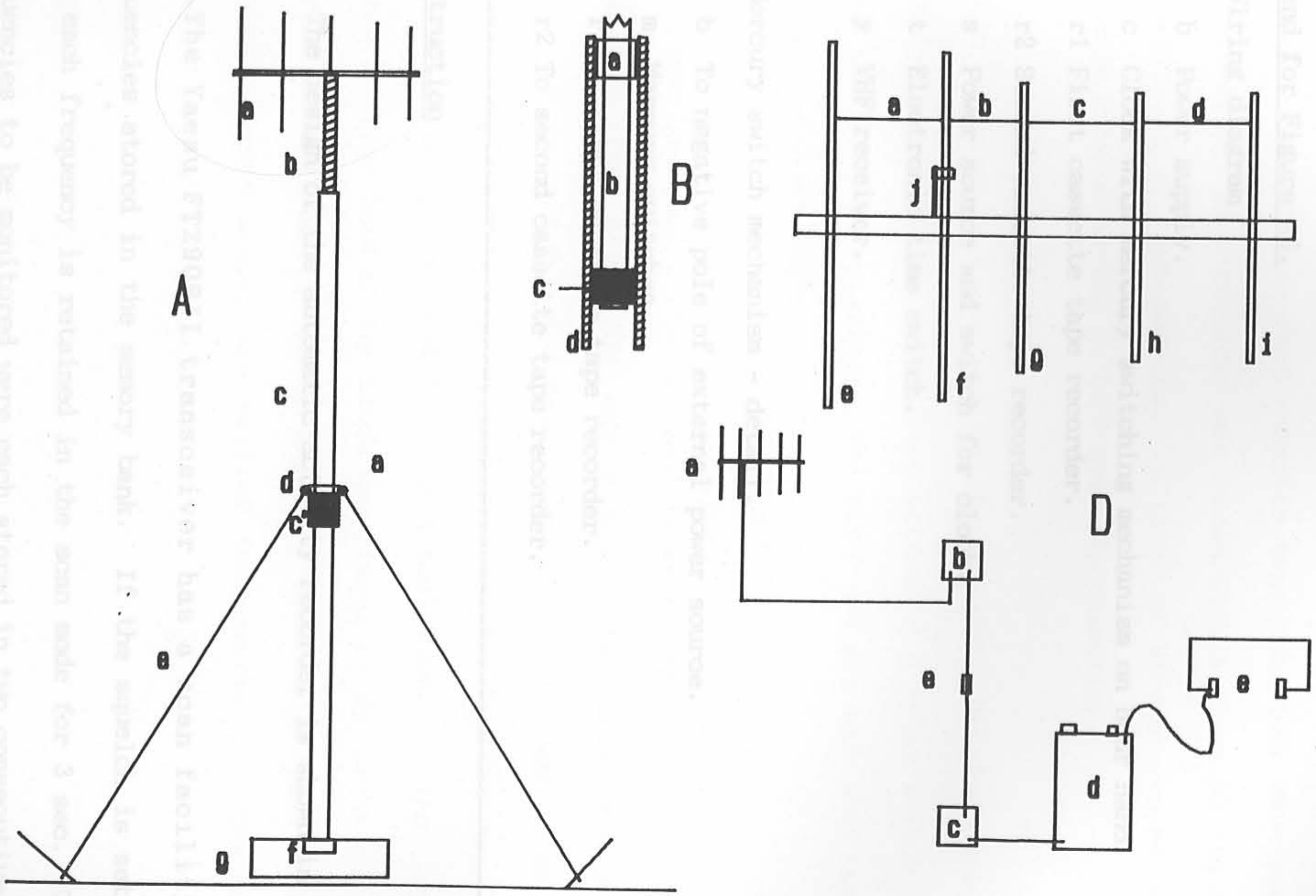


Figure A5. Telemetry station. See text for legend.

# APPENDIX A6

## Automatic Activity Recorder

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Legend for Figure A6.

A Wiring diagram

- b Power supply.
- c Clock with mercury switching mechanism on hour hand.
- r1 First cassette tape recorder.
- r2 Second cassette tape recorder.
- s Power source and switch for clock.
- t Electronic time switch.
- y VHF receiver.

B Mercury switch mechanism - detail.

- b To negative pole of external power source.
- m Mercury switches.
- r1 To first cassette tape recorder.
- r2 To second cassette tape recorder.

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Construction

The design of the automatic activity recorder is shown in Fig. A6.

The Yaesu FT290RII transceiver has a scan facility which scans frequencies stored in the memory bank. If the squelch is set to fully off, then each frequency is retained in the scan mode for 3 sec. The four jackal frequencies to be monitored were each stored in two consecutive memory slots - ie. the scan mode remained on each jackal frequency for 6 sec. The ninth memory slot contained an arbitrary FM frequency which resulted in a hissing sound distinctly different from the Upper Side Band mode used for the jackal frequencies. Signal output was conveyed to the input sockets of two cassette tape recorders.

Two Audiodek[R] Auto-Stop cassette tape recorders were used to store the activity data. Each recorder was loaded with a clean 90 min cassette tape at the beginning of each session. A total of 90 min recording time was thus available without having to turn over the cassettes.

An electronic timer switch (G van Urk, Potchefstroom University, Potchefstroom, RSA) was used which activated a relay switch between a power source and the tape recorders. The timer was set such that current would flow for 1 min in every 8 min.

A modified wall clock was used to shift power supply from Recorder 1 to Recorder 2 after 5 h. The minute and second hands were removed from the clock. Two mercury switches were glued to the hour hand as shown in Fig. A6B. With this configuration, power supply is shifted from one tape recorder to the other at the 9 'o clock and 3 'o clock positions. At the beginning of each session the hour hand of the clock was placed in the 10 'o clock position i.e. Recorder 1 received the power supply. After 5 h -ie. at the 3 'o clock position - power supply was shifted to Recorder 2. The 90 min of tape therefore stores 12 h of data.

Operation

Each jackal's frequency was stored with a different discrepancy from the true frequency - i.e. the audible tone of each collar was different. Once the scan mode was operating correctly, the lead to the recorders was plugged into the output socket of the transceiver. Record buttons were depressed on both tape recorders, the clock handle was shifted to the 10 'o clock position and the clock was activated. The input lead was removed from Recorder 1. When the timer activated Recorder 1, the date and time of commencement of the session was noted via the condenser microphone onto the tape in Recorder 1. When the timer switched off after one min the lead was re-inserted for commencement of automatic recording.

At the end of each session the clock was switched off, the recorders switched off and the tapes removed.

Data Transcription

After being rewound each tape was transcribed onto a data sheet. As the time of the first recording was known, as well as the spacing of each subsequent recording, the time of each scan could be calculated. In the case of the activity collar, the number of signals/second indicated activity or inactivity. In the case of the normal collars, shifts in signal strength and tone were used to ascertain whether or not the jackal was active. Shifts to a new memory slot is marked by a beep tone. As the sequence of scan was known, position relative to the FM marker slot facilitated the identification of the jackal being monitored. The tone setting differences assisted in identifying the frequency without the need to refer to the marker slot.

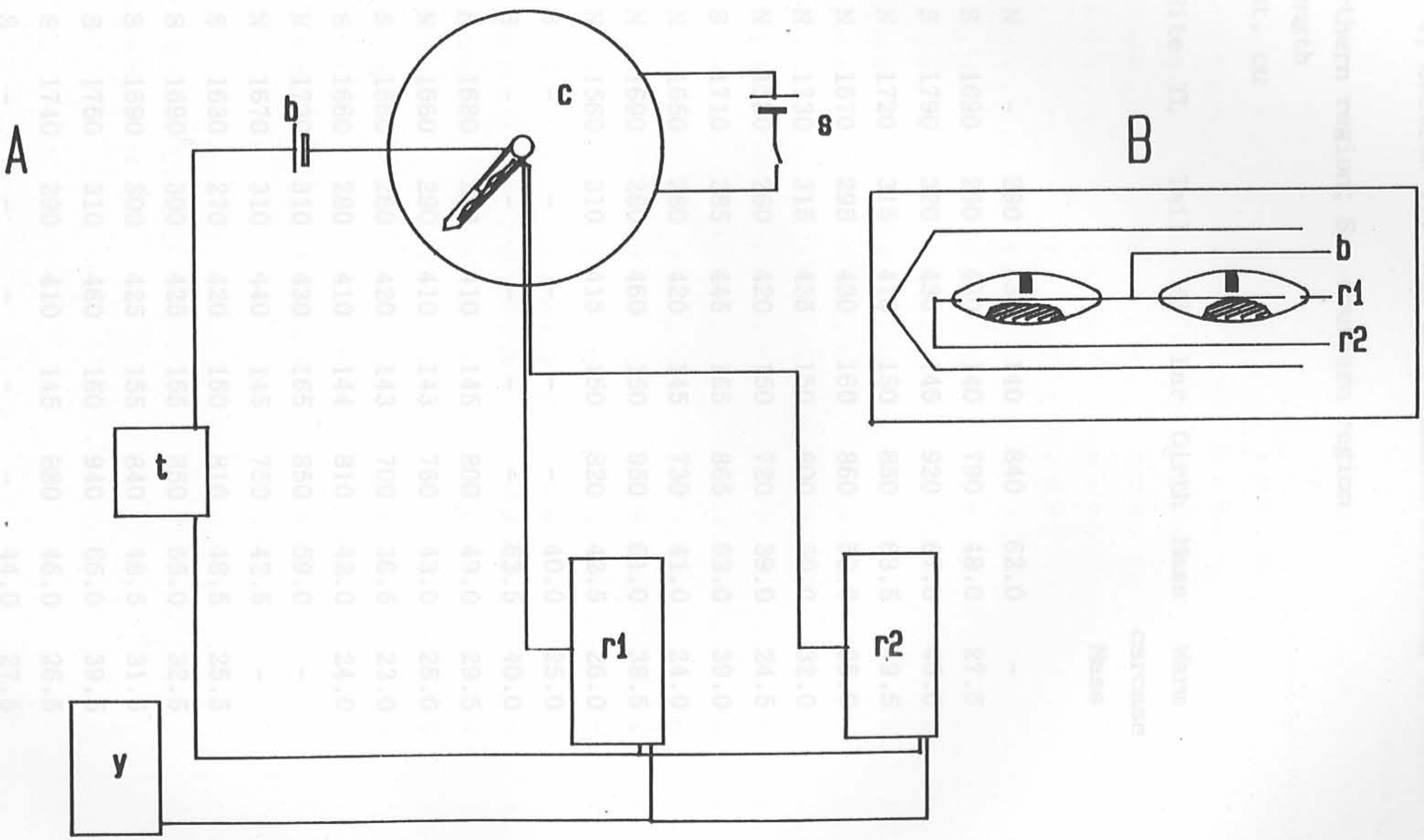


Figure A6. Automatic activity recorder. See text for legend.

# APPENDIX A7

Masses and measurements of impala collected for baseline study, (Chapter 4, Section 1). All measurements according to Ansell (1965).

Site: N = northern region; S = southern region
TL = total length
HF = hind foot, *cu*

| Date | Sex | Site | TL | Tail | HF | Ear | Girth | Mass | Warm carcase Mass |
|---|---|---|---|---|---|---|---|---|---|
| 140486 | M | N | - | 290 | 430 | 140 | 840 | 62.0 | - |
| 140486 | F | S | 1690 | 290 | 430 | 140 | 790 | 48.0 | 27.5 |
| 140486 | M | S | 1790 | 320 | 430 | 145 | 920 | 67.0 | 45.0 |
| 220486 | M | N | 1720 | 315 | 415 | 150 | 850 | 63.5 | 49.5 |
| 220486 | M | N | 1670 | 295 | 430 | 160 | 860 | 53.0 | 35.0 |
| 220486 | F | N | 1730 | 315 | 435 | 150 | 800 | 50.0 | 32.0 |
| 250486 | F | N | 1580 | 260 | 420 | 150 | 720 | 39.0 | 24.5 |
| 280486 | M | S | 1710 | 285 | 445 | 155 | 865 | 63.0 | 39.0 |
| 290486 | F | N | 1650 | 280 | 420 | 145 | 730 | 41.0 | 24.0 |
| 050586 | M | N | 1690 | 260 | 460 | 150 | 950 | 61.0 | 38.5 |
| 050586 | F | N | 1560 | 310 | 415 | 150 | 820 | 42.5 | 26.0 |
| 120586 | F | S | - | - | - | - | - | 40.0 | 25.0 |
| 120586 | M | S | - | - | - | - | - | 63.5 | 40.0 |
| 200586 | F | N | 1680 | 280 | 410 | 145 | 800 | 49.0 | 29.5 |
| 200586 | F | N | 1660 | 290 | 410 | 143 | 760 | 43.0 | 26.0 |
| 270586 | F | S | 1550 | 260 | 420 | 143 | 700 | 36.5 | 23.0 |
| 270586 | F | S | 1660 | 280 | 410 | 144 | 810 | 42.0 | 24.0 |
| 020686 | M | N | 1730 | 310 | 430 | 165 | 850 | 59.0 | - |
| 020686 | F | N | 1670 | 310 | 440 | 145 | 750 | 42.5 | - |
| 090686 | M | S | 1630 | 270 | 420 | 150 | 810 | 48.5 | 25.5 |
| 230686 | M | S | 1690 | 300 | 425 | 155 | 850 | 55.0 | 32.5 |
| 230686 | F | S | 1590 | 300 | 425 | 155 | 840 | 48.5 | 31.5 |
| 300686 | M | S | 1750 | 310 | 460 | 160 | 940 | 65.0 | 39.5 |
| 300686 | F | S | 1740 | 290 | 410 | 145 | 880 | 46.0 | 26.5 |
| 050886 | F | S | - | - | - | - | - | 44.0 | 27.5 |
| 140886 | F | S | 1590 | 270 | 425 | 145 | 880 | 40.0 | 23.5 |

## Appendix A8. Impala Kidney Fat Indices and adrenal masses - Section 1, Baseline Data.

| Number | Fat | Kidneys | KFI | Adrenals L | Adrenals R | Adrenals Tot |
|---|---|---|---|---|---|---|
| K618 | 450,4 | 172,6 | 261,0 | | | |
| K625 | 452,4 | 177,0 | 255,6 | | | |
| K626 | 716,2 | 218,5 | 327,8 | | | |
| K630 | 308,6 | 140,6 | 219,5 | | | |
| K631 | 234,1 | 165,2 | 141,7 | | | |
| K634 | 184,0 | 117,0 | 157,3 | | | |
| K635 | 804,5 | 190,7 | 421,9 | | | |
| K638 | 12,2 | 147,1 | 8,3 | | | |
| K640 | 222,8 | 102,6 | 217,2 | 1,1 | 1,2 | 2,3 |
| K641 | 600,6 | 175,5 | 342,2 | 1,5 | 1,7 | 3,2 |
| K643 | 83,6 | 125,8 | 66,5 | 1,2 | 1,0 | 2,2 |
| K652 | 321,3 | 141,1 | 227,7 | 1,0 | 1,2 | 2,2 |
| K656 | 271,7 | 293,0 | 92,7 | 1,4 | 1,8 | 3,2 |
| K659 | 160,2 | 162,5 | 98,6 | 1,6 | 1,7 | 3,3 |
| K660 | 85,5 | 140,6 | 60,8 | 1,6 | 1,4 | 3,0 |
| K663 | 237,3 | 113,3 | 209,4 | 1,1 | 1,1 | 2,2 |
| K667 | 41,4 | 169,6 | 24,4 | 1,7 | 1,7 | 3,4 |
| K686 | 729,7 | 162,8 | 448,2 | | | |
| K689 | 75,3 | 217,5 | 34,6 | 2,1 | 1,3 | 3,3 |
| K690 | 103,5 | 178,5 | 58,0 | 1,7 | 1,5 | 3,2 |
| K6113 | 116,9 | 162,2 | 72,1 | 1,6 | 1,4 | 3,0 |
| K6115 | 615,1 | 146,3 | 420,4 | | | |
| K6119 | 278,8 | 160,9 | 173,3 | | | |
| K6122 | 25,7 | 175,2 | 14,7 | | | |
| | | | 181,3 | | | 2,9 |
| | | | (136,2) | | | (0,49) |

Mean (std.dev.)

All masses in g.

# APPENDIX A9

Ages and dental attrition of impala collected for baseline study (Chapter 4, Section 1)

Site: N = northern region; S = southern region.

Ageing techniques: M = Murray 1980
S = Spinage 1971
RH = Roettcher & Hoffman 1970

V = vertical attrition of incisor-canine complex elements:
0 = none
1 = tip of tooth rounded
2 = tip of tooth substantially flattened
3 = tooth worn to mid-crown
4 = only stump of crown remaining
5 = total vertical attrition

G = grooves in the neck region of incisor-canine complex elements:
0 = none
1 = slight indication of groove
2 = well defined groove
3 = deep groove - half or more of diameter of tooth

The most advanced value was used for each of pair of teeth.

C = canine; 3 = $I_3$; 2 = $I_2$; 1 = $I_1$

| No | Sex | Site | M | S | RH | V | | | | G | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | C | 3 | 2 | 1 | C | 3 | 2 | 1 |
| 006 | M | N | 5.5 | D | 06 | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| 004 | F | N | 5.5 | D | 07 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 010 | M | N | 6.5 | D | 10 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 002 | M | N | 4.5 | D | 06 | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| 106 | F | N | 2.0 | 3 | -- | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 061 | M | N | 2.0 | 3 | 01 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 125 | F | N | 6.5 | D | 12 | 5 | 5 | 4 | 4 | 3 | 3 | 3 | 3 |
| 018 | M | N | 5.5 | D | 06 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 126 | M | N | 5.5 | D | 06 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 059 | F | N | 2.0 | A | 02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 096 | F | N | 2.0 | 3 | 01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 060 | M | N | 4.5 | B | 05 | 2 | 2 | 0 | 0 | 0 | 0 | 1 | 0 |
| 080 | F | N | 2.0 | 3 | 01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 079 | M | N | 6.5 | D | 07 | 2 | 2 | 1 | 0 | 2 | 0 | 2 | 0 |
| 081 | M | N | 2.0 | A | 02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| No | Sex | Site | M | S | RH | V | | | | G | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | C | 3 | 2 | 1 | C | 3 | 2 | 1 |
| 072 | F | N | 2.0 | 3 | 02 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 071 | M | N | 6.5 | D | 08 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| 073 | M | N | 5.5 | D | 06 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 029 | M | N | 5.5 | D | 06 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| 030 | M | N | 2.5 | A | 03 | 1 | - | 0 | 0 | 0 | 0 | 0 | 0 |
| 031 | F | N | 8.5 | F | 10 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| 028 | M | N | 5.5 | D | 05 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 001 | M | N | 7.5 | F | 06 | 3 | 3 | 3 | 1 | 2 | 0 | 2 | 0 |
| 070 | F | N | 6.5 | D | 06 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| 034 | F | N | 2.0 | 3 | -- | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 104 | M | N | 2.5 | B | 03 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 005 | M | N | 2.0 | 3 | 02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 095 | F | N | 2.5 | A | 05 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 027 | M | N | 2.5 | B | 03 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 076 | M | N | 2.5 | B | 03 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 042 | F | N | 4.5 | B | 05 | 2 | 2 | 0 | 0 | 0 | 0 | 1 | 0 |
| 043 | F | N | 5.5 | D | 07 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 044 | M | N | 6.5 | D | 10 | 2 | 2 | 0 | 0 | 0 | 0 | 1 | 0 |
| 041 | M | N | 2.5 | A | 05 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 105 | F | N | 5.5 | D | 05 | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| 110 | M | N | 5.5 | D | 07 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 040 | F | N | 2.0 | 3 | 02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 039 | F | S | 5.5 | D | 08 | 4 | 4 | 3 | 2 | 2 | 2 | 2 | 0 |
| 033 | F | S | 2.5 | A | 02 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 045 | F | S | 6.5 | F | 12 | 5 | 5 | 5 | 4 | - | - | - | 3 |
| 046 | M | S | 2.5 | A | 04 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 048 | M | S | 2.5 | A | 01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 055 | | S | 4.5 | D | 07 | 2 | 2 | 1 | 1 | 0 | 0 | 0 | 0 |
| 038 | F | S | 2.0 | 3 | -- | - | - | - | - | - | - | - | - |
| 057 | F | S | 7.5 | F | 10 | 4 | 4 | 4 | 1 | 2 | 2 | 2 | 2 |
| 058 | M | S | 2.5 | A | 02 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 022 | M | S | 2.5 | A | 02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 037 | F | S | 8.5 | F | 12 | 5 | 5 | 5 | 5 | - | - | - | - |
| 017 | M | S | 2.0 | 3 | 02 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 036 | F | S | 2.5 | 3 | 02 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 035 | M | S | 8.5 | F | 10 | 4 | 4 | 1 | 1 | 1 | 0 | 2 | 0 |
| 016 | F | S | 2.0 | 3 | 02 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 032 | F | S | 3.5 | A | 02 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 066 | M | S | 3.5 | B | 04 | 2 | 2 | 2 | 1 | 1 | 0 | 1 | 0 |
| 067 | F | S | 4.5 | D | 06 | 4 | 3 | 3 | 2 | 2 | 0 | 2 | 2 |
| 068 | M | S | 2.0 | A | 02 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 015 | F | S | 5.5 | B | 07 | 3 | 3 | 3 | 2 | 1 | 0 | 1 | 1 |
| 051 | M | S | 2.5 | A | 02 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 049 | F | S | 5.5 | D | 07 | 2 | 2 | 1 | 0 | 2 | 0 | 1 | 0 |
| 050 | M | S | 4.5 | B | 04 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 025 | F | S | 8.5 | F | 10 | 3 | 3 | 2 | 0 | 3 | 1 | 2 | 0 |
| 014 | F | S | 2.5 | B | 02 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 013 | M | S | 5.5 | D | 08 | 4 | 4 | 4 | 2 | 2 | 1 | 2 | 2 |
| 020 | M | S | 2.5 | A | 02 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 026 | M | S | 8.5 | F | 08 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 1 |
| 077 | M | S | 2.5 | A | 03 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| No | Sex | Site | M | S | RH | V | | | | G | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | C | 3 | 2 | 1 | C | 3 | 2 | 1 |
| 078 | M | S | 2.5 | A | 02 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 052 | M | S | 6.5 | D | 10 | 3 | 3 | 3 | 1 | 1 | 0 | 2 | 1 |
| 053 | M | S | 2.5 | B | 02 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 024 | F | S | 2.5 | A | 03 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 088 | F | S | 2.0 | A | 02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 082 | F | S | 8.5 | F | 12 | 5 | 5 | 5 | 4 | 3 | 3 | 3 | 3 |
| 089 | M | S | 2.5 | B | 02 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 084 | M | S | 8.5 | F | 10 | 2 | 2 | 1 | 1 | 0 | 0 | 2 | 1 |
| 086 | F | S | 2.0 | 3 | 01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 087 | F | S | 2.0 | 3 | 01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 083 | F | S | 7.5 | D | 10 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 2 |
| 085 | F | S | 2.0 | 3 | 01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 090 | F | S | 8.5 | F | 12 | 5 | 5 | 5 | 4 | - | - | - | 3 |
| 091 | F | S | 7.5 | D | 12 | 5 | 4 | 4 | 4 | - | 3 | 3 | 3 |
| 092 | M | S | 6.5 | D | 07 | 3 | 3 | 3 | 2 | 1 | 0 | 2 | 0 |
| 093 | F | S | 5.5 | D | 05 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| 094 | F | S | 2.0 | 3 | 01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 023 | F | S | 4.5 | B | 05 | 3 | 3 | 3 | 2 | 2 | 0 | 1 | 0 |
| 021 | F | S | 4.5 | D | 06 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| 097 | F | S | 2.0 | 3 | 01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 012 | F | S | 5.5 | D | 08 | 3 | 3 | 3 | 2 | 3 | 2 | 3 | 2 |
| 011 | F | S | 8.5 | F | 12 | 4 | 3 | 2 | 1 | 3 | 1 | 2 | 1 |
| 009 | M | S | 2.0 | 3 | 02 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 008 | M | S | 5.5 | D | 05 | 3 | 3 | 3 | 1 | 2 | 0 | 1 | 0 |
| 007 | M | S | 5.5 | D | 06 | 3 | 3 | 3 | 1 | 2 | 0 | 1 | 0 |
| 003 | M | S | 2.0 | 3 | 01 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 019 | F | S | 6.5 | D | 07 | 2 | 2 | 0 | 0 | 3 | 1 | 3 | 0 |
| 054 | M | S | 2.5 | A | 02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 056 | M | S | 2.5 | A | 02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 108 | M | S | 2.0 | 3 | -- | | - | - | - | - | - | - | - |
| 109 | F | S | 5.5 | D | 07 | 2 | 2 | 1 | 0 | 1 | 0 | 2 | 2 |
| 062 | F | S | 6.5 | D | 08 | 4 | 4 | 4 | 3 | 3 | 2 | 3 | 2 |
| 118 | F | S | 2.5 | B | 03 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 119 | F | S | 8.5 | F | 12 | 3 | 3 | 1 | 1 | 3 | 2 | 3 | 3 |
| 114 | M | S | 5.5 | D | 05 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 116 | F | S | 5.5 | D | 12 | 5 | 5 | 4 | 3 | 2 | 2 | 2 | 2 |
| 117 | M | S | 2.5 | A | 03 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 113 | M | S | 3.5 | A | 03 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 115 | F | S | 6.5 | D | 08 | 4 | 4 | 3 | 2 | 1 | 0 | 2 | 2 |
| 120 | M | S | 2.5 | A | 03 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 121 | F | S | 2.5 | A | 03 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 122 | F | S | 8.5 | F | 12 | 5 | 5 | 5 | 4 | - | 3 | 3 | 3 |
| 123 | F | S | 8.5 | F | 12 | 5 | 5 | 5 | 5 | - | - | - | - |
| 124 | M | S | 6.5 | D | 08 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 063 | F | S | 2.0 | 3 | 01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 064 | M | S | 2.5 | A | 03 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 127 | M | S | 6.5 | D | 07 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 128 | F | S | 6.5 | D | 10 | 4 | 3 | 3 | 2 | 2 | 1 | 2 | 0 |
| 065 | M | S | 6.5 | D | 07 | 2 | 2 | 2 | 1 | 0 | 0 | 1 | 0 |

# APPENDIX A10

## Impala data - Section 3.

| Number | Date collected | Mass | Pregnant | Foetal Mass | Sex |
|---|---|---|---|---|---|
| M0186 | 22/10/86 | - | Y | - | - |
| M0286 | 24/10/86 | 48,0 | Y | 2,0 | F |
| M0386 | 26/10/86 | 45,0 | Y | 2,0 | M |
| M0486 | 26/10/86 | 46,0 | Y | 1,5 | M |
| M0586 | 03/11/86 | 38,0 | Y | - | - |
| M0686 | 04/11/86 | 46,5 | Y | 2,5 | F |
| M0786 | 06/11/86 | 43,5 | Y | 2,5 | M |
| M0886 | 06/11/86 | 45,0 | Y | 3,5 | F |
| M0986 | 06/11/86 | 43,5 | Y | 4,3 | M |
| M1086 | 07/11/86 | 44,0 | Y | - | - |

All masses in kg.

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# APPENDIX A11

## Impala data - Section 4.

| Number | Date collected | Pregnant | Foetal Mass | Sex |
|---|---|---|---|---|
| M0188 | 07/09/88 | Y | 0,31 | F |
| M0288 | 07/09/88 | Y | 0,45 | F |
| M0388 | 08/09/88 | Y | 0,36 | F |
| M0488 | 08/09/88 | Y | 0,41 | F |
| M0588 | 09/09/88 | Y | 0,57 | M |
| M0688 | 09/09/88 | Y | 0,63 | M |
| M0788 | 09/09/88 | Y | 0,55 | F |
| M0888 | 10/09/88 | Y | 0,40 | F |
| M1088 | 10/09/88 | Y | 0,86 | M |
| M1188 | 10/09/88 | Y | 0,36 | F |
| M1288 | 12/09/88 | Y | 0,45 | F |
| M1388 | 14/09/88 | Y | 0,57 | M |
| M1688 | 15/09/88 | Y | 0,56 | F |
| M1788 | 15/09/88 | Y | 0,60 | M |

All masses in kg.
(A11)

# APPENDIX A12

## Impala external parasites - Chapter 4, Section 4.

| | TICKS | | | | | | | | | | | | | | | | | | | | | | | | | LICE | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Boophilus decoloratus* | | | | | | | | | | | | | | | | | | | | *Riphicephalus zambesiensis* | | | | | *Linognathus sp.* | | | | | *Damilinia sp.* | | | | |
| | Adult | | | | | Engorged adult female | | | | | Nymphae | | | | | Larvae | | | | | Nymphae | | | | | | | | | | | | | | |
| NO | T | G | L | E | B | T | G | L | E | B | T | G | L | E | B | T | G | L | E | B | T | G | L | E | B | T | G | L | E | B | T | G | L | E | B |
| M0188 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| M0288 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 3 | 0 | 2 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| M0388 | 0 | 6 | 65 | 7 | 0 | 0 | 0 | 17 | 0 | 0 | 1 | 5 | 36 | 19 | 2 | 3 | 13 | 8 | 8 | 7 | 0 | 0 | 4 | 11 | 0 | 1 | 1 | 6 | 0 | 12 | 2 | 0 | 0 | 1 | 0 |
| M0488 | 9 | 14 | 44 | 14 | 5 | 0 | 2 | 7 | 0 | 0 | 7 | 28 | 33 | 32 | 11 | 1 | 8 | 26 | 53 | 17 | 0 | 0 | 5 | 0 | 0 | 2 | 0 | 4 | 0 | 203 | 0 | 0 | 0 | 0 | 0 |
| M0588 | 0 | 8 | 91 | 11 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 32 | 101 | 60 | 2 | 0 | 14 | 46 | 111 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 54 | 2 | 0 | 17 | 11 | 0 | 0 | 0 | 13 |
| M0688 | 1 | 49 | 117 | 20 | 5 | 0 | 7 | 16 | 1 | 0 | 0 | 24 | 101 | 126 | 6 | 0 | 25 | 64 | 220 | 20 | 0 | 0 | 2 | 0 | 0 | 1 | 10 | 47 | 2 | 41 | 19 | 0 | 0 | 0 | 4 |
| M0788 | 4 | 29 | 85 | 8 | 5 | 0 | 0 | 7 | 0 | 0 | 4 | 12 | 74 | 42 | 5 | 6 | 23 | 109 | 111 | 25 | 0 | 1 | 2 | 0 | 1 | 1 | 93 | 7 | 0 | 41 | 0 | 0 | 0 | 0 | 2 |
| M0888 | 12 | 46 | 58 | 45 | 4 | 0 | 6 | 7 | 0 | 1 | 11 | 37 | 58 | 98 | 5 | 3 | 22 | 0 | 229 | 14 | 0 | 1 | 19 | 3 | 1 | 10 | 428 | 176 | 6 | 83 | 0 | 0 | 0 | 0 | 2 |
| M1088 | 1 | 11 | 19 | 18 | 2 | 0 | 0 | 1 | 0 | 0 | 1 | 7 | 37 | 113 | 1 | 0 | 1 | 17 | 278 | 8 | 0 | 1 | 0 | 0 | 0 | 5 | 1 | 19 | 0 | 14 | 3 | 0 | 0 | 0 | 34 |
| M1188 | 1 | 5 | 51 | 52 | 11 | 0 | 0 | 5 | 2 | 3 | 0 | 2 | 42 | 138 | 5 | 0 | 5 | 47 | 281 | 5 | 0 | 0 | 3 | 0 | 0 | 1 | 1 | 27 | 0 | 2 | 1 | 0 | 0 | 0 | 3 |
| M1288 | 1 | 6 | 16 | 55 | 2 | 0 | 0 | 0 | 3 | 0 | 1 | 15 | 16 | 153 | 0 | 0 | 1 | 2 | 69 | 2 | 0 | 0 | 0 | 4 | 0 | 0 | 1 | 3 | 0 | 0 | 4 | 0 | 0 | 0 | 9 |
| M1388 | 0 | 2 | 14 | 63 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 27 | 143 | 3 | 0 | 0 | 7 | 214 | 3 | 0 | 0 | 1 | 0 | 1 | 0 | 42 | 12 | 0 | 16 | 3 | 0 | 0 | 0 | 1 |
| M1688 | 0 | 5 | 17 | 16 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 3 | 10 | 64 | 0 | 1 | 1 | 4 | 83 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 1 |
| M1788 | 0 | 4 | 18 | 33 | 3 | 0 | 0 | 1 | 3 | 0 | 0 | 13 | 35 | 130 | 4 | 0 | 5 | 21 | 14 | 4 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 3 | 2 | 4 | 0 | 1 | 0 | 0 | 15 |

T = tail; G = Metatarsal glands; L = Legs; E = Ears; B = body.

APPENDIX A12

Histopathologist's report
Chapter 4, Section 4

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Ons verw | U verw | Datum DEPT PATHOLOGY

18 January 1990

Dear Dr McKenzie

IMPALA SKIN IN FORMALIN

Herewith the microscopical findings in the skin specimens from Impalas submitted to me.

M3/88 - OUR REF S1115/89

Epidermis normal
There is a conspicious perivascular infiltration of round cells and eosinophils around superficial dermal blood vessels. The sweat glands are moderately dilated and lined by cuboidal epithelium. Hairfollicles are mostly in a telogen phase and void of hair. A few of the larger deep dermal follicles are in anagen phase and contain normal hair. The walls of the blood vessels seem thickened.

M4/88 - OUR REF S1116/89

This section is identical in all aspects to the above. The section is not cut perfectly perpendicularly and some hair are visible on the surface.

M5/88 - OUR REF S1117/89

Epidermas normal
Sweat glands and cell infiltrate as in M3/88
Hair follicles are dilated, mostly empty while some contain thin hair which are broken off below the level of the epidermis. All hair follicles are in the telogen phase. No hair visible above the level of the epidermis.

M6/88 - OUR REF S1118/89

Very similar to M5/88. A few of the deeper larger hair follicles contain hair and seem to be in anagen phase.



2/.....

M7/88 - OUR REF S1119/89

Epidermis normal
Superficial hair follicles are moderately dilated but most are empty, i.e. does not contain hair remnants or even keratin. The large deep follicles do contain hair. The perivascular cell infiltrate is less intensive than in the previous cases described above.

M8/88 - OUR REF S1120/89

Very similar to M7/88. Some eosinophils present in deeper dermis at the level of the sweat and sebaceous glands. Only club hairs, in telogen phase present.

M9/88 - OUR REF S1121/89

Epidermis normal
Hair follicles are in a better condition showing normal hair growth in some of these a few follicles show superficial dilatation and contain hair in telogen phase. The cell infiltrate is mild with only the odd round cell or eosinophil around sub-epidermal blood vessels. The blood vessel walls seem thickened.

M10/88 - OUR REF S1122/89

This section show features very similar to those of M9/88. Most follicles contain hair but seem to be in the telogen phase.

M11/88 - OUR REF S1123/89

Epidermis normal, sweat glands moderately dilated and lined by flattish epithelium. Moderate number of round cells and eosinophils around sub-epidermal blood vessels. Blood vessel walls seen thickened. Most hair follicles are in telagen phase but contain hair.

COMMENTS: I am not familiar with the normal histology of the Impala skin. In any domesticated ruminant the numbers of eosinophils and round cells found in these sections would be far greater than normal. What bothers me is that these cells were present in your controls as well as the cases showing clinical alopecia - admittedly in lesser numbers though.

My speculation is that the hair are mostly in a telogen phase and not well anchored in the hair follicles. Some form of parasitic allergy is probably present resulting in rubbing and thus resulting in mechanical loss of hair followed by clinical alopecia.



3/....

Examination of the Pilansberg specimens revealed the following:

P01 - OUR REF S1789/89

Epidermis normal, hair follicles mostly in telogen phase but contain hair shafts. Sweat glands moderately dilated lined by cuboidal epithelium. Moderate numbers of round cells and some eosinophils around subepidermal blood vessels. The walls of the latter are not thickened.

P03 - OUR REF S1790/89

Small focal crust on epidermis - unknow cause. Hair follicles telogen phase but contain hair, many round cells and numerous eosinophils around sub-epidermal blood vessels. Sweat glands dilated and epithelium on the flat side (low cuboidal).

P06 - OUR REF S1791/89

Many hairs on surface, most follicles in telogen phase. Epidermis normal. Sebaceous glands prominent. Sweat glands normal. Blood vessel walls moderately thickened. Very few cells present, only a few round cells and a single eosinophil were noticed.

P08 - OUR REF S1792/89

Epidermis normal, sweat glands slightly diated. Most hair follicles in telogen phase. Mild to moderate infiltration of round cells and eosinophils around sub-epidermal blood vessels. Blood vessel walls normal thickness.

I hope that these findings and comments will be of some value and use to you.

Sincerely

Prof IBJ van Rensburg
ACTING HEAD : DEPT PATHOLOGY
VK

*Short Communications/Kort Mededelings*

# Increasing the rate of recovery of projectile syringes and of animals darted at night

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*Received 1 November 1988; accepted 16 January 1989*

Reflective material applied to commercially available projectile syringes was successfully used to reduce loss of darts and to facilitate following of impala *Aepyceros melampus*, black-backed jackals *Canis mesomelas*, spotted hyaenas *Crocuta crocuta* and lions *Panthera leo* darted at night. Attachment of reflective fabric to darts of several types is illustrated. The modification described is simple and economical, and has the added advantage of reducing littering during darting operations.

Deur weerkaatsende materiaal op verdowingspyle te plak is die verlies van pyle tydens wildvangpogings verminder. Agtervolging van rooibokke *Aepyceros melampus*, rooijakkalse *Canis mesomelas*, gevlekte hiënas *Crocuta crocuta* en leeus *Panthera leo* wat in die nag met pyle verdoof is, is ook hierdeur vergemaklik. Die aanheg van weerkaatsende materiaal op verdowingspyle van verskillende soorte word ge-illustreer. Die modifikasie is eenvoudig en ekonomies, en het die bykomende voordeel dat moontlike omgewingsbesoedeling tydens wildvangoperasies verminder word.

**Keywords:** Capture, dart, immobilization, projectile syringe, tele-injection.

Capture or innoculation of wild animals through the remote administration of various cataleptic drugs and vaccines has become commonplace in the fields of wildlife research and wildlife management. Such tele-injection or 'darting' is achieved through various applicator and projectile systems which are commercially available. Considerable expense is often incurred through the loss of projectiles, and even greater losses may result if, in the case of immobilization, a darted animal is lost to sight before the drug takes effect.

Richardson (1983) suggested attachment of reflective material to home-made darts. This paper describes the use of a highly reflective material on commercially available projectile syringes used during nocturnal immobilization procedures over a period of three years in Botswana.

Telinject (Telinject SA, Randburg, RSA), Palmer Cap-Chur (Photo Agencies, Johannesburg, RSA) and Fauncap (Fauncap (Pty.) Ltd., Klaserie, RSA) darts were modified for nocturnal use. As most projectile syringes provide minimal surface area for the attachment of reflective material, a highly reflective material — 8910 Silver Scotchlite Reflective Fabric (3M, Johannesburg, RSA) which has a reflectivity of 450 candelas/lux/$m^2$ — was used. As little as 1 $cm^2$ of this material is clearly visible at night for over 200 m using a 200 000 c.p. spotlight for illumination.

The material was tailored to suit the dart being modified. As this material is not self-adhesive, a suitable epoxy glue (Pratley Quickset Clear Glue, Pratley Manufacturing & Engineering Co. (Pty.) Ltd., Krugersdorp, RSA) was used to attach the fabric to the darts.

Reflective strips were attached to the flight portion of the dart or as near to the rear end of the dart as possible. Attachment sites for reflective material on several commercially available projectile syringes are shown in Figure 1.

Impala *Aepyceros melampus*, black-backed jackals *Canis mesomelas*, spotted hyaenas *Crocuta crocuta* and lions *Panthera leo* were successfully immobilized at night using reflective darts. Of nine jackals darted, four pulled

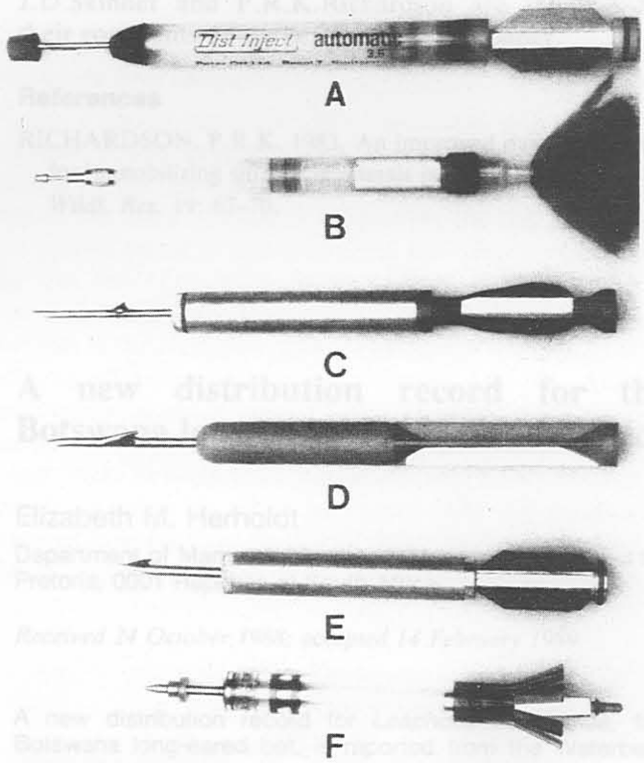


**Figure 1** Reflective material (Scotchlite 8910, 3M, Johannesburg) attached to commercially available projectile syringes. Reflective portions show up white on the photograph. (A) Dist-Inject. Peter Ott H E, Postfach CH4007, Basel, Switzerland. (B) Telinject. Telinject GmbH, D6725, Romerberg, W.Germany / Telinject SA, P.O. Box 2377, Randburg, 2125 RSA. (C) Palmer Capchur with plastic tail flight modification. Palmer Capchur Chemical Equipment Co. Inc., Palmer Village, Box 867, Douglasville, Georgia 30133, USA / Photo Agencies, Johannesburg, RSA. (D) Fauncap. Fauncap (Pty.) Ltd., Box 70, Klaserie, 1381 RSA. (E) Palmer Capchur with aluminium and feather tail flight modification. (F) Paxarm. Paxarm Ltd., P.O. Box 317, Timaru, New Zealand. (Photograph: University of Pretoria.)

the darts out, all of which were recovered by searching with a spotlight. In all cases, the reflectivity of the darts facilitated identification and following of darted jackals under conditions (dark, in moderately dense vegetation cover with many other jackals in the vicinity) in which this would otherwise have been extremely difficult. Of particular value was the fact that the darted animals could be followed at a suitable distance (50–80 m), thereby exceeding flight distance and avoiding further panic following the initial trauma of the darting. Two of the jackals which pulled the darts out were lost to sight, while all those retaining their darts were followed until the drugs took effect.

Of four impala immobilized, only one shed its dart, which was later recovered. All the impala were followed until tractable. However, in the instances where the darts remained attached, the reflectivity was invaluable in identifying the animal within the herd. In one case an impala was followed at a distance of 150 m with the dart clearly visible. Impala were noted to take fright at seeing a foreign object (i.e. a dart) attached to the flank, and it is possible that this effect is exacerbated by the reflectivity of the darts. Intermittent illumination alleviated this problem.

Reflective darts facilitated the identification and following of five darted lions and three darted hyaenas until tractable. A fourth hyaena removed and destroyed the dart shortly after darting. The remains of the dart were successfully recovered by torchlight.

Over three years of nocturnal immobilizations numerous darts missed their targets. While few, if any, could have been recovered at night under normal circumstances, the reflective material assisted in the recovery of nearly all darts. Penetration of thick vegetation or sand can render the reflectivity ineffective, and accounted for the few darts that were not found. On several occasions reflective darts were lost during the day despite bright colouration of the flights (Telinject), but were easily recovered by returning to the site at night with a spotlight or torch.

In attaching reflective material to darts care should be taken to ensure that edges are firmly adhered, as loose reflective material can adversely influence the aerodynamic properties of the dart. Epoxy adhesives are preferable to contact adhesives in this regard. In none of the darts so far modified has securely adhered reflective fabric been found to influence the function of the darts in any way. Reflectivity, even from the curved surfaces, is excellent, although there are always angles at which little or no reflection is achieved. The observer must be as close as possible to the source of illumination for optimum results, as the angle between incident and reflected light influences the reflectivity considerably. The brightly coloured self-adhesive reflective fabrics used by Richardson (1983) have a reflectivity only one third that of the silver fabric (i.e. 160 candelas/lux/$m^2$). These fabrics may, however, serve to increase the visibility of the darts during daylight particularly if the darts are not constructed of brightly coloured materials, and combinations of highly reflective and brightly coloured reflective fabrics could be used to optimize recovery rate of lost darts.

Attachment of reflective material to projectile syringes has two main advantages: First, efficiency and reliability of nocturnal immobilizations is enhanced and second, the recovery rate of darts lost by day or by night is considerably improved, resulting in a saving in time and expense. The incidental advantage of more efficient removal of unsightly and potentially dangerous equipment from the site, often a nature conservation area, also bears mention.

**Acknowledgements**

I thank Des Anderson and Gregory McKenzie for assistance in obtaining suitable reflective material, and L.P. Colly for the use of some projectile syringes. The technique was developed while conducting research supported by the Foundation for Research Development, The Mammal Research Institute and Mashatu Game Reserve. Research was undertaken with the permission of the Office of the President and the Department of Wildlife and National Parks, Botswana. J.D.Skinner and P.R.K.Richardson are thanked for their comments on earlier drafts of this paper.

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# A new distribution record for the Botswana long-eared bat in South Africa

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*Received 24 October 1988; accepted 14 February 1989*

A new distribution record for *Laephotis botswanae*, the Botswana long-eared bat, is reported from the Waterberg area of the north-western Transvaal, based on four specimens collected over seven months. Some observations on the natural history of this species are made.

'n Nuwe verspreidingsrekord vir *Laephotis botswanae*, die Botswana-langoorvlêrmuis, gebaseer op vier eksemplare versamel oor 'n termyn van sewe maande, word gerapporteer vanaf die Waterberg-distrik van die noordwes-Transvaal. Waarnemings rakende hierdie spesies se algemene biologie word ook genoteer.

**Keywords:** Bat, mammal distribution, Transvaal mammals, Vespertilionidae

The Botswana long-eared bat, *Laephotis botswanae* Setzer, 1971, has previously been recorded within South

# Humane modification of steel foothold traps

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A modification of a steel foothold trap is described which successfully eliminates direct injury to trapped animals through: (i) reduction of impact force per unit area by increasing surface area of jaws; (ii) cushioning of impact by incorporating pliancy in one of the jaws, and (iii) cushioning of impact and prevention of laceration by padding of the widened jaws. The padding used is easily replaced — an aspect which may encourage the use of this humane modification. Use of the padded trap should reduce mortalities and injuries in non-target species. The successful capture of seven black-backed jackals *Canis mesomelas* using padded traps is reported.

'n Modifikasie van 'n slagyster word beskryf wat direkte besering aan diere uitskakel deur: (i) die slag per oppervlakte-eenheid te verminder deur die vangoppervlak van die slagysterkaak te vergroot; (ii) die slag te versag deur een van die kake buigsaam te maak, en (iii) 'n kussinglaag op die kake aan te bring om sodoende die slag te versag en latere besering te verhoed. Gebruik van die modifikasie word vergemaklik deur die maklike vervangbaarheid van die kussinglaag. Nie-teiken diere wat gevang word, behoort aan minder beserings en vrektes onderworpe te wees. Gemodifiseerde slagysters is suksesvol aangewend vir die vang van sewe rooi-jakkalse *Canis mesomelas*.

**Keywords:** Carnivore trapping, jackal, problem animal capture, trap design

## Introduction

Successful live capture of carnivores often proves to be an obstacle to research or management-orientated projects (van der Merwe 1953; Lynch 1980; Ferguson 1980). One of the most successful techniques for the capture of small canids is the modified foothold trap (Payne, Jenkins & Provost 1966; Gipson & Sealander 1972; Drewek 1980; Rowe-Rowe & Green 1981; Windberg, Anderson & Engeman 1985). The greatest advantage of this technique is that no part of the mechanism is visible when set, thus minimizing, although not eliminating, the problem of trap avoidance. Various modifications can be made to reduce trauma if the animals are to be used for live studies. Traps may be padded with soft material (Drewek 1980; Rowe-Rowe & Green 1981) or rubber-like compounds (e.g. Olsen, Linhart, Holmes, Dasch & Male 1986). However, if the width of the jaws underneath the padding remains narrow, the force per unit area exerted by the closing jaws of the trap remains considerable. This is sometimes alleviated by weakening the springs of the trap (Drewek 1980). However, weakened springs also extend the closing time of the trap, which may result in capture avoidance by the intended subject (pers. obs.; Linhart, Dasch, Male & Engeman 1986), and does not necessarily eliminate trauma to the animal (Drewek 1980; Olsen *et al.* 1986; Olsen, Linscombe, Wright & Holmes 1988).

Padded foothold traps are commercially available in the USA and Canada (Soft Catch™, Woodstream Corporation, Lititz, Pennsylvania 17543, USA). As padded foothold traps are not easily available in southern Africa where foothold traps are commonly used, and as many unpadded traps are currently in use, this paper describes a simple, effective modification of an available trap for the humane capture of jackal-sized carnivores.

## Materials and Methods

Figure 1 shows the unmodified foothold trap (Brock Tuchten, Johannesburg, RSA). The width of the impact surface of the jaws is 4 mm. After safely securing the trap in the open position, or removing the coil springs, 5–7 mm of metal is removed from the inner surface of the free jaw (Figure 2). Strips of mild steel plate (28 mm × 1,5 mm) are then cut to size to fit the inner surfaces of the trap jaws, and are brazed or welded to the jaws at all points of contact (Figures 3 & 4). After thoroughly cleaning the trap and filing the edges and corners of the plates, padding material (closed-cell foam, 9 mm thick; Moroak C.C., Johannesburg, RSA) is cut to size (care must be taken to ensure that the padding material is wider than the metal plates by 2–3 mm in all directions) and adhered to the inner plate surfaces using

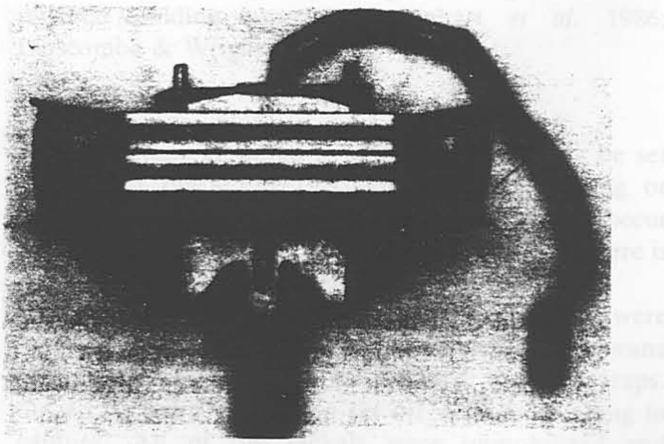


**Figure 1** Unmodified steel foothold trap ('Jackal', Brock Tuchten, Johannesburg, RSA). (Photographs: University of Pretoria.)

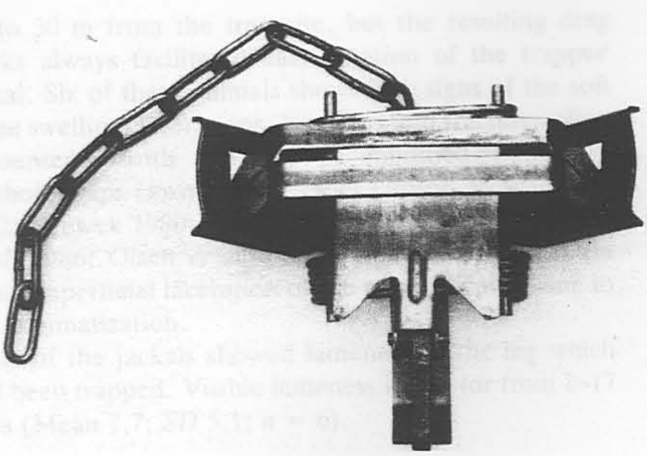
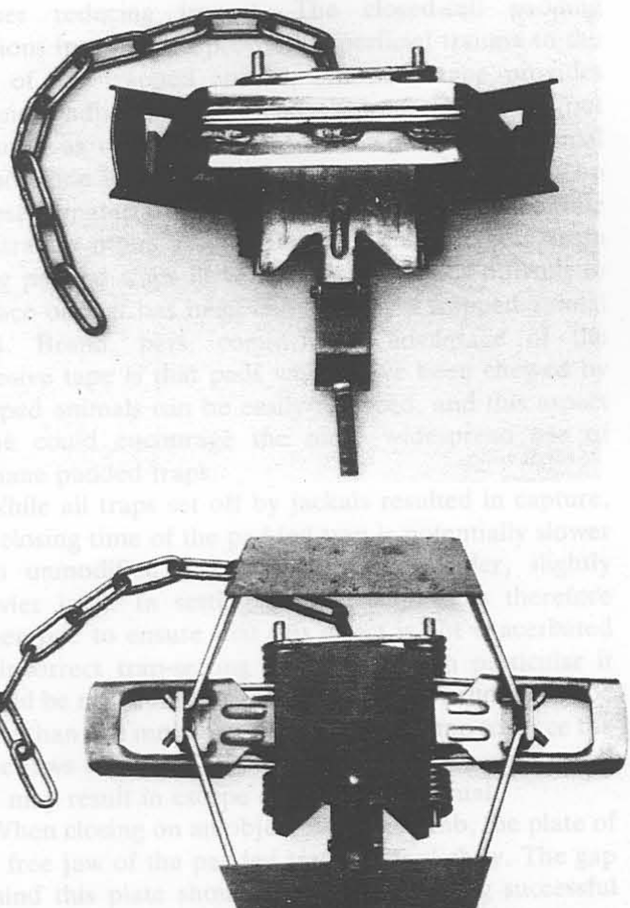


**Figure 2** Five to seven millimetres of metal removed from inner surface of free jaw.



**Figures 3 & 4** Metal plates welded to inner surfaces of jaws.

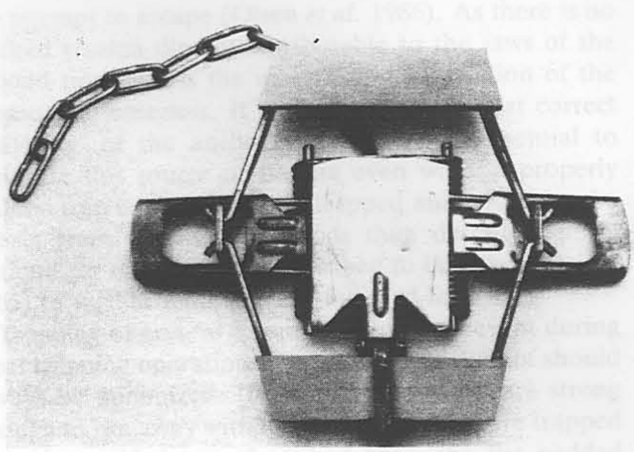


**Figure 5** Closed-cell foam pads adhered to inner surfaces of widened jaws.

**Figure 6** Testing of padded trap.

double sided adhesive tape (3M, Johannesburg, RSA)(Figure 5). Contact glue should not be used as the strong smell may result in trap avoidance. Modifications of this method for use on larger or smaller traps and for traps already being used by farmers and problem animal control units are easily made.

One of the coil springs can be removed to reduce closing impact. This may, however, result in the escape of the subject owing to prolonged closing time and/or reduced holding properties (Linhart *et al.* 1986; Linscombe & Wright 1988).

## Results

Foothold traps modified as described can safely be set off against one's fingers (Figure 6). No bruising or lacerations occur. Mild transient erythema may occur following removal of the hand from the trap, but there is no sign of oedematous swelling.

Seven black-backed jackals *Canis mesomelas* were captured in Mashatu Game Reserve, Botswana (22°10′S / 29°10′E) using the padded foothold traps. On no occasion was a trap set off without resulting in capture. All of the jackals were immobilized and released from the traps within 1 h of capture. Traps were attached via a spring to a heavy metal weight (3–4 kg) with irregular projections. The weights were dragged for up to 30 m from the trap site, but the resulting drag marks always facilitated easy location of the trapped jackal. Six of these animals showed no signs of the soft tissue swelling, lacerations, luxations and fractures often encountered with the use of modified ('padded') foothold traps (Payne *et al.* 1966; Gipson & Sealander 1972; Drewek 1980; Rowe-Rowe & Green 1981; Olsen *et al.* 1986; Olsen *et al.* 1988). One jackal suffered a minor superficial laceration of the trapped paw owing to self traumatization.

Six of the jackals showed lameness of the leg which had been trapped. Visible lameness lasted for from 2–17 days (Mean 7,7; *SD* 5,1; $n = 6$).

## Discussion

The widening of the jaws from 4 to 28 mm reduces the impact force per unit area by a factor of 7. The gap behind the plate of the free jaw provides 'give', thus further reducing impact. The closed-cell padding cushions impact, and prevents superficial trauma to the foot of the trapped animal. Adhesive tape provides sufficient adhesion of the pads — total adhesion is not required as once the trap is closed the target animal cannot slide its paw out of the trap even if there is no adhesive material between the plates and pads. Time constraints often prevent farmers and trappers from using padded traps in which the padding is difficult to replace once it has been damaged by a trapped animal (D.J. Brand, pers. comm.) An advantage of the adhesive tape is that pads which have been chewed by trapped animals can be easily replaced, and this aspect alone could encourage the more widespread use of humane padded traps.

While all traps set off by jackals resulted in capture, the closing time of the padded trap is potentially slower than unmodified traps owing to the wider, slightly heavier jaws. In setting padded traps it is therefore imperative to ensure that this effect is not exacerbated by incorrect trap-setting procedure — in particular it should be noted that soil covering the jaws should not be more than 5–8 mm deep. Requiring the trap to force the wide jaws through a layer of thick, possibly compacted, soil may result in escape of the target animal.

When closing on an object such as a limb, the plate of the free jaw of the padded trap bends slightly. The gap behind this plate should be re-set following successful trapping. After many captures, this plate may become weakened, and may need to be replaced.

Padded traps should be stored for short periods in the open position to maintain the cushioning properties of the padding material. Pads should be removed for long-term storage of traps in the closed position.

From observations of trapped jackals it is evident that considerable effort is expended in attempting to escape from the trap, particularly when approached for immobilization or release. It is most probable that ligaments, tendons and muscles of the trapped limb are strained during this process. Even muscles and tendons of the free limbs can show signs of trauma resulting from the attempt to escape (Olsen *et al.* 1986). As there is no marked trauma directly attributable to the jaws of the padded trap, this is the most likely explanation of the subsequent lameness. It appears therefore that correct 'buffering' of the anchor via a spring is essential to minimize this source of trauma even when a properly padded trap is being used. If trapped animals are to be left in traps for longer periods than described here, tranquilizer tabs should be attached to the traps (Balser 1965) to further minimize self-inflicted injuries.

Trapping of non-target species is a likely event during most trapping operations, and the effects thereof should always be minimized. If large species which are strong enough to run away with the trap and anchor are trapped with the padded trap described here, the flat padded surface facilitates the withdrawal of the trapped limb from the small trap. Smaller non-target species can be released relatively unharmed from the trap.

## Conclusion

Any live-trapping of animals should be undertaken by the most humane method possible, irrespective of what the fate of the trapped animal is to be. A trap which is claimed to be atraumatic should pass the most stringent test, and any further possible improvements must be applied. While longer periods between capture and removal may result in more considerable trauma than reported here, the modified trap itself would comply with even the most stringent ethical standards.

The fact that suitably padded foothold traps are not readily available in southern Africa and many other areas at present makes it necessary for the most humane modifications possible to be made to standard foothold traps before they are used in the field.

## Acknowledgements

I thank Dirk Brand for invaluable advice on jackal capture. This modification was developed while conducting research supported by the Foundation for Research Development (CSIR), the Mammal Research Institute and Mashatu Game Reserve. Research was undertaken with the permission of the Office of the President and the Department of Wildlife and National Parks, Botswana. J.D. Skinner and J.W.H. Ferguson are thanked for their comments on earlier drafts of this paper.

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# The ruminant dental grooming apparatus

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Correlations between dental morphology and dietary preferences in ruminants explain the similarities but not the differences in relative incisor width encountered within the group. Observations on African browsing antelope have revealed extensive use of the lateral anterior dental elements for grooming purposes using a distinctive upward sweeping movement of the head. Inspection of these dental elements ($I_2$, $I_3$ and C) reveals a comb-like array remarkably similar to the prosimian tooth-comb. An hypothesis is presented to explain differences in incisor morphology based on the use of the teeth for purposes other than eating. The alternative biological role has implications for the use of dental characteristics in the determination of the feeding ecology of living and extinct ruminants.

KEY WORDS:—Dental morphology – ruminants – grooming – parasites – feeding ecology.

CONTENTS



## INTRODUCTION

Mammalian dentition is a key element in the morphological and ecological classification of species and is thus of fundamental importance to taxonomists and ecologists alike. The distinctive patterns of dental morphology associated with different dietary specializations provide us with a valuable insight into the feeding ecology of mammals, whether living or extinct. However, this easily observed and generally well preserved 'peephole' has been used so often and for so long that a particular relationship between form and function—that is that feeding habits are the over-riding determinant of dental morphology—is often assumed. Considerable controversy therefore surrounded the suggestion that the comb-like mandibular incisors characteristic of some prosimian primates had evolved specifically as a grooming organ (Cuvier & St. Hilaire, 1825; Stein, 1936; Roberts, 1941; Beuttner-Janusch & Andrew, 1962; Martin, 1972; Gingerich, 1975; Szalay & Seligsohn, 1977; Schwartz, 1979; Eaglen, 1980; Gingerich & Martin, 1981; Rose, Walker & Jacobs, 1981; Rosenberger & Strasser, 1985; Eaglen, 1986). To date the grooming hypothesis appears to have gained sufficient support (Roberts, 1941; Beuttner-Janusch & Andrew, 1962; Szalay & Seligsohn, 1977; Eaglen, 1980; Rose *et al.*, 1981; Rosenberger & Strasser, 1985) and, for the moment at least, the case rests. This paper reports the occurrence of a specialized dental grooming apparatus that is widespread amongst ruminant herbivores, and which closely resembles the prosimian tooth-comb.

The incisor teeth of mammals, being the most anterior elements of the dental array, are generally ascribed a 'nipping', 'cutting', 'holding' or 'collecting' function (DeBlase & Martin, 1974). A 'typical' incisor consists of a single relatively deep root and a medium to high spatulate crown—and a row of six such incisors forms a knife edge along the anterior aspect of the jaw which, in occlusion with its counterpart in the other jaw, forms a self-evident food collecting organ. In the case of the ruminants, the lower incisors and the incisiform canine (together here referred to as the incisor-canine (IC) complex) occlude against the fibrous dental pad of the upper jaw. This arrangement, together with the lips, performs the grasping and cutting action required for the ingestion of the vegetable diet.

Extant ruminants are classically referred to as grazers, mixed feeders or browsers according to the composition of their observed diet. Alternatively browsers, which selectively feed on nutritious leaves and shoots, may be classified as concentrate selectors, while grazers may be referred to as bulk feeders (Hofmann & Stewart, 1972). It has been noted that incisor morphology differs

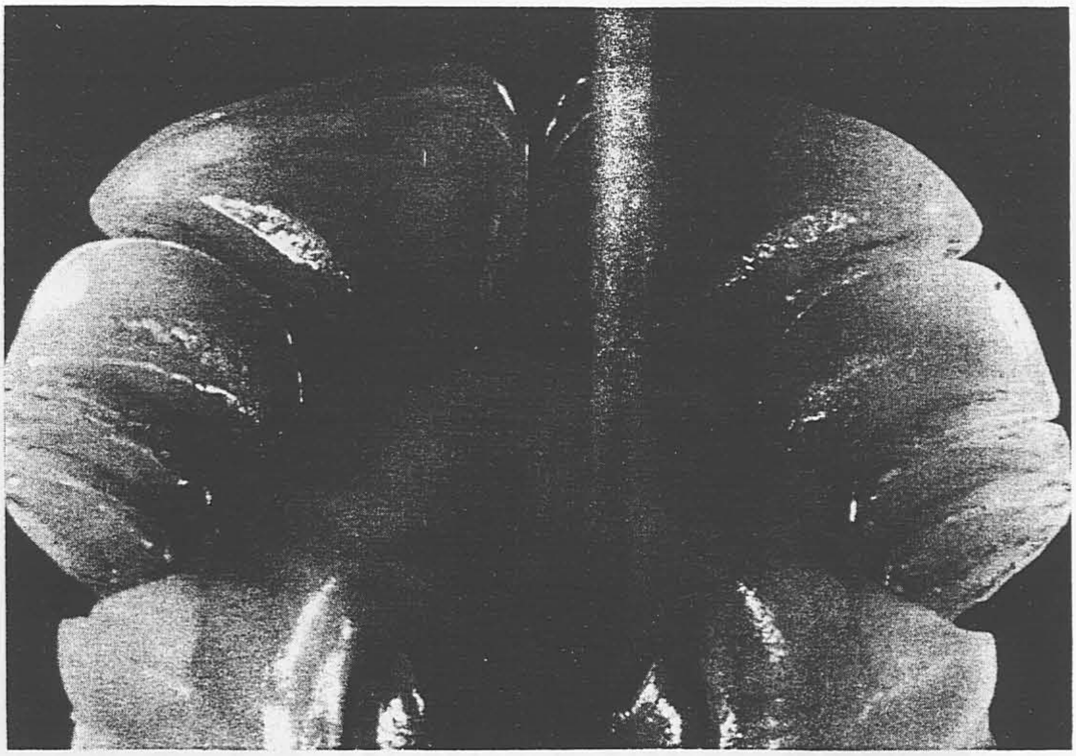

Figure 1. The incisor-canine complex of the lower jaw of an adult impala (*Aepyceros melampus*) showing the considerable percentage of the complex contributed to by $I_1$, and the needle-like structure of the lateral elements ($I_3$ and canine). (Photo: University of Pretoria.)

between these various groups: the incisors of grazers tend to be of an even size, while in browsers and mixed feeders the central incisor is laterally expanded with a concomitant decrease in the width of the lateral elements of the IC complex (Von Lehmann, 1961; Boue, 1970; Janis & Ehrhardt, 1988) (Fig. 1). Being selective feeders, the general narrowing of the muzzle and incisor row observed in the browsers is interpreted as a requirement of this selective feeding habit (Owen-Smith, 1982; Janis & Ehrhardt, 1988). The question of why the narrowing of the incisor row and muzzle is accompanied by expansion of the first incisors and reduction in size but not number of the lateral elements has not previously been addressed.

The expanded central incisors of browsers, sometimes called the pincers (Von Lehmann, 1961; Boue, 1970), comprise up to 60% of the total length of the IC complex (Pockock, 1935; Boue, 1970; Janis & Ehrhardt, 1988) (Fig. 1). While the first two elements ($I_1$ & $I_2$) of the IC complex appear well suited to a food collecting function, occlusion of the needle-like third incisor and canine against the dental pad is ineffectual in grasping or cutting food material (Fig. 2). In addition, these teeth are delicate and are relatively loosely embedded in their alveoli. By inference, these lateral teeth are regarded as vestigial by many authors. However, the persistence of these apparently vestigial lateral teeth does require some explanation, and it has been suggested that they perform a scraping, combing action "from the corners of the lips" during browsing (Boue, 1970). It is possible, however, that in seeking a feeding related function for these enigmatic teeth, or in inferring vestigiality, we have overlooked the fact that teeth are not only used for eating.

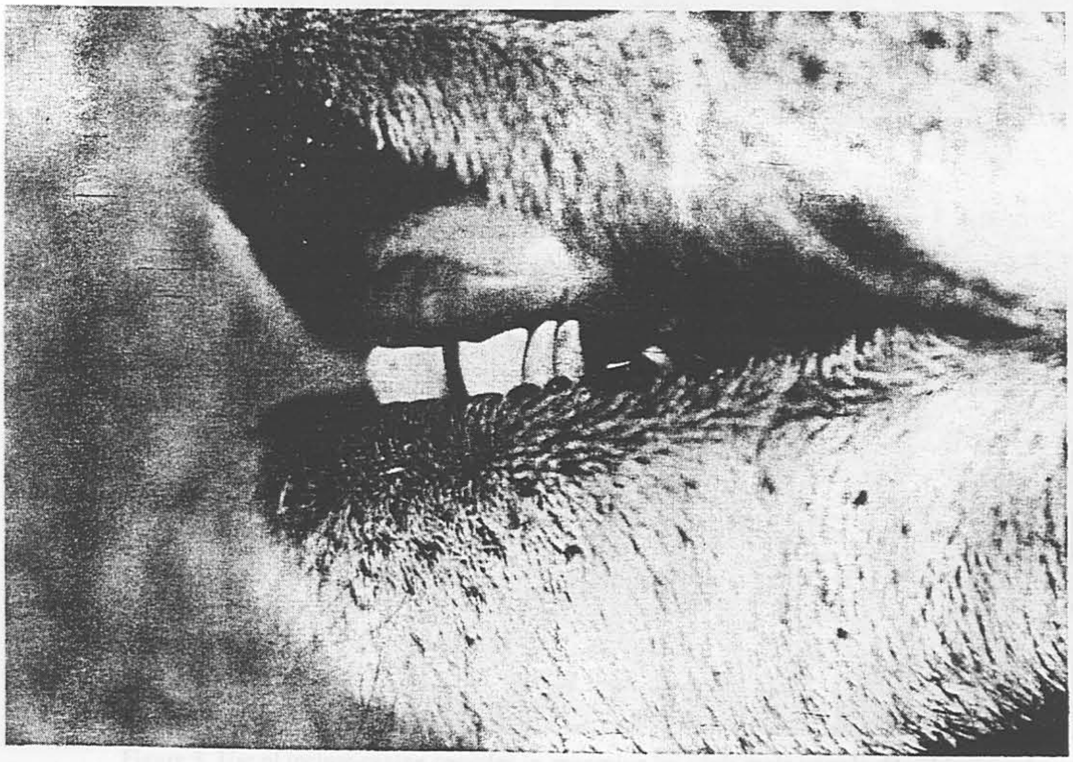

Figure 2. Lateral elements of impala incisor-canine complex *in situ*.

IN MOVING LATERALLY: THE ALTERNATIVE BIOLOGICAL ROLE

Grooming of the pelage forms an important part of the behavioural repertoire of many mammals. The primary function of this behaviour is the maintenance of the skin and associated pelage through the removal of parasites, debris or water, alignment of the hairs of the coat and sometimes the dispersion of odours or secretions through the pelage (Rosenberger & Strasser, 1985). A secondary social function has developed in many group-living species.

To facilitate effective grooming, specialized structures are found associated with the hind feet of many mammals (Dubost, 1970). The comb-like lower incisors of prosimians and tree-shrews are another example of anatomical specialization to facilitate grooming requirements (Cuvier & St. Hilaire, 1825; Roberts, 1941; Beuttner-Janusch & Andrew, 1962; Szalay & Seligsohn, 1977; Eaglen, 1980; Rose *et al.*, 1981; Rosenberger & Strasser, 1985; Eaglen, 1986).

Inspection of the lateral components of the IC complex of browsers and mixed feeders reveals a comb-like structure remarkably similar to the prosimian tooth-comb (Fig. 1). These elements are high-crowned, with a strong median ridge on the lingual surface, and with needle-like tips. The tips are aligned in a neat row directed upwards and outwards (Fig. 2). Observations on three species of African browsing antelope, impala (*Aepyceros melampus*), kudu (*Tragelaphus strepsiceros*) and steenbok (*Raphiceros campestris*) have shown that this dental assemblage is used extensively for grooming all accessible parts of the body. A distinct upwards motion of the head is used to comb the teeth through the pelage (Fig. 3). Only close observation reveals that the teeth, not the tongue, are used in this process. Figure 4 shows the alignment of the mandible and teeth relative to the flank with

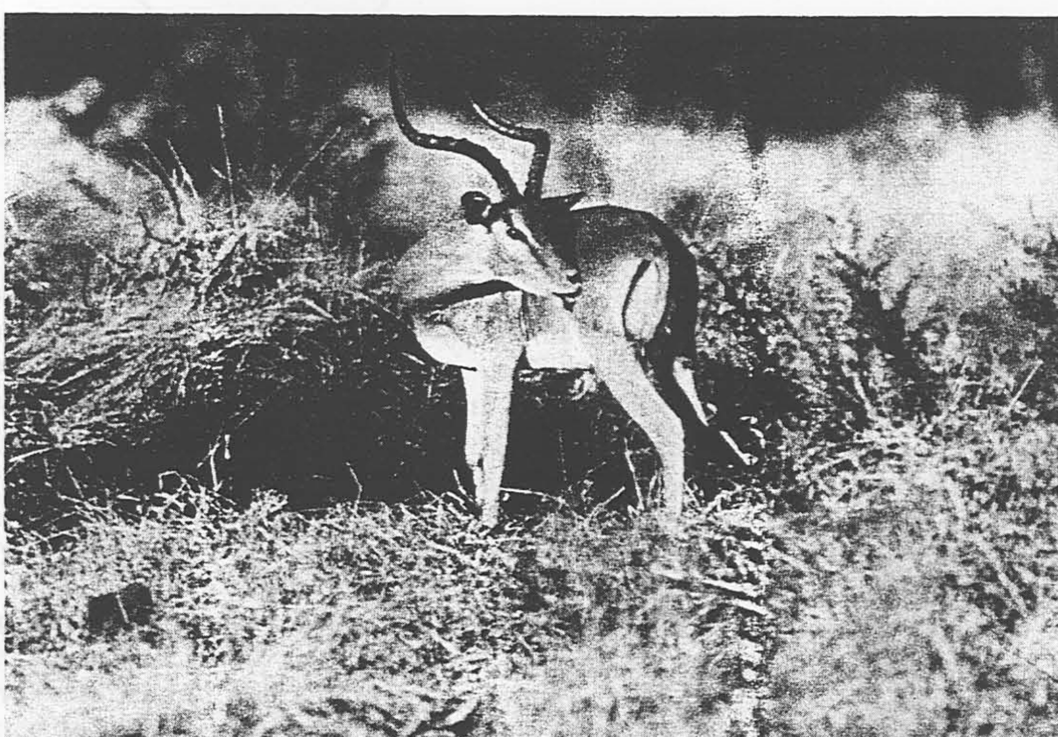

Figure 3. Use of incisor-canine complex in grooming by adult male impala. Head is moved vertically upwards against the body in this position.

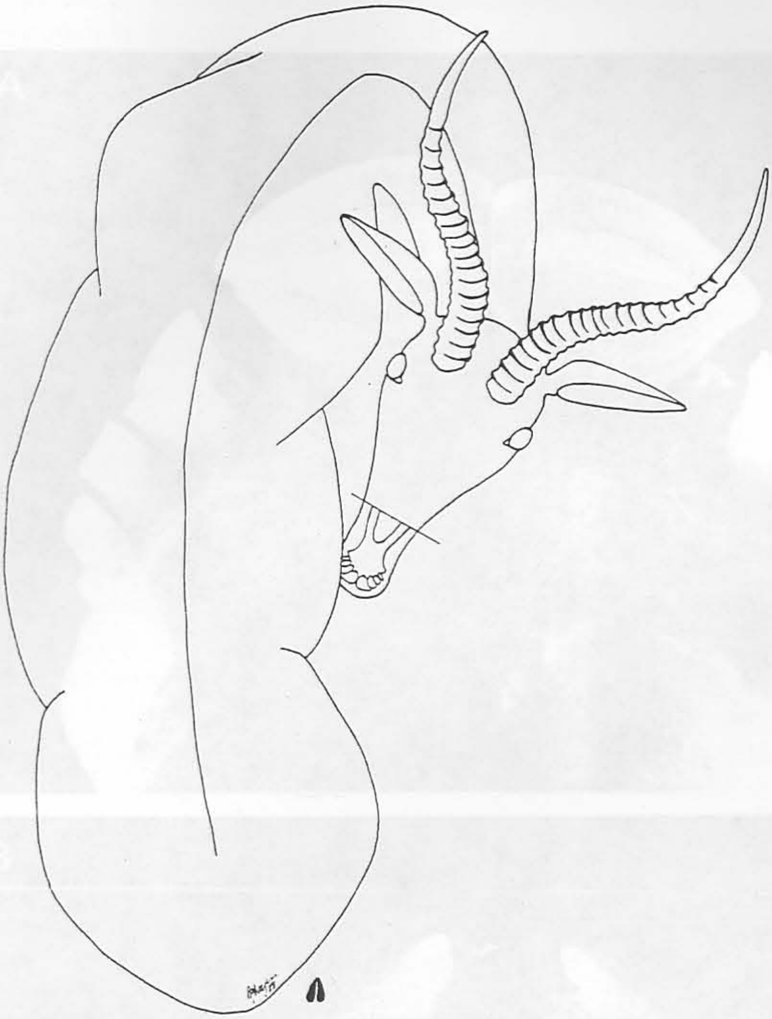

Figure 4. Alignment of components in a typical grooming posture of impala. (Artwork: A. van Rooyen.)

the head in a grooming position. It can be seen that in such a position the toothcomb is so aligned as to rake evenly the selected part of the pelage with a vertical movement of the head. In the narrowing of the muzzle, widening of the first incisor and alignment of the other incisor-canine complex elements, a selective feeding adaptation has been combined with an effective grooming tool.

One limitation of this morphological adaptation is that not all parts of the body are equally accessible. In particular, the head and neck cannot be groomed with the teeth at all. However, behavioural adaptation compensates for this deficiency through ritualized mutual allogrooming, in which individual antelope use their teeth to groom the necks and heads of other herd or family members.

Mammalian grooming behaviour has been shown to control external parasites effectively (Snowball, 1956; Bell, Jellison & Owen, 1962; Riek, 1962; Bennett, 1969), and seasonal and spatial differences in parasite abundance may therefore be expected to influence grooming frequency. While dental attrition through grooming activity is not expected to be severe (Eaglen, 1986), grooming has been shown to result in wear grooves in the anterior teeth of primates (Rose *et*

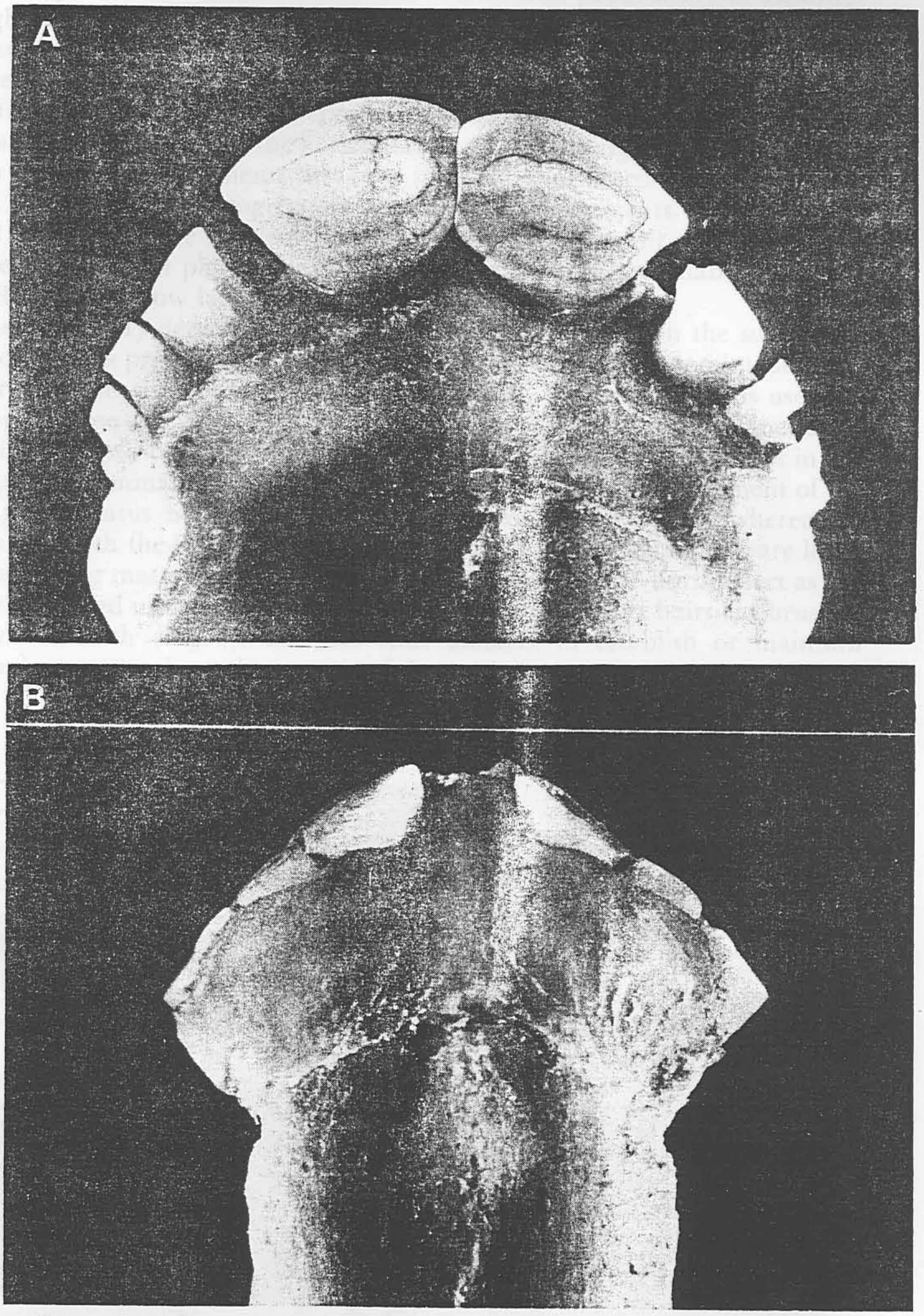


Figure 5. Progressive attrition of incisor-canine complex of impala. A, Horizontal attrition of $I_1$ due to eating function. Vertical attrition of $I_2$, $I_3$ and canine due to grooming activity—tips rubbed against skin. Note notches caused by hair being drawn between teeth. B, Vertical attrition due to grooming progressed to involve all elements of incisor-canine complex. (Photos: University of Pretoria.)

*al.*, 1981). Similarly, prolonged use of the incisor-canine complex for grooming could be responsible for dental attrition in herbivores, particularly in localities with high external parasite abundance, and may indicate the extent to which the dental array is applied to this particular function.

Figure 5 demonstrates progressive wear of the incisor canine complex of adult impala from Mashatu Game Reserve in Botswana (22°10'S; 29°00'E). Feeding-related attrition accounts for the horizontal wear of $I_1$ and $I_2$ in Fig. 5A. Vertical attrition of the lateral elements first seen in Fig. 5A is caused by the grooming activity, and eventually progresses to involve all the elements. Eventually, in very old animals, all the IC elements may be worn down to (or even below) the gum line in a vertical plane (Fig. 5B). These old animals are unable to groom effectively, as they now lack the grooming apparatus.

Rose *et al.* (1981) demonstrated clear microscopic grooves on the surfaces of incisors of various prosimian primates which were ascribed to grooming activity. These grooves clearly indicated the extent to which the tooth-comb is used for grooming in those species, and finally ended the controversy over the function of the prosimian tooth-comb. No such clear microscopic grooves are evident in the IC complex of ruminants. This can be ascribed to the fact that movement of the grooming apparatus is against the lie of the hair in ruminants, whereas in primates it is with the lie of the hair. In the latter, the individual hairs are long, and loops of long matted hair therefore would result in a 'rope-burn' effect as the hairs are realigned using the teeth. In the herbivores, the short hairs are brushed aside by the teeth (Fig. 6), and are thus unlikely to establish or maintain microscopic grooves along the crowns of the teeth.

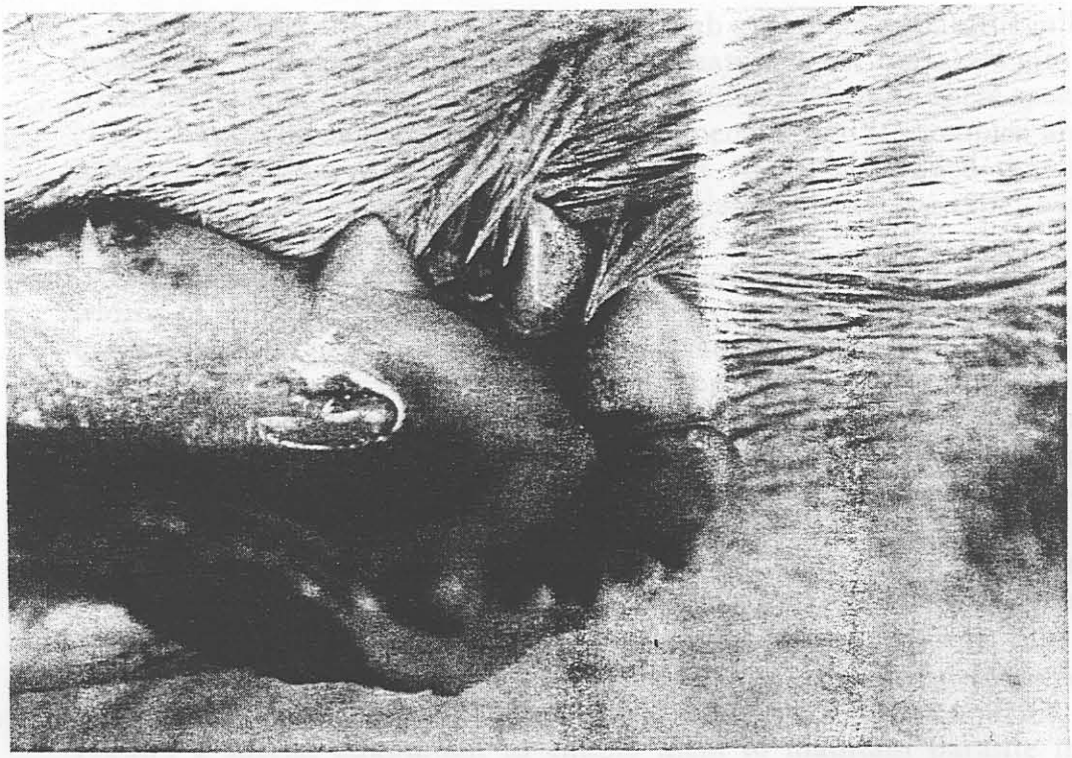

Figure 6. Simulated combing action of incisor-canine complex of impala.

Figure 7. Radiograph indicating macroscopic notches in neck regions of incisors due to grooming activity. (University of Pretoria.)

In ruminants the neck regions of the teeth of the IC complex are, however, subject to a high rate of attrition by the short hairs of the pelage relative to the attrition of the enamel crown. This results in unusual shapes representing macroscopic grooves in old animals which have used their teeth extensively for grooming (Figs 5A, 7).

## RE-INTERPRETATION OF STRUCTURE

In considering the utility of the tooth-comb grooming apparatus in browsing herbivores, it becomes apparent that this feature must be taken into account when correlating dental characteristics to feeding ecology in these species. Boue (1970) has declared that the fine lateral elements of the IC complex are used in selective browsing, while Janis & Ehrhardt (1988) concluded that the ratio between the widths of $I_1$ and $I_3$ was correlated to dietary type, without an explanation for the correlation.

From Janis & Ehrhardt's impressive collection of data on relative incisor widths of numerous ungulates it is apparent that most of those ruminants with the largest ratio of $I_1$ to $I_3$ (i.e. with small lateral elements which could form a tooth-comb) are small to medium-sized browsers or mixed feeders. Other authors have also noted that the inequality of the incisors is most obvious in the small and medium-sized browsers and mixed feeders, is less apparent in the larger browsing species, and is generally minimal in the grazers (Pockock, 1935; Von Lehmann, 1961; Boue, 1970).

Browsers are by nature selective feeders, and come into close contact with vegetation in their quest for selected food items (Dubost, 1979), particularly during the drier months of the year when suitable browse occurs as a clumped resource in moist microhabitats. In so doing, they are potentially exposed to a greater external parasite infestation than the grazers of the open plains, and may require a special adaptation to enable them to maintain parasite infestation within acceptable limits.

In collecting young, nutritious leaves and shoots, browsers experience minimal attrition of their incisors, while grazers of coarse grass experience severe incisor attrition. Spinage (1973) has shown that M1 wear in grazers is generally in unison with incisor wear, while browsers incisor wear proceeds at a relatively slower rate than molar wear. This difference is all the more significant when it is noted that the incisor row of extant grazers is of a far more robust nature than that of the browsers. Thus it is possible that small and medium-sized browsers have been able to set aside their lateral teeth for a purpose unrelated to eating without risking a rapid loss through attrition of the remaining 'collector' incisors—much in the way that the prosimian tooth-comb evolved without affecting feeding ability (Beuttner-Janusch & Andrew, 1962). The parallel between prosimian and ruminant tooth combs is further highlighted by the appearance of the canine in this complex in both groups (assuming that the third element of the prosimian tooth-comb is indeed a canine (Eaglen, 1986)). As in the case of the prosimians (Szalay & Seligsohn, 1977), the inclusion of the canine in the ruminant dental grooming array is highly significant: through inclusion of the canine, an additional long, narrow interdental space is created without, in the case of browsers, a significant addition to the cutting edge created by the incisors. The close similarity in form of the third incisor and the incisiform canine and the persistence of the latter throughout the group indicates the presence of a selective force of not inconsiderable magnitude.

Several variations on the general browser theme serve to place this hypothesis in perspective:

(1) Most very small antelope possess a diastema between the first incisors, as illustrated in Fig. 8. Boue (1970) explained the presence of the diastema as an adaptation for scraping leaves from branches. However, the medial compensation of these teeth in the small browsers (Fig. 8) belies a feeding function of the diastema, and suggests that the teeth are laterally displaced for a reason other than the creation of a gap. Furthermore, it is unlikely that a creature with teeth would resort to scraping branches and thorns against the sensitive gingival mucous membrane at the base of the diastema, and if the branch were of a suitable size for the teeth flanking the diastema to scrape off the leaves and bark, there would be a very real risk of the branch becoming stuck in the diastema. Alternatively, the existence of an effective dental grooming organ in the correct position in these small browsers would necessitate the lateral displacement of the first incisors, there being a limit to the fan-like expansion of $I_1$ in a lateral direction.

(2) African grazing ruminants classified as fresh grass grazers by Janis & Ehrhardt (1988) without exception exhibit an uneven incisor morphology more similar to the browsers than to the regular grazers. This was not discussed by those authors. These species select green grass in tall stands of vegetation near water, and are thus exposed to considerable vegetation contact, again more similar to the browsers than to the grazers of the open plains. Incisor attrition would also be lower in these selective green grass grazers, thus mirroring the selective pressures working on browser incisor morphology. The lateral elements of the incisor canine complexes of these species form a comb-like array as in the case of the browsers.

(3) It would be unreasonable to expect all ruminants to follow a single simple rule regarding their dental morphology. Thus some authors have noted

Figure 8. Diastema between first incisors of chevrotain (*Tragulus javianicus*). Note medial compensation of $I_1$ almost closing the diastema. (Photo: University of Pretoria.)

exceptions to the trend towards unequal incisors in browsers and mixed feeders—the camelids (Boue, 1970; Janis & Ehrhardt, 1988) and the musk deer (Boue, 1970) both have more evenly sized incisors than would be expected. Coincidentally, these species also have considerably larger canines than 'average' browsers or mixed feeders. If indeed these species are subject to the same selective pressures as the other browsers/mixed feeders, then these large canines could inhibit the development of a grooming function of the IC complex or, alternatively, could themselves perform an analogous function.

## CONCLUSION: SOMETHING TO CHEW ON

Structure and function are the inextricably linked features that occupy the time of evolutionary biologists. It is sometimes taken as axiomatic that "only after the mechanical functions of character complexes are understood can the study of the biological roles of these features proceed based on adequate foundations" (Bock & Von Wahlert, 1965). In considering mammalian teeth, the interpretation of structure has facilitated explanation of feeding function even when the species concerned has been extinct for millions of years. In the case of ruminant dentition, our preoccupation with the functional description along historical lines has obscured the true biological role. When eating is assumed to be the primary function of teeth, explaining all variations we find in structure without question, enigmatic structures and correlations remain. With ruminant incisors, a reversal of the traditional sequence leads to a new interpretation of the biological role, and explains enigmatic structures very well suited to a previously overlooked function.


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