Overview of Goals and Methods for Ecological and Taphonomic Censusing of Modern Vertebrate Bones

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Research Goals

1) Obtain statistically viable samples of the surface (modern) bone assemblage (macro- and micro vertebrates) in order to characterize the species present and their relative abundances.
2) Compare results with other types of censuses (live animal counts, trapping samples, etc.) in order to establish how bone surveys may contribute to ecological monitoring programs.
3) Establish baseline data for different habitats and ecosystems using bone surveys so that ecological change can be monitored in future standardized surveys.
4) Document the impact of different types of predators (e.g., lions vs. hyenas) on prey populations through analysis of damage patterns to the bones and survival of different skeletal parts.
5) Calibrate rates of weathering in different habitats and climates to establish a way to estimate time-since-death for skeletal remains.

Methods

The key to successful bone surveying is one or more team members who is/are able to identify species and body parts in the field from fragementary skeletal remains. This is a skill that can be acquired through study of museum osteology collections. Sketching of the most common bones that survive in surface assemblages (e.g., skulls, jaws, teeth, ends of major limb bones) from different aspects (distal, proximal, lateral, medial views) plus practice in the field is the best way to learn bone identification. Even experienced workers take reference skeletons (for example, borrowed from a museum's Department of Osteology) into the field, as well as reference books that aid in identification. If ID is uncertain, it is very important to mark the bones or skeletons with ?? on the data sheets, photograph and/or collect them and identify them using comparative collections before finalizing the data.

Fred Lala Odock (KWS), Tyler Faith and I prepared a printed “Bone Guide” for common East African mammals using the NMNH osteology collections, organizing this so that same limb bones of similar-sized animals were on the same page (e.g., impala and Grant’s gazelle), in different views. This is very useful, but it is always better to take comparative collections of common animals along to the field if possible.

Example of a page from the (Draft) Bone Identification Guide for East African Mammals.

1) Bone Transects.

Using airphotos, satellite imagery and/or maps, or ground surveys, areas for sampling and general locations for transects are chosen. On the ground, the end points (and any points where the transect is broken or changes direction) must be documented using GPS to provide coordinates that can be entered into a GIS system. Transects usually were oriented North-South or East-West in Amboseli Park, Kenya, to make it easier to keep on a straight line using a compass or GPS. Accurate GIS coordinates allow calibration of the area searched and also permit future surveys of the same area. Transect width is determined by visibility; in dense vegetation, 10 – 30 meters either side of the midline (often where a vehicle is driven); in open vegetation 30-50 m either side. Bones that are outside this area should be excluded from the transect sample, but if unusual or part of a skeleton that is inside the limit, these may be noted.

Usually two to four individuals walk over transects, covering as much of the ground as possible and flagging the bones, and the leader follows along and records on standardized data sheets all bone occurrences that they find. Bones that cannot be identified or those of special taphonomic interest are collected for later checking. An OCCURRENCE is one to many bones in close spatial proximity belonging to one individual animal. Body parts likely belonging to the same individual but dispersed more than 15 – 20 m away from each other generally are given separate occurrence numbers. Also, when two different animals occur at the same place, they are given separate occurrence numbers. One person should be responsible for making final decisions about identification and for collecting all required information on the data sheets; this is very important to assure that differences between transects are not due to differences in observer methods or ability.

Data recorded include: taxon, age (adult, juvenile, state of tooth eruption), skeletal parts present, habitat, weathering stage, breakage and other damage features such as tooth marks, degree of burial (see sample data sheet on following page). In Amboseli, we continued the transect until we had 20 individuals ("MNI" = mininum number of individuals). Alternatively, one can sample all bones in a specified transect length, e.g., 1 km. MNI is based on the number of different individual animals that can account for the documented bones; decisions are made in the field, based on body size, species ID, growth stage (juvenile vs. adult), weathering stage, etc. The general approach in Amboseli was to assume that an unknown bone was not a separate individual unless it could be demonstrated to be; i.e., a conservative position that worked against inflating the MNI count. For more information on the prototype sampling methods in Amboseli Park, Kenya, see Behrensmeyer and Dechant, 1980; Behrensmeyer, 1993. Generally, a sample of at least 100 MNI is necessary to characterize the common species in a particular habitat (i.e., 5-6 transects), though more may be required to capture the rare species. In Amboseli, we were able to do 2-3 transects in a day, thus it is possible to obtain an adequate sample of

Modern Bone Surveys - Taphonomy

DATE: ____________

NAME(S): ____________

Sheet Number

HABITAT: ____________

TRANSECT: ____________

Direction and Width of Transect: ____________

Starting Point: ____________

GPS: ____________

Occurrence #	Taxon	Rel. Age	Dental Age	Weathering	New indiv ?	BONES

NOTES:

NOTES:

NOTES:

NOTES:

NOTES:

NOTES:

Notes on Transect:

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several different habitats in a week of bone surveying. This depends, of course, on the density of bones on the ground and the time required by the team to locate and identify these bones.

Amboseli bone survey crew exposing and recording bones in the swamp margin habitat. Note yellow survey flags and clipboard. Photo by C. Badgley

2) Targeted samples.

Additional sampling can be used to document the effects of the dispersal and destruction of carcasses around predator dens or areas of particular concentration ("predation arenas"), including human habitation sites. For example, this can involve radial transects around known hyena denning areas and investigation of other places where hyenas or other predators are known to "lie up" during the day (e.g., dense clumps of grass, palm woodlands) as well as direct observations of predators and scavengers at kills, when possible.

3) Small mammal bone concentrations.

These occur around predator roosts and marking areas (latrines) and provide information that cannot be gathered efficiently on the walking transects, where small animal bones can easily be missed. It is best to collect bulk samples of these concentrations, including carnivore scat piles and owl pellets, for later processing and identification in the laboratory. Such concentrations and their context (e.g., under a tree, on a rocky outcrop) should be photographed and described PRIOR to collection, and a GPS and/or map record must be made of their location.

4) Bone and carcass mapping.

With modern GPS technology, it is possible to map every bone or carcass on a transect by recording GPS coordinates for the center of the occurrence. This can be done in selected areas to provide detailed maps of the landscape distribution of the skeletal remains and the species they represent. This will allow researchers to develop a picture of where different species are dying and how this may change through time. If one has a Hand-held Computer–GPS data logging capability, the time devoted to recording the position of each bone occurrence is minimal; however, if one has to write down the numbers for each occurrence, this can significantly increase the time for each transect. Thus the team leader must decide how to balance the benefits of more detailed spatial data and the need for large transect samples, based on the goals of the project.

Analysis

After data are collected, they should be entered in standardized spreadsheet format that preserves as much information as possible. Separate forms will be needed for presence/absence of skeletal parts, damage patterns, and spatial (GPS) data. Data entry should be done as soon as possible after field work and museum checking of the "??" specimens. Although electronic data collecting cuts out this step and saves time, it is also subject to data loss or corruption in electronic media. I still prefer taking the primary data by hand on paper and making this the permanent field data archive (which can easily be scanned for distribution).

Comparative analysis can test for differences in taxonomic composition, skeletal part survival, damage features in different transects and habitats. For Amboseli, data from the early surveys have been stored and analyzed using Excel, FileMaker, and PAST or R, and new data will be entered in the same software. Various types of quantitative visualization analysis (e.g., Multidimensional Scaling, Principal Components Analysis, Correlation metrics) can be used to test for trends and establish the significance of observed differences between samples from different habitats, and for differences through time once there are multi-year samples.

Analysis will allow researchers to address the following questions (examples):

1) What are the differences in species richness, relative abundance and spatial distribution of major herbivore species in different habitats and ecosystems, as represented in the bone assemblages? How does this compare with census data on changes in the live herbivore populations?

2) How does the number of bones per individual on the ground surface with proximity to human habitation sites, hyena denning areas or other places where predator/scavengers (of both micro and macro-vertebrates) tend to concentrate their activities?

3) What is the relationship of carnivore damage and skeletal part survival to body size?

4) How does the ratio of juvenile to adult skeletal remains vary across habitats, and what does this indicate about predator pressure on the prey population?

Live census information for the larger herbivore species in many Kenyan ecosystems has been collected throughout the past several decades by ecologists, including Kenya Wildlife Service staff. Also, there are ongoing studies of predator populations in a number of different areas. Such ecosystems can serve as testing grounds for the bone surveys. The same is also true for large animal populations in national parks and reserves in other countries around the world. The main limiting factor for bone surveys is bone visibility – ecosystems where bones are visible on the ground, either perennially or seasonally, are the most appropriate targets for this method.

Caveats about the Amboseli Bone Survey Data

<u>Skeletal parts – proportions of different limb bones</u>

There is a potentially serious problem with differential identifiability of limb fragments, as some limb shafts are more recognizable than others (e.g., tibia, radius). It is safer to restrict analysis to bones that have at least one end, rather than attempting to include the shaft pieces. These can be analyzed separately, and if there are identifiability issues, at least these should be about the same across different samples collected at the same time, and identified by the same person.

In the 1970's, we did not pay much attention to limb fragments, and I cannot claim that this is comparable to the later samples from Amboseli. I have also learned a lot about identification of fragments since the 1970's. There weren't as many, in any case, since hyena processing was so low then. In the 2000's samples, the procedure has been to note every fragment and to attempt identification to limb element or other skeletal region. This may inflate the numbers of radii, tibiae, etc.; the way to sort them out of the database is to look for "side indet." – if there wasn't enough to tell left or right, then they probably should be grouped with the "limb frags" category and excluded from limb element analyses.

<u>Taxa – identification issues</u>

For the most part, since I have been involved in the identification from the start of the Amboseli project, there should be consistency across the decades...except for the fact that my competence at fragment ID may have fluctuated somewhat. In 1975 as well as later years, the usual procedure was to refer to museum skeletons we had in the field, or use the bone book, for hard to ID bones. We also took back to Nairobi those that we could not identify in the field, including all bird specimens.

There has been a general tendency to assign poorly preserved limb elements and other parts to Wildebeest if they are the right size and are clearly bovid, which may have inflated the WB totals at the expense of Kongoni, Oryx, or Waterbuck. In later years, I tried to be conservative, assigning such elements to "Artiodactyl" or "Bovid." But there may be some unevenness in how this was done from year to year. The numbers of the other bovids are small, in any case, so there may not be much effect. We were careful to distinguish WB from COW wherever there were likely to be cow bones in the mix. The same goes for SHOAT (sheep and goat) vs. Thompson's Gazelle, Reedbuck and Bushbuck, and we may have inflated TG at the expense of the other wild bovids of this general size category (more likely in the later samples than in 1975, as we were quite careful when we started the transects).