

## MAMMUTHUS EXILIS FROM THE CALIFORNIA CHANNEL ISLANDS: HEIGHT, MASS, AND GEOLOGIC AGE

LARRY D. AGENBROAD

*The Mammoth Site, P.O. Box 692, Hot Springs, SD 57747;  
larrya@mammothsite.org*

*Abstract*—It can be demonstrated that *Mammuthus exilis* was present, in its normal size range, for at least the temporal period of ca. 200,000 to 11,000 years ago. Columbian mammoths (*Mammuthus columbi*) were also present, in lesser numbers, during that time span. In 1990, Louise Roth calculated body mass of island mammoths using the humerus and femur of two *M. exilis* individuals. At that time she was limited to using only museum specimens, due to the policies of the land owners on Santa Rosa Island. In 1994, we excavated the most complete specimen of *M. exilis* yet recovered. Beginning that winter, a pedestrian survey, searching for mammoth remains, was initiated. The survey was controlled by GPS (Global Positioning System) data entry for locations. The survey was conducted through 2008, producing more than 380 localities for mammoth remains on the islands of San Miguel, Santa Rosa, and Santa Cruz. Using specimens collected during these surveys, plus the donation of materials collected by the ranch families, the Los Angeles County Museum, and the Orr collections housed at the Santa Barbara Museum of Natural History, new and expanded interpretations and inferences are provided. The temporal range of island mammoths' residency has been expanded, plus the maximum size of *M. exilis* is considerable less than reported in earlier literature.

### INTRODUCTION

The origin of island mammoths (*Mammuthus exilis*) was initially thought to have been derived from *Mammuthus imperator* (Osborn 1942; Hooijer 1976). However, a reassessment has placed 'primitive *M. imperator*' as conspecific with *Mammuthus meridionalis*, and 'advanced *M. imperator*' with *M. columbi* (Agenbroad 2003). Don Johnson (1978) concluded that *M. exilis* was derived from *M. columbi*, as did Madden (1977, 1981).

There have been multiple references to the occurrence of three sizes of mammoths on the Channel Islands (Stock 1935; also cited in Orr 1968 and Roth 1990) that stood, "up to 8 or 9 feet tall at the shoulder". Orr (1968) even suggested there were multiple species of small mammoths on the islands. Stock and Roth had very limited data from which to draw their conclusions. Roth used museum collections, as at that time the islands were private and access was limited. Phil Orr had obtained access to the islands and collected a greater mass of osteological material, but there is no record he used it quantitatively.

Prior to the 1994 discovery of a nearly complete skeleton (Agenbroad et al. 1995), this unique paleontological resource (*M. exilis*) of the California Channel Islands was poorly known. It was decided to analyze the metric attributes of the expanded collection of *M. exilis* specimens to estimate the skeletal shoulder height and body mass of the animals. Additional desired results were determining the total number of mammoth species on the islands, and the temporal range for the species.

### METHODS

In 1995 we initiated an ongoing pedestrian survey for mammoth remains. Locations of mammoth remains are recorded with a global positioning system (GPS) (Agenbroad 1998). Collected specimens are housed at the Santa Barbara Museum of Natural History (SBMNH) which also contains the Orr collections. The SBMNH has been designated as the official repository for Channel Islands National Park (CHIS) paleontology. In addition, there was the

extensive osteological collection from Santa Rosa Island, amassed by Boris Woolley, and donated to the SBMNH after his death.

Using the combined osteological collections from the SBMNH and the Los Angeles County Museum (LACM), there is sufficient material for body mass calculations and shoulder heights for a dozen individuals, using both humeri and femora from each individual. Shoulder height of *M. exilis* is calculated from the humerus length, using Harington et al. (1974) methodology. Body mass (weight) has been calculated from both humeri and femora lengths, using equations cited in Roth (1990), from earlier studies.

## RESULTS

### *Shoulder Height*

Table 1 and Figure 1 summarize the data for 12 complete humeri specimens. These data provide a skeletal shoulder height range from 1371–1929 mm. All specimens had fused articular surfaces, indicating that they were mature individuals, and reflect probable differences in age and gender. The mean skeletal height for 12 individuals is 1717 mm. These results are in contrast to the, “8- to 9-foot ‘intermediate’ forms,” cited by earlier researchers (Stock 1935; Orr 1968; Roth 1990).

One humerus used by both Stock (1935) and Roth (1990) measured 833 mm in length, giving estimates of an individual with a 2750 mm shoulder height. In the opinion of this author, it is more likely that it falls within the range of a small (female) Columbian mammoth. Both species were found on the islands (ca. 90% *M. exilis* to 10% *M. columbi*) (Agenbroad 1998). Using the Columbian mammoth population at the Mammoth Site of Hot Springs, SD as an example (Agenbroad and Mead 1994), the smallest humerus yet recovered from a minimum of 56 individuals of adolescent to adult, male mammoths is 1000 mm. A humerus of 833 mm is only 167 mm (16.7%) less than the smallest *M. columbi* at Hot Springs, which is well within the estimated 25% size difference due to female/male sexual dimorphism. The 1000 mm South Dakota specimen is 344 mm (34.4%) greater than the longest island mammoth humerus used in this study. That value exceeds the estimated difference due to sexual dimorphism.

### *Body Mass*

Using humeri data (n=12), the mass for *M. exilis* is calculated to range from 380 to 949 kg with an average of 714 kg (Table 1, Fig. 2). Using a different equation, as calculated using femur length, mass is slightly greater: 516 to 1151 kg (Table 2, Fig. 2). The average mass for 12 individuals based on calculations using femora is 759 kg. Roth (1990) states that based on data from living elephants, the femur length calculation is the more appropriate metric for determining mass. Plotting mass from both the humeri and the femora length (Fig. 2), there is an overlap of calculated masses, with 83% of the individuals falling between 500 kg and 950 kg.

### *Temporal Range*

Fully developed *M. exilis* remains are known from the basal conglomerates of the Pleistocene Santa Rosa Island Formation. That geologic unit was dated by Uranium/Thorium (U/TH) at > 200,000 years ago (Orr 1968), and *M. exilis* remains are found to the upper 10 cm of the modern surface. It must be remembered that the existing islands are

Table 1. *Mammuthus exilis* humeri calculations for mass and skeletal shoulder height. ~ indicates that no repository number was listed on the specimen.

Specimen #	Length (mm)	Mass (kg)	Shoulder ht. (mm)
~	606	767	1782
231	466	380	1371
185	621	820	1826
48/48	637	877	1873
94	651	930	1914
6/96	525	523	1544
231 (?)	484	421	1423
CIT-173	530	536	1559
67790	560	621	1647
193	632	858	1859
8/94a	656	949	1929
8/94b	639	884	1879
Mean	584	714	1717
Range	466–656	380–949	1371–1929

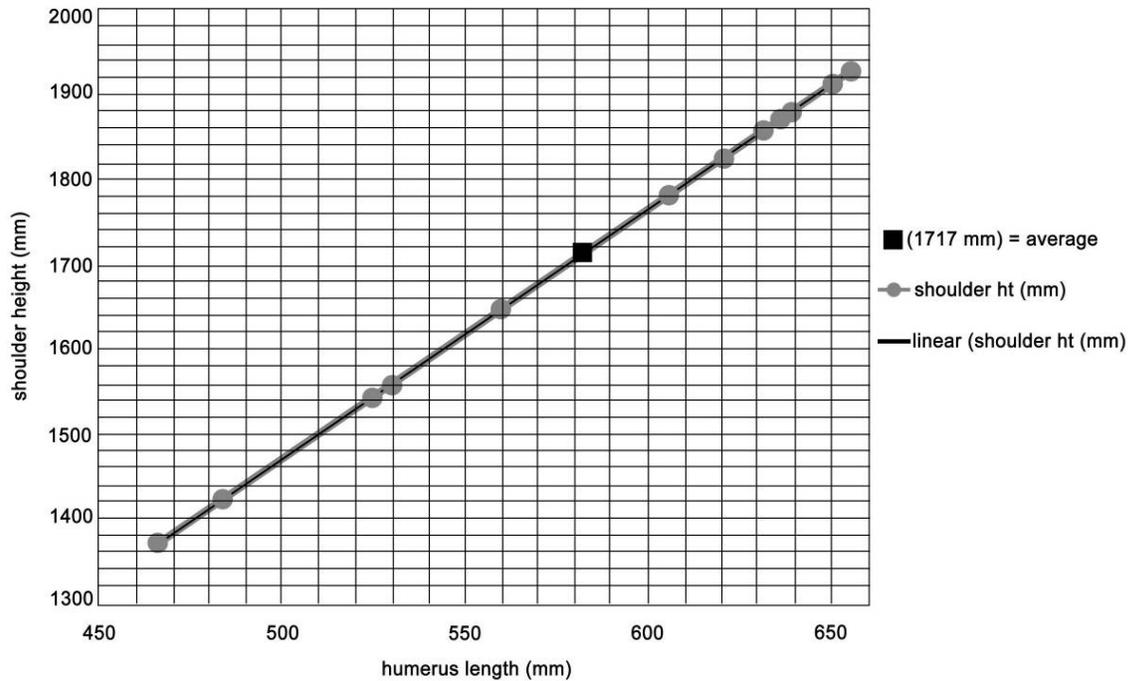


Figure 1. Skeletal shoulder height versus humerus length for *Mammuthus exilis*.

the uplands of the ancient Pleistocene island of Santarosae (Orr 1968). As much as 76% of the Pleistocene island has been inundated by post-Pleistocene eustatic sea level rise (Agenbroad 1999). The conclusion is that *M. columbi* initially (and perhaps periodically) colonized the Pleistocene island, Santarosae. Shortly after colonization, the island selected for smaller forms, and quickly formed the island pygmy mammoths.

Sondaar (1977) concluded that island forms reach a reduced size quickly and endure until extinction. Once the Santarosae island form (*M. exilis*) was established, it remained, essentially unchanged until the youngest radiocarbon date of 11,030 yr BP (CAMS-71697), contemporary with the arrival of humans (Agenbroad et al. 2005) as evidenced at Arlington Springs, on Santa Rosa Island (Johnson et al. 2002).

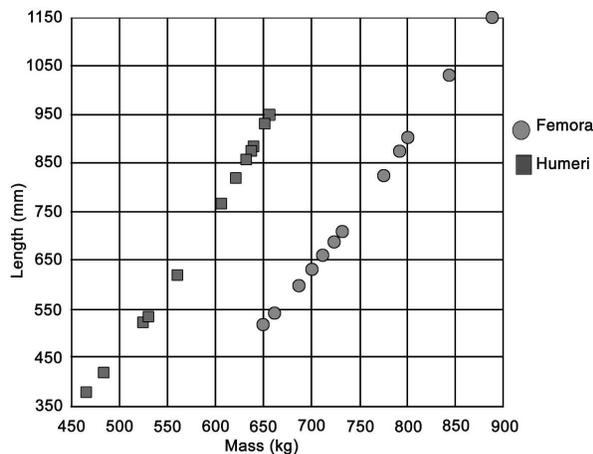


Figure 2. Mass (kg) versus length (mm) for humeri and femora for *Mammuthus exilis*.

### SUMMARY AND CONCLUSIONS

Using the data provided by at least 12, each, of humeri and femora of the island mammoths, it can be demonstrated that there are only two species of mammoths on the California Channel Islands: *M. columbi*, the continental mammoth, and *M. exilis*, the island mammoth. Using these data it can further be concluded that *M. exilis* did not exceed 1929 mm in skeletal shoulder height, or more than 949 kg in weight. Average values for skeletal shoulder height and weight are 1717 mm, height (from humeri data, Table 1), and 759 kg in mass (from femora data, Table 2), respectively. Using Table 1, it can be stated that for island mammoths ranging between

Table 2. *Mammuthus exilis* femora calculations for mass.

Specimen #	Length (mm)	Mass (kg)
1947	886	1151
SMICR	661	541
306	842	1029
209b	723	687
209c	700	630
d1	731	708
d2	649	516
6/96	686	598
WC1	774	823
WC2	711	658
8/94a	791	873
8/94b	800	899
Mean	746	759
Range	649–886	516–1151

1400 and 1900 mm in skeletal shoulder height, each increase of 100 mm in height equates to ca. 100 kg increase in mass. It also appears that *M. exilis* was resident on the island(s) from ca. 200,000 U/T years ago until human arrival, at 11,030 radiocarbon years ago (Agenbroad et al. 2005).

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