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Dogs were domesticated in the Arctic: Culling practices and dog sledding at Ust'-Polui

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ABSTRACT

Domestication has particular salience in archaeology, and numerous recent theoretical papers describe this process as a set of evolutionary, ongoing, social, and material relationships between humans and select other species. In contrast, analytical papers on the domestication of dogs nearly always involve a search for their origins as marked by changes in genes and morphologies. This article explores this contrast through the examination of dog remains from the Iron Age Ust'-Polui site in the western Siberian Arctic. Many of the numerous dogs represented at this site were killed and probably consumed when young, likely as part of sacrifices. Others at the site were intentionally buried. Ust'-Polui also contains abundant evidence of advanced dog sledding, including probable harness parts and portions of several complex sleds. Sacrificing and otherwise killing dogs is a domestication practice, as these activities are a form of selective breeding. Domestication of dogs at Ust'-Polui and elsewhere is more than selective breeding, as it is enabled and dependent upon specific landscapes, built things, and other species. At Ust'-Polui these at a minimum included a rich local environment, sleds and harness swivels, and freshwater fish, all of which intertwined in making the particular domestic relationships at the site possible.

1. Introduction

The study of domestication is widely acknowledged to be of fundamental importance in archaeology (Kintigh et al., 2014), but the ways in which it is studied and described are highly variable. Many recent definitions of animal domestication argue that one of its most identifying features is influence upon or control of animal breeding over multiple generations resulting in genetic, morphological, developmental, and behavioral changes in those animals (Clutton-Brock, 2012; Larson and Burger, 2013; Russell, 2011; Zeder, 2015). In mammals, this pattern has been referred to as the domestication syndrome (Wilkins et al., 2014). Correspondingly, many archaeological papers explicitly analyzing animal domestication focus on the emergence of changes in the genes and skeletal morphologies of past animals thought to be the outcomes of changes in the selection process. Animal domestication in such approaches is in effect examined as the evolution of an ecotype or a form of initial speciation caused by our intervention in animal reproduction—the bodily outcomes of domestication are of interest.

The selective breeding of domestication can be carried out in many ways. Perhaps the most familiar form of selective breeding is pairing chosen males and females and allowing only them to reproduce by isolating or (in the case of males) castrating them. Many modern dog breeds of course developed through such highly restrictive practices over the past few centuries (American Kennel Club, 2006; Larson et al., 2012). Another approach (sometimes carried out in association with paired breeding) is to cull unsuitable individuals and their offspring. Culling patterns (demographic profiles) have long been used as evidence for initial domestication of some species, including in some cases where no morphological change is yet apparent (Bökönyi, 1969; Chaplin, 1969; Ducos, 1978; Hesse, 1982; Zeder and Hesse, 2000). Motivations for culling in the past were undoubtedly variable and not always undertaken with a specific evolutionary outcome in mind. As Larson and Fuller (2014:116) have recently stated, animal domestication has been "driven by selection pressures created by both unintentional and deliberate human actions". Animal sacrifice and other sorts

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of ritual slaughter are modern culling practices and part of the context for killing and consumption of domestic animals in many societies (Ingold, 1986:243; Russell, 2011:88–91). Culling can also be undertaken based on assessment of an animal's qualities for tasks such as hunting, herding, and transport. Coppinger and Coppinger (2016:181) term these latter processes "postzygotic selection", or the "favoring and supporting certain animals or culling individuals that are not wanted". Culling-based approaches to selection must shape evolutionary outcomes—they eliminate animals from the breeding pool—as do the more familiar domestication practices of paired breeding and castration.

At the same time, domestication clearly involves more than selective breeding and its bodily outcomes. By default, domestication is constituted by inter-species interaction (people and animals) occurring far beyond just the contexts of breeding, as domestic animals are at times fed, provided care, and otherwise socialized. Breeding alone does not ensure the perpetuation of domestic relationships. Many definitions of domestication in fact insist upon its multigenerational structure (Zeder, 2015; see Russell, 2011 for an extensive historical review of domestication definitions). Selective breeding of course can result in offspring that are easier for humans to be with. However, actual day-to-day interaction between people and animals, the experience of each other's dispositions, needs, capacities, and limitations, is also essential in carrying out our lives together. In other words, domestication is always a social process, not just a bodily one (Lien, 2015). Domestication is also dependent upon and enmeshed with various forms of material culture, landscapes, and suites of other organisms (Anderson et al., 2017; Loovers, 2015; Terrell et al., 2003). Working relations with domestic animals are perhaps most overtly dependent on and enabled by things such as harnesses, sleds, saddles, and food, the latter 'fueling' an animal's ability to engage in tasks. Even selective breeding itself can require things such as pens and tethers to limit or encourage animals' encounters with others. Tools such as knives are also used in domestication (even when strictly defined), in particular to cull or castrate individuals deemed unsuitable for reproduction.

Many scholars also now describe domestication as a mutualistic and co-evolutionary process where both humans and domestic animals (and plants) reshape environments and landscapes, and in turn are affected themselves by these changes, both in terms of their life histories and evolution (McClure, 2015; O'Connor, 1997; Smith, 2006; Zeder, 2016). Further, domestication is defined as an emergent or ongoing process rather than a threshold passed long ago with the first appearance of genotypic or phenotypic difference. Larson and Burger (2013:198) state that, "Because the evolution of domestic animals is ongoing, the process of domestication has a beginning but not an end". Such an understanding of domestication appears to be cognizant of the fact that the controls over breeding in place during the initial emergence of a domestic animal (and other aspects of these relationships) do not simply cease or radically transform once the animal is physically distinct from its wild counterparts. Put another way, there is no unequivocal point at which domestication ends and some other practices (such as husbandry or breeding) begin. Further acknowledgement of this perspective can be seen in the writing of scholars (e.g., Zeder, 2016) who discuss "initial domestication" in contrast to domestication in general, and describe organisms evolving closely with humans as "domesticates" rather than domesticated—something finished or complete. This is recognition of domestication as an unfolding relationship and not a discrete distant moment of accomplishment marked solely by bodily change—it is more than an instant of speciation. Overall, one can argue that archaeologists seem to no longer view domestication as a revolution, and that as such one can study these processes and relationships long after they first become apparent in bodily change.

However, if archaeology has truly embraced such understandings of domestication, why are recent archaeological studies explicitly on dog domestication (e.g., Germonpré et al., 2011; Frantz et al., 2016; Larson et al., 2012; Pionnier-Capitan et al., 2011; Thalmann et al., 2013, among many others) overwhelming dominated by research designed to understand the places and timing of dog origins and not on our subsequent 15,000+ years of life together? A noticeable disconnect persists between our domestication theories and how we analytically engage with these processes and relationships when we are dealing with dogs (and other animals). For example, why are we so interested in when dogs' heads first attained a certain shape or how often they interbred with wolves, but at the same time not investigating how selection was carried out, or when dogs began to regularly pull sleds, carry packs, hunt with us, and share our diseases and parasites? As a discipline we still seem to value some parts of domestication far more than others. Taking our own theories and definitions seriously requires some reconsideration of what counts as domestication research.

The Arctic is a compelling place to examine dog domestication. This region has never been proposed as an origin place for dogs, yet people and dogs have carried out lives together in parts of the Arctic for millennia. Dogs surely did not arrive in the Arctic ready-made for surviving its climate, particularly if they first originated from wolves in the far warmer climate of Southeast Asia (e.g., Pang et al., 2009; Savolainen et al., 2002; Wang et al., 2016). Grey wolves have evolved in relation to specific climates and environments (Gefen et al., 2004), and one should expect some such changes in dogs (Coppinger and Coppinger, 2016:212), who have lived with us in the Arctic for at least ~9000 years (Pitulko and Kasparov, 2017). It also seems unlikely dogs were always involved in the daily pulling of sleds or herding of reindeer, two of their iconic roles in some parts of the north. These practices probably also shaped their domestication, including their body conformations. For example, some modern northern dog breeds have body forms that make them far more efficient long distance runners than other breeds, presumably as a result of domestication (Bryce and Williams, 2017). Additionally, the deep histories of the material things (sleds, harnesses, whips, and so on) that enable such northern dog practices have seen very little systematic research in the Arctic. Perhaps most telling, even the word domestication is rare in archaeological papers on Arctic dogs (e.g., Brown et al., 2013, 2015; Morey and Sørensen, 2002; Morrison, 1984; Park, 1987; but see Pitulko and Kasparov, 2017), suggesting we still largely understand this ongoing process to have been achieved and completed outside the region.

This paper uses archaeological data from the Ust'-Polui site in the Yamal region of Russia to show how Arctic dog domestication practices can be investigated in new ways. Ust'-Polui has one of the largest assemblage of dog remains from the far north, making it ideally suited to this task. Further, it has a remarkable artifact collection that too informs about the unique forms of domestication practices present in this portion of the North. Regional ethnography is used in support of our interpretations of this remarkable material.

2. Setting and background

Ust'-Polui is located within the modern city of Salekhard at the confluence of the Polui and Ob rivers (Fig. 1). The site is at the western edge of high ground overlooking the floodplains of these two rivers, and the Polar Ural Mountains are about 50 km to the west-northwest. Today the local area is forested tundra, and open tundra is intermittently present just a few kilometers to the north. The northern border of the site is near a small creek and its western margin the bank of the Polui River (Fig. 2). Archaeological deposits were found extending ~130 m south from the creek and ~70 m east from the riverbank.

Most of the intact portions of Ust'-Polui appear to now be excavated, but substantial portions of the central site area were destroyed by modern construction. The first formal research was conducted at the site in 1935–6, and subsequent excavations occurred in 1946 (limited surface collection only), 1991, 1993–5, and 2006–2015 (Adrianov, 1936a, 1936b, 1936c; Fedorova and Gusev, 2008; Gusev and Fedorova, 2012, 2017; Moshinskaia, 1953, 1965). A small portion of the northeastern part of the site consisted of permafrost-preserved deposits that produced perishable items, including wood zoomorphic and

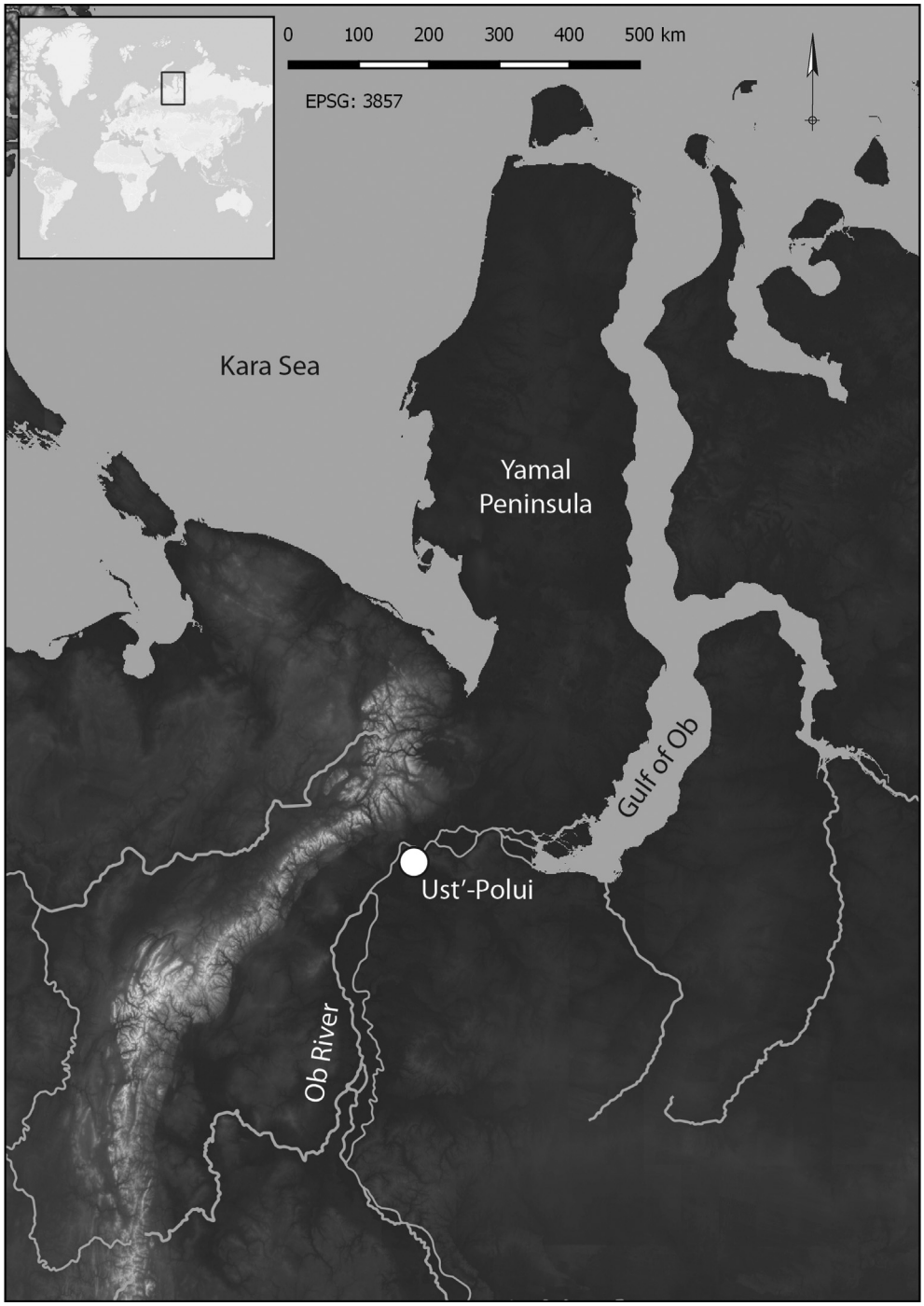

Fig. 1. Map of the study area, with the location of Ust'-Polui and major geographical features indicated. The map was created using Landsat open access data, courtesy of the U.S. Geological Survey.

anthropomorphic sculptures, birch bark containers, wood sled parts and skis, and numerous other objects. Preservation at the site was otherwise fair, with substantial numbers of osseous, ceramic, stone, bronze, and iron artifacts being present. The size of the overall artifact assemblage is estimated to be well over 50,000 objects.

The faunal remains from 1993 and later excavations of Ust'-Polui have been systematically described (Bachura et al., 2017), except for those from the 2007–8 excavations, which were lost in a fire while curated. The described assemblage consists of nearly 48,000 specimens. Remains of freshwater fish account for nearly half of the identified specimens. Mammal remains make up about one-third of the identified remains, with ~63% of these being from reindeer, and ~21% from dogs (NISP = 6615) (Bachura et al., 2017). Only four wolf specimens are present. Bird remains account for about one-fourth of the assemblage, and most of these are from ptarmigan and waterfowl. The 1930s faunal collections (excavated by Adrianov) are largely undocumented and do not appear to have been systematically collected.

Near the northeastern edge of the site was a ditch or moat (1.2 to 1.6 m deep by 1.3–1.6 m wide at its base) and just inside it a simple wood post fence (Fig. 2). It is possible that these features previously enclosed the site area, or at least that portion not along the riverbank. A small wood footbridge spanning the moat was also present in this area. The dimensions of the moat and fence led the excavators to suggest it was unsuitable for use as a fortification and that it may have been a

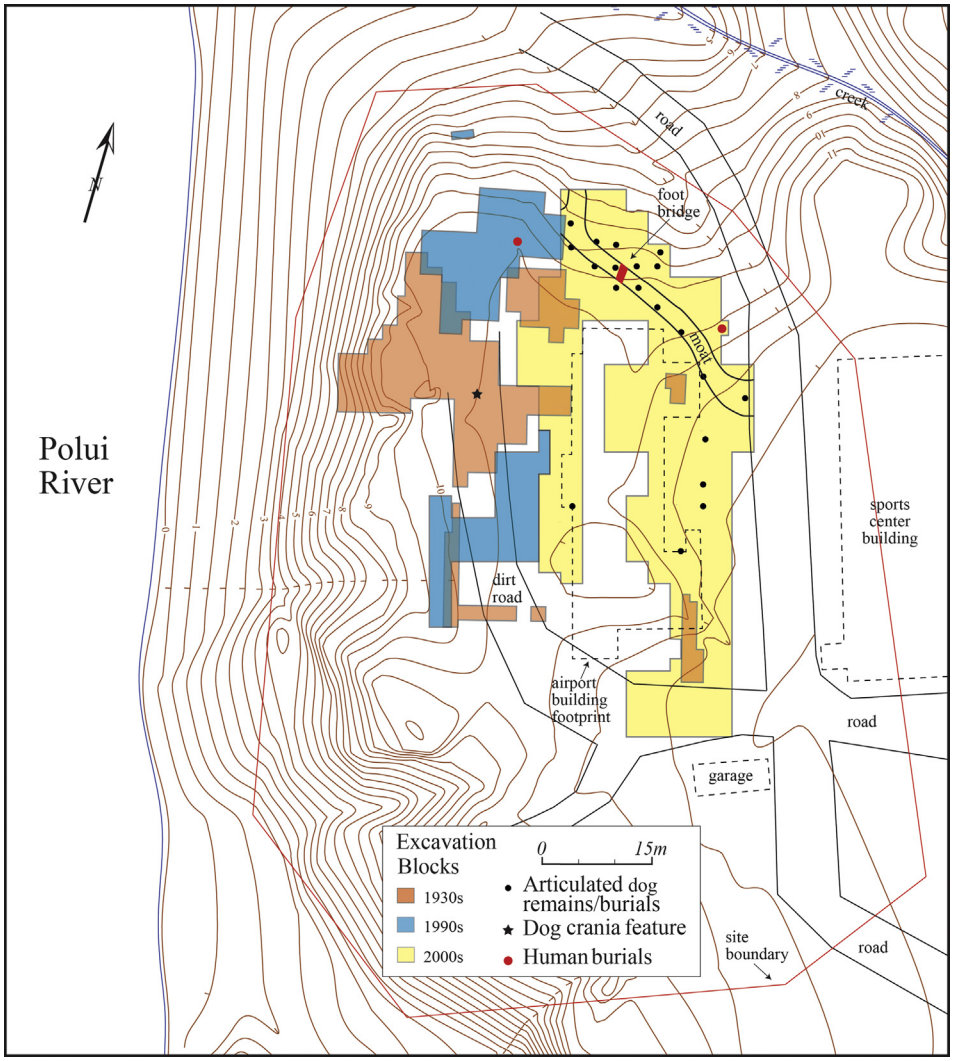

Fig. 2. Topographical map of the Ust'-Polui site with excavation blocks and major site features indicated.

symbolic barrier (Gusev and Fedorova, 2012). Gusev and Fedorova (2012), both of whom have led excavations at Ust'-Polui since the 1990s, refer to the site as a sanctuary ('sviatilishche') or sacrifice site, arguing that regional forager groups recurrently carried out sacred practices at this location (see Moszyńska, 1974 for very similar arguments). Their interpretation is based on the very unusual nature of the site contents and structure. For example, a suite of embellished objects were found at Ust'-Polui, including several human figurines and other anthropomorphic depictions, some very similar to historical idols from the region (Fedorova, 2014; Gusev and Fedorova, 2017). Perhaps most important here are the unusually abundant dog remains at Ust'-Polui, including a concentration of 15 crania found by Adrianov in the 1930s (described below), interpreted to be the remains of sacrifices. Finally, artifacts were often found in loose concentrations, including in oval or round patches, and sometimes adjacent to large stones or on prepared surfaces; these are thought to remnants of ritual constructions that were built upon prepared surfaces. Earlier generations of site investigators also claimed multi-community ritual practices occurred at Ust'-Polui, but some suggested that at least parts of the site formed as a result of mundane daily activities (Moszyńska, 1974; Gusev and Fedorova, 2012). For example, Moszyńska (1974:77, 106–8), using only Adrianov's field notes, argued for the presence of pit houses at Ust'-Polui, and in places refers to the site area as a fortified hill. House remains, however, were not confirmed in any subsequent phase of excavation at the site.

The chronology of Ust'-Polui has been described in detail in Losey et al. (2017a, 2017b). This chronology is built upon 42 radiocarbon dates on wood charcoal, 20 dates on human and faunal bone (including 7 dates on dog remains), and 2 dates on grave accoutrements. Four dendrochronology assessments are also available. Modeling of the radiocarbon dates indicates Ust'-Polui was occupied for just a few centuries, most likely from ~260 BCE to 140 CE.

3. Dogs in regional ethnography

Northwestern Siberia has a relatively rich ethnographic record, including some details on human-dog relations and practices. For example, regional literature describing Nenets, Khanty, and Mansi states that in the recent past human consumption of dogs was rare, but did occur, sometimes when groups experienced dietary stress, and in at least one case as a regular dietary practice (Elert, 2006:330, 338, 365; Gemuev et al., 2005:129; Khomich, 1966:135). Further, while many accounts refer to dogs as unclean or impure animals, one source specifically mentions eating young dogs, which were regarded as a delicacy (Alekseev, 1941: 378).

Dog sacrifice too is described in the Yamal region, with dogs being killed to honor kin spirits and deities (Golovnev, 1995:405, 412–3, 443; Khomich, 1966:206–7; Lukina and Ryndina, 1987:118–9; Perevalova, 2004:235–6, 292–3). In the historic period, such ritualized killings were conducted at lakes (Perevalova, 2004:236) and special ritual centers,

including on the Angal'sk Peninsula just 5–6 km north of Ust'-Polui (Perevalova, 2004:292-3). This location was in part a meeting place for Khanty and Nenets where human, dog, and particularly domestic reindeer sacrifices were conducted, meals were shared, and food and other offerings were left in an effort to ensure regional peace.

Other contexts for ritualized slaughter of dogs are also occasionally described in the literature. Golovnev (1995:404) reports that dogs were regularly sacrificed in rituals related to the various openings of the Lower World (a tier of the cosmos), including births, deaths, menstruation, disease outbreaks, river openings, and floods (see also Lekhtisalo, 1998; Zen'ko-Nemchinova, 2006). Dog sacrifices were also carried out to mark returning from major hunting or fishing trips, and at periodic regional festivals (Aksianova et al., 2005:155; Moszyńska, 1974:283; Perevalova, 2004:292). All sacrifices described by Golovnev (1995) involved utilizing a loop to asphyxiate the animal, and he and Lukina and Ryndina (1987:87, 119) report that the skulls and furs of such dogs were left at ritual sites. Eating of sacrificed dogs is not mentioned in the sources we consulted, and in several cases is described as forbidden (Lukina and Ryndina, 1987:87, 199). Use of fur from sacrificed dogs for clothing is reported in one source, which was done to honor the same spirit(s) to which the dog was sacrificed (Aksianova et al., 2005:155).

Historically, dogs were also intentionally killed for other purposes, such as at the death of a human. Details on such rites are sparse, but dogs are described as being 'sent' with their owners (Kar'ialainen, 1994:93). This involved placing their bodies across the grave of the deceased human (Zen'ko, 1997:58, 107; Zen'ko-Nemchinova, 2006). Killing dogs to use their fur in clothing is also widely reported (Bogordaeva, 2006:19, 128, 174; Elert, 2006:330; Fedorova, 1994:122, 184; Golovnev, 1995:404; Khomich, 1966:117; Kushelevskii, 1868:59-60; Lukina, 2010:133; Perevalova, 2004:291-3). Culling old dogs is also described among at least one Nenets kin group (Golovnev, 1995:405). All dogs among this group were said to be owned by the group's most important deity, which itself was honored with dog sacrifices.

Some Khanty and Mansi treated special dogs very much like humans at death, placing them in small house-shaped containers set on pilings near human graves, which had the same form (Golovnev, 1995:269; Ides and Brandt, 1967:72-3; Zen'ko, 1997:57). Alternatively, such dogs were taken to the forest and buried in the ground (Zen'ko, 1997:57). In-ground burial of old dogs is also reported among one Nenets group, who reportedly saw a level of equality between themselves and some dogs, and thus offered them burials (Zen'ko-Nemchinova, 2006:241–2). Interviews conducted by Losey and Nomokonova (with D. Arzyutov) in 2018 also documented in-ground dog burial practices among some tundra Nenets households, which were described as efforts to show respect to the animals.

Hunting with dogs for a wide array of fauna is well documented in regional ethnography (Elert, 2006:330, Gemuev et al., 2005:81, 91; Golovnev, 1995:269, 314; Khomich, 1966:66, 69, 71, 73–5; Lukina, 2010:198; Lukina and Ryndina, 1987:17, 183), including for many of the birds and mammals represented in the Ust'-Polui faunal assemblage. Dog sledding is reported for the Khanty and Mansi in the forested regions around Ust'-Polui and to the south, and to a far lesser degree for the Nenets on the tundra to the north, who historically relied far more heavily on reindeer for transport. Some Nenets groups engaged in dog sledding to hunt polar bears or seals on the sea ice, or to access fishing areas (Gemuev et al., 2005:425; Khomich, 1966:69, 75, 97, 99). Nenets dog sleds are described as smaller and faster versions of those used with reindeer (Gemuev et al., 2005:425; Verbov, 2017:158–9). We are unaware of any descriptions of swivels (which are abundant at Ust'-Polui; see Section 5) in local dog harness equipment. The Khanty and Mansi more regularly used dog sleds than the Nenets, particularly along major rivers or in areas where lichens were poor and unsuitable for sustaining working reindeer (Fedorova, 1994:82–7; Gemuev et al., 2005:85, 225; Lukina and Ryndina, 1987:135; Perevalova, 2004:287). This sledding was highly variable, ranging from multiple dogs rapidly pulling light and narrow sleds, to dogs and humans working together to pull simple sleds or toboggans loaded with wood, water, and fish. The rapid or advanced sleds are again described as smaller versions of those used with reindeer, having narrow rails or skis, and a raised cargo bed, which in some cases were supported by vertically oriented stanchions (Fedorova, 1994:82–4; Gemuev et al., 2005:225). More broadly in Siberia, however, vertical and reclined stanchions can both be found in dog and reindeer sleds—neither form alone is particularly diagnostic of the kinds of animals that were used to pull them (Levin and Potapov, 1961:74:11–77). Among the Khanty and Mansi, some dogs were kept largely for pulling sleds, and others mostly for hunting, but hunting dogs at times pulled sleds, and sled dogs occasionally hunted (Fedorova, 1994:84–5; Gemuev et al., 2005:85, 225).

4. Materials and methods

Dog remains from Adrianov's 1935–6 excavations at Ust'-Polui, curated at the Zoological Institute of the Russian Academy of Science in St. Petersburg, were first examined. Given that these remains were not systematically collected, they are considered separately in the quantitative analyses below, unless otherwise noted. Adrianov's research at the site is described in Chernetsov and Moszyńska (1974). Dog remains from the 1993–2015 excavations were also analyzed, and these are curated at the Institute of Plant and Animal Ecology, Ural Division of the Russian Academy of Science, Ekaterinburg. For these materials, we focused our analyses on the long bones and skulls, with the exceptions being when articulated dog remains were recovered. Dog remains recovered in 1991 and 2007–8 are now lost and unavailable for study. Finally, sled parts and possible harnessing-related artifacts from the 1991 through 2015 excavations were studied at the Yamal-Nenets Region Museum Complex of I.S. Shemanovsky, Salekhard.

Dog crania and mandibles were previously analyzed through three-dimensional geometric morphometrics by Drake et al. (2017). Isolated limb bones were identified through size and shape comparisons to those from the site's whole or nearly whole dog burials, and by comparison to those from local wolves and Arctic foxes. Stable carbon and nitrogen isotope analysis of bones (mostly scapulae) from 32 individual dogs, other site fauna, and two human burials are described in Losey et al. (2017a, 2017b). Dog limb elements were assigned to broad age range categories using epiphyseal fusion patterns (von Pfeil and DeCamp, 2009). Crania and mandibles were assigned as juvenile or adult based on the presence or absence of deciduous dentition, or the clear presence of alveoli from deciduous dentition in cases where teeth were lost post-mortem. Dogs are considered here to loose their deciduous dentition by approximately six months of age (Geiger et al., 2016). All cranium, mandible, and long bone dimensions were taken following Losey et al. (2011, 2017a, 2017b). Body mass estimates were made based on mandible and crania lengths and long bone dimensions following Losey et al. (2017a, 2017b). Withers height estimations were made with limb bone lengths using Harcourt's (1974) regression formulae. All analyzed elements were examined for macroscopic traces of gnawing (Lyman, 1994:206-216) and butchery (Noe-Nygaard, 1989), both of which were recorded in terms of presence or absence and location. Cut mark placement was also noted.

5. Results

5.1. Part representation and number of individuals

For this study, we assessed body part representation by calculating minimum number of individuals (MNI) represented by only the long bones, crania, or mandibles, for several reasons. First, most of the site deposits were unseived, meaning that the absence of smaller elements (e.g. lower leg elements) might be due to recovery methods. Second, vertebrae and ribs in terrestrial mammals are generally less dense than limb bones and the skull, meaning that they are more susceptible to pre-

and post-depositional attrition (Stiner, 2002). Third, vertebrae and ribs probably have a higher chance of being misidentified than limb and skull elements. The overall minimum number of individual dogs represented at the site was calculated by assessing the minimum number of long bones, crania, and mandibles present (with age taken into consideration), with the Adrianov materials considered separately from those from the later excavations.

For the Adrianov dog remains, the MNI for the skull is 16 (left mandibles), and the MNI for the limbs is 12 (right radii), for a skull to postcranial ratio of 1.33 to 1.0. For the later excavations, the MNI for the limb elements is 79 (left humerii), and that for the skulls is 116 (right mandibles), for a ratio of 1.47–1.0. Together, the two datasets conservatively represent a minimum of 128 dogs (116 right mandibles in the recent excavations and 12 in the Adrianov sample). This figure does not include the dog remains lost from 1991 and 2007–8 excavations, which were never quantified.

5.2. Dog remains context

Contextual information varies for the Ust'-Polui materials, with such data being particularly scant for the Adrianov and 1990s excavations. Adrianov's trench in the central western portion of the site uncovered a feature consisting of 15 dog crania within an area of 80 cm^2, all with their braincases missing, probably through perimortem fracture (Figs. 2 and 3) (Moszyńska, 1974). One adjacent excavation unit held another two dog crania, while the unit on the opposite side of crania feature produced an antler knife handle with its base carved with an image said by some to be a dog wearing a harness (Moszyńska, 1974:89–90) (Fig. 4). The Adrianov collection also contains 28 mandibles, 14 humeri, 16 ulnae, 21 radii, 9 femora, and 11 tibiae. Precise context is not available for these elements, but Moszyńska (1974) indicates no mandibles were found with the crania.

The vast majority of the dog remains from the 1990–2015 excavations were found isolated and scattered across the entire excavated area, with some important exceptions. The northeastern portion of the site around the footbridge and moat, along with the eastern margin of the site, produced four fully articulated adult dog skeletons, five articulated adult skeletons lacking skulls, and two nearly complete articulated juvenile skeletons (Bachura and Kosintsev, 2014) (Fig. 5). Some of the skeletons were within the sediments that in-filled the moat, while others were along its margins. All are believed to be primary burials—none show evidence of gnawing or exhibit traces of weathering due to exposure. Articulated partial dog skeletons and groups of disarticulated elements from the same individual were also found across this area. These include axial skeletons and partial limbs from 13 individuals, separate vertebrae columns from another 13 individuals, limbs (without feet) from at least 9 individuals, and articulated feet from at least 16 individuals. Bachura and Kosintsev (2014) suggest at least some of these partial skeletons originated from whole body burials that were disturbed by later occupations, or became disarticulated by slumping down into the moat. If correct, as many as 37 partial or whole dog burials may have been present, with at least some being disturbed while still partially fleshed. Note that the two human burials at Ust'-Polui were also located at the northeastern margin of the site (Fig. 2). The excavation units with the articulated dog remains also produced many disarticulated dog elements, and numerous other faunal remains, including those from reindeer, birds, and fish, all of which are suspected to be human food remains (Bachura et al., 2017). A single dog cranium recovered in 2006 in the central site area was placed on the end of a stick, perhaps as part of a display (Gusev and Fedorova, 2012).

5.3. Bone modification

Other dog remains possibly displayed at the site or worn on the body are four mandibles, all with single holes drilled through the masserteric fossa (Fig. 6). Two are from individuals under six months of age, and two from dogs six months of age or older. All were found in the central or eastern portion of the site area.

Cut marks were found on some of the Ust'-Polui dog remains. Unless otherwise indicated, all percentages below are cut marks per NISP for each whole element or element fragment. In Adrianov's collection, two mandibles and one cranium show cut marks; none of the postcranial elements were modified. The cranium has cut marks on the occipital condyles, and the mandibles on the ramus and mandibular condyle. In

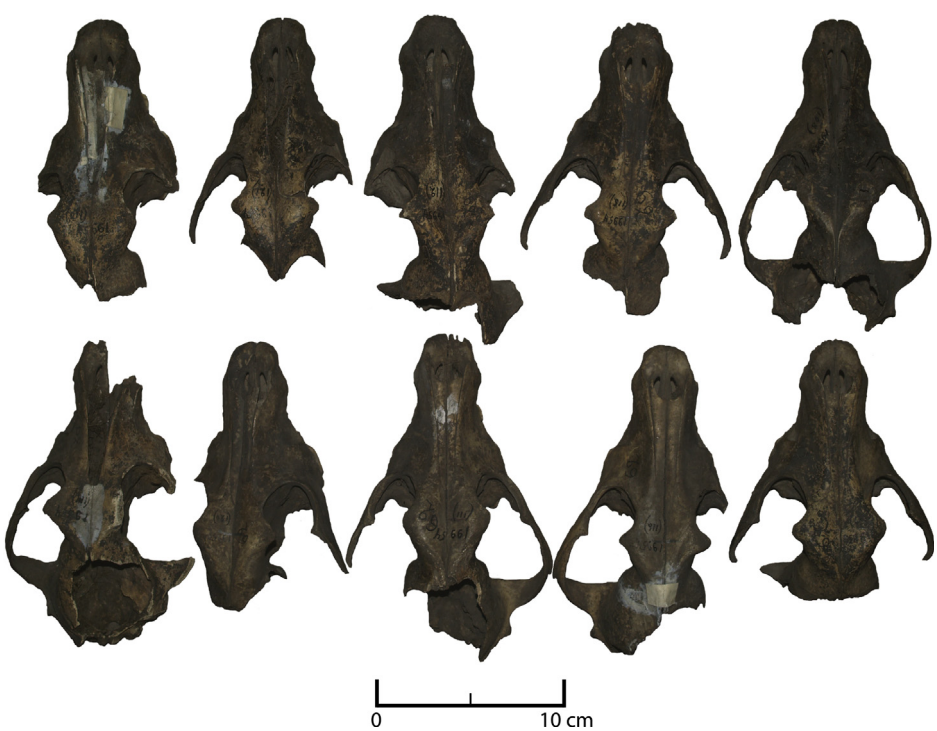

Fig. 3. Ten of the dog skulls found by Adrianov in the 1930 s in a feature at Ust'-Polui.

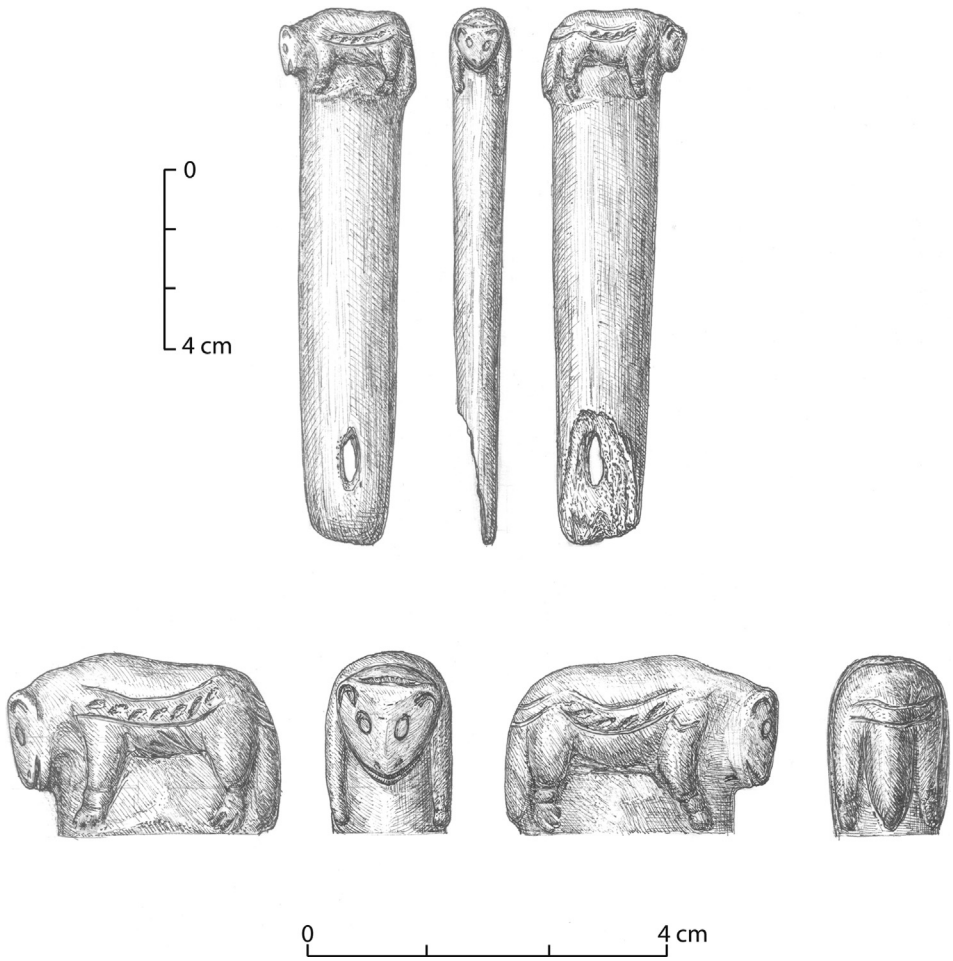

Fig. 4. An antler knife handle from Ust'-Polui, with a zoomorphic image at one end. Moszyńska (1974) interpreted this image as a dog wearing a harness.

Fig. 5. Articulated dog remains from Ust'-Polui. (a) Whole dog burial found in 2011; (b) dog burial with its skull found in 2010; (c) articulated dog skull and cervical vertebrae found in 2014.

the more recently excavated sample, 4.1% of the assessed specimens (crania, mandibles, long bones) display cut marks. These include five (4.6%) crania, all of which are cut on the occipital condyles. Only one mandible (from a dog < 6 months of age) from this sample was cut (< 0.1%), with the mark being on the body. For the limb bones, 7 humeri (3.3%), 4 ulnae (2.2%), 3 radii (0.6%), 25 femora (12.8%), and 9 tibiae (4.8%) exhibited cut marks, and all were on or near the epiphyses and perpendicular to the long axis. All of these cut elements were isolated specimens. Together, these bone modification and disarticulation patterns are consistent with butchery and not merely skinning of the dog carcasses (Binford, 1978, 1981).

Gnawing marks consistent with medium to large size carnivores (fox to wolf size) were also observed on the Ust'-Polui dog remains, but only on the isolated skeletal elements. In the Adrianov sample, only a single mandible was gnawed, and the crania and limb bones show no such traces. In the sample from the later excavations, 10.2% of the total observed specimens were gnawed. These include 16 cranial specimens (14.8%), 43 mandibles (18.0%), 18 humeri (8.5%), 19 ulnae (10.3%), 13 radii (7.3%), 7 femora (3.6%), and 17 tibiae (9.1%).

5.4. Body mass estimation

Body mass estimations were made on 63 mandibles and 31 humeri (Fig. 7). Humeri were utilized because these are the latest fusing long bones and should provide body mass estimates for individuals at least 10 months of age, who would have been near or already at adult body size. The estimated mean body mass based on the humeri is 16.8 kg (st. dev. 3.4), and the range from 9.1 to 22.9 kg. The lower quartile is 14.7 and the upper quartile at 19.4 kg.

Mandibles provide the maximum number of possible body mass estimates for the Ust'-Polui sample, and both dentally juvenile and adult specimens were analyzed (Fig. 7). The mandible estimations

Fig. 6. Two of the modified dog mandibles from Ust'-Polui.

range from 0.9 to 24.1 kg, and 32 of the 63 assessed specimens (50.8%) had values below the 14.7 kg lower quartile value obtained for the humeri. Further, 45 of the assessed mandibles (71.4%) produced values below the humeri mean value of 16.8 kg.

5.5. Withers (shoulder) height estimation

Withers height estimations provide an indication of the overall body size of the adult Ust'-Polui dogs. Right radii constituted the greatest number (MNE = 45) of fully fused elements that could be used for withers height estimations (Fig. 8). The mean estimated shoulder height based on the radii is 50.2 cm (st. dev. = 3.3), with the ranging extending from 44.3 to 56.9 cm. The lower quartile is 48.1 and the upper quartile at 51.8 cm.

5.6. Ageing

In the dog remains recovered from the 1990s and later excavations, dental eruption patterns indicate 19.4% of the crania and 23.1% of the mandibles are from individuals less than 6 months of age (Fig. 9). Note that the number of assessable mandibles (MNI = 117) is far greater than the number of assessable crania (MNI = 67). No crania or mandibles with unerupted deciduous dentition were identified, providing no

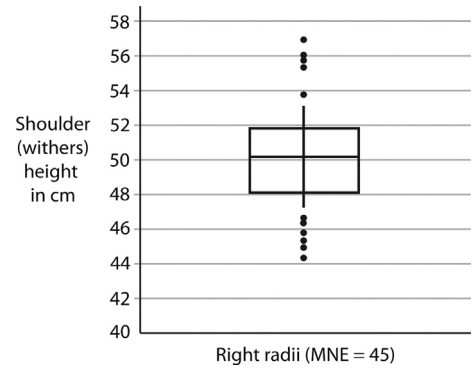

Fig. 8. Shoulder or withers height estimates for the adult dogs at Ust'-Polui calculated on whole radii lengths. The black dots are outliers, the vertical whiskers mark one standard deviation, the rectangle edges mark the upper and lower quartiles, and the horizontal line the mean.

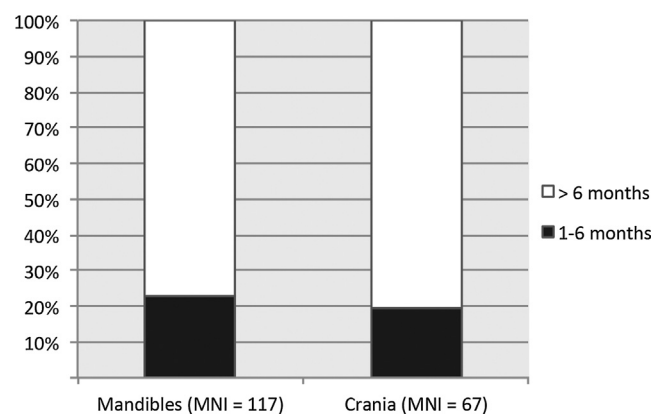

Fig. 9. Ageing data for the Ust'-Polui dogs using dental eruption.

evidence for the presence of dogs less than about one month of age (Arnall, 1960).

Fusion of the long bone epiphyses is useful for assessing the minimum number of individuals less than 11–12 months of age; after this age, fusion is typically complete in dogs (von Pfeil and DeCamp, 2009). Assessable humerii represent more individual dogs than any other limb element at the site (MNI = 78), and 44.6% of these are from osteologically immature individuals (Fig. 10).

5.7. Sleds and swivels

Parts of several wood sleds were recovered from Ust'-Polui in the later phases of excavation, all in the sediment within the moat (Gusev, 2014) (Fig. 11), including four runner fragments, six stanchion

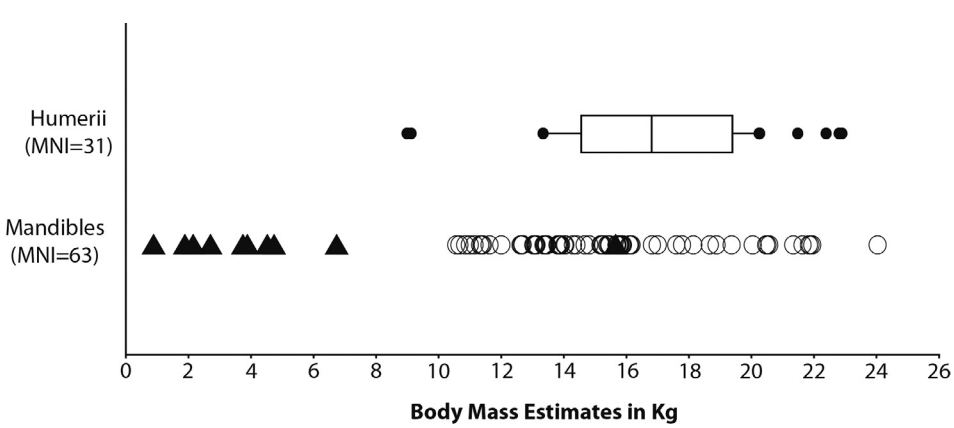

Fig. 7. Body mass estimations for dogs at Ust'-Polui. The box plot shows body mass estimations for fully fused dog humeri. The black dots are outliers, the horizontal whiskers mark one standard deviation, the rectangle edges mark the upper and lower quartiles, and the vertical line the mean. The lower points are body mass estimates for mandibles, with the triangles marking the juveniles, the circles the adults. Note that the one 'juvenile' specimen within the adult range was likely an individual that retained a deciduous tooth into adulthood.

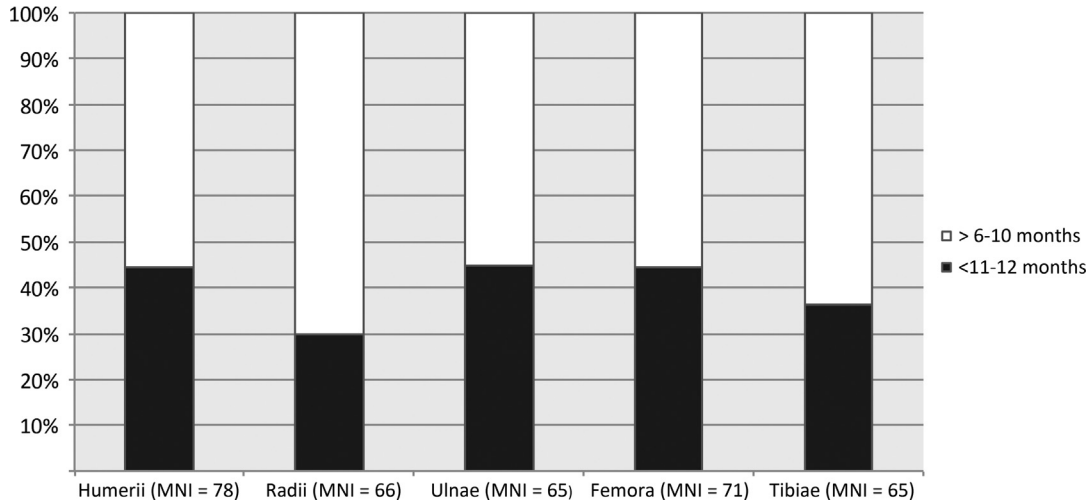

Fig. 10. Ageing data for the Ust'-Polui dogs using long bone fusion.

fragments, and a single runner fragment with a single stanchion in place. The first runner fragment is 107 × 5.6 cm wide, with two widely spaced platforms with rectangular holes for stanchions that appear to have been vertically oriented (not reclined as in nearly all modern local reindeer sleds (Golovnev et al., 2016)) (Fig. 11a). The second runner fragment is 84 × 5 cm, and has a platform section with a rectangular hole that appears to have held a vertically positioned stanchion (Fig. 11b). The third runner fragment is broken through its stanchion platform, and near its intact end is a round hole; the fragment is 31 × 4.6 cm (Fig. 11c). The platform itself also has a hole drilled through it from the side, presumably to secure the stanchion. The fourth runner fragment is similar to the previous item, being broken through its stanchion platform and with a hole near its intact end; it is 19 × 3.2 cm (Fig. 11d). The last runner fragment was found with one vertical stanchion still in place. The intact end of the runner curves slightly upward, and the stanchion has a rectangular hole through it, probably for a cross-support; the runner fragment is 37 cm long by 4 cm wide, and the stanchion fragment is 24 cm long (Fig. 11e). The remaining stanchions are fragmentary but similar in form to that found with the last runner described above.

At least four types of antler swivels were found at Ust'-Polui, including at least 93 swivel parts from Adrianov's trenches (Moszyńska, 1974:322), and 173 from the 1990s and later excavations (Gusev, 2014). Two of the types (Fig. 12) have direct analogs in historic swivels that formed parts of sled dog harness (see Section 6). The first type is formed by a round to subrectangular plate with four holes around its periphery and one hole at its center (Fig. 12a). A pin passes through the central hole, and the near the end of the pin are one or more holes for attachment of lines. A total of 53 plates or plates with pins in place were found in the later excavations at Ust'-Polui. Such quantification is

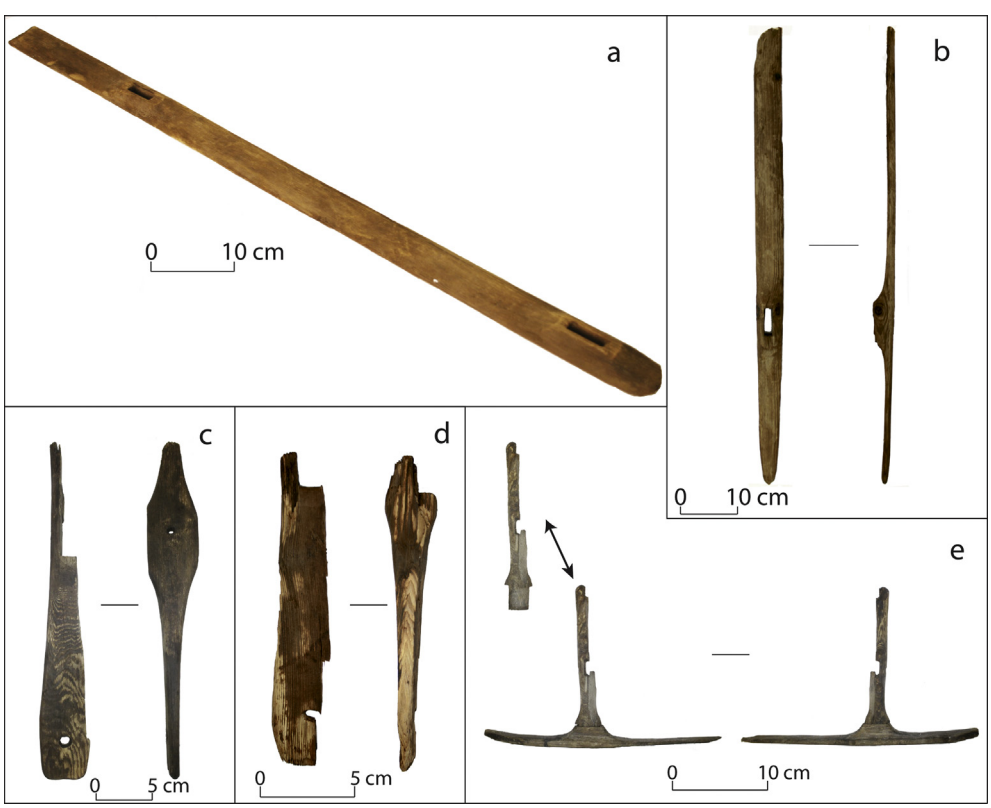

Fig. 11. Wood sled parts from Ust'-Polui. (a) sled runner fragment with two stanchion platforms; (b) sled runner fragment with one stanchion platform; (c) sled runner fragment broken through its stanchion platform; (d) sled runner fragment broken through its stanchion platform; (e) small sled runner fragment with intact horizontal stanchion.

Fig. 12. Examples of two swivel types present at Ust'-Polui. (a) subrectangular plate and pin form of swivel; (b) elongated tab and socket form of swivel.

unavailable for the Adrianov collection, but multiple such specimens are shown in Chernetsov and Moszyńska (1974). The second swivel type consists of an elongated rectangular tab with a hole at one end and a socket at the opposite end (Fig. 12b). A pin passed through the socket in line with the long axis of the piece. At least two such swivels were found by Adrianov (Moszyńska, 1974:265), and one was found in the later excavations.

6. Discussion

Contextual, osteological, artifactual, and ethnographic evidence together can be used to make inferences about the complex set of dog domestication practices that occurred at Ust'-Polui. The number of dogs represented at the site is unprecedented in the Yamal region. Well over 4000 specimens representing a minimum of 128 dogs are present, and this far underestimates the numbers once present. Large portions of the site were destroyed by development, and collections from several years of excavations are lost. The next largest dog assemblage in the region (Nadym Fortified Village, 15th to 18th centuries AD) produced 1001 dog specimens, less than one-fourth the amount seen at Ust'-Polui (Vizgalov et al., 2013). All other sites in the region, including those closer in age to Ust'-Polui, have generated a few hundred dog specimens or less (Vizgalov et al., 2013).

Domestication practices at Ust'-Polui can be grouped into those that were fleeting, and those that were recurrent. Most of the dog remains at Ust'-Polui were found disarticulated and many were fragmented, much like the site's other faunal remains (Bachura et al., 2017). Some of the dog remains are from individuals that were clearly butchered—4.1% of the total from the later excavations display cut marks. Unfortunately, no comparative data on cut mark frequencies is available for other fauna at Ust'-Polui. The only other regional site with cut mark data (analyzed by Nomokonova and Losey) is Iarte 6 on the Yamal peninsula (11th century AD), where 6.5% of the site's well-preserved reindeer remains have butchery marks (Nomokonova et al., 2017). While additional comparative information is needed to fully assess the meaning of cut marks on the Ust'-Polui dog remains, we suggest these marks indicate some dogs here were used as food, a practice reported in regional ethnography.

We also suspect that dogs were sometimes killed and butchered on the site. Dog skull elements represent far more individuals at the site than do postcranial remains—in the later excavations, at a rate of almost 1.5–1.0. The opposite pattern holds for the site's reindeer remains, whose skull fragments are rare compared to postcranial remains (MNE nor MNI figures are available) (Bachura et al., 2017). Wild reindeer, which aside from fish were probably the single most important food animal at Ust'-Polui, were presumably killed some distance away and their heads not transport to the site (Bachura et al., 2017). The dominance of head elements in the dog remains may indicate local killing and butchery, or even the preferential transport of dog skulls to the site. Further, ~10% of the dog remains from the later excavations are gnawed (including skulls), indicating that body parts with some nutritional value were left at the site, not just 'clean' skeletal elements. This too suggests some on-site killing and butchery.

The overall age profile for the Ust'-Polui dogs mirrors the ethnographically described preference for the consumption of young dogs, to some extent. Nearly 45% of the dogs at the site were under one year of age at the time of death. Recall too that just over 71% of the mandibles came from dogs below the mean estimated adult body size. In other words, smaller and younger dogs numerically dominate the assemblage. Overall there is little to distinguish the disarticulated Ust'-Polui dog remains from other faunal remains at the site—they are cut, sometimes broken, and scatted throughout the excavated area. All of this points to some killing and consumption of dogs by humans.

Culling old dogs or killing them at the death of their owners, both of which are documented in regional ethnography, do not correspond well with the patterns observed at Ust'-Polui. Many of the dogs are juveniles, and none of the remains were found directly with human burials. Some slaughtering of dogs for their fur cannot be excluded, but this alone would not explain the cut marks on the long bones and skulls—disarticulating the limbs and removing the head is not necessary for skinning. Further, if skinning for the production of clothes were the primary motive behind the deposition of the dog remains at Ust'-Polui, why would we not see similar numbers of dog remains at other regional sites?

Some ritualized killing and consumption of dogs at Ust'-Polui is likely. First, Moszyńska (1974:277–283) and Gusev and Fedorova (2012) have both argued that Ust'-Polui was a major multi-ethnic ritual center where various sacrifices were carried out. As mentioned above, dog sacrifices were historically conducted at such locations, including one just a few kilometers from the site. Second, the concentration of crania found by Adrianov, and the relative abundance of crania at the site relative to postcranial remains suggest some preferential treatment of dog heads and perhaps also local killing. Further, a few dog remains at Ust'-Polui appear to have been displayed by being suspended on sticks or straps, or even worn on the body, and all such instances involved crania or mandibles. Recall that local ethnographic accounts sometimes describe leaving the heads and furs from sacrificed dogs at ritual sites. Displaying dog head parts, gathering the heads of killed dogs in certain areas of the site, and transporting or leaving more heads at Ust-Poui than postcranial remains indicate that special attention was given to these parts, all of which is consistent with ritualized killing. Butchery and eating of sacrificed dogs is not historically documented, but sharing of other food at sacrifice sites is reported. Perhaps dog meat was such a food when Ust'-Polui was in use. Transportation of dogs from multiple regional settlements to Ust'-Polui for sacrifice and consumption also could help explain the abundance of the dog remains, which is clearly atypical for the broader area.

Sacrificing and other ritualized killing of dogs, all of which are forms of culling, are fleeting domestication practices, even from the perspective of the narrowest definitions of domestication, which focus mostly on reproductive control. Scholars decades ago proposed that initial domestication of some animals (including dogs) was motivated by a need for sacrificial victims (Hayden, 1995; Rodrique, 1992), and a similar idea was recently reintroduced and revised by Willerslev et al. (2015) as a motivation for reindeer domestication. These proposals (whether or not they are correct), and archaeological research on dogs and ritual slaughter more broadly, miss the fact that the abrupt moments of sacrificing domestic animals, killing them, is domestication—there is no more absolute way to 'control' an individual's ability to reproduce than by killing it. The age profile of the Ust'-Polui dogs indicates that nearly 45% of the individuals were under one year of age at the time of death, and around 23% were under six months of age. Modern dogs normally become sexually mature no earlier than at 10–11 months of age (Geiger et al., 2016; somewhat earlier maturation

ages are observed in free-ranging dogs with very high mortality rates (Paul et al., 2016)). Killing dogs less than one year of age, whether for sacrificial needs or dietary ones (or both), almost certainly ensured these animals never had the chance to reproduce, and killing older ones prevented them further producing offspring.

Coppinger and Coppinger (2016:213–4) have stated that there is "no solid evidence" for paired breeding of dogs prior to the Late Holocene, and that postzygotic selection was by far the longer standing practice. Bozell (1988:97), using both archaeological and ethnographic data, argued that dogs on the North American plains were sometimes culled in similar ways to that seen at Ust'-Polui, and these behaviors constituted "breeding practices". Such methods of selection are perhaps indicative of the difficulty of fully controlling dog sexual selection among mobile societies where dogs were mostly free ranging, and even the lack of need or desire for such reproductive control. The bodily outcomes of postzygotic selection should be some level of morphological, genetic, and behavioral heterogeneity, which probably has a number of benefits. Over the long term, this could have produced populations of dogs that were in some ways healthier. Such dogs presumably would have avoided the problems caused by paired (prezygotic) breeding now widely seen in our modern breed-standard animals. Further, diversity in dog ability, body size, and disposition was probably conductive to the animals fulfilling multiple fluid roles—as companions, sled pullers, and hunting partners, all of which are reported in regional ethnography. Heterogeneity, however, would be constrained and directed to some extent by other factors, including the local environment and climate, which are always selective agents in evolution, including domestication.

Selective breeding though is not the end point of domestication, nor does it alone bring about domestication or domestic animals. Recurrent practices and experiences with other species, landscapes, and made things are essential. For example, even the most finely bred sled dog must be repeatedly harnessed and engaged in pulling sleds with other dogs, as well as nurtured, disciplined, and fed, to function well in this particular working relationship (Coppinger and Coppinger, 2001:157–188). These practices and experiences too build and shape bodies, both chemically and structurally. Further, a sled dog must learn to communicate and collaborate with people and other dogs to become fully adept at this task—domestication is also learning or enskilment process, and an overtly social one. Just as importantly, it is in such recurrent shared experiences that emotional bonds can form between species.

A few adult and juvenile dogs at Ust'-Polui were buried, some as whole animals, and others without their heads. The latter of these may be sacrifices, albeit in a form not evident in regional ethnography. The whole body burials also could be dogs that were given mortuary rites at death. These show no evidence of perimortem trauma, and were not buried directly with humans. They were found in the same general areas of the site where two human burials were located (Losey et al., 2017a, 2017b; Fig. 2). These burials could have been parts of mortuary rites for dogs (as described ethnographically), indicating the development of a close dog and human social bond—the animals in effect being treated as other than human forms of persons (see Losey et al., 2011 for similar arguments). Alternatively, they could be sacrificed animals that were killed in ways that leave no skeletal signature, such as strangulation.

Stable carbon and nitrogen isotope data for the Ust'-Polui dogs demonstrates that they had diets rich in freshwater fauna, mostly fish from the Ob River and its tributaries (Losey et al., 2017a, 2017b). These bone chemistry values are also some of the most tangible evidence of the multi-species and landscape aspects of domestication. Maintaining many working dogs (particularly sled dogs during working periods) in cold environments requires feeding them, as such animals have very high energy requirements which cannot be met by their own foraging activities (Gerth et al., 2010; Loftus et al., 2014). This is most clearly illustrated by ethnographic survey data for Siberia, where dogs were shown to be the dominant transport animals (as opposed to reindeer) only in those areas where substantial numbers of dogs could be adequately provisioned—areas with rich fisheries or those where intensive sea mammal hunting was common (Davydov and Klokov, 2018). The Ob River and its rich fishery (Vizgalov et al., 2013), along with human efforts to obtain, store, and process the fish, enabled the presence of large numbers of dogs in this landscape, and allowed for particular ways of being with those dogs.

For example, having many dogs probably enhanced food procurement for humans by aiding in hunting and assisting in transport of people and loads. Unfortunately, the material outcomes of hunting with dogs in the north remain poorly understood, making it difficult to demonstrate exactly how past dogs were engaging in these activities with their human counterparts. Regardless, it is entirely reasonable to suspect dogs were involved in hunting at Ust'-Polui. This presumably had some economic and dietary benefits for people, but potentially also some detrimental effects on regional faunal, particularly those that were food items for humans and dogs.

Dogs' participation in pulling sleds is equally challenging to assess in archaeology, in part because the material evidence for these working relationship is often meager and ambiguous, but also because dog sledding encompasses a wide range of practices and materials. Assessing the practices of dog sledding is nonetheless important, as these ways of being with dogs are and were part of their domestication across the north. In parts of the North American Arctic, recurrent and rapid dog sledding is occasionally inferred through the combined presence of dog remains, harness and trace parts, and sleds, particularly the 'built-up' sled—a sled with thin rails and an raised platform (cf., Hall, 1978; Sheppard, 2004). All three groups of indicators are present at Ust'-Polui, including parts of several narrow-railed sleds with stanchions, numerous dog remains, and a large collection of swivels. In regard to the latter, swivels similar to those in Fig. 12 have been documented as dog harness parts in Chukotka (Bogoras, 1904–1909:109) and in several areas of the North American Arctic (Birket-Smith, 1929a:180, 1929b:75, 259; Nelson, 1983:210–211) (Supplementary Table 1).

Complicating this to some degree is the presence of possible reindeer head gear at Ust'-Polui, which some suggest (along with the swivels) was used with early domestic working deer, and others argue was used with tamed wild deer used as hunting decoys (Fedorova, 2000, 2006; Gusev et al., 2016; Moszyńska, 1974). The functions of the headgear, however, require further evaluation, and the swivel types shown in Fig. 12 do not match any of those we have seen in modern reindeer gear. All historical records indicate domestic reindeer herds were quite small in Yamal prior to the 17th century AD (Stépanoff, 2017), let alone over 2000 years ago. Small numbers of domestic reindeer likely could not alone account for the more than 250 swivels found at Ust'-Polui. Additionally, while the adult dogs at Ust'-Polui are relatively small, they are within the size range of historic sled dogs from the Arctic, which have surprisingly varied body masses (Supplementary Table 2; Pitulko and Kasparov, 2017). The Ust'-Polui dogs also have withers heights within the range of modern breed-standard Siberian huskies (American Kennel Club, 2006). Further suggestive of dog sledding is the possible image of a dog wearing a harness at Ust'-Polui (Fig. 4).

Pitul'ko (1998; Pitulko and Kasparov, 2017) has argued that dog sledding was critical to Arctic coastal adaptations in Siberia beginning in the Early Holocene. This is almost entirely based on his research at the Zhokov site (nearly 3000 km east-northeast of Ust Polui), where ~9000 year old dog remains have been found in association with a wood sled runner and toggles said to be parts of harnessing equipment (Pitulko and Kasparov, 1996, 2017). It is unclear if the Zhokov runner had stanchions or cross beams (or both), but holes for attachment of some elements are present. To us the toggles are not particularly convincing evidence of dog sledding, as they could have been used for virtually any sort of attachment needs. Regardless, if dog sledding

occurred at Zhokov, then a 7000 year gap exists in the whole of Siberian and the Russian Far East until its next appearance. For example, Pitulko and Kasparov (2017) state that dog sledding was practiced at Ust'-Polui, and suggest it also occurred at the Aachim-Mayak site in Chukotka (based on body size alone), both of which date to ~2000 years ago. No evidence for dog sledding between these two periods is presented, and we too are unaware of any such data. Clear evidence of dog sledding in the archaeological record of Chukotka seems to be otherwise absent (Bronshtein et al., 2016). Mannermaa et al. (2014) suggest that some Middle Holocene sled parts (those with longitudinal grooves) in Finland were possibly from sleds pulled by dogs. However, the overall archaeological evidence for dog sledding in Fennoscandia is meager (Viranta and Mannermaa, 2018). In the North American Arctic, the archaeological history of dog sledding is also poorly understood, with its earliest appearance perhaps being only ~1500 years ago (Sheppard, 2004; Friesen and Mason, 2016). In sum, the various lines of evidence presented here from Ust'-Polui appear to constitute some of the most substantial and clearest early evidence for advanced dog sledding anywhere in the Arctic.

Just as food and landscape enabled and sustained certain dog domestication practices and shaped bodily outcomes, so did engaging with made things such as sleds and harnesses. Involving dogs in pulling sleds as a recurrent practice probably selected for some dogs and against others. The strain of this activity likely caused some dogs to perish, and involvement in sledding helped people to identify dogs to be culled and those to be maintained. At the same time, having dogs and the equipment to transport people and the fish they caught helped to sustain more dogs. How dogs were harnessed (styles varied in the recent past (Levin and Potapov, 1961:74)), how efficiently types of sleds bore loads, how often and for what duration dogs pulled loads, and over what terrain they dragged them, all affected dietary requirements and bodily development, including skeletal morphologies. Added to this are the ways in which people trained or disciplined dogs involved in sledding, ranging from practices of minimal intervention, to severe beatings and even tooth removal to prevent gnawing of traces. These latter processes require things such as whips, clubs, hammers, and files. All of these material things and the practices involved with them also clearly shape life histories and evolution—they allowed dogs and humans to be together in distinct ways, to be domestic in this portion of the Arctic.

7. Conclusion

If we follow some of our own disciplinary definitions of domestication as a set of ongoing evolutionary, material, and social processes, then dogs were indeed domesticated in the Arctic, and are in fact still being domesticated across the planet. Our implicit understanding of domestication in archaeology though still suffers from a Neolithic Revolution hangover—we think, practice, and advertise domestication research as if it were largely the search for a long-past threshold marked by bodily change resulting from selective breeding. Everything thereafter was somehow different and of less relevance. The study of bodily changes is important to the study of domestication, but such changes are not domestication itself. Rather, they are one of many forms of evidence that can be scrutinized to assess the processes and relationships that constitute domestication.

In many ways, the practitioners of genetics and morphometrics are colonizing domestication as an area of research. Archaeology needs to embrace the insights offered by these fields, but we should also recognize their limits and our own unique ways of contributing to the unfolding story of domestication. Basic zooarchaeology as well as artifact and contextual analyses have much to offer, providing critical detail on the many fleeting and recurrent processes of domestication. Such research takes us far beyond determining points of origin and the classification of specimens as wild, domestic, and hybrid, and fully into the processes of selection, the entanglement of many species and things, and the complex ways domestication affects human-animal experience and evolution.

Finally, taking our own theories seriously explodes domestication research beyond its so-called cradles or origin points to regions and peoples often considered mere recipients of the finished products of this process. The Arctic is precisely such a place, geographically removed from where modern dogs' ancestors first began to live with humans, but where people and dogs (and other species) nonetheless crafted remarkably complex lives together over many thousands of years. These relationships are just worthy of our attention as where dogs first emerged.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.jaa.2018.06.004.

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