7-2024

Biostratigraphic Revision of *Esthonyx* (Tillidontia, Mammalia) in the Contect of Climate Change in the Lower Eocene of the Bighorn Basin, Wyoming

John Colter Johnson
University of Nebraska-Lincoln, cjohnson223@huskers.unl.edu

BIOSTRATIGRAPHIC REVISION OF *ESTHONYX* (TILLODONTIA, MAMMALIA) IN THE CONTEXT OF CLIMATE CHANGE IN THE LOWER EOCENE OF THE BIGHORN BASIN, WYOMING

By

John Colter Johnson

A THESIS

Presented to the Faculty of

The Graduate College at the University of Nebraska

In Partial Fulfillment of Requirements

For the Degree of Master of Science

Major: Geosciences

Under the Supervision of Professor Ross Secord

Lincoln, NE

July, 2024

BIOSTRATIGRAPHIC REVISION OF *ESTHONYX* (TILLODONTIA, MAMMALIA) IN THE CONTEXT OF CLIMATE CHANGE IN THE LOWER EOCENE OF THE BIGHORN BASIN, WYOMING

John Colter Johnson, M.S.

University of Nebraska, 2024

Advisor: Ross Secord

Esthonyx is an early Eocene tillodont found in North America, Europe, and India. The genus was named by E. D. Cope in 1874 based on specimens from the San Jose Formation in New Mexico. Since then, several species of *Esthonyx* have been described from North America alone. The best record of *Esthonyx* comes from the central Bighorn Basin (BHB) in Wyoming, where it appears in 220 localities in a 640 m-thick stratigraphic succession. Since the last summary of *Esthonyx* in the BHB (Gingerich and Gunnell, 1979; Schankler, 1980; Gingerich, 1989), several hundred new specimens have been collected and curated at the Denver Museum of Nature and Science and the Smithsonian National Museum of Natural History. Herein, I revise the taxonomy and stratigraphic distribution of *Esthonyx* in the central BHB. I also compare taxonomy and body mass changes with the paleoclimate record, including two hyperthermals recently identified in the study area. I identify three species of *Esthonyx* in the Wasatchian sequence: *E. spatularius* Cope, 1880, *E. bisulcatus* Cope, 1874, and *E. acutidens* Cope, 1881, using previous diagnoses, novel character combinations, and character quantifications. Additional undescribed species of *Esthonyx* may be present in the study

area. My results slightly extend the stratigraphic ranges of the three species described by previous studies, but they also reveal a strong correlation between smaller body size in *Esthonyx bisulcatus* and the ETM2 and H2 hyperthermals.

DEDICATION

This thesis is dedicated to my family, who made my journey through academia possible, especially my grandmothers, Mary and Joyce (Mayce), who sparked my love of paleontology and writing; my grandfathers, Bud and Glenn, who taught me hard work and how to find enjoyment in what I do; my parents, Doug and Amy, for their love and support to get me to this point; and lastly my wife, Amanda, for bringing out the best in me and supporting me to be the very best, even when it has not always been easy.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

pg.

INTRODUCTION

Tillodontia is an extinct order of eutherian mammals known from North America and Eurasia. They likely originated in Asia (Beard, 1998), where their diversity is highest. Twenty-four genera are recognized: seventeen from Asia, five from North America, and two from Europe (Mckenna and Bell, 1997; Rose et al., 2013; Smith et al., 2016). The oldest known tillodonts appear in the early Paleocene of Asia, and they probably did not reach North America until the latest Paleocene (Clarkforkian North American land-mammal age or NALMA), when *Azygonyx* appeared (Secord et al., 2006; Secord, 2008), along with the first rodent immigrants on the continent (Beard, 1998). The appearance of *Megalesthonyx* in the late Wasatchian NALMA (early Eocene) and *Trogosus* and *Tillodon* in the middle Eocene (Bridgerian NALMA) may be subsequent immigrants (Gingerich et al., 2009). North American tillodonts were extinct by the late Bridgerian and they left no known descendants (Lucas and Schoch, 1998).

The fossil record of the Bighorn Basin of Wyoming, USA, preserves the richest and most stratigraphically complete record of tillodont evolution in North America. The basin has over 2,000 m of superposed fossil vertebrate localities, spanning nearly the entirety of the Clarkforkian and Wasatchian land-mammal ages but lacking the youngest portion of the Wasatchian (late Wa-7) and the Wasatchian-Bridgerian boundary. The most extensive collections of Wasatchian tillodonts are from the Willwood Formation in the central Bighorn Basin (Fig. 1), according to Schankler, 1980. The Bighorn Basin is ideal for studying early Eocene tillodont taxonomy and biostratigraphy, due to the abundance of fossils and the unusually complete stratigraphic record. Moreover, several transient warming events, known as “hyperthermals,” have been identified in the Bighorn Basin

(Abels et al., 2012, 2016; Widlansky et al., 2022), providing an opportunity to compare the tillodont fossil record with some of these climate events.

Gingerich and Gunnell (1979) and Schankler (1980) described the taxonomy and stratigraphic ranges of tillodonts in the Bighorn Basin. Hundreds of new tillodont fossils have been collected in the ensuing four decades of fieldwork by Drs. Kenneth Rose, Amy Chew, Thomas Bown, Kimberly Nichols, and their students. Three genera are recognized in the Wasatchian NALMA: *Azygonyx*, *Esthonyx*, and *Megalesthonyx*. *Azygonyx* is best known from the Clarkforkian but ranges into the early Wasatchian NALMA and, although uncommon at that time, overlaps with the range of *Esthonyx*. *Megalesthonyx* is a rare taxon known only from the latest Wasatchian (Wa-7; Rose, 1972), and it is not considered further here. *Esthonyx* is the best-represented Wasatchian genus, containing at least three species. Schankler (1980) provided the most recent biostratigraphy for *Esthonyx* in the central and southern basin.

I re-evaluate the alpha taxonomy and stratigraphic distribution of *Esthonyx* in the central Bighorn Basin. I gathered data from specimens curated at the Denver Museum of Nature and Science (DMNS) and the National Museum of Natural History (USNM). Additional specimens on loan from DMNS or USNM at Johns Hopkins University (JHU) and Colorado State University (CSU) were studied. I revised the stratigraphic ranges for the species of *Esthonyx* studied here, placing them in a geochronologic context using pre-existing stratigraphic levels established by Bown et al. (1994) and current paleomagnetic interpretations (Clyde et al., 2007). I employed the natural log of the occlusal area of the first lower molar in specimens of *Esthonyx* as a proxy for body mass (Gingerich, 1974). I used my revision of biostratigraphy to compare taxonomic and body-mass changes across two hyperthermals, the Eocene Thermal Maximum 2 (ETM2) and H2 (Abels et al., 2012, 2016; Barnet et al., 2019; Widlansky et al., 2022), and evaluated the possible effects of these hyperthermals on species of *Esthonyx*.

Institutional Abbreviations

AMNH, American Museum of Natural History (New York, NY); BLM, United States Bureau of Land Management (Washington, DC); CSU, Colorado State University (Fort Collins, CO); DMNS, Denver Museum of Nature and Science (Denver, CO); JHU, Johns Hopkins University (Baltimore, MD); UNL, University of Nebraska- Lincoln (Lincoln, NE); UNSM, University of Nebraska State Museum (Lincoln, NE); USNM, National Museum of Natural History (Washington, D.C.).

BACKGROUND

Distribution of Tillodonts in North America

Five tillodont genera are recognized in North America: *Azygonyx, Esthonyx, Megalesthonyx, Trogosus,* and *Tillodon*. All of these genera are best known from the Rocky Mountain region but can be found throughout Eocene age rocks of North America. *Azygonyx* is the oldest North American tillodont, known only from Clarkforkian and early Wasatchian deposits of the Bighorn Basin (Gingerich, 1989). *Esthonyx* appears in Wasatchian deposits across North America, including Wyoming, New Mexico, Baja California (Mexico), Colorado, and Virginia (Gingerich and Gunnell, 1979; Novacek et al., 1991; Rose, 1999). *Megalesthonyx* is known from the late Wasatchian (Wa-7) of the Bighorn Basin, the Bridgerian NALMA in the Huerfano Formation in Colorado, and the

Wind River Formation in Wyoming (Rose, 1972; Gingerich and Gunnell, 1979; Stucky, 1984; Williamson et al., 1996). *Trogosus* and *Tillodon* are the last of the North American tillodonts and they are restricted to the Bridgerian NALMA (Robinson et al., 2004). *Trogosus* is widespread, having been found in Wyoming, Colorado, and California (Miyata and Deméré, 2016), whereas *Tillodon* is known only from the Bridger Formation in Wyoming (Gazin, 1976). Of these five genera, only *Azygonyx*, *Esthonyx*, and *Megalesthonyx* are known from the Bighorn Basin.

Geological Setting and Biostratigraphy

The Bown et al. Composite Stratigraphic Section (BCS) — Fossil specimens examined in this thesis come from the Willwood Formation of the central Bighorn Basin, Wyoming (Fig. 1). Bown et al. (1994) compiled a composite section spanning roughly 750 m of strata and over 1000 fossil localities in this area. 220 of these localities have produced specimens of *Esthonyx*. Hereafter, this section is referred to as the BCS. The BCS was constructed by tracing beds between local sections. Bown et al. (1994) start their section east of Worland, Wyoming, then continue into the Fifteen Mile Creek area section, beginning at 180 m (Fig. 1). Bown et al. (1994) end their section near Tatman Mountain and the Crow Woman Buttes Divide (recently renamed from Squaw Buttes; USGS Geographic Names Information System) at the highest stratigraphic levels (Fig. 1) (Bown et al., 1994). Bown et al. (1994) re-evaluated meter levels for additional localities in the Elk Creek and Elk Creek Rim areas (Fig. 1) that were originally measured by Schankler and Wing as part of Schankler, 1980. Additional description of this section can be found in Bown et al. (1994).

However, one problem with correlating between Schankler's (1980) composite section and the BCS is large discrepancies between Schankler's meter levels in the Elk Creek and Elk Creek Rim areas (Fig. 1), and the BCS. Below the 380-meter level, the BCS and Schankler (1980) composite sections differ by only a few meters, but at higher levels they can differ by 60–70 m (Bown et al., 1994; Clyde et al., 2007). Clyde et al. (2007) noted a significant discrepancy in the stratigraphic level of the C24r-C24n polarity chron reversal between the BCS and Schankler (1980) sections. They suggested that this discrepancy is due to either: (1) the greater thickness of the Elk Creek section, or (2) a possible miscorrelation by Bown et al. (1994) of this section to Elk Creek Rim. For these reasons, Clyde et al. (2007) recommended keeping localities in the Elk Creek area separate from the BCS. I follow that recommendation in this thesis. For this thesis, nearly all *Esthonyx* specimens came from localities within the Fifteen Mile Creek area, with only an insignificant number of specimens from the upper localities of Elk Creek or Elk Creek Rim.

In 2012, Sand Creek Divide was tied into the BCS, extending the section down to the Paleocene- Eocene boundary, providing a record for the Paleocene-Eocene Thermal Maximum (PETM) in the central basin (Rose et al., 2012).

The BCS begins at the base of the Willwood Formation (0 m), recognized by the lowest stratigraphically continuous reddish paleosol. The colorful Willwood Formation rests conformably on the drab-colored Fort Union Formation of late Paleocene age. The Willwood Formation is overlain by the Tatman Formation of late early Eocene age (latest Wasatchian, Wa-7) (Bown et al., 1994). The boundary between the Fort Union and Willwood formations corresponds with the onset of Paleocene-Eocene Thermal

Maximum (PETM), which is recognized by a large, negative carbon isotope excursion (CIE) (Zachos et al., 2001; Rose et al., 2012). The base of this CIE corresponds with the Paleocene-Eocene boundary and approximately with the Clarkforkian-Wasatchian boundary (Bowen et al., 2001; Rose et al., 2012). The onset of the PETM, and the base of the Willwood Formation, begin at ca. 55.8 Ma (Li et al., 2022).

Magnetic polarity chrons in the Bighorn Basin were most recently re-evaluated by Clyde et al. (2007) and correlated here to the most recent Geomagnetic Polarity Time Scale (Ogg, 2020). The BCS includes magnetochrons C24r and C24n (Fig. 2). According to the Geomagnetic Polarity Time Scale (GPTS, Ogg, 2020), these chrons were deposited between 57.101 Ma (base of C24r) and 52.540 Ma (base of C23r). Clyde et al. (2007) revised the earlier correlations of Tauxe et al. (1994), interpreting their N2 zone as a normal polarity overprint in the upper part of C24r. I follow their interpretation. Five polarity subchrons were recognized in C24n by Ogg (2020): C24n.3n, C24n.2r, C24n.2n, C24n.1r, C24n.1n. However, Clyde et al. (2007) carried over seven subchrons recognized by Tuaxe et al. (1994) in C24n, complicating correlations to the GPTS. They assigned the lowest normal subchron, beginning at about 400 m, to C24.3n but did not discuss correlation of the other subchrons. However, an $^{40}Ar/^{39}Ar$ age of 52.8 ± 0.3 Ma, derived from sanidine crystals (Wing et al., 1991), occurs in a normal subchron at 634 m near the top of the Willwood formations (Fig. 2). Ogg's age constraints place the bentonite in C24.1n. Thus, I interpret this subchron and normal subchron above it (separated by a brief reversal), as C24.1n. Notably, both C24.1n and C24n.3n are long normal intervals, compared with the shorter C24n.2n. This is consistent with the interpretation of Clyde et al. (2007) of the basal subchron representing C24n.3n and the joining of the two uppermost subchrons into C24.1n. Taking durations into consideration, the two short middle subchrons in the BCS probably correlate to C24.2n in the GPTS (Ogg, 2020).

Recognition of Wasatchian Biozones in the BCS — All localities in the BCS correlate to the Wasatchian land-mammal age (Bown et al., 1994).

Schankler (1980) recognized six faunal zones in the Schankler and Wing (S-W, cite his dissertation if you are doing to refer the S-W section) central Bighorn Basin section: the Lower and Upper *Haplomylus-Ectocion* Range-Zones (50–200 m, 200–380 m), the *Bunophorus* Interval-Zone (380–530 m), and the Lower, Middle, and Upper *Heptodon* Range-Zones (530–580 m, 580–670 m, 670–773 m) (Fig. 2). Schankler based the lower boundaries of the *Bunophorus* Interval-Zone, the *Heptodon* Range-Zone, and the Middle and Upper subzones of the *Heptodon* Range-Zone on the first occurrences of single taxa, whereas the boundaries of his other zones were defined during intervals of high faunal turnover, which he called "biohorizons" (Fig. 2).

Schankler described three Biohorizons: A, B, and C (Fig. 2). These biohorizons corresponded with the boundaries of several of his faunal zones. The *Haplomylus-Ectocion* Range-Zone was divided into Upper and Lower units at Biohorizon A (200 m in the S-W). The boundary between the *Haplomylus-Ectocion* Range-Zone and *Bunophorus* Interval-Zone was placed at Biohorizon B (380 m in the S-W). The base of the *Bunophorus* Interval-Zone was defined by the first appearance of *Bunophorus*, which Schankler (1980) described as the "sole new genus" at Biohorizon B. Schankler (1980) placed the boundary between the *Bunophorus* Interval-Zone and overlying *Heptodon* Range-Zone at Biohorizon C (Fig. 2, 530 m in the S-W). The boundary between the Lower and Middle subzones of the *Heptodon* Range-Zone was defined by the first appearance of *Hyopsodus powellianus,* which Schankler (1980) placed at 580 m in the S-W. Lastly, the boundary between the Middle and Upper *Heptodon* Range-Zones was characterized by the first appearance of *Lambdotherium popoagicum* at 670 m in the S-W (Schankler, 1980).

Shortly after Schankler (1980) established his Wasatchian biozonation in the central Bighorn Basin, Gingerich (1983) divided the early and middle Wasatchian into five separate biozones (Wa-1 through Wa-5) using the fossil record of superposed localities in the northern Bighorn Basin. Gingerich (1983) also recognized the *Heptodon* (Wa-6) and *Lambdotherium* (Wa-7) zones based on Schankler's biozones, the Lower *Heptodon* Range-Zone and the Upper *Heptodon* Range-Zone, respectfully. Gingerich (2001) subsequently modified some of his lower five zones and added the Wa-M (*Meniscotherium priscum*) and Wa-0 (*Sifrhippus sandrae*) zones, both of which occur in the PETM, resulting in the current zones listed above. Currently, there are nine biozones recognized in the Wasatchian in the northern Bighorn Basin: in stratigraphic sequence from oldest to youngest, they are Wa-M, Wa-0, Wa-1, Wa-2, Wa-3, Wa-4, Wa-5, Wa-6, and Wa-7 (Fig. 4) (Gingerich, 1983; Archibald et al., 1987; Gingerich, 1991; Gingerich, 2001; Gingerich and Clyde, 2001). Only the lower part of Wa-7 is present in the Bighorn Basin (Bown and Schankler, 1980; Schankler, 1980).

Some authors continued to use Schankler's (1980) zonation in the central Bighorn Basin (e.g., Secord et al., 2008), while most use a modified version of the northern Bighorn Basin biozones (Rose et al., 2012; Chew, 2009).

I used Gingerich's (2001) zonation and was able to recognize all of the biozones except Wa-1 (Fig. 2). Biozone boundaries were placed based on published first occurrences of defining taxa (Chew, 2015, supplemental data) and an unpublished dataset of mammalian occurrences for the upper part of the BCS, generously provided by Dr. Chew. There are several instances of boundary-defining index taxa possibly appearing below the traditional positions of boundaries (e.g., Smith, 2001). Because rare occurrence of index tax below their well-documented range could be the result of contamination in the collections or in the field, I placed biozone boundaries at the lowest level where there is more than one occurrence of the defining taxon. The defining taxa for Wa-1 and Wa-2, *Cardiolophus radinskyi* (Wa-1) and *Arfia shoshoniensis* (Wa-2), both first occur at ~45 m in the BCS. *Cardiolophus radinskyi* ranges into Wa-2, implying that Wa-1 is missing in this section, possibly due to a depositional hiatus or very slow accumulation rates. Additionally, Wa-M has not been recognized in the BCS (Rose et al., 2012). Meter levels for each faunal zone in the BCS are as follows: Wa-0 (<45 m), Wa-2 (~45–140 m), Wa-3 (~140–240 m), Wa-4 (~240–390 m), Wa-5 (~390–430 m), Wa-6 (~430–591 m), Wa-7 (601 m). The index taxon for each biozone is shown in Figure 2.

Biohorizons and Faunal Events — Schankler (1980) described Biohorizon A (200 m in the S-W), Biohorizon B (380 m in the S-W), and Biohorizon C (530 m in the S-W) in his stratigraphic section (Fig. 2). He described these biohorizons as “turnover intervals”, or intervals of local mammal “extinction” followed by origination. Bown et al. (1994) identified Biohorizon A and B in the BCS, recognizing them over thicker stratigraphic intervals (180-213 and 380 m, respectively) (Fig. 2). Subsequent authors have challenged the validity of Biohorizon A, arguing that it may be an artifact of sampling intensity, noting that it seems to be absent in the northern Bighorn Basin or Clarks Fork Basin (Badgley and Gingerich, 1988; Badgley, 1990; Bown et al., 1994;

Wing et al., 2000). However, Chew (2009) argued that Schankler's Biohorizon A and B were legitimate intervals of faunal change. Using a quantitative analysis that corrected for significant differences in sampling intensity, Chew (2009) found that disappearance rates increased in Biohorizon A and appearance rates increased in Biohorizon B. Chew (2009) did not evaluate the validity of Biohorizon C, which had been discounted by earlier studies (Bown et al., 1991; 1994; Bown and Kraus, 1993). Schankler (1980) suggested that Biohorizon C represented a large influx of immigrants into the basin, followed by a smaller "extinction" event ~25 m higher. However, Bown et al. (1991, 1994) and Bown and Kraus (1993) combined Biohorizon C with Biohorizon B, believing that Schankler (1980) had almost certainly documented the same episode of faunal turnover in different areas due to measurement and/or correlation errors in the upper part of Schankler's section.

In addition to Schankler's (1980) biohorizons, Chew (2015) described two additional faunal turnover "events" she named B1 and B2 that occurred stratigraphically immediately above Biohorizon B. She argued that these events corresponded to the ETM2 and H2 hyperthermals based on their stratigraphic positions relative to Biohorizon B. These faunal events were later shown to approximately correspond with ETM2 and H2 based on carbon isotope excursions in paleosol carbonates from directly relevant fossil localities and nearby sections (Widlansky et al., 2022). The stratigraphic positions of ETM2 (~408–426 m) and H2 (~430–460 m), based on Widlansky et al. (2022), are shown in Figure 2 along with Schankler's biohorizons A, B, and C, and Chew's faunal events.

Paleoclimate and Hyperthermals

The chronostratigraphic framework of the BCS allows for correlation to several hyperthermals, recognized in both marine and terrestrial records by negative CIEs (e.g., Abels et al., 2016; Barnet et al., 2019). In the northern part of the Bighorn Basin (McCullough Peaks), four small hyperthermals following the PETM have been recognized: ETM2, H2, I1, and I2 (Abels et al., 2012, 2016). Both ETM2 and H2, and I1 and I2, are "paired" hyperthermals, paced orbitally by 100,000 kyr eccentricity maxima (Barnet et al., 2019). Of these, only ETM2 and H2 have been identified in the central Bighorn Basin. Faunal turnover during Chew's B1 and B2 events was modest compared with the PETM and Schankler's Biohorizon B, the latter of which is not associated with a CIE (Abels et al., 2012; Widlansky et al., 2022). In contrast to faunal changes at the PETM, where approximately 40% of species become smaller (Secord et al., 2012), Chew (2015) did not find a coordinated shift to smaller body sizes associated with these lesser hyperthermals. However, D'Ambrosia et al. (2017) reported decreases in the body size of two taxa (*Arenahippus* and *Diacodexis*) during ETM2, based on a much smaller sample size from McCullough Peaks area of the Bighorn Basin. The I1 and I2 hyperthermals have not been confidently recognized in the BCS study area (Widlansky et al., 2022), but they have been located at McCullough Peaks in poorly fossiliferous strata (Abels et al., 2016).

An increase in global temperature of ca. 5°C in the late Wasatchian is inferred from leaf-margin analyses in the region (Wing and Greenwood, 1993; Wilf, 2000; Wing et al., 2000). This increase presumably marks the onset of the Early Eocene Climatic Optimum (EECO), which saw the warmest temperatures of the Cenozoic, including pronounced warming in the mid-latitudes (e.g., Zachos et al., 2001). Unlike the hyperthermals discussed above, the EECO is not marked by changes in the carbon isotopes record. The onset of the EECO occurs near the Wa-6/Wa-7 boundary based on the correlation of floras and mammal zones between the Green River and Bighorn basins (Wing and Greenwood, 1993; Wilf, 2000; Wing et al., 2000). Mammalian faunas attained peak species diversity during the EECO in Wind River and Bridger basins, and probably elsewhere (Woodburne et al., 2009a, 2009b). Samples of vertebrate specimens from Wa-7 in the Bighorn Basin, however, are limited.

MATERIALS AND METHODS

I examined more than 600 fossil specimens of *Esthonyx* in the USNM and DMNS collections, as well as material on loan from DMNS to Dr. Kenneth Rose at JHU. I measured length and width for 558 of these, and 97 specimens with more complete dentitions were borrowed for further study at UNSM.

Information about fossil localities and meter levels was taken from specimen tags and cross-referenced with Chew's (2015) supplemental data and unpublished database containing specimen information and catalog numbers. Many of these localities had stratigraphic meter levels reported by Bown et al. (1994), allowing for further confirmation using their data. Other localities not reported by Bown et al. (1994) were reported in the field notes and unpublished data of Chew, Nichols, and Bown (*e.g.*, Colorado State University localities and Rose and Chew’s unpublished localities). These localities were not tied into the BCS in 1994, but their stratigraphic levels have since been estimated.

I measured the specimens to the nearest 0.01 mm using digital calipers. Each dimension was measured at least three times and averages recorded. Length and width of all teeth were measured using the methods and dental landmarks described by Gingerich (1976, fig. 6). The averages of length and width were calculated when both left and right dentitions from the same individual were available. This provided a single measurement for each individual. The length and width of all teeth were measured onsite at the various collections.

I made additional measurements on the borrowed specimens using a binocular microscope and digital calipers. I conducted additional measurements on dP4/4 and P4/4-M3/3 for the borrowed specimens. Incisors, canines, dP2/2-3/3, and P2/2-3/3 were rare, but length and width were measured when available. For dp4 and p4-m3, additional measurements included the anterior-posterior length of the trigonid and talonid basins, the maximum height from the cervical margin to the occlusal surface of the trigonid and talonid along the buccal side, and the distances between the paraconid-metaconid, metaconid-protoconid, and protoconid-paraconid (See Fig. 3 for landmarks and Table 1 for measurements). For dP4 and P4-M3, additional measurements included maximum tooth height from the cervical margin to the occlusal surface along the buccal side, distances between the paracone-metacone, metacone-protocone, protocone-paracone, paracone-parastyle, and metacone-metastyle. The last two metrics provide a measure of the development of the parastylar and metastylar lobes (See Fig. 3, Table 2 for measurements). In addition to measurements, molds, casts, photographs, and hand-drawn illustrations were made for key specimens.

Body-Size Proxy- ln of m1 Area – The natural log of the area (length x width) of m1 was used as a body size proxy to investigate changes through time in *Esthonyx* species. This method is commonly used for tracking body size changes in eutherian mammals (e.g., Gingerich and Gunnell, 1979; Gingerich, 1989; Secord et al., 2012). Gingerich (1974) demonstrated that m1 was typically the least variable tooth in various eutherian mammals and, therefore, was most appropriate for comparing size differences among species. Other studies have found strong correlations between body mass and the natural log of m1 area in mammals (e.g., Gingerich, 1976; Gingerich et al., 1982). Although measurements of limb bones may sometimes yield more accurate estimates of body mass than tooth dimensions (Damuth and MacFadden, 1990), first lower molars are far more abundant and practical for tracking body size changes through time.

Cusp Position of p4 Trigonid – Previous authors used the positions of the p4 paraconid, protoconid, and metaconid to distinguish species of *Esthonyx* (Gazin, 1953; Gingerich and Gunnell, 1979). Descriptions range from these cusps forming a closed equilateral triangle to being more open. To quantify different the shapes of triangles subtended by the three cusps, I measured the distances between the three cusps and calculated the cosine at each vertex. According to Gazin (1953) and Gingerich and Gunnell (1979), the angle with the vertex on the protoconid is the most useful in differentiating species. The equation I used to determine the angle at the protoconid is as follows:

$$\text{Protoconid Angle} = cos^{-1}(\frac{a^2+b^2-c^2}{2ab})$$

Where a, b, and c represent the distance from paraconid to protoconid (*a*), protoconid to metaconid (*b*), and metaconid to paraconid (*c*).

SYSTEMATIC PALEONTOLOGY

Class MAMMALIA Linnaeus, 1758

Order TILLODONTIA Marsh, 1875

Family ESTHONYCHIDAE Cope, 1883

Anchippodontidae Gill, 1872, p. 11

Tillotheriidae Marsh, 1875, p. 221

Esthonychidae Cope, 1883, p. 80

ESTHONYX Cope, 1874

Esthonyx Cope, 1874, p. 6. Type: *Esthonyx bisulcatus* Cope.

Plesiesthonyx Lemoine, 1891, p. 276.

Type of genus — USNM 1103, left mandible with p3, m1–m3, from Arroyo Blanco, San Juan Basin, New Mexico. Collected by E. D. Cope in 1874.

Referred taxa — North American species: *Esthonyx bisulcatus* Cope, 1874; *E. spatularius* Cope, 1880; *E. acutidens* Cope, 1881. European species: *E. munieri* Lemoine, 1891.

Age and Distribution — Common from the late Paleocene (Clarkforkian) through the early Eocene (Wasatchian) of Wyoming, New Mexico, and Colorado. Last North American occurrence in the early Bridgerian (Br-1a) of the Wind River Basin, Wyoming. In the Paris Basin of Europe, present during the early Eocene (Sparnacian or Cuisian). In addition, Morris (1966) and Novack et al. (1991) reported cf. *Esthonyx* sp. from Baja California, Mexico (n=1); Rose (1999) reported *Esthonyx* sp. from Virginia, USA (n=1); and Rose et al. (2009) and Smith et al. (2016) reported *Esthonyx* sp. from India (n=1).

Esthonyx spatularius Cope, 1880

Figures 6–7, Tables 5–6

Esthonyx spatularius Cope, 1880, p. 908. Cope, 1881, p. 186. Cope, 1885, p. 211, Pl. 24a, fig. 22–25. Gingerich and Gunnell, 1979, p. 142, Pl. 3, fig. 5. Gingerich, 1989, p. 24. Rose et al., 2012, p. 34, fig. 19A–E, 20A–I. Rose et al., 2013, p. 846, fig. 3.1.

Esthonyx burmeisteri (in part), Cope, 1885, p. 204.

Esthonyx sp. indent., Dorr, 1952, p. 91, Pl. 7, fig. 7. Dorr, 1978, p. 83.

Esthonyx spatularius (in part), Gazin, 1953, p. 21, fig. 4.

Esthonyx bisulcatus (in part), Denison, 1973, p. 14. Mckenna, 1960, p. 85, fig. 43. Delson, 1971, p. 353.

Esthonyx cf. *bisulcatus,* Gazin, 1962, p. 42.

Holotype— AMNH FM 4809, eight associated teeth with left p3 and left m3. Posterior portion of right m1 or m2 present as well. Collected by J. L. Wortman in 1880 from the Gray Bull beds of the Bighorn Basin (Gazin, 1953; discussion on p. 21–23). AMNH FM 4809 was one of three of the first vertebrate fossils ever collected from the Bighorn Basin.

Referred specimens — DMNS specimens: EPV.91202, Lm2–m3 and Rm1–m3; and 92923, Lp4–partial m2. USNM specimens: USNM PAL 490643, Lp3–m3 and Rm1–m3 with associated post cranial material; 495160, Lm1, LP3–M3, and RP2–M1; 495497, Lp4; 523655, Ldp4–m1; 523656, RM1; 523657, Lm1 and associated material; 523663, Lp4 and Rm2; 523665, Ldp3–dp4, Rdp4 with erupting p2; 523666, Lm2–m3; 523669, Rp4; 523672, RP3 and RM2–M3; 523674, Unassociated Rm1, Ldp4, Lm3, Lp4; 523676, Rm3; 523677, Unassociated Rm2–m3, Rm2, and LM1; 545176, Ldp3–m1 (including dp4); 768814, Rp4 and m3, LP3, LM1–M3, RP3–M3; 768815, Rp3–p4, LP4–M1, RP4–M2; 768818, Lm2 and Rm1–m3; 768819, RC–M2, LI2–M3; 768822, Lp3–m2, Ri2–m2, and LP3–P4; 768823, Rm3; 768824, Lp4–m3 and Rc–m3; 768831, Rp2–m1. See Appendix for additional specimens.

Biostratigraphic Range and Localities in the study area — *Esthonyx spatularius* ranges from Wa-0 at Sand Creek Divide (Rose et al., 2012) through the first ~10 meters of Wa-5 in the BCS. Central Bighorn Basin localities are as follows: DMNS localities V-73027, V-73034, V-73037, V-73044; USGS localities D-389, D-1202, D-1242, D-1243, D-1251, D-1289, D-1301, D-1303, D-1335, D-1340, D-1342, D-1373, D-1389. D-1391, D-1414, D-1415, D-1441, D-1454, D-1460, D-1527, D-1560, D-1577, D-1633, D-1716, D-1866, D-1880, D-1924, D-1952, D-1967; University of Wyoming locality UW-25; Willwood localities (DMNS and USNM) WW-55; Yale localities Y-80, Y-104, Y-119, Y-132, Y-149, Y-156, Y-157, Y-206, Y-290, Y-294, Y-296L, Y-350, Y-351, and Y-421.

Description —Lower Dentition: *Esthonyx spatularius* has a fused mandibular symphysis (Fig. 6) with a lower dental formula of 2.1.3.3. *Esthonyx spatularius* appears to lack an i3 while retaining the characteristic large front two incisors and incisor-like canine known in all species of the genus (e.g., USNM PAL 490643, 768822). Incisors and canines are large and the crown of i2 is spatulate-shaped. The concave side of the i2 is divided down the center by a longitudinal rib of thinner enamel. The p2 is double-rooted (Fig. 6). All molars have a greatly reduced metastylid (Fig. 6). The trigonid of p4 tends to have its paraconid and metaconid closer together, resembling an equilateral triangle with the protoconid (Fig. 6). The angles of these triangles are somewhat variable but average about 58.2° at the protoconid (Fig. 5; Table 4).

Upper Dentition: Several specimens (e.g., USNM PAL 768814) of *Esthonyx spatularius* preserve associated upper and lower dentitions, allowing for confident identifications of isolated upper teeth. Upper dental formula for *E. spatularius* is 2.1.3.3. The upper cheek teeth of *E. spatularius* are relatively small compared to other Bighorn Basin *Esthonyx*, with a double-rooted P2. The upper molars are square in shape, with laterally compressed metastyles and parastyles (Fig. 7). P4 is small and triangular, with a distinctly separate paracone and metacone. M1 and M2 have a large parastylar and metastylar lobe present, but parastylar and metastylar cusps are not well defined. These lobes appear flat across the buccal margin in occlusal view (Fig. 7). M3 has an elongated parastyle but has only a hint of a metastyle (Fig. 7).

Amended Diagnosis —Gazin (1953) and Gingerich and Gunnell (1979) provide adequate diagnoses for *Esthonyx spatularius* in comparison to *E. bisulcatus,* and *E. acutidens.* They also distinguish these species from *Esthonyx munieri* and other North American tillodonts. *E. spatularius* is smaller than *E. bisulcatus* and *E. acutidens*, overlapping only slightly in the m1 area of *E. bisulcatus* (Gazin, 1953; Gingerich and Gunnell, 1979). They described the P2/2 of *E. spatularius* and *E. bisulcatus* as double-rooted, while *E. acutidens* is single-rooted. Additionally, *Esthonyx spatularius* has been described as differing from *E. bisulcatus* in having a more closed p4 trigonid basin, with the paraconid, protoconid, and metaconid forming the points of an equilateral triangle (Gingerich and Gunnell, 1979). This agrees with my measurements. The protoconid angle of *E. spatularius* averages 58.15°, while *E. bisulcatus* averages 74.36° (Fig. 5; Table 4). *E. acutidens* does not differ from *E. spatularius* and has a closed trigonid.

I found additional differences between the species. When observed in the occlusal view, the mesial end of p2 of *Esthonyx spatularius* and *E. acutidens* is directed buccally (Fig. 6). This differs from *Esthonyx bisulcatus* where the p2 is parallel with the other premolars, molars, and ramus of the jaw (Fig. 10). *Esthonyx spatularius* and *E. acutidens* tend to have much smaller metastylids than *E. bisulcatus*. When viewing upper dentition in occlusal view, *E. spatularius* differs from *E. bisulcatus* and *E. acutidens* by having a flattened metastyle and parastyle on the M1 and M2 (Fig. 7). *Esthonyx spatularius* is like *E. acutidens* in having upper teeth that are all close in size and it differs from *E. acutidens* in having the M2 closer in size to its P4 and M1.

Discussion —Simpson (1937) showed that the upper size range of *Esthonyx spatularius* overlapped with the smaller species of *E. bisulcatus,* suggesting that *E.*

spatularius should be synonymized with *E. bisulcatus.* Gingerich and Gunnell (1979) and Gingerich (1989) also found some size overlap between the two species but kept them separate, as did Schankler (1980). Results from this study show a considerable overlap in m1 size (Fig. 4: Table 3) between these species, but morphologic criteria, such as the protoconid angle of p4 and presence of i3, strongly indicate the presence of two distinct species (e.g., Fig. 5; Table 4).

In their revision of Wind River Basin tillodonts, Stucky and Krishtalka (1983) stated that P2/2 was single-rooted in both *Esthonyx spatularius* and *E. bisulcatus*, in contrast to previous descriptions of it being double-rooted in both species (Gazin, 1953; Gingerich and Gunnell, 1979). I found no evidence for a single-rooted P2/2 in either species and I consider this interpretation erroneous.

Esthonyx bisulcatus Cope, 1874

Figures 8–11, Tables 7–12

Esthonyx bisulcatus Cope, 1874, p. 6. Cope, 1875, p. 24. Cope, 1877, p. 154, Pl. 40, figs. 27–33. Gazin, 1953, p. 17, figs. 1–3. Kelley and Wood, 1954, p. 340, figs. 3a, b. Guthrie, 1967, p. 33. Gingerich and Gunnell, 1979, p. 144, Pl. 3, figs. 6, 7. Rose et al., 2013, p. 846, figs. 3.2, 3.4, 3.5.

Esthonyx burmeisterii Cope, 1874, p. 7. Cope, 1875, p. 24. Cope, 1877, p. 156, Pl. 40, fig. 26.

Esthonyx acer Cope, 1874, p.7.

Esthonyx burmeisterii (in part), Cope, 1884, p. 479, figs. 23, 24. Cope, 1885, p. 204, Pl. 24c, figs. 1–10.

Synonyms — *Esthonyx burmeisterii* Cope, 1874; *Ethonyx acer* Cope, 1874.

Holotype — USNM 1103, left mandible with p3, m1–m3, from Arroyo Blanco, San Juan Basin, New Mexico. Collected by E. D. Cope in 1874.

Referred specimens — DMNS specimens: EPV. 91675, Palate with RI1–C and P3–M3 and associated incisors; 91716, Lp4, R molar, upper molar portion; 91985, Associated teeth, L molar, Rp2 and m3, and LM2; 92160, Lp4–m1, LI2; 92203, Ri2, Rp4–m3, and RI2; 92208, Lp2, Ldp4–m1, and Lm2; 92791, R lower molar, RM2; 124357, Ldp4–m3, Rdp4–m1, and LC. USNM specimens: USNM PAL 487886, Li2–c, Ri2, Rp4, Rm1–m2, LP3–M1, and RP4–M1; 487889, Lp4–m3, Rp3, Rm2, and Rm3; 487903, Rp4–m2; 490635, Lp2–m2; 495050, Rm1, Rm3, LP3–M3, RM1–M3; 495160, Lm1, LP3–M3, RP2–M1; 495175, Rp4, Rm3, and RM1; 495176, Lm1, 495445, RdP4; 509596, Ldp4–m1 with symphysis in jaw; 510865, Lp4–m3, Rm2–m3, LP3–P4, LM2–M3, and RP3–M3; 511071, Skull with L and R P2–M1(with dP3 and dP4), and L and R i1–m1 (with dp3 and dp4); 521531, RP3–M1; 523664, Lm3 and Rm1–m3; 523671, Rp4–m3; 523673, Rm1 and m2; 523675, Rp4 and Rm2–m3; 523678, Lm3 and Rm2; 523679, Rm2; 523681, Lm3; 523685, Lm2 and Rp3–m1; 523690, Rm2 and Rm3; 523692, Lp4–m3 (with additional Lm3, probably unassociated), LP3–M1, and RP3–M2; 523696, RP4; 523699, Lm1–m3, LM3, and RM1; 527541, Lp3–m3, Rp4–m1, and Rm3; 527706, Lp3–m1, Rm1–m3, upper C; 540180, Lp3–m2; 540207, Rdp4–m1; 541885, Rdp4–m1; 544740, Lm1–m3, Rdp3, dp4–m1, Rm2–m3, L and R M1–M2; 712650, Lp3–m3, Rp4–

m2; 712651, i1–i3; 712652, Lp3–m3; 712654, Lm1–m3; 712655, Ldp4–m3 and Rdp4–m3; 712656, Rm1–m3; 712657, Lm1–m2; 712658, Ldp4–m2 and Rdp3–m2; 712708, Lm1–m3; 712709, Lm1–m3; 712710, Rp4–m2; 712711, Rdp4–m2; 712712, Rdp4–m2; 768812, Lp3–m1, Rm2–m3, LP3–M3, R P4–M2; 768813, Lm1–m3, LP3–M3, RM2–M3; 768817, Lm1–m2 and LM2; 768821, Ldp4–m1 and Rdp4–m1; 768825, Li3–m3, Rp2–m3, LP3–M3, RM1–M3; 768827, Rp2, Rp4, Rm3, LP4–M1, RM2; 768828, Ldp4–m1, RdP3–dP4; 768829, LP4–M3, RM1–M3; 768833, Lm1–m2, LC1–M3; 768835, Lp2–dp3, Rp2–dp4, RdP3–M1; 768836, Lc, Ldp3–m1; 768837, Ldp4–m3; 768838, Lm3, Rp3–m3, RM1–M3; 768839, Ldp3–m1 and Rdp4–m1; 768840, LP2–M2 and RP4–M3; 768842, LM2–M3; 768847, Rm1–m3; 768849, Rdp3–dp4; 768852, Ldp3–dp4; 768853, Ldp3–m1, Rm1, and Rm3; 768854, Rm2–m3; 768856, Lp4–m3, Ri2–m3; 768859, Lp4–m3 and Rm1–m3; 768861, Lp4–m3; 768863, Rdp4–m2; 768866, Lp3–m3, Ri2, and Rm2–m3; 768868, Lp2, Lp4–m2, Rp3–m3, and associated anterior teeth. See Appendix for additional specimens.

Biostratigraphic Range and Localities in the study area — *Esthonyx bisulcatus* ranges from mid Wa-3 to Wa-7. Central Bighorn Basin localities are as follows: DMNS Locality V-73016; USGS Localities D-1162, D-1169, D-1174, D-1175, D-1177, D-1192 high, D-1201, D-1204, D-1206, D-1222, D-1229, D-1258, D-1293, D-1297, D-1303, D-1306, D-1310, D-1311, D-1312, D-1316, D-1320, D-1322, D-1324, D-1325, D-1326, D-1335, D-1338N, D-1341, D-1342, D-1346, D-1349, D-1350, D-1373, D-1382, D-1387, D-1388, D-1389, D-1392, D-1400, D-1441, D-1414, D-1415, D-1418, D-1419, D-1421, D-1425, D-1426, D-1429, D-1431, D-1436, D-1438, D-1451, D-1452, D-1454, D-1459, D-1459, D-1460, D-1464, D-1467, D-1473, D-1474, D-1491, D-1495, D-1504, D-1507, D-1510, D-1511, D-1527, D-1530, D-1531, D-1532, D-1537, D-1538, D-1541, D-1554, D-1563, D-1565, D-1567, D-1573, D-1583, D-1588, D-1592, D-1597, D-1602, D-1603, D-1604, D-1633, D-1635, D-1645, D-1660, D-1660 B, D-1665, D-1668, D-1699, D-1712, D-1727, D-1737, D-1767, D-1775, D-1792, D-1800, D-1823, D-1833, D-1843, D-1847, D-1863, D-1876, D-1881, D-1882, D-1917, D-1923, D-1924, D-1935, D-1951, D-1967, D-1994; University of Michigan UM-RB 8; Willwood localities (DMNS and USNM) WW-8, WW-32, WW-34, WW-54, WW-55, WW-137, WW-315; Yale Localities Y-34, Y-39, Y-45B, Y-55, Y-67, Y-69, Y-84, Y-100, Y-104, Y-131, Y-132, Y-156, Y-157, Y-175, Y-283, Y-289, Y-290, Y-296L, Y-324, Y-344, Y-351, Y-363, and Y-459.

Description —Lower Dentition: *Esthonyx bisulcatus* has a fused mandibular symphysis (e.g., USNM PAL 511071). The lower dental formula is 3.1.3.3. The i3 is small and peg-like (Fig. 10). The p2 is double-rooted and is positioned in the jaw so that it is parallel with p3 and the ramus (Fig. 10). The p4 is characterized by a more open trigonid (Fig. 8) with an average protoconid-angle of 74.4°, but a wide range of 68.1° to 84.5° (Fig. 5; Table 4). A pronounced, well-developed metastylid is present on all lower molars (Figs. 8, 10-11). It forms a forked or leaf-shaped pattern with the paraconid and metaconid in lingual view. The metastylid, although always present, varies in expression between individuals, according wear stage. The metastylid varies from half the height of the metaconid to nearly its entire height.

Upper Dentition: *Esthonyx bisulcatus* has an upper dental formula of 2.1.3.3. The cusps of the upper teeth are acute, with a parastyle, metastyle, and external cingulum present on P4–M3 (Fig. 9). The parastyle and metastyle create a J or L-shaped buccal edge. The parastyle is longer and more vertical than the metastyle. The degree of development varies among individuals but the pattern is still present (Fig. 9). *Esthonyx bisulcatus* has a well-developed hypocone on the molars (Fig. 9). The upper P2 is double-rooted. P3 and P4 are small relative to M1 (Fig. 9; Table 8). P4 is square-shaped when viewed occlusally and is lingually flattened (Fig. 9). The metacone and paracone of P4 are distinct and nearly separate (Fig. 9). This is unlike other species, where the metacone and paracone are closer together. M1 and dP4 are nearly identical. M1 is the squarest of the three molars. M2 and M3 are usually wider than M1 and have more pronounced parastyles and metastyles (Fig. 9). M2 and M3 are the most variable, suggesting the preferred teeth for identification are P4 and M1.

Amended Diagnosis — Gingerich and Gunnell (1979) illustrated the natural log of m1 area for *Esthonyx bisulcatus* from the northern Bighorn Basin (see Gingerich and Gunnell, 1979, Table 2). They showed a wide size distribution ranging from ~3.70 to just below 4.0 in the natural log of the m1 area. This range overlaps with their measurements of the upper limits of *E. spatularius* and the lower limits of *E. acutidens*. However, I find that the range is much broader in the BCS *E. bisulcatus*, ranging from 3.48–4.18 (Table 3). This almost entirely overlaps with *E. spatularius* and *E. acutidens,* making *E. bisulcatus* much harder to distinguish based on size alone. The P2/2 of *E. bisulcatus* was described as double-rooted, while *E. acutidens* was described as single-rooted. Additionally, they noted that *E. bisulcatus* has a more open p4 trigonid basin, as compared to the closed trigonid seen in *E. spatularius* and *E. acutidens* (Gingerich and Gunnell, 1979). Similarly, I found that the protoconid angle of *E. spatularius* and *E. acutidens* averages 58.15° and 61.50°, respectively, while *E. bisulcatus* averages 74.36° (Fig. 5; Table 4).

I found that *Esthonyx bisulcatus* differs further by retaining the i3, while the other species have lost it (Fig. 10). When observed in occlusal view, the p2 of *Esthonyx bisulcatus* is parallel with the other premolars, molars, and ramus of the jaw (Fig. 10). This differs from the p2 of *E. spatularius* and *E. acutidens*, which are directed buccally (Fig. 6). *Esthonyx bisulcatus* tends to have much larger metastylids on the lower teeth than *E. spatularius* and *E. acutidens*. *Esthonyx bisulcatus* has a parastyle that creates a J or L shape with the metastyle (Fig. 9). On the P4, the paracone and metacone are more separated in *E. bisulcatus* than in *E. acutidens,* and *E. bisulcatus* has a significantly reduced ridge between the cusps (Fig. 9). The P4 of *E. bisulcatus* is smaller than M1 and M2 (Table 7), while *E. acutidens* has the P4 and M1 close to the same size, with the M2 being the largest upper tooth (Table 13).

Discussion — *Esthonyx bisulcatus* varies in size more than the other described species in this study due primarily to shifts in body size through the stratigraphic sequence (Fig. 4). A shift to smaller m1 size occurs at 360 m, with the peaks of this shift occurring at 410–412 m and again at 430–440 m. This interval corresponds to the ETM2 (409–420 m) and H2 (434–444 m) hyperthermals and the B1 and B2 faunal events (Fig. 2). The smallest individuals of *E. bisulcatus* in the entire record occur during this interval. Below 360 m, specimens identified as *E. bisulcatus* are morphologically consistent with the hypodigm of *E. bisulcatus* and have an average ln of m1 area of 3.93, which is virtually identical to that holotype from New Mexico (3.92, USNM 1103) (Gingerich and Gunnel, 1979).

Esthonyx acutidens Cope, 1881

Figures 12–13, Tables 13–14

Esthonyx acutidens Cope, 1881, p. 185. Cope, 1885, p. 210, Pl. 24a, figs. 17, 18, 20, 21. White, 1952, p. 192. Gazin, 1953, p. 24, figs. 6–8. Robinson, 1966, p. 43, Pl. 5, fig. 8. Guthrie, 1971, p. 79. West, 1973, p. 125, Pl. 11, figs. a, b. McKenna, 1976, p. 354, fig. 1. Gingerich and Gunnell, 1979, p. 145.

Esthonyx cf. *acutidens,* Gazin, 1952, p. 21. Gazin 1962, p. 42, Pl. 1, fig. 3.

Holotype — AMNH 4807, left m2 and m3, from the Wind River Formation, Wind River Basin, Wyoming. Collected by E. D. Cope (1881).

Referred specimens — USNM specimens: USNM PAL 490634, Lm2–m3; 495158, Ri2, Rp3–m3, and Lp3–m3; 495164, Lm2–m3; 509669, RM1–M2; 523688, Rm1 and LM2; 523700, Rdp3–m1, additional Rp4, LM1–M2, and additional LM1; 533621, Rp2–m3; 712713, Lp3–m3; 768811, LP4–M3, RC–M3; 768816, Rm1 (with unassociated material); 768830, Lp3–p4, Lm3, and Rm1–m2; 768831, Rp2–m1; 768832, Lp3–m3, Rp3–m1, and associated anterior teeth; 768844, Lp3–m3, Rp2–m3, LP3–M3, and RP3–M3; 768845, Lp4–m2; 768846, Lp3–m3, Rp2–m3, LP2–M3, and RM1–M3; 768850, LP3–M2 and RP3–M2; 768851, Lm2–m3 and Rp3; 768855, Lp4–m3 and Rp4–m3; 768860, Lm1–m3 and associated i2; 768862, Rp4–m3; 768864, Lp3–m3; 768865, Lp3–m3; 768867, LdP4, RP3–M2 (associated?); 768874, Lp4–m3, Rp4–m2, RP3–M3; 768875, Lp2–p3, Rp4–m1; 768876, Lp4–m2 and Rp4–m1. See Appendix for additional specimens.

Biostratigraphic Range and Localities in the study area — *Esthonyx acutidens* ranges from faunal event B1 of Chew (2015) in Wa-5 into Wa-7 (Fig. 2). Central Bighorn Basin localities are as follows: USGS Localities D-1162, D-1166, D-1174, D-1177, D-1198 B, D-1198 H, D-1229, D-1310, D-1325, D-1326, D-1339, D-1345, D-1381, D-1402, D-1403, D-1410, D-1431, D-1436, D-1454, D-1464, D-1467, D-1468, D-1469, D-1473, D-1491, D-1510, D-1532, D-1541, D-1583, D-1598, D-1603, D-1647, D-1657, D-1688, D-1699, D-1735, D-1737, D-1743, D-1757, D-1781, D-1828, D-1829, D-1843, D-1881, D-1947, D-2056; Willwood localities (DMNS and USNM) WW-63, WW-317; Yale Localities Y-39, Y-45s, Y-168, Y-176, Y-181, D-192s, Y-193, Y-320, and Y-461.

Description — Lower Dentition*: Esthonyx acutidens* has a fused mandibular symphysis with the lower dental formula 2.1.3.3. *Esthonyx acutidens* lacks an i3 while retaining the characteristic large front two incisors and incisor-like canine (e.g., USNM PAL 768811). *Esthonyx acutidens* is large compared to other *Esthonyx*. The p2 roots are variable, ranging from single-rooted (Fig. 12) to partially fused double-rooted, resembling a figure-eight in the occlusal view. The p4 trigonid resembles that of *E. spatularius* forming a nearly equilateral triangle (Fig. 5; Table 4). *Esthonyx acutidens* lacks a metastylid on the m3 and has a very small to absent metastylid on m1 and m2. The m3 has an elongated talonid with a well-developed hypoconulid (Fig. 12). The cheek teeth are wide at the cervical margin, gradually narrowing toward the occlusal surface. The cheek teeth are tall and hypsodont. Molar talonids are large and open anterior-posteriorly (Fig. 12).

Upper Dentition*: Esthonyx acutidens* has an upper dental formula of 2.1.3.3. The skull of *E. acutidens* has an elongated rostrum that houses two large upper incisors and an incisor-like canine. Specimens such as USNM PAL V.18202 (Gazin, 1953; from the Wind River Basin), USNM PAL 768846, and USNM PAL 768850 have incisors that are displaced distally, creating a midline diastema between the left and right I1. P2 is single-rooted (Fig. 13). P3 resembles other *Esthonyx* but is more robust. P4 is proportionally large and close to the molars in size. The P4 tends to have its paracone and metacone close together, forming more of a descending ridge (metacone to paracone) than two distinct cusps. In P4–M3, the parastyle and metastyle are pronounced and well-developed (Fig. 13). The parastyle and metastyle resemble two large circles and are similar in size (Fig. 13).

Amended Diagnosis —Gazin (1953) and Gingerich and Gunnell (1979) noted that *Esthonyx acutidens* is the largest of the three species in this Wasatchian lineage and that the P2/2 of *E. acutidens* is single-rooted. Additionally, *E. acutidens* has been described as differing from *E. bisulcatus* by having a more closed p4 trigonid basin, with the paraconid, protoconid, and metaconid forming the points of an equilateral triangle (Gingerich and Gunnell, 1979). I found that the protoconid angle of *E. acutidens* averages 61.5 (Fig. 5; Table 4), agreeing with the previous description of the trigonid of p4.

Esthonyx acutidens tends to have much smaller metastylids than *E. bisulcatus,* and in some cases, *E. acutidens* completely lacks a metastylid. When viewing the upper dentition in occlusal view, *E. acutidens* has large parastyles and metastyles that are equal in size and are much more circular (Fig. 13), differing from the flatter metastyles and parastyles of *E. spatularius* and *E. bisulcatus*.

Esthonyx sp. cf. *E. bisulcatus*

Figure 14, Table 15

Referred specimen — USNM PAL 495174, Rc and Rp4–m1.

Biostratigraphic Range and Localities in the study area — USNM PAL 495174 comes from USGS Locality D-1388 at 360 m near the top of Wa-4.

Description. —Lower Dentition: The specimen is a right dentary fragment with p4–m1 and an associated lower canine. The p4 and m1 are complete but both show significant wear (Fig. 14). The p4 trigonid basin is open with a protoconid angle of 79.3°. The natural log of the m1 area is 3.77. Linear measurements can be found in Table 15.

USNM PAL 495174 has a distinctive metastylid that is large and oddly placed at the center of the talonid basin of the p4. The p4 metastylid is much more robust than that of the m1, is closer to the center of the talonid basin, and comprises nearly the entirety of the basin. The p4 metastylid is worn but still apparent.

Discussion — Because of its size, and the structure of the m1, and the protoconid angle of the p4, I refer USNM PAL 495174 to *Esthonyx* sp. cf. *E. bisulcatus*. 3 (Fig. 4, Table 3). The protoconid angle of the p4 (79.3°) is within the range of *E. bisulcatus* but outside the ranges of *E. spatularius* and *E. acutidens* (Fig. 5, Table 4).

Although USNM PAL 495174 is identified as *Esthonyx* sp. cf. *E. bisulcatus,* it differs from all other specimens examined for this study in having a uniquely positioned p4 metastylid. It is common for *Esthonyx* species to have a metastylid on their molars and to have the metastylid stretching towards the talonid basins of the molars. However, on USNM PAL 495174, a large metastylid is present on the p4 in addition to the m1. The p4 metastylid is also uniquely situated in the center of the talonid basin. Because USNM PAL 495174 is the only specimen exhibiting this trait among a large sample, it likely represents an aberrant individual of *E. bisulcatus*. However, the possibility that it represents a rare, undescribed species of *Esthonyx* cannot be ruled out. Additional specimens exhibiting these characteristics would ideally be needed before naming a new species.

DISCUSSION

At least three species of *Esthonyx* can be distinguished in the collections I studied: *E. bisulcatus, E. acutidens,* and *E. spatularius*. Some large specimens in the early Wasatchian may represent another species of *Esthonyx* or they may be late-occurring individuals of *Azygonyx*. However, these specimens morphologically agree with *E. bisulcatus* and were placed in that species. USNM PAL 495174 — identified by this study as *Esthonyx* sp. cf. *E. bisulcatus* — could also represent an undescribed species.

This study's results help refine the stratigraphic ranges of *Esthonyx spatularius*, *E. bisulcatus*, and *E. acutidens* (Fig. 4). Gingerich and Gunnell (1979) recognized both *E. spatularius* and *E. bisulcatus* in the Bighorn Basin but suggested they were two parts of a single, continuous anagenetic lineage with *E. spatularius* transitioning to *E. bisulcatus* from the early to late Wasatchian. However, Schankler (1980) subsequently found that *E. bisulcatus* ranged further downward into his *Haplomylus*-*Ectocion* Range-Zone (upper Wa-3 and Wa-4, Fig. 2), significantly overlapping with *E. spatularius*. Chew (2015) later extended the range of *E. spatularius* upward into Wa-5 to faunal turnover event B2. A reevaluation of specimen identifications indicates that the last occurrence of *E. spatularius* occurs slightly lower at faunal event B1. In the upper part of his section, Schankler (1980) found that *E. bisulcatus* and *E. acutidens* overlapped in his *Heptodon* Range-Zone (= Wa-6, lower Wa-7 in this study, Fig. 2). Results from this study extend the range of *E. acutidens* downward to the middle part of Wa-5 (base of ETM2) and corroborate the overlap of these taxa in Wa-6.

Of the species considered, *Esthonyx bisulcatus* is the most common. *Esthonyx bisulcatus* has the longest biostratigraphic range, first occurring low in Wa-3 (166–170 m) and ranging through Wa-6 (last occurrence at 591 m, Fig. 4). Accounts of *Esthonyx bisulcatus* from other sections and basins indicate it ranges into Wa-7 (Gazin, 1953; Gingerich and Gunnell, 1979; Clyde, 2001). Schankler (1980) showed *E. bisulcatus* ranging into his upper *Heptodon* range zone, which should be equivalent to Wa-7 in the study area (Fig. 2). I found no specimens of *E. bisulcatus* that were unequivocally documented from Wa-7. Wa-7 is poorly sampled in the Bighorn Basin, however, and most localities are not tightly correlated into the BCS. *Esthonyx acutidens* also ranges into Wa-7 and Br-1a (early Bridgerian) in other basins (Gazin, 1953; Gingerich and Gunnell, 1979; Stucky and Krishtalka, 1983).

***Esthonyx* Species Range Revision**

The last occurrence of *Esthonyx spatularius* and the first occurrence of *E. acutidens* coincide with the hyperthermal ETM2 (Fig. 4) and are coincident with faunal turnover event B1. Chew (2015) placed the last appearance of *E. spatularius* slightly higher at faunal event B2, but reidentification of specimens indicate it occurred lower. This study also lowered the first occurrence of *E. acutidens* to near the base of ETM2. As described above, *Esthonyx spatularius* and *E. acutidens* can be differentiated by morphological differences, such as the number of roots on second premolars. *Esthonyx acutidens* is also considerably larger (Fig. 4, Tables 3, 13-14). Thus, these species do not appear to represent segments of an anagenetic lineage.

Paleobiogeography

Numerous first appearances of mammalian taxa occur during the PETM as their geographic ranges shifted in response to warming. Some immigrants entered North America from other continents, such as Asia, across high-latitude land bridges (Koch et al., 1992; Secord et al., 2012), while others probably originated in North America (Rose et al., 2012). ETM2 does not appear to be associated with intercontinental immigration (Chew, 2015), and thus, the sudden appearance of *E. acutidens* probably represents a range shift in North America. The disappearance of *E. spatularius* could also be associated with a range shift or extinction due to climate and environmental stresses associated with the hyperthermal, ETM2. Fossils from other basins with strong chronostratigraphic control are needed to test these possibilities.

Body Size Changes

The shifts in the body size of *Esthonyx bisulcatus* (Fig. 4) are noteworthy as well. The first of these shifts to smaller body size (using the ln of m1 area as a body size proxy) begins at about 355 m, directly below Schankler's Biohorizon B. Biohorizon B does appear to be associated with climate change (Abels et al., 2012; Widlansky et al., 2022) but a second shift to smaller body size occurs at ~409 m, corresponding with the onset of ETM2. ETM2 is followed immediately by H2 at approximately 409–444 m. The smallest individuals of *E. bisulcatus* appear in or on the margins of the stratigraphic interval bounded by these hyperthermals. It should be noted that because the BCS is a composite of stratigraphic sections tied together through long bed traces, sometimes over difficult terrain (Bown et al., 1994), stratigraphic uncertainly through the ETM2 and H2 interval is at least ± 5 m and probably greater. Thus, it may be difficult to distinguish differences in body size in the short interval of cooling between these hyperthermals, although, the 3-point moving average exhibits two negative peaks that approximate ETM2 and H2 (Fig. 4).

A shift to smaller body size is a hallmark of the PETM in which about 40% of mammalian species became smaller, sometimes by more than 50%, while no species appears to get larger (Gingerich, 1989; Clyde and Gingerich, 1998; Secord et al., 2012). Notably, this includes the tillodont *Azygonyx*, which underwent a body size reduction of about 40% based on a small sample of first molars (Gingerich, 1989; Secord et al., 2012, table S7). ETM2 and H2 are far less studied than the PETM, and mammal fossils from these later hyperthermals are known only from the Bighorn Basin. In the McCullough Peaks area of the Bighorn Basin, D'Ambrosia et al. (2017) noted decreases in body size in the equid *Arenahippus* and the artiodactyl *Diacodexis* in ETM2, based on fairly small sample sizes. They suggested this may indicate an ecological "dwarfing" response similar to that at the PETM. However, using a much larger data set from the southern basin, Chew (2015) found a proliferation of body size changes during faunal events B1 and B2 (corresponding with ETM2 and H2 hyperthermals) rather than a coordinated "dwarfing" as interpreted in the PETM. She found that about 20% of genera became smaller and about 20% larger (specific genera not provided). Thus, it may be that the decrease in body size of *Esthonyx bisulcatus* was more of an exception than the norm among Wasatchian taxa during ETM2 and H2. Nevertheless, climate change appears to have played an important role in shaping the biogeographic and evolutionary history of *Esthonyx*.

CONCLUSIONS

This study encompasses a reevaluation of the taxonomy and biostratigraphy of the largest collection of *Esthonyx* known from anywhere in the world. The general stratigraphic sequence of species found here is consistent with earlier studies, but the stratigraphic ranges of species are refined. The first occurrences of *E. spatularius*, *E. acutidens*, and *E. bisulcatus* are extended downward and occur lower than previously reported. Also, the last occurrence of *E. spatularius* occurs slightly lower than previously reported. These range extensions resulted in the stratigraphic overlap of *E. bisulcatus* and *E. spatularius* over a longer interval in the early Wasatchian than previously recognized (now from Wa-3 to Wa-5). Similarly, the downward extension of *E. acutidens* to the middle part of Wa-5 (base of ETM2) corroborates previous reports of overlap with *E. bisulcatus*, extending the overlap range into Wa-5.

With these new range extensions, the last occurrence of *Esthonyx spatularius* and the first occurrence of *E. acutidens* now correspond with the base of ETM2 (Fig. 4). These taxa do not appear to be segments of an anagenetic lineage. Warming and concurrent ecological changes during ETM2 may have changed the geographic range of taxa bringing *E. acutidens* into the Bighorn Basin, and a range shift pushing *E.*

spatularius out of the basin or driving it to extinction. A marked shift in *E. bisulcatus* to the smallest body sizes occurs in the stratigraphic interval encompassing the ETM2 and H2 hyperthermal pair (Fig. 4). Although this shift resembles shifts to smaller body sizes that appear in some other lineages during the PETM, previous work suggests that body size changes during ETM2 may not have the same ecological basis. Nevertheless, climate change during the ETM2 and H2 hyperthermals appears to have played a key role in the biogeography and evolution of *Esthonyx* species.

ACKNOWLEDGEMENTS

I would like to thank the University of Nebraska-Lincoln Department of Earth and Atmospheric Sciences for the opportunity to earn a Master's Degree; the National Science Foundation (Grant EAR 2124939 to my advisor, R. Secord), Nebraska Geological Society, and AAPG for providing financial support for this research; D. Krause, K. MacKenzie, for access to specimens at DMNS; A. Millhouse for access to specimens at USNM; K. Rose for access to specimens at JHU; K. Nichols and T. Bown for access to specimens at CSU; the crews of the JHU and USGS paleontology expeditions for collection of specimens; the crews of the CSU Paleontology Field School for collection of specimens; R. Secord, A. Chew, R. M. Joeckel, and D. Harwood for being members of my committee; R. Secord for being my advisor and the advice, contributions, and corrections to this thesis; A. Chew and K. Rose for their contributions and advice in researching this topic; C. Herbal for assistance in fossil preparation and casting of specimens; L. Howard, J. McCloskey, A. English, and B. Lindgren for their help, advice, and encouragement; G. Corner for assistance in research; A. Johnson for her edits of my thesis. I also thank all those along the way within UNL, CSU, DMNS, and those I have met on my adventures in the Bighorn Basin for inspiring me and helping drive my love and interest in mammalian paleontology.

LITERATURE CITED

Abels, H.A., Clyde, W.C., Gingerich, P.D., Hilgen, F.J., Fricke, H.C., Bowen, G.J., & Lourens, L.J. 2012. Terrestrial carbon isotope excursions and biotic change during Palaeogene hyperthermals. Nature Geoscience 5:326–329. doi:10.1038/ngeo1427.

Abels, H.A., Lauretano, V., van Yperen, A.E., Hopman, T., Zachos, J.C., Lourens, L.J., Gingerich, P.D., & Bowen, G.J. 2016. Environmental impact and magnitude of paleosol carbonate carbon isotope excursions marking five early Eocene hyperthermals in the Bighorn Basin, Wyoming. Climate of the Past 12:1151–1163. doi:10.5194/cp-12-1151-2016.

Badgley, C. 1990. A statistical assessment of last appearances in the Eocene record of mammals. in, Dawn of the Age of Mammals in the Northern Part of the Rocky Mountain Interior, North America. Geological Society of America Special Paper No. 243, eds. T. M. Bown & K. D. Rose, 153-68. Boulder, CO: Geological Society of America.

Badgley, C. & Gingerich, P. D. 1988. Sampling and faunal turnover in early Eocene mammals. Palaeogeography, Paleoclimatology, Palaeoecology 63:141-57.

Barnet, J. S. K., Littler, K., Westerhold, T., Kroon, D., Leng, M. J., Bailey, I., Röhl, U., & Zachos, J. C. 2019. A high-fidelity benthic stable isotope record of Late Cretaceous–early Eocene climate change and carbon-cycling. Paleoceanography and Paleoclimatology 34:1-20.

Beard, K. C. 1998. East of Eden: Asia as an important center of taxonomic origination in mammalian evolution: Bulletin of Carnegie Museum of Natural History 34:5-39.

Bowen, G. J., Koch, P. L., Gingerich, P. D., Norris, R. D., Bains, S., & Corfield, R. M. 2001. Refined isotope stratigraphy across the continental Paleocene-Eocene boundary on Polecat Bench in the northern Bighorn Basin, in Gingerich, P. D. (Ed.), Paleocene-Eocene stratigraphy and biotic change in the Bighorn and Clarks Fork basins, Wyoming, University of Michigan Papers on Paleontology 33:73-88.

Bown, TM., & Kraus, M.J. 1993. Time-stratigraphic reconstruction and integration of paleopedologic, sedimentologic, and biotic events (Willwood Formation, lower Eocene, northwest Wyoming, U.S.A.). Palaios 8:68-80.

Bown, T.M., Kraus, M.J., & Rose, K.D. 1991. Temporal holostrome reconstruction of the Willwood Formation and the reapportionment of paleopedologic, sedimentologic, and paleobiologic events in time [abs.]. Journal of Vertebrate Paleontology, 11 (supplement to no. 3):17A.

Bown, T.M., Rose, K.D., Simons, E.L., & Wing, S.L. 1994. Distribution and stratigraphic correlation of upper Paleocene and lower Eocene fossil mammal and plant localities of the Fort Union, Willwood, and Tatman formations, southern Bighorn Basin, Wyoming. U.S. Geological Survey Professional Papers. 1540:1-103 + maps.

Bown, T. M. & Schankler, D. M. 1980. A review of the Proteutheria and Insectivora of the Willwood Formation (lower Eocene), Bighorn Basin, Wyoming. U.S. Geol. Surv. Prof. Pap.

Chew, A.E. 2009. Paleoecology of the early Eocene Willwood mammal fauna from the central Bighorn Basin, Wyoming. Paleobiology 35:13–31. https://www.jstor.org/stable/20445619

—— 2015. Mammal faunal change in the zone of the Paleogene hyperthermals ETM2 and H2. Climate of the Past 11:1223–1237. doi:10.5194/cp-11-1223-2015.

Clyde, W.C. 2001. Mammalian biostratigraphy of the McCullough Peaks area in the northern Bighorn Basin, in Gingerich, P.D. (Ed.), Paleocene- Eocene stratigraphy and biotic change in the Bighorn and Clarks Fork Basins, Wyoming. University of Michigan, Papers of Paleontology 33:109- 126.

Clyde, W. C., and Gingerich, P. D. 1998. Mammalian community response to the latest Paleocene thermal maximum: An isotaphonomic study in the northern Bighorn Basin, Wyoming. Geology 26, no. 12:1011-1014.

Clyde, W.C., Hamzi, W., Finarelli, J.A., Wing, S.L., Schankler, D., & Chew, A. 2007. Basin-wide magnetostratigraphic framework for the Bighorn Basin, Wyoming. Geological Society of America Bulletin 119:848–859. doi:10.1130/B26104.1.

Cope, E.D. 1874. Report upon vertebrate fossils discovered in New Mexico, with description of new species. Annual Report of the Chief of Engineers, U.S. Army Appendix FF:589-606 (Separatum p. 1-18).

—— 1875. Systematic catalogue of Vertebrata of the Eocene of New Mexico, collected in 1874. Report to the Engineer Dept., U.S. Army, Washington, p. 5-37.

—— 1877. Report upon the extinct Vertebrata obtained in New Mexico by parties of the expedition of 1874. Chapter XII, Fossils of the Eocene period. Geographical Surveys West of One-Hundredth Meridian, G. M. Wheeler, Corps of Engineers, U.S. Army, Washington 4:37-282.

—— 1880. The Northern Wasatch fauna. American Naturalist 14:908-909.

—— 1881. On the Vertebrata of the Wind River Eocene beds of Wyoming. Bulletin United State Geological Survey Terr 6:183-202.

—— 1883. On the mutual relations of the bunotherian Mamrnalia. Proc. Acad. Nat. Sci., Philadelphia 35: 77-83.

—— 1884. The Creodonta. Amer. Naturalist 18:255-267, 344-353, 478485.

—— 1885. The Vertebrata of the Tertiary formations of the West. Book I. Report U.S. Geol. Surv. Terr., F.V. Haden, Washington 3: 1-1009.

D'Ambrosia, A.R., Clyde, W.C., Fricke, H.C., Gingerich, P.D., & Abels, H.A. 2017. Repetitive mammalian dwarfing during ancient greenhouse warming events: Science Advances 3:1-9. doi:10.1126/sciadv.1601430.

Damuth, J., and MacFadden, B. J. 1990. Body size in mammalian paleobiology: estimation and biological implications: Cambridge, Cambridge University Press, p. 397.

Delson, E. 1971. Fossil mammals of the early Wasatchian Powder River local fauna, Eocene of northeast Wyoming. Bull. Amer. Mus. Nat. Hist. 146:305-364.

Denison, R. H. 1937. Early lower Eocene mammals from the Wind River Basin, Wyoming. Proc. New England Zool. Club 16:11-14.

Dorr, J.A. 1952. Early Cenozoic stratigraphy and vertebrate paleontology of the Hoback Basin, Wyoming. Bull. Geol. Soc. Amer. 63:59-94.

—— 1978. Revised and amended fossil vertebrate faunal lists, early Tertiary, Hoback Basin, Wyoming. Contrib. Geol., Univ. Wyoming 16:79-84.

Gazin, C. L. 1952. The lower Eocene Knight Formation of western Wyoming and its mammalian faunas. Smithsonian Misc. Coll. 117(18):1-82.

—— 1953. The Tillodontia: an early Tertiary order of mammals. Smithsonian Miscellaneous Collections 121(10):1-110.

—— 1962. A further study of the lower Eocene mammalian faunas of southwestern Wyoming. Smithsonian Misc. Coll. 144(1):1-98

—— 1976. Mammalian Faunal Zones of the Bridger Middle Eocene. Smithsonian Contributions to Paleobiology 26:1-25.

Gill, T. 1872. Arramgement of the families of mammals with analytical tables. Smithsonian Miscellaneous Collections 11(230): i-vi, 1-98.

Gingerich, P. D. 1974. Size variability of the teeth in living mammals and the diagnosis of closely related sympatric fossil species. Jour. Paleont. 48:895-903.

—— 1976. Cranial anatomy and evolution of early Tertiary Plesiadapidae (Mammalia, Primates). The University of Michigan Papers on Paleontology 15:141.

—— 1983. Paleocene-Eocene faunal zones and a preliminary analysis of Laramide structural deformation in the Clark's Fork Basin, Wyoming.Wyoming Geological Association Guidebook 34:185-195.

—— 1989. New earliest Wasatchian mammalian fauna from the Eocene of northwestern Wyoming: composition and diversity in a rarely sampled high-floodplain assemblage: University of Michigan Papers on Paleontology 28: 1-97.

—— 1991. Systematics and evolution of early Eocene Perissodactyla (Mammalia) in the Clarks Fork Basin, Wyoming. Contributions from the Museum of Paleontology, University of Michigan 28:181-213.

—— 2001. Biostratigraphy of the continental Paleocene-Eocene boundary interval on Polecat Bench in the northern Bighorn Basin, in Gingerich, P.D. (Ed.), Paleocene- Eocene stratigraphy and biotic change in the Bighorn and Clarks Fork Basins, Wyoming, University of Michigan Papers of Paleontology 33:37- 73.

Gingerich, P.D., & Clyde, W.C. 2001. Overview of mammalian biostratigraphy in the Paleocene-Eocene Fort Union and Willwood formations of the Bighorn and Clarks Fork basins, in Gingerich, P.D. (Ed.), Paleocene- Eocene stratigraphy and biotic change in the Bighorn and Clarks Fork Basins, Wyoming. University of Michigan Papers of Paleontology 33:1-14.

Gingerich, P.D., & Gunnell, G.F. 1979. Systematics and evolution of the genus Esthonyx (Mammalia, Tillodontia) in the early Eocene of North America. Contributions from the Museum of Paleontology, University of Michigan 25(7):125-153.

Gingerich, P. D., Smith, B. H., and Rosenberg, K. 1982. Allometric scaling in the dentition of primates and prediction of body weight from tooth size in fossils: American Journal of Physical Anthropology 58, no. 1:81-100.

Gunnell, G.F., Murphey, P.C., Stucky, R.K., Townsend, K.E.B., Robinson, P., Zonneveld, J.-P., & Bartels, W.S. 2009. Biostratigraphy and biochronology of the latest Wasatchian, Bridgerian, and Uintan North American Land Mammal "Ages", in Albright, L.B., III, (Ed.), Papers on Geology, Vertebrate Paleontology, and Biostratigraphy in Honor of Michael O. Woodburne: Museum of Northern Arizona Bulletin 65:279–330.

Guthrie, D. A. 1967. The mammalian fauna of the Lysite member, Wind River Formation (Early Eocene) of Wyoming. Memoirs S. Calif. Acad. Sci. 5:1-53.

—— 1971. The mammalian fauna of the Lost Cabin member, Wind River Formation (lower Eocene) of Wyoming. Ann. Carnegie Mus. 43:47-113.

Kelley, D. R. & Wood, A.E. 1954. The Eocene mammals from the Lysite Member, Wind River Formation of Wyoming. Jour. Paleont. 28:337-366.

Koch, P. L., Zachos, J. C., and Gingerich, P. D. 1992. Correlation between isotope records in marine and continental carbon reservoirs near the Palaeocene/Eocene boundary: Nature 358, no. 6384:319-322

Lemoine, V. 1891. Étude d'ensemble sur les dents des mammifères fossiles des environs de Reims. Bull. Soc. Geologique de. France 19:263-290.

Li, M., Bralower, T. J., Kump, L. R., Self-Trail, J. M., Zachos, J. C., Rush, W. D., & Robinson, M. M. 2022. Astrochronology of the Paleocene-Eocene Thermal Maximum on the Atlantic Coastal Plain. Nature Communications 13, no. 5618:1-13.

Linnaeus, C. 1758. Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis, in Tomus I. (Ed.), decima, reformata. Holmiae. Stockholm: L. Salvii, 1-824.

Lucas, S. G. & Schoch, R. M. 1998. Tillodontia; pp. 268-273 in Janis, C. M., Scott, K. M., & Jacobs, L. L. (Eds), Evolition of Tertiary Mammals of North America. Volume 1: Terrestrial Carnivores, Ungulates, and Ungulatelike Mammals. Cambridge University Press, Cabridge, UK.

Marsh, 0. C. 1875. New order of Eocene mammals. Amer. Jour. Sci. 9:1-221.

McKenna, M. C. 1960. Fossil Mammalia from the early Wasatchian Four Mile fauna, Eocene of Northwest Colorado. Univ. Calif. Publ. Geol. Sci. 37:1-130.

—— 1976. Esthonyx in the upper faunal assemblage, Huerfano Formation, Eocene of Colorado. Jour. Paleont. 50:354-355.

McKenna, M.C. & Bell, S.K. 1997. Classification of mammals above the species level. New York, Columbia University Press: 1-631.

Miyata, K., & Deméré, T.A. 2016. New material of a 'short-faced' Trogosus (Mammalia, Tillodontia) from the Delmar Formation (Bridgerian), San Diego County, California, U.S.A.: Journal of Vertebrate Paleontology 36:e1089878. doi:10.1080/02724634.2016.1089878.

Morris, W. J. 1966. Fossil mammals from Baja California: New evidence on early Tertiary migrations. Science 153:1376-1378.

Novacek, M. J., Ferrusquía-Villafranca, I., Flynn, J. J., Wyss, A. R., & Norell, M. 1991. Wasatchian (Early Eocene) mammals and other vertebrates from Baja California, Mexico: the Lomas Las Tetas De Cabra fauna. Bulletin of the American Museum of Natural History 208:1-88.

Ogg, J.G. 2020. Chapter 5 - Geomagnetic Polarity Time Scale. in Gradstein, F.M., Ogg, J.G., Schmitz, M.D., and Ogg, G.M. (Eds.), Geologic Time Scale 2020, Elsevier: 159–192. doi:https://doi.org/10.1016/B978-0-12-824360-2.00005-X.

Robinson, P. 1966. Fossil Mammalia of the Huerfano Formation, Eocene, of Colorado. Bull. Peabody Mus. Nat. Hist., Yale Univ. 21:1-85.

Robinson, P., G.F. Gunnell, S.L. Walsh, W.C. Clyde, J.E. Storer, R.K. Stucky, D.J. Froehlich, I. Ferrusquía-Villafranca, & M.C. McKenna. 2004. Wasatchian through Duchesnean Biochronology, in M.O. Woodburne (Ed.), Late Cretaceous and Cenozoic Mammals of North America. Columbia University Press: 106-155.

Rose, K.D. 1972. A new tillodont from the Eocene upper Willwood Formation of Wyoming. Postilla 155:1-13

—— 1999. Fossil mammals from the early Eocene Fisher/Sullivan site, in R.E. Weems and G.J. Grimsley (Ed.), Early Eocene vertebrates and plants from the Fisher/Sullivan Site (Nanjemoy Formation) Stafford County, Virginia. Virginia Division of Mineral Resources. Publication 152:133-138.

Rose, K.D., Chew, A.E., Dunn, R.H., Kraus, M.J., Fricke, H.C., & Zack, S.P. 2012. Earliest Eocene mammalian fauna from the Paleocene-Eocene Thermal Maximum at Sand Creek Divide, southern Bighorn Basin, Wyoming. University of Michigan Papers on Paleontology 36:1-122.

Rose, K.D., Kumar, K., Rana, R.S., Sahni, A., & Smith, T. 2013. New hypsodont tillodont (Mammalia, Tillodontia) from the early Eocene of India: Journal of Paleontology 87:842–853. doi:10.1666/13-027.

Rose, K.D., Rana, R.S., Sahni, A., Kumar, K., Singh, L., & Smith, T. 2009. First Tillodont from India: Additional evidence for an early Eocene faunal connection between Europe and India? Acta Palaeontologica Polonica 54:351–355. doi:10.4202/app.2008.0067.

Schankler, D. 1980. Faunal zonation of the Willwood Formation in the central Bighorn Basin, Wyoming, in Gingerich, P.D. (Ed.), Early Cenozoic paleontology and stratigraphy of the Bighorn Basin, Wyoming. University of Michigan Papers of Paleontology 24:99-114.

Secord, R. 2008. The Tiffanian land-mammal age (middle and late Paleocene) in the northern Bighorn Basin, Wyoming: Papers on Paleontology 35:1-192.

Secord, R., Gingerich, P. D., Smith, M. E., Clyde, W. C., Wilf, P., & Singer, B. S. 2006. Geochronology and mammalian biostratigraphy of middle and upper Paleocene continental strata, Bighorn Basin, Wyoming: American Journal of Science,306:211-245.

Secord, R., Wing, S.L., & Chew, A.E. 2008. Stable isotopes in early Eocene mammals as indicators of forest canopy structure and resource partitioning. Paleobiology 32(2):282-300.

Secord, R., Bloch, J.I., Chester, S. G. B., Boyer, D. M., Wood, A. R., Wing, S. L., Kraus, M. J., McInerney, F. A., & Krigbaum, J. 2012. Evolution of the earliest horses driven by climate change in the Paleocene-Eocene Thermal Maximum. Science 335:959-962. doi:10.1126/science.1213859.

Simpson, G. G. 1937. Notes on the Clark Fork, upper Paleocene, fauna. Amer. Mus. Novitates, 954: 1-24. - 1951. Hayden, Cope, and the Eocene of New Mexico. Proc. Acad. Nat. Sci. Philadelphia 103:1-21.

Smith, K.T. 2001. Reassessing the Lambdotherium first appearance datum (Wasatchian, early Eocene) in the Bighorn Basin, Wyoming: PaleoBios 21(2):1-11.

Smith, T., Kumar, K., Rana, R.S., Folie, A., Solé, F., Noiret, C., Steeman, T., Sahni, A., & Rose, K.D. 2016. New early Eocene vertebrate assemblage from western India reveals a mixed fauna of European and Gondwana affinities. Geoscience Frontiers 7:969–1001. doi:10.1016/j.gsf.2016.05.001.

Stucky, R. K. 1984. Revision of the Wind River faunas, early Eocene of central Wyoming. Part 5. Geology and biostratigraphy of the upper part of the Wind River Formation, northeastern Wind River Basin. Annals of Carnegie Museum 53:231-294.

Stucky, R.K. & Krishtalka, L. 1983. Revision of the Wind River faunas, early Eocene of central Wyoming. Part 4. The Tillodontia. Annals of Carnegie Museum: Carnegie Museum of Natural History 52(17):357-391.

Tauxe, L., J. Gee, Y. Gallet, T. Pick, & T.M. Bown. 1994. Magnetostratigraphy of the Willwood Formation, Bighorn Basin, Wyoming: New constraints on the location of the Paleocene/Eocene boundary. Earth and Planetary Science Letters 125:159–172, doi: 10.1016/0012-821X(94)90213-5.

USGS, Geographic Names Information System, https://edits.nationalmap.gov/apps/gaz-domestic/public/all-official-sq-names (accessed March 2024).

West, R. M. 1973. Geology and mammalian paleontology of the New Fork-Big Sandy area, Sublette County, Wyoming. Fieldiana, Geol. 29:1-193.

White, T. E. 1952. Preliminary analysis of the vertebrate fossil fauna of the Boysen Reservoir area. Proc. U.S. Nat. Mus. 102:185-207.

Widlansky, S.J., Secord, R., Snell, K.E., Chew, A.E., & Clyde, W.C. 2022. Terrestrial carbon isotope stratigraphy and mammal turnover during post-PETM hyperthermals in the Bighorn Basin, Wyoming, USA. Climate of the Past 18:681–712. doi:10.5194/cp-18-681-2022.

Wilf, P. 2000. Late Paleocene-early Eocene climate changes in southwestern Wyoming: paleobotanical analysis. Geological Society of America Bulletin 112, no. 2:292-307.

Williamson, T.E., Lucas, S.G., & Stucky, R.K. 1996. Megalesthonyx hopsoni (Mammalia: Tillodontia) from the early Bridgerian (Gardnerbuttean) of the Wind River Formation, northeastern Wind River Basin, Wyoming. Proceedings of the Denver Museum of Natural History, Series 3, No. 13.

Wing, S. L., Bao, H. M., & Koch, P. L. 2000. An early Eocene cool period? Evidence for continental cooling during the warmest part of the Cenozoic, in Huber, B. T., MacLeod, K., and Wing, S. L., (Eds.), Warm climates in earth history. Cambridge, Cambridge University Press: 197-237.

Wing, S.L., Bown, T.M., & Obradovich, J.D. 1991. Early Eocene biotic and climatic change in interior western North America. Geology 19:1189. doi:10.1130/0091-7613(1991)019<1189:EEBACC>2.3.CO;2.

Wing, S. L., & Greenwood, D. R. 1993. Fossils and fossil climate: the case for equable continental interiors in the Eocene. Philosophical Transactions of the Royal Society of London, Biological Sciences 341, no. 1297:243-252

Woodburne, M.O., Gunnell, G.F., & Stucky, R.K. 2009a. Climate directly influences Eocene mammal faunal dynamics in North America. Proceedings of the National Academy of Sciences 106:13399–13403. doi:10.1073/pnas.0906802106.

—— 2009b. Land mammal faunas of North America rise and fall during the Early Eocene Climatic Optimum. Denver Museum of Nature & Science, Denver Museum of Nature & Science Annals, doi:10.55485/RKCK3803.

Zachos, J., Pagani, M., Sloan, L., Thomas, E., & Billups, K. 2001. Trends, rhythms, and aberrations in global climate 65 Ma to present. Science 292:686–693. doi:10.1126/science.1059412.

FIGURE 1: Map of central and southern Bighorn Basin showing main collecting areas. Modified from Chew (2009). Small lines represent the sections used to establish meter levels for the composite section (BCS, see text for explanation) of Bown et al. (1994). The base of the BCS is shown by the solid black lines that are southeast of Worland, Wy. **Abbreviations: FMC,** Fifteen Mile Creek region; **EC,** Elk Creek; and **ECR,** Elk Creek Rim.

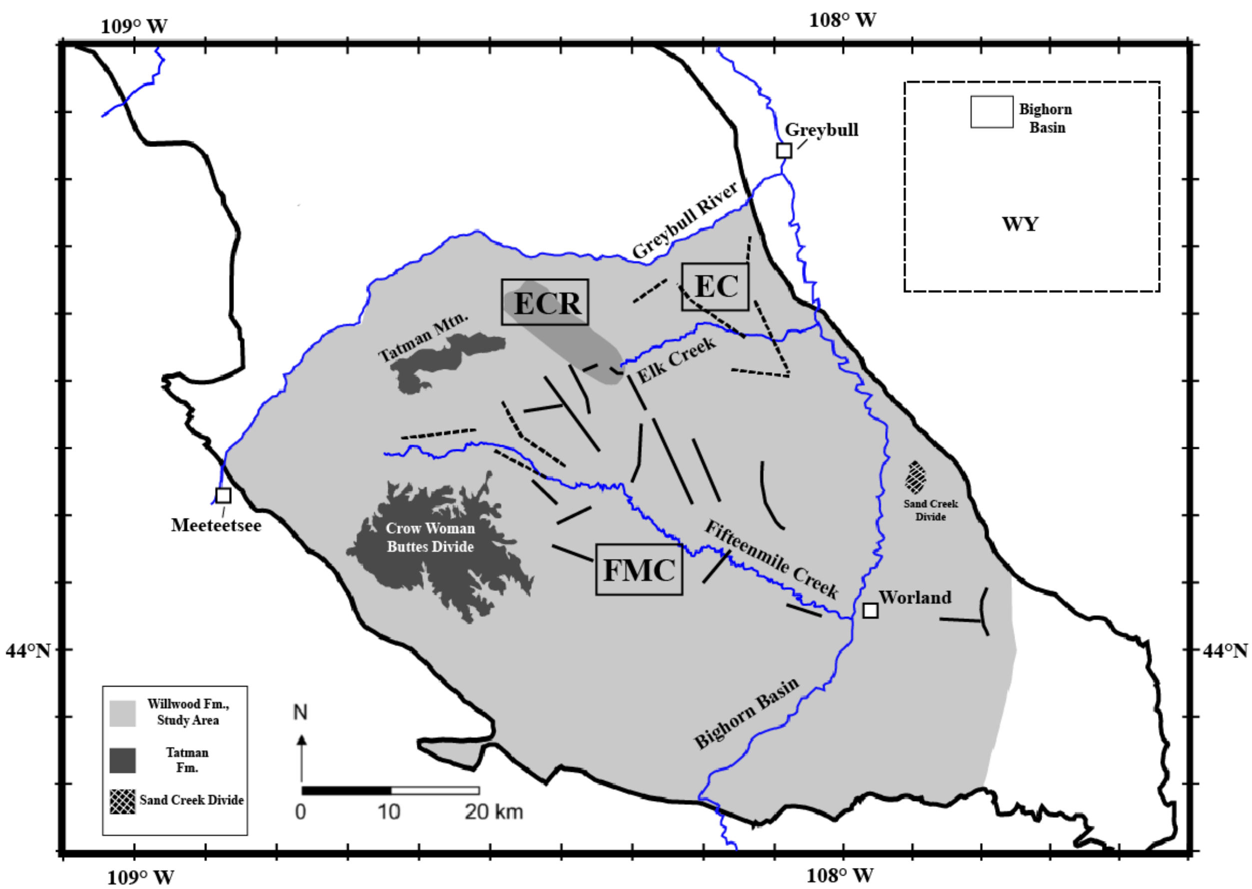

FIGURE 2: Comparison biozonations, biohorizons, and bioevents used by various authors and for this study in the central Bighorn Basin. Schankler's work is based on a composite section of different thickness from the BCS (Bown et al., 1994). For this study "biohorizons" and "bioevents" follow Schankler (1980) and Chew (2015). First appearances of the taxa defining the Wa biozones used in this paper follow Gingerich (see discussion in text). Magnetic polarity chrons from Clyde et al. 2007 and dates from Ogg, 2020. Shaded area at top of This Paper's column represents poorly sampled and described section of the BCS.

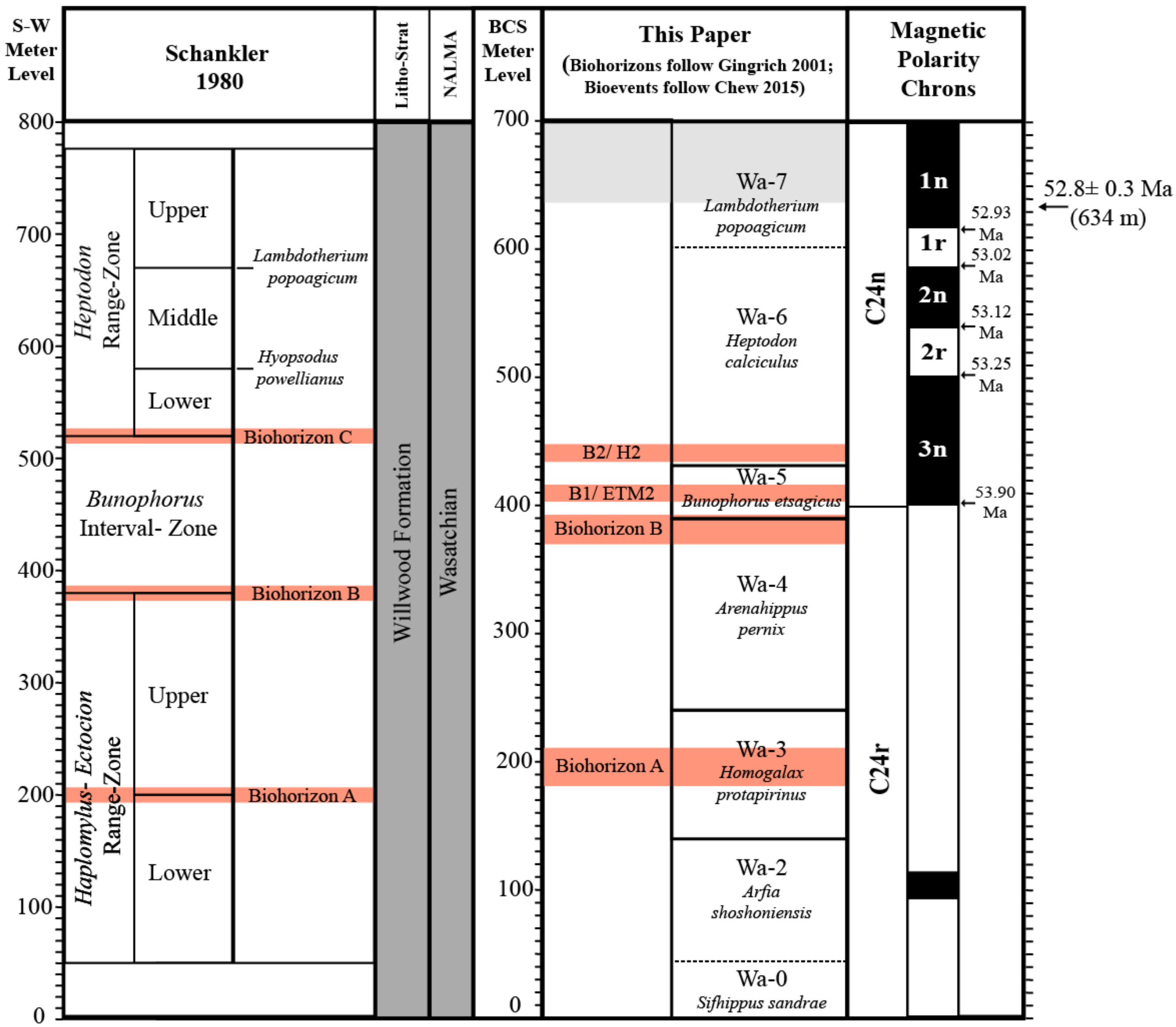

FIGURE 3: Lines of measurements for borrowed specimens. Specimens borrowed from USNM and measured at UNSM. **A.** height measurements of lower dentition; **B.** length, width, and basin length of lower dentition; **C.** length, width, and basin length of m3; **D.** distance between cusps on lower dentition; **E.** length and width of upper dentition; **F.** distance between cusps (*A, B, C)* and length of parastyle (*D)* and metastyle (*E*); **G.** height of upper dentition. Abbreviations and descriptions in Tables 1 and 2. Specimens not to scale.

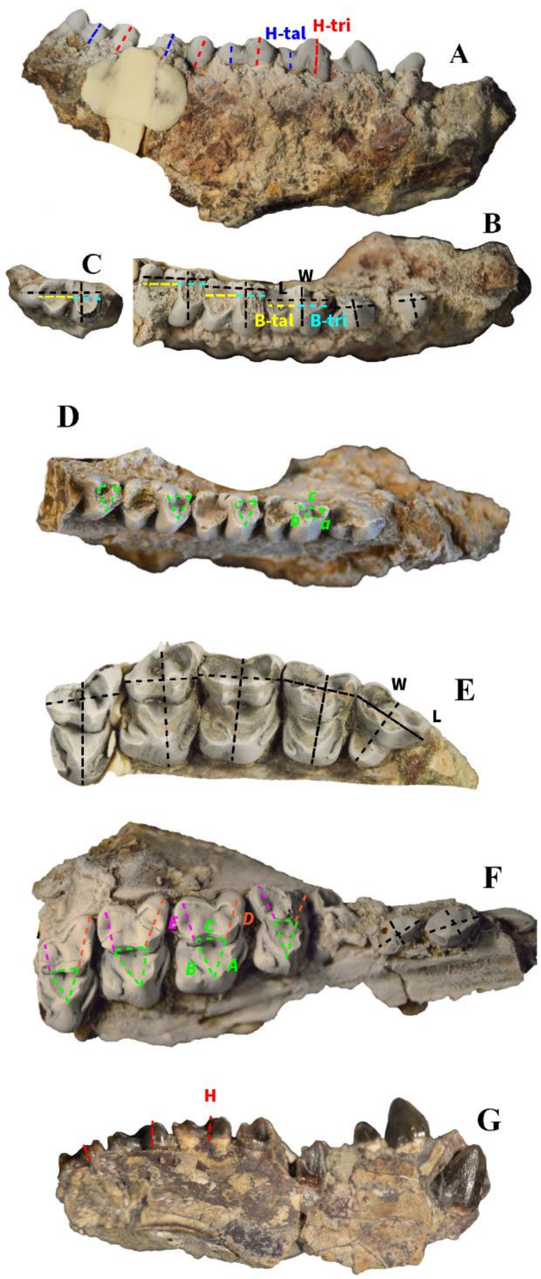

FIGURE 4: Stratigraphic chart showing from left to right: meter level, natural log (ln) of m1 area for *Esthonyx* species, magnetic polarity chrons from Clyde et al. (2007), stratigraphic ranges of *Esthonyx* species as determined in this study, and biozones used in this study. Green bars indicate positions of ETM2 and H2 hyperthermals. Gray bars indicate positions of PETM hyperthermal and Biohorizon B. 52.8 in Wa-7 is radiometric date from volcanic ash. Dashed vertical lines indicate where species are expected to continue, but no specimens were identified. Dotted horizontal line at 634 m represents bentonite layer used for dating the upper portion of the BCS.

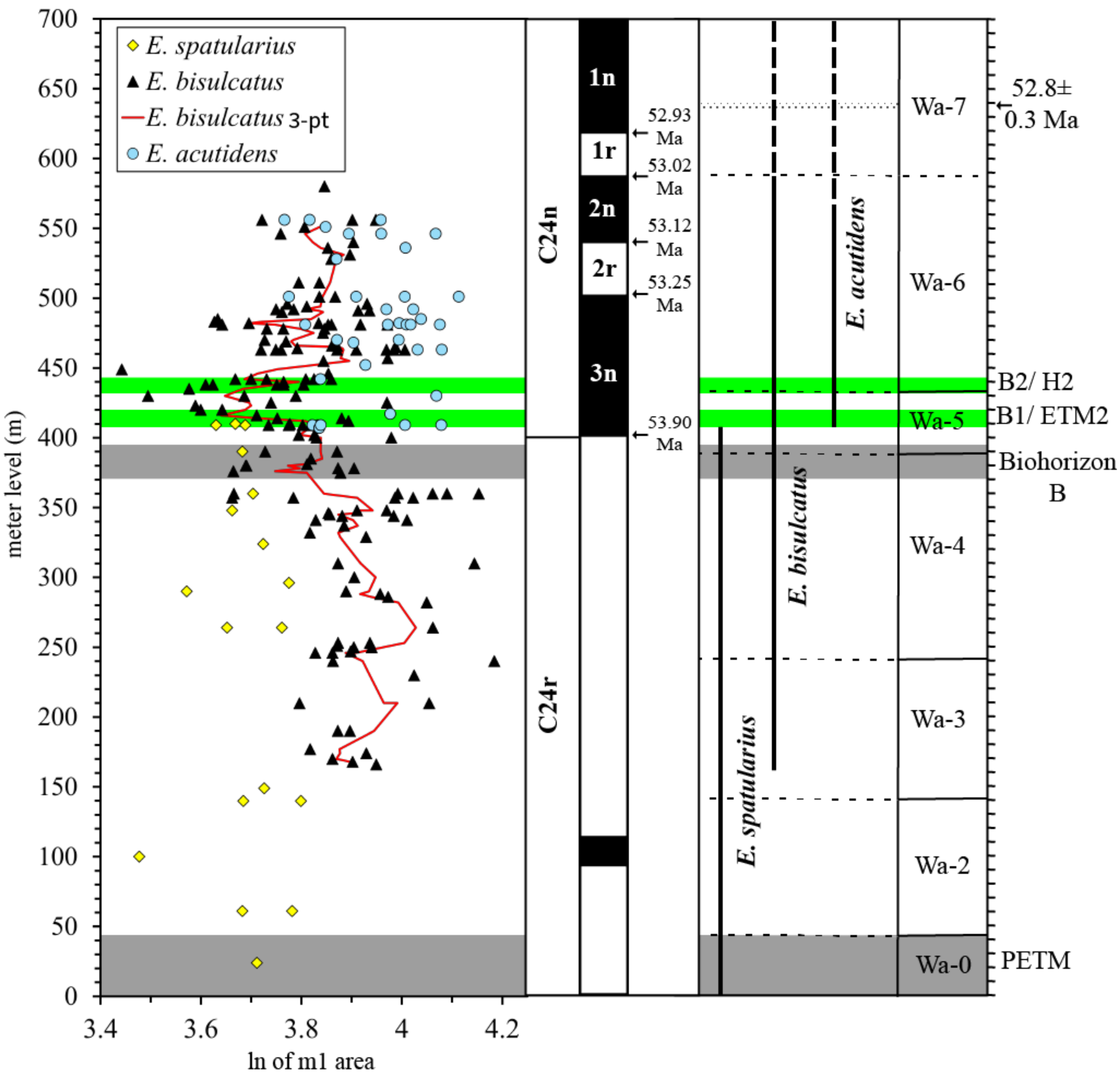

FIGURE 5: Scatterplot showing distribution of protoconid angle of p4 trigonid relative to stratigraphic level. A smaller angle indicates a more closed trigonid with cusps forming an equilateral triangle.

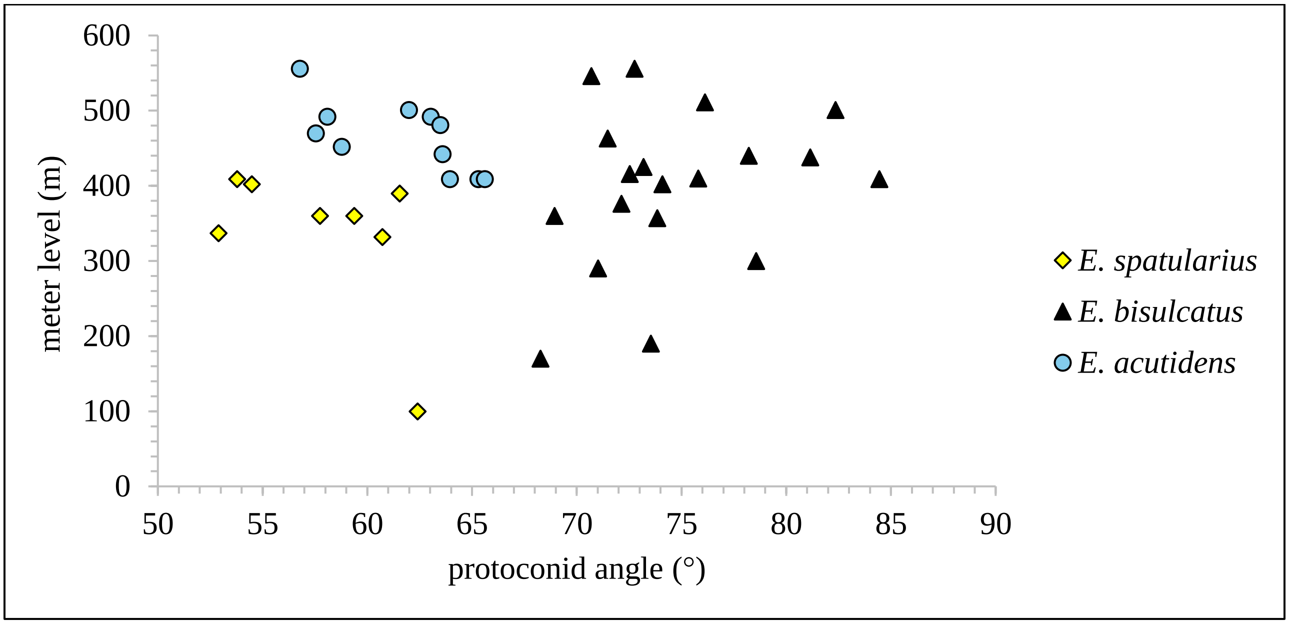

FIGURE 6: Left mandible of *Esthonyx spatularius* (USNM PAL 490643) with partial canine and p3-m3. **A**, occlusal view; **B**, buccal view. From Y-119, 100 m. Note the roots of a double rooted p2.

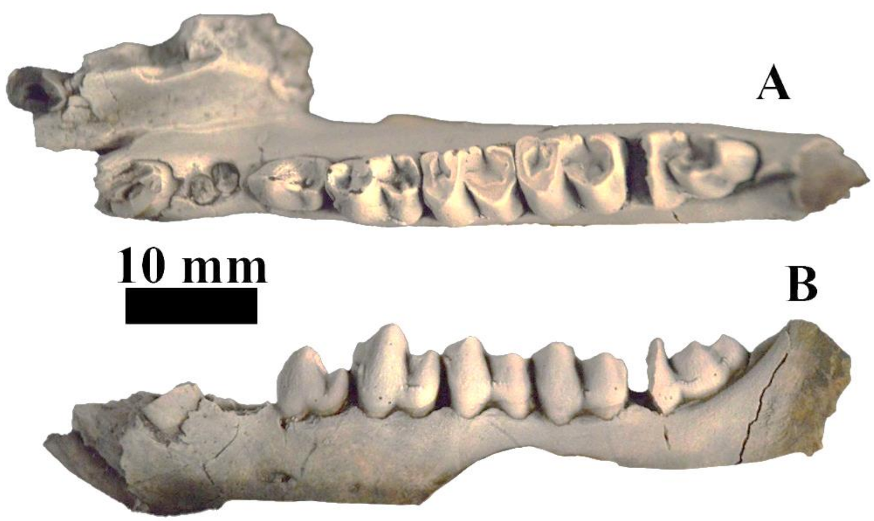

FIGURE 7: Right maxilla of *Esthonyx spatularius* (USNM PAL 768814) with P3 (protocone)-partial M3 in occlusal view. From D-1373, 337 m.

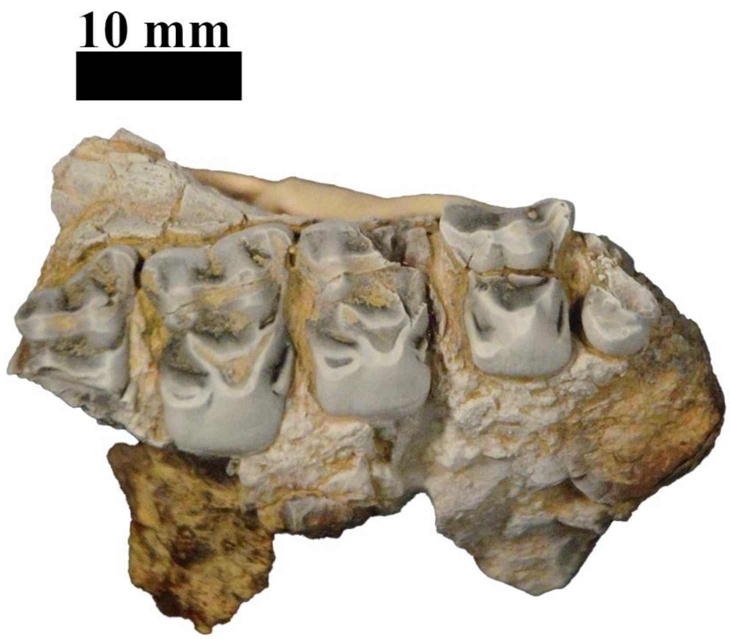

FIGURE *8*: Right mandible of *Esthonyx bisulcatus* (USNM PAL 768838) with p3-partial m3. **A**, buccal view; **B**, occlusal view. From D-1206, 438 m.

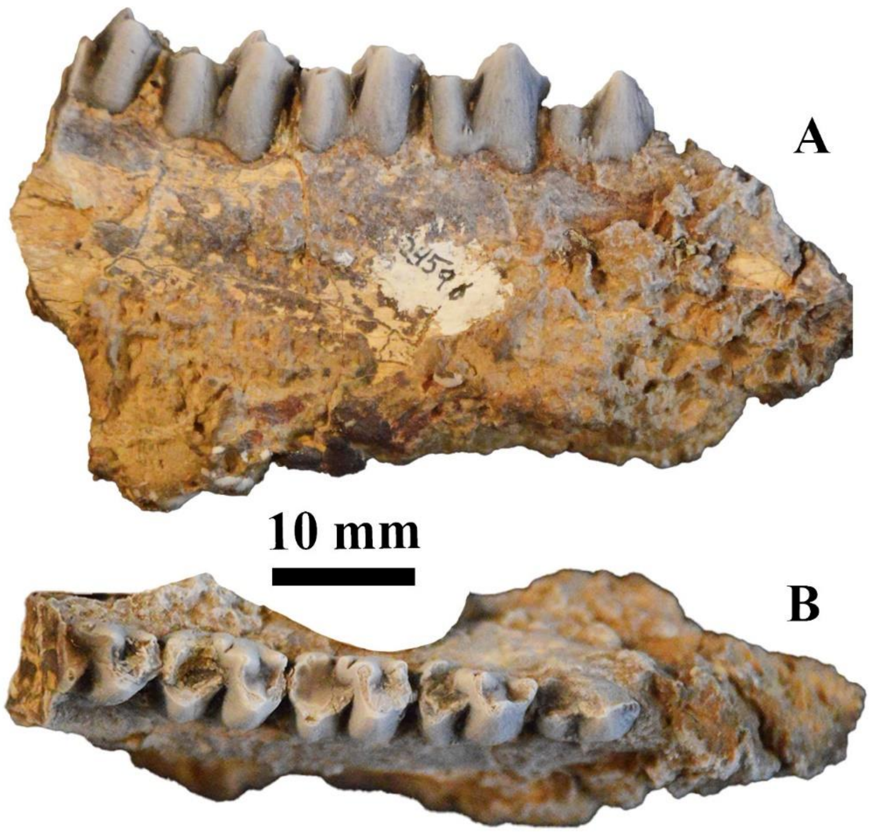

FIGURE 9: Left maxilla of *Esthonyx bisulcatus* (USNM PAL 768813) with partial P3-partial M3 in occlusal view. From D-1382, 430 m.

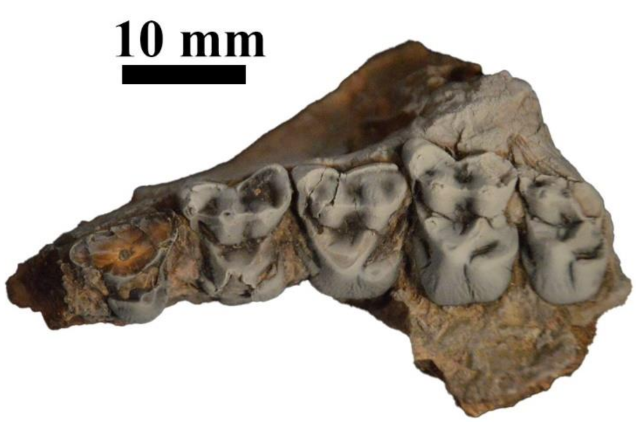

FIGURE 10: Left mandible of *Esthonyx bisulcatus* (USNM PAL 768825) with i2- m3. **A.** occlusial view: **B.** buccal view. From D-1554, 416 m. Note peg-like i3 and double-rooted p2 with roots that are parallel to jaw.

FIGURE 11: Left mandible of *Esthonyx bisulcatus* (USNM PAL 490635) with partial c1, dp2-4, m1-2. **A**, buccal view; **B**, occlusal view. From D-1325, 438 m

FIGURE 12: Right mandible of an *Esthonyx acutidens* (USNM PAL 533621) with p2-m3. **A**, buccal view; **B**, occlusal view; **C**, occlusal view of m3. From D-1436, 492 m.

FIGURE 13: Right maxilla of *Esthonyx acutidens* (USNM PAL 768811) with I2- M3 in occlusal view. From D-1467, 546 m. Specimen includes left and right I1, and left C, P4-M3, which are not pictured.

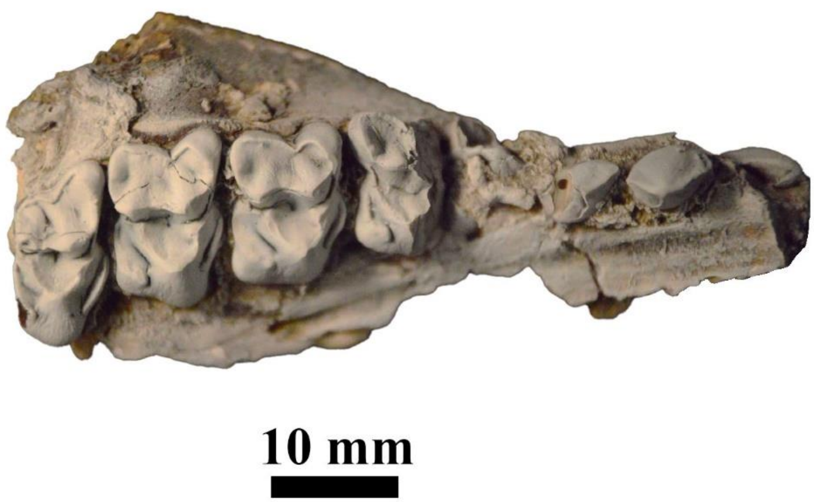

FIGURE 14: Right mandible of *Esthonyx* sp., cf. *bisulcatus* (USNM PAL 495174) with p4- m1. **A**, occlusal view; **B**, buccal view. Specimen includes right c1, not pictured below. From D-1388, 360 m.

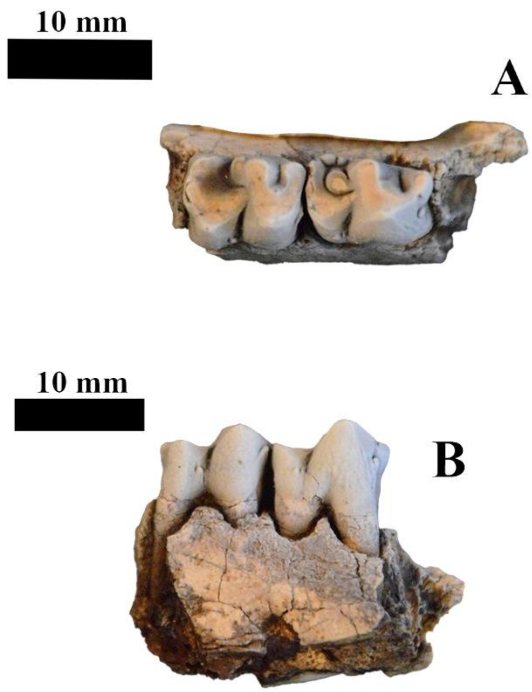

TABLE 1: List of lower dental measurements conducted on borrowed specimens of *Esthonyx* from study area. Specimens borrowed from USNM and measured at UNSM.

	Measurement	Symbol	Description
Lower Dentition	Length	L	From the most anterior point to the most posterior point.
	Width	W	Across the widest portion of the tooth. Buccal to the lingual side of trigonid.
	Trigonid Length	B-tri	From the anterior side of the paraconid to the posterior side of the metaconid. Longest point of trigonid.
	Talonid Length	B-tal	From the posterior side of the metaconid to the hypoconulid.
	Trigonid Height	H-tri	The max height from the cervical margin to the occlusal surface along the buccal side of the trigonid basin.
	Talonid Height	H-tal	The max height from the cervical margin to the occlusal surface along the buccal side of the talonid basin.
	Paraconid to Protoconid	*a*	From the center of the paraconid cusp to the center of the protoconid cusp.
	Protoconid to Metaconid	*b*	From the center of the protoconid cusp to the center of the metaconid cusp.
	Metaconid to Paraconid	*c*	From the center of the metaconid cusp to the center of the paraconid cusp.

TABLE 2: List of lower dental measurements conducted on borrowed specimens of *Esthonyx* from study area. Specimens borrowed from USNM and measured at UNSM.

	Measurement	Symbol	Description
Upper Dentition	Length	L	From the most anterior point to the most posterior point.
	Width	W	Across the widest portion of the tooth. From the ectoflexus to the lingual edge of the tooth. Does not include metastyle and parastyle.
	Height	H	Maximum height from cervical margin to highest point on the occlusal surface.
	Paracone to Protocone	*A*	From the center of the paracone cusp to the center of the protocone cusp.
	Protocone to Metacone	*B*	From the center of the protocone cusp to the center of the metacone cusp.
	Metacone to Paracone	*C*	From the center of the metacone cusp to the center of the paracone cusp.
	Paracone to Parastyle	*D*	From the center of the paracone to the furthest point on the parastyle. Measures the total length of parastyle.
	Metacone to Metastyle	*E*	From the center of the metacone to the furthest point on the metastyle. Measures the total length of metastyle.

TABLE 3: Dental measurements for lower m1 of the three species of *Esthonyx* from study area. Populations of *Esthonyx bisulcatus* have been divided at the 400 m level due to differences in body size. **Abbreviations**: **n**, sample size of specimens with m1 present on at least one side; **SD**, standard deviation.

	Species	*n*	Ln m1 area Mean	Ln m1 area Range	SD
m1	*E. spatularius*	18	3.69	3.48 – 3.8	0.08
	E. bisulcatus *Total	153	3.84	3.44 – 4.18	0.12
	E. bisulcatus *Below 400 m	58	3.90	3.66-4.18	0.12
	E. bisulcatus *Above 400 m	95	3.80	3.44-4.01	0.11
	E. acutidens	36	3.95	3.77– 4.11	0.10

TABLE 4: Dental measurements for lower p4 of *Esthonyx* species from study area. **Abbreviations and symbols**: **n**, sample size of specimens with p4 present on at least one side; **proto.**, protoconid; **∠,** angle.

	Species	*n*	Mean proto. ∠ of p4	Range proto. ∠ of p4
p4	*E. spatularius*	8	58.2°	52.9° – 64.7°
	E. bisulcatus	20	74.4°	68.1° – 84.5°
	E. acutidens	12	61.5°	53.1° – 65.6°
	Esthonyx cf. bisulcatus	1	79.3°*	–

TABLE 5: Statistics for lower teeth of *Esthonyx spatularius* from the study area. **Abbreviations**: ***n***, sample size; **Min.**, minimum; **Max.**, maximum; **SE**, standard error of mean; **SD**, standard deviation; **CV%,** coefficient of variation given as a percentage. Measurements in mm.

		N	Min.	Max.	Mean	SE	SD	CV%
p2	L	4	4.08	4.79	4.45	0.15	0.30	6.8
	W	4	2.71	3.15	2.92	0.10	0.21	7.1
p3	L	8	5.07	6.53	5.89	0.15	0.42	7.1
	W	8	3.55	4.23	3.91	0.09	0.25	6.3
p4	L	16	6.38	7.84	7.25	0.11	0.45	6.2
	W	16	4.29	5.62	4.82	0.09	0.34	7.1
m1	L	24	6.44	7.98	7.32	0.08	0.41	5.6
	W	24	4.62	6.03	5.48	0.07	0.33	6.0
m2	L	25	7.10	8.68	7.91	0.09	0.46	5.8
	W	26	5.56	7.39	6.24	0.08	0.42	6.7
m3	L	24	7.38	10.44	9.44	0.15	0.71	7.5
	W	24	4.72	6.38	5.39	0.08	0.39	7.2

TABLE 6. Statistics for upper teeth of *Esthonyx spatularius* from the study area. Abbreviations as in Table 5. Measurements in mm.

		n	Min.	Max.	Mean	SE	SD	CV%
P2	L	1	–	–	4.91	–	–	–
	W	1	–	–	3.07	–	–	–
P3	L	2	7.27	7.33	7.30	0.03	0.04	2.1
	W	2	6.86	7.05	6.96	0.10	0.13	6.7
P4	L	7	6.23	7.88	6.85	0.21	0.56	8.0
	W	7	7.67	9.54	8.58	0.24	0.64	9.2
M1	L	10	6.80	8.28	7.69	0.16	0.51	5.1
	W	11	9.64	12.91	10.48	0.29	0.96	8.7
M2	L	12	7.00	8.66	7.98	0.15	0.51	4.2
	W	12	9.72	12.07	10.79	0.20	0.69	5.7
M3	L	10	5.88	7.17	6.62	0.14	0.45	4.5
	W	8	8.40	10.22	9.64	0.22	0.61	7.6

TABLE 7: Statistics for lower teeth of *Esthonyx bisulcatus* from study area. Abbreviations as in Table 5. Measurements in mm.

		n	Min.	Max.	Mean	SE	SD	CV%
p2	L	16	3.38	5.94	4.92	0.25	0.82	17.4
	W	16	2.77	3.98	3.28	0.10	0.34	10.5
p3	L	28	4.69	7.03	6.05	0.11	0.59	9.8
	W	28	2.65	5.17	3.87	0.11	0.56	14.5
p4	L	57	6.02	8.65	7.59	0.07	0.54	7.1
	W	57	3.63	6.22	4.92	0.07	0.55	11.1
m1	L	158	6.69	9.54	7.98	0.04	0.53	6.7
	W	158	4.55	7.08	5.81	0.04	0.48	8.2
m2	L	107	6.72	9.77	8.15	0.05	0.54	6.7
	W	112	4.69	7.28	6.04	0.05	0.50	8.3
m3	L	65	5.36	11.46	9.66	0.12	0.94	9.7
	W	71	3.82	8.03	5.34	0.07	0.60	11.3

TABLE 8: Statistics for upper teeth of *Esthonyx bisulcatus* from study area. Abbreviations as in Table 5. Measurements in mm.

		n	Min.	Max.	Mean	SE	SD	CV%
P2	L	1	–	–	5.15	–	–	–
	W	1	–	–	3.35	–	–	–
P3	L	16	6.26	8.14	7.36	0.14	0.54	7.3
	W	16	5.70	8.64	7.15	0.16	0.63	8.8
P4	L	31	6.65	8.50	7.48	0.09	0.48	6.4
	W	31	7.67	10.11	8.75	0.12	0.64	7.4
M1	L	54	6.85	8.82	7.86	0.06	0.45	5.7
	W	52	8.63	11.29	9.85	0.10	0.69	7.0
M2	L	40	6.66	9.63	8.00	0.10	0.66	8.2
	W	41	8.57	12.85	10.58	0.13	0.85	8.0
M3	L	26	5.49	8.17	6.83	0.11	0.55	8.1
	W	26	8.01	11.52	9.71	0.16	0.79	8.2

TABLE 9: Statistics for lower teeth of *Esthonyx bisulcatus* from below 400 m in study area. Abbreviations as in Table 5. Measurements in mm.

		n	Min.	Max.	Mean	SE	SD	CV%
p2	L	1	–	–	5.28	–	–	–
	W	1	–	–	3.43	–	–	–
p3	L	7	5.91	7.03	6.40	0.16	0.42	6.6
	W	7	3.27	4.96	4.08	0.23	0.60	14.7
p4	L	21	7.08	8.53	7.75	0.09	0.41	5.2
	W	20	3.63	6.22	5.11	0.13	0.57	11.2
m1	L	59	6.92	9.54	8.17	0.07	0.57	7.0
	W	59	4.75	7.08	5.98	0.07	0.52	8.6
m2	L	37	5.10	7.25	6.12	0.8	0.49	8.1
	W	39	7.14	9.62	8.22	0.07	0.45	5.4
m3	L	22	8.15	11.46	9.77	0.18	0.86	8.8
	W	24	4.24	6.31	5.32	0.11	0.56	10.5

TABLE 10: Statistics for upper teeth of *Esthonyx bisulcatus* from below 400 m in study area. Abbreviations as in Table 5. Measurements in mm.

		n	Min.	Max.	Mean	SE	SD	CV%
P2	L	0	–	–	–	–	–	–
	W	0	–	–	–	–	–	–
P3	L	0	–	–	–	–	–	–
	W	0	–	–	–	–	–	–
P4	L	4	7.00	8.11	7.69	0.25	0.50	6.5
	W	4	7.97	9.32	8.59	0.33	0.66	7.7
M1	L	6	7.24	8.23	7.75	0.17	0.41	5.3
	W	6	9.75	11.29	10.26	0.23	0.55	5.4
M2	L	9	6.66	8.51	7.85	0.21	0.64	8.2
	W	9	9.03	11.95	10.40	0.33	0.98	9.4
M3	L	3	7.03	7.73	7.31	0.21	0.37	5.1
	W	3	9.04	11.14	10.14	0.61	1.05	10.4

TABLE 11: Statistics for lower teeth of *Esthonyx bisulcatus* from above 400 m in study area. Abbreviations as in Table 5. Measurements in mm.

		n	Min.	Max.	Mean	SE	SD	CV%
p2	L	8	4.1	5.94	4.90	0.25	0.70	14.4
	W	8	2.77	3.98	3.28	0.13	0.37	11.2
p3	L	20	4.69	6.94	5.92	0.14	0.61	10.3
	W	20	2.65	5.17	3.809	0.12	0.55	14.6
p4	L	34	6.02	8.65	7.50	0.10	0.61	8.1
	W	35	3.76	6.09	4.85	0.08	0.50	10.2
m1	L	93	6.69	8.93	7.86	0.05	0.46	5.8
	W	93	4.55	6.53	5.74	0.04	0.42	7.2
m2	L	66	6.72	9.77	8.09	0.69	0.56	7.0
	W	68	5.14	6.95	6.03	0.55	0.45	7.5
m3	L	40	5.36	11.42	9.64	0.16	1.01	10.5
	W	44	4.4	8.03	5.39	0.09	0.61	11.3

TABLE 12: Statistics for upper teeth of *Esthonyx bisulcatus* from above 400 m in study area. Abbreviations as in Table 5. Measurements in mm.

		n	Min.	Max.	Mean	SE	SD	CV%
P2	L	1	–	–	5.35	–	–	–
	W	1	–	–	3.35	–	–	–
P3	L	15	6.26	8.14	7.37	0.14	0.56	7.6
	W	15	5.70	8.64	7.15	0.17	0.65	9.1
P4	L	26	6.65	8.5	7.47	0.93	0.48	6.4
	W	26	7.67	10.11	8.74	0.13	0.64	7.4
M1	L	46	6.85	8.82	7.87	0.07	0.46	5.8
	W	45	8.63	11.03	9.76	0.10	0.67	6.9
M2	L	28	6.77	8.84	7.96	0.11	0.58	7.3
	W	28	8.57	11.58	10.53	0.13	0.68	6.5
M3	L	21	5.49	8.17	6.79	0.12	0.56	8.3
	W	21	8.01	11.52	9.62	0.17	0.79	8.2

TABLE 13: Statistics for lower teeth of *Esthonyx acutidens* from BCS. Abbreviations as in Table 5. Measurements in mm.

		n	Min.	Max.	Mean	SE	SD	CV%
p2	L	4	3.38	4.99	4.10	0.34	0.67	16.3
	W	4	3.19	3.98	3.42	0.19	0.38	11.1
p3	L	14	6.02	7.11	6.67	0.08	0.28	4.3
	W	14	3.98	4.79	4.32	0.07	0.27	6.2
p4	L	33	6.99	8.66	7.79	0.08	0.43	5.5
	W	33	4.67	5.99	5.21	0.06	0.33	6.4
m1	L	46	7.16	9.41	8.11	0.08	0.53	6.6
	W	46	5.58	6.96	6.33	0.06	0.41	6.5
m2	L	39	7.20	9.08	8.25	0.08	0.48	5.8
	W	38	5.76	7.19	6.34	0.07	0.41	6.5
m3	L	39	9.15	12.09	10.51	0.12	0.76	7.2
	W	38	5.02	6.65	5.68	0.07	0.41	7.3

TABLE 14: Statistics for upper teeth of *Esthonyx acutidens* from study area. Abbreviations as in Table 5. Measurements in mm.

		n	Min.	Max.	Mean	SE	SD	CV%
P2	L	1	–	–	4.06	–	–	–
	W	1	–	–	6.11	–	–	–
P3	L	6	7.03	8.45	8.02	0.22	0.53	6.7
	W	6	7.00	9.12	7.65	0.32	0.79	10.4
P4	L	10	7.17	10.12	8.00	0.27	0.86	10.8
	W	10	8.18	11.08	9.57	0.33	1.05	11.0
M1	L	15	7.01	8.99	8.11	0.16	0.62	7.6
	W	15	9.36	11.96	10.87	0.21	0.82	7.5
M2	L	18	7.32	9.19	8.02	0.20	0.45	5.6
	W	17	10.31	13.04	11.47	0.11	0.81	7.0
M3	L	14	5.87	8.98	7.10	0.21	0.79	11.1
	W	14	9.82	13.15	10.88	0.24	0.88	8.1

TABLE 15: Measurements for USNM PAL 495174 (*Esthonyx* sp., cf. *bisulcatus*). Abbreviations as in Table 1. Measurements in mm.

p4	L	8.03
	W	5.33
	B-tri	4.70
	B-tal	3.74
	H-tri	6.16
	H-tal	4.44
m1	L	7.76
	W	5.60
	ln of m1 Area	3.77
	B-tri	4.19
	B-tal	3.94
	H-tri	5.82
	H-tal	4.45

Specimen #	Location	Genus	Species	Element	Locality	Meter Level(m)
USGS 27142	USNM Drawer 236	*Esthonyx*	*acutiden*	R p/4-m/3 (m/2-m/3 partly)	D-1947	407
USGS 26979	USNM Drawer 239	*Esthonyx*	*acutidens*	R m/1	D-1829	501
USGS 8905	USNM Drawer 238	*Esthonyx*	*acutidens*	L m/1	Y-45s	470
USGS 1554	USNM Drawer 238	*Esthonyx*	*acutidens*	L m/1-m/2	D-1166	481
USNM PAL 768874	USNM Drawer 238	*Esthonyx*	*acutidens*	L p/4-m/3 trigonid, R p/4-m/2, R P3/-M/3	D-1229	481
USNM PAL 768816-Rm/1	USNM Drawer 234	*Esthonyx*	*acutidens*	2 L p/4, R p/4, and R m/1	D-1454	409
ND	R17 219 L23	Esthonyx	*acutidens*	L M2/, and lower R p4 and m1	D-1381	430
USNM 490634	USNM Drawer 237	*Esthonyx*	*acutidens*	L m/2-m3	D-1325	438
USNM 523688	USNM Drawer 237	*Esthonyx*	*acutidens*	R m/1, L M2/	D-1699	463
USNM PAL 768845	USNM Drawer 238	*Esthonyx*	*acutidens*	L p/4-m/2	D-1162	481
USNM PAL 768865	USNM Drawer 240	*Esthonyx*	*acutidens*	L p/3-m/3 (m/3 broken)	D-1436	492
USNM 533621	JHU Cabinet	*Esthonyx*	*acutidens*	R p/2-m/3	D-1436	492
USNM 495158	USNM Drawer 239	*Esthonyx*	*acutidens*	R i/2, p/3-m/3, L p/3-m/3	D-1431	501
USGS 8306	USNM Drawer 239	*Esthonyx*	*acutidens*	R dp/4-m/1	D-1468	501
USNM PAL 523700	USNM Drawer 239	*Esthonyx*	*acutidens*	R dp/3-m/1, addit. R p/4, Addit. L M1/?, L M1/-M2/?	WW-63	536
USNM PAL 768864	USNM Drawer 240	*Esthonyx*	*acutidens*	L p/3-m/3	D-1464	546

USNM PAL 768860	USNM Drawer 240	*Esthonyx*	*acutidens*	i/2, L m/1-m/3	D-1828	546
USNM PAL 768811	JHU Cabinet	*Esthonyx*	*acutidens*	L P4/-M3/, R C-M3/, tooth frags and bits	D-1467	546
USNM PAL 768855	USNM Drawer 240	*Esthonyx*	*acutidens*	L p/4-m/3, R p/4-m/3	D-1583	551
USNM PAL 768867	USNM Drawer 240	*Esthonyx*	*acutidens*	R P3/-M2/, L DP4/ (assoc?), Assoc.	D-1473	556
USGS 12971	USNM Drawer 240	*Esthonyx*	*acutidens*	L p/4-m/1	D-1647	591
ND	R17 220 L2	Esthonyx	*acutidens*	teeth, R P4, L M3, LP1 or P2, R m1* (Smashed)	WW-317	*Missing
USGS 24580	USNM Drawer 234	*Esthonyx*	*acutidens*	R m/3	D-1743	385
USGS 23653	USNM Drawer 236	*Esthonyx*	*acutidens*	R M1/	Y-461	405
USGS 7543	USNM Drawer 236	*Esthonyx*	*acutidens*	L m/2-m/3	D-1454	409
USGS 27151	USNM Drawer 236	*Esthonyx*	*acutidens*	L m/1	D-1454	409
USNM PAL 768831	USNM Drawer 236	*Esthonyx*	*acutidens*	R p/2-m/1	D-1454	409
USGS 24027	USNM Drawer 236	*Esthonyx*	*acutidens*	R m/3	D-1541	414
USGS 8578	USNM Drawer 236	*Esthonyx*	*acutidens*	L p/3-p/4	D-1410	417
USGS 8420	USNM Drawer 236	*Esthonyx*	*acutidens*	R m/3, L m/1-m/3	D-1410	417
USGS 9082	USNM Drawer 236	*Esthonyx*	*acutidens*	R m/3	D-1402	420
USGS 23655	USNM Drawer 236	*Esthonyx*	*acutidens*	R m/3	D-1403	420

USGS 26888	USNM Drawer 236	*Esthonyx*	*acutidens*	R m/2-m/3	Y-320	423
USGS 4202	USNM Drawer 236	*Esthonyx*	*acutidens*	R p/3-p/4	D-1326	425
USGS 12983	USNM Drawer 236	*Esthonyx*	*acutidens*	Ussoc. L p/4, R m/2	D-1598	428
USGS 4268	USNM Drawer 237	*Esthonyx*	*acutidens*	L M2/	D-1310	442
USNM PAL 768876	USNM Drawer 237	*Esthonyx*	*acutidens*	L p/4-m/2, R p/4-m/1	D-1688	442
USGS 19336	USNM Drawer 237	*Esthonyx*	*acutidens*	R m/3	D-1657	443
USNM PAL 768875	USNM Drawer 237	*Esthonyx*	*acutidens*	L p/2-p/3, m/1, m/3	D-1603	463
USGS 26894	USNM Drawer 237	*Esthonyx*	*acutidens*	L M2/	D-1881	463
USGS 22749	USNM Drawer 238	*Esthonyx*	*acutidens*	RM1/-M3/	D-1737	463
USGS 24598	USNM Drawer 238	*Esthonyx*	*acutidens*	R m/1 and m/3	D-1757	468
USGS 1093	USNM Drawer 238	*Esthonyx*	*acutidens*	L p/3-m/3	D-1198 B	470
USGS 1262	USNM Drawer 238	*Esthonyx*	*acutidens*	L M1/	D-1198 H	470
USNM PAL 768846	USNM Drawer 238	*Esthonyx*	*acutidens*	L p/3-m/3, R p/2-m/3, L P2/-M3/, R M1/-M3/	D-1162	481
USGS 1555	USNM Drawer 238	*Esthonyx*	*acutidens*	L m/2	D-1166	481
USGS 279	USNM Drawer 238	*Esthonyx*	*acutidens*	R m/1-m/2	D-1177	481
USGS 278	USNM Drawer 238	*Esthonyx*	*acutidens*	R m/2-m/3	D-1177	481

USGS 287	USNM Drawer 238	*Esthonyx*	*acutidens*	L m/1-m/3	D-1177	481
USNM PAL 768844	USNM Drawer 238	*Esthonyx*	*acutidens*	L p/3-m/3, R p/2-m/3, L P3/-M3/, R P3/-M3/	D-1177	481
USGS 10255	USNM Drawer 238	*Esthonyx*	*acutidens*	R p/4, L m/1-m/2	D-1510	482
USGS 23661	USNM Drawer 238	*Esthonyx*	*acutidens*	L m/1 and m/3	D-1532	485
USGS 7057	USNM Drawer 238	*Esthonyx*	*acutidens*	R dp/4-m/1	D-1491	486
USGS 8608	USNM Drawer 239	*Esthonyx*	*acutidens*	R m/2	D-1345	491
USGS 8685	USNM Drawer 239	*Esthonyx*	*acutidens*	L M2/-M3/	D-1469	491
USNM PAL 768851	USNM Drawer 239	*Esthonyx*	*acutidens*	L m/2-m/3, R p/3	D-1174	501
USGS 8435	USNM Drawer 239	*Esthonyx*	*acutidens*	R m/2	D-1431	501
USNM 495164	USNM Drawer 239	*Esthonyx*	*acutidens*	L m/2-m/3 "half"	Y-39	501
USGS 8629	USNM Drawer 239	*Esthonyx*	*acutidens*	L m/2	Y-39	501
USGS 8005	USNM Drawer 239	*Esthonyx*	*acutidens*	R m/1-m/3	Y168	501
USGS 26958	USNM Drawer 239	*Esthonyx*	*acutidens*	L M2/-M/3	D-1843	528
USGS 26959	USNM Drawer 239	*Esthonyx*	*acutidens*	L P/4-M3/	D-1843	528
USGS 27161	USNM Drawer 239	*Esthonyx*	*acutidens*	R p/4-m/2(part)	D-1843	528
USNM 509669	USNM Drawer 239	*Esthonyx*	*acutidens*	R M1/-M2/	D-2056	531

USGS 26969	USNM Drawer 239	*Esthonyx*	*acutidens*	R p/4	Y-176	531
USGS 8342	USNM Drawer 240	*Esthonyx*	*acutidens*	R P4/-M3/	Y-181	541
USGS 17994	USNM Drawer 240	*Esthonyx*	*acutidens*	L p/3-m/2, R m/1	Y-193	546
USGS 8934	USNM Drawer 240	*Esthonyx*	*acutidens*	R m/1-m/3	Y-192s	546
USNM 712713	USNM Drawer 240	*Esthonyx*	*acutidens*	L p/3-m/3	D-1473	556
USGS 22743	USNM Drawer 240	*Esthonyx*	*acutidens*	L m/2-m/3	D-1473	556
USGS 24588	USNM Drawer 240	*Esthonyx*	*acutidens*	L p/4-m/2	D-1781	556
USGS 22745	USNM Drawer 240	*Esthonyx*	*acutidens*	L m/2-m/3, L M3/ with outlines of P3/-M2/	D-1735	561
USGS 8708	USNM Drawer 239	*Esthonyx*	*acutidens*	R m/3	Y-39	580
USNM PAL 768832	USNM Drawer 236	*Esthonyx*	*acutidens*	L p/3-m/3, R p/3-m/1?, Assoc. anterior teeth. L P3/-M3/	D-1454	409
USNM PAL 768830-Bigger	USNM Drawer 236	*Esthonyx*	*acutidens*	L p/3-p/4, m/3, R m/1-m/2	D-1454	409
USNM PAL 768862	USNM Drawer 240	*Esthonyx*	*acutidens*	R p/4-m/3	D-1339	452
USGS 24582	USNM Drawer 236	*Esthonyx*	*bisulcatus*	L m/1	D-1541	414
USNM PAL 768837	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L dp/4-erupting m/3	D-1660	442
USGS 26162	USNM Drawer 237	*Esthonyx*	*bisulcatus*	R m/1	D-1833	463
USGS 26077	USNM Drawer 238	*Esthonyx*	*bisulcatus*	R m/1-m/3	D-1737	466

USNM 495176	USNM Drawer 239	*Esthonyx*	*bisulcatus*	L m/1	D-1474	496
USNM PAL 495160	USNM Drawer 234	*Esthonyx*	*bisulcatus*	R P2/-M1/, LP3/-M3/, L m/1	Y-104	140
USNM 523658	USNM Drawer 234	*Esthonyx*	*bisulcatus*	assoc. dentition	D-1633	149
USNM PAL 768817	USNM Drawer 234	*Esthonyx*	*bisulcatus*	L m/1-m/2, L M2/, assoc. other dent.	Y-363	190
USGS 7094	USNM Drawer 234	*Esthonyx*	*bisulcatus*	L dp/4-m/1	Y-290	210
USNM 544740	JHU Cabinet	*Esthonyx*	*bisulcatus*	L&R M1/-M2/, L m/1-m/3, Rdp/3?, dp/4-m/1, R m/2-m/3 insitu	Y-344	210
USGS 12960	USNM Drawer 234	*Esthonyx*	*bisulcatus*	ussoc. Teeth, R p/3, R m/1	D-1645	240
USGS 7100	USNM Drawer 234	*Esthonyx*	*bisulcatus*	R m2/	Y-351	240
USGS 26999	USNM Drawer 234	*Esthonyx*	*bisulcatus*	R M3/, R p/3, R m/2	D-1935	250
USNM 523664	USNM Drawer 234	*Esthonyx*	*bisulcatus*	L m/3, R m/1-m/3	WW-55	250
USGS 8924	USNM Drawer 234	*Esthonyx*	*bisulcatus*	L m/2	D-1419	260
USGS 4225	USNM Drawer 234	*Esthonyx*	*bisulcatus*	R. M1/-M2/	D-1297	261
USGA 7948	USNM Drawer 234	*Esthonyx*	*bisulcatus*	L m/2, and ussoc.	D-1297	261
USGS 8078	USNM Drawer 234	*Esthonyx*	*bisulcatus*	L M1/	D-1389	264
USGS 9667	USNM Drawer 234	*Esthonyx*	*bisulcatus*	R M2/	D-1389	264
USGS 8077	USNM Drawer 234	*Esthonyx*	*bisulcatus*	L dp/3-dp/4	D-1389	264

USGS 13784	USNM Drawer 234	*Esthonyx*	*bisulcatus*	L p/3 & m/1, R m/2	D-1389	264
USGS 1986	USNM Drawer 234	*Esthonyx*	*bisulcatus*	R P4/	Y-289	280
USGS 10233	USNM Drawer 240	*Esthonyx*	*bisulcatus*	R p/3-m/1	D-1418	282
USGS 4227	USNM Drawer 234	*Esthonyx*	*bisulcatus*	L m/2-m/3	D-1392	292
USNM 523673	USNM Drawer 234	*Esthonyx*	*bisulcatus*	R m/1, m/2	Y-156	310
USNM 523675	USNM Drawer 234	*Esthonyx*	*bisulcatus*	R p/4, L talonid of m/2-m/3	Y-156	310
USGS 24599	USNM Drawer 234	*Esthonyx*	*bisulcatus*	R p/4-m/1, other parts of molars.	D-1775	329
USGS 7362	USNM Drawer 234	*Esthonyx*	*bisulcatus*	misc. teeth, looking at the L m/3, and R P4/	Y-157	332
USGS 4214	USNM Drawer 234	*Esthonyx*	*bisulcatus*	L p/4	Y-157	332
USGA 4263	USNM Drawer 234	*Esthonyx*	*bisulcatus*	ussoc. L m/1 & m/2	Y-459	332
USGS 13656	USNM Drawer 234	*Esthonyx*	*bisulcatus*	L m/1	D-1373	337
USGS 4283	USNM Drawer 234	*Esthonyx*	*bisulcatus*	R p/4-m/1, L m/2	D-1335	341
USGS 4284	USNM Drawer 234	*Esthonyx*	*bisulcatus*	L P4/-M1/	D-1335	341
USGS 8367	USNM Drawer 234	*Esthonyx*	*bisulcatus*	R P4/-M1/	D-1335	341
USGS 1974	USNM Drawer 235	*Esthonyx*	*bisulcatus*	3 ussoc. Teeth. L m/1	D-1201	344
USGS 8272	USNM Drawer 235	*Esthonyx*	*bisulcatus*	L m/2	Y-131	348

USGS 4260	USNM Drawer 235	*Esthonyx*	*bisulcatus*	Ussoc. 2 L m/1s, and m/2	Y-131	348
USGS 7933	USNM Drawer 235	*Esthonyx*	*bisulcatus*	L m/2	D-1415	354
USGS 8915	USNM Drawer 235	*Esthonyx*	*bisulcatus*	R m/2	D-1415	354
USGS 27075	USNM Drawer 235	*Esthonyx*	*bisulcatus*	R m/2	D-1924	357
USGS 27074	USNM Drawer 235	*Esthonyx*	*bisulcatus*	R m/1	D-1924	357
USGS 4212	USNM Drawer 234	*Esthonyx*	*bisulcatus*	R dp/3-m/1	D-1303	360
USGS 7040	USNM Drawer 234	*Esthonyx*	*bisulcatus*	R m/1	D-1387	360
USNM 712650	USNM Drawer 235	*Esthonyx*	*bisulcatus*	L p/3-m/3, R p/4-m/2	Y-132	360
USGS 10460	USNM Drawer 235	*Esthonyx*	*bisulcatus*	L M2/	D-1303	360
USGS 13664	USNM Drawer 235	*Esthonyx*	*bisulcatus*	R M2/	D-1303	360
USGS 7256	USNM Drawer 235	*Esthonyx*	*bisulcatus*	L m/1	Y-132	360
USGS 27055	USNM Drawer 235	*Esthonyx*	*bisulcatus*	R p/4	D-1923	362
USGS 12957	USNM Drawer 235	*Esthonyx*	*bisulcatus*	L P4/, R M2/-M3/	D-1635	370
USNM 523678	USNM Drawer 235	*Esthonyx*	*bisulcatus*	R m/2, L m/3	WW-32	370
USGS 2385	USNM Drawer 235	*Esthonyx*	*bisulcatus*	R m/2	Y-283	370
USNM 487903	USNM Drawer 235	*Esthonyx*	*bisulcatus*	R p/4-m/2	Y-84	380

USGS 7251	USNM Drawer 235	*Esthonyx*	*bisulcatus*	R m/2	D-1421	381
USNM 523679	USNM Drawer 235	*Esthonyx*	*bisulcatus*	R m/2	D-1341	384
USNM 712708	USNM Drawer 240	*Esthonyx*	*bisulcatus*	L m/1-m/2, erupting m/3	D-1792	385
USGS 8972	USNM Drawer 235	*Esthonyx*	*bisulcatus*	L m/3	D-1342	390
USGS 4216	USNM Drawer 235	*Esthonyx*	*bisulcatus*	bits and pieces. L m/1, m/3, R p/4, m/2	D-1342	390
USGS 19348	USNM Drawer 235	*Esthonyx*	*bisulcatus*	L p/4, L M/2	D-1712	390
USGS 9091	USNM Drawer 234	*Esthonyx*	*bisulcatus*	R p/4	D-1222	400
USGS 10241	USNM Drawer 236	*Esthonyx*	*bisulcatus*	L M1/-M3/	D-1538	405
USGS 7763	USNM Drawer 234	*Esthonyx*	*bisulcatus*	L m/2-m/3	D-1460	409
USGS 23658	USNM Drawer 236	*Esthonyx*	*bisulcatus*	R m/1	D-1454	409
USGS 7545	USNM Drawer 236	*Esthonyx*	*bisulcatus*	misc teeth with p/4s.	D-1454	409
USNM 511071	JHU Cabinet	*Esthonyx*	*bisulcatus*	Skull w/ L & R P2/, DP3/-4/, M1/, L&R i/1-c, p/2, dp/3-/4, m/1	D-1454	409
USNM PAL 768829	USNM Drawer 236	*Esthonyx*	*bisulcatus*	L P4/-M3/, R M1/-M3/	D-1350	410
USGS 7331	USNM Drawer 236	*Esthonyx*	*bisulcatus*	L P4/-M1/	D-1527	410
USNM 523681	USNM Drawer 236	*Esthonyx*	*bisulcatus*	L m/3	D-1863	414
USNM PAL 768825	USNM Drawer 236	*Esthonyx*	*bisulcatus*	L i/3-m/3, R p/2-m/3 trigonid, R M1/-M3/, L P3/-M3/	D-1554	416

USNM 495445	USNM Drawer 236	*Esthonyx*	*bisulcatus*	R DP4/	D-1530	420
USGS 12975	USNM Drawer 236	*Esthonyx*	*bisulcatus*	R p/4-m/1, L p/4	D-1597	420
USGS 4269	USNM Drawer 234	*Esthonyx*	*bisulcatus*	R M2/, M3/ (M2/ measurments)	D-1324	424
USGS 4238	USNM Drawer 234	*Esthonyx*	*bisulcatus*	L m/2, R m/1	D-1326	425
USGS 4253	USNM Drawer 236	*Esthonyx*	*bisulcatus*	R m/3	UM-RB 8	425
USGS 4217	USNM Drawer 236	*Esthonyx*	*bisulcatus*	L m/1-m/3	D-1326	425
USGS 4266	USNM Drawer 236	*Esthonyx*	*bisulcatus*	L p/2-p/3	D-1326	425
USGS 4234	USNM Drawer 236	*Esthonyx*	*bisulcatus*	R m/1-m/3	D-1326	425
USGS 4239	USNM Drawer 236	*Esthonyx*	*bisulcatus*	L p/4	D-1326	425
USGS 4246	USNM Drawer 236	*Esthonyx*	*bisulcatus*	R. m/3	D-1349	430
USGS 4249	USNM Drawer 236	*Esthonyx*	*bisulcatus*	L p/4	D-1349	430
USGS 4247	USNM Drawer 236	*Esthonyx*	*bisulcatus*	L m/1-m/2	D-1349	430
USNM PAL 712651 & USNM PAL 712652	USNM Drawer 237	*Esthonyx*	*bisulcatus*	Anterior teeth and L p/3-m/3	D-1876	435
USNM PAL 768838	USNM Drawer 237	*Esthonyx*	*bisulcatus*	R p/3-m/3 trigonid, L m/3, R M1/-M3/	D-1206	438
USGS 24596	USNM Drawer 236	*Esthonyx*	*bisulcatus*	R p/3-p/4, part m/1, m/2	D-1206	438

USGS 4208	USNM Drawer 236	*Esthonyx*	*bisulcatus*	R m/2?	D-1322	438
USGS 4207	USNM Drawer 236	*Esthonyx*	*bisulcatus*	L m/2-m/3	D-1322	438
USNM 509596	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L dp/4-m/1 w/ symp.	D-1320	438
USGS 4210	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L M1/-M3/	D-1320	438
USGS 4206	USNM Drawer 237	*Esthonyx*	*bisulcatus*	R dp/3-m/1	D-1320	438
USGS 4209	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L M1/	D-1322	438
USGS 8054	USNM Drawer 237	*Esthonyx*	*bisulcatus*	R&L m/1-m/2	D-1400	438
USGS 7922	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L dp/3-dp/4, addition L dp/4	D-1400	438
USGS 8930	USNM Drawer 237	*Esthonyx*	*bisulcatus*	R m/2-m/3	D-1459	438
USGS 7632	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L m/3	D-1452	440
USNM 712658	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L dp/4-m/2, R dp/3-m/2	D-1688	442
USGS 4267	USNM Drawer 236	*Esthonyx*	*bisulcatus*	L m/2	D-1310	442
USGS 18295	USNM Drawer 236	*Esthonyx*	*bisulcatus*	R p/4	D-1588	442
USGS 22744	USNM Drawer 236	*Esthonyx*	*bisulcatus*	L m/1	D-1660 B	442
USGS 23654	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L M1/	D-1204	442
USGS 4241	USNM Drawer 237	*Esthonyx*	*bisulcatus*	R m/2 *2	D-1204	442

USNM PAL 768840	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L P2/-M2/, R P4/-M3/	D-1310	442
USGS 13005	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L M1/	D-1311	442
USGS 4242	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L P3/-M1/	D-1311	442
USGS 24576	USNM Drawer 237	*Esthonyx*	*bisulcatus*	R p/3	D-1660	442
USGS 8501	USNM Drawer 237	*Esthonyx*	*bisulcatus*	R p/4, with roots of p/2-p/3	D-1429	446
USGS 8500	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L M1/-M3/	D-1429	446
USGS 8242	USNM Drawer 237	*Esthonyx*	*bisulcatus*	R m/2-m/3	D-1429	446
USGS 8241	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L m/1-m/2	D-1429	446
USGS 10234	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L dp/4-m/1	D-1537	449
USGS 22756	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L m/2	Y-100	455
USGS 22757	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L p/3-m/1	Y-100	455
USGS 24591	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L dp/3-dp/4, R dp/4-erupting m/2	Y-100	455
USGS 19354	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L p/4	D-1668	460
USGS 19379	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L p/4, m/1?	D-1699	463
USNM 712710	USNM Drawer 237	*Esthonyx*	*bisulcatus*	R p/4-m/2	D-1699	463
USGS 12974	USNM Drawer 237	*Esthonyx*	*bisulcatus*	R P4/-M2/	D-1603	463

USGS 19377	USNM Drawer 237	*Esthonyx*	*bisulcatus*	R P3/-M2/	D-1699	463
USGS 27158	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L m/2-m/3	D-1699	463
USGS 23664	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L m/1, R dp/4, m/2, L M1/	D-1699	463
USGS 27159	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L m/2	D-1699	463
USGS 34602	USNM Drawer 237	*Esthonyx*	*bisulcatus*	R m/1-m/3	D-1699	463
USGS 12997	USNM Drawer 238	*Esthonyx*	*bisulcatus*	R P3/-M3/	D-1495	464
USNM 712656	USNM Drawer 238	*Esthonyx*	*bisulcatus*	R m/1-m/3	D-1495	464
USNM PAL 768866	USNM Drawer 240	*Esthonyx*	*bisulcatus*	L p/3-m/3, R i/2?, m/2-m/3	D-1425	465
USGS 12976	USNM Drawer 238	*Esthonyx*	*bisulcatus*	L P4/-M3/	D-1592	466
USGS 12977	USNM Drawer 238	*Esthonyx*	*bisulcatus*	L m/3	D-1592	466
USGS 26075	USNM Drawer 238	*Esthonyx*	*bisulcatus*	symphysis with L p/3-p/4, R m/1	D-1737	466
USGS 8813	USNM Drawer 238	*Esthonyx*	*bisulcatus*	R DP4/-M1/	Y-45B	470
USGS 24595	USNM Drawer 240	*Esthonyx*	*bisulcatus*	L m/1, R m/1-m/2	D-1767	475
USGS 7284	USNM Drawer 238	*Esthonyx*	*bisulcatus*	L m/1-m/2	D-1511	478
USGS 13003	USNM Drawer 238	*Esthonyx*	*bisulcatus*	L P3/-M1/	D-1511	478
USGS 22754	USNM Drawer 238	*Esthonyx*	*bisulcatus*	R m/1-m/3	D-1727	478

USGS 24584	USNM Drawer 238	*Esthonyx*	*bisulcatus*	L m/1	D-1727	478
USGS 8361	USNM Drawer 238	*Esthonyx*	*bisulcatus*	L DP4/-M1/	D-1162	481
USGS 8759	USNM Drawer 238	*Esthonyx*	*bisulcatus*	R dp/3-m/1	D-1229	481
USGS 1477	USNM Drawer 238	*Esthonyx*	*bisulcatus*	L M2/-M3/, and others.	D-1229	481
USGS 1020	USNM Drawer 238	*Esthonyx*	*bisulcatus*	R dp/4-m/1	D-1162	481
USGS 4256	USNM Drawer 238	*Esthonyx*	*bisulcatus*	L m/1-m/2 (m/1 is just talonid)	D-1162	481
USGS 276	USNM Drawer 238	*Esthonyx*	*bisulcatus*	L m/1-m/2	D-1177	481
USGS 284	USNM Drawer 238	*Esthonyx*	*bisulcatus*	L m/2	D-1177	481
USGS 4244	USNM Drawer 238	*Esthonyx*	*bisulcatus*	R P4/-M1/	D-1316	481
USGS 10253	USNM Drawer 238	*Esthonyx*	*bisulcatus*	L P4/-M1/	D-1510	482
USNM 712712	USNM Drawer 238	*Esthonyx*	*bisulcatus*	R dp/4-m/2	D-1510	482
USGS 4251	USNM Drawer 238	*Esthonyx*	*bisulcatus*	R dp/4-m/1	D-1312	483
USGS 19347	USNM Drawer 238	*Esthonyx*	*bisulcatus*	L p/2-part p/4	D-1531	485
USGS 22746	USNM Drawer 238	*Esthonyx*	*bisulcatus*	R dp/3-dp/4	D-1531	485
USGS 10247	USNM Drawer 238	*Esthonyx*	*bisulcatus*	R m/1 (others ussoc.)	D-1532	485
USGS 10489	USNM Drawer 238	*Esthonyx*	*bisulcatus*	R m/3	D-1565	485

USGS 7060	USNM Drawer 238	*Esthonyx*	*bisulcatus*	L M1/-M2/	D-1491	486
USGS 1846	USNM Drawer 239	*Esthonyx*	*bisulcatus*	L m/1, m/3	D-1169	491
USGS 8034	USNM Drawer 239	*Esthonyx*	*bisulcatus*	R m/1	D-1436	492
USNM 712709	USNM Drawer 240	*Esthonyx*	*bisulcatus*	L m/1-m/3	D-1436	492
USGS 19364	USNM Drawer 239	*Esthonyx*	*bisulcatus*	R p/4	D-1563	493
USGS 9387	USNM Drawer 239	*Esthonyx*	*bisulcatus*	R m/1	D-1507	494
USGS 9418	USNM Drawer 239	*Esthonyx*	*bisulcatus*	L M1/	D-1507	494
USGS 7704	USNM Drawer 239	*Esthonyx*	*bisulcatus*	R DP3/-M1/	D-1474	496
USNM PAL 768854	USNM Drawer 239	*Esthonyx*	*bisulcatus*	R m/2-m/3	D-1174	501
USNM 495175	USNM Drawer 239	*Esthonyx*	*bisulcatus*	R p/4, M1/, part m/3	D-1431	501
USGS 8481	USNM Drawer 239	*Esthonyx*	*bisulcatus*	R P4/-M1/	D-1175	501
USNM PAL 768847	USNM Drawer 239	*Esthonyx*	*bisulcatus*	R m/1-m/3	D-1573	511
USGS 8695	USNM Drawer 239	*Esthonyx*	*bisulcatus*	L m/3, R M1/	D-1438	516
USGS 27160	USNM Drawer 239	*Esthonyx*	*bisulcatus*	L m/1	D-1843	528
USGS 23659	USNM Drawer 240	*Esthonyx*	*bisulcatus*	R P4/-M1/	D-1464	546
USNM 521531	USNM Drawer 240	*Esthonyx*	*bisulcatus*	R P3/-M1/	D-1583	551

USNM PAL 768856	USNM Drawer 240	*Esthonyx*	*bisulcatus*	L p/4-m/3, R i/2-m/3	D-1473	556
USGS 7548	USNM Drawer 240	*Esthonyx*	*bisulcatus*	R dp/3-m/1	D-1473	556
USGS 7563	USNM Drawer 240	*Esthonyx*	*bisulcatus*	R. m/1	D-1473	556
USGS 9731	USNM Drawer 234	*Esthonyx*	*bisulcatus*	R M2/	V-73016	
USNM 541885	JHU Cabinet	*Esthonyx*	*bisulcatus*	R dp/4-m/1	Y-351	240
USNM 540207	JHU Cabinet	*Esthonyx*	*bisulcatus*	R dp/4-m/1	WW-55	250
USGS 2129	USNM Drawer 234	*Esthonyx*	*bisulcatus*	L m/1	D-1258	288
USNM 527541	JHU Cabinet	*Esthonyx*	*bisulcatus*	L p/3-m/3, R p/4-m/1, R m/3	Y-156	310
USGS 8996	USNM Drawer 235	*Esthonyx*	*bisulcatus*	R m/1	D-1421	381
USNM 523685	USNM Drawer 236	*Esthonyx*	*bisulcatus*	R p/3-m/1, L m/2	D-1310	442
USGS Cat. No. 21839	JHU Cabinet	*Esthonyx*	*bisulcatus*	R m/1-m/2, Lots of post cran, with more teeth insitu.	D-1660	442
USNM Cat. No. 487889	JHU Cabinet	*Esthonyx*	*bisulcatus*	L p/4-m/2, part L m/3, R p/3, R m/2, part m/3	D-1994	482
USGS 10251	USNM Drawer 239	*Esthonyx*	*bisulcatus*	R p/3-m/1	D-1426	490
USGS 8571	USNM Drawer 239	*Esthonyx*	*bisulcatus*	L m/1	Y-55	501
USGS 10245	USNM Drawer 239	*Esthonyx*	*bisulcatus*	L p/3-m/1	D-1567	531
USNM Cat. No. 487886	JHU Cabinet	*Esthonyx*	*bisulcatus*	Li/2-C, R i/2, L P3/-M1, R P4/-M1/, R m/1-m/2, R p/4, frags	WW-8	540
USNM 523671	USNM Drawer 234	*Esthonyx*	*bisulcatus*	r P/4-M/3	Y-296L	290
USGS 8368	USNM Drawer 234	*Esthonyx*	*bisulcatus*	Misc. teeth, R m/1, L m/2, R m/2, L M1/	D-1335	341

USGS 1907	USNM Drawer 234	*Esthonyx*	*bisulcatus*	R m/1-m/3, other teeth in matrix	D-1201	344
USGS 26942	USNM Drawer 235	*Esthonyx*	*bisulcatus*	L m/1	D-1882	345
USGS 27149	USNM Drawer 234	*Esthonyx*	*bisulcatus*	L m/1-m/3	D-1967	357
USGS 4213	USNM Drawer 234	*Esthonyx*	*bisulcatus*	l p/4-m/1	D-1303	360
USGS 82706	USNM Drawer 235	*Esthonyx*	*bisulcatus*	L p/4-m/3	D-1414	378
USGS 27139	USNM Drawer 236	*Esthonyx*	*bisulcatus*	L and R m/1	D-1951	402
DMNH 126591	CSU Lab	Esthonyx	*bisulcatus*	right lower m1	CSU 8 /4970	166
DMNH 126481	CSU Lab	Esthonyx	*bisulcatus*	right lower m1	2m above CSU 8	168
EPV.92203	R17 220 L40	Esthonyx	*bisulcatus*	man, R p4-m3, i2, and R I2?	D-1192 high	170
DMNH 126482	CSU Lab	Esthonyx	*bisulcatus*	right lower m1 and partial m2	CSU 2A/ 4963	174
USNM PAL 768859	USNM Drawer 240	*Esthonyx*	*bisulcatus*	L p/4-m/3, R m/1 (tal)-m/3	D-1847	190
DMNH 77262-A	CSU Lab	Esthonyx	*bisulcatus*	assoc teeth two right lower m1 and one left lower m1	CSU 62	246
DMNH 68825	CSU Lab	Esthonyx	*bisulcatus*	left lower m1	CSU 44/ 5611	247
DMNH 68654	CSU Lab	Esthonyx	*bisulcatus*	Right lower m1 and m3	CSU 3/ 4965	251
DMNH 65510	CSU Lab	Esthonyx	*bisulcatus*	Right Ramus m1	CSU 19 / 5041 ?	253
DMNH 65509	CSU Lab	Esthonyx	*bisulcatus*	Left lower m1	CSU 19 / 5041 ?	253
DMNH 77296	CSU Lab	Esthonyx	*bisulcatus*	Right lower m1 (?)	CSU 63/ 6201	286
USNM 527706	JHU Cabinet	*Esthonyx*	*bisulcatus*	L p/3-m/1, R m/1-m/3, C?	WW-137	300
ND -21-132	R17 240 L47	Esthonyx	*bisulcatus*	3 teeth, lower p4, m1 or m2?	Y-131	346
USNM 712657-A	USNM Drawer 235	*Esthonyx*	*bisulcatus*	L m/1-m/2	D-1967	357

USNM 712657-B	USNM Drawer 235	*Esthonyx*	*bisulcatus*	R m/2- m/3	D-1967	357
USNM 712657-C	USNM Drawer 235	*Esthonyx*	*bisulcatus*	L p/4-m/1	D-1967	357
ND -21-29	R17 240 L50	Esthonyx	*bisulcatus*	3 pieces, one two jaw p4 and m1, possible m2, sym?	D-1388	360
DMNH 77173	CSU Lab	Esthonyx	*bisulcatus*	Mandibular L (I1-I2, C, P1, P4-M2) R. (P3-M3)	CSU #57	375
ND -21-82	R17 240 L56	Esthonyx	*bisulcatus*	Beautiful assoc. jaws and teeth (I found it!)	D-1293	376
USNM PAL 768821	USNM Drawer 235	*Esthonyx*	*bisulcatus*	L dp/4-m/1, R broken dp/4 and m/1	Y-67	380
USGS 13780	USNM Drawer 235	*Esthonyx*	*bisulcatus*	R m/1 and m/3, L m/1	D-1342	390
EPV.91716	R17 220 L40	Esthonyx	*bisulcatus*	Teeth, L p/4, r m/1 or m/2, incisor, Mx/ portion	WW-315	401
USNM PAL 768827	USNM Drawer 236	*Esthonyx*	*bisulcatus*	R p/2?, p/4, m/3, R M2/, L P4/-M1/	D-1951	402
EPV.92160	R17 220 L40	Esthonyx	*bisulcatus*	man, L p4-m1, L I2	D-1951	402
USNM PAL 768833	USNM Drawer 236	*Esthonyx*	*bisulcatus*	L m/1-m/2 , anterior lower teeth. L C1/-M3/.	D-1460	409
USNM PAL 768826-A	USNM Drawer 236	*Esthonyx*	*bisulcatus*	L m/1	D-1454	409
USNM PAL 768826-C	USNM Drawer 236	*Esthonyx*	*bisulcatus*	R m/1	D-1454	409
EPV.91985	R17 220 L40	Esthonyx	*bisulcatus*	teeth, assoc.R m3, R p2*, L M2*, L m1 or m2	D-1823	409
USNM PAL 768861	USNM Drawer 240	*Esthonyx*	*bisulcatus*	L p/4-m/3	D-1306	410
USNM 712654	USNM Drawer 240	*Esthonyx*	*bisulcatus*	L m/1-m/3	D-1411	412
ND	R17 220 L5	Esthonyx	*bisulcatus*	Jaw with multiple teeth, NICE!!!	Y-69	414
USNM PAL 768828	USNM Drawer 236	*Esthonyx*	*bisulcatus*	L dp/4-m/1, R DP3/-DP4/, assoc.	Y-324	420

EPV.91675	R17 220 L40	Esthonyx	*bisulcatus*	palate, R I1-C, P3-M3, R I1-I2	D-1204	441
USNM PAL 768842	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L M2/-M3/	D-1451	448
DMNH 134713	CSU Lab	Esthonyx	*bisulcatus*	left Ramus , I,P1,P2-M3	CSU#134	457
USNM PAL 523692-A	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L p/4-m/3, additol m/3, L P3/-M1/, R P3/-M2/	D-1881	463
USNM PAL 768835	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L p/2-dp/3, R p/2-dp/4, R DP3/-M1/	D-1602	463
USNM PAL 768836	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L erupt C, dp/3-m/1	D-1604	463
USNM 523690	USNM Drawer 237	*Esthonyx*	*bisulcatus*	R m/2*, R m/3	D-1833	463
USNM PAL 768839	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L dp/3-m/1, R dp/4-m/1	D-1833	463
USNM 510865	JHU Cabinet	*Esthonyx*	*bisulcatus*	R m/2-m/3, L p/4-m/3(part), R P3/-M3/, L P3/-P4/, L M2/-M3/	D-1699	463
USNM 712655	USNM Drawer 238	*Esthonyx*	*bisulcatus*	L dp/4-errupt. m/3 trig, R dp4-errupt m/3 trig.	Y-34	469
USNM PAL 768863	USNM Drawer 240	*Esthonyx*	*bisulcatus*	R dp/4-m/2	D-1162	481
USGS 8460	USNM Drawer 238	*Esthonyx*	*bisulcatus*	R m/1	D-1177	481
ND	R17 219 L4	Esthonyx	*bisulcatus*	L m/3, L m/1, R m/1 and m/2	D-1162	481
USNM 523696	USNM Drawer 239	*Esthonyx*	*bisulcatus*	R* P4/, I	D-1346	491
ND	R17 219 L19	Esthonyx	*bisulcatus*	R m1 in jaw, no other teeth	D-1338N	491
USNM 712711	USNM Drawer 239	*Esthonyx*	*bisulcatus*	R dp/4* -m/2	D-1474	496
USNM 523699	USNM Drawer 239	*Esthonyx*	*bisulcatus*	L m/1-m/3, R M1/, L M3/	WW-54	501

USNM PAL 768848	USNM Drawer 239	*Esthonyx*	*bisulcatus*	L m/1-m/2, R m/2 (Talonid)-m/3 (erupting), assoc. c/1, with roots of p/2, L m/3 included, but broke .	DPC-11	536
USNM PAL 490635	USNM Drawer 237	*Esthonyx*	*bisulcatus*	L p/2-m/2	D-1325	438
USNM PAL 768812	JHU Cabinet	*Esthonyx*	*bisulcatus*	L p/3-m/1, R m/2-m/3, L P3/-M3/ (M3/ Separate), R P4/-M2/	D-1467	546
USNM PAL 768857	USNM Drawer 240	*Esthonyx*	*bisulcatus*	L m/2-m/3, R p/3 and m/1-m/3	D-1583	551
USNM 540180	JHU Cabinet	*Esthonyx*	*bisulcatus*	L p/3-m/2	D-1473	556
USNM PAL 768852	USNM Drawer 239	*Esthonyx*	*bisulcatus*	L dp/3-dp/4	Y-39	580
USNM PAL 768853	USNM Drawer 239	*Esthonyx*	*bisulcatus*	L dp/3-m/1, R m/1 and m/3	Y-39	580
USNM PAL 768849	USNM Drawer 239	*Esthonyx*	*bisulcatus*	R dp/3-dp/4	Y-175	610
EPV.92208	R17 220 L40	Esthonyx	*bisulcatus*	man, L p2,dp4-m1, m2 (assoc?)	D-1917	*Missing
EPV.92791	R17 220 L40	Esthonyx	*bisulcatus*	teeth, incisor*, R M2, R m1 or m2	D-1800	*Missing
ND -21-151	R17 240 L47	Esthonyx	*bisulcatus*	3 parts, all upper dentition, L M2 and M3	D-15045?	*Missing
EPV.124357	R17 220 L40	Esthonyx	*bisulcatus*	man, L C, dp4-m3, R dp4-m1	D-1459 upper purple/red	438m
USNM PAL 768868-A	USNM Drawer 241	*Esthonyx*	*bisulcatus*	Lp/2, p/4-m/2, R p/3-m/3, with assoc. anterior teeth present, but smashed.	D-1665	
USNM PAL 768868-B	USNM Drawer 241	*Esthonyx*	*bisulcatus*	L dp/2-m/3	D-1665	
USNM PAL 768813	JHU Cabinet	*Esthonyx*	*bisulcatus*	L m/1-m/3, L P3/-M3/, R M2/-M3/	D-1382	
USNM Cat. No. 495050	JHU Cabinet	*Esthonyx*	*bisulcatus*	R m/1, m/3, R (Part M1/) M2/-M3/, L P3/-M3/	WW-34	
USNM 527696	JHU Cabinet	*Esthonyx*		L M1/-M3/	Y-120	100
USNM 523614	USNM Drawer 234	*Esthonyx*		R m/2	Y-104	140
USNM 533412	JHU Cabinet	*Esthonyx*		L m/2-m/3, I frags.	Y-143	240

USNM 527732	JHU Cabinet	*Esthonyx*	R m/1-m/2, M3/, frags. All loose	Y-143	240
USGS 26081	USNM Drawer 234	*Esthonyx*	L p/4-m/3, R p/3, m/1-m/2	D-1931	315
USGS 4277	USNM Drawer 234	*Esthonyx*	fused anterior jaw. No p/4-m/3	D-1335	341
USGS 4287	USNM Drawer 235	*Esthonyx*	R M1/	D-1335	346
USGS 27062	USNM Drawer 235	*Esthonyx*	L p/4-m/2	D-1924	357
USGS 7255	USNM Drawer 235	*Esthonyx*	R DP3/	Y-132	360
USGS 1854	USNM Drawer 235	*Esthonyx*	L M1/-M2/, R M3/	D-1216	380
USNM 495171	USNM Drawer 235	*Esthonyx*	R m/1-m/3	D-1555	394
USGS 286	USNM Drawer 236	*Esthonyx*	R m/3	D-1350	409
USGS 27140	USNM Drawer 236	*Esthonyx*	L m/1-m/2	D-1454	409
USGS 26198	USNM Drawer 236	*Esthonyx*	R p/4-m/1	D-1779	412
USGS 4265	USNM Drawer 234	*Esthonyx*	R p/4 (part of m/1)	D-1326	425
USGS 4236	USNM Drawer 236	*Esthonyx*	R dp/4	D-1326	425
USGS 4248	USNM Drawer 236	*Esthonyx*	R m/2-m/3	D-1349	430
USNM 52383	USNM Drawer 236	*Esthonyx*	R m/3	D-1876	435
USGS 4307	USNM Drawer 236	*Esthonyx*	R p/4-m/1	D-1377	436

USGS 8767	USNM Drawer 236	*Esthonyx*	R p/3-p/4	D-1398	438
USGS 4207	USNM Drawer 237	*Esthonyx*	R m/2	D-1322	438
USNM 523684	USNM Drawer 237	*Esthonyx*	R M1/-M3, other teeth in box, but are	D-1404	438
USGS 12966	USNM Drawer 237	*Esthonyx*	R M3/	D-1310	442
USGS 13004	USNM Drawer 237	*Esthonyx*	L DP3/-DP/4	D-1311	442
USGS 19334	USNM Drawer 237	*Esthonyx*	L M1/	D-1588	442
USGS 19368	USNM Drawer 237	*Esthonyx*	L DP4/	D-1659	442
USGS 12978	USNM Drawer 237	*Esthonyx*	L m/2	D-1629	445
USNM 523686	USNM Drawer 237	*Esthonyx*	L DP3/-M1/, R DP4/-M1/	Y-227	457
USGS 22755	USNM Drawer 238	*Esthonyx*	L p/4-m/2	D-1727	478
USGS 4255	USNM Drawer 238	*Esthonyx*	L P4/	D-1162	481
USGS 1556	USNM Drawer 238	*Esthonyx*	L M1/	D-1166	481
USNM 540172	JHU Cabinet	*Esthonyx*	R p/3-p/4, m/3, L P3/-M1/, canine and max frag. Assoc.	D-1316	481
USGS 4250	USNM Drawer 238	*Esthonyx*	L m/3	D-1312	483
USGS 8205	USNM Drawer 239	*Esthonyx*	L P3/-M3/	D-1338N	491

USGS 8567	USNM Drawer 239	*Esthonyx*		R p/4-m/1, L p/2, p/4, m/2-m/3	Y-55	501
USGS 12955	USNM Drawer 239	*Esthonyx*		R m/2	D-1625	516
USGS 12964	USNM Drawer 240	*Esthonyx*		unnumbered jaw, R dp/4-m/1	D-1583	551

USGS 8543	USNM Drawer 239	*Esthonyx*		R DP3/-DP4/	Y-39	580
USNM 712657-D	USNM Drawer 235	*Esthonyx*		L dp/4?	D-1967	357
USNM PAL 768820	USNM Drawer 235	*Esthonyx*		R P4/-M1/	D-1635	370
USNM 523695	USNM Drawer 238	*Esthonyx*		R dp/2-m/1	D-1160	470
USNM 495174	USNM Drawer 235	*Esthonyx*	sp. Cf. *E. bisulcatus*	R p/4-m/1	D-1388	360
USNM 523655	USNM Drawer 234	*Esthonyx*	*spatularius*	L dp/4-m/1	Y-206	140
USNM 523657	USNM Drawer 234	*Esthonyx*	*spatularius*	L m/1, and assoc.	D-1633	149
USGS 4222	USNM Drawer 234	*Esthonyx*	*spatularius*	L m/1-m/2.	D-1389	264
USNM PAL 768815	USNM Drawer 234	*Esthonyx*	*spatularius*	R P4/-M2/, L P4/-M1/, R p/3-p/4	Y-157	332
USNM PAL 768814	USNM Drawer 234	*Esthonyx*	*spatularius*	R p/4 and m/3, Upper L P3/, M2/ (M1/ and M3/), R P4/-M2/, M3/ and P3/.	D-1373	337
USGS 26160	USNM Drawer 234	*Esthonyx*	*spatularius*	L m/1	V-73037	61

USNM 545176	JHU Cabinet	*Esthonyx*	*spatularius*	L dp/3-dp/4-m/1	D-1243	348
USGS 26088	USNM Drawer 236	*Esthonyx*	*spatularius*	R m/1-m/3	D-1866	423
EPV.92923	R17 220 L40	Esthonyx	*spatularius*	man, left p4-part of m2	UW-25	24
USGS 19338	USNM Drawer 234	*Esthonyx*	*spatularius*	R m/1	V-73027	30
USGS 8323	USNM Drawer 234	*Esthonyx*	*spatularius*	L m/3	73034	34
USGS 26159	USNM Drawer 234	*Esthonyx*	*spatularius*	L m/1	V-73037	61

USNM Cat. No. 490643	JHU Cabinet	*Esthonyx*	*spatularius*	L p/3- m/3, R m/1-m/3, Postcran	Y-119	100
USNM 523656	USNM Drawer 234	*Esthonyx*	*spatularius*	R M1/	D-1633	149
USGS 7093	USNM Drawer 234	*Esthonyx*	*spatularius*	Ussoc! R m/2, L. p/4?	Y-290	210
USNM 523663	USNM Drawer 234	*Esthonyx*	*spatularius*	L p/4, R m/2	Y-351	240
USGS 7246	USNM Drawer 234	*Esthonyx*	*spatularius*	L M2/-M3/	Y-351	240
USNM 523665	USNM Drawer 234	*Esthonyx*	*spatularius*	L dp/3-dp/4, R dp/4, and L erupting p/2?	WW-55	250
USNM 523666	USNM Drawer 234	*Esthonyx*	*spatularius*	L m/2 and m/3	D-1389	264
USGS 4205	USNM Drawer 234	*Esthonyx*	*spatularius*	R p/3, m/1-m/3	D-389	264

USNM 523669	USNM Drawer 234	*Esthonyx*	*spatularius*	R p/4	Y-294	270
USGS 26996	USNM Drawer 234	*Esthonyx*	*spatularius*	R. m/1	Y-296L	290
USGS 12962	USNM Drawer 234	*Esthonyx*	*spatularius*	L m/1	Y-350	290
USNM PAL 768818	USNM Drawer 234	*Esthonyx*	*spatularius*	R m/1-m/3, L m/2	D-1441	296
USGS 26875	USNM Drawer 234	*Esthonyx*	*spatularius*	L p/3-m/1	D-1880	310
USNM 523672	USNM Drawer 234	*Esthonyx*	*spatularius*	R M2/-M3/, R P3/	D-1880	310
USNM 523674	USNM Drawer 234	*Esthonyx*	*spatularius*	R m/1, L dp/4, L m/3, L p/4 (ussoc.)	Y-156	310
USGS 10228	USNM Drawer 234	*Esthonyx*	*spatularius*	L p/2, m/2, L M1/, R m/1	D-1577	311
USGS 1866	USNM Drawer 234	*Esthonyx*	*spatularius*	R p/3-m/1	D-1202	324
USGS 1872	USNM Drawer 234	*Esthonyx*	*spatularius*	R M2/	D-1202	324
USGS 4215	USNM Drawer 234	*Esthonyx*	*spatularius*	R m/2	Y-157	332
USGS 4286	USNM Drawer 234	*Esthonyx*	*spatularius*	R M3/	D-1335	341
USGS 4285	USNM Drawer 234	*Esthonyx*	*spatularius*	L m/3	D-1335	341
USGS 4271	USNM Drawer 234	*Esthonyx*	*spatularius*	R m/2	D-1289	342
USGS 1726	USNM Drawer 235	*Esthonyx*	*spatularius*	L P4/-M1/, L p/4	D-1243	348

USGS 8913	USNM Drawer 235	*Esthonyx*	*spatularius*	L P4/-M3/	D-1415	354
USGS 4278	USNM Drawer 235	*Esthonyx*	*spatularius*	R M3/	D-1391	356
USNM 523676	USNM Drawer 235	*Esthonyx*	*spatularius*	R M3/	D-1924	357
USGS 27044	USNM Drawer 235	*Esthonyx*	*spatularius*	R M1/-M2/, R m/3	D-1924	357
USGS 27147	USNM Drawer 235	*Esthonyx*	*spatularius*	R m/2-m/3	D-1967	357
USNM PAL 768824	USNM Drawer 235	*Esthonyx*	*spatularius*	L p/4-m/3, R c/1-m/3	Y-132	360
USGS 10452	USNM Drawer 235	*Esthonyx*	*spatularius*	R m/2-m/3	D-1303	360
USNM 523677	USNM Drawer 235	*Esthonyx*	*spatularius*	R m/2-m/3, R m/2, L M1/?	Y-149	360
USGS 4270	USNM Drawer 235	*Esthonyx*	*spatularius*	L m/3	D-1303	360
USGS 4223	USNM Drawer 235	*Esthonyx*	*spatularius*	R M2/-M3/	D-1251	378
USGS 4229	USNM Drawer 235	*Esthonyx*	*spatularius*	R M2/	D-1301	378
USNM PAL 768823	USNM Drawer 235	*Esthonyx*	*spatularius*	R m/3	D-1414	378
USGS 8725	USNM Drawer 235	*Esthonyx*	*spatularius*	R m/2, L m/3	D-1414	378
USGS 8011	USNM Drawer 235	*Esthonyx*	*spatularius*	L m/3 (m/2 is in jaw too, but really)	D-1242	379

USGS 13776	USNM Drawer 234	*Esthonyx*	*spatularius*	R m/3	D-1342	390
USNM PAL 768822	USNM Drawer 235	*Esthonyx*	*spatularius*	L p/3-m/2, R i/2-m/2, L P3/-P4/	Y-80	390
USNM 495497	USNM Drawer 235	*Esthonyx*	*spatularius*	L p/4	Y-421	390
USGS 10349	USNM Drawer 235	*Esthonyx*	*spatularius*	L M2/	D-1560	392
USGS 19375	USNM Drawer 235	*Esthonyx*	*spatularius*	R M1/ ?	D-1716	397
USGS 19376	USNM Drawer 235	*Esthonyx*	*spatularius*	L p/4,m/1, m/3, L m/2, L P4/	D-1716	397
USGS 7764	USNM Drawer 236	*Esthonyx*	*spatularius*	L m/1-m/2	D-1460	409
USGS 10449	USNM Drawer 236	*Esthonyx*	*spatularius*	L m/2	D-1460	409
USGS 22759	USNM Drawer 236	*Esthonyx*	*spatularius*	L p/4, R M2/-M3/	D-1454	409
USGS 7540	USNM Drawer 236	*Esthonyx*	*spatularius*	L m/2-m/3, Random m/1 (Not the same)	D-1454	409
USGS 9779	USNM Drawer 236	*Esthonyx*	*spatularius*	R p/4-m/3 (m/2)	D-1527	410
USGS 26912	USNM Drawer 236	*Esthonyx*	*spatularius*	R m/2	Y-324	420
USGS 27063	USNM Drawer 234	*Esthonyx*	*spatularius*	L m/2-m/3, R m/2-m3	V-73044	
DMNH 65275	CSU Lab	Esthonyx	*spatularius*	left ramus m1-m2	CSU 12	34
DMNH 65507	CSU Lab	Esthonyx	*spatularius*	assoc. teeth, I and ramus, right m1	CSU 24/ 5046	119
DMNH 68808	CSU Lab	Esthonyx	*spatularius*	Left Ramus dp4- m1	CSU 9	155
DMNH 65508	CSU Lab	Esthonyx	*spatularius*	right lower m1	CSU 31/5041 ?	177
EPV.91202	R17 220 L40	Esthonyx	*spatularius*	man, L m2-m3, R m1-m3, symphysis	USGS D-1952	400

DMNH 126240	CSU Lab	Esthonyx	*spatularius*	Left ramus, P4-M2, L up. M1, C/I	7379	*Missing
DMNH 65513	CSU Lab	Esthonyx		left lower p4	CSU 13/ 4975	46
DMNH 65271	CSU Lab	Esthonyx		right lower m1	CSU 1	65
DMNH 126593	CSU Lab	Esthonyx		right upper M3	CSU 59	127
DMNH 65270	CSU Lab	Esthonyx		Right Ramus,M1-M2 assoc. Roots	CSU 11	145
DMNH 65272	CSU Lab	Esthonyx		Left Maxilla M1-M2	CSU 11	145
DMNH 65276	CSU Lab	Esthonyx		Right Maxella, P4-M3	CSU 10	160
DMNH 126237	CSU Lab	Esthonyx		Left ramus, m1 (tal) and m2	4970	166
DMNH 68824	CSU Lab	Esthonyx		Left lower m1 or m2	CSU 8 /4970	166
DMNH 126651	CSU Lab	Esthonyx		right lower m1	CSU 8 /4970	166
DMNH 65418	CSU Lab	Esthonyx		left max molar	CSU 8 /4970	166
DMNH 68604	CSU Lab	Esthonyx		Right ramus m3	CSU 8	166
DMNH 68810	CSU Lab	Esthonyx		Left Ramus m3	CSU 8	166
DMNH 126483	CSU Lab	Esthonyx		Assoc. right lower m2 and m3	CSU 8/ 4970	166
DMNH 65274	CSU Lab	Esthonyx		right upper M1	CSU 2A/ 4963	174
DMNH 77270	CSU Lab	Esthonyx		Right upper P4	CSU 2A/ 4963	174
DMNH 126613	CSU Lab	Esthonyx		assoc. max teeth	CSU 76	179
DMNH 68603	CSU Lab	Esthonyx		left Maxilla P4-M3	CSU 2B	180
EPV.124575	R17 220 L40	Esthonyx		man, L and R m3, L mx trig	D-1461 high	180
DMNH 126862	CSU Lab	Esthonyx		right ramus M2-M3	CSU 120	185
DMNH 126859	CSU Lab	Esthonyx		Left lower m1	CSU 120	185
DMNH 65512	CSU Lab	Esthonyx		right lower m2	CSU 15/ 5037	190
DMNH 97544	CSU Lab	Esthonyx		left lower m2	CSU 39/ 5606	190
USNM 523660	USNM Drawer 234	*Esthonyx*		R M1/, L M2/, R m/1	Y-290	210
EPV.124427	R17 220 L40	Esthonyx		man, R m1 or m2, assoc. teeth	Y-386	230

DMNH 126589	CSU Lab	Esthonyx	right up. M1	CSU 61	237
USNM 523661	USNM Drawer 234	*Esthonyx*	L P4/ and assoc.	Y-351	240
EPV.92133	R17 220 L40	Esthonyx	tooth, R Upper I2 or C	Y-143	240
DMNH 77262-B	CSU Lab	Esthonyx	second right lower m1	CSU 62	246
DMNH 77515	CSU Lab	Esthonyx	left lower p4	CSU 62/ 6200	246
DMNH 68625	CSU Lab	Esthonyx	Left ramus m3	CSU 3/ 4965	251
EPV.124428	R17 220 L40	Esthonyx	man, left m2-m3	Y-286 low	270
EPV.92952	R17 220 L40	Esthonyx	Teeth, R m/2 and m/3	WW-220	270
USGS 19360	USNM Drawer 234	*Esthonyx*	R M3/, R m/2	Y-289	280
EPV.127186	CSU Lab	Esthonyx	R up. M1/ Lingual portion	19145	322
DMNH 126590	CSU Lab	Esthonyx	left up. C and M2	CSU 72	348
USNM 495165	USNM Drawer 235	*Esthonyx*	L m/2, R di/2*,L &R DP3/-DP4/	D-1334	360
ND -21-45	R17 240 L53	Esthonyx	assoc. teeth and bone Lp/3-Lm/3, RM2/	D-1387	360
ND -21-40	R17 240 L47	Esthonyx	tooth and jaw fragments	D-1387	360
USNM PAL 768819	USNM Drawer 235	*Esthonyx*	R C-M2/, L I2/-M3/	D-1340 (15m below)	364
ND -21-86	R17 240 L53	Esthonyx	Teeth, fragments	D-1293 white	376
EPV.91777	R17 220 L40	Esthonyx	man, L dp4-m1	D-1157	378
USNM PAL 768816-Lp/4	USNM Drawer 234	*Esthonyx*	2 L p/4, R p/4, and R m/1	D-1454	409
USNM PAL 768816-Lp/4	USNM Drawer 234	*Esthonyx*	2 L p/4, R p/4, and R m/1	D-1454	409
USNM PAL 768816-Rp/4	USNM Drawer 234	*Esthonyx*	2 L p/4, R p/4, and R m/1	D-1454	409

USNM 523626	USNM Drawer 236	*Esthonyx*	L m/3	D-1823	409
USNM PAL 768830-Smallwe	USNM Drawer 236	*Esthonyx*	R p/4 -m/1 trigonid	D-1454	409
USNM PAL 768826	USNM Drawer 236	*Esthonyx*	L m/1, m/3, R m/1, m/2, L M1/, P4/, P4/ (Small), L P3/-M1/, broken M3/, M3/ complete	D-1454	409
USNM PAL 768826-B	USNM Drawer 236	*Esthonyx*	L m/3	D-1454	409
USNM PAL 768826-D	USNM Drawer 236	*Esthonyx*	R m/2	D-1454	409
USNM PAL 768826-E	USNM Drawer 236	*Esthonyx*	L M1/	D-1454	409
USNM PAL 768826-F	USNM Drawer 236	*Esthonyx*	L P4/	D-1454	409
USNM PAL 768826-G	USNM Drawer 236	*Esthonyx*	L P4/ (Small)	D-1454	409
USNM PAL 768826-H	USNM Drawer 236	*Esthonyx*	R P3/-M1/	D-1454	409
USNM PAL 768826-I	USNM Drawer 236	*Esthonyx*	R broken M3/	D-1454	409
USNM PAL 768826-J	USNM Drawer 236	*Esthonyx*	R M3/ complete	D-1454	409
EPV.91670	R17 220 L40	Esthonyx	max, L P3-P4	D-1411 high	412
EPV.91644	R17 220 L40	Esthonyx	tooth, R m3	D-1411 low	412
EPV.91438	R17 220 L40	Esthonyx	Tooth, R M2/	WW-300	420
ND	R17 220 L5	Esthonyx	2 jaws with multiple teeth,	Y-320	423
EPV.91615	R17 220 L40	Esthonyx	tooth, R p4	D-1525	425
EPV.91685	R17 220 L40	Esthonyx	tooth, L Upper I1	D-1309	426
ND	R17 219 L23	Esthonyx	2 molars L m1 and R m2	D-1381	430

USNM PAL 768841	USNM Drawer 237	*Esthonyx*	L p/2-m/1, L P2/-P3/	D-1452	440
EPV.91603	R17 220 L40	Esthonyx	Man, R m/2-3	WW-314	440
EPV.91676	R17 220 L40	Esthonyx	man, max, assoc. teeth and bone frags	D-1204	441
EPV.91582	R17 220 L40	Esthonyx	man, L dp3-dp4	D-1204	441
USNM PAL 768834-m/3	USNM Drawer 237	*Esthonyx*	R m/3	D-1204	442
USNM PAL 768834-m/1	USNM Drawer 237	*Esthonyx*	L m/1	D-1204	442
DMNH 126557	CSU Lab	Esthonyx	left ramus m3	CSU 101	442
DMNH 126250	CSU Lab	Esthonyx	Assoc. right lower m2 and m3	4968	450
ND	R17 220 L5	Esthonyx	teeth, multiple inscisors, L P4/ and LM3/	D1536	450
USNM 523691	USNM Drawer 237	*Esthonyx*	L p/2, R m/2-m/3, assoc. up I	D-1833	463
USNM PAL 523692-B	USNM Drawer 237	*Esthonyx*	L m/3	*D-1881*	463
USNM 523689	USNM Drawer 237	*Esthonyx*	R dp/4, assoc.	D-1699	463
USNM PAL 768843	USNM Drawer 238	*Esthonyx*	L dp/4- m/1 in crypt, and R M?/ .	D-1777	465
USNM PAL 768858	USNM Drawer 240	*Esthonyx*	L p/3-m/3, R p/2-m/2	D-1662	470
EPV.127188	CSU Lab	Esthonyx	Maxilla, L P3-M3	8213	470
DMNH 126861	CSU Lab	Esthonyx	Tal. Of L m1	CSU 121	470
ND	R17 221 L53	Esthonyx	man, with roots and i. molars in box too, R p/4, Rm/1	Y-45	470
USGS 1022	USNM Drawer 238	*Esthonyx*	L&R m/2	D-1162	481
USGS 3585	USNM Drawer 238	*Esthonyx*	L M1/	D-1177	481

USGS 282	USNM Drawer 238	*Esthonyx*	L P3/-M2/	D-1177	481
ND -21-201	R17 240 L47	Esthonyx	R m1 in jaw, no other teeth	Y-42	481
ND	R17 219 L4	Esthonyx	Ugly bits and pieces, nice eurupting p/4 and m1	D1162	481
USNM PAL 768877	USNM Drawer 239	*Esthonyx*	R m/3	Y-47	489
EPV.91521	R17 220 L40	Esthonyx	Man, R m2-m3	D-1507	494
USGS 8718	USNM Drawer 239	*Esthonyx*	R M2/	D-1433	501
EPV.93024	R17 220 L40	Esthonyx	man, L p3-4, m2? Assoc?	D-1174	501
EPV.91986	R17 220 L40	Esthonyx	Teeth, L p/2, Lp/4, Incisor	WW-268	501
USNM 490595	USNM Drawer 239	*Esthonyx*	R p/3-m/2	Y-186	511
USNM PAL 768850	USNM Drawer 239	*Esthonyx*	R P3/-M2/, L P3/-M2/, assoc. dent	D-1534	536
??- Misslabled in Excel	USNM Drawer 240	*Esthonyx*	L m/2-m/3	Y-193	546
USNM 523701	USNM Drawer 240	*Esthonyx*	R M2/, L M1/	WW-41	551
EPV.92661	R17 220 L40	Esthonyx	teeth, assoc. I, L M2 or M3	D-1781	556
USGS 19371	USNM Drawer 239	*Esthonyx*	L m/3	Y-39	580
USGS 8542	USNM Drawer 239	*Esthonyx*	L p/4-m/1	Y-39	580
No Meter Levels					
EPV.91787	R17 220 L40	Esthonyx	tooth, R p4	D-1477	*Missing
EPV.91583	R17 220 L40	Esthonyx	man, max, R dp4-tal m1, R DP3-DP4	D-1525	*Missing
EPV.93060	R17 220 L40	Esthonyx	man, L dp3-dp4, m1-m2	D-1960N	*Missing

ND	R17 220 L5	Esthonyx	1 jaw teeth in matrix	WW-318	*Missing
ND	R17 240 R21	? Esthonyx	Ugly jaws	*Missing	*Missing
ND -21-71	R17 240 L47	Esthonyx	L p/4 and m/1	WW-27	*Missing
ND	R17 221 R49	Esthonyx	L m/1- part m/2, L m/3, R m/3, L P3/	WW-337	*Missing
EPV. 92665	R17 220 L40	Esthonyx	Teeth, fragments, L P3/ and LM3/	WW-152	*Missing
EPV.91514	R17 220 L40	Esthonyx	man, max, R p/4-m/1 trig, L M1/ trig	WW-187	*Missing
DMNH 126592	CSU Lab	Esthonyx	right up. M1	CSU 86	*Missing
DMNH 126860	CSU Lab	Esthonyx	Left lower p4	CSU 118	*Missing
DMNH 126858	CSU Lab	Esthonyx	Right Ramus, p4-M1, triganid of m2	CSU 118	*Missing
DMNH 126226	CSU Lab	Esthonyx	Left ramus m1 (talanid) and m2	7381	*Missing
DMNH 126235	CSU Lab	Esthonyx	Assoc. teeth and Bone	7376	*Missing
DMNH 127154	CSU Lab	Esthonyx	right lower m3	CSU 112/ 8212	*Missing
USNM 533411	JHU Cabinet	*Esthonyx*	R M1/-M2/	WW-127	
USNM 533517	JHU Cabinet	*Esthonyx*	L p/3-m/1, part m/2, and m/3	UW-27	
USNM 544818	JHU Cabinet	*Esthonyx*	R part of P4/, M1/-M3/	D-2059	