Actualistic butchery studies in zooarchaeology: Where we've been, where we are now, and where we want to go

By: Charles P. Egeland, Briana L. Pobiner, Stephen R. Merritt, & Suzanne Kunitz

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Abstract:
Carcass butchery is a culturally mediated behavior that reflects the technological, social, economic, and ecological factors that influence human diet and foodways. Butchery behavior can thus reveal a great deal about the lives of past peoples. Actualism provides a critical link between the dynamics of carcass butchery and the static remains of the archaeological record. This study provides an overview of actualistic butchery studies in zooarchaeology over the past century and a half. A systematic search through the English literature identified a total of 236 such studies published between 1860 and 2021. Thematic analysis revealed several trends. The most common themes have been the identification of signature criteria for different taphonomic effectors, the use of butchery traces to characterize the nature of human intervention with carcasses, and the documentation of butchery in an ethnoarchaeological context. Methodologically, the bulk of this research has focused on the butchery of large bovids with lithic implements, largely as a means to explore Paleolithic subsistence. Actualistic approaches will benefit from (1) additional work with non-bovid taxa and with other tool raw materials, (2) applications to broader anthropological issues, and (3) a concerted effort to replicate existing studies and design future studies with replication in mind.

Keywords: Zooarchaeology | Taphonomy | Butchery | Actualism | Experimental archaeology

Article:

1. Introduction

Over 150 years ago, paleontologist Édouard Lartet (1860: 471) reported "incisions" on the fossilized remains of mammals recovered from Pleistocene deposits in western Europe. Based on experiments with modern bones, he concluded that these marks could only have been produced on fresh carcasses by stone, rather than metal, implements. While Lartet's intention was to present evidence in support of humanity's deep antiquity, his work also, and perhaps inadvertently, ushered in an actualistic approach to the reconstruction of past butchery behavior that remains a key component of zooarchaeology to this day.[1] Actualism is the historical sciences' answer to that most fundamental of problems: the study of past events that, by definition, cannot be observed. As we use the term here, actualism involves (1) observations of modern processes in action, (2) the establishment of cause-and-effect relationships between those modern processes and their products and, finally, (3) the use of analogical reasoning to infer past

processes whose products share one or more non-trivial feature(s) with the modern product(s) (Binford, 1981, Brain, 1981, Gifford-Gonzalez, 1989, Gifford-Gonzalez, 1991, Lyman, 1994, Pobiner and Braun, 2005a). We need look no further than Lartet himself for an example of this approach in action. Rather than rely on the simple presence of the incisions as evidence for ancient stone tool butchery, he told the President of the Geological Society that "I have satisfied myself, by experiments on recent bones, that the action of a metallic saw would not produce the transversally striated plane of section which you must have observed on those ancient bones…but I have obtained *analogous results* by employing as a saw those flint knives, or splinters with a sharp chisel-edge, found in the sands of Abbeville" (ibid: 473; emphasis added). Marean (1995) usefully distinguished between experimental and naturalistic actualism. Experimental actualism directly controls the variables that influence the outcome, as in studies that purposely vary the raw material of butchery tools to identify differences in cut mark morphology between, say, metal and stone knives (Greenfield, 1999). Naturalistic actualism, on the other hand, observes processes and their outcomes but does not intentionally manipulate the variables. This includes ethnoarchaeological studies like that of Bunn et al. (1988), who documented the butchery and transport of large mammals by Hadza hunter-foragers.

Butchery, defined by Lyman (1987: 252) as "the human reduction and modification of an animal carcass into consumable parts," can reveal a great deal not only about past diets, but resource intensification (Jin and Mills, 2011, Lupo et al., 2013), carcass acquisition strategies (Bunn and Kroll, 1986), social dynamics and food sharing (Marshall, 1994, Stiner et al., 2009), animal symbolism and ritual (Klenck, 1995, Stolle, 2020, Seike and Watanabe, 2021), social transmission and cultural norms (Yellen, 1977, Blasco et al., 2013), technological change (Greenfield, 2000, Pierce et al., 2018, Delsol, 2020), and even handedness (Bromage and Boyde, 1984, Pickering and Hensley-Marschand, 2008). Building on Lartet's foundation, actualism has come to play an increasingly important role in reconstructing this important component of past human behavior. In this paper, we present a quantitative analysis of topical trends within experimental and ethnoarchaeological actualistic butchery studies over the past century and a half. In doing so, we highlight major themes and tie them to historical developments in the field. We close by identifying research gaps and outlining avenues for further research.

2. Methods

We started with a list of journals that, based on thematic content and/or the prior knowledge of one or more analysts, was most likely to contain relevant actualistic studies. This list included flagship journals such as *American Antiquity*, *Journal of Archaeological Science*, and *International Journal of Osteoarchaeology* and lesser-known publications such as *Bulletin of Experimental Archaeology*. The citation information and an electronic copy of those studies already known by the analysts to be in one of these journals were added to a Zotero library. A systematic search of the title, abstract, and keywords within each journal was then conducted with combinations and variations of the terms "experimental," "ethnoarchaeological," and "butchery." This initial search phase resulted in 144 potentially relevant studies. During the second search phase, the bibliographies of all 144 studies were scanned for additional potentially relevant studies published as books, book chapters, and journal articles. Dissertations or theses (e.g., Sadek-Kooros, 1966, Davis, 1985, Bartram, 1993, Nilssen, 2001, Abe, 2005) were not included because (1) as unpublished studies, they were historically less accessible and, thus, exerted only minimal influence on the trajectory of actualistic butchery research and/or (2) the data contained within them later appeared in a published venue that was captured by our search.

The Zotero library was updated as new studies were identified. Five iterations of this bibliography scan procedure exhausted all novel references. After the phase one and two searches, the Zotero library contained a total of 318 potentially relevant studies published through April of 2021.

Based on an examination of titles, abstracts, and keywords, and guided by Lyman's (2018) quantitative analysis of the neotaphonomic literature, we developed a preliminary list of "major research goals" by which to categorize the actualistic butchery studies. A single random sample of 20 studies was then drawn for each analyst to independently classify into one or more of these preliminary categories. We then assessed inter-observer error and refined the classification scheme. This process was repeated four times, which resulted in the final list of categories used to classify all the studies (Table 1). These categories represent the major goal(s) of a study rather than reports of incidental findings and are not mutually exclusive (that is, a study can fall into more than one category). At this stage, we decided to include in the analysis two types of studies that are not often considered "butchery" *sensu stricto*, namely those that involved (1) human tooth-marking during consumption (e.g., Lloveras et al., 2009) and (2) bone damage caused by hunting weaponry (e.g., Smith et al., 2007). Conversely, we eliminated those that involved (1) thermal alterations to bone during cooking or heating (e.g., Gilchrist and Mytum, 1986) (studies of bone breakage like pot-sizing or comminution associated with cooking and grease rendering were included), (2) anecdotal ethnographic descriptions of or interviews about butchery rather than systematic ethnoarchaeological analyses of faunal assemblages (e.g., Peale, 1871, Wilson, 1924, Leechman, 1951), (3) analyses of ethnohistorical faunal assemblages (e.g., Møbjerg and Robert-Lamblin, 1989, Enloe, 1993), (4) production of bone tools (e.g., Mateo-Lomba et al., 2020) (studies that used bone tools for butchery were included), (4) analysis of bone from human feces (e.g., Crandall and Stahl, 1995), (5) use wear on butchery tools (e.g., Hester et al., 1976, Alhaïque and Lemorini, 1996), and (6) research published in languages other than English (e.g., Henri-Martin, 1910, Chaix and Sidi Maamar, 1992, Laroulandie, 2001, Alcántara García et al., 2006).

Table 1. Categories of major research goals of actualistic behavior (note that categories and subcategories are not mutually exclusive).

Category	Subcategory	Description	Examples
1		Establish signature criteria for different human taphonomic effectors during butchery	
	1i	Distinguish tool type within the same raw material	Use cut mark morphology to distinguish lithic handaxe from lithic flake; use cut mark morphology to distinguish serrated knife from non-serrated knife; use percussion mark

			morphology to distinguish hammerstone from anvil stone
	1ii	Distinguish raw material type	Use cut mark morphology to distinguish stone tool from bamboo tool; use cut mark morphology to distinguish flint stone tool from quartzite stone tool; compare cut mark frequencies produced by obsidian stone tools with those produced by flint stone tools
	1iii	Distinguish tools with different physical properties	Compare cut mark frequencies produced by sharp stone tools with those produced by dull stone tools
	1iv	Develop signature criteria for human tooth marks	Examine tooth marks created by human consumption
	1v	Develop signature criteria for hunting weapon impact marks	Examine marks created by projectile weapons
	1vi	Evaluate effect of physical property (ies) of butchered substrate on butchery traces	Compare cut mark frequencies on carcasses of different body size or taxon; compare bone breakage between bones of different internal bone structure or bone thickness
2		Develop utility indices and/or return rates	Deflesh animal carcass and measure meat weights by bone or body portion; crack open bones and measure marrow weight by bone;

			measure the amount of marrow extracted per unit time
3		Evaluate the efficiency and/or utility of different human taphonomic effectors during butchery	Compare tool strokes between stone tools of different morphologies; compare the ease of butchering with different stone tool types; compare how much time it takes to butcher with different stone tool types
4		Identify butcher attributes from taphonomic traces	
	4i	Skill and/or experience of the butcher	Compare cut mark frequency between butchers of different experience levels; compare butchery time between butchers of different experience levels; document bone breakage patterns created by novice butchers; compare length of cut marks created by butchers of different experience levels; track efficiency of meat removal as butcher gains experience
	4ii	Physical attributes of the butcher (e.g., strength, biometric variation)	Document the amount of force required to produce a cut mark; explore the relationship between butchery efficiency and grip strength
	4iii	Number of butchers	Compare cut mark frequency on bones

			butchered by a single individual with that on bones butchered by more than one individual; compare cut mark orientation on bones butchered by a single individual with that on bones butchered by more than one individual
	4iv	Handedness of butcher	Use cut mark morphology to identify directionality; use cut mark orientation to identify directionality
5		Identify the presence and/or nature of human intervention through the frequency, anatomical location, and/or morphology of butchery traces	
	5i	Develop criteria to identify specific butchery activities	Use cut mark placement to distinguish defleshing from disarticulation; use fragmentation to identify grease rendering; compare bone breakage between different marrow extraction techniques
	5ii	Identify the state of the carcass (includes all studies that explore timing of access to carcasses)	Use cut mark placement to distinguish butchery of fleshed carcass from butchery of defleshed carcass; use bone breakage to distinguish fragmentation of heated bones from

			that of unheated bones; use cut mark morphology to distinguish butchery of fresh carcass from butchery of decomposed carcass
	5iii	Estimate processing intensity	Explore the relationship between tool strokes and cut mark frequency; explore the relationship between hammerstone blows and percussion mark frequency; explore the relationship between intensity of marrow extraction and bone fragmentation
	5iv	Identify human involvement with carcasses	Determine if human butchery results in diagnostic marks or breakage; compare morphology of cut marks or human bone breakage with the marks and bone breakage created by non-human processes; determine if human butchery and transport result in diagnostic patterns of skeletal element frequencies
6		Evaluate the effects pf post-depositional processes on butchery traces	Evaluate the effects of burial or sediment abrasion on the morphology of cut marks
7		Document butchery in an ethnoarchaeological context	Document carcass transport of contemporary people; document carcass

		sharing among contemporary people; document the butchery procedure among contemporary people
8	Non-systematic, exploratory study	Anecdotal descriptions of experimental butchery

A total of 236 actualistic butchery studies was included in the final analysis. Each pair of analysts (cpe-blp, cpe-srm, cpe-sk, blp-sk, sk-srm, blp-srm) was assigned a random set of these studies for independent classification into one or more of the final categories in Table 1. Across all six pairs of analysts, partial or full agreement on classification to category (e.g., Category 1) was achieved for 85.3 % of the studies. Partial or full agreement on classification to category and subcategory (e.g., Category 1, Subcategory 1i) was achieved for 78.4 % of the studies. Any unresolved discrepancies among pairs were discussed by all four analysts (for raw data, summary tables of analyst agreement, and citation information for the entire sample of studies, see the Supplemental Information). We also recorded several variables for each study, including the butchery activities performed, the raw material of the butchery tool(s), and the experience level of the butcher (Table 2). Many studies fell into more than one category and/or subcategory and analyzed several variables simultaneously, so the denominator used to calculate relative frequencies is the total number of times a category/subcategory or variable value appeared in the sample, which is often higher than the total number of studies. The only exception to this is the relative frequency of studies per decade, which is based on the total number of studies.

Table 2. Variables assigned to actualistic butchery studies

Variable	**Value**
Study type	
	Experimental
	Ethnoarchaeological
Butchery activity	Hunting
	Skinning
	Evisceration
	Defleshing
	Disarticulation
	Marrow extraction
	Grease extraction
	Cooking (includes boiling, roasting, etc.)
	Consumption
Zooarchaeological attribute	
	Cut marks
	Chop marks
	Percussion marks

	Skeletal part profiles
	Bone breakage (includes percussion notches)
	Projectile impact marks
	Tooth marks (human)
Raw material	
	Stone + (if specified) specific raw material (e.g., flint, obsidian)
	Metal + (if specified) specific raw material (e.g., steel, bronze)
	Bamboo
	Shell
	Bone
	Antler
	Coconut
Tool type	
	Flake (stone or bone only) + (if specified) retouched, unretouched, denticulate, microlith, point
	Core (stone only) + (if specified) chopper
	Biface (stone only)
	Handaxe (stone only)
	Hammerstone (stone only)
	Anvil (stone only)
	Projectile point
	Knife (metal only) + (if specified) serrated knife, non-serrated knife, butcher knife, meat cleaver, pocket knife
	Scalpel (metal only)
	Machete (metal only)
	Axe (metal only)
	Hatchet (metal only)
Time Period	
	Paleolithic + (if specified) Lower Paleolithic, Oldowan, Acheulean, Middle Paleolithic, Upper Paleolithic, Epipaleolithic
	Paleoindian + (if specified) Clovis, Folsom
	Mesolithic
	Neolithic
	Holocene + (if specified) Middle Holocene, Late Holocene
	Late Archaic
	Bronze Age
	Iron Age

	Late Prehistoric
	Protohistoric
	Historic + (if specified) Medieval
Animal species	Linnean binomen
Animal family	Taxonomic family
Animal type	
	Mammal
	Reptile
	Fish
	Bird
	Marsupial
Animal size (after Assefa, 2006; Brain, 1974; Bunn 1982)	
	Size Class 1A (<10 lbs)
	Size Class 1 (10—–50 lbs)
	Size Class 2 (50—–250 lbs)
	Size Class 3 (250—–750 lbs)
	Size Class 4 (750—–2000 lbs)
	Size Class 5 (2000—–6000 lbs)
	Size Class 6 (>6000 lbs)
Animal ontogenetic age	
	Adult
	Subadult (includes juveniles)
	Fetal
Butcher experience	
	Expert
	Novice
Carcass part (s)	
	Complete carcass
	Half carcass
	Limb segment
	Axial segment
Carcass condition	
	Fully fleshed
	Partially defleshed
	Frozen
	Fresh
	Thawed
	Desiccated

3. Results

3.1. Frequency over time

Lartet's (1860) seminal experiments represent the earliest actualistic butchery study that we identified in the English language literature. It is not until a century later that researchers again took an actualistic approach to butchery behavior (Fig. 1).[2] The number of studies rose gradually from the 1970s through the 1990s and reached a plateau in the 2000s. A torrent of actualistic butchery studies followed in the 2010s. The first year and four months of the 2020s saw the publication of 10 studies. At that pace of publication, a total of 75 actualistic butchery studies will appear in the 2020s.

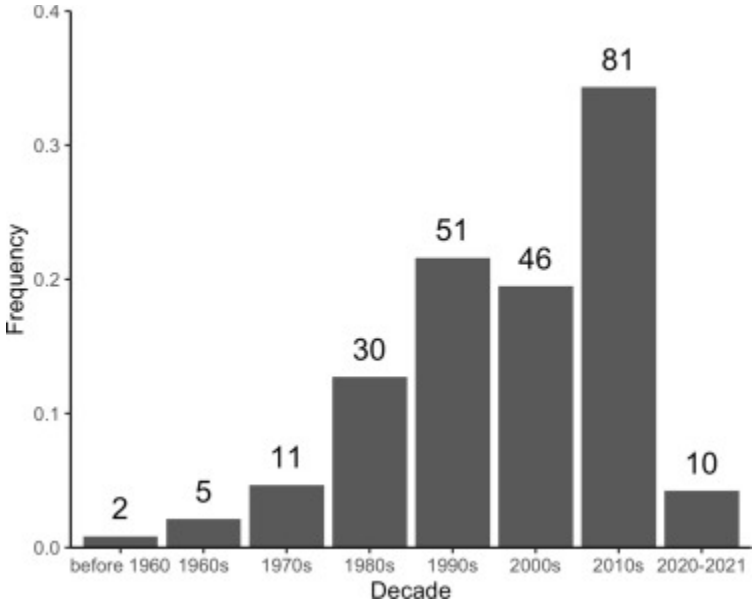

Fig. 1. Bar graph of the absolute and relative frequencies of actualistic butchery studies published ny decade. Note the denominator is the total number of studies (n=236).

3.2. Categories and subcategories

Fig. 2 shows that Category 1, an example being Spenneman's (1986) experiments to identify signature criteria for cut marks created by bamboo tools, and Category 5, which is exemplified by the use of the morphology and location of experimentally produced chop marks to reconstruct early medieval butchery practices (Wijngaarden-Baaker, 1987), are the most common categories. Category 7 appears in intermediate frequency and is represented by analyses of ethnoarchaeological faunal assemblages, including Binford's (1978) classic work among the Nunamiut of Alaska. The remaining categories are relatively rare and appear no more than 20 times.

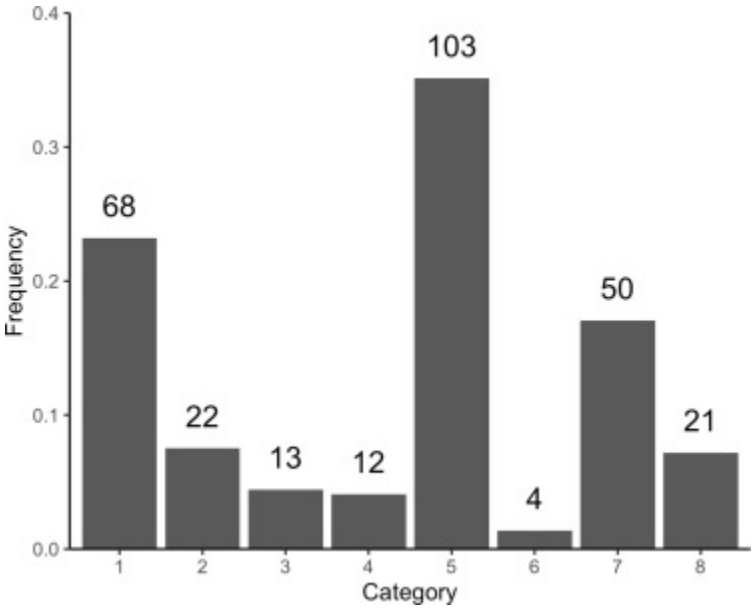

Fig. 2. Bar graph of the absolute and relative frequencies of categories of major research goals of actualistic butchery studies. Note the denominator is the total number of categories that appeared the sample (n=293).

Categories 1 (Fig. 3), 4 (Fig. 4), and 5 (Fig. 5) include several subcategories. Most Category 1 studies, which attempt to establish signature criteria for butchery implements, focus on distinctions between tool type (e.g., cut marks created by retouched and unretouched shell knives; Toth and Woods, 1989) or raw material (e.g., cut marks created by steel and lithic knives; Krasinski, 2018). The identification of butcher attributes (Category 4), while a rare research goal overall, tends to emphasize the skill/experience (e.g., Stavrova et al., 2019) and strength (e.g., Potter, 2005) of butchers. Category 5 studies seek to identify criteria that establish the presence and/or characterize the nature of human involvement with animal carcasses. A majority of these studies compared the marks (Eickhoff and Herrmann, 1985), breakage patterns (Sadek-Kooros, 1972), or skeletal part frequencies (O'Connell et al., 1988) produced by human butchery behavior with those of non-human agents such as carnivores. Many Category 5 studies also used actualistic butchery traces to distinguish specific activities, as Heinrich (2014) did by employing fracture patterns to identify grease extraction in the historic period, or to reveal something about the condition of the butchered carcass, as with Domínguez-Rodrigo's (1997) use of cut mark frequency and location to determine if early Pleistocene hominins accessed partially or fully fleshed carcasses. A handful of Category 5 studies looked at how butchery marks and bone breakage correlate with butchery effort (e.g., Lupo et al., 2013).

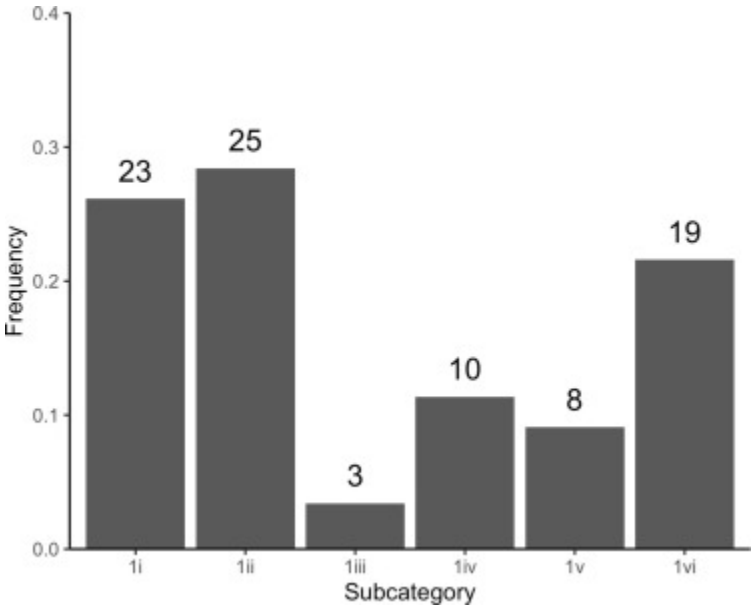

Fig. 3. Bar graph of the absolute and relative frequencies of subcategories within Category 1 of major research goals of actualistic butchery studies. Note the denominator is the total number of times that Category 1 appeared in the sample (n=88).

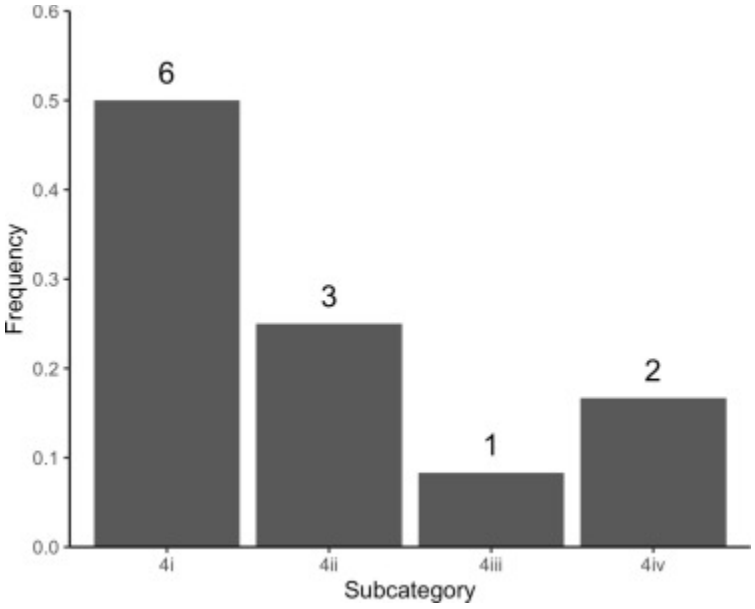

Fig. 4. Bar graph oof the absolute and relative frequencies of subcategories within Category 4 of major research goals of actualitsic butchery studies. Notes the denominator is the total number of times that Category 4 appeared in the sample (n=12).

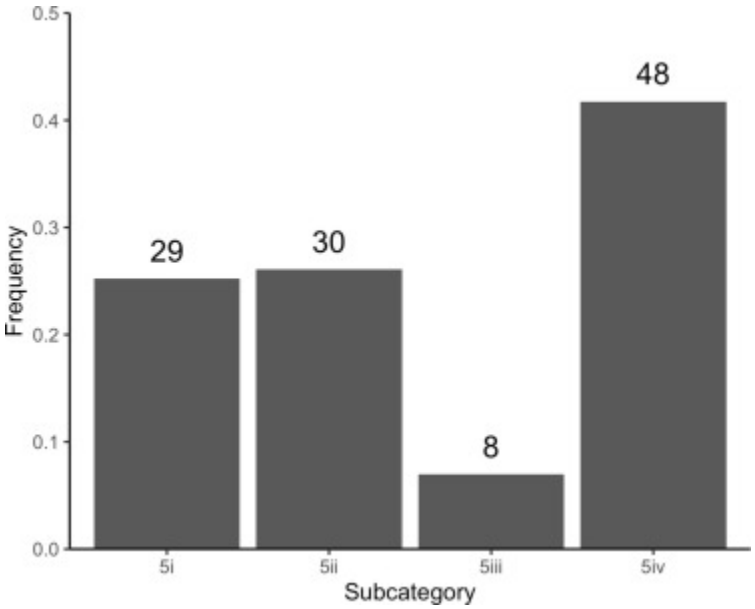

Fig. 5. Bar graph of the absolute and relative frequencies of subcategories within Category 5 of major research goals of actualistic butchery studies. Note the denominator is the total number of times that Category 5 appeared in the sample (n=115).

3.3. Temporal trends in categories and subcategories

The representation of categories and subcategories fluctuated over time (Fig. 6). Ethnoarchaeological studies (Category 7) are especially common in the 1960s and 1990s. While Category 5 studies were rare before the 1980s, they made up a significant and consistent component of actualistic research through the 2000s and became the most frequent category by the 2010s. Prior to the 2000s, Category 1 studies were uncommon or absent, but their frequency picked up considerably in the 2000s and 2010s. Category 2 studies (the development of utility indices and/or return rates) were prevalent in the 1990s but rare otherwise. Category 3 (evaluate the efficiency and/or utility of different butchery implements), 4, 6, and 8 (non-systematic, exploratory studies) were only sporadically represented.

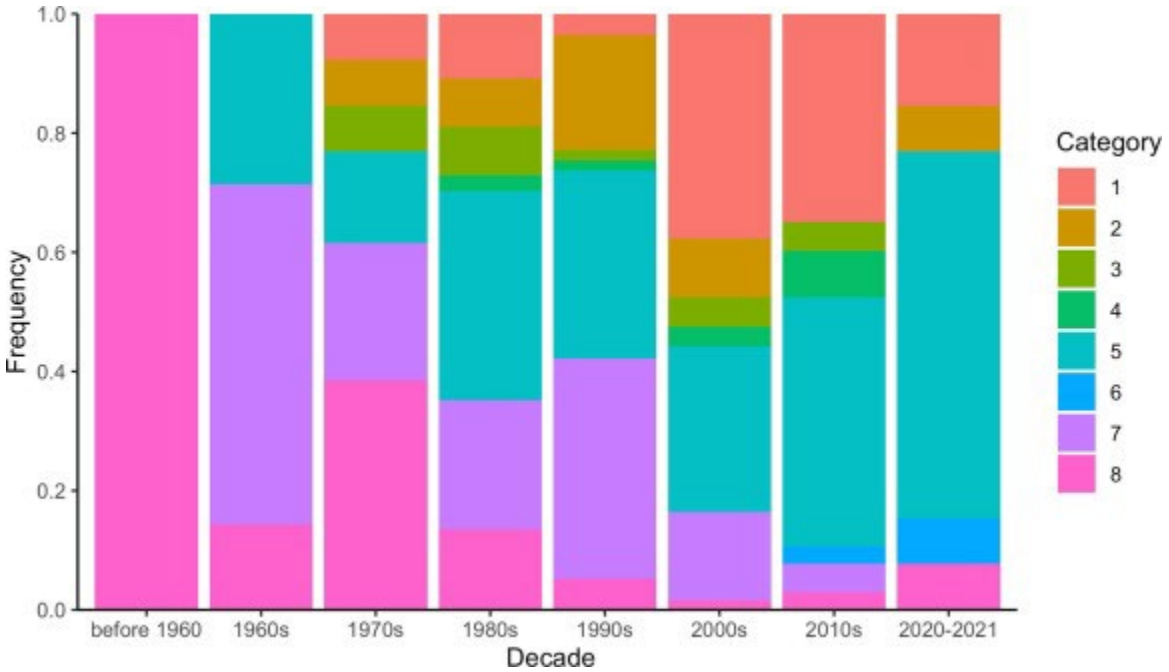

Fig. 6. Stacked bar graph of the relative frequencies of categories of major research goals of actualistic butchery studies by decade.

3.4. Study type and period of interest

A vast majority of the studies (n = 179, 75.8 %) used an experimental approach, while fewer (n = 50, 21.2 %) focused on ethnoarchaeology. However, a handful (n = 7, 3.0 %), like Fernández-Jalvo and Andrews's (2011) study of the morphology and frequency of human tooth marks, generated both experimental and ethnoarchaeological data. Applications of actualistic butchery to the Paleolithic dominate the literature (Fig. 7). In a distant second place is the Paleoindian period, while the Bronze Age and Historic period are tied for third place. The diversity of archaeological periods did expand over time, however, and reached a high of 11 in the 2000s (Fig. 8).

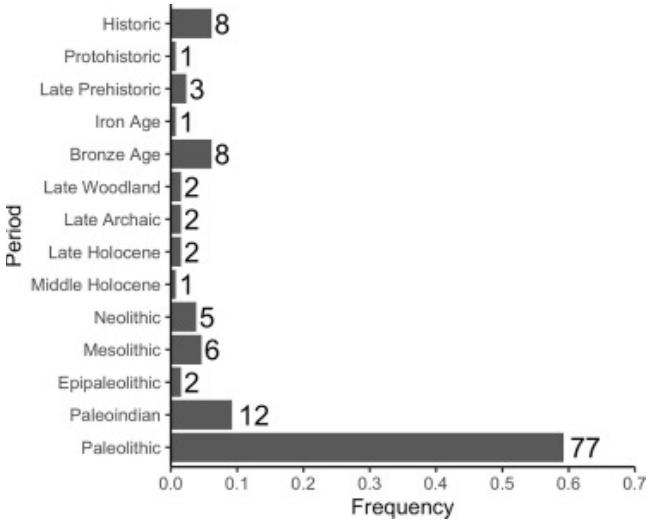

Fig. 7. Bar graph of the absolute and relative frequencies of the time periods to which actualistic butchery studies were applied. Note the denominator is the total number of times that a value for the variable "time period" appeared in the sample (n=130).

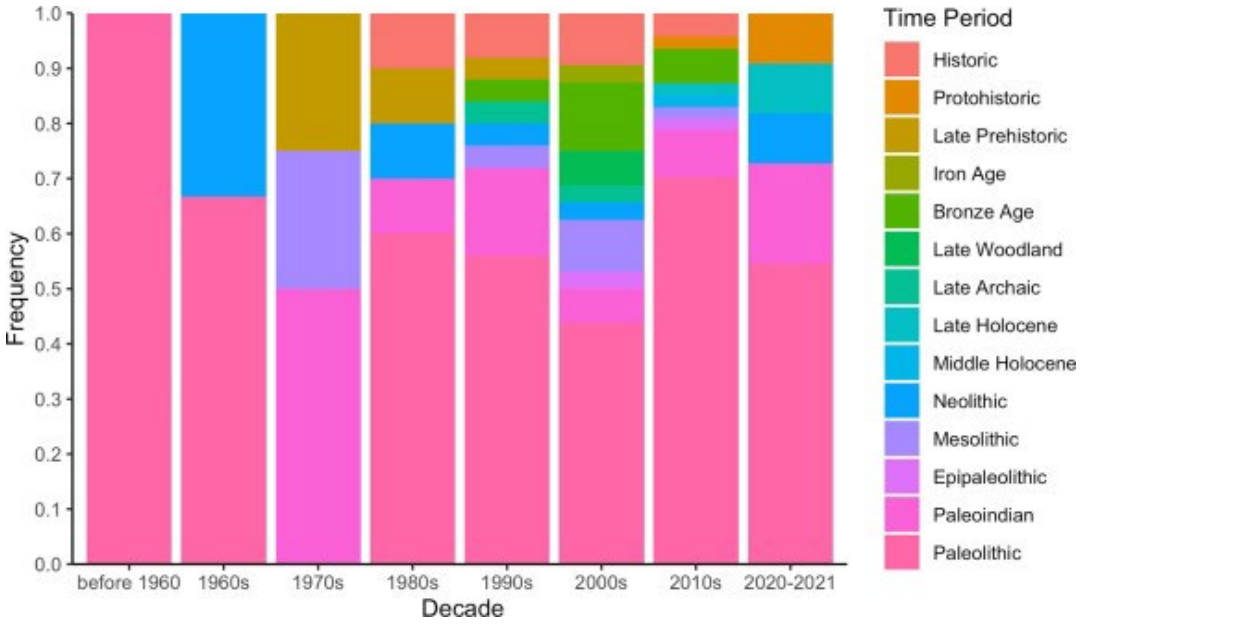

Fig. 8. Stacked bar graph of the relative frequencies of time periods to which actualistic butchery studies were applied by decade.

3.5. Raw material

Fig. 9 shows that nearly all studies included the use of either stone or metal implements for butchery. Bamboo (West and Louys, 2007), bone (Shipman and Rose, 1983), coconut (Choi and Driwantoro, 2007), shell (Buc et al., 2010), and antler (Letourneux and Pétillon, 2008) tools appeared in only a few studies.

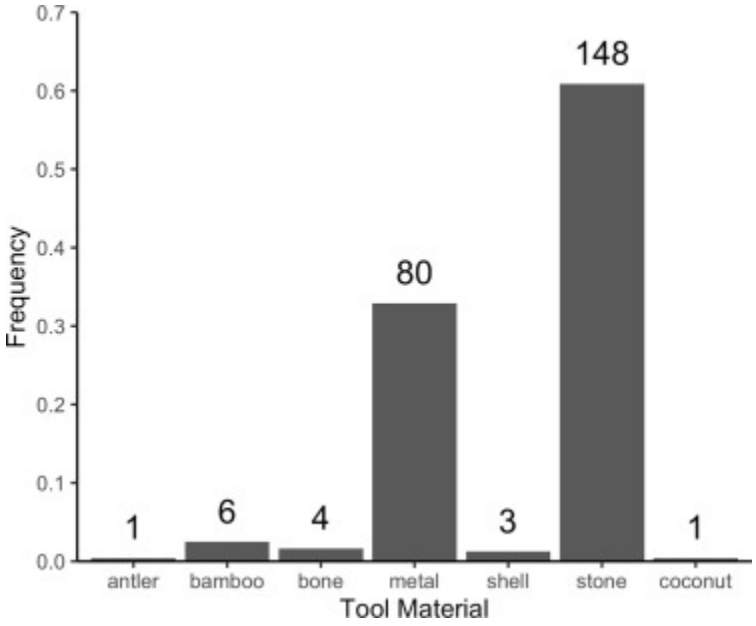

Fig. 9. Bar graph of the absolute and relative frequencies of tool raw material used in actualistic butchery studies. Note the denominator is the total number of times that a value for the variable "tool raw material" appeared in the sample (n=243).

3.6. Animal type

Mammals and, more specifically, bovids, were by far the most common subjects of actualistic butchery (Fig. 10).

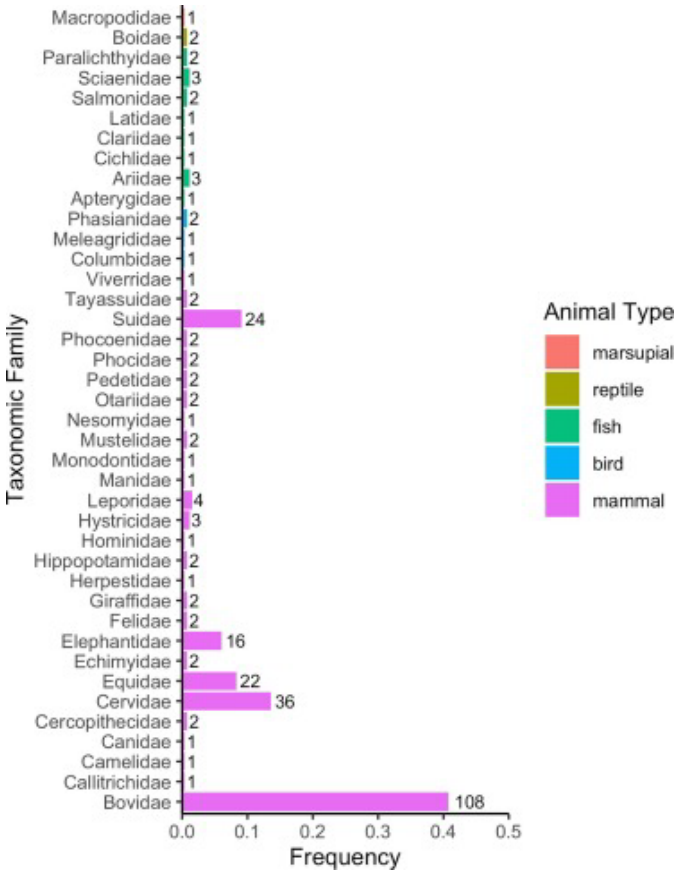

Fig. 10. Bar graph of the absolute and relative frequencies of taxonomic families used as subjects in actualistic butchery studies. Note the denominator is the total number of times that a value for the variable "taxonomic family" appeared in the sample (n=265).

3.7. Activities and butchery traces

Most studies involved carcass defleshing, but a wide variety of other butchery activities, including disarticulation, skinning, and marrow extraction, also commonly occurred (Fig. 11). It is perhaps unsurprising, then, that the most frequently recorded butchery traces were cut marks and bone breakage (Fig. 12).

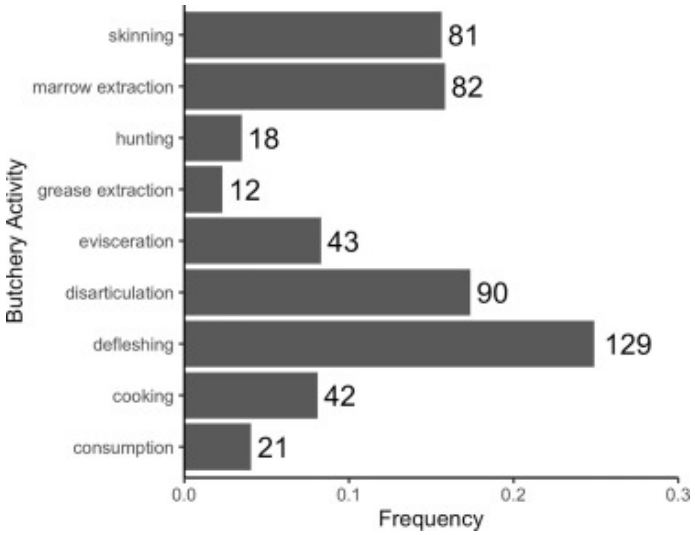

Fig. 11. Bar graph of the absolute and relative frequencies of butchery activities documented in the actualistic butchery studies. Note the denominator is the total number of times that a value for the variable "butchery activity" appeared in the sample (n=518).

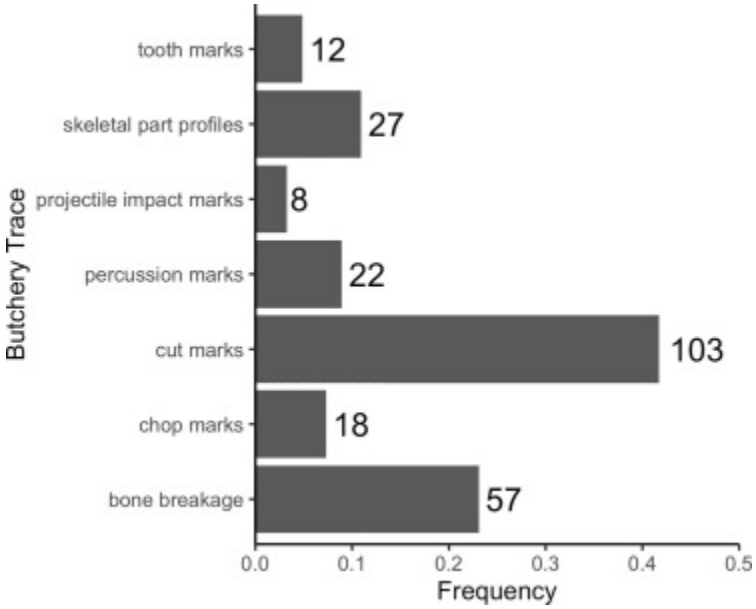

Fig. 12. Bar graph of the absolute and relative frequencies butchery traces documented in actualistic butchery studies. Note the denominator is the total number of times that a value for the variable "butchery trace" appeared in the sample (n=247).

4. Discussion

4.1. Where we've been

The broad thematic developments in actualistic butchery studies—a handful of anecdotes followed by a shift toward ethnographic work and, eventually, a surge in more tightly controlled experiments—echoes in many ways the growth of bone surface modification studies in archaeology more generally (James and Thompson, 2015). Lartet's anecdotal actualism was an important if not central piece of evidence for the great antiquity of humanity. Most mid-19th century European natural historians focused on the stratigraphic association of lithic implements

(mainly Acheulean handaxes) with the fossils of extinct fauna (Grayson, 1983, Van Riper, 1993, Sackett, 2000, Sackett, 2014, Gamble, 2021). However, Sackett (2000: 47) has argued that Lartet's butchery marks were "far more difficult to refute than simple geological association between human and animal remains," a point that convinced prominent scholars such as Charles Lyell (1863: 126) of humans' contemporaneity with extinct animals. While descriptions of indigenous butchery practices appeared in traveler's accounts (e.g., Tixier, 1844: 171), ethnographies (e.g., Densmore, 1918: 443–444), and archaeological reports (e.g., Morlot, 1861: 304) before and after Lartet's time, actualistic studies of butchered faunal remains did not resurface in the literature until the late 1950s and 1960s. They included Kitching's (described in Dart, 1959: 185–187) impromptu trials in bone breakage, Swauger and Wallace's (1964) informal experiments in carcass skinning using Paleolithic and Neolithic stone tools, and the ethnoarchaeological work of Gould (1967) among the indigenous peoples of western Australia and Zierhut (1967) among the Cree of north-central Canada. Perhaps the most well-known was C.K. Brain, 1967, Brain, 1969 analysis of the bone refuse of Khoi pastoralists in Namibia. The catalyst for this work was Raymond Dart, who famously—and colorfully—asserted in 'The Predatory Transition from Ape to Man' (1953) that the fossil bone assemblages from Makapansgat, Taung, and other South African caves, deposited as they were without associated stone tools, represented the implements and food remains of carnivorous (some might say murderous) australopithecines. Brain showed that human butchery and carnivore scavenging produced redundant patterns of bone survivorship that could be predicted by the inherent properties of the bones themselves. This in turn suggested that bone representation in the South African caves likely did not result, as Dart originally claimed, from the bone collecting and modifying proclivities of hominins but, rather, from on-site destructive processes.

The butchery-focused ethnoarchaeology of Gould, Zierhut, and especially Brain coincided with a broader shift within archaeology away from descriptive culture history and toward hypothesis-driven explanatory frameworks (Willey and Sabloff, 1993, Trigger, 2006). More important, however, was the growing appreciation among faunal analysts for the relevance of animal remains to reconstructions of human behavior (Robison, 1987, Lyman, 2016). The importance of ethnoarchaeology to this transformation was fully established by the 1970s and was exemplified by the work of Crader, 1974, Gifford, 1980, Yellen, 1977, and Binford (1978). The latter two were especially relevant because they focused on butchery behavior with the explicit intent to use the resulting bone refuse to explain variability in ancient faunal assemblages. A series of pioneering experimental studies appeared at this time as well. Kitching's one-off trials aside, Sadek-Kooros (1972) and Bonnichsen (1973) were the first to use actualistic data to distinguish human from non-human bone breakage, while Walker and Long (1977) published the first attempt since Lartet's observations to use cut mark morphology to identify the type and raw material of butchery tools. Of note, too, were Frison's (1978; Frison and Reher, 1973) experiments in bison butchery, which influenced many reconstructions of prehistoric subsistence on the Great Plains of North America.

The publication in 1981 of two landmark volumes, *The Hunters or the Hunted?* by C.K. Brain and *Bones* by Lewis Binford, heralded a new phase in the development of actualistic butchery studies. Grounded firmly in an actualistic framework, both books, while not unprecedented (e.g., Behrensmeyer, 1975, Behrensmeyer and Hill, 1980, Shipman, 1981), were instrumental in establishing taphonomy as an essential component of zooarchaeology. They also raised serious questions about then-conventional interpretations of ancient butchery behavior.

The title of Brain's book cleverly encapsulated his conclusions about South African australopithecines, while the subtitle of Binford's book, *Ancient Men and Modern Myths*, reflected his skepticism regarding, among other things, the socio-economic analogies that were being drawn between Early Pleistocene archaeological sites from Africa and the settlements of contemporary hunter-foragers. These two contributions challenged researchers to use actualism to rigorously test hypotheses about ancient butchery behavior. The response to this challenge, whether explicit or incidental, was swift, and over the next two decades actualistic butchery studies appeared in many publications, including the highly influential symposia volumes *Animals and Archaeology* (Clutton-Brock and Grigson, 1983), *Bone Modification* (Bonnichsen and Sorg, 1989), and *From Bones to Behavior* (Hudson, 1993).

Four foci emerged among this flurry of research in the 1980s and 1990s. The first involved skeletal element representation and the search for distinctively human patterns of carcass handling, distribution, and especially transport. Much of this work was ethnoarchaeological in nature, the largest sample of which derived from observations among the Hadza of Tanzania (Monahan, 1998). Closely aligned with this was a second focus, namely the development of economic utility indices. Lyon, 1937, White, 1952, White, 1953, White, 1954, White, 1955, and Perkins and Daly (1968) had argued that butchery decisions were influenced by the distribution of meat and other useable tissues on a carcass. Binford (1978: 15) used actualistic butchery of caribou and sheep to quantify the "economic anatomy" of a carcass, and the 1990s in particular saw the derivation of similar indices for a variety of other species, from harp seals (Lyman et al., 1992) and horse (Outram and Rowley-Conwy, 1998) to guanaco (Borrero, 1990) and bison (Brink, 1997). The third and fourth foci emphasized, respectively, butchery marks and bone breakage. A handful of studies sought to establish morphological criteria that could differentiate marks produced by different types and/or raw materials of butchery tools (Spenneman, 1986, Toth and Woods, 1989), but the majority focused on distinguishing the marks and breakage characteristic of butchery from those produced by non-human agents (Bonnichsen and Will, 1980, Potts and Shipman, 1981, Stanford et al., 1981, Bunn, 1983). Faunal analysts also began to collect data on the frequency and anatomical location of butchery marks in experimental and ethnoarchaeological contexts to test specific hypotheses about ancient butchery procedures (Wijngaarden-Baaker, 1987) or the condition of a butchered carcass (Blumenschine, 1988, Lupo, 1994, Selvaggio, 1994).

A good deal of the actualistic butchery work conducted at this time was couched within the ongoing debate about the carcass acquisition strategies of early hominins. The dense accumulations of Early Pleistocene-aged animal fossils and stone tools discovered at Olduvai Gorge (Tanzania), Koobi Fora (Kenya), and elsewhere in East Africa were initially interpreted as the remnants of camps where hominins repeatedly converged to perform subsistence and social activities (Isaac, 1969, Isaac, 1978, Leakey, 1971). Many components of this "home base" model, including a sexual division of labor and the transport, delayed consumption, and sharing of carcass parts, were predicated on hominins accessing and butchering substantial quantities of meat and other edible tissues. Based in part on patterns of bone representation and cut mark morphology and placement, Binford, 1981, Binford, 1988 came to nearly the opposite conclusion: the fossil assemblages were the remains of desiccated carcasses quickly picked-over by hominin scavengers for abandoned flesh scraps and marrow. This challenge to the home base model ignited what later came to be known as the "hunting-versus-scavenging debate" (Domínguez-Rodrigo, 2002, Domínguez-Rodrigo and Pickering, 2003, Pobiner, 2020). Two important issues were at stake, and attempts to resolve them largely explain the increased

frequency of Category 5 studies in the 1980s and 1990s and Category 7 studies in the 1990s (Fig. 6). The first was whether hominins were involved at all in the accumulation of the bones at these sites. Many of the marks and breakage patterns observed on the fossils resembled those seen on actualistically butchered bones, which confirmed that hominins did in fact butcher at least some carcasses (Bunn et al., 1980, Bunn, 1981, Potts and Shipman, 1981, Blumenschine and Selvaggio, 1988). The second, and, it turned out, much more controversial, issue was the timing of hominin access to carcasses. Did hominins acquire and butcher fully fleshed carcasses, a behavior that implied at least kleptoparasitism if not hunting, or did they passively scavenge the scraps left behind by dominant carnivore competitors? Actualistic studies of skeletal element representation and economic utility were used to determine if hominins accessed and transported the choice portions of carcasses, as might be expected under an early access scenario, or if they were limited to the low-yield parts that would have been left behind for passive scavengers (Bunn et al., 1988, Blumenschine, 1991, Blumenschine and Madrigal, 1993, Lupo, 1998). The frequency and anatomical location of actualistic butchery marks were also used to establish the order of hominin access to carcasses (Selvaggio, 1994, Capaldo, 1997, Domínguez-Rodrigo, 1997).

The proving ground for most of these data was Level 22 of the FLK locality (FLK 22, aka the "*Zinjanthropus* Floor") at Olduvai Gorge. It was here that Mary Leakey (1971) and her team had excavated what was then the largest, most well-preserved, and most well-dated Early Pleistocene zooarchaeological assemblage in the world. The application of actualistic butchery data to the FLK 22 collection resulted in divergent interpretations of hominin carcass foraging behavior. While some detected evidence for passive scavenging of felid kills (Blumenschine, 1995), others argued for confrontational scavenging or hunting (Domínguez-Rodrigo, 1999). A consensus remained elusive throughout the 1990s, but the development of actualistic butchery studies within the context of the hunting-versus-scavenging debate nevertheless produced significant methodological advancements in zooarchaeology. Actualistic data showed, for instance, that butchery mark location may help reveal the timing of hominin access to carcasses (Domínguez-Rodrigo, 1997). This required highly precise locational data—down even to the specific section and aspect of a long bone—and encouraged the development of digital and, later, digital 3D approaches to the recording of butchery trace location (Abe et al., 2002, Mora et al., 2022).[3]

Another discussion that galvanized actualistic butchery research in the 1980s and 1990s was the nature of Paleolithic humans' interactions with extinct proboscideans. Investigators conducted experiments and collected ethnoarchaeological data to evaluate if and how Paleolithic peoples hunted and butchered these enormous animals (Stanford et al., 1981, Crader, 1983, Frison, 1986, Frison, 1989, Haynes, 1987, Haynes, 1991, Fisher, 1992, Laub, 1992). This work was particularly relevant to broader debates about the peopling of the Americas, as the presence and frequency of proboscidean butchery sites were used to evaluate the timing of human entry into the Americas (Dincauze, 1984, Morlan, 1988) and humans' role in the extinction of megafauna (Fisher, 1984, Grayson, 1984).

The proliferation of Category 1 studies beginning in the 2000s reflected a growing interest among zooarchaeologists in variation between and within types of butchery traces. Morphological differences in actualistic cut marks, for example, were used to distinguish lithic from non-lithic butchery implements (Chase, 2005, West and Louys, 2007), lithic raw material types (Greenfield, 2006, Maté-González et al., 2018), and varieties of lithic tools (de Juana et al., 2010, Boschin and Crezzini, 2012, Val et al., 2017). These data allowed zooarchaeologists to

explore how ancient peoples adopted and employed technology, including the origins and spread of metallurgy (Greenfield, 2000), lithic raw material selection and curation (Courtenay et al., 2019), and the function of specific artifacts such as handaxes (Yravedra et al., 2010). Researchers also began to examine how butchery traces were affected by the physical properties of bone, as size, taxon, and internal structure were all identified as factors conditioning the frequency and morphology of butchery marks (Pobiner and Braun, 2005b, de Juana and Domínguez-Rodrigo, 2011, Archer and Braun, 2013). Additional sources of variation were investigated through analyses of bone damage from hunting weaponry (Duches et al., 2016) and human chewing (Landt, 2007). Interest in the personal attributes of ancient butchers was signaled by the emergence, albeit in small numbers, of Category 4 studies in the 2000s and 2010s. There was an emphasis on the role of skill and experience in the butchery process (Willis and Boehm, 2015, Pobiner et al., 2018, Merritt and Peters, 2019), although other attributes like strength (Key and Lycett, 2018) and handedness (Pickering and Hensley-Marschand, 2008) were explored as well.

The carcass acquisition strategies of early hominins continued to be an important motivation for Category 5 studies in the 2000s and 2010s, although the focus of study design and application expanded to sites other than FLK 22 (Lupo and O'Connell, 2002, Merritt, 2017, Merritt and Davis, 2017, Pobiner et al., 2018). Closely related to this was the rapid growth starting in the 2010s in applications of 3D technologies and Bayesian and machine learning statistical approaches to the morphological description and classification of actualistic butchery traces (Pante et al., 2017, Krasinski, 2018, Otárola-Castillo et al., 2018, Moclán et al., 2019). Building on the work of Binford (1981), researchers also turned to actualism to help identify and isolate specific phases of the butchery process. It was found, for example, that patterns of bone breakage and detailed morphometric analysis of butchery mark placement and morphology could distinguish tasks such as skinning, defleshing, disarticulation, and grease rendering (Fairnell, 2008, Val and Mallye, 2011, Galán López and Domínguez-Rodrigo, 2013, Heinrich, 2014, Merritt, 2017, Morin and Soulier, 2017, Soulier and Costamagno, 2017). While rare overall, a handful of studies at this time also tested the validity of zooarchaeological proxies of butchery intensity. Faunal analysts had long assumed (and reasonably so) that the frequency of butchery marks or the degree of bone fragmentation reflected in some way the amount of time or effort that people invested in butchery. These proxies could thus be used to trace resource intensification, subsistence stress, or differential investment in specific taxa or particular butchery tasks (Guilday et al., 1962, Parmalee, 1965, Binford, 1988, Marshall and Pilgram, 1991, Potter, 1995, Outram, 1999). Actualistic tests of these hypotheses were mixed. No relationship was found between the frequency of butchery marks and butchery effort (Egeland, 2003, Pickering and Egeland, 2006, Pobiner et al., 2018), which confirmed earlier suspicions of the fortuitous, epiphenomenal nature of some butchery marks (Lyman, 1995). Ethnoarchaeological data showed that a relationship between butchery mark frequency, bone fragmentation, and resource intensification exists, but it is complex and sometimes indirect (Lupo et al., 2013).

4.2. Where we are now, and where we want to go

Perhaps the clearest pattern to emerge from this analysis is the uneven representation of research foci. This is especially evident for time period (the Paleolithic), tool raw material (stone), animal type (mammals, especially large bovids), and butchery trace (cut marks). The common element seems to be researchers' interest in the subsistence of Paleolithic peoples. Subsistence strategies are a critical component of any cultural system, and stone was, of course,

the material of choice for many subsistence tasks in the Paleolithic. The bones of large mammals are among the most conspicuous types of refuse at Paleolithic sites, and cut marks provide the most direct evidence for consumption. In terms of specific research goals, most actualistic butchery studies have focused on signature criteria for taphonomic effectors and the presence and/or nature of human intervention with carcasses. This is also probably associated with a focus on the Paleolithic. Researchers recognized, especially after Brain and Binford threw down the taphonomic gauntlet, that clear and consistent cause-and-effect linkages were required before anything could be said about the subsistence behavior of hominins—many of whom were not *Homo sapiens*—from a remote period practicing a lifestyle not replicated by any living humans. What we might call actualistic butchery's "Paleo-centrism" stemmed in part from the recognition that answers to seemingly prosaic questions about carcass access or the features that distinguish carnivore tooth marks from stone cut marks, while certainly important in their own right, were also essential to broader discussions about human behavioral evolution such as humans' ascendance to apex predator status and the emergence of human forms of social organization (Leakey, 1971, Isaac, 1978, Binford, 1981, Potts, 1988, Blumenschine, 1991, Oliver, 1994, Rose and Marshall, 1996, O'Connell et al., 2002, Stiner et al., 2009, Domínguez-Rodrigo and Cobo-Sánchez, 2017).

This leads us to consider several major avenues for future research. Actualism offers an indispensable tool for reconstructing the butchery and subsistence practices of past peoples. Having said that, it is especially important to address the gaps laid bare by this analysis: more work is needed with small mammals and non-mammals, with raw materials other than stone, and with a mind toward applications to a wider range of time periods. While some cause-and-effect relationships established for the butchery of large mammals with stone tools no doubt apply to other taxa and other raw materials, there are others that probably do not. Diversifying the foci of actualistic butchery is therefore required to (1) determine the generalizability of the cause-and-effect relationships identified thus far and, at the same time, (2) identify those observations that are contingent on factors such as those summarized in Table 2. We also think that actualistic data have much to say about issues that extend beyond butchery and subsistence. Prominent examples include the aforementioned explorations of Paleolithic hominin sociality and Greenfield's (2000) use of actualistic butchery to track the spread of metallurgy in the Neolithic and Early Bronze Age of Europe. Pierce et al., (2018: 13) in fact drew on the latter to examine the adoption of metal tools by Protohistoric groups of the Great Plains and, in doing so, concluded that "bone modification analysis can be used…to enter into larger discussions about how and where technologies spread and how new technologies and items are incorporated into existing indigenous cultural systems." We therefore believe that applications of actualistic butchery data to matters of general archaeological and anthropological significance are rife with opportunities.

Take, for instance, the fundamental but often fraught role of analogy in archaeological inference (Wylie, 2002). Actualistic butchery—built as it is on analogical reasoning—provides fertile ground for debates about the construction and application of analogy in the historical sciences (Seetah, 2008, Domínguez-Rodrigo, 2012). As another example, consider that tool-assisted butchery involves a good deal of practical know-how: only experienced, highly skilled individuals can rapidly and with minimal or no error reduce a carcass into useful (however that is defined) portions. Such mastery requires thousands of repetitions within a narrow domain of knowledge and practice and, like experts in other technical tasks, expert butchers can rapidly assess problems, respond to changing conditions, and perform through distractions (for examples among subsistence butchers, see O'Connell et al., 1988, Yellen, 1991, Abe, 2005; for an example

among artisanal butchers, see Ocejo, 2017: 122–126). Butchery therefore shares many features of what cognitive anthropologists call "expert technical cognition" (e.g., Wynn and Coolidge, 2014) and "embodied cognition" (e.g., Marchand, 2010). As with other crafts, butchery is also learned within a social context via informal and formal (guilds, apprenticeships) mechanisms. Butchery therefore has much to contribute to wider issues of human cognition, learning, and craft specialization, and it is actualism that can provide the cause-and-effect observations required to identify the zooarchaeological correlates of butchers' embodied knowledge (Seetah, 2019). Studies that explore the effects of experience, learning curves, and social traditions are a step in this direction (Yellen, 1977, Mooketsi, 2001, Padilla Cano, 2008, Blasco et al., 2013, Willis and Boehm, 2015, Pobiner et al., 2018).

The last issue we touch on involves study replication. We acknowledge that this is easier said than done given the immense number of variables potentially at play during even a single phase of carcass butchery. We also agree with Porter (2016: 457-458), who has argued that researchers "rarely regard [replication] as worthwhile…[t]hey will get little credit if they succeed, and may have their competence or their objectivity called into question if their results diverge from the original study." What is more, grant agencies' preference for novelty (real or perceived) makes funding for "mere" replicative studies difficult to come by. Nevertheless, replication is critical for progress in actualistic butchery studies specifically and an essential component of standard scientific praxis more generally. It should come as no surprise, then, that we advocate for replication of every actualistic study. While still rare in the actualistic butchery literature, blind tests, assessments of inter-observer error, and other attempts at follow-up studies nonetheless signal a recognition of the importance of replication (Blumenschine et al., 1996, Archer and Braun, 2013, Domínguez-Rodrigo et al., 2017). Just as crucial is the need to design actualistic studies that *enable replication in the first place* (Merritt et al., 2019). This is not a new recommendation (e.g., Lubinski and Shaffer, 2010: 249), but it bears repeating: replication requires crystal clear methodologies and a catalog of as many variables as possible—even those that are not necessarily relevant to the hypotheses being tested. At a minimum, we recommend that every actualistic butchery study include information on the variables in Table 2. It is also vital, especially for ethnoarchaeological studies where variables cannot be intentionally manipulated, to describe the behavioral, ecological, and social context of butchery. This study design protocol not only facilitates replication but allows other researchers to (1) evaluate the impact of confounding and/or lurking variables, (2) assess a study's realism, generality, and precision (sensu Capaldo, 1998), (3) determine the reproducibility of a study's findings, and (4) avoid sequestration in expert knowledge traditions that stifle collaboration and hinder discipline-wide acceptance of terminology and methodology (for examples in the analysis of bone surface modifications specifically, see James and Thompson, 2015).

5. Conclusions

Over a century and a half's worth of actualistic butchery studies has offered critical insights into the subsistence practices of past peoples. The first published study was spurred by the scientific pursuit for humanity's lost Stone Age past. Since then, questions engendered by the Paleolithic—especially the carcass acquisition strategies of early Pleistocene hominins—have factored heavily, but by no means exclusively, in the approach's thematic and methodological trajectory. One notable consequence of this "Paleo-centrism" is a literature dominated by studies involving the stone or metal tool-assisted butchery of large bovids by, or to reconstruct the lives of, hunter-foragers. Nevertheless, a wide variety of other issues have been explored through actualistic butchery, and zooarchaeologists would do well to continue this diversification in

research foci. An actualistic approach to butchery also promises to make significant contributions to issues that extend far beyond diet and subsistence. A few examples include the nature of analogical inference in the historical sciences, the evolution of sociality and humans' ascendance to apex predator status, the adoption and spread of technology, the nature of embodied cognition, and the process of craft specialization. As the number of actualistic butchery studies continues to grow, it is important to pay more than lip service to replication—and, just as critically, to design studies that facilitate replication.

CRediT authorship contribution statement

Charles P. Egeland: Conceptualization, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. Briana L. Pobiner: Conceptualization, Investigation, Writing – original draft, Writing – review & editing. Stephen R. Merritt: Investigation, Writing – review & editing. Suzanne Kunitz: Investigation, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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