

RESEARCH ARTICLE

First Phalanx Morphometrics Reveals Camelid Morphotype Variability at Los Batanes (11th/12th c. CE), Southern Coastal Peru

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ABSTRACT

Archaeological excavations at Los Batanes in the Sama Valley (southern Peru) have brought to light a newly founded diasporic settlement following the demise of the Tiwanaku State (ca. 500–1000 CE). Previous research has suggested that the residents practiced a multiresource agropastoral subsistence strategy, with South American camelids (SACs) serving as the primary large mammals. Native to the Andean highlands, camelids at Los Batanes (500 masl) highlight the need to evaluate which species were herded in the hyperarid coastal desert of southern Peru to elucidate their economic function. In this study, we analyze camelid first phalanges from Los Batanes using established morphometric techniques and compare our results with reference datasets derived from modern camelid species. Our findings reveal significant morphometric variability in camelids from Los Batanes, with sizes spanning the range of extant SAC species. The predominance of large-sized camelids in the sample, alongside evidence of small and intermediate forms, shows a diversified morphotype selection by ancient agropastoralists. These results indicate the presence of more than one camelid species or breed. This study provides critical baseline data on species diversity, advancing our understanding of pre-Hispanic herding practices and camelid uses in the hyperarid coastal environments.

1 | Introduction

1.1 | Camelid Morphometrics

Zooarchaeological morphometrics analyze the size and shape of animal bones from archaeological contexts to identify species and subspecies and to assess population variability. Through various morphometric techniques, archaeologists have documented animal size and shape, affording critical information on processes of domestication and breed selection (Albarella 2002; Evin et al. 2013; Yu et al. 2022). In this paper, we apply first phalanx morphometrics to examine morphotype variability in

South American camelids (SACs) from Los Batanes, an early second-millennium site in far southern coastal Peru. Our results shed light on herd structure and economic roles of SACs among ancient agropastoral groups in arid coastal environments.

Extant South American camelids (order Artiodactyla, sub-order Tylopoda, family Camelidae) encompass two genera (*Vicugna* and *Lama*) and four species. The Vicuña (*Vicugna vicugna* [Molina 1782]) and guanaco (*Lama guanicoe* [Müller 1776]) are the wild species and presumed ancestors of their domesticated forms: the alpaca (*Vicugna pacos* [Linnaeus 1758]) and llama (*Lama glama* [Linnaeus 1758]) (Wheeler 2012). For

a long time, Andean archaeologists have struggled to identify archaeological camelid remains at the species level. Methods used include morphometrics (Miller 1979; Wing 1972), dental morphology (Wheeler 1982), fiber analysis (Viscarra et al. 2010; Wheeler et al. 1995), and ancient DNA (Abbona et al. 2020) to differentiate archaeological SAC remains, each with limitations in applicability and identifiability. So far, linear morphometrics remains one of the most established and widely used approaches for assessing morphotype variability in ancient SAC populations, although geometric morphometric studies are advancing rapidly (Le Neün et al. 2023; L'Heureux and Hernández 2021).

It has been suggested that extant South American camelids underwent significant genetic bottlenecks, leading to a loss of diversity during the early colonial period (Wheeler et al. 1995; Diaz-Maroto et al. 2021). Post- and pre-Hispanic crossbreeding among camelid species further complicates their taxonomic history and poses challenges for drawing analogies between modern species and archaeological specimens (Díaz-Lameiro et al. 2022). Based on first phalanx linear morphometrics, archaeological camelids have been assigned to different “morphotypes” (*sensu* Gasco and Marsh 2015). Although morphology is a function of both shape and size, previous studies have relied primarily on size gradients of modern camelid species to assign archaeological camelids to morphotypes represented by the modern SACs. Vicuña and alpaca are currently considered small-bodied camelids, while guanaco and llama are categorized as large-bodied morphotypes (Le Neün et al. 2023).

1.2 | Camelid Biogeography and Pastoralism

Far southern Peru features a sharp rise in elevation from the Pacific Ocean and hyperarid coastal desert at 0–500 masl to the intermountain valleys (500–3500 masl) and highlands (*altiplano*) above 3500 masl. All extant SACs are well-adapted to the high-altitude ecozones (i.e., *puna*), though vicuñas, as picky grazers and obligatory drinkers, are now limited to the alpine *puna* grasslands (Franklin 1982).

Archaeological evidence from the Andean highlands shows early use of SACs and the development of pastoralism, which involved herding llamas and alpacas for meat, bone, grease, fiber, and dung (Mengoni Goñalons and Yacobaccio 2006; Moore 2016; Yacobaccio 2021). Llamas, valued for their large body size and hardiness, were also used as pack animals in long-distance trade (Browman 1974; Vallières 2016; Webster and Janusek 2003). Alpacas, by contrast, are more gracile and unsuited for carrying heavy loads, but they produce finer fibers for textiles (Browman 1974).

Pastoralism provided a stable subsistence base in the marginal environments of the Andean highlands, where agriculture is limited to frost-resistant crops like tubers and chenopods (Langlie and Capriles 2021). While agropastoral groups were initially localized in resource extraction and material exchange (Capriles Flores 2011), they expanded their influence into nonnative ecozones as early as the Formative period (1500 BCE–500 CE) using llama caravans (Núñez and Dillehay 1979). The rise of early and subsequent complex societies in the south-central highlands is

closely linked to caravan trade and pastoralism (Browman 1981; Goldstein 2005; Murra 1975; Smith and Janusek 2014; Stanish et al. 2010). Llama caravans supported altitudinal (“vertical”) resource exchange into the 20th century, until eventually supplanted by rail and vehicle transport (Masuda 1985).

1.3 | Coastal Pastoralism

Archaeological studies attest to the geographic extent and temporal variation of ancient Andean pastoralism (Capriles Flores and Tripcevich 2016). Coastal pastoralism is especially notable, as herders no longer keep camelids in the arid coastal deserts nowadays. Camelid remains in archaeological contexts provide direct evidence of husbandry near the coast (e.g., Shimada and Shimada 1985; Szpak et al. 2014; Wheeler et al. 1995), and molecular studies further confirm some local herding in these regions (e.g., Dufour et al. 2014; Thornton et al. 2011; Tomczyk et al. 2019). In far southern Peru, evidence of coastal pastoralism has been limited (Bonavia 2008), but a growing body of data identifying camelid species and morphotypes highlights diverse herding strategies and uses along the coastal desert (de France 2016; Wheeler et al. 1995). While first phalanx morphometrics has been applied to coastal Moche and Wari sites (e.g., Alaica et al. 2021; Tomczyk 2024; Vásquez Sánchez and Rosales Tham 2024), it has not been systematically applied in the post-Tiwanaku context of southern coastal Peru.

Here, we examine 59 camelid first phalanges from domestic midden deposits at Los Batanes (11th–12th century CE) to establish morphotype variability of local camelid herds. Applying linear morphometrics, we compare these specimens to published data on extant and archaeological samples to approximate morphotype variability and infer possible breeds and economic uses of camelids by coastal agropastoralists at Los Batanes.

2 | Multiresource Agropastoralism at Los Batanes (11th–12th Century CE), Middle Sama Valley

The middle Sama Valley (ca. 500 masl) lies at the ecotone between the Andean mountains and the Pacific littoral (Figure 1). The valley bottom has supported maize and other hardy crops for at least a millennium, while the surrounding coastal desert plains feature seasonal fog oases that once attracted highland grazers (Julien 1985; Lavallée et al. 2011). Today, small camelid herds are kept in the Tarata Valley, the upper Sama River tributary, and wild guanacos inhabit the mountains above 3000 masl.

In the early second millennium CE, new settlements with distinct material culture, known as Cabuza, were established in the valley (Baitzel and Rivera Infante 2019). Cabuza is linked to emigrants from the Tiwanaku heartland or colonies who dispersed after the Tiwanaku state collapse around 1000 CE (Owen 2005). Los Batanes, the largest preserved Cabuza site in the middle Sama Valley, offers insights into post-Tiwanaku diasporic life. Excavated domestic structures reveal evidence of multiresource agropastoral subsistence. Occupants consumed and likely cultivated maize, chenopods, and chili peppers, kept camelids, guinea pigs, and dogs, and acquired fish and marine mollusks for food (Baitzel et al. 2023; Folk 2020). Preliminary

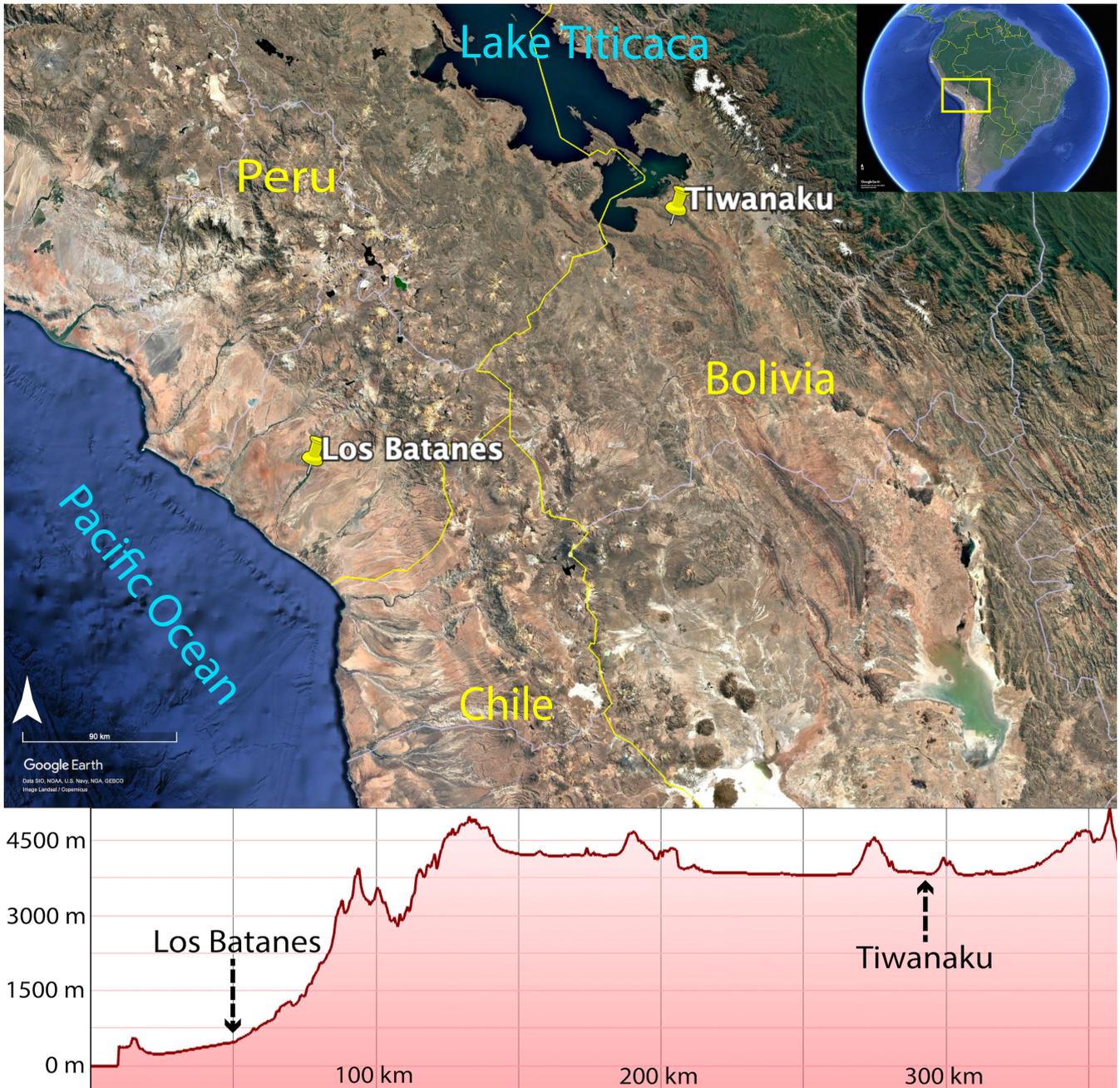


FIGURE 1 | Locations of Los Batanes and Tiwanaku archaeological sites in the south-central Andes with associated elevation change shown below. [Colour figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com)]

zooarchaeological analysis has documented a total number of 13,958 vertebrate specimens, in which disarticulated South American camelids make up a substantial portion by number (NISP=4390, 31.5% of total NISP) and weight (44.2kg, 66.7% of total weight). The analyzed camelid bones, with evidence of butchery and tool making, consist of cranial, axial, and appendicular parts, indicating access to camelids in full and local processing (see also Baitzel et al. 2023). Secondary animal products, including raw and processed camelid fiber as well as dung, are found throughout the domestic assemblage at Los Batanes, attesting to the importance of local husbandry. Assessing camelid morphotypes would help provide further insights into the herding strategies by local agropastoralists and economic contributions of camelids to the post-collapse diaspora.

3 | Materials and Methods

3.1 | Sample Selection and Measurement

Zooarchaeological analysis of the Los Batanes fauna was conducted in 2022 and 2023 under the direction of Sarah Kennedy. Identifications followed comparative collections and osteological guides (Altamirano Enciso 1983; Pacheco Torres et al. 1986). Zhu selected 59 complete camelid first phalanges for measurement. The specimens were excavated during the 2018, 2019, and 2022 field seasons from three site areas. Fifty phalanges came from midden associated with the architectural collapse of a multiroom residential compound in the site's northern area. Five others were from similar above-surface midden deposits and a below-ground

midden feature in two residential compounds in the central part of the site. Four were recovered from above-surface midden associated with a smaller residential compound between the central and northern mounds. Phalanges with unfused epiphysis or extensive wear were excluded to ensure measurement comparability. Two specimens (3477_M2.p, 150.p) exhibited mild-to-moderate exostoses on the lateral diaphysis, resembling pathology described by Susan deFrance (2010, Figure 13). Zhu included them for analysis, as the exostoses did not affect the measurements.

Zhu took linear measurements following von den Driesch (1976) and Kent (1982) (Figure 2). These include (1) maximum length proximal-distal (M1; equivalent to von den Driesch GL); (2) medio-lateral breadth of proximal articular surface (M2; equivalent to von den Driesch BFp); (3) plantar-dorsal height of proximal articular surface (M3; equivalent to Kent FP1V3/BP1V179); (4) breadth of distal articular surface (M4; equivalent to von den Driesch BFd); and (5) height of distal articular surface (M5; equivalent to Kent FP1V5/BP1V181). Each measurement was taken three times with a digital caliper (0.01-mm precision); averages were used to control for intra-observer error and were rounded to the nearest 0.1 mm.

3.2 | Dataset Information

For osteometric comparison, Zhu compiled a reference dataset of modern camelid species using published data from Kent (1982), Gasco (2012), and Le Neün et al. (2023). The geographic origin and sample size for each camelid species vary across these sources (see Gasco 2012, Table 7.2; Kent 1982, Table IV.2; Le Neün et al. 2023, Supplementary Data 1). For instance, Gasco's (2012) llama data are based mainly on specimens from the Bolivian *altiplano* and Argentina, while Kent (1982) measured llamas primarily from Peru. Guanacos in Kent's (1982) dataset were recognized as southern Patagonian subspecies, larger than the "Andean guanacos" from high-altitude western Argentina in Gasco's (2012) dataset (Gasco and Marsh 2015, 680).

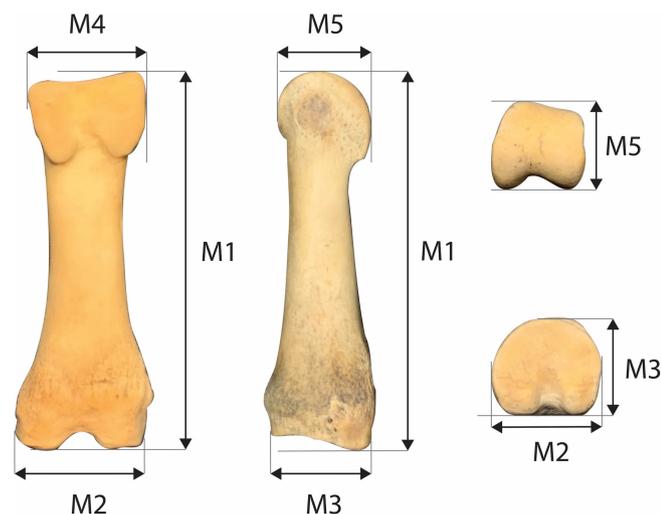


FIGURE 2 | Linear measurements M1–M5 for camelid first phalanx (adapted from Kent 1982, Figure IV.1). [Colour figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com)]

3.3 | Morphometric Analyses

The continued growth and refinement of modern reference databases have made osteometric comparison of archaeological SACs with modern species a viable approach for assessing camelid morphotype variation across the Andes (e.g., Izeta et al. 2009; Gasco 2012; Le Neün et al. 2023; and references therein). To account for size differences between forelimb and hindlimb phalanges, we distinguish front from hind first phalanges using Kent's (1982, Figure IV.12) method, which shows front phalanges have more slanted distal condyles. Age/maturity was controlled by selecting fused phalanges corresponding to individuals over 1.5 years old (Kent 1982). Sexual dimorphism is known to be minimal among SACs and is not recorded in first phalanges (Kaufmann and L'Heureux 2009).

We used summary datasets from Kent (1982) and Gasco (2012) for bivariate plots, and individual measurements in Le Neün et al. (2023, Supplementary Data 1) for principal component analysis (PCA) to assess osteometric variability and infer archaeological camelid morphotypes at Los Batanes. We also compared Los Batanes data with those from Le Neün et al. (2023, Supplementary Data 1), a cemetery site in northern Chile (Labarca and Gallardo 2015), and a multisite sample from Holocene central-west Argentina (Gasco 2012) using geometric mean (GM; see Izeta 2010). Zhu conducted all data analyses and visualizations in R (R Core Team 2023) using packages ggplot2 (Wickham 2016) and Factoextra (Kassambara and Mundt 2020).

4 | Results

Raw measurement for 59 phalangeal samples (32 front, 27 hind, MNI=8, conservatively estimated without regard to side, size, or context) is provided in Table S1. Forty-nine samples (83%) yielded complete measurements for linear dimensions M1–M5, enabling PCA and morphotype comparison through GM. The remaining 10 samples, with incomplete measurements due to erosion or breakage, were excluded from PCA and GM analysis. Overall, camelid first phalanges from Los Batanes exhibit internal variability for each linear dimension (Table S2).

4.1 | Bivariate Plots

Bivariate plots of paired dimensions M2/M3 and M1/M3 of front phalanges illustrate morphometric variability indicative of body size (Figures 3 and 4). Archaeological specimens (black dots) from Los Batanes are shown against the estimated measurement ranges for modern camelid species, represented by the mean and two standard deviations.

Modern camelid species show a size gradient from small-bodied (vicuña, alpaca) to large-bodied (guanacos, llamas), with notable overlap between wild and domesticated species within each group, as well as between domesticated species (Figures 3 and 4). Kent's (1982) Peruvian llamas are larger than Bolivian and Argentine llamas (Gasco 2012). Patagonian guanacos (Kent 1982) are also larger than Andean guanacos (Gasco 2012).

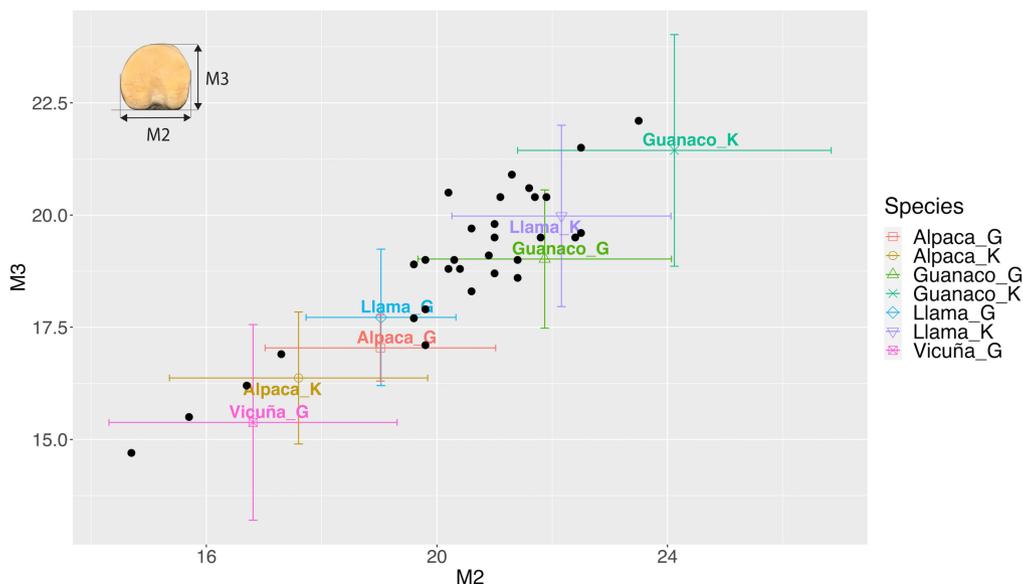


FIGURE 3 | Measurements M2/M3 (in mm) of *front* first phalanges, comparing samples from Los Batanes (black dots) with reference datasets (K=Kent 1982, G=Gasco 2012). A graph with labeled archaeological specimens is shown in Figure S1. For modern reference data, see Data S1. [Colour figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com)]

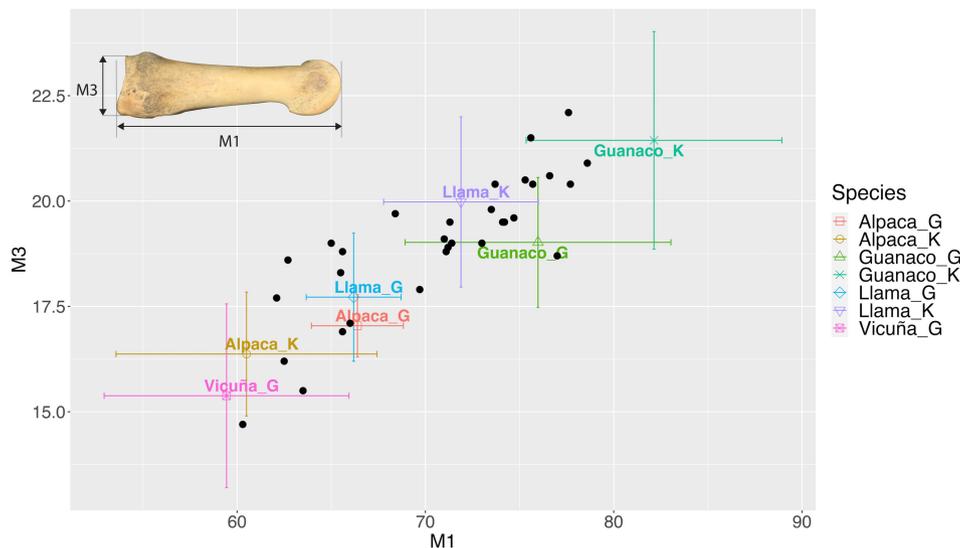


FIGURE 4 | Measurements M1/M3 (in mm) of *front* first phalanges, comparing samples from Los Batanes (black dots) with reference datasets (K=Kent 1982, G=Gasco 2012). A graph with labeled archaeological specimens is shown in Figure S1. For modern reference data, see Data S1. [Colour figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com)]

Morphometric results of camelid first phalanges from Los Batanes span the size range of modern species (Figures 3 and 4). Paired variables M2/M3 (Figure 3) identify four specimens aligning with modern vicuñas or alpacas, while three larger specimens fall near alpacas or Bolivian/Argentine llamas but are below the Peruvian llama/guanaco range. Most specimens ($n=24$) fall within the large-bodied Peruvian llama/guanaco range, with one exceptionally large matching Patagonian guanacos.

The biplot of measurements M1/M3 (Figure 4) reveals a wide distribution, with slight differences in specimen placement compared to M2/M3. Two morphotype groups are distinguishable: a small-bodied group ($n=10$) aligning with vicuñas, alpacas, and Bolivian/Argentine llamas, and a large-bodied group ($n=20$) within the

range of Peruvian llamas and guanacos. One specimen (4141_M1) falls outside the range of modern species, showing an intermediate size between the small and large groups (Figure S2).

Plotting measurements M2/M3 and M1/M3 for hind phalanges reveals a similar pattern. For hind phalanx M2/M3 (Figure S3), most measurements ($n=13$) cluster within the range of Peruvian llamas and guanacos. Few specimens ($n=7$) fall within the range of alpacas, vicuñas, and Bolivian/Argentine llamas, indicating small-bodied morphotypes. Six specimens are intermediate in size between Bolivian/Argentine llamas and Peruvian llamas. One specimen matches the size of southern guanacos. Hind phalanx M1/M3 (Figure S4) similarly shows 21 specimens aligning with Peruvian llamas and guanacos, including two specimens as large

as Patagonian guanacos, while six specimens fall within the range of Bolivian/Argentine llamas/alpacas. Additionally, one small specimen is comparable in size to modern vicuñas.

4.2 | PCA

PCA was conducted on 49 first phalanx measurements (front and hind) to compare specimens from Los Batanes with modern reference samples (Figures 5 and 6).

PCA results clearly associate Los Batanes samples with distinct modern morphotypes. Sixteen front phalanx specimens align with the guanaco morphotype group, although this group also includes large-sized llamas and an alpaca. Five specimens are exclusively associated with domesticated species, while four are characterized by a vicuña-like morphotype (Figure 5). One front phalanx outlier (3379.1) is notable for its shorter length (M1) relative to the size of

its proximal and distal facets (M2/M3 and M4/M5; see Table S1). A similar prevalence of guanaco and large llama morphotypes ($n=19$) is also observed in the hind first phalanges. At least three specimens align more closely with domesticated species, and one falls within the vicuña range (Figure 6). Another hind phalanx outlier (3185_M2) can be tentatively assigned to llamas based on raw measurements; its position in the diagram likely reflects its disproportionately large distal height (M5; see Table S1).

4.3 | GM

Based on GM, Figure 7 illustrates both site-specific camelid morphotype variability and inter-site morphotype comparison. Large-bodied camelids dominate the Los Batanes sample as indicated by the interquartile range. The majority (3/4) of Los Batanes camelids fall above the median of modern llamas, but only the largest 1/4 match the interquartile range of modern

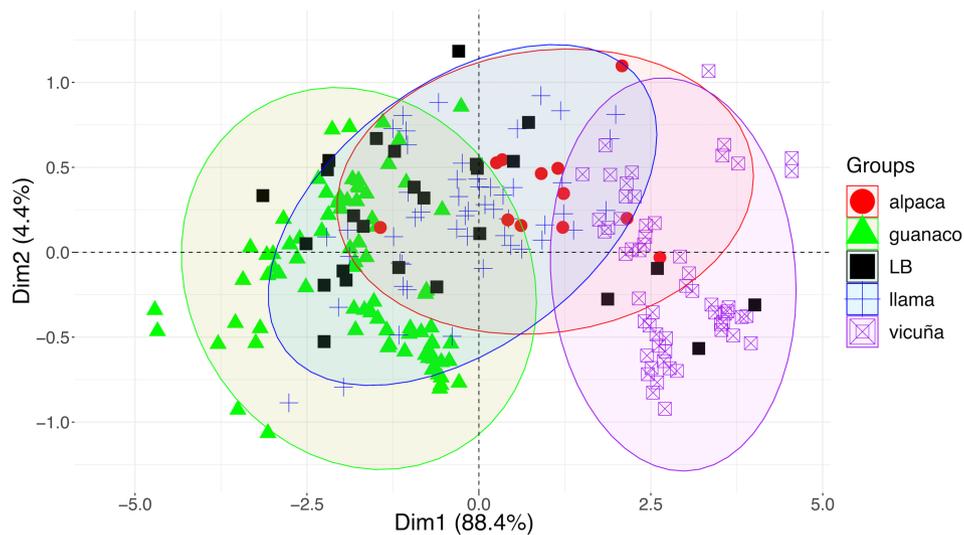


FIGURE 5 | PCA diagram based on *front first* phalanges, with ellipses representing 95% concentration (reference and archaeological data are available in Data S2). [Colour figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com)]

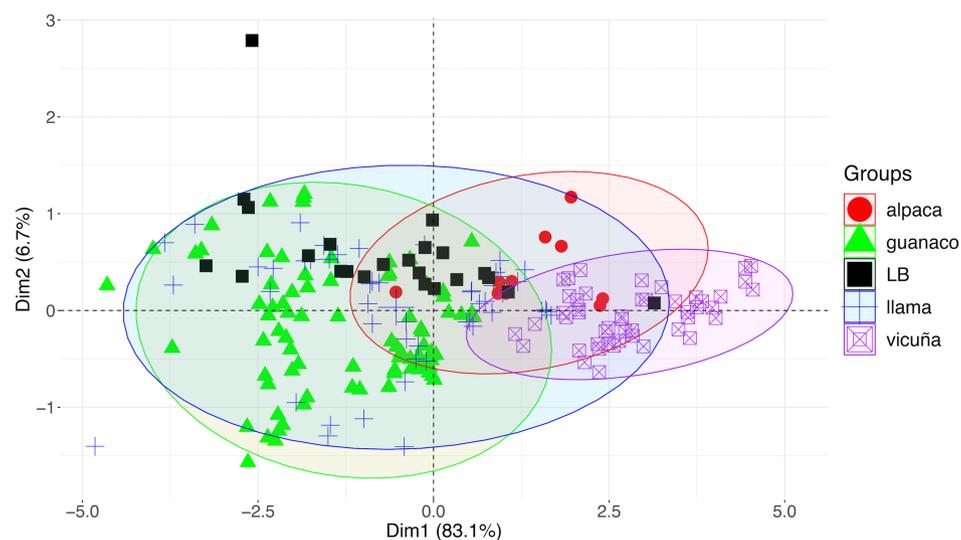


FIGURE 6 | PCA diagram based on *hind first* phalanges, with ellipses representing 95% concentration (reference and archaeological data are available in Data S2). [Colour figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com)]

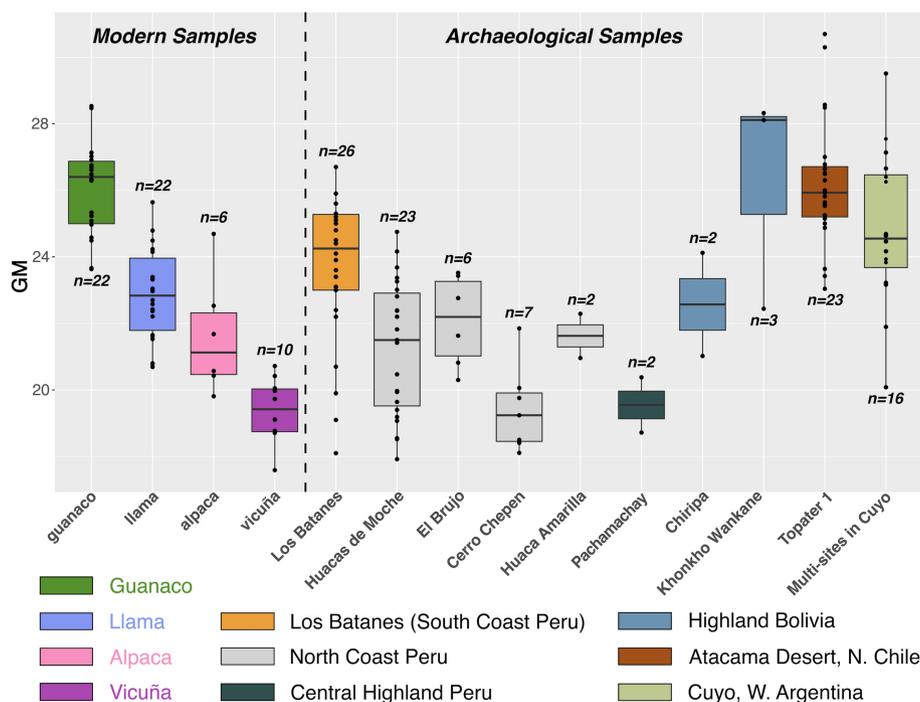


FIGURE 7 | Box plot comparing morphotype variability among archaeological and modern camelid samples through geometric mean (GM). Adapted from Le Neün et al. (2023) (see Data S3). [Colour figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com)]

guanacos. In the smallest 1/4 of the Los Batanes sample, two specimens are comparable to the median range of modern llamas and the upper boundary of the alpaca interquartile range. The remaining four specimens align more closely with small alpacas and vicuñas.

The Los Batanes sample stands out for its wide spread and predominance of large-bodied morphotypes compared to other archaeological sites (Figure 7). Similar emphasis on large-sized camelids is seen at Khonkho Wankane (Bolivian *altiplano*), Topater 1 Cetemery (high-altitude Atacama Desert, Northern Chile), and mid-to-late Holocene sites in the Cuyo region (central-west Argentina). Archaeological samples could be confounded by differences in sample size. Sites with comparable sample sizes, like Huacas de Moche (HDM; $n=23$) and Topater 1 ($n=23$), provide more robust comparisons to Los Batanes ($n=26$). Despite the broad range of HDM and Topater 1 samples, their specimens are distributed differently from those of Los Batanes: HDM camelids are evenly distributed between a llama/alpaca-sized group and a vicuña-sized group, while Topater 1 has no vicuña-like specimens. Therefore, the diversity in sample distribution among archaeological sites reflects morphotype variability rather than simply being a result of sample size.

5 | Discussion

Before discussing the implications of these results for coastal camelid pastoralism in the pre-Hispanic Andes and the economic use of camelids at Los Batanes specifically, we briefly

want to return to the limitations of morphometric analyses for taxonomic identification. All three statistical methods face difficulties distinguishing between wild and domesticated camelids of similar size, and even between domesticated species from different regions. This is partly due to small reference datasets, especially for modern alpacas; Kent (1982) includes only 26 individuals and Le Neün et al. (2023) include 6. Although reference data for llamas, guanacos, and vicuñas has increased, more work is needed to establish morphotype baselines for different breeds, subspecies, and camelids of defined geographic origins, such as guanacos and vicuñas in southern Peru. Moreover, modern extant camelid species and breeds represent only a small fraction of the camelid breeds—and possibly even species—that existed during pre-Hispanic times (Diaz-Maroto et al. 2021; Wheeler et al. 1995). In this regard, our morphometric results are at best reflecting camelid morphotypes, which may or may not be associated with a modern SAC species.

Camelids at Los Batanes demonstrate remarkable intra-population morphotype variation. Large-bodied camelids predominate, with strong evidence of small and intermediate-sized individuals, though in smaller numbers. The camelid assemblage at Los Batanes shows high morphometric variability compared to other modern and archaeological assemblages reported in the literature. Because our sampling strategy prioritized specimen preservation, the sample size does not allow for meaningful spatial comparison. Given the presence of different morphotypes at Los Batanes, it would be intriguing to test, with expanded samples and analyses of zooarchaeological/artifactual assemblages, whether certain residential compounds are associated with the husbandry or consumption of particular morphotypes.

Across the pre-Hispanic Andes, camelid morphotypes varied by culture group, subsistence strategy, and region (Figure 7). In the

south-central highlands, assemblages are predominately composed of large-sized camelid morphotypes (Capriles Flores 2011; Gasco and Marsh 2015). In contrast, archaeological sites on the north coast of Peru show a focus on small-to-intermediate camelids (Vásquez Sánchez and Rosales Tham 2024). Los Batanes, a coastal site with environmental conditions similar to the north coast (low altitude, warm arid climate), exhibits a prevalence of large-to-intermediate camelids, akin to patterns in the south-central highlands. This notable difference may be explained by the cultural affinity of Los Batanes herders with the Tiwanaku culture. It is likely that camelids at Los Batanes were brought from the highlands—similar to evidence from human and plant remains (Baitzel et al. 2023)—or bred from highland animals.

Even though some camelid morphotypes from Los Batanes resemble those of modern wild guanacos and vicuñas (Figures 3–6), the context of these remains in midden deposits of a late first-millennium CE settlement should allow us to rule out a large representation of wild camelids, suggesting that most of these animals were domesticated. To our knowledge, vicuñas have not been reported in the coastal region, but the taxonomic affiliation of vicuña-sized camelids on Peru's northern and southern coasts requires further testing, potentially with ancient DNA (Diaz-Maroto et al. 2021; Shimada and Shimada 1987). Nevertheless, the presence of guanaco remains at Los Batanes cannot be ruled out, as these animals have been reported in coastal deserts during the austral winter when fog (*garúa*) nourishes patches of seasonal vegetation (*lomas*), including in the Sama Valley (González et al. 2006; Lavallée et al. 2011). Herders at Los Batanes would have exploited the Sama Valley *lomas* as pasture for their camelid herds during the highland dry season. They may also have hunted wild guanacos or deer that were attracted from their highland habitats to these temporary vegetation patches (Baitzel et al. 2023; deFrance 2016).

Economic uses of camelids also influenced anthropogenic selection for body size. Large camelids at Los Batanes were probably used as pack animals moving highland products such as quinoa, tubers, and obsidian to the coast (Baitzel et al. 2023). Three percent ($n=2$) of the first phalanges in this study exhibited pathologies characteristic of pack animals at other Andean sites, indicating that some camelids from Los Batanes served as cargo animals (deFrance 2010). The discovery of camelid fibers, yarns, spindle whorls, and textiles at Los Batanes indicates localized fabric production and may explain the presence of smaller camelids. Small camelids in our sample, similar in morphotype to modern alpacas, may have been kept for their higher-quality fibers. Found in domestic midden deposits alongside camelid bones with extensive evidence of butchery and food processing, camelids at Los Batanes were also kept for consumption. Because the sample reflects only a subset of the once-living herds that were consumed, more evidence is needed to assess the relative contributions of different herding and culling strategies to the formation of the zooarchaeological assemblage. At this stage, it is reasonable to suggest that local agropastoralists used camelids for mixed purposes, with large-sized individuals particularly suited for caravan transport.

The multipurpose use of camelids at Los Batanes gives weight to their adaptive roles in provisioning, sustaining identities, and fostering regional networks in a period of collapse and social

reconfiguration (Baitzel et al. 2023). The possible use of camelid caravans raises the need to reevaluate localized strategies for coping with uncertain socio-political landscapes. Although the dispersal of settlements and contraction of regional trade have been observed along the coastal valleys of far southern Peru in the wake of the Tiwanaku collapse (Owen 2005), this study contributes to a more complex understanding of diasporic economies and cultural practices, highlighting continued regional connections, if not organized in the same manner as during the state period (Sharratt et al. 2015).

6 | Conclusion

In sum, our analysis suggests a diversity of camelid morphotypes at Los Batanes in the Sama Valley, southern coastal Peru. While our sample may not fully represent the once-living herds, the predominance of large-bodied camelids alongside intermediate and small forms indicates a distinct pattern of morphotype variability. This may reflect the presence of different taxa or breeds, as well as varied economic uses of camelids at Los Batanes, contrasting with the north coast's emphasis on smaller camelids. The discovery of multiple camelid morphotypes in domestic contexts within a hyperarid environment warrants further investigation into consumption patterns, herding strategies, breeding techniques, and potential lost camelid breeds. These questions should be tackled by future analyses concerning body part representation, age, disease, modifications, and fiber, combining biomolecular methods such as isotopic analysis and ancient DNA.

Above all, camelid first phalanx measurements from Los Batanes provide by far the largest dataset documenting the morphometric variability of ancient camelid populations in the Atacama Desert of far southern coastal Peru. These findings will advance our understanding of the geographic extent of pastoralism in the pre-Hispanic Andes, and assess the advantages and limitations of using linear morphometrics to characterize animal body size and evaluate morphotype variation.

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Ethics Statement

The data were excavated and analyzed with permission of the Ministerio de Cultura Peru Resolución Directoral N° 191-2022-DCIA/MC.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data are available through this paper and [Supporting Information](#).

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.