Report of Animal Bones from Tjarnargata 3C, Reykjavík, Iceland

Dr. Sophia Perdikaris
Colin Amundsen
Dr. Thomas H. McGovern

CUNY Northern Science and Education Center

NORSEC

CUNY Doctoral Program in Anthropology
Brooklyn College Zooarchaeology Laboratory
Hunter College Bioarchaeology Laboratory

March 26th , 2002
Contact: SophiaP@brooklyn.cuny.edu
A product of the North Atlantic Biocultural Organization (NABO) Research Cooperative.

EXECUTIVE SUMMARY

During rescue excavations in downtown Reykjavík in 1999 nearly 100 kg of well-preserved animal bone was recovered in investigations at Tjarnargata 3 C by Fornleifastofnun Islands (FSÍ) directed by Mjöll Snaesdóttir. This bone collection (or archaeofauna) was largely sieved (4 mm and 1 mm mesh wet screen) and represents one of the largest archaeofauna recovered from Iceland to date. Analysis was carried out at City University of New York's Northern Science & Education Center's two zooarchaeology laboratories at Brooklyn College and Hunter College in 2000-01. The analyzed bone materials were returned for long term curation at the National Museum of Iceland in January 2002.

The Tjarnargata 3C collections derive from a widespread sheet midden deposit that post-dates an AD 1500 tephra, and probably represents refuse discarded by multiple households and local shops and factories. While the collection cannot be closely dated, the great majority of the bone collection probably derives from the 18th and early 19th centuries- a period of rapid urbanization of central Reykjavik. This collection thus differs from virtually all other previously studied Icelandic bone materials that derive from single farms and from the activities of one or two household units, and some of these differences are apparent in the condition of the recovered bone. The collection shows some distinctive urban characteristics, with clear indication of local butchery being significantly supplemented by meat-rich joints presumably imported from nearby farms provisioning the growing city. The remains of some preserved hams almost certainly indicate trans-Atlantic shipment, and serve to illustrate the expanded dietary range of the urbanizing population. Other bone remains illustrate another side of early modern city life: rodent gnawed bones, remains of stray dogs, scavenging gulls and fulmars, and other elements of an unwanted commensual "urban fauna". The collections also reflect the source of early Reykjavik's prosperity, and are dominated by fish bones. These are nearly all cod, and the ratio of the skeletal elements present and the reconstructed live length strongly suggest intensive preserved fish preparation (probably for stockfish) was a major activity in the locality.

This well preserved and carefully excavated archaeofauna thus sheds light on an important period in the development of modern Reykjavik, and represents a unique urban collection for Iceland. We recommend that any additional excavations in the town center area attempt to recover more bone material, especially from closely datable contexts.

Table of Contents

Executive summary	1
Introduction	4
Laboratory methods	4
Overview of Species Present	5
Quantification	10
Bone Preservation & Taphonomy	11
Mammal Element Frequency	15
Fish Element Frequency	20
Fish Length Reconstruction	22
The Archaeofauna in Context	23
Recommendations	24
Acknowledgements	25
References	25
Appendix	
Digital Archive (CD)	

Introduction- data and methods

After an initial analysis in mid-1998, the site of Tjarnargata 3C in downtown Reykjavik was excavated in the summer of 1999 by Fornleifastofnun Íslands. The open-area excavation sampled c.100kg of bones from an area c. 8m x 12m. The total sample was taken from a 40-60cm-thick layer of mixed peat, turf, ash and bone debris (context 9, ca 45 cu meters). The layer immediately below context 9 has been identified as volcanic tephra from Katla's eruption in AD 1500, giving the context for this collection a *terminus post quem* of early 16th century. Turf debris within context 9 also includes the 1500 tephra to further support this relative date. This context also includes 17th ,18th , & 19th century ceramic shards. The deposit as a whole is early modern in date (with most of the bone deriving from the 18th and early 19th c) and probably represents a gradual accumulation rather than a single dumping event. The Tjarnargata 3C deposit is not directly associated with structures, although it is possible that the source of the midden was located near the 1999 excavation. Overall preservation was excellent and the 100kg taken represents only about 10-15% of the total assemblage (Snæsdóttir 1999). Most of the material was wet-sieved through 4 mm mesh with an approximate 10% sample being wet sieved through 1 mm mesh as recovery check. No significant differences were found in identified fragment size or species diversity between the 4 mm and 1 mm sieved samples, though the 1 mm mesh did generate more unidentifiable fragments in the > 1 cm range. As there was no stratigraphic basis for sub-division, the archaeofauna was analyzed as a unit.

Laboratory Methods: Analysis was carried out primarily at Brooklyn College's Zooarchaeology Laboratory (Dr. Sophia Perdikaris director) with assistance from the Hunter College Bioarchaeology Laboratory for bird identifications. While students helped in initial sorting, all final identifications and data entry was carried out by Dr. Perdikaris, advanced CUNY doctoral candidate Colin Amundsen, or Dr. Thomas McGovern (director of Hunter Bioarchaeology Lab). Extensive use was made of the major comparative collections of N Atlantic fish and birds housed at the CUNY laboratories, with some assistance from the collections of the American Museum of Natural History (for which the authors are very grateful). All fragments were sorted by family (mammal, fish, mollusca, bird) and all fragments were identified as fully as possible with current methods (no sub-sampling or restricted-element-range approaches were employed). All measurements follow the metrical standard of Von Den Dreisch (1976) unless otherwise noted, measurements taken with digital calipers to the mm. Basic data was recorded through the NABO Zooarchaeology working group NABONE system (7th edition, see NABO website www.geo.ed.ac.uk/nabo for updates and sample data sets) which combines Access database with specialized Excel Spreadsheets. A full data archive with coding manual is in the CD R attached to this report, and is also available via nabo@voicenet.com. The NABONE package allows application of multiple measures of abundance, taphonomic indicators, and skeletal element distribution (see Appendix and all text figures) and is the

current standard record for Icelandic archaeofauna. Blank NABONE templates are included in the digital archive for the convenience of other workers. NABONE is freeware and should be cited as " North Atlantic Biocultural Organization Zooarchaeology Working Group (2002) *NABONE Zooarchaeological Recording Package 7th edition*, CUNY, NY."

Overview of Species Present

Table 1 provides an overview of species present in the Tjarnargata 3C archaeofauna, while tables 3, 4, 5 and 6 provide fuller taxonomic breakdown of mammals, birds, fish and mollusca respectively.

Table 1 Summary Overview

Taxon		NISP	% of whole	% of group
DOMESTICATES				
Bos taurus	Domestic Cattle	387	0.56	32.49
Equus caballus	Domestic Horse	10	0.01	0.84
Canis familiaris	Domestic Dog	40	0.06	3.36
Sus scrofa	Domestic Pig	19	0.03	1.60
Ovis aries	Domestic Sheep	8	0.01	0.67
Capra hircus	Domestic Goat		0.00	0.00
Ovis/Capra sp.	Caprine	727	1.06	61.04
total Ovis/Capra		735	1.07	61.71
total Domesticates		1191	1.74	
SEALS				
Phoca vitulina	Harbor or Common seal	1	0.00	100.00
Phocid sp.	Seal species	4	0.01	
total Phocid		5	0.01	
CETACEA				
Great whale		2	0.00	14.29
Cetacea sp.		12	0.02	85.71
total Cetacea		14	0.02	

OTHER MAMMALS			
Alopex lagopus	3	0.00	
total Other Mammals	3	0.004	
BIRDS			
Wildfowl - sea birds	30	0.04	100.00
Wildfowl - land birds		0.00	0.00
Domestic fowl		0.00	0.00
Bird sp.	54	0.08	
Total Birds	84	0.12	
FISH			
Gadid sp.	24658	36.66	99.39
Salmonid sp.	0	0.00	0.00
Other Fish	152	0.22	0.58
Fish sp.indet.	38819	56.55	
Total Fish	63,629	94.60	
MOLLUSCA			
Mollusca sp.	2334	3.40	
Total Mollusca	2334	3.40	
TOTAL NISP (Identified fragments) =	67,260	100.00	
Small Terrestrial Mammal	9		
Medium Terrestrial Mammal	1075		
Large Terrestrial Mammal	367		
Unident. Mammal Frags	756		
TOTAL TNF (all fragments) =	69,467		

As the summary of table 1 demonstrates, the great majority of bones that could be identified to species, genera, or family (NISP, number of identified specimens) were fish (63,629 fragments or about 95% of collection), with mollusca (2334), birds (84), arctic fox (3), seal (5), whale (14), and domestic mammals (1,191) making up the remaining five percent. The zooarchaeological (rather than taxonomic) categories of “small terrestrial mammal” (cat-fox sized), “medium terrestrial mammal (pig-sheep-goat-large dog sized) and “large terrestrial

mammals (cattle or horse) mainly include vertebral, rib, and long bone shaft fragments that could not be securely identified further, and are probably virtually all from domestic mammals already identified on other elements. The 756 completely unidentifiable fragments were all mammalian, and likewise probably represent fragments of species already identified. The total bone collection including these unidentified fragments thus produces a TNF (total number of fragments) of 852 specimens. Figure 1 graphically compares the major identified taxa, emphasizing the numerical dominance of fish remains. Table 2 presents a breakdown of identified mammals, which include all known Icelandic domestic mammals except the very rare cat, at least one species of seal (the harbor or common seal still present in nearby waters), some fragments of great whale bone, and a few elements of arctic fox. Note that the term "caprine" refers to sheep and goat collectively. As most elements of these closely related species cannot be reliably distinguished, it is common zooarchaeological practice to combine the totals of bones that can be identified to species level (in this case 8 sheep bones) with the larger number of bones that can only be identified as one or the other (in this case 727 fragments).

Table 2 Tjarnargata 3 C Mammals

Scientific Names	*English Common Names*	*NISP Count*	*% Identified Mammals*
Bos taurus dom.	Cattle	378	32.25
Equus caballus	Horse	10	0.85
Canis familiaris	Dog	40	3.41
Sus scrofa	Pig	19	1.62
Ovis aries	Sheep	8	0.68
Ovis/ Capra sp. Indet.	Caprine	704	60.07
Phoca vitulina	common or harbor seal	1	0.09
Phocid species	seal species	5	0.43
Cetacea sp.	whale species	4	0.34
Alopex lagopus	arctic fox	3	0.26
	Total	1172	

Figure 2 presents the relative percentages of domestic mammals, illustrating the approximate 2 : 1 ratio of caprines to cattle and the trace presence of pig, horse, and dog bone. The dog remains come from at least three different animals of medium size (very similar to modern Icelandic dogs). They do not seem to reflect either food consumption or deliberate burial (dog burials are common in pre-christian contexts), but are similar to the frequent finds of semi-articulated remains of feral strays common in urban contexts down to the 19th century in New York. The volume of urban refuse provides a niche for scavengers, and feral dog packs were a fact of urban life in most towns of the Early Modern period.

Table 3 presents the breakdown of identified bird remains (30 of a total of 83 fragments that were clearly bird bone), and the relative percentages of all bird remains (column 4) and those identified to taxon (column five).

Table 3 Bird species Tjarnargata 3 C

Scientific name	Common English Name	NISP	% NISP	% ID Bird
Fulmarus glacialis	Fulmar	13	15.66	43.33
Fratercula arctica	Puffin	6	7.23	20.00
Pluvialis apricaira	Golden plover	1	1.20	3.33
Larus canus	Common gull	3	3.61	10.00
Larus argentatus	Herring gull	3	3.61	10.00
Larus species	Gull species	4	4.82	13.33
Aves species indeterminate	Unidentified bird	53	63.86	
total identified birds		30		
total all bird bone		83		

Figure 3 illustrates the relative proportions of the identified birds. Note the importance of Fulmar bones (ca 40%) and gulls (ca 33%). While Puffin were regular items of traditional Icelandic diet and appear in many rural site collections, fulmar and gulls are rare in most other Icelandic archaeofauna. Like the feral dogs, fulmar and gulls are characteristic scavengers (especially of fisheries refuse) and are common elements of a commensual urban fauna that is a byproduct of the adaptive niches unwittingly opened by concentrations of human activities not found in dispersed rural settlements.

Table 4 presents the fish remains, including the 24,810 specimens that could be taxonomically identified and the 38,819 that could be only identified as fish species. As figure 4 illustrates, the gadid (cod) family completely dominated the identified specimens (>90 %) with no salmonids and only traces of wolf fish and flatfish. Figure 5 illustrates the gadidae identified to species level. While six species are present, the great majority of identified remains are Atlantic cod (*Gadus morhua*), with Haddock (*Melanogrammus aeglfinus*) as the second most common identified fish.

Table 4 Fish Remains	Tjarnargata 3 C			
Scientific Names	***English Common Names***	NISP Count	% all ID Fish	% of Family
Gadidae				
Gadus morhua	Atlantic cod	14,643	59.02	74.88
Pollachius virens	Saithe	498	2.01	2.55
Melanogramus aeglfinus	Haddock	3,308	13.33	16.92
Molva molva	Ling	1,098	4.43	5.62
Brosme brosme	Torsk	7	0.03	0.04
Gadidae, sp. Indet.	Gadid family	5,105	20.58	
Other Identified Fish				
Hippoglossus hippoglossus	Halibut	40	0.16	
Pleuronectidae sp.	Right eye Flounders	96	0.39	
Anarchichas lupus	Wolfish	16	0.06	
Unidentified Fish				
Fish, sp. & family Indet.	Fish species	38,819		
Total Fish		**63,630**		

Figure 6 and table 5 present the molluscan remains, which include at least four species but are dominated by the common blue mussel (*Mytilus edulis*) long harvested for both bait and human food in Iceland.

Table 5 Mollusca	Tjarnargata 3 C		
Scientific Name	***English Common Name***	***NISP***	***% ID Mollusca***
Littorina littorae	Common periwinkle	5	0.22
Balanus sp.	Barnacle sp.	5	0.22
Mytilus edulis	Mussel	2229	95.91
Mya sp.	Clam sp.	85	3.66
Mollusca sp.		10	
Total Mollusca		2334	

Age at Death

While the domestic mammal remains did not contain enough tooth rows for a reasonable attempt to reconstruct mortality profiles in detail from analysis of patterns of tooth eruption and wear (Payne 1973, 1984), a number of specimens were clearly from animals less than 3 months old. These “neonatal” remains are presented in table 6. The percentage of neonatal cattle is fairly typical for rural sites, and certainly reflects the byproduct of a dairy economy (for discussion and

references see Halstead 1998). The presence of both cattle and caprine (almost certainly sheep) neonates in the Tjarnargata 3 C collection hints at the presence of a nearby working farm for at least part of the period of the context's deposition.

Quantification Methods

Quantification in this report follows NABO ZWG recommendations by making NISP (number of identified specimens) the basic quantitative measure, as this simple counting technique has proven robust in numerous sampling experiments (Grayson 1984, Gilbert & Singer 1982, Ringrose 1993, Pilgrim & Marshall 1995, Gautier 1984, Lie 1980) and is easily replicable across investigators. However, as the collection is dominated by fish bones (63,629 fish fragments of a total of 69,467 all fragments) , and this family is in turn dominated by one species (cod) virtually any quantitative method can be relied upon to document this overwhelming pattern of relative abundance.

However, if we limit ourselves to the 1,141 domestic mammal bones identified to taxa, a more effective and appropriate comparison becomes possible between different methods (Table 6, Figure 2). NISP (number of identified specimens) counts simply total all fragments that can be identified to species level or to some other useful taxonomic level (eg: "Caprine" and "Ovis/Capra" include both the bones that can be securely identified as either sheep or goat and the much larger number of fragments that must be one or the other but cannot be assigned to species.). MNI (minimum number of individuals) attempts to reduce interdependence (multiple bones from the same skeleton being counted) by estimating the smallest number of animals that would have had to die to produce the skeletal elements identified to the same species. MAU mean (minimum animal unit = RF of Perkins & Daly, see Daly 1969) divides the NISP count per element by the number of times the bone element appears in the species' body then takes the mean of the result for the whole skeleton (for detailed discussion see Grayson 1984). There is a large literature on the statistical behavior of these different indicators (see Grayson 1984, Rackham 1994, Reitz & Wing 1999, Gilbert & Singer 1982, Lie 1980, Lyman 1994, Pilgrim & Marshall 1995, Payne 1972), but most workers today employ different quantitative approaches selectively according to the depositional context. Catastrophic deposits (rapidly accumulating sudden events such a ship wreck, bison kill, etc.) involving nearly whole skeletons may justify an MNI approach, but most accretional deposits (such as gradually accumulating trash piles and middens) are better handled with NISP and other indicators (for discussion see McGovern et al. 1996, Meltzer et al. 1992).

As Table 7 and Figure 7 demonstrate, all three methods produce broadly similar results when applied to the domestic mammal bones from Tjarnargata 3 C, indicating that caprine (sheep and goat) bones are something like twice as common as cattle bones, and that pig and dog remains make up a small part of the collection.

Table 7

Tjarnargata 3 C Quantification comparisons

Mammals

	NISP	MNI	MAU mean
Cattle	378	8.5	1.91
Dog	40	3	0.15
Pig	19	3.5	0.1
Caprine	704	27	4.13
Totals	1141	42	6.29

Calculated Relative %	NISP	MNI	MAU mean
Cattle	33.13	20.24	30.37
Dog	3.51	7.14	2.38
Pig	1.67	8.33	1.59
Caprine	61.70	64.29	65.66

Note that MNI produces the outlying estimate, emphasizing the dog and (especially) the pig remains. This is a predictable characteristic of MNI, which is very sensitive to anomalous distributions of elements, and tends to over-count rare animals represented by a limited range of skeletal elements. As we will discuss below, pig bones in the Tjarnargata 3C archaeofauna have a distribution very different from the rest of the domestic mammals, and the dogs do not seem to have been part of anyone's diet in early modern Reykjavik.

Bone Preservation & Taphonomy

Most bones present in living animals in ancient farmyards have disappeared entirely, recycled by many efficient agents of attrition or victims of soil acidity or reworking of deposits. The bone fragments usually available for study by a zooarchaeologist are the exceptions to this rule, and inevitably form a small and usually biased sample of a lost whole. The process of transformation by attrition is called *taphonomy*, and represents a major sub-field of zooarchaeology in its own right (Lyman 1994, 1996). Archaeofauna (like pollen grains, seeds, or insect parts) are thus proxy indicators of the relative abundance and role of animals in a past economy and environment, and analysts must be aware of the impact of taphonomic processes that intervene between present sample and past target population.

NABONE software tracks several taphonomic indicators, the most useful of which are burning, fragmentation, and animal gnawing. Table 8 presents data comparing fragmentation of mammal bones (identified and unidentified) from the

Tjarnargata 3 C (TJR3C) archaeofauna and from the mid-10th c. midden unit M contexts of the small site of Sveigakot (SVK) in Mývatnssveit (Vésteinsson 2000, Tinsley 2002a,b, McGovern et al. 2001, McGovern 1999, Ogilvie & McGovern 2000). The contexts at Sveigakot are still under excavation and analysis, and these preliminary results are presented here for comparative purposes only. While dating to the Landnám period, Sveigakot's archaeofauna is in many ways fairly typical of most rural site collections we have studied, and is used here as a comparative yardstick.

Table 8

	Tjarnargata 3 C Mammals			Sveigakot "M" (ca. mid 10th c AD) Mammals	
Fragmentation	**Size (cm)**	**NISP**	**% TJR 3**	**NISP**	**% SVK M**
	<1	208	6.14	1505	20.65
	1-2	423	12.49	3240	44.45
	2-5	1146	33.84	2247	30.83
	5-10	1117	32.98	225	3.09
	>10	493	14.56	70	0.96
	Total	3387		7289	

As figure 8 illustrates, the Sveigakot collection has a different pattern of fragmentation, with many fewer large bones surviving and many more small fragments in the 1- 2 cm range. As both sites were sieved (using the same apparatus and many of the same excavators), we feel that this difference in fragmentation represents a genuine pattern of deposition rather than an artifact of excavation and recovery strategy. The SVK pattern is far more common on most sieved rural collections, and appears to reflect differing degrees of bone fragmentation during butchery and food preparation and different patterns of refuse disposal.

Table 9 **Burning**

	Tjarnargata 3 C Mammals		Sveigakot "M" (ca. mid 10th c AD) Mammals	
	NISP	**% TJR 3**	**NISP**	**% SVK M**
Unburnt	3135	92.56	6147	81.42
Black	114	3.37	157	2.55
White	79	2.33	971	15.80
Scorched	59	1.74	14	0.23
total	3387		7289	

In most Icelandic collections, **burnt bone** fragments represent the last remnants of bone used for fuel or simply disposed of through burning. Table 9 again compares patterns in burning recorded on all mammal bone fragments from both Tjarnargata 3 C and Sveigakot unit M. Bones were recorded as unburnt, black burned, white burned (calcined), and scorched. Black and white burned bones

have been combusted in a fire, with the white calcined bone exposed to the higher heat. Scorch marks on bone (blackened patches) usually reflect over-done roasts (in which most of the bone was still protected by meat) and do not indicate that bone was deliberately burnt as fuel. As figure 9 illustrates, the major difference between these two collections is in the relative proportion of strongly burnt calcined bone. As in most other sieved rural collections, white and black burnt bone that have been directly exposed to fire make up a significant proportion of the total bone sample. The process of burning progressively drives off the organic fraction of bone, leaving a shrunken and extremely brittle mineralized residue (which is extremely resistant to further chemical decay and thus is often the only surviving bone material on sites having acid soils). Most of the white calcined bone is unidentifiable and tends to fragment into small pieces. Part of the difference in fragmentation between these two samples is certainly the different frequency of white burnt bone, though it is well to note that in both collections the great majority of bones are not burnt at all.

Gnawing by animals is another source of bone attrition, and in some collections from Norse Greenland up to 30% of the mammal bones show some form of carnivore gnawing (McGovern 1985). Icelandic collections usually show far lower frequencies of animal gnawing, and the Tjarnargata 3 C archaeofauna is no exception in this respect. What is unusual is the presence of rodent (probably rat) tooth marks as well as medium carnivore (presumably domestic or feral dog), which have not been previously recorded in Iceland. Table 10 presents these data (mammals only), again using the Sveigakot unit M material as a comparison. Figure 10 provides illustration, comparing the rural Landnám period SVK M with the urbanizing early modern collection from TJR 3 C.

Table 10 Gnawing

Marks	NISP	TJR 3	NISP	SVK M
None	3343	98.79	7275	99.81
Dog	26	0.77	14	0.19
Rodent	13	0.38		
Dog & Rodent	2	0.06		
total	3384		7289	

Butchery marks accumulate on animal bones at several stages in the transformation of a live animal into a human meal, and reflect the interplay of basic mammalian anatomy with human technology, economic choices and culturally determined food ways. Some marks are left on bone by the act of slaughter (mainly depressed fracture to the frontals), more marks (mainly by heavy cleaver or axe) are left by the disjointing of the carcass into cuts of meat for cooking, other marks are left by cooks and diners (usually marrow extraction and knife slice marks). Table 11 presents the recorded butchery marks on mammal bone (both in absolute numbers and %) from Tjarnargata 3 C, again making use of the Sveigakot M unit data for comparison.

Table 11
NISP count
Tjarnargata 3 C Butchery Marks

	No marks	Split	Knife Cut	Chopped	Chopped & Knife cut	Biperforated Metapodial
Cattle	356	5	11	15	1	
Caprine	651	13	21	9		29
Pig	13		6			
Dog	40					
Horse	10					

Sveigakot M Upper (ca mid 10th c AD)

	No Marks	Split	Knife cut	Chopped	Biperforated Metapodial
Cattle	217	6		9	
Caprine	548	38	1	7	0
Pig	97		1	8	
Dog	0				
Horse	13	1			

Tjarnargata 3 C
% of Marked Bones By Taxon

Taxa	Split	Knife Cut	Chopped	Chopped & Knife cut
Cattle	1.40	3.09	4.21	0.28
Caprine	2.00	3.23	1.38	0.00
Pig		46.15		
Dog				
Horse				

Sveigakot M Upper (ca mid 10th c AD)
% of Marked Bones By Taxon

Taxa	Split	Knife Cut	Chopped	Chopped & Knife cut
Cattle	2.59		3.88	
Caprine	6.40	0.17	1.18	
Pig	0.00	0.94	7.55	
Dog				
Horse	7.14			

As the table indicates, there are far more knife slice marks on the later Tjarnargata 3 C collections, especially (proportionately) on the pig bones. Biperforated caprine metapodials (cannon bones) are a characteristic method of extracting marrow by making a hole in the proximal articular facet of the

metatarsus or metacarpus and a second hole in the plantar surface near the distal end of the bone. Marrow can be sucked out without danger of bone splinters while neatly preserving a bone element much used for a variety of craft items (toggles, needle cases etc.). Biperforation is common on Icelandic and Shetlandic sites after ca. AD 1100 (Bigelow 1985), but does not seem to have been part of the original Viking age pattern as it is absent on 10th-11th c sites in Iceland and never seems to have been adopted by the Greenlanders (but see also Enghoff in press). The higher percentage of longitudinally split caprine bone at SVK M in table 10 reflects the older processing method.

Figures 11 and 12 compare the pattern of butchery marks between TRJ 3 C and SVK M, illustrating some of the differences. Pig butchery patterns are clearly distinct at the two sites, the Settlement Period site showing a mix of knife cut marks (mainly by servers and diners) and heavy chopping marks from primary dismemberment while the Early Modern site's pig remains have only slice marks. Unsurprisingly, the pre-christian Sveigakot horses show splitting of long bones for marrow extraction while such marks are absent from the Tjarnargata 3C horse bones.

Mammal Element Frequency

The causes of different recovered frequencies of different skeletal elements in different archaeofauna has long been a topic of intensive research in zooarchaeology (Daly 1969, Binford 1976, 1981, Crabtree 1990,1996, Speth 1983, Lyman 1994, Hesse 1982, Davis 1987, Amorosi et al. 1994, 1996, 1997, Halstead 1998 Grayson 1984, Lyman 1992, Marshall & Pilgrim 1991, Payne 1972, 1973, Perdikaris 1993, 1996, 1998,1999). The absence or disproportionate presence of particular bones can convey important cultural information such as long distance transport of cuts of meat, status or wealth differences, ethnic differences, changing food ways, or changing availability of species in the local environment. However, animal skeletons have their own inherent characteristics (bone density, shape, pattern of articulation) that tend to impose structure on any collection. Likewise, different taphonomic histories (acid soil, frost action, butchery strategy, scavenger gnawing, burning, etc.) produce different patterns of bone attrition and survival. Some skeletal elements are extremely dense (most mandibles, teeth) and usually appear in considerable numbers even on "ravaged" sites that have been subjected to extreme attrition. Other elements (proximal humerus, proximal femur) are far less dense and are also located at points of articulation (shoulder, hip) that tend to be heavily damaged during primary disjointing (especially if heavy metal cutting tools are used). Some elements are associated with major muscle masses (humerus, femur, proximal radius, proximal tibia) or substantial amounts of recoverable bone marrow (metatarsus, metacarpus) and others (toes) are associated with less recoverable meat. Complicating factors are the presence of "riders"- low meat value bones that are tightly bound to higher value elements by tendons and ligaments (tarsals and carpals) and tend to travel with them, the varied industrial utility of low meat value elements like antler, hoof, and horn, and cultural and situational factors

affecting desirability of a cut of meat. Some cultures (many hunter-gatherers) regularly discard most skull bones at the kill site, while others (like the medieval and early modern Icelanders) make extensive use of meat, brains, and other tissue associated with the bones of the skull. Butchers able to slaughter animals close to their point of final consumption are able to make fuller use of carcasses than those facing a long walk from kill site to consumption site. Finally, not all bone elements are equally identifiable in most collections due to biological similarity of elements in related species that can be expected to occur in a known region or period (archaeofauna composed entirely of whales and mice are a notable, if rare exception). Most mammal vertebrae and ribs, and many long bone shaft fragments cannot be securely identified to species level and are properly assigned by most workers to the more vague (if safer) categories of "large terrestrial mammal" , "medium terrestrial mammal" and the like (see table 1).

This complex web of interdependent variables makes element frequency study one of the most challenging areas of zooarchaeological analysis and interpretation and has long generated controversy and multiple interpretations of data sets (Binford 1981). Most modern workers suggest employing a range of indicators (Rackham 1994, Payne 1972) and the NABONE package provides a number of tools for investigating element frequency.

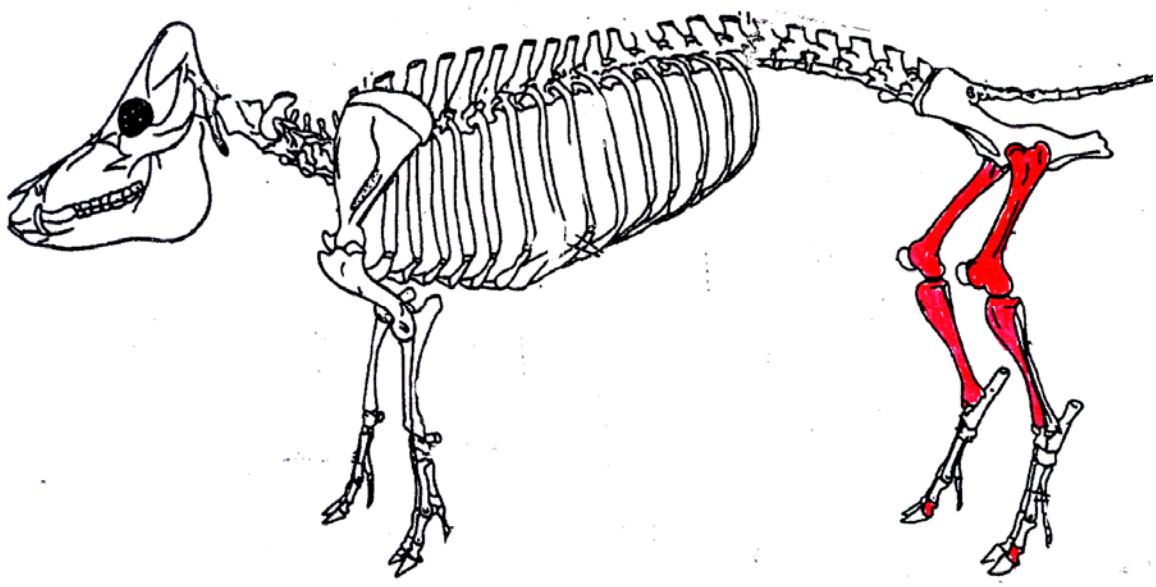
A first step is to inspect the general distribution of archaeologically recovered bones over the known pattern of the animal's skeleton. Figure 13 presents this pattern for the Tjarnargata 3C cattle bones, arranged in ranked MAU (minimal animal unit) order from most common to least common element. MAU (Binford 1978) is the count of bone fragments identified for each skeletal element divided by the number of times the element appears in a live animal's body. This compensates for the different number of bones in different species' skeletons (cows with two toes per foot, horses with one, humans and seals with five) so that element frequency patterns are not shaped by simple biology. As Figure 13 illustrates, despite MAU division, some elements are far more common than others (mandible, innominate, scapula, proximal and distal femur, proximal ulna, skull fragments) and some are rare or absent (sternum, proximal tibia, second and third toes). Some of this patterning is probably due to simple bone density (mandibles) but the frequency of femoral fragments suggests (but does not prove) a concentration of meat rich bone elements, and the absence of hooves (phalanx 3) is interesting.

Figure 14 presents the same ranked MAU pattern for the Caprines (sheep and goat, here probably entirely sheep). The concentration of top ranked maxillae, scapulae, and mandibles again suggests a mix of factors including bone density and the Icelandic fondness for the traditional half-sheep's -cranium dish *svið* (well attested in rural Icelandic collections dating back to first settlement). The next most common ranking of tibia shaft, distal humerus, femoral shaft, innominate, and proximal radius and the low ranking/absent status of hoof bones

again flags a possible concentration of meat rich bone elements for further investigation.

Figure 15 presents the same ranked MAU for the much smaller number of pig bones recovered, and serves to illustrate a very different pattern from the ranked MAU of cattle or caprines. In this case, most of the skeleton is not present, and the bones that are present are nearly all femoral or tibia fragments (with a single second toe bone). Something clearly seems to separate the recovered bone distribution pattern of pigs from that of the cattle and caprines.

It is also useful to aggregate bone elements (riders as well) into major body parts for a more generalized (and more immediately understandable) pattern of relative percent of body part frequency (based on MAU). Figure 16 presents these data for the Tjarnargata 3 C cattle, illustrating the relative abundance of cranial and upper limb bones. Note that the small number of ribs and vertebrae are an artifact of analysis, and most of these (very abundant) bones are probably in the "large terrestrial mammal" category. Figure 17 presents the same data for Tjarnargata 3 C caprines, again illustrating the abundance of upper limb bones and cranial fragments relative to the rest of the skeleton. Figure 18 presents these same data for pig remains from the site, dramatically indicating the marked difference between the pig element frequency and that of both cattle and caprine



at Tjarnargata 3 C.

Figure 19. Tjarnargata 3 C Pig bone element distribution

Figure 19 places these bones in the articulated skeleton of a pig (colored bones), and serves to clarify the nature of the pig remains recovered from the Early Modern contexts at Tjarnargata 3 C. These elements (with numerous slice marks) are most economically explained as the remains of imported cured ham

(possibly with a side order of pickled pigs feet) rather than a continuation of settlement age traditions of pig keeping in Iceland or a re-introduction of large scale piggery. Live pigs were probably not a feature of early urban life in Reykjavik, but some residents were wealthy enough to enjoy imported ham.

While we appear to have discovered the reason for the radically different bone element distribution of pigs as compared to caprines and cattle at Tjarnargata 3C, we are left with an unresolved issue. Does the distribution of cattle and caprine bone we have documented reflect the transport of selected cuts of meat butchered elsewhere as well as nearby slaughter and butchery of whole sheep and cattle? Can we distinguish patterns resulting from differential survival due to bone density or random taphonomic attrition? These questions lead us into a more systematic comparison of issues of bone density and economic utility.

Bone Density and MGUI

In 1978 Binford and Bertram introduced a set of measures of both bone density and what Binford (1976, 1981) later termed a "modified general utility index" (MGUI) for different parts of the mammalian skeleton. Based on ethoarchaeological observation of modern Inuit hunters and a limited number of sheep and caribou carcasses Speth's (1983) application of these measures to the Garnsey Bison Kill site was a widely influential demonstration of the potential of the general MGUI method for the reconstruction of past economic choices by prehistoric hunters, both expanding and refining the approach. Subsequently a number of workers have worked to expand the range of species for which bone element density and MGUI assessments are available and to refine the basic methods of quantifying both bone density and MGUI (Lyman 1994, Marshall & Pilgrim 1991). Controversy continues about the most accurate method of quantifying bone density (resonance, CAT scans, volumetric approaches) and there is no single recognized standard, though in practice Binford and Speth's approaches remain influential. There are inherent limits to reasonable precision in measurement of bone density, as there is variability between individuals of the same species, and bone density of the same individual will change through life with age and in response to nutrition, activity level, and general health. It is also notable that with a few exceptions most of the current bone density tables differ in rank order of only a few elements, though numerical figures vary more widely. As may be expected, the ranking of associated meat/marrow/tissue utility inherent in the MGUI index is also inevitably somewhat imprecise and inevitably contingent upon cultural variables harder to quantify than straightforward carcass dissection results. In the current (2002 7th edition) NABONE package we provide minor modifications and extensions of the Binford/Speth density and MGUI figures, but our basic approach is to accept the limited precision of both sets of measures and group both MGUI and bone density estimates by quartiles (4th). This approach lumps elements into four categories (most dense to least dense, highest MGUI to lowest) in an explicit attempt to sacrifice what may be spurious precision for a more generalized but perhaps more accurate overview.

Figure 20 compares bone density and MGUI ranking for a structured "ravaged" dummy data set holding only the most dense (first quartile) bones. Figure 21 presents a structured "gourmet" dummy data set that holds only the highest value (first quartile) MGUI scoring bones. As the graphs indicate, very dense bones have a range of associated MGUI values (and vice versa) but there is a tendency for many of the densest bones to also be highest in MGUI score. This problem of equi-finality has been noted by Lyman (1992, 1994), and it is a practical problem encountered in the analysis of real archaeofauna as well. Figure 22 again makes use of the preliminary mid-10th century Sveigakot midden caprine sample to demonstrate this point. Where animals are mainly butchered and consumed at or very near the same locality and bone refuse from primary disjointing, meal preparation, and discarded dinner waste are all deposited in the same context (and subjected to similar post depositional taphonomic attrition) the pattern of rank order of bone density and MGUI often closely mirror each other.

This is not the case for pigs, cattle, or caprines in the Tjarnargata 3 C archaeofauna. Figure 23 illustrates the pig element quartile ranks for MGUI and density, and not surprisingly this apparent collection of ham bones produces a graph strikingly similar to the "gourmet" dummy data profile of Figure 22. Figure 24 presents the element quartile rank comparison for the Tjarnargata 3 C cattle remains, and while the overall pattern resembles the Sveigakot graph (Figure 23) there is a significant "surplus" in the first ranking MGUI quartile. Figure 25 presents the same ranked quartile data for the Tjarnargata 3 C caprines, and an identical pattern is evident.

While it is very likely that many entire cattle and sheep were killed and butchered nearby and became part of the overall archaeofauna, this analysis of mammalian body part distribution strongly suggests that this near-site butchery was supplemented by additional cuts of meat (mainly haunches and flanks from the upper body) imported from some more distant site. The mammalian bone element distribution thus indicates that as downtown Reykjavik urbanized and acquired a significant non-agricultural population the new town developed means for provisioning the new citizens. The Tjarnargata 3 C mammalian archaeofauna suggests that (at least in this district) the new urban population enjoyed access to high quality cuts of meat from Icelandic cattle and sheep as well as the occasional imported ham from abroad.

Fish Element Frequency

As noted above, the great majority of the bone fragments in the Tjarnargata 3 C collection are from fish and by far the most common species identified are Atlantic cod and Haddock. Both species are thankfully still common in Icelandic waters, and archaeofauna dating back to Landnám times (Tinsley 2001, Perdikaris in press, McGovern et al. 2001) regularly contain remains of both

species. In the past decade, a tremendous amount of work has been carried out by scholars in the North Atlantic region focused on the nature of the changing fisheries in different areas (Barrett et al 1999, Barrett 1994, Cerron-Carrasco 1994, Colley 1983, Enghoff 1994, Nicholson 1998, Perdikaris 1994, 1996, 1999) and particularly on the zooarchaeological distinction of subsistence from fully commercial fishing. Species abundance, species diversity, cut marks, reconstructed live length and recovered element frequency are all lines of evidence employed by NABO scholars in this investigation (Perdikaris 1999). The Tjarnargata 3 C collections were mainly deposited during a known period of fully industrial commercialization at the largest fishing port in southern Iceland and should reflect a clear-cut zooarchaeological signature for commercialization.

As indicated in table 4, the Tjarnargata 3C archaeofauna has two indicators of possible commercialization- a very large concentration of fish bones and a restricted range of species centered on large gadids (esp. Atlantic cod). Cut marks are rarely seen on fish bone (a skilled fish cutter normally leaves few marks) and are not present on either cod or haddock bones identified from Tjarnargata 3C. Element distribution provides more interesting patterning, based on a very large sample (cod NISP =14,746, haddock NISP= 3,311), and shows a strong contrast between the two major species. Table 12 presents Haddock element distribution by morphologic zone (see digital archive for all raw data).

Table 12
HADDOCK ELEMENT DISTRIBUTION

	MAU	MAU %
Olfactory	38.00	6.56
Occipital	2.50	0.43
Otic	20.00	3.45
Investing	1.00	0.17
Lateral	49.60	8.56
Opercular	33.75	5.83
Mandicular	6.50	1.12
Hyoid Arch	30.00	5.18
Branchial Arch	3.00	0.52
Pectoral Girdle	230.00	39.71
Pelvic Girdle	0.00	0.00
Vertebral Column	113.67	19.62
Caudal Skeleton	51.25	8.85
total	579.27	100

Table 13 presents the same data for Atlantic Cod.

Table 13
COD ELEMENT DISTRIBUTION

	MAU	MAU %
Olfactory	1184.50	18.12
Occipital	282.00	4.31
Otic	368.00	5.63
Investing	146.50	2.24
Lateral	1511.40	23.12
Opercular	634.50	9.71
Mandicular	464.50	7.11
Hyoid Arch	668.50	10.23
Branchial Arch	11.67	0.18
Pectoral Girdle	577.50	8.83
Pelvic Girdle	0.00	0.00
Vertebral Column	630.26	9.64
Caudal Skeleton	57.36	0.88

As in the discussion of mammal skeletal element frequency above, MAU is the raw count of bones per element divided by the number of times the element occurs in the animal's body and is used to normalize comparisons across species with different skeletal proportions. As Figures 26 and 27 illustrate, the element distribution of these two fish species is very different in the Tjarnargata 3 C collection, with many more mouth parts present for cod than haddock.

This trend is clarified by a direct comparison (Figure 28) between the cranial (head) and axial (body and tail vertebrae) skeletal elements of the two species. While the haddock bones fall more or less evenly between head and tail segments (normalized by MAU), there is a clear imbalance between the many cod heads in the collection and the limited number of vertebrae. If we focus upon the vertebral series themselves as presented in Figure 29 (thoracic = neck/upper body , precaudal= upper body, caudal= tail) the contrast between the distribution of the recovered vertebrae of the two species is striking.

This very large and well excavated collection of fish remains does have clear pattern in the distribution of elements which strongly indicates that these two gadid family fish were being treated in a very different way in Early Modern Reykjavik. Haddock remains are present in more or less even balance between head and body/tail, and there is no shortage of haddock caudal vertebra. By contrast, there is either an oversupply of cod heads or a shortage of cod bodies, particularly the caudal vertebral series. This pattern is consistent with the

preparation of preserved fish (especially dried stockfish) in which the head is removed (leaving the cleithrum behind in the body), the fish is gutted, and the upper vertebral series is pulled away. This leaves the cleithrum and the caudal vertebral series in the exported product. The rest of the fish (head, thoracic, and most precaudal vertebrae) was traditionally used for domestic consumption or discarded. The contrasting MAU % (element as % of total preserved skeleton) of the cleithrum in the Tjarnargata 3 C archaeofauna is instructive: for haddock it is 34.69 %, for cod only 0.90%. Element distribution strongly indicates that most Atlantic Cod were being processed for export on a large scale, while Haddock was probably mainly locally consumed as fresh fish.

Fish Length Reconstruction

Thanks to the sustained efforts of many scholars (Wheeler & Jones 1989, Leach 1986, Morales & Rosenlund 1979), it is possible to reconstruct approximate live length from several fish bone elements commonly recovered from archaeological sites. The large Tjarnargata 3 C collection provided 184 vomers, 489 maxillae, 592 dentaries, 91 atlas vertebrae, and 24 cleithrum of Atlantic Cod that were measurable (table 14).

Table 14 Tjarnargata 3 C Cod

	Measured size (mm)				
	VOMER	PREMAXILLA	DENTARY "A"	ATLAS	CLEITHRUM
Number of Specimens	184	489	592	91	24
Mean	26.25	13.22	8.25	12.62	17.97
Standard Deviation	4.62	2.46	2.01	2.26	6.01
CV	17.60	18.61	24.39	17.94	33.44
Range - maximum	34.93	20.09	15.25	18.22	27.29
Range - minimum	10.80	5.39	2.64	6.89	7.74

Table 15 presents the reconstructed live length for premaxilla, dentary, and cleithrum. All data is in the digital archive attached.

Table 15 Tjarnargata 3 C Reconstructed live length
Cod

	PREMAXILLA	CLEITHRUM	DENTARY "A"
Number of Specimens	489	24	592
Mean	814.43	625.44	763.30
Standard Deviation	149.62	248.03	161.84
CV	18.37	39.66	21.20
Range - maximum	1232.42	959.34	1324.44

Figure 30 shows the distribution of the dentary and premaxillary size reconstructions, illustrating the correspondence of the two measurements in a

uni-modal distribution between approximately 600 and 1100 cm total length. This is also what has been termed the “stockfish window” (Perdikaris 1999). Which is the observed size range of fish that allows for stockfish to be effectively cured through air drying. Through empirical observations it has been determined that fish much smaller than this range dry too hard, while fish much larger tend to rot rather than cure. As both dentary and premaxilla are mouth parts likely to be discarded or consumed locally and not shipped with a cured product, this total length reconstruction thus probably documents the approximate size of fish exported.

However, some cod remains do not fit the element distribution “export” pattern and a few cleithra do survive in the Tjarnargata 3 C collection 9 (24 cleithra vs. 592 measurable dentaries). Figure 29 compares the distribution of the total length reconstruction of the numerous mouthparts to the few cleithra (using % rather than NISP count). While a few of the cleithra do come from stockfish sized fish, their distribution is far less strongly uni-modal, and a near majority of these elements clearly come from fish too small to be effectively prepared as stockfish. It would appear that small cod as well as haddock were being retained for domestic consumption in Early Modern Reykjavik.

The massive fish bone collection from Tjarnargata 3C thus effectively demonstrates a range of predicted zooarchaeological indicators for commercial fishing, and allows a better understanding of the interaction of a large scale export trade in prepared cod fish and a domestic market for haddock and some cod (perhaps mainly the unsold bycatch). The collection thus provides a useful benchmark for further zooarchaeological investigation of Icelandic and North Atlantic fisheries.

The Archaeofauna In Context

Thanks to nearly two decades of cooperative research, Iceland has one of the best zooarchaeological records of any part of the North Atlantic and new archaeofauna like the Tjarnargata 3 C collection can be placed in a larger context. Five other early modern collections of comparable size are most suited to comparison with the Tjarnargata 3 C materials: Viđey and Bessastađir in the greater Reykjavik area, two phases of the Storaborg farm mound on the south coast, and the church farm of Svalbarđ in the far northeast. Figure 31 compares the domestic mammals for these collections. The Tjarnargata 3 C domestic mammal mixture is predictably most similar to the other southern sites, with a relatively high ratio of cattle to caprines. Viđey and Bessastađir also boasted a few probable hams in the Early Modern period, likely associated with their high status and connection to the Danish colonial administration (Amorosi 1996). However, the concentration of dog remains and the realization that many of the cattle and sheep bones deposited at Tjarnargata 3 C probably came from animals raised elsewhere may remind us that this is not an archaeofauna from a

single farm or even a complex manor like Bessastađir. Figure 32 places the Tjarnargata 3 C collections in the wider perspective of the whole archaeofauna from these Early Modern sites. This figure demonstrates the special character of these early urban deposits, and the role of fishing and fish processing in the life of the town. While the domestic mammal component of the Tjarnargata 3 C collections resembles in many ways the assemblages from prosperous southern farms and elite manors nearby, the dominance of fish remains correctly reminds us of a fishing station engaged in the sort of large scale export of the products that were to guarantee Iceland's modernization and to underwrite the development of Reykjavik from a cluster of farms and manors to a vibrant modern city.

Recommendations for Further Work

The richness of the Tjarnargata 3 C archaeofauna suggests the value for research, history, and education of large systematically recovered collections of bone and other environmental samples during rescue excavation. The large sample size (especially fish) allowed establishment of a benchmark signature of fully commercial fish processing that will be of considerable value to researchers working in Iceland and in the rest of the North Atlantic for years to come. The indications of a fairly rich diet associated with large scale fish processing (and a commensual urban fauna) raises questions about the precise source of the archaeofauna that can only be resolved through further investigation. While the Tjarnargata 3 C sample could not be closely dated or tied to a specific set of structures and households, the archaeofauna nevertheless provides an intriguing hint of the process of urbanization of the capital city of Iceland. If additional samples can be obtained from secure contexts it will certainly be possible to apply the methods demonstrated in this report to provide a fresh view of Reykjavik's past, connecting future finds to the existing database. If more well-excavated collections of animal bones can be obtained from more closely datable contexts nearby that can be tied to particular households or businesses, then Zooarchaeology should be able to contribute far more substantially to the understanding of processes of urbanization and commercialization in early Reykjavík. This report thus should represent a first step towards additional investigation rather than any final statement.

We specifically recommend:

- Every attempt be made to collect animal bone material exposed during any further work in downtown Reykjavik.
- Continued systematic sieving to recover fish bone and to preserve comparability to the Tjarnargata 3 C collection.
- Priority be given to collecting stratified samples datable to century scale and associated with known buildings and activity areas.

Acknowledgements: The authors would like to gratefully acknowledge the sustained support of the NABO research cooperative and the generosity of its members in promoting international, interdisciplinary research projects and for providing stimulating discussion and interaction over the past decade. Research based results reported here are the product of generous support from the US National Science Foundation (Office of Polar Programs Arctic Social Science, Research Experience for Undergraduates Program, and Anthropology Program), the Icelandic Science Council, National Geographic Society, PSC-CUNY Grants Program, and the Archaeological Institute Iceland. We would particularly like to thank the student assistants who worked so diligently in the Brooklyn College laboratory: Julie Anidjar, Matthew Brown, Jennifer Braun, Yekaterina Krivogorskaya, Brianna Meyers, and Marianna Betti.

References

Amundsen, Colin 1999 Early Medieval Iceland and Paleofisheries Research: a preliminary report;, paper presented at *Historical Dimensions of Human Adaptability and Environmental Change in the North Atlantic Regions* workshop hosted by NABO and the Stefansson Arctic Inst. Akureyri Iceland July 16-21 1999.

Amundsen, Colin 2002, An Archaeofauna from Miðbaer on Flatey in Breiðafjorð in NW Iceland, *Environmental Archaeology 6*, in press.

Amorosi, Thomas 1996. *Icelandic Paleoeconomy*, unpublished PhD dissertation, CUNY.

Amorosi, T.; T. McGovern and S. Perdikaris. 1994. Bioarchaeology and Cod Fisheries, A New Source of Evidence. *Cod & Climate Change*. J. Jakobssen & S. Schopka (eds). ICES, Copenhagen 198:31-48.

Amorosi, T.; J. Woollett; S. Perdikaris; T. McGovern, 1996 Regional Zooarchaeology & Global Change Research: Problems and Potentials. *World Archaeology*, 28(1):126-157

Amorosi T., Buckland P., Dugmore A., Ingimundarsson J. & McGovern T.H. 1997. Raiding the Landscape: Human impact in the North Atlantic, in: B. Fitzhugh & T. Hunt (eds.) *Island Archaeology*, special edition of *Human Ecology*,25(3):491-518.

Barrett, J.H. 1995 *"Few know an earl in fishing clothes": Stockfish and the economy of Scandinavian Scotland*, PhD thesis Glasgow Univ.

Barrett, J.H., R. Nicholson & R. Ceron-Carrasco 1999. Archaeo-ichthyological evidence for long term socioeconomic trends in northern Scotland 3500 BC to AD 1500, *Jour. Arch. Sci*. 26:353-388

Bigelow G.F. 1985 Sandwick Unst and the Late Norse Shetlandic Economy, in B. Smith (ed) *Shetland Archaeology, New Work in Shetland in the 1970's*, Shetland Times Press, Lerwick, pp 95-127.

Binford L. R. 1976 *Nunamuit Ethnoarchaeology*, Academic Press NY.

Binford, L.R 1981. *Bones: Ancient Men and Modern Myths*. Academic Press, New York

Ceron-Carrasco, Ruby 1994. The investigation of fish remains from an Orkney farm mound, in W. Van Neer (ed) *Fish Exploitation of the Past*: Proceedings of the 7th meeting of the ICAZ fish remains working group, Tervuren Belgium pp 207-210.

Colley, S.M. 1983 The role of fish bone studies in economic archaeology with special reference to the Orkney Isles. PhD thesis U Southampton, Southampton UK.

Crabtree, P. J. 1990. Zooarchaeology and Complex Societies: some uses of faunal analysis for the study of trade, social status and ethnicity. *In Archaeological Method and Theory, Vol 2*, University of Arizona Press, Tuscon

Crabtree, P. J. 1996. Production and consumption in an early complex society: animal use in Middle Saxon East Anglia. *World Archaeology* 28(1)

Daly, P. 1969. Approaches to Faunal Analysis in Archaeology. *American Antiquity* 34(2)

Davis, S.J.M. 1987. *The Archaeology of Animals*. Batsford Ltd, London

Driesch, A von den. 1976. *A Guide to the Measurement of Animal Bones from Archaeological Sites.* Peabody Museum Bulletin 1, Peabody Museum of Archaeology and Ethnology, Harvard University, Cambridge, Massachusetts

Enghoff, I. B. 1994 Fishing in Denmark during the Ertebolle Period, *Intl. Jour. Osteoarchaeology* 4: 65-96.

Gilbert, A & Singer, B. 1982. Reassessing zooarchaeological quantification. *World Archaeology* 14 (1)

Grayson, D. K. 1984. *Quantitative Zooarchaeology*. Academic press, Orlando

Halstead, Paul, 1998. Mortality Models and Milking: problems of uniformitarianism, optimality, and equifinality reconsidered, *Anthropozoologica* 27: 3-20.

Hesse, B. 1982. Bias in the zooarchaeological record. In D. H. Ubelaker & H. J. Viola (eds), *Plians Indian Studies:* Smithsonian Contributions to Anthropology 30

Leach, F. 1986 A method for the analysis of Pacific Island fishbone assemblages and an associated database management system, *Jour. Arch. Sci.* 13:147-159.

Lie, R. 1980. Minimum Number of Individuals from Archaeological samples. *Norwegian Archaeological Review 13 (1)*

Lyman , R.L. 1996, *Taphonomy*, Cambridge U.P.

Lyman, R. L. 1994. Quantitative Units and Terminology in Zooarchaeology. *American Antiquity* 59 (1)

Lyman, R.L 1992. Anatomical Considerations of Utility Curves in Zooarchaeology. *Journal of Archaeological Science* 19

Marshall, F. & Pilgram, A. 1991. Meat versus within-bone nutrients: another look at the meaning of body-part representation in archaeological sites. *Journal of Archaeological Science 18*

Meltzer, D., Leonard, R. & Stratton, S. 1992. The Relationship between sample Size and Diversity in Archaeological Assemblages. *Journal of Archaeological Science 19*

McGovern T.H., Amorosi T., Perdikaris S. & Woollett J.W. 1996. Zooarchaeology of Sandnes V51: Economic Change at a Chieftain's Farm in West Greenland, *Arctic Anthropology* 33(2)94-122.

McGovern T.H., Sophia Perdikaris, Clayton Tinsley, 2001 Economy of Landnam: the Evidence of Zooarchaeology, in Andrew Wawn & Thorunn Sigurðardottir (eds.) A*pproaches to Vinland* , Nordahl Inst. Studies 4, Reykjavik. Pp 154-166.

McGovern, T.H. 1999
Preliminary Report of Animal Bones from Hofstadir , *and* Area G excavations 1996- 97, *Archaeologica Islandica* 1.

McGovern, T.H. 1985. Contributions to the Paleoeconomy of Norse Greenland. Acta Archaeologica 54

Morales, Arturo & Knud Rosenlund 1979. *Fish Bone Measurements: An Attempt to Standardize the Measuring of Fish bones from Archaeological Sites.* Steenstrupia, Copenhagen.

Nicholson, R. 1998. Fishing in the Northern Isles: a case study on fish bone assemblages from two multi-period sites on Sanday, Orkney. *Environmental Archaeology 2 : 15-28.*

North Atlantic Biocultural Organization Zooarchaeology Working Group 2002. *NABONE Zooarchaeological Recording Package 7th edition*, CUNY, NY.

Ogilvie, A. & McGovern, T. 2000. Sagas and Science: Climate and Human Impacts in the North Atlantic. In Fitzhugh, W. & Ward, E. (eds.) *Vikings: The North Atlantic Saga*. Smithsonian Institution Press

Payne, S. 1973. Kill-off patterns in sheep and goats: the mandibles from Asvan Kale. Journal of Anatolian Studies 23

Payne, S. 1972. On the interpretation of bone samples from archaeological sites. In E.S. Higgs (ed), Papers in Economic Prehistory. Cambridge University Press, Cambridge

Pilgrim, T. & Marshall, F. 1995. Bone Counts and Statisticians: a Reply to Ringrose. *Journal of Archaeological Science 22*

Perdikaris, S. 1993. Status and Economy: A Zooarchaeological Perspective from the Iron Age Site of Aker, Norway. Masters Thesis Hunter College

Perdikaris, S. 1999. From chiefly provisioning to commercial fishery: Long term economic change in Arctic Norway. Peter Rowley Conwy (ed). *World Archaeology* 30 (3):388-402

Perdikaris, S. 1996. Scaly Heads and Tales: Detecting Commercialization in Early Fisheries. *Archaeofauna*. Ichthyoarchaeology and the Archaeological record. Proceedings of the 8th meeting of the ICAZ Fish Remains Working Group, Madrid, Spain; A. Morales (ed.). 5 (1996): 21-33.

Perdikaris, S. 1998 The Transition to a Commercial Economy: Lofoten Fishing in the Middle Ages, A Preliminary Report. 7th ICAZ Conference Proceedings, September 1994, Konstanz, Germany. *Anthropozoologica* no 25-26/1997:505-510.

Rackham, James 1994 *Animal Bones*, U California Press, Berkeley.

Reitz E. & E. Wing 1999. *Zooarchaeology*, Cambridge U.Press.

Speth, J. 1983. Bison Kills and Bone Counts: Decision making by Ancient Hunters. University of Chicago Press, Chicago.

Tinsley, Clayton M. 2002a The Viking settlement of northern Iceland: a zooarchaeological perspective, Environmental *Archaeology 6,* Oxbow, (in press).

Tinsley, Clayton M, 2002b The zooarchaeology of settlement: some quantitative questions, Proceedings of the 21st Nordic Archaeology Conference Akureyri Iceland (in press).

Vesteinsson, Orri, 2001, *Archaeological investigations at Sveigakot 1998-2000*, Reykjavik, FSÍ.

Wheeler, A. & A.K.G.Jones 1989. *Fishes*, Cambridge U. Press.

Note: this excel spreadsheet contains the 33 figures fo
Report of Animal Bones from Tjarnargata 3 C, R
by
Sophia Perdikaris, Colin Amundsen, and Tom M
CUNY Northern Science & Education Center, N
submitted to Fornleifastofnun Islands Feb-02

Figure numbers key to text references.
Tables in text (Word)
See digital archive for all basic data and graphics

r the
eykjavik, Iceland

cGovern
ABO

s spreadsheets.

Figure 1

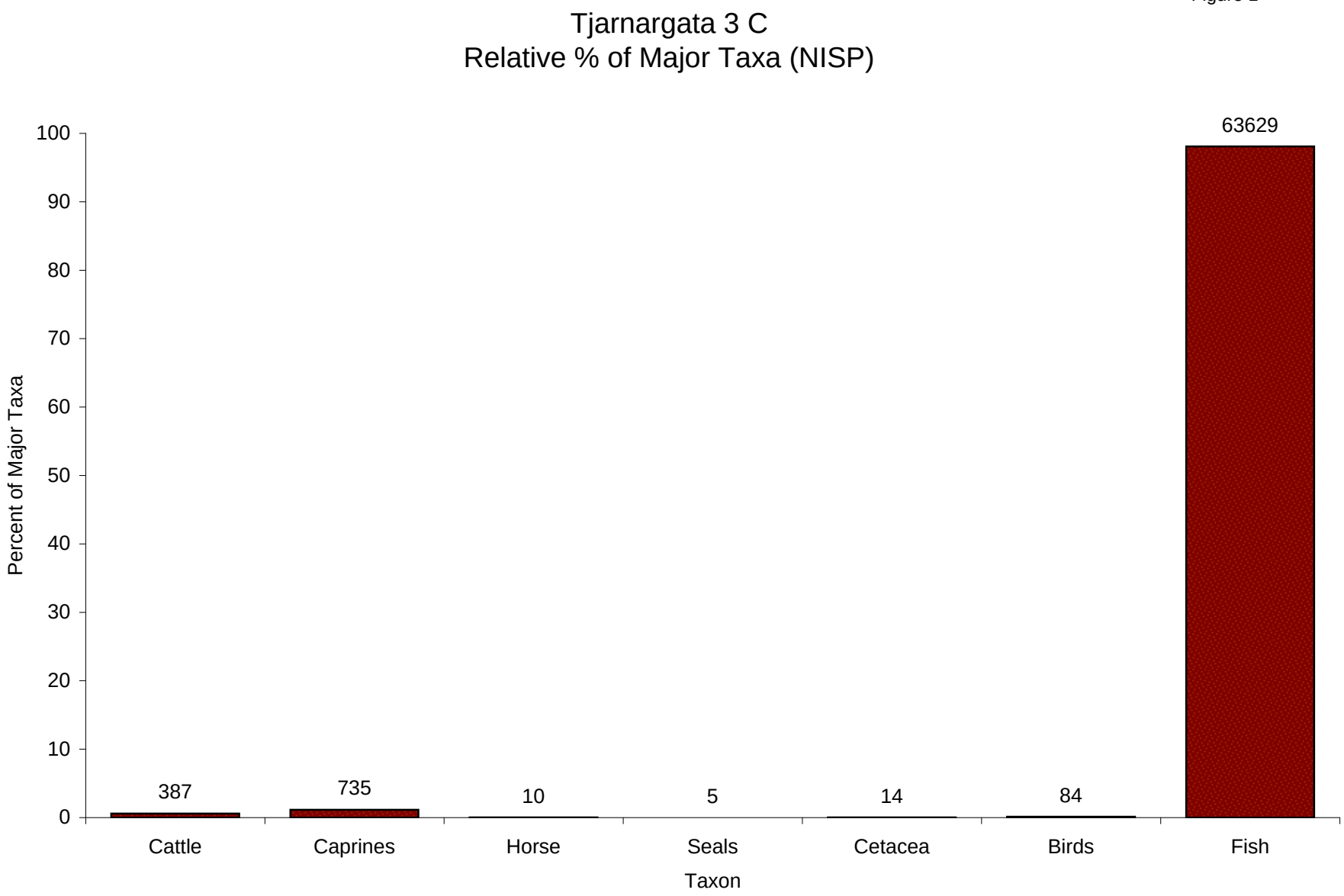

Tjarnargata 3 C
Relative % of Major Taxa (NISP)
Percent of Major Taxa
100
90
80
70
60
50
40
30
20
10
0
387
735
10
5
14
84
63629
Cattle
Caprines
Horse
Seals
Cetacea
Birds
Fish
Taxon

Figure 2

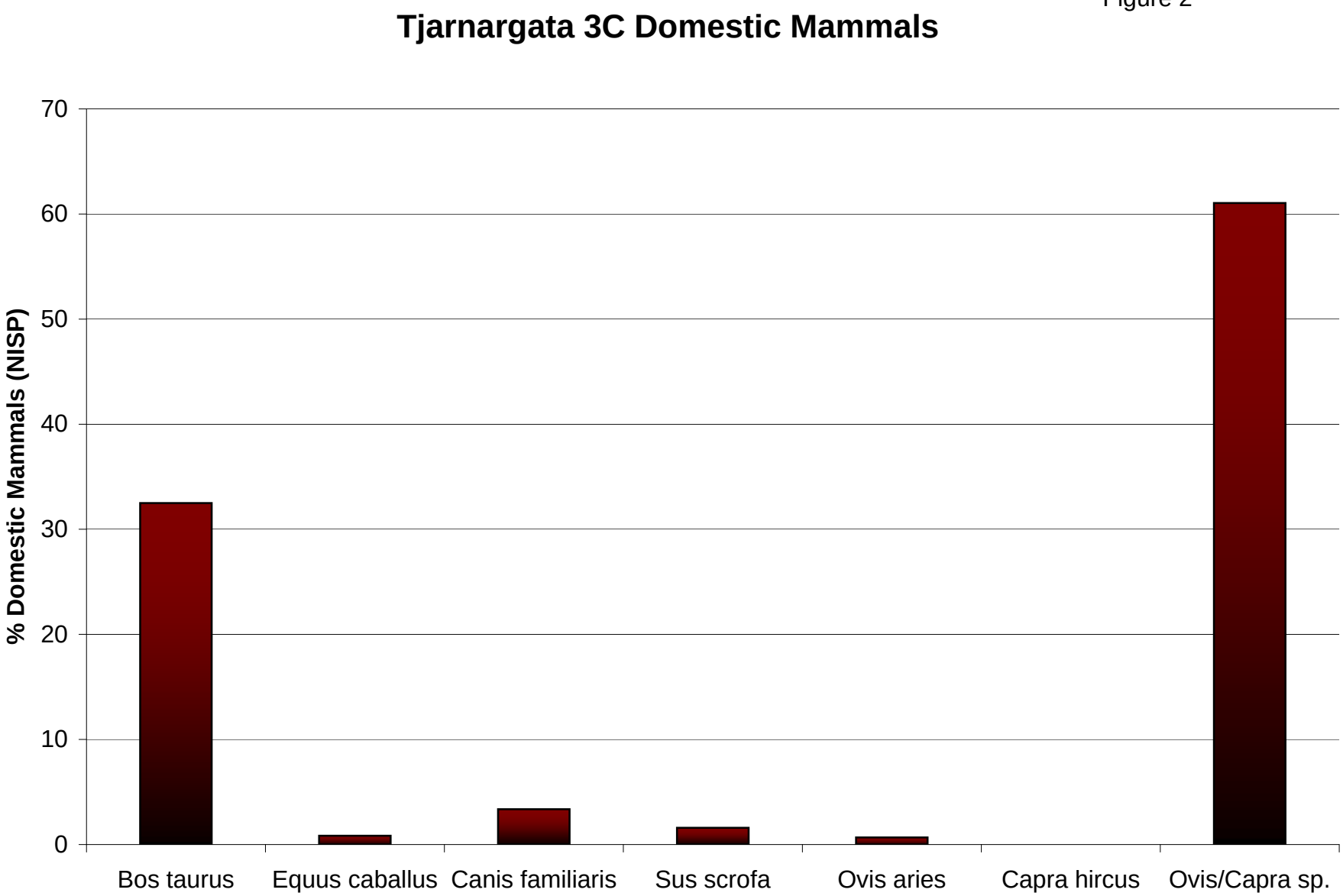

Tjarnargata 3C Domestic Mammals
% Domestic Mammals (NISP)
70
60
50
40
30
20
10
0
Bos taurus
Equus caballus
Canis familiaris
Sus scrofa
Ovis aries
Capra hircus
Ovis/Capra sp.

Figure 3

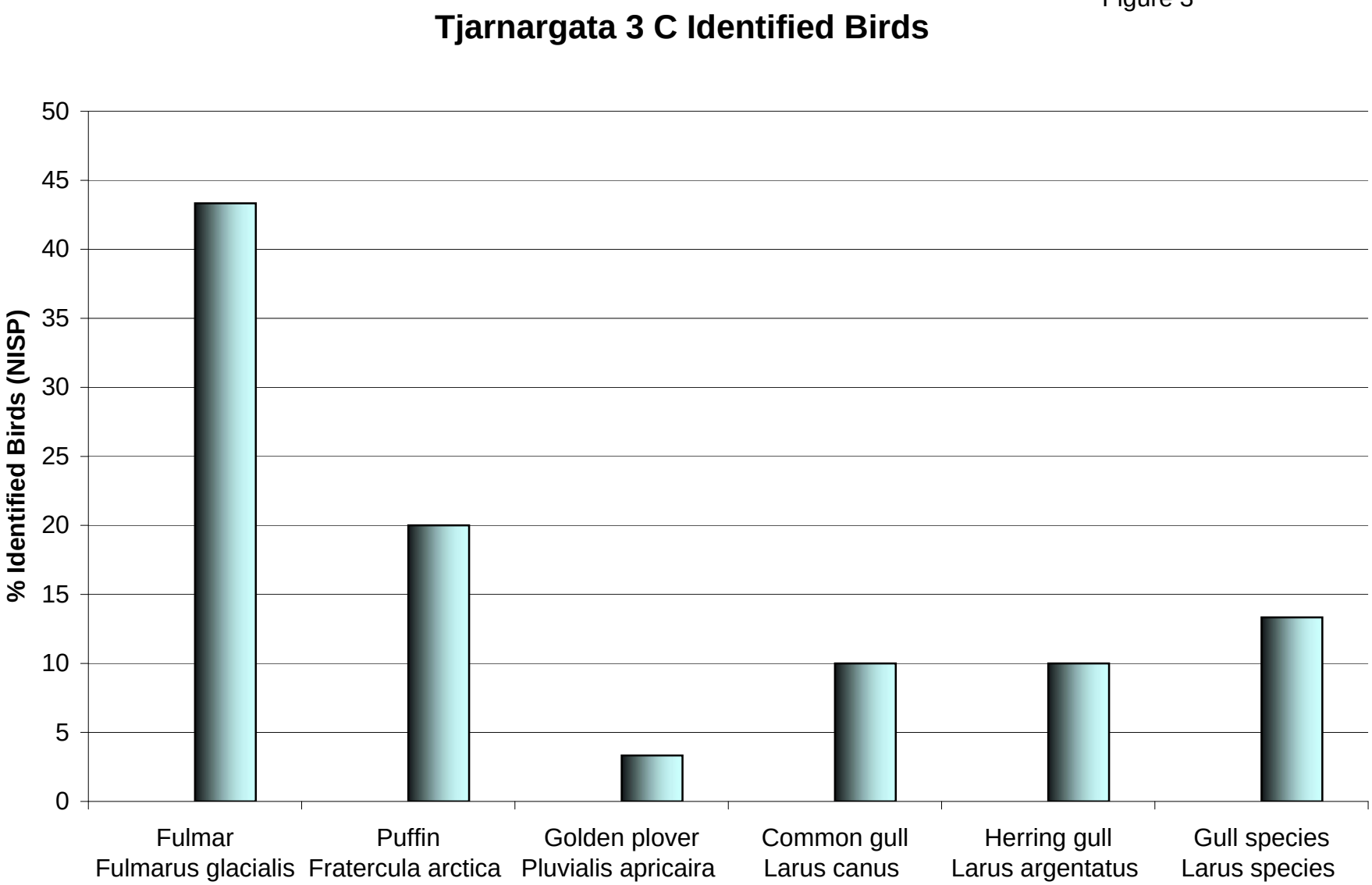

Tjarnargata 3 C Identified Birds
% Identified Birds (NISP)
50
45
40
35
30
25
20
15
10
5
0
Fulmar
Fulmarus glacialis
Puffin
Fratercula arctica
Golden plover
Pluvialis apricaira
Common gull
Larus canus
Herring gull
Larus argentatus
Gull species
Larus species

Figure 4

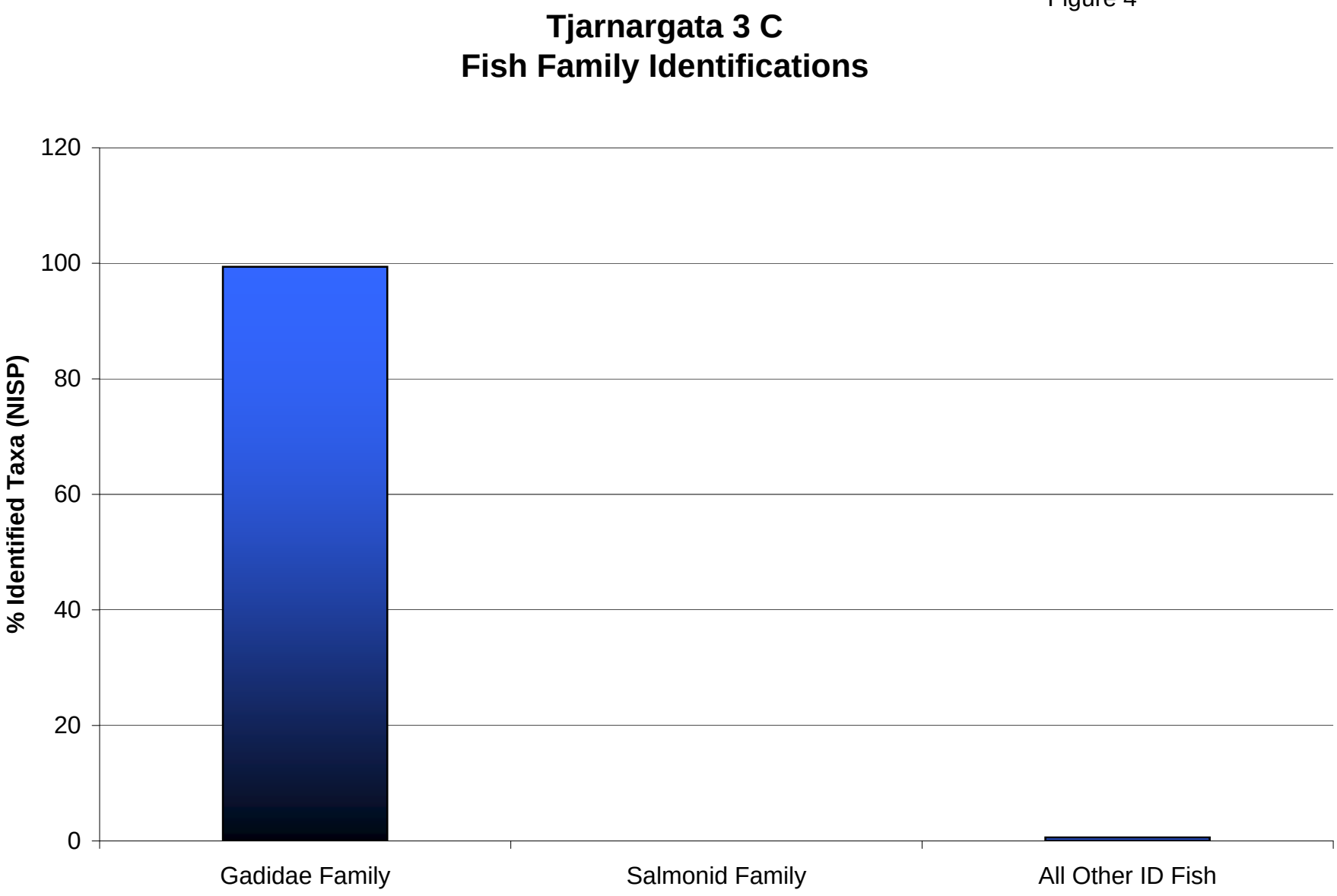

Tjarnargata 3 C
Fish Family Identifications
% Identified Taxa (NISP)
120
100
80
60
40
20
0
Gadidae Family
Salmonid Family
All Other ID Fish

Figure 5

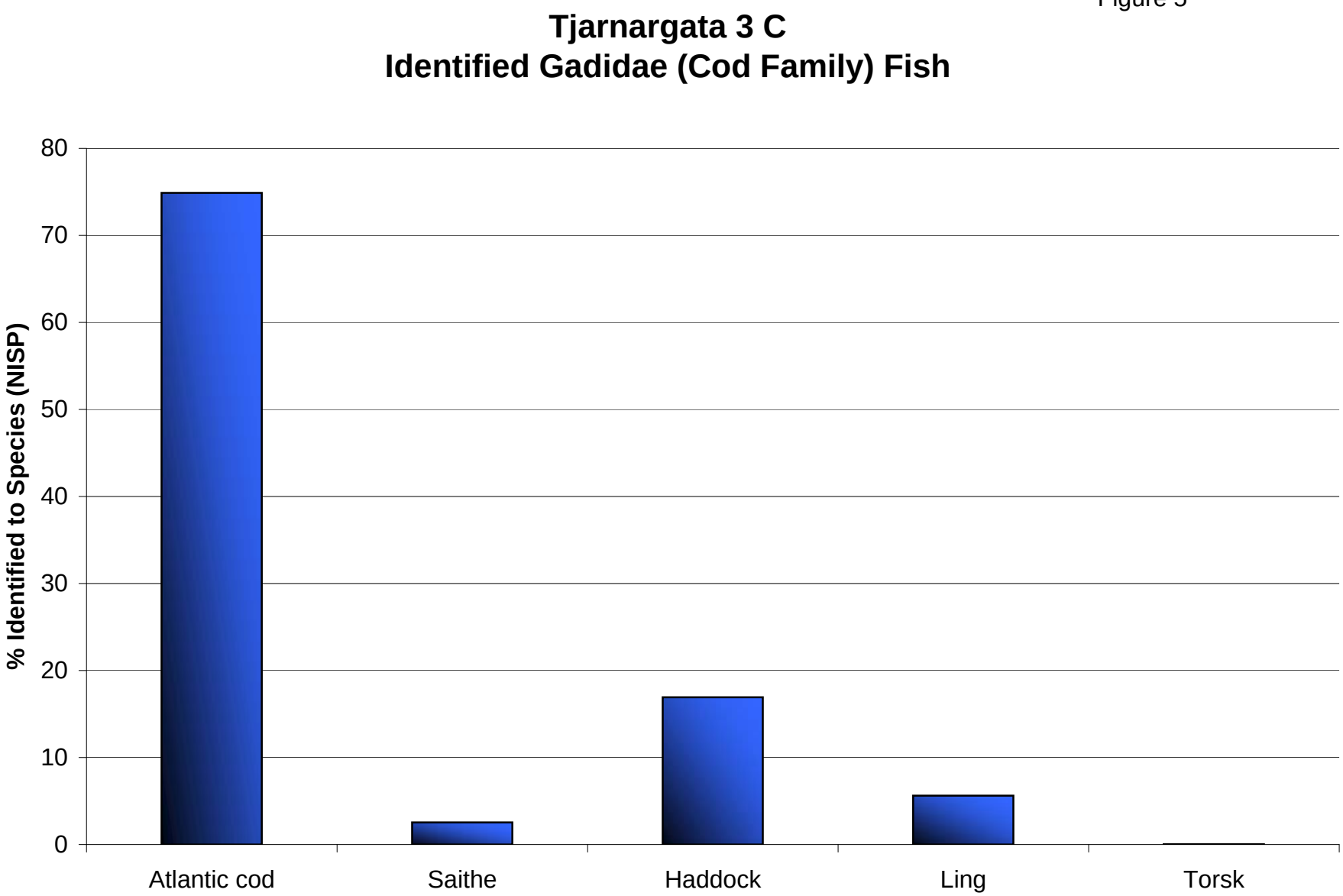

Tjarnargata 3 C
Identified Gadidae (Cod Family) Fish
% Identified to Species (NISP)
80
70
60
50
40
30
20
10
0
Atlantic cod
Saithe
Haddock
Ling
Torsk

Figure 6

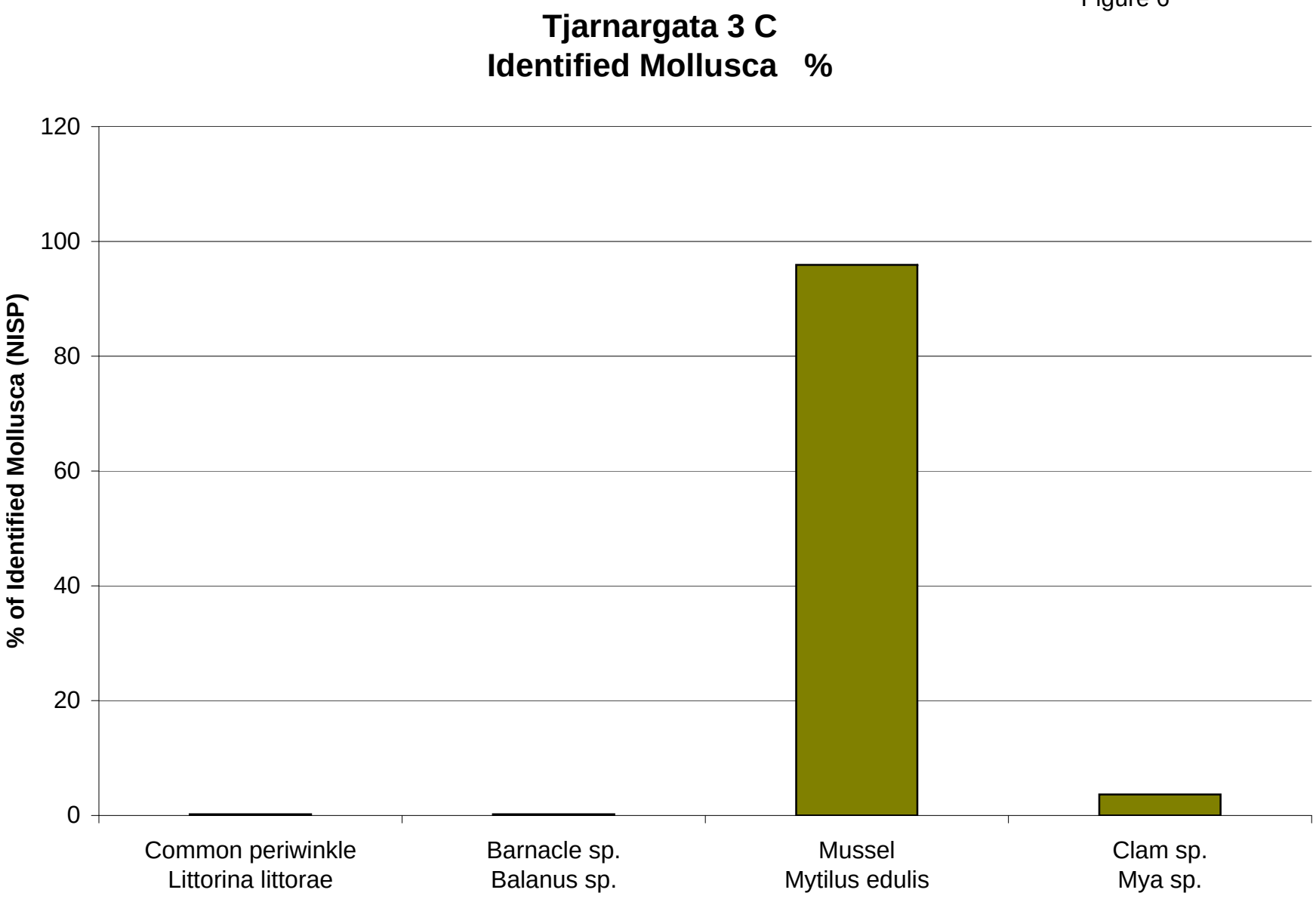

Tjarnargata 3 C
Identified Mollusca %
% of Identified Mollusca (NISP)
120
100
80
60
40
20
0
Common periwinkle
Littorina littorae
Barnacle sp.
Balanus sp.
Mussel
Mytilus edulis
Clam sp.
Mya sp.

Figure 7

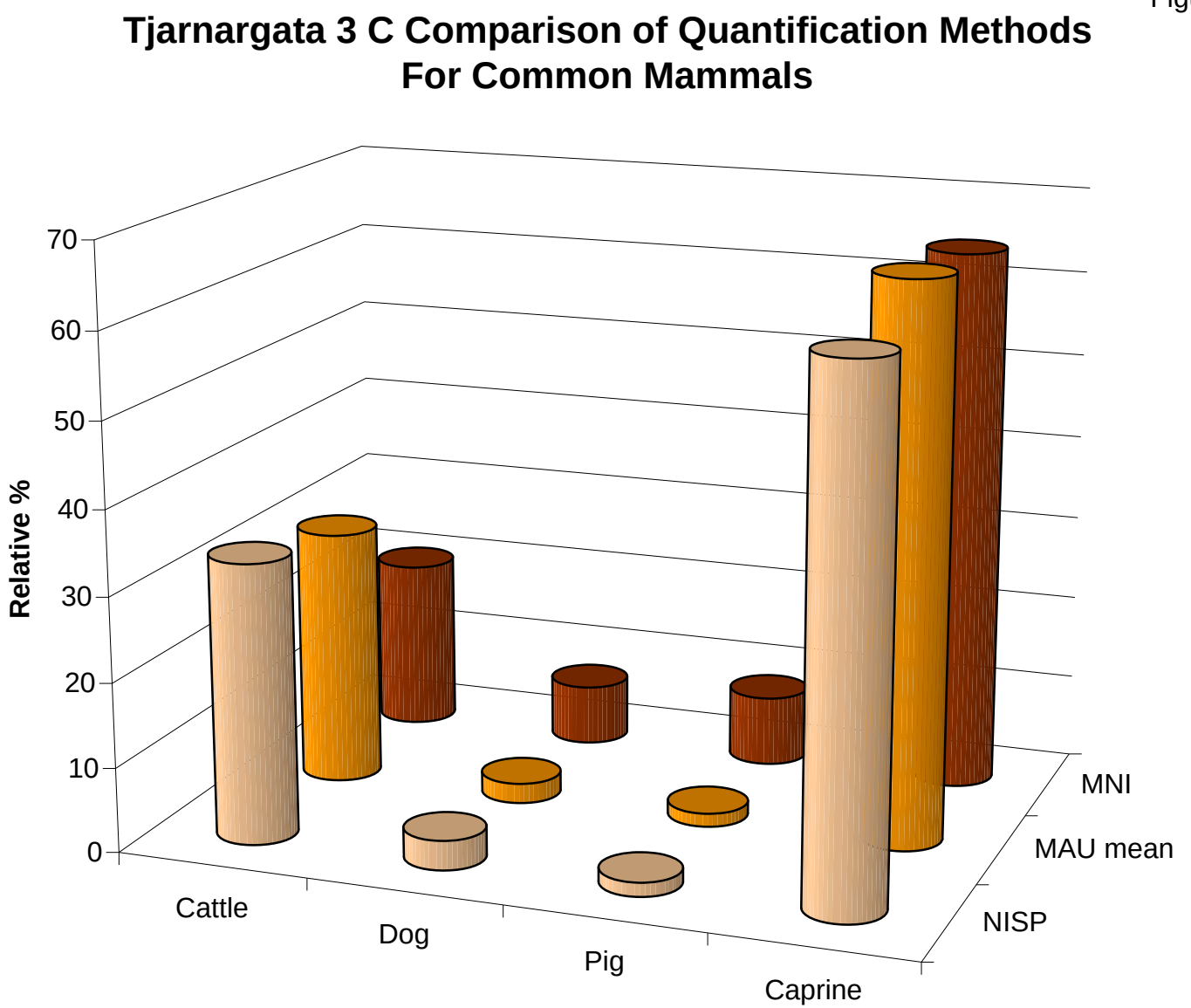

Tjarnargata 3 C Comparison of Quantification Methods
For Common Mammals
Relative %
70
60
50
40
30
20
10
0
Cattle
Dog
Pig
Caprine
MNI
MAU mean
NISP

Figure 8

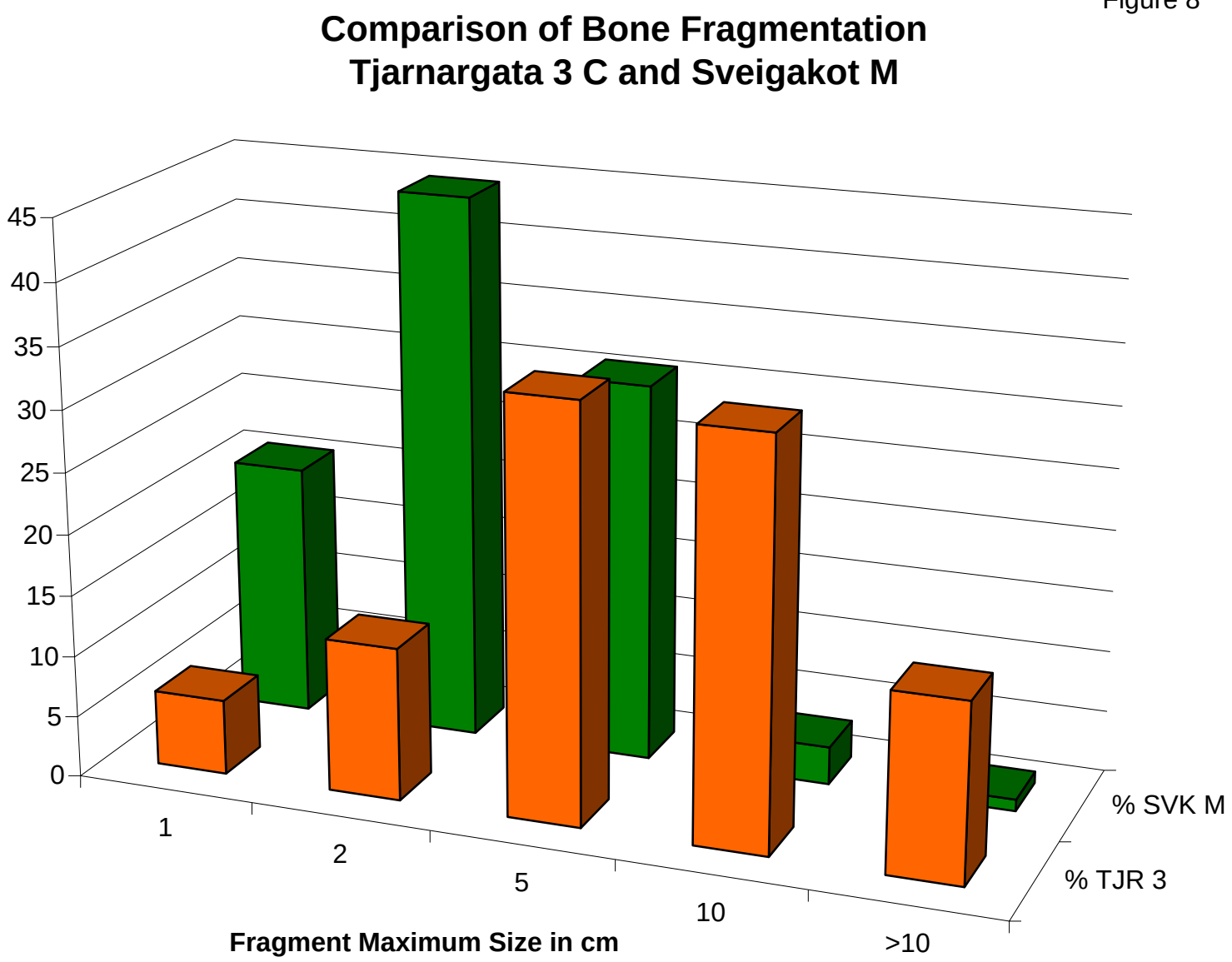

Comparison of Bone Fragmentation
Tjarnargata 3 C and Sveigakot M
45
40
35
30
25
20
15
10
5
0
1
2
5
10
>10
Fragment Maximum Size in cm
% SVK M
% TJR 3

Figure 9

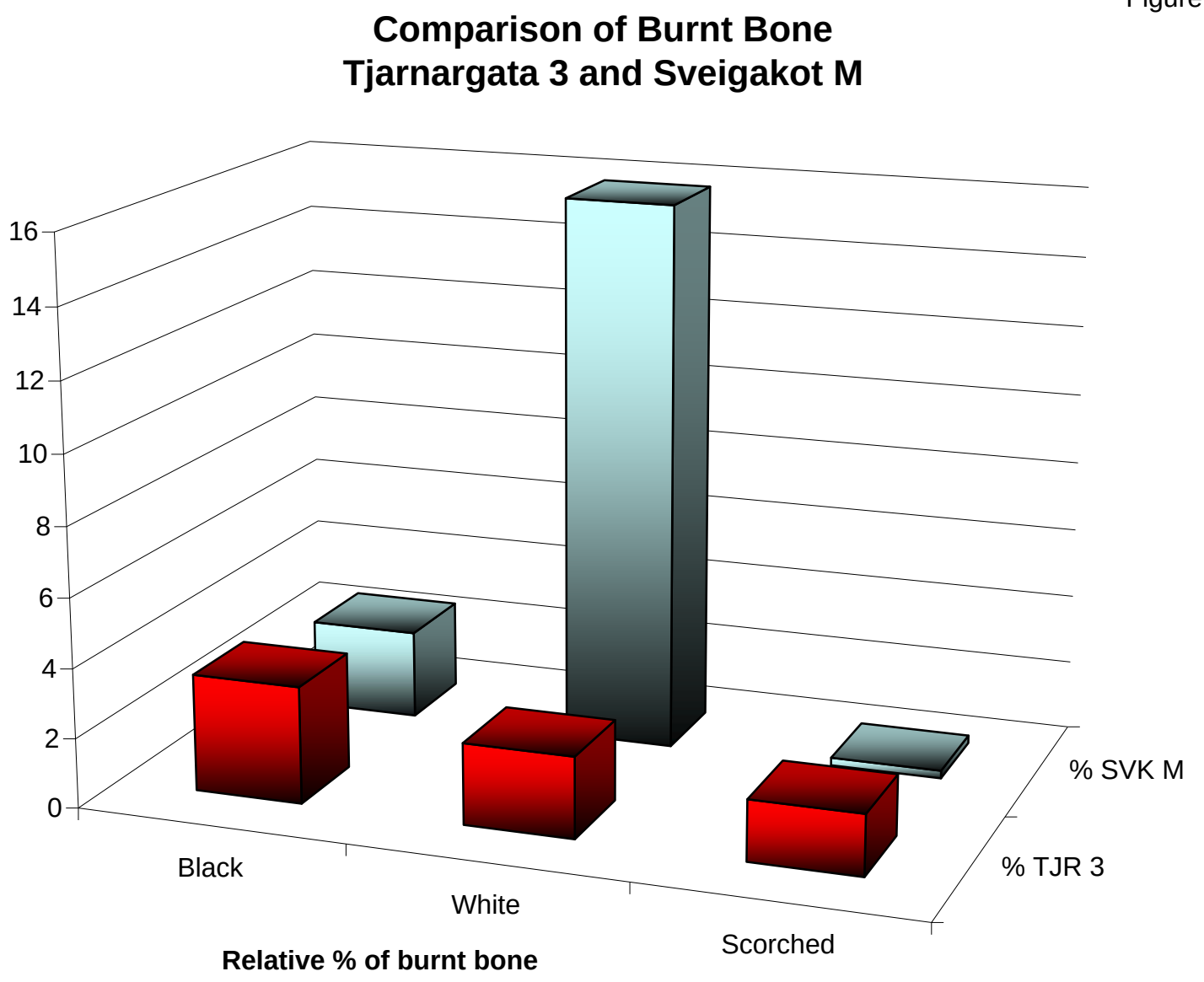

Comparison of Burnt Bone
Tjarnargata 3 and Sveigakot M
16
14
12
10
8
6
4
2
0
Black
White
Scorched
Relative % of burnt bone
% SVK M
% TJR 3

Figure 10

Comparison of Animal Gnawing on Bones from Tjarnargata 3 C and Sveigakot M

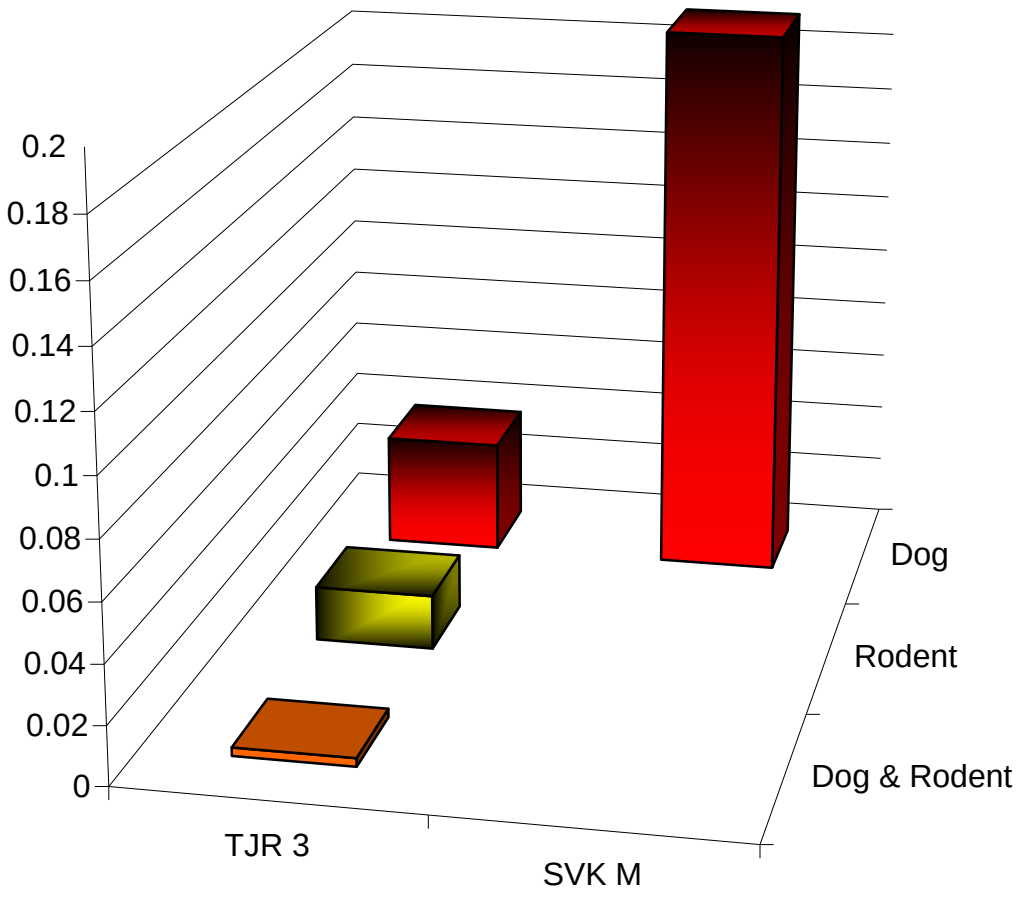


Figure 11

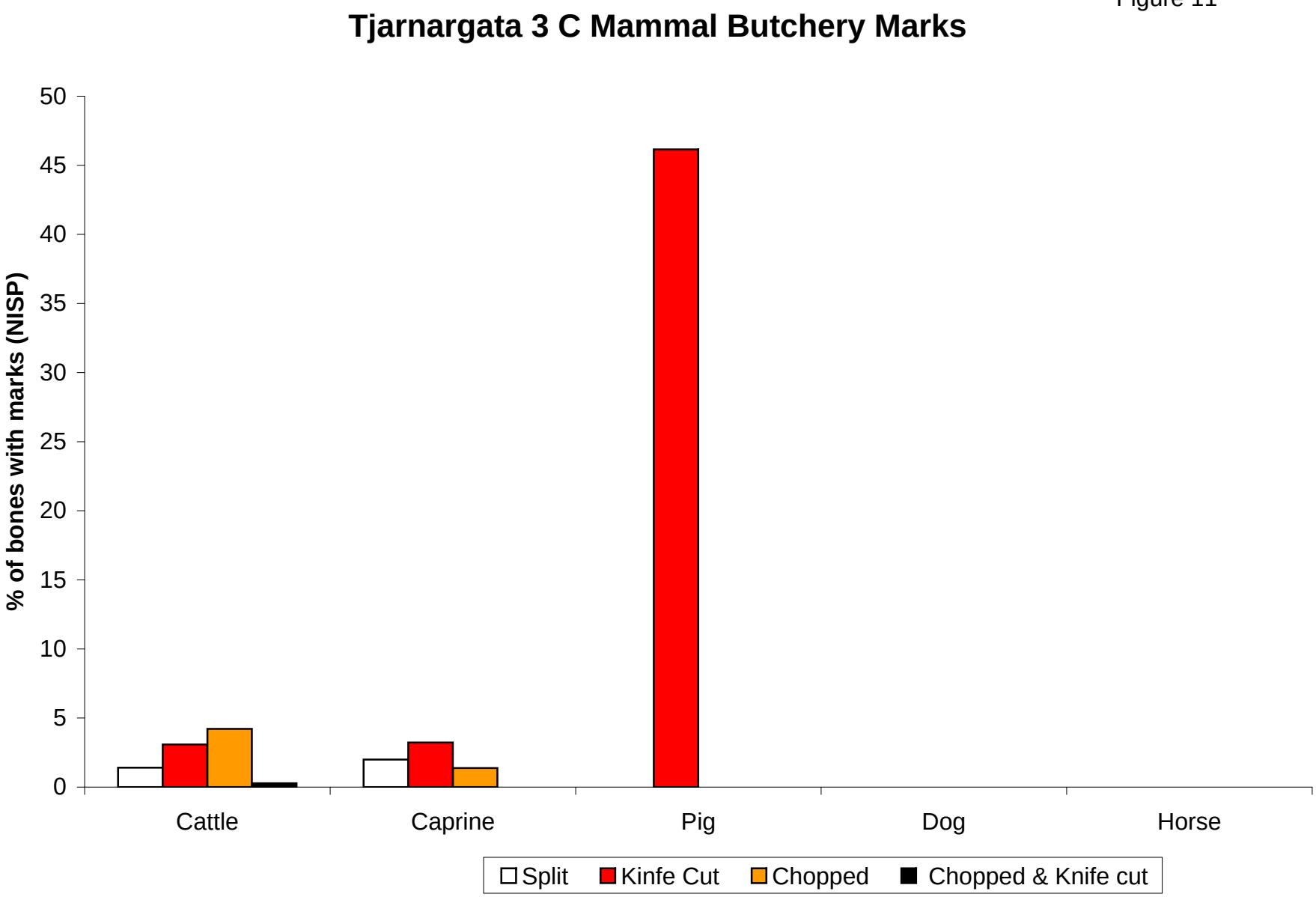

Tjarnargata 3 C Mammal Butchery Marks
% of bones with marks (NISP)
50
45
40
35
30
25
20
15
10
5
0
Cattle
Caprine
Pig
Dog
Horse
Split
Kinfe Cut
Chopped
Chopped & Knife cut

Figure 12

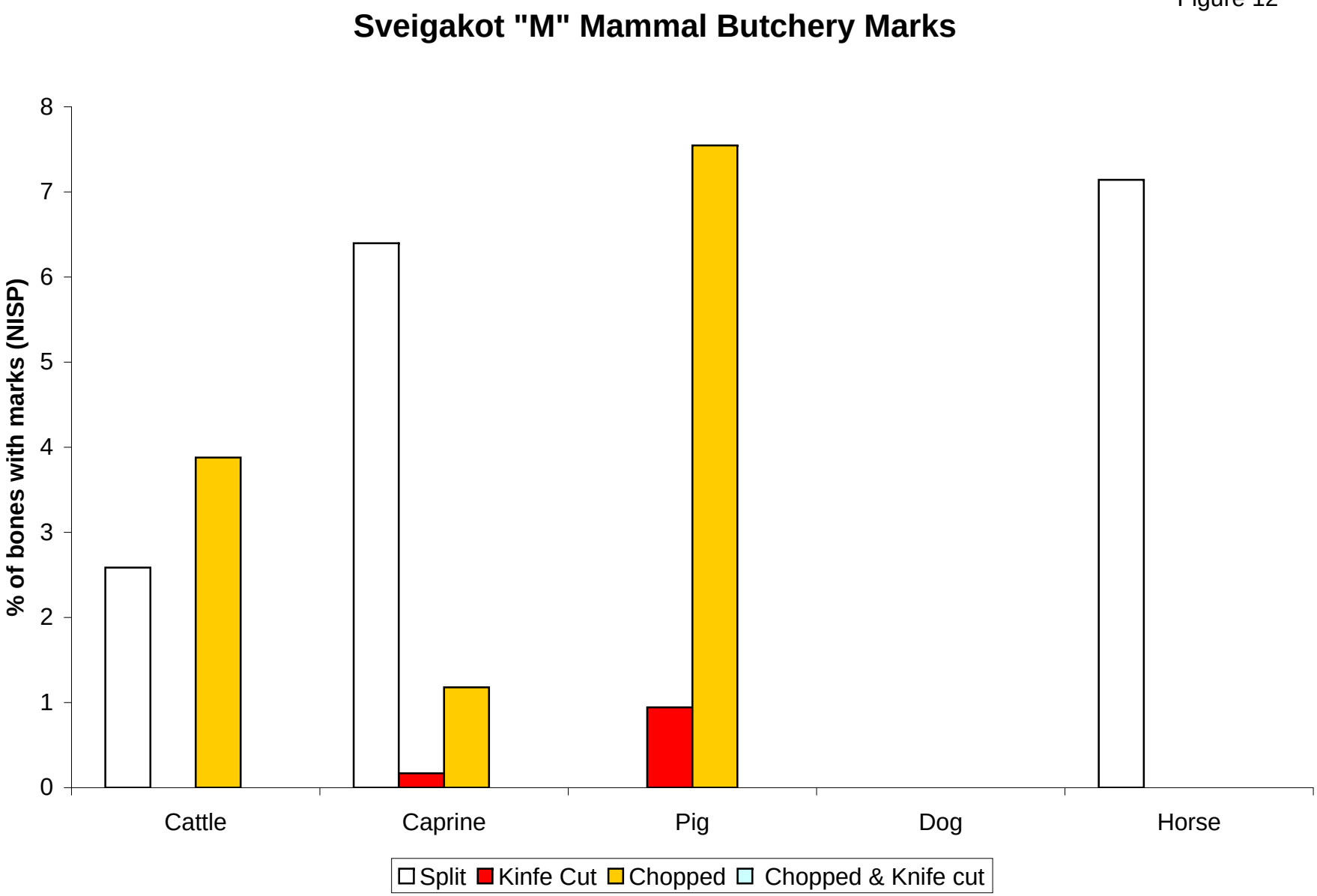

Sveigakot "M" Mammal Butchery Marks
% of bones with marks (NISP)
0
1
2
3
4
5
6
7
8
Cattle
Caprine
Pig
Dog
Horse
Split
Kinfe Cut
Chopped
Chopped & Knife cut

Figure 13

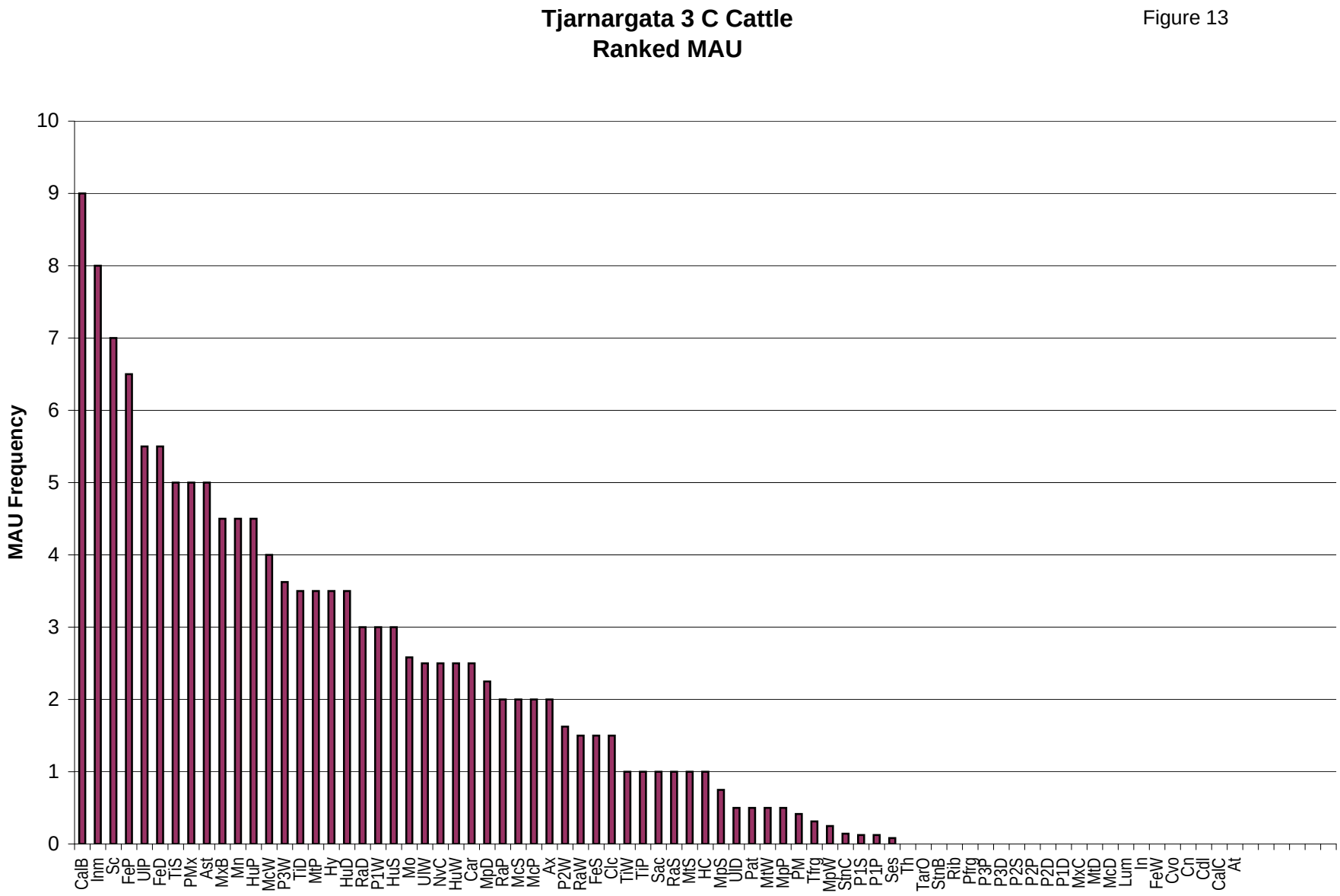
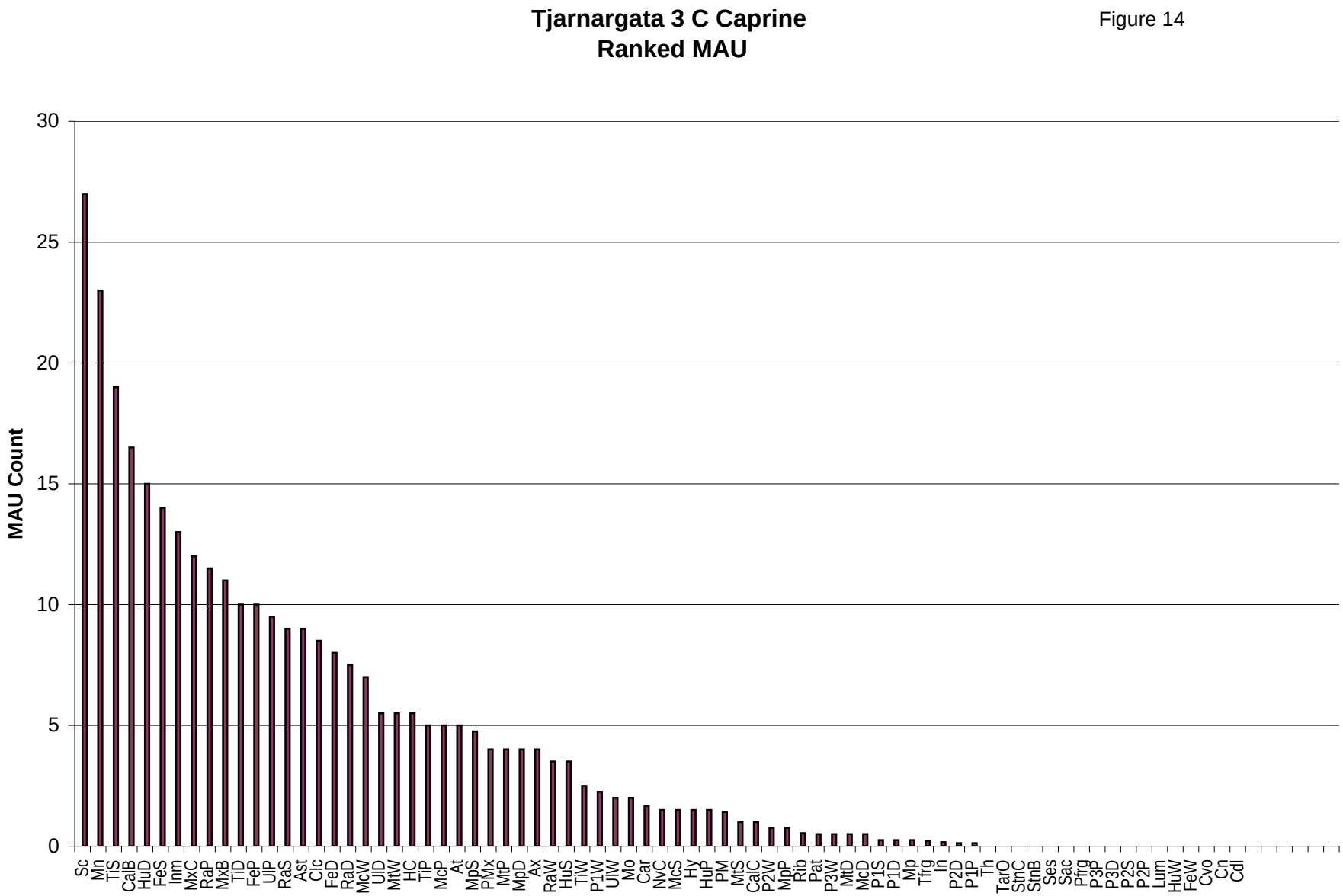

Tjarnargata 3 C Cattle
Ranked MAU
MAU Frequency
0
1
2
3
4
5
6
7
8
9
10
CalB
Inm
Sc
FeP
UlP
FeD
TiS
PMx
Ast
MxB
Mn
HuP
McW
P3W
TiD
MtP
Hy
HuD
RaD
P1W
HuS
Mo
UlW
NvC
HuW
Car
MpD
RaP
McS
McP
Ax
P2W
RaW
FeS
Clc
TiW
TiP
Sac
RaS
MtS
HC
MpS
UlD
Pat
MtW
MpP
PM
Tfrg
MpW
StnC
P1S
P1P
Ses
Th
TarO
StnB
Rib
Pfrg
P3P
P3D
P2S
P2P
P2D
P1D
MxC
MtD
McD
Lum
In
FeW
Cvo
Cn
Cdl
CalC
At

Figure 14


Tjarnargata 3 C Caprine
Ranked MAU
MAU Count
30
25
20
15
10
5
0
Sc
Mn
TiS
CalB
HuD
FeS
Inm
MxC
RaP
MxB
TiD
FeP
UlP
RaS
Ast
Clc
FeD
RaD
McW
UlD
MtW
HC
TiP
McP
At
MpS
PMx
MtP
MpD
Ax
RaW
HuS
TiW
P1W
UlW
Mo
Car
NvC
McS
Hy
HuP
PM
MtS
CalC
P2W
MpP
Rib
Pat
P3W
MtD
McD
P1S
P1D
Mp
Tfrg
In
P2D
P1P
Th
TarO
SnC
StnB
Ses
Sac
Pfrg
P3P
P3D
P2S
P2P
Lum
HuW
FeW
Cvo
Cn
Cdl

Tjarnargata 3 C Pig
Ranked MAU

Figure 15

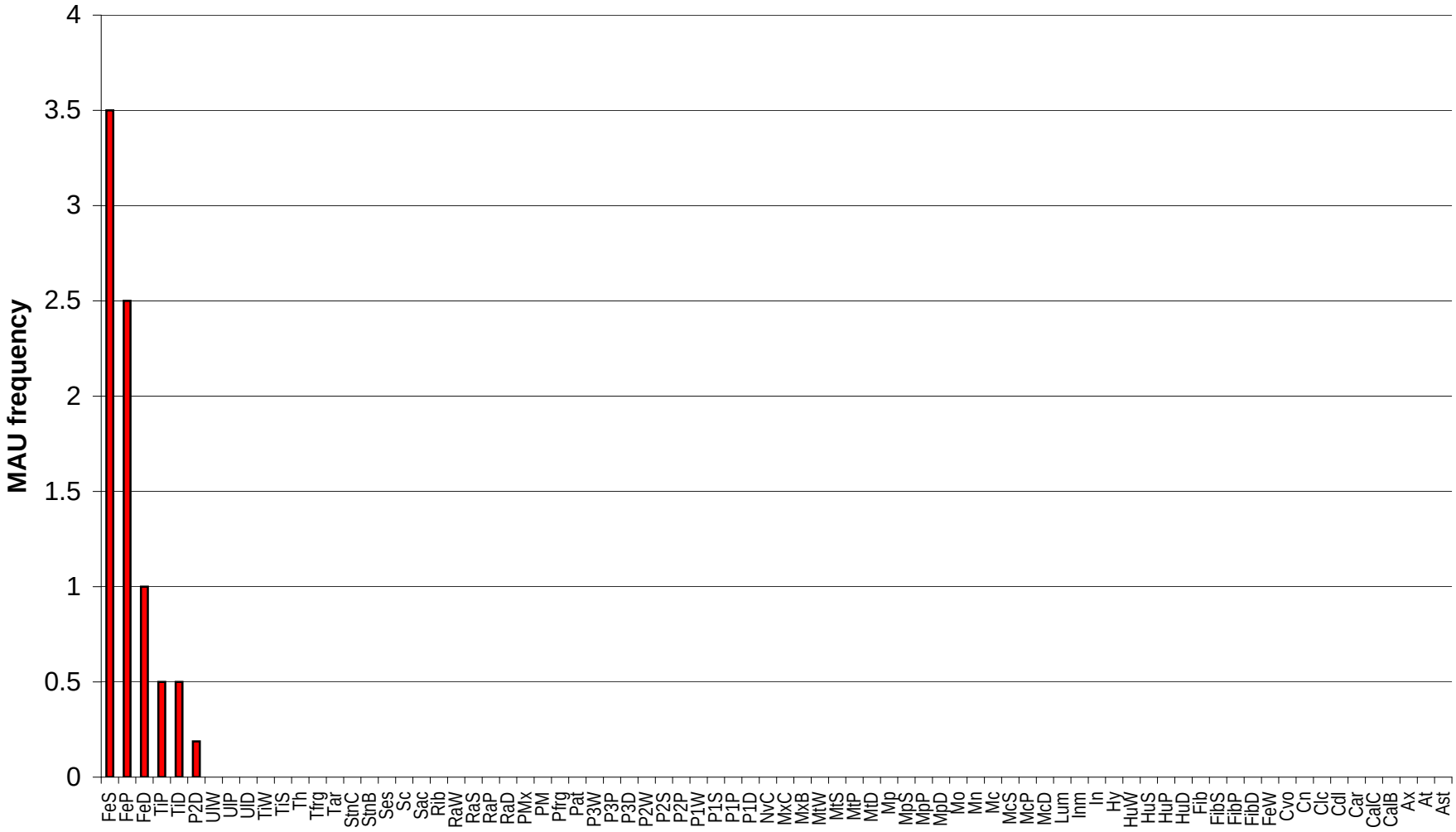


Figure 16

Tjarnargata 3 c Cattle Bone Element Distribution

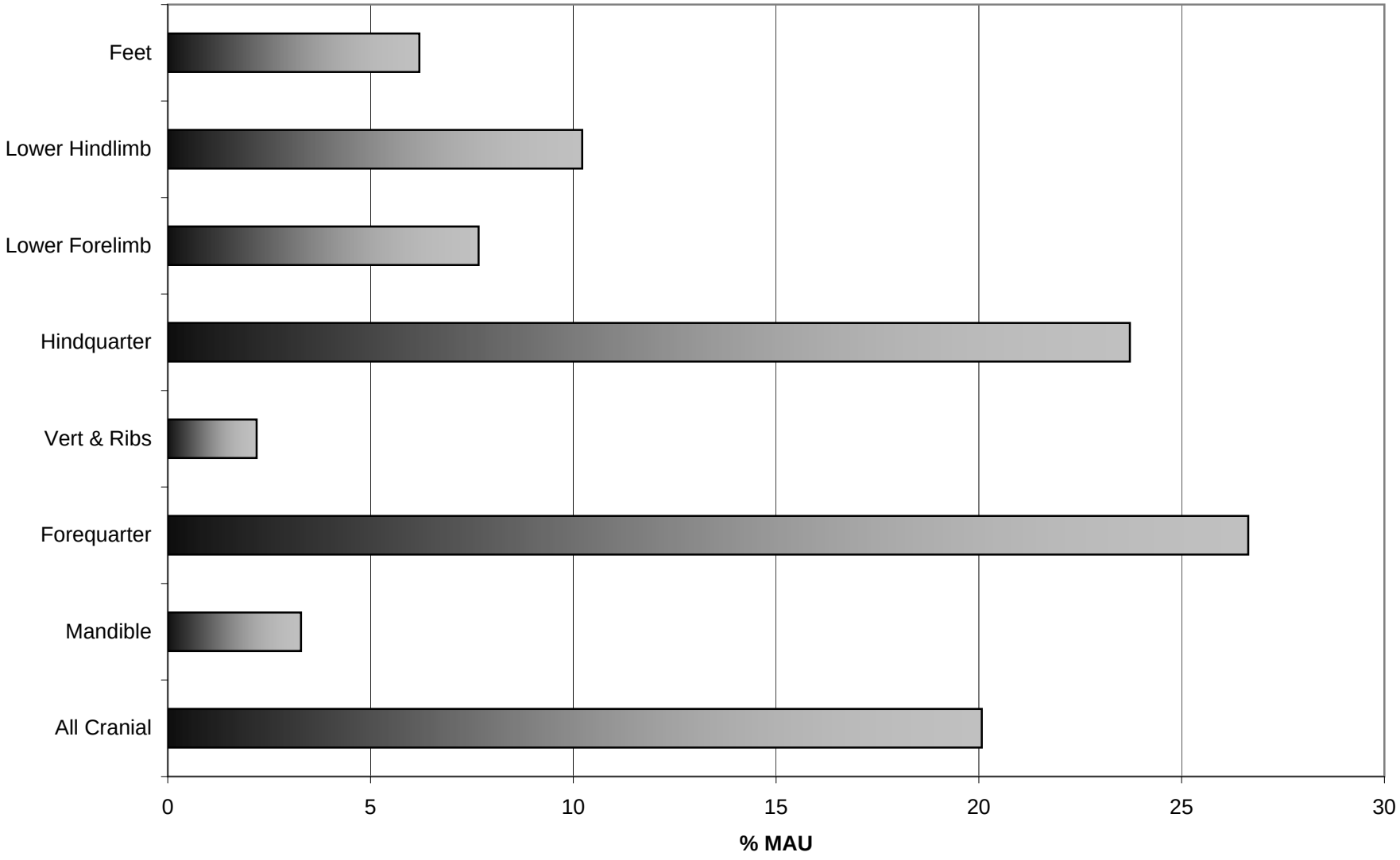


Figure 17

Tjarnargata 3 c CAPRINE Bone Element Distribution

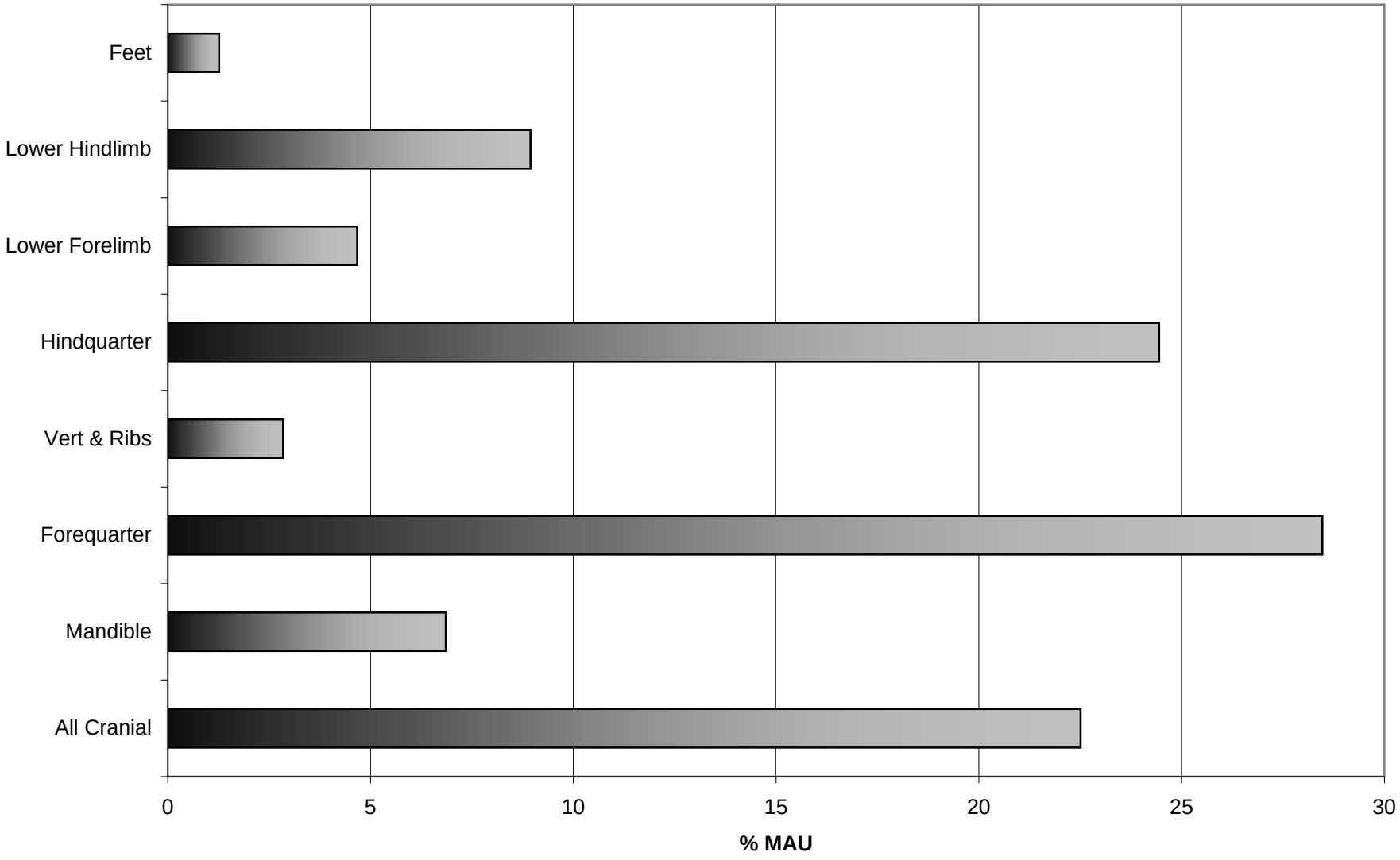
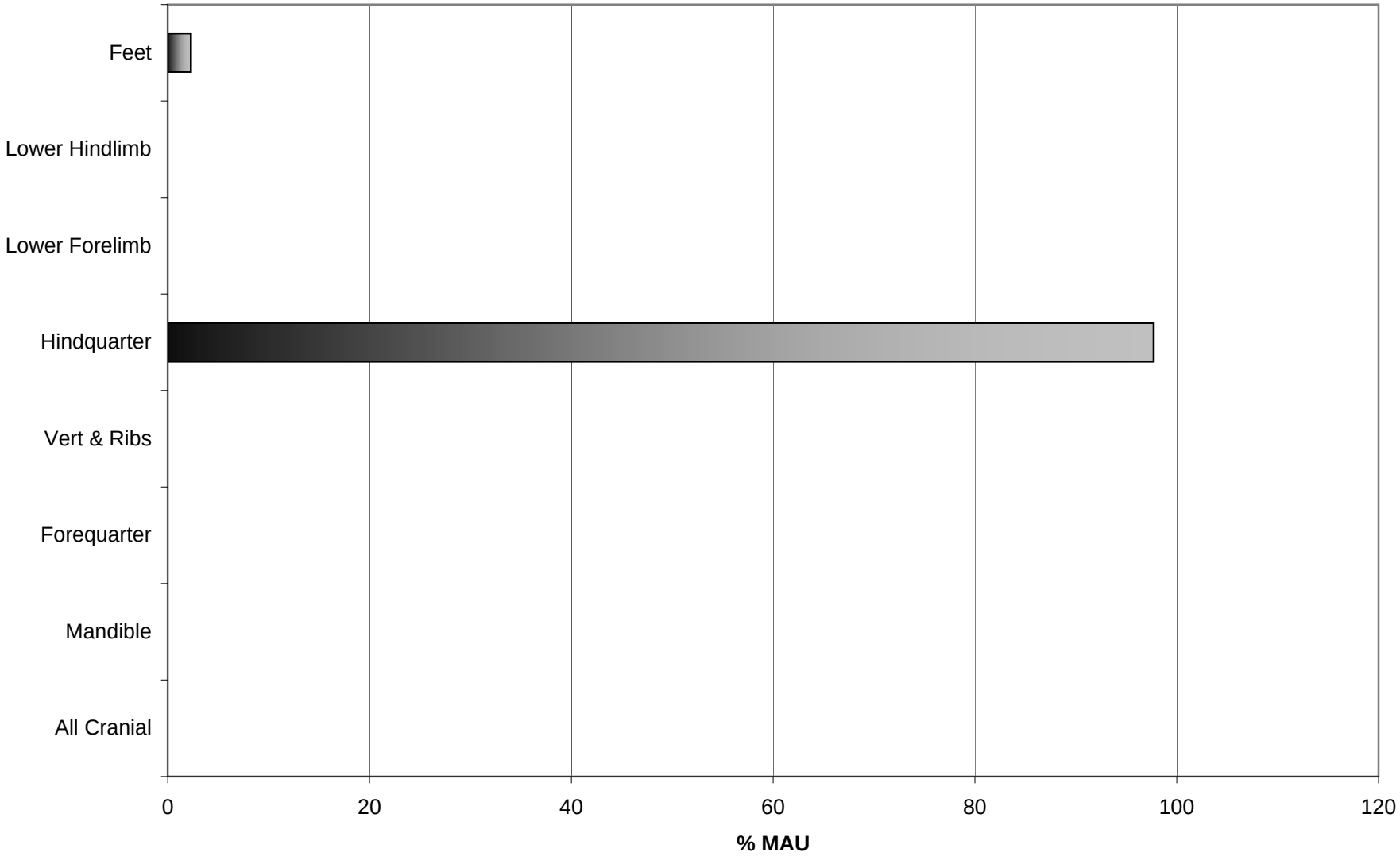


Figure 18

Tjarnargata 3 c Pig Bone Element Distribution



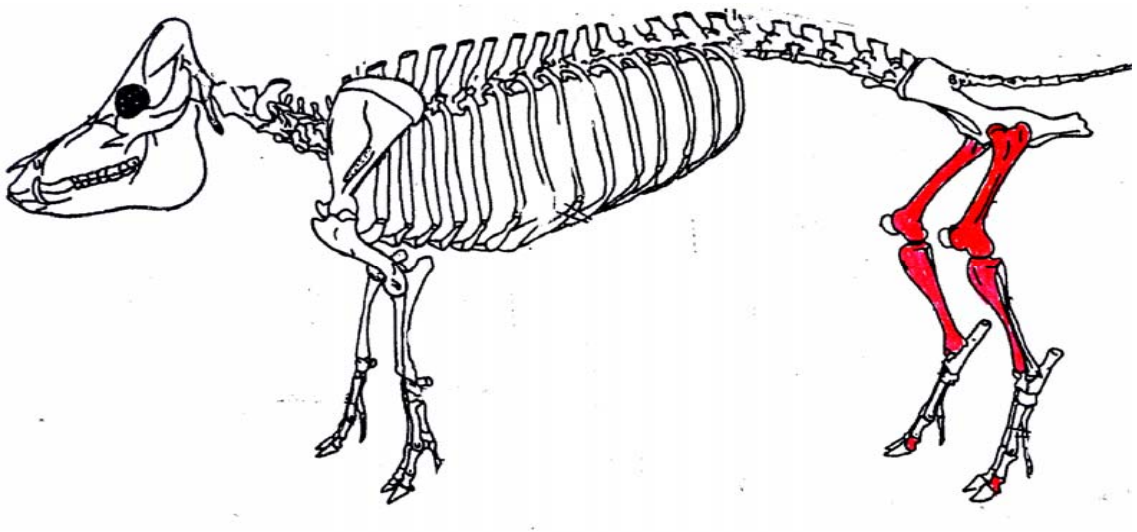


Figure 19

Figure 20

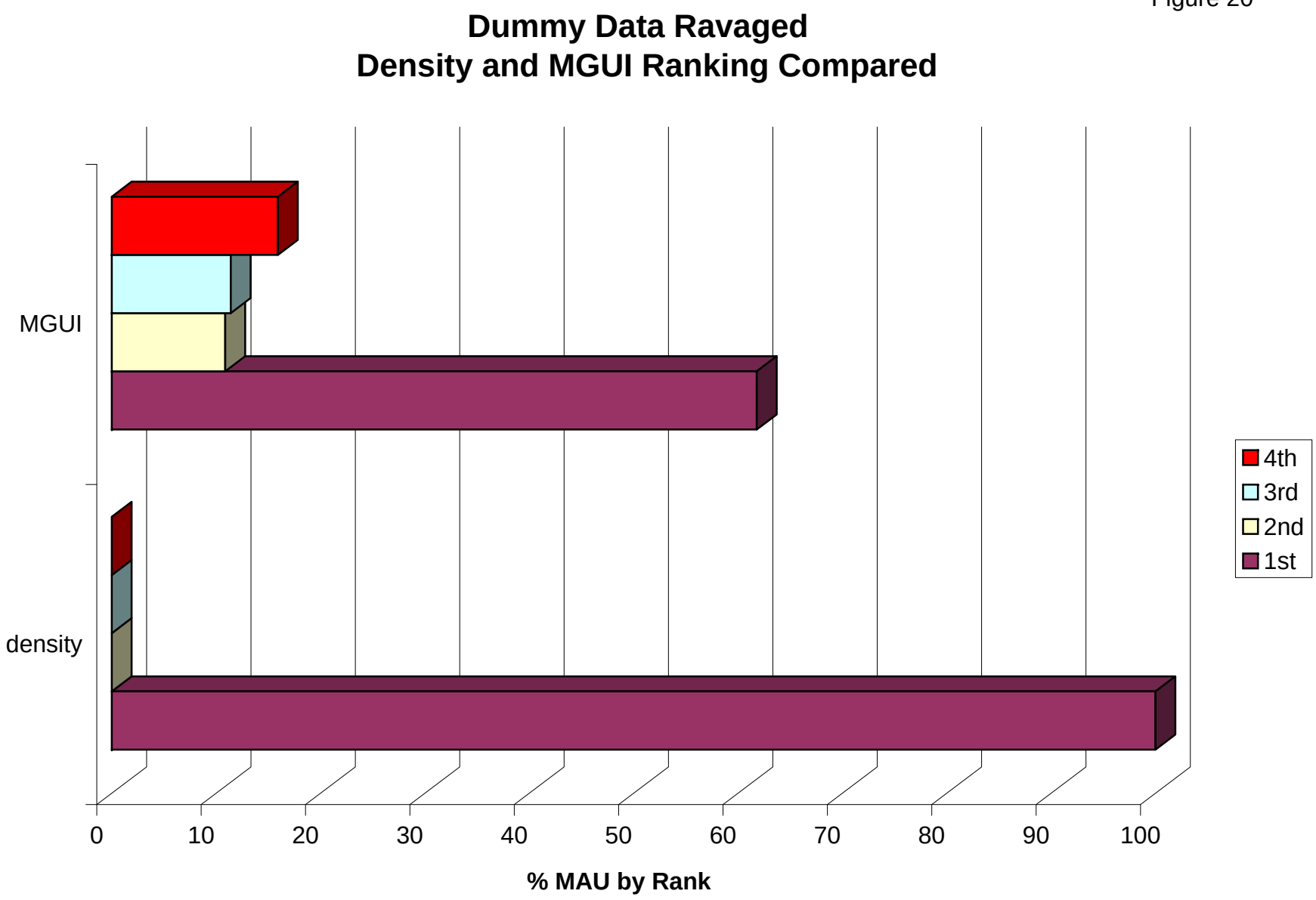
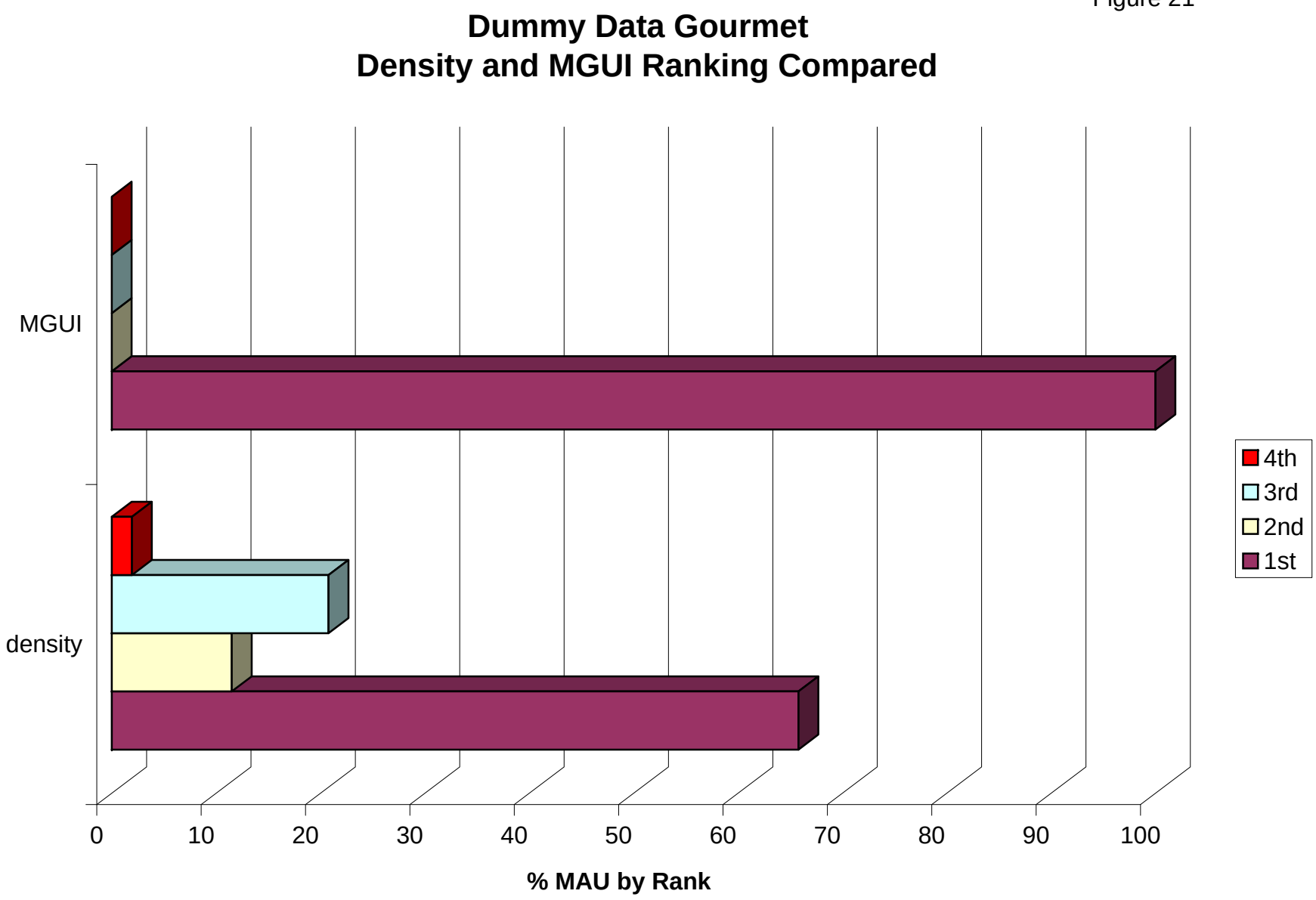

Dummy Data Ravaged
Density and MGUI Ranking Compared
MGUI
density
0
10
20
30
40
50
60
70
80
90
100
% MAU by Rank
4th
3rd
2nd
1st

Figure 21


Dummy Data Gourmet
Density and MGUI Ranking Compared
MGUI
density
0
10
20
30
40
50
60
70
80
90
100
% MAU by Rank
4th
3rd
2nd
1st

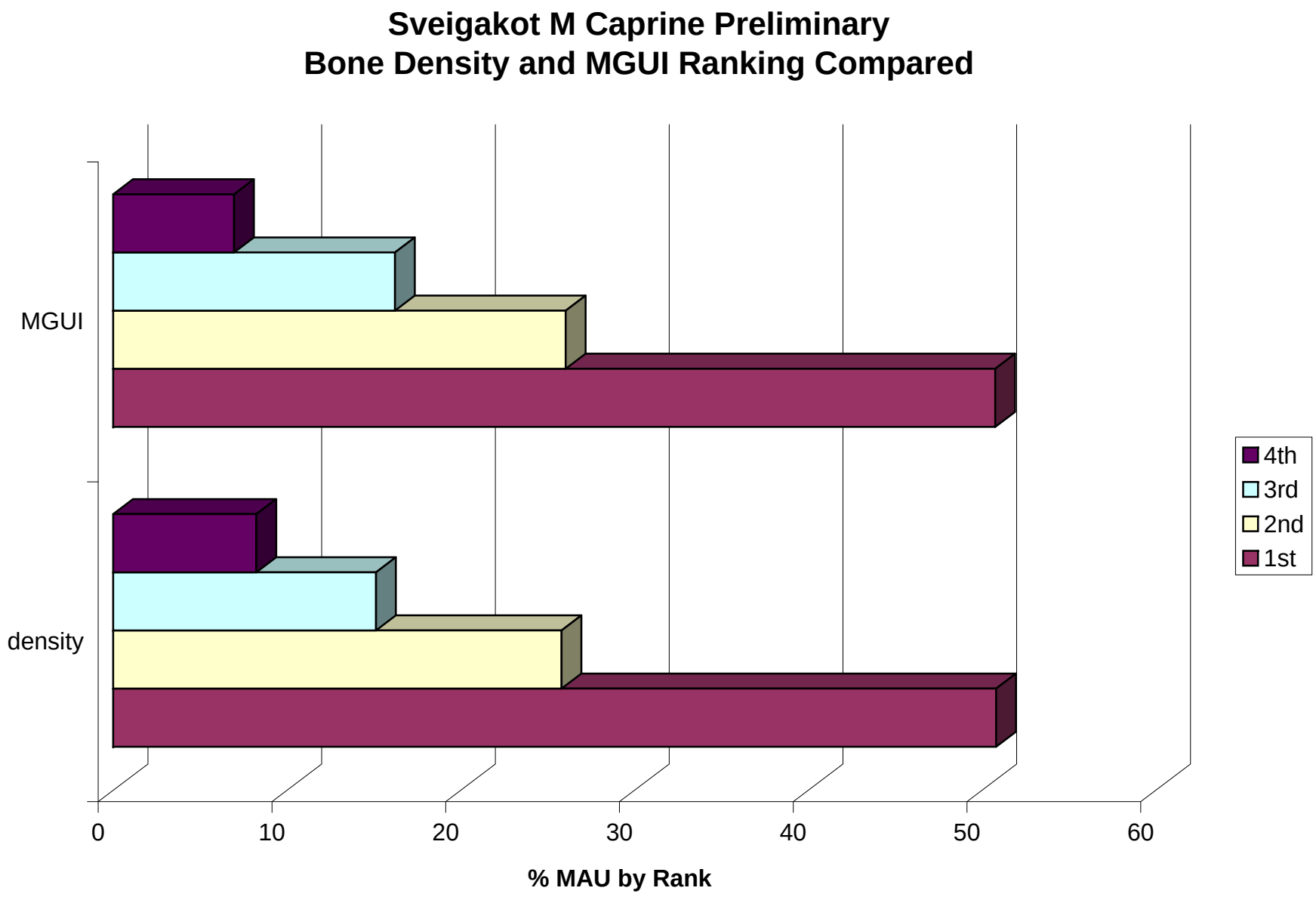

Sveigakot M Caprine Preliminary
Bone Density and MGUI Ranking Compared
MGUI
density
0
10
20
30
40
50
60
% MAU by Rank
4th
3rd
2nd
1st

Figure 23

Tjarnargata 3 c Pig Bone Density and MGUI Ranking Compared

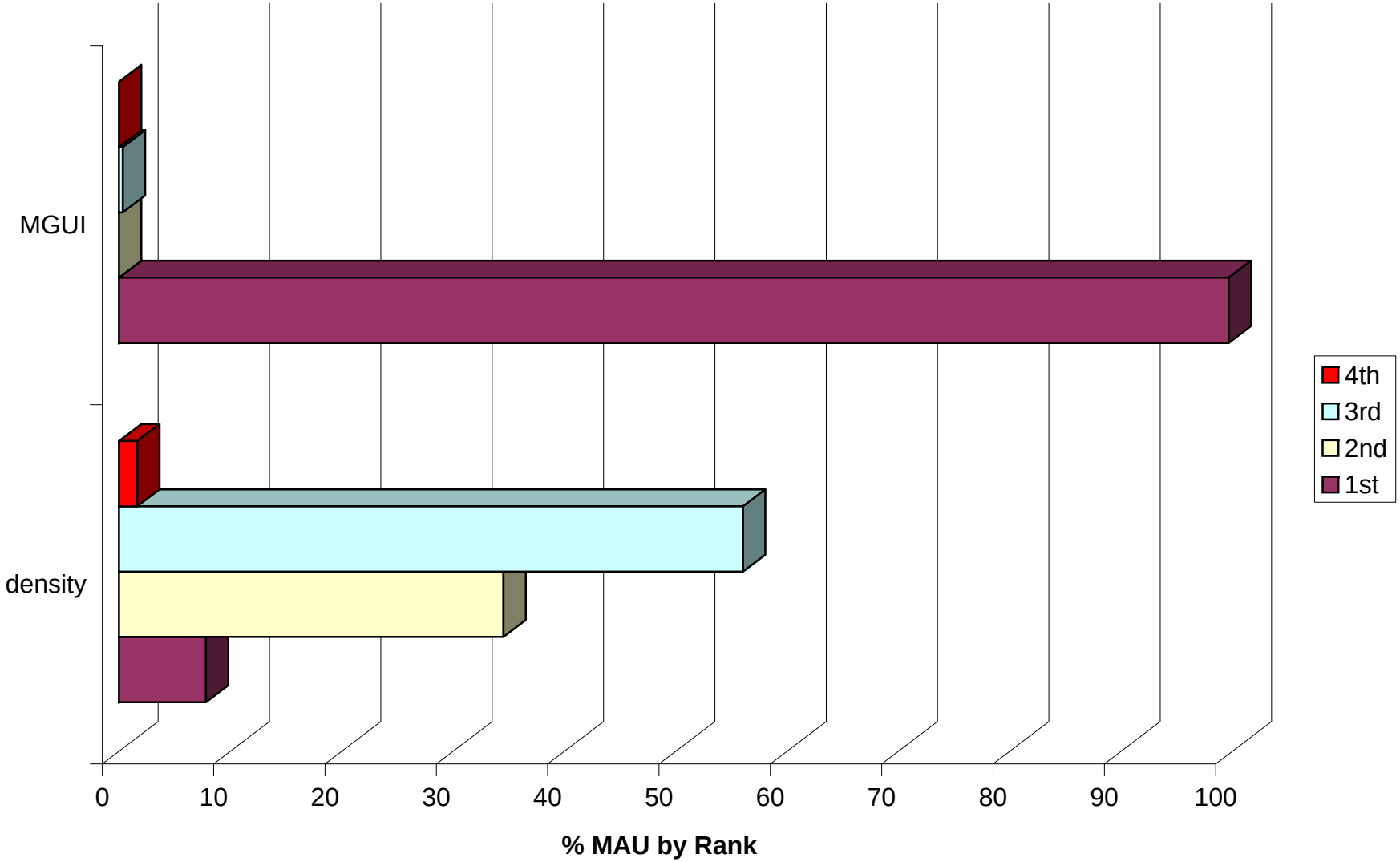


Figure 24

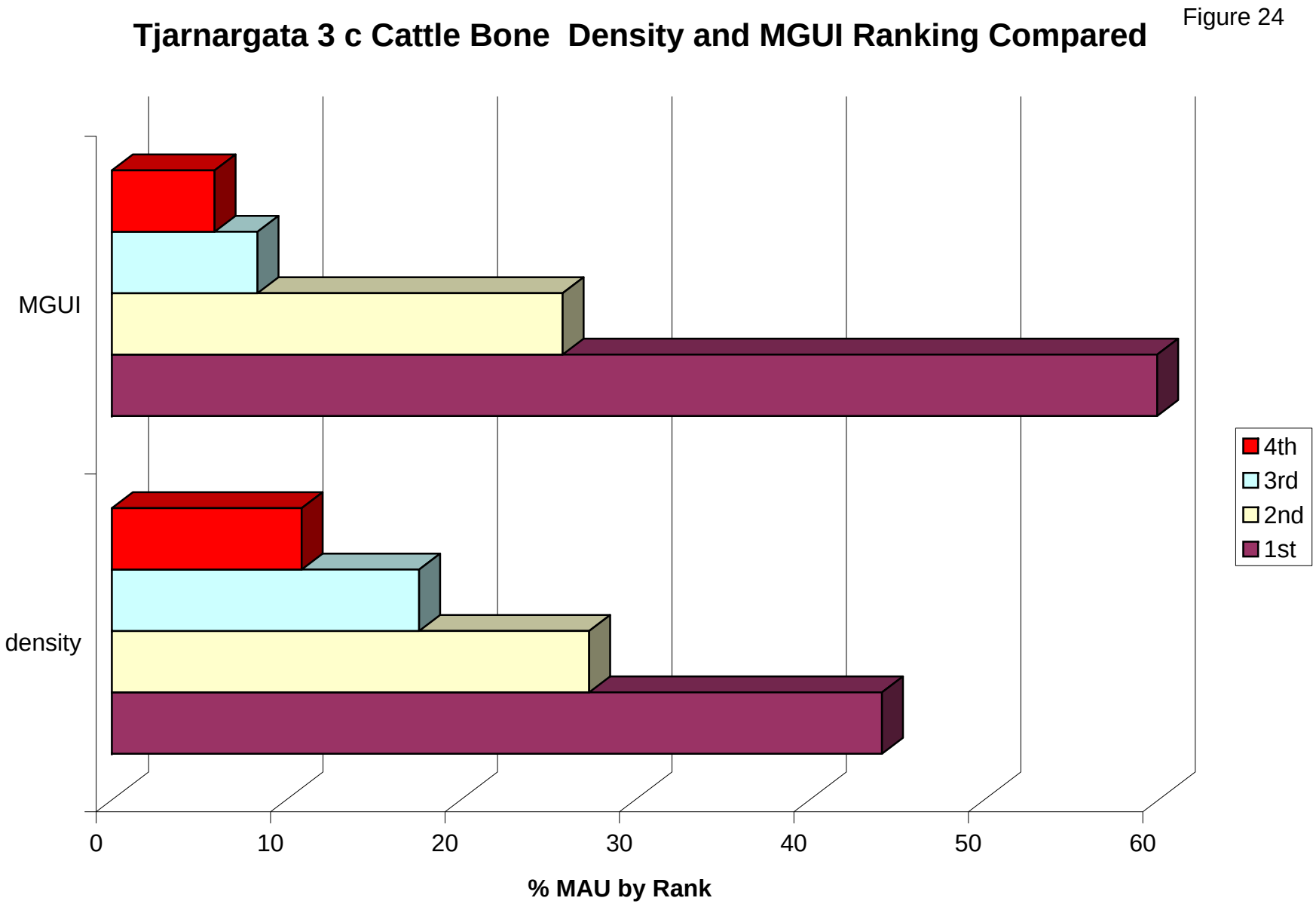

Tjarnargata 3 c Cattle Bone Density and MGUI Ranking Compared
MGUI
density
0
10
20
30
40
50
60
% MAU by Rank
4th
3rd
2nd
1st

Figure 25

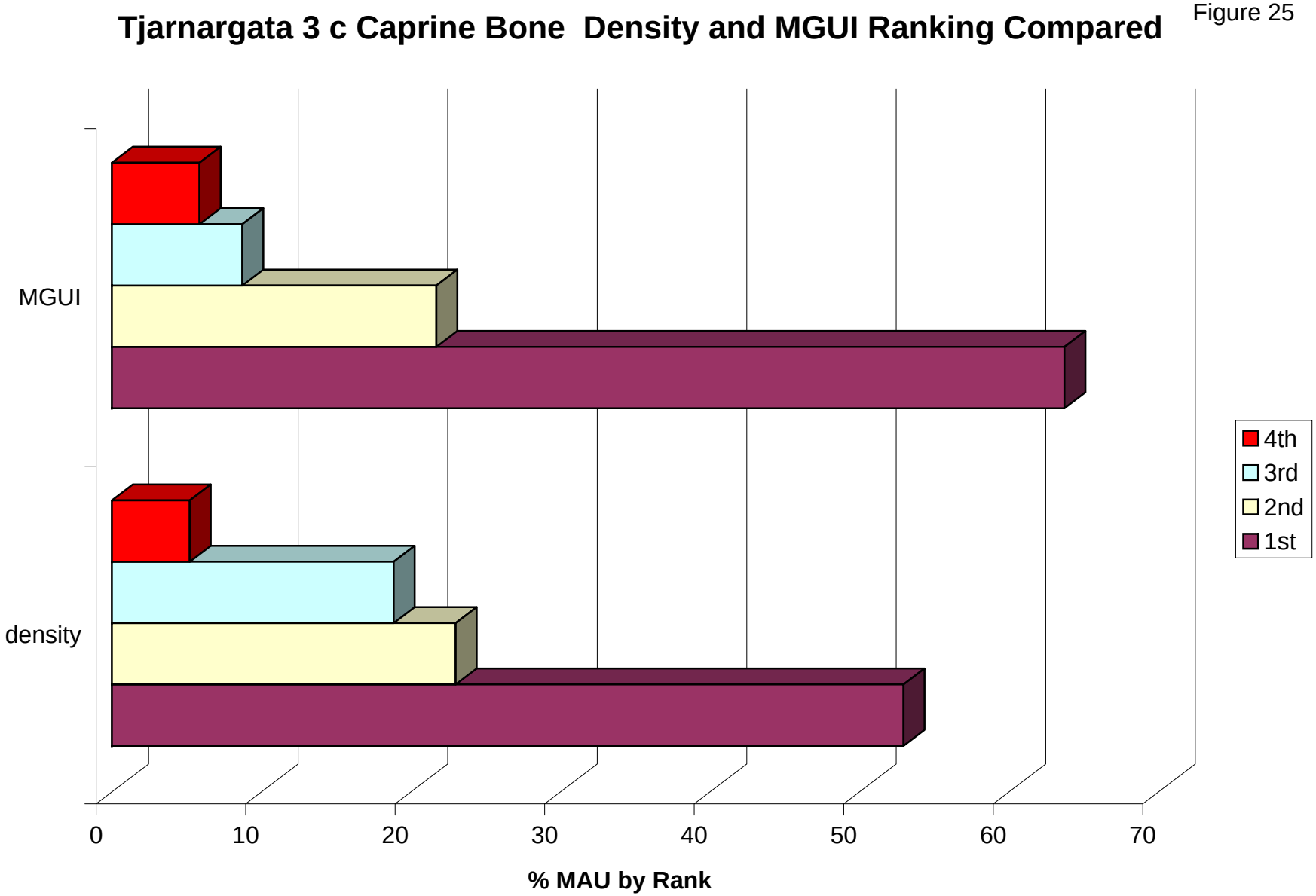

Tjarnargata 3 c Caprine Bone Density and MGUI Ranking Compared
MGUI
density
0
10
20
30
40
50
60
70
% MAU by Rank
4th
3rd
2nd
1st

Figure 26

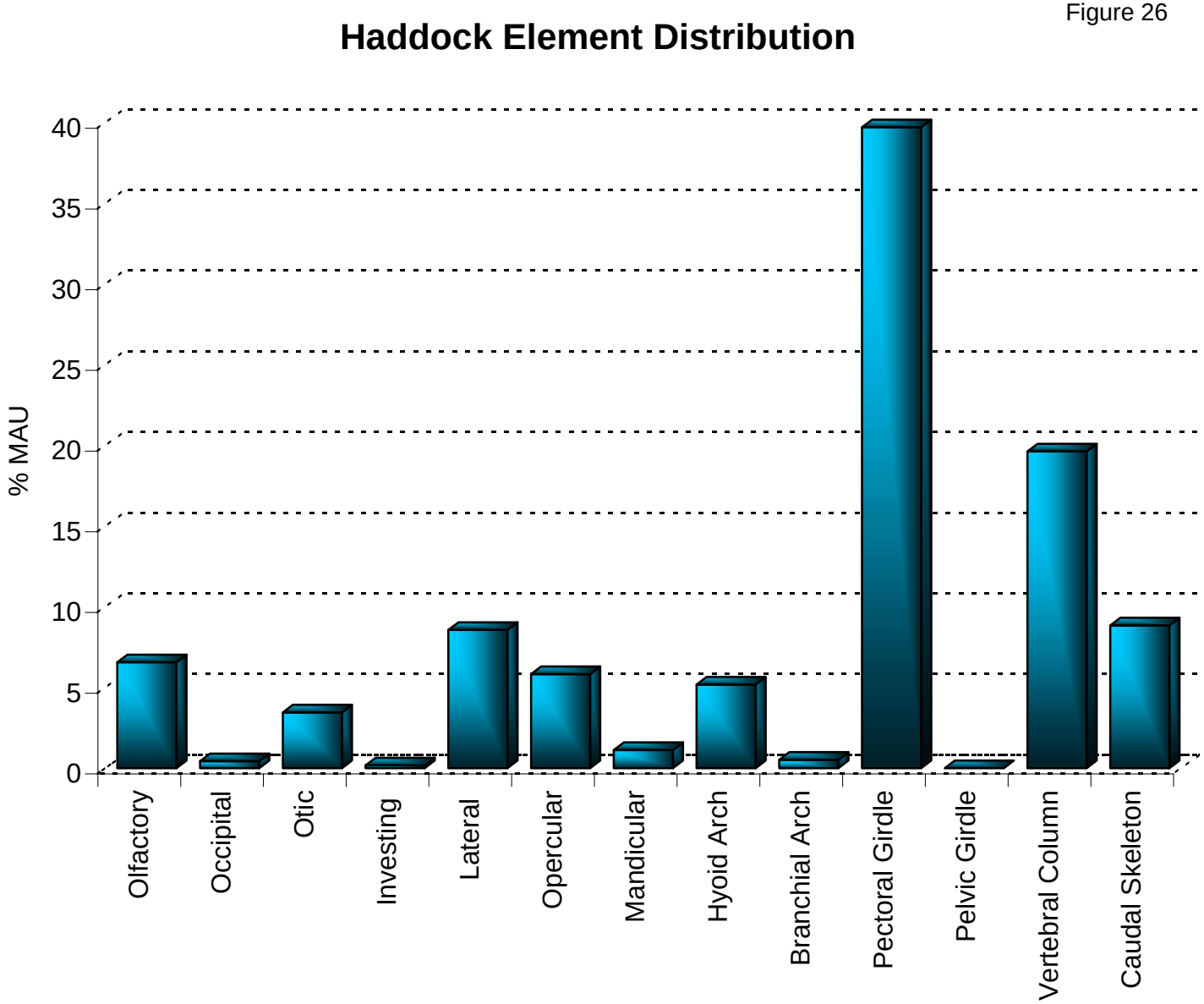
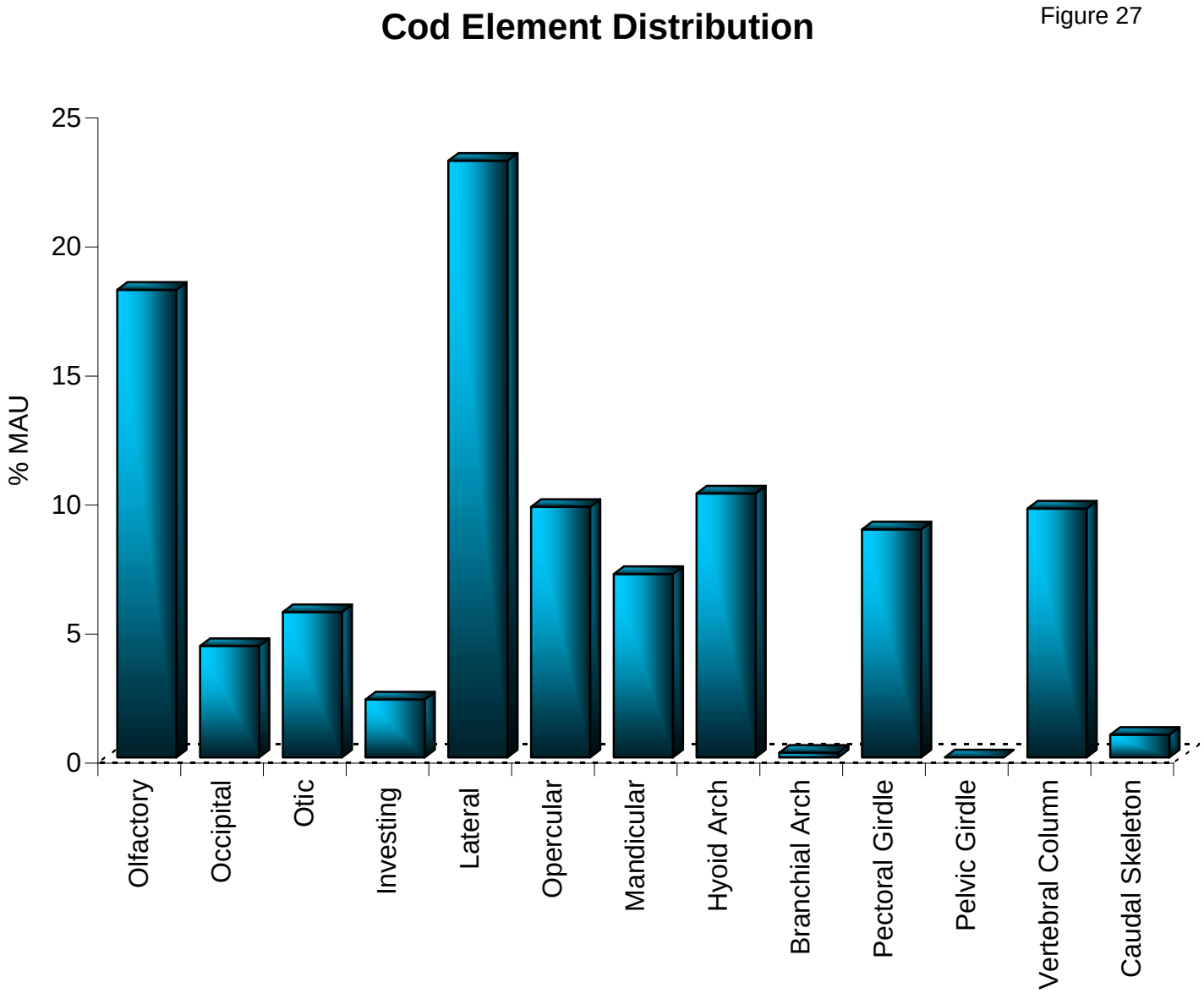
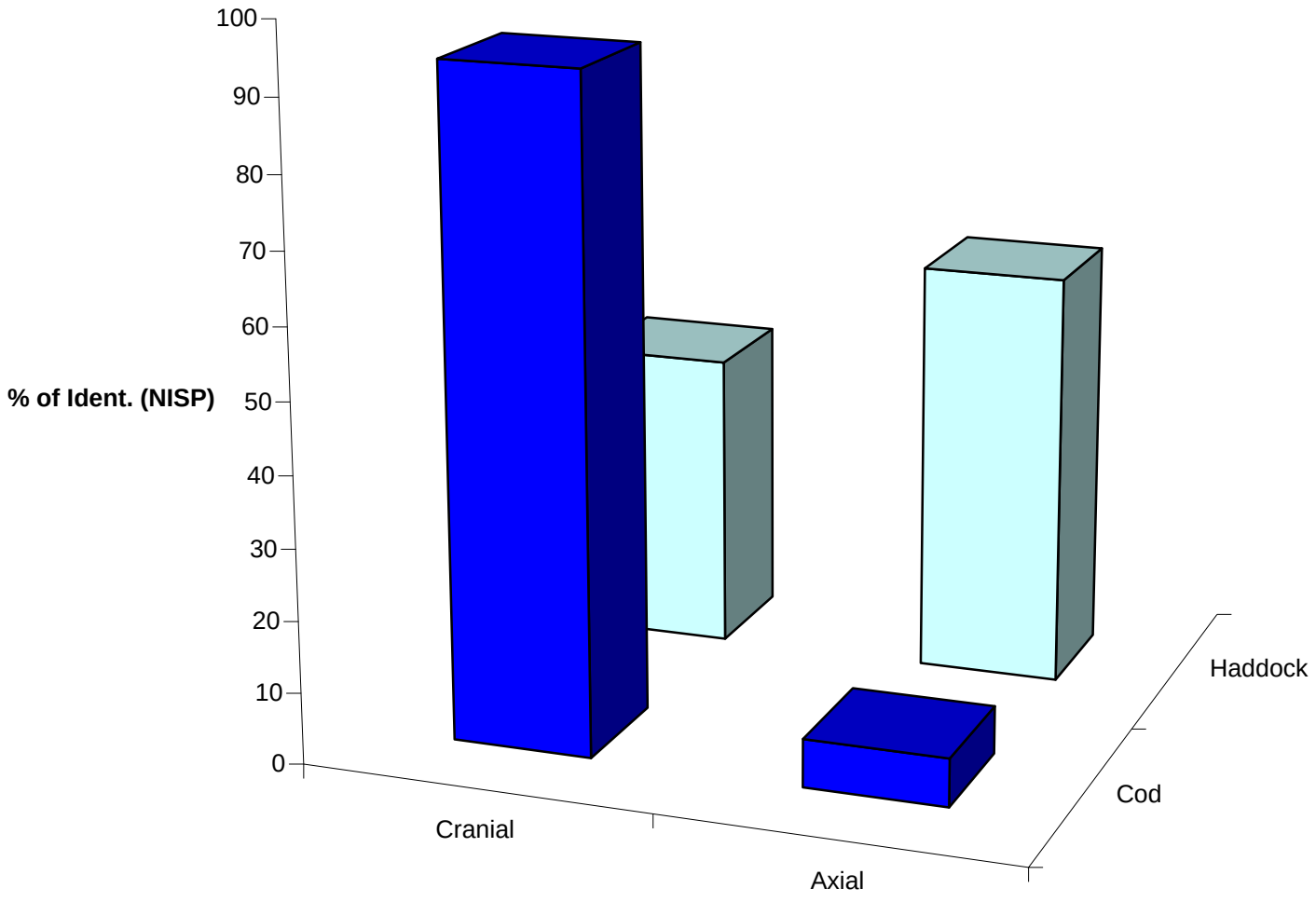

Haddock Element Distribution
% MAU
0
5
10
15
20
25
30
35
40
Olfactory
Occipital
Otic
Investing
Lateral
Opercular
Mandicular
Hyoid Arch
Branchial Arch
Pectoral Girdle
Pelvic Girdle
Vertebral Column
Caudal Skeleton

Figure 27


Cod Element Distribution
% MAU
25
20
15
10
5
0
Olfactory
Occipital
Otic
Investing
Lateral
Opercular
Mandicular
Hyoid Arch
Branchial Arch
Pectoral Girdle
Pelvic Girdle
Vertebral Column
Caudal Skeleton

Tjarnargata 3 C Cod and Haddock Element Distribution

Figure 28



Cod and Haddock Vertebral Series

Figure 29

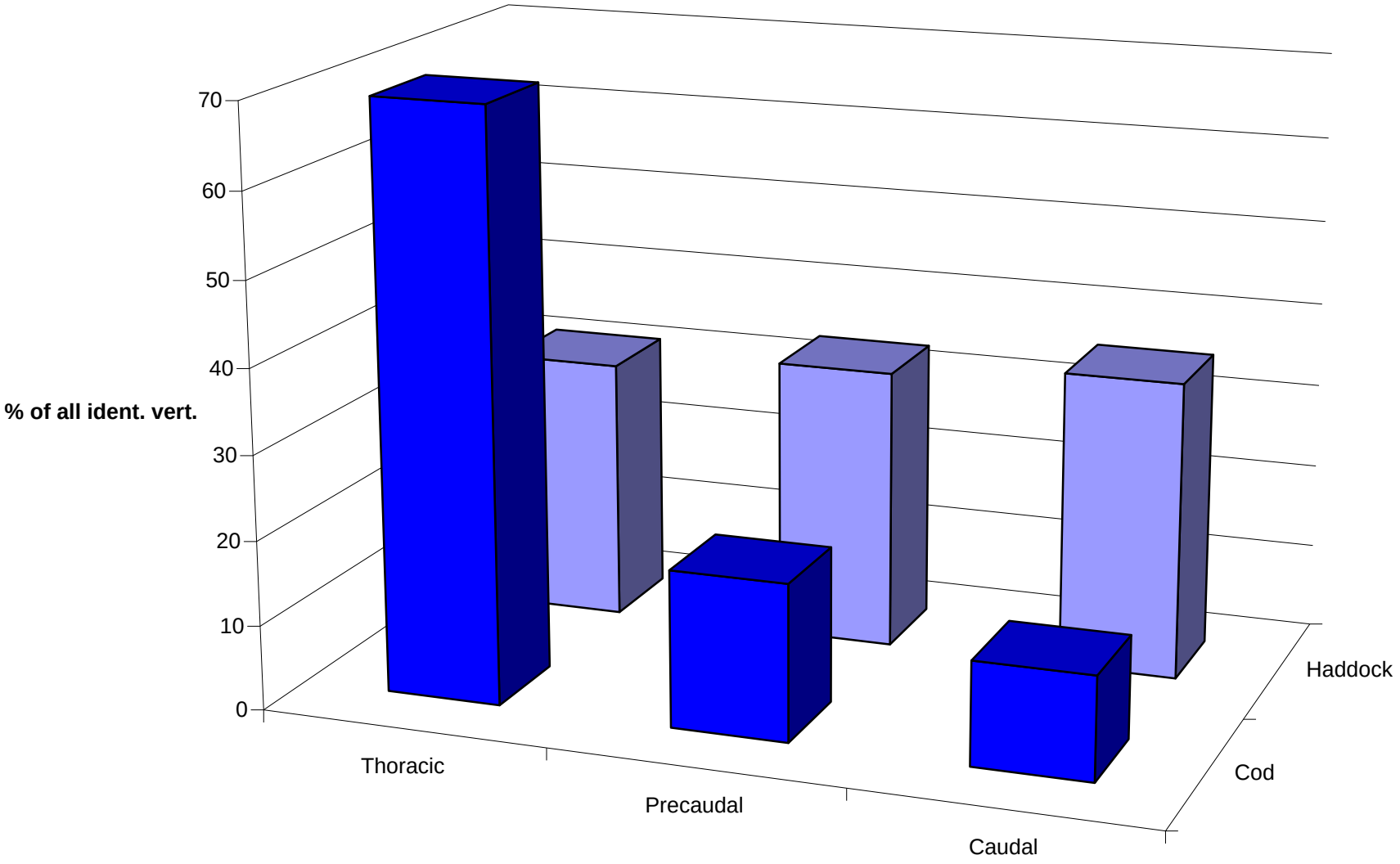


Figure 30

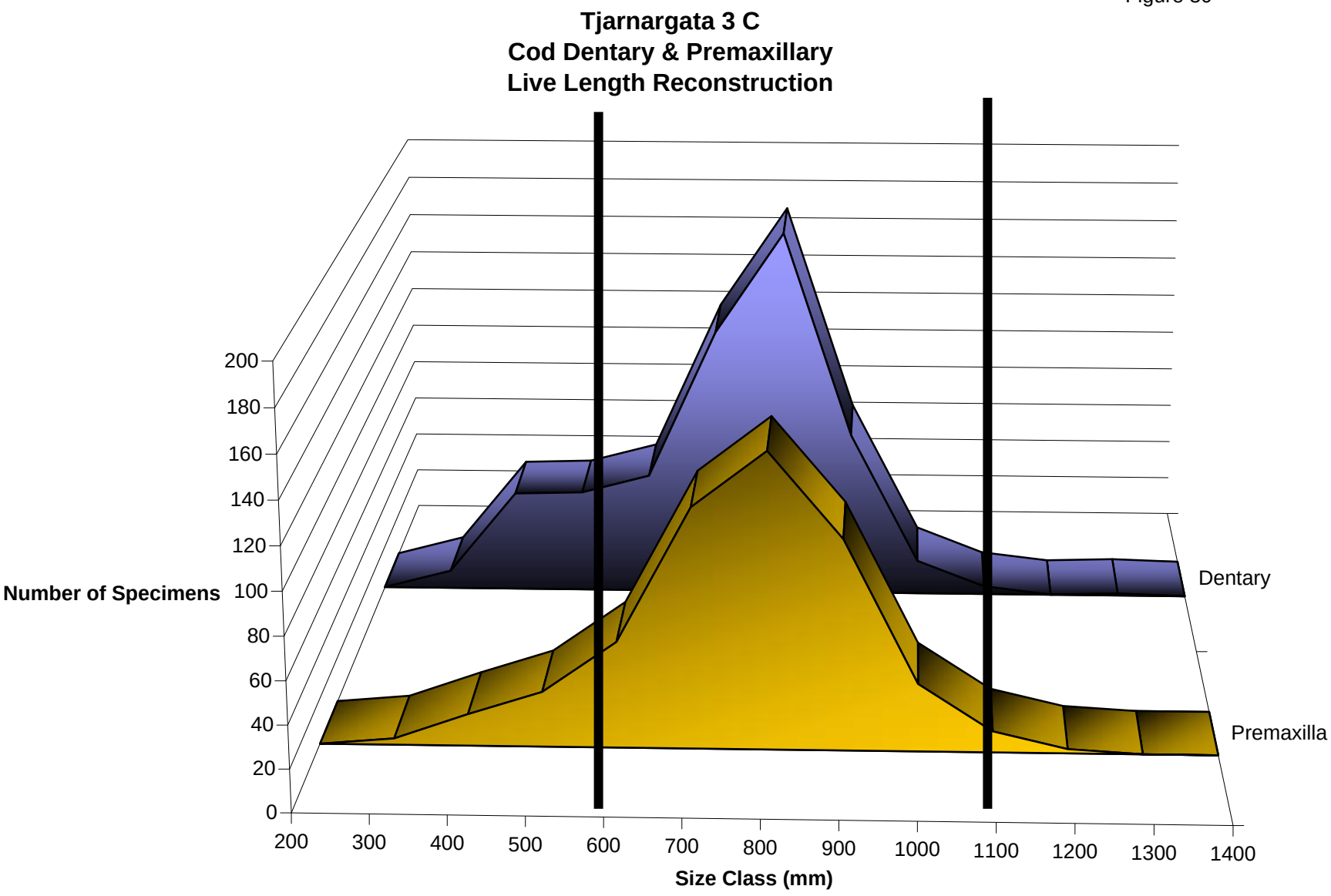

Tjarnargata 3 C
Cod Dentary & Premaxillary
Live Length Reconstruction
Number of Specimens
0
20
40
60
80
100
120
140
160
180
200
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
Size Class (mm)
Dentary
Premaxilla

Figure 31

Tjarnargata 3 C
Cod Length Reconstructions (%)

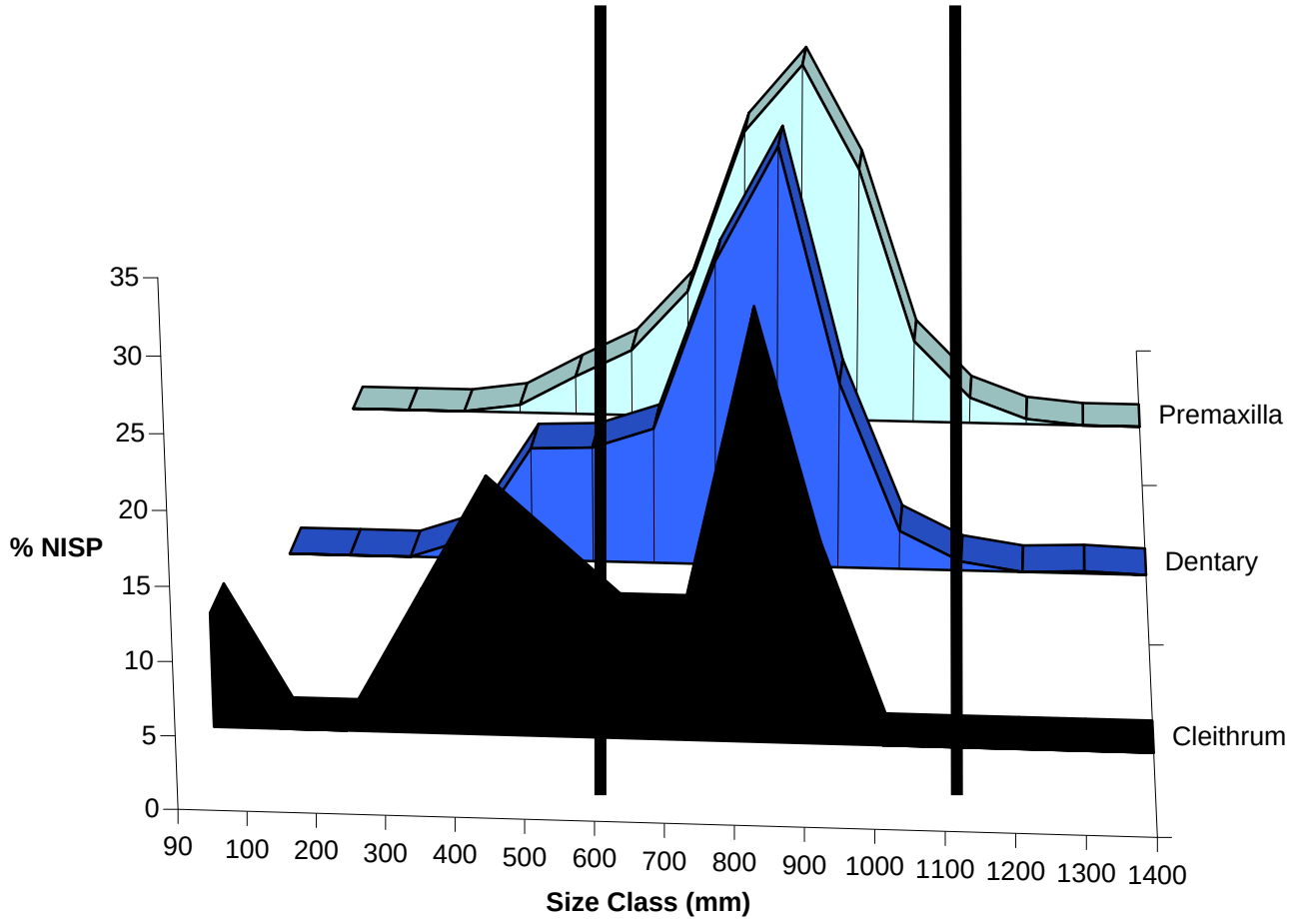


Figure 30

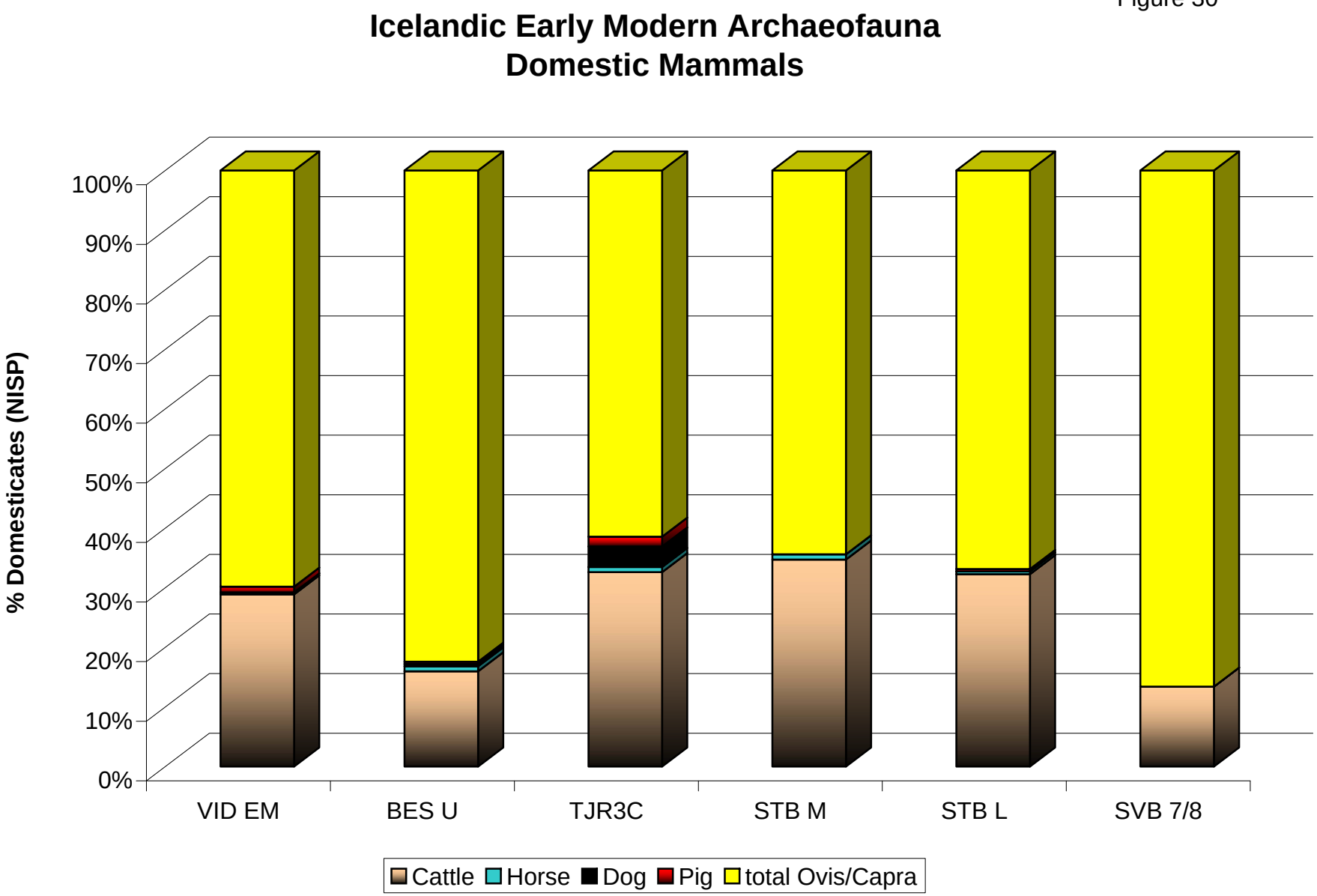
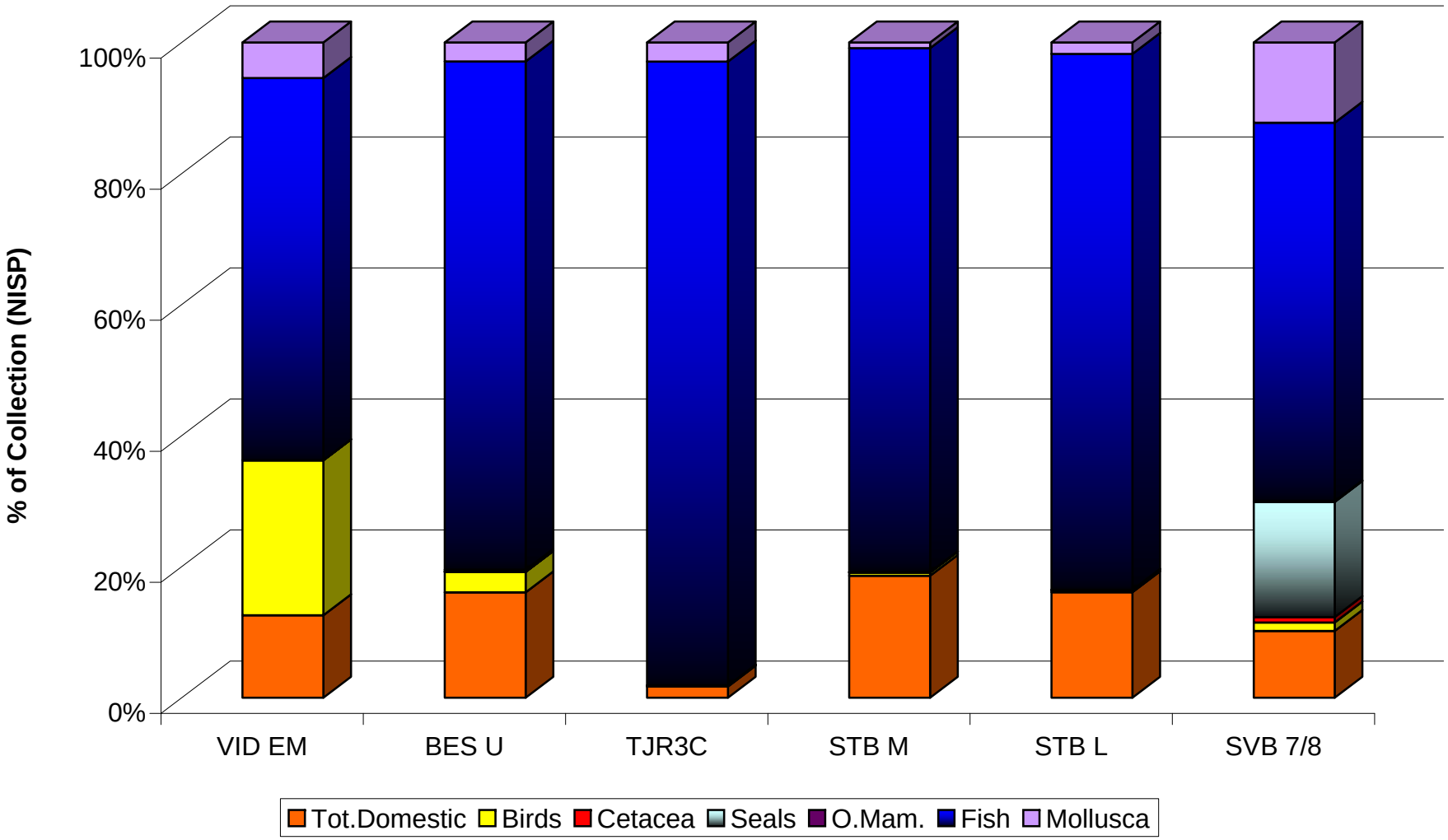

Icelandic Early Modern Archaeofauna
Domestic Mammals
% Domesticates (NISP)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
VID EM
BES U
TJR3C
STB M
STB L
SVB 7/8
Cattle
Horse
Dog
Pig
total Ovis/Capra

Figure 31

Icelandic Early Modern Archaeofauna
Major Taxa