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IMPLICATIONS OF BODY-MASS ESTIMATES FOR DINOSAURS

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ABSTRACT—Body-mass estimates have been made for 220 of the over 300 generally accepted dinosaur genera. The 1–10 ton body-mass category is the modal one for all dinosaur genera, dinosaurs on nearly every continent, dinosaurs during most stages of the Mesozoic, and dinosaurs in two of the three peak historical periods of dinosaur discoveries. Carnivorous dinosaurs were much smaller than herbivores during the Late Jurassic and again in the Late Cretaceous: at other times the two were roughly equivalent in mass. In terms of discovery of dinosaur genera over time, there has been a simultaneous increase in proportion of very small (under 10 kg) dinosaurs and a relative decline in giant dinosaurs (10–100 tons). This suggests that early researchers tended to collect giant dinosaurs.

INTRODUCTION

Despite the existence of small dinosaurs (see Callison and Quimby, 1984), the dinosaurs' general large size has caused them to capture both the public and scientists' imagination. The purpose of this work is to analyze the entire dinosaur fossil record with respect to body masses.

There has been much research in recent years on the biology of body size (Calder, 1984; Schmidt-Nielsen, 1984). Size is important in the study of reproductive rates, speed of movement, distance travelled, etc., to say nothing of anatomy, physiology, and ecology (Wing and Sues, 1992). Body-mass estimates for many dinosaur genera are useful for paleoecological studies of dinosaur populations, such as those done by Farlow (1976) and Beland and Russell (1979).

Sixteen papers have been published, between 1905 and 1986, regarding the determination of dinosaur body mass (for a bibliographical listing, see Chure and McIntosh, 1989:216). Among early works, Colbert's (1962) is the most comprehensive. He provided body-mass estimates for 14 well-known dinosaur genera. Since his study, a number of authors (e.g., Bakker, 1980) have followed his lead, using volumetric displacement of scale models to calculate body masses. Hotton (1980) showed the distribution of over 50 unspecified dinosaur genera in terms of body mass. It was based on comparative allometric relationships (cubic scaling of body length, etc.) with the specimens upon which Colbert's (1962) scale models had been based.

The purpose of this work is to: 1) provide a compendium of masses (see Appendix) for as many valid dinosaurian genera as possible using only reliable methods (see below), 2) determine whether the body-mass clustering of genera in dinosaurian taxa resembles that of modern mammals, 3) compare and contrast the body-mass distribution of dinosaurian genera with that of mammals, 4) reexamine the biogeographic and temporal distribution of dinosaurian genera in the light of body masses, 5) compare and contrast the body-mass distribution of carnivorous and herbivorous dinosaurs, 6) compare and contrast the dates of discovery of small and large dinosaurs.

Because the rate at which dinosaurian genera are described (6 per year on average: Dodson and Dawson, 1991) is so great, a work like this is out of date before it is published. It is current as of the compilation by Weishampel et al. (1992), with the addition of the following more recently described genera: *Andesaurus* (Calvo and Bonaparte, 1991), *Amargasaurus* (Salgado and Bonaparte, 1991), *Dyslocosaurus* (McIntosh et al, 1992), *Eoraptor* (Sereno et al., 1993), and *Utahraptor* (Kirkland et al., 1993).

METHODS

Almost every skeletal feature in linear dimension correlates positively with body mass. However, an accurate estimate of body mass can only be made through the use of skeletal features that have been tested and found to have a close allometric relationship between some linear variable and body mass.

Anderson et al. (1985) have shown that there is an unexpectedly close correlation between femoral and/or humeral circumference and body mass for land vertebrates. This correlation is quite independent of the magnitude of body mass, lower-level taxonomy, or thermal physiology. A separate regression is necessary for bipeds and quadrupeds, and both were used by Anderson et al. (1985) to estimate the body masses of several dinosaurian genera. Inasmuch as limb-bone circumference is directly related to the bearing of body mass whereas pelvic height of scale models (e.g., Colbert, 1962) is only incidentally related to mass, mid-shaft limb-bone circumference is probably the most accurate method available for estimating the body masses of extinct tetrapods.

Whenever limb bones were known from skeletal material of a given genus of dinosaur, I measured, from the cited literature, the diameter of the mid-shaft of the femur and/or humerus from various longitudinal perspectives. After averaging the values, I multiplied it by pi in order to convert it into circumference, and then used the regressions in Anderson et al. (1985) to estimate the body masses of the specimen of the genus. Because body mass estimates differ significantly when different methods are used on even the same specimen (Anderson et al., 1985), I did not quote specific values for body mass but placed genera into order-of-magnitude categories (e.g., 1–10 kg, 10–100 kg, 100 kg–1 ton), each of which I subdivided into thirds (e.g., 1–4 tons, 4–7 tons, and 7–10 tons for the 1–10 ton category).

If a body mass estimate had been made for a given genus by a previous researcher (e.g., Colbert, 1962; Bakker, 1980), I incorporated it into the database and marked it with an asterisk (*). Whenever I used pelvic heights for my own body mass estimates, I used the reference models in Colbert (1962), but calibrated them according to the Anderson et. al. (1985) data (which had suggested that several of the Colbert models had been too ponderous). In a few cases in the compendium (i.e., Giffin, 1989), I used cranial capacity (Jerison, 1973) to estimate body mass for dinosaurs that have no known postcranial remains. While this cannot, of course, be used for precise body-mass estimates, it can be used to place genera into different order-of-magnitude body-mass categories.

Disappointingly, many putatively valid genera are based on fragmentary remains. In such cases body-mass estimates were not attempted unless enough of the skeleton is known for the cited author to have made an estimate of the dinosaur's size. From this, a pelvic height (and hence a body mass) was estimated. Again, this cannot be very accurate, but it is suitable for placing genera into body-mass categories.

There is a large range of body masses for adult (i.e., sexually mature) members of a given dinosaurian genus, particularly if dinosaurs grew indeterminately as do modern reptiles. This is another reason why body-mass estimates were expressed as body mass categories and not specific values of body mass. The placing of a dinosaur genus in a given mass category means that most adult members of the genus fitted in that category and does not imply that all did, nor that adult members of the genus actually ranged in mass through all the values of the category.

Measurements from specimens identified as juveniles were not used in the database except in rare cases (and then labeled as such) when the only known usable specimen of a genus was a juvenile (i.e., *Mussaurus* and three other genera). These were included in the database for the sake of completeness but were not, of course, included in any of the histograms or calculations in this work.

The variation in adult body mass among congeneric dinosaurian individuals is significant. However, where there is a large range of sizes for a given genus in a collection (Dodson et al., 1980; Russell and McIntosh, 1980), the modal value tends to be near the maximum value. For this reason, whenever there was a range of values for body mass available for a genus, I used the largest value. However, in most cases, the values in the database are necessarily based on a single specimen, as nearly half of all dinosaur genera are known from only one specimen (Dodson, 1990).

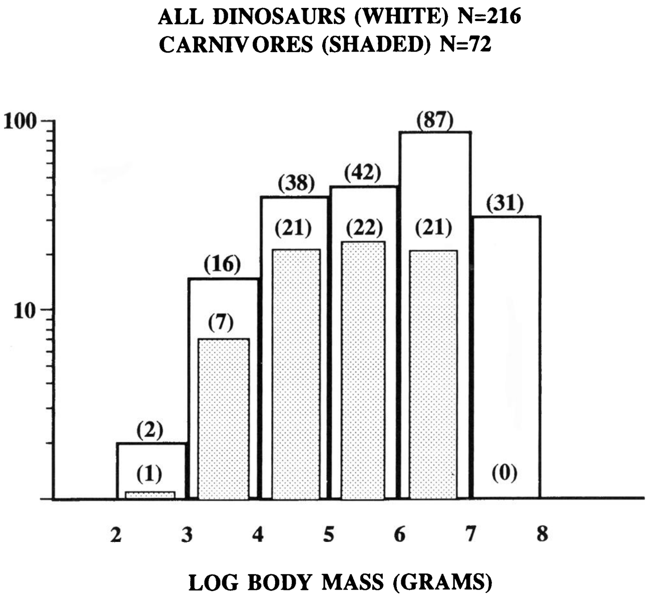

FIGURE 1. Weight-category distribution of all 216 adult dinosaur genera in the compendium (Appendix), and all 72 carnivore genera of same.

Once the data (genera) were assembled, the database was expressed as a histogram (Fig. 1), with numbers included above the bars of the histogram. Next, the database was divided into geographic areas (Fig. 2), and then subject to an analysis according to the three historical periods of greatest dinosaur diversity (Fig. 3). This was followed by a stage-by-stage analysis (Fig. 4) with very brief stages combined together with longer stages (as in Dodson, 1990). In order to determine if there have been any obvious mass-related biases of dinosaur collection over time, the three peak historical periods of dinosaur description (Dodson and Dawson, 1991) were each expressed in terms of the body masses of the dinosaurs discovered (Fig. 5). For the biogeographic analysis (Fig. 2), Australia and Antarctica were omitted because of the paucity of their dinosaurian remains. For the carnivore/herbivore analysis, only the staurikosaurids, herrerasaurids, and theropods were accepted as carnivorous. For the stage-by-stage analysis (Fig. 4), the 100 g–1 kg category was omitted because only two adult dinosaur genera occur in that category.

ANALYSIS

The database (Appendix) reveals that dinosaurs ranged in mass over six orders of magnitude, with the

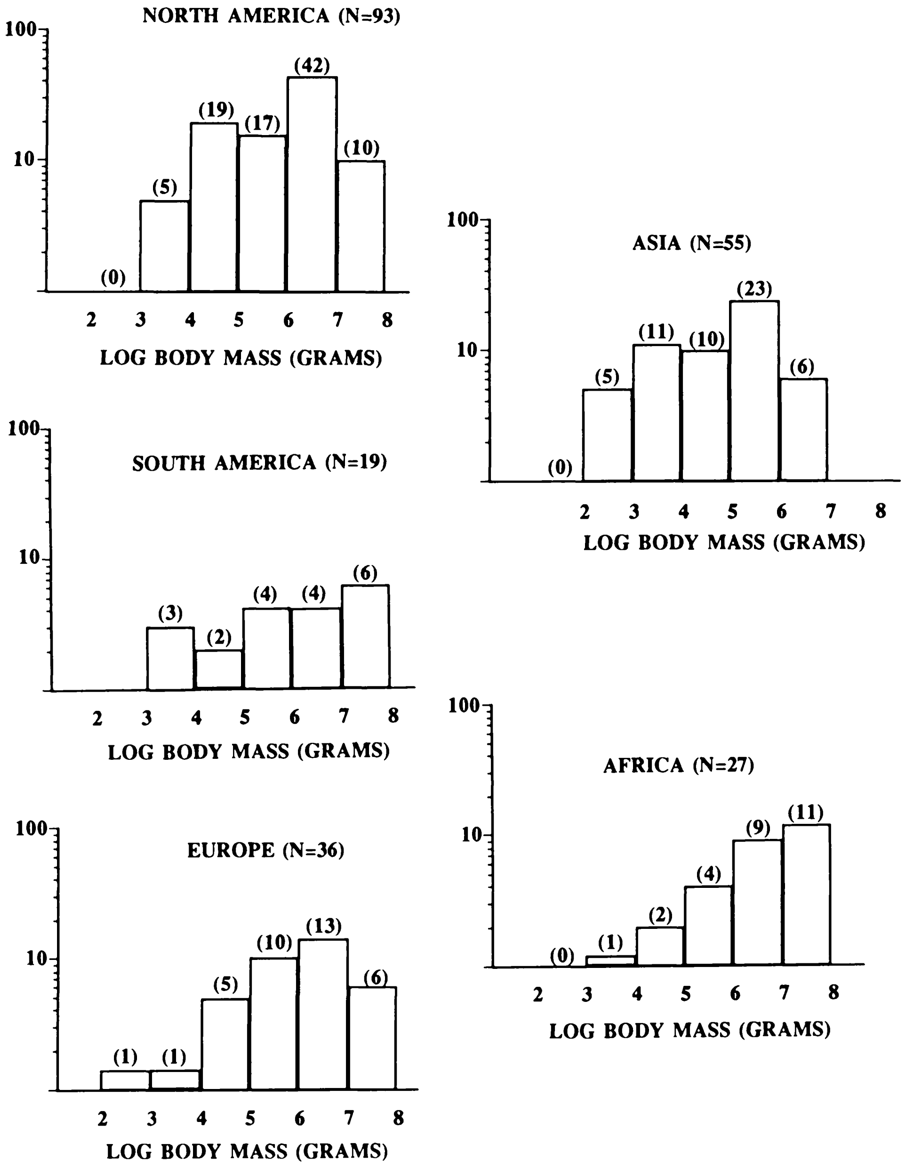

FIGURE 2. The biogeographic distribution of dinosaurs sorted by body weight.

1–10 ton category being the modal weight range for dinosaurs. The distribution of the 216 adult dinosaur genera by body mass (Fig. 1) is similar to that of the 50 unspecified genera in Hotton (1980). This suggests that the relative number of genera in body mass categories is well established for dinosaurs and will not change substantially as a result of future discoveries.

Dinosaurs show a different relationship of body mass versus taxonomy than do mammals. Among mammalian orders, 51% of genera, on average, fall in the modal body-mass category of each order, with a range from 34% to 62% (Peczkis, 1988). To compare this with dinosaurs, I used dinosaur suborders (because there are only 2 commonly-recognized dinosaur orders). The modal body-mass category (in terms of percentages of total genera) varies greatly by suborder: 31% (Theropoda), 53% (Ceratopsia), 58% (Sauropodomorpha), 58% (Ornithopoda), 78% (Pachycephalosauria), 79% (Ankylosauria), and 100% (Stegosauria). Although the order is more inclusive than the suborder, it is the dinosaurian suborders that are more heterogenous in terms of body mass than are mammalian orders. It thus appears that dinosaurs were less conservative in terms of evolution of a variety of body masses per equivalent taxon, than were mammals.

The modal body-mass category for modern mammals is 10–100 g (Hotton, 1980), whereas that of therapsids was 1–10 kg (Peczkis, unpubl. data). By contrast, only a small percentage of dinosaur genera were under 10 kg (Fig. 1). At the same time, only a minority of dinosaurs were in the giant (10–100 ton) range, meaning that most dinosaurs were no heavier than a large modern elephant.

Dinosaurs do not appear to show any great differences in terms of body mass relative to biogeography (Fig. 2). Except for Africa and South America (and then barely), the 1–10 ton category is the modal category for dinosaur genera on all continents. Africa has a larger fraction (nearly half) of its dinosaurs being giant (10–100 tons) than any other continent. However, the significance of this is uncertain, as the sample is small and Africa has not been well explored for dinosaurs. A clue to this distribution is the fact that 12 of the 27 African dinosaur genera (Fig. 2e) are Jurassic, a time of high sauropod diversity (see below).

The dinosaurs were very unevenly distributed during Mesozoic time, with most known genera appearing during three small intervals of the Mesozoic (Dodson, 1990). The first peak of diversity was the Norian-Sinemurian interval (Fig. 3a), followed by a larger peak during the Kimmeridgian-Tithonian (Fig. 3b), and finally by the largest peak in the Campanian-Maastrichtian (Fig. 3c). The first peak (Fig. 3a) was relatively homogenous in terms of numbers of genera in the various body mass categories. The second peak (Fig. 3b) was characterized by the dominance of large sauropods (10–100 tons), whereas the final peak (Fig. 3c) was marked by the overwhelming dominance of genera of the 1–10 ton category, especially herbivores. The significance of the disparity between large herbivores and carnivores is discussed below.

Since most dinosaurian genera existed for only one Mesozoic stage (Dodson, 1990), the foregoing analysis (Fig. 3a–c) involves the amalgamation of genera not all of which were contemporaries of each other. For this reason, the entire Mesozoic was subject to a stage-by-stage analysis (Fig. 4) in order to show the number of herbivorous and carnivorous genera, relative to body mass, in existence during each stage.

As a result, several trends can be seen. During all but a few of the Mesozoic stages, dinosaurs in the 1–10 ton category were the most numerous (Fig. 4). The larger sauropods (10–100 tons) were rare in the earliest stages of dinosaur evolution, peaked in the Late Jurassic, and then had a smaller peak in the Late Cretaceous (when dinosaurs peaked as a whole). Very small dinosaurs (1–10 kg) appeared infrequently and without any obvious trend throughout the Mesozoic. Dinosaurs in the 100 kg–1 ton and 1–10 ton categories appear closely to reflect overall dinosaur diversity trends throughout the Mesozoic. But since these two categories comprise the majority of dinosaur genera, they determine the diversity trend for all dinosaurs.

Carnivores comprise a greater fraction of dinosaurs in the 10–100 kg and 100 kg–1 ton categories than in any other. In fact, three-fourths of all carnivore genera were under 1 ton. This demonstrates that carnivores as a whole were significantly smaller than herbivores. However, there appear to be different evolutionary ten-

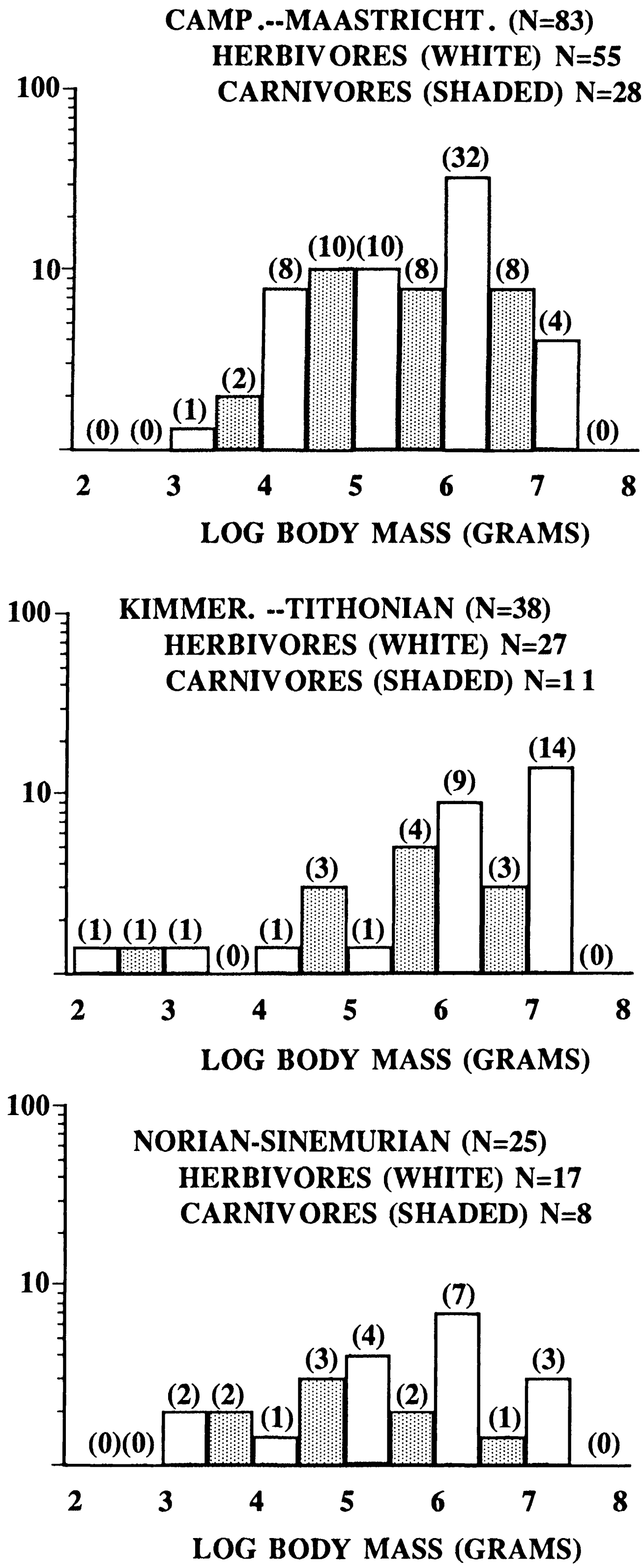

FIGURE 3. The body-weight distribution of dinosaur genera during the three greatest periods of dinosaur diversity in the Mesozoic.

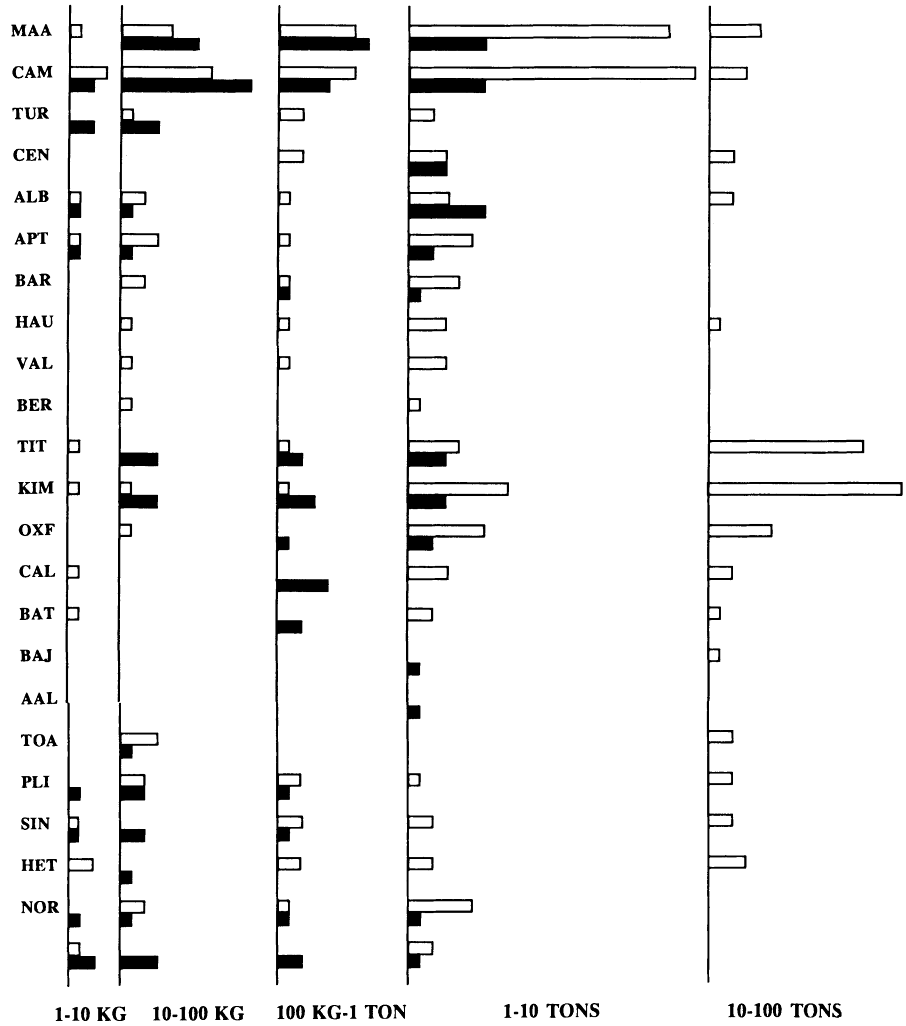

FIGURE 4. Body-weight categories of dinosaur herbivores (white bars) and carnivores (black bars) during stages of the Mesozoic.

dencies, with regards to this, in the Mesozoic (Fig. 4). In the Late Triassic and Early Jurassic, there appears to be a rough equivalence in size between herbivores and carnivores. In the Late Jurassic, carnivores are markedly smaller than herbivores, especially because of the large numbers of giant sauropods. In the Early Cretaceous, carnivores and herbivores are once again roughly equivalent in mass. Finally, in the Late Cretaceous, carnivores are again significantly smaller than herbivores, though the disparity was not as extreme as in the Late Jurassic.

Carnivores are absent in the 10–100 ton category (Fig. 1). This suggests that the giant size of sauropods was an evolutionary strategy to avoid predation. If so, it is analogous to modern mammals. The largest land mammals alive today (rhinoceri, hippopotami, and elephants) are herbivores with no comparatively-sized carnivores in existence. These large mammals, at least when adult, are almost never attacked by predators (Schaller, 1972). The largest known therapsids were also entirely herbivorous for possibly the same evolutionary reasons (Peczkis, unpubl. data).

Dodson and Dawson (1991) have pointed out that there are three historical periods when dinosaur genera were discovered at greater rates than at any other time. They are: 1870–1900, 1900–1940, and 1970–present. The analysis of the body masses of dinosaurs discovered during these three historical periods (Fig. 5) show several trends. The 1–10 ton category is overwhelmingly dominant in the two most recent periods of dinosaur discovery, thus following the previously-discussed tendencies for this category to dominate. Very small dinosaurs (under 10 kg) increase from none in the first period, to 6% in the middle period, and amount to 17% of the dinosaur genera named during the most recent (i.e., current) period. Giant sauropods (10–100 tons) show nearly the opposite trend. They account for 36% of the genera in the earliest period of discovery,

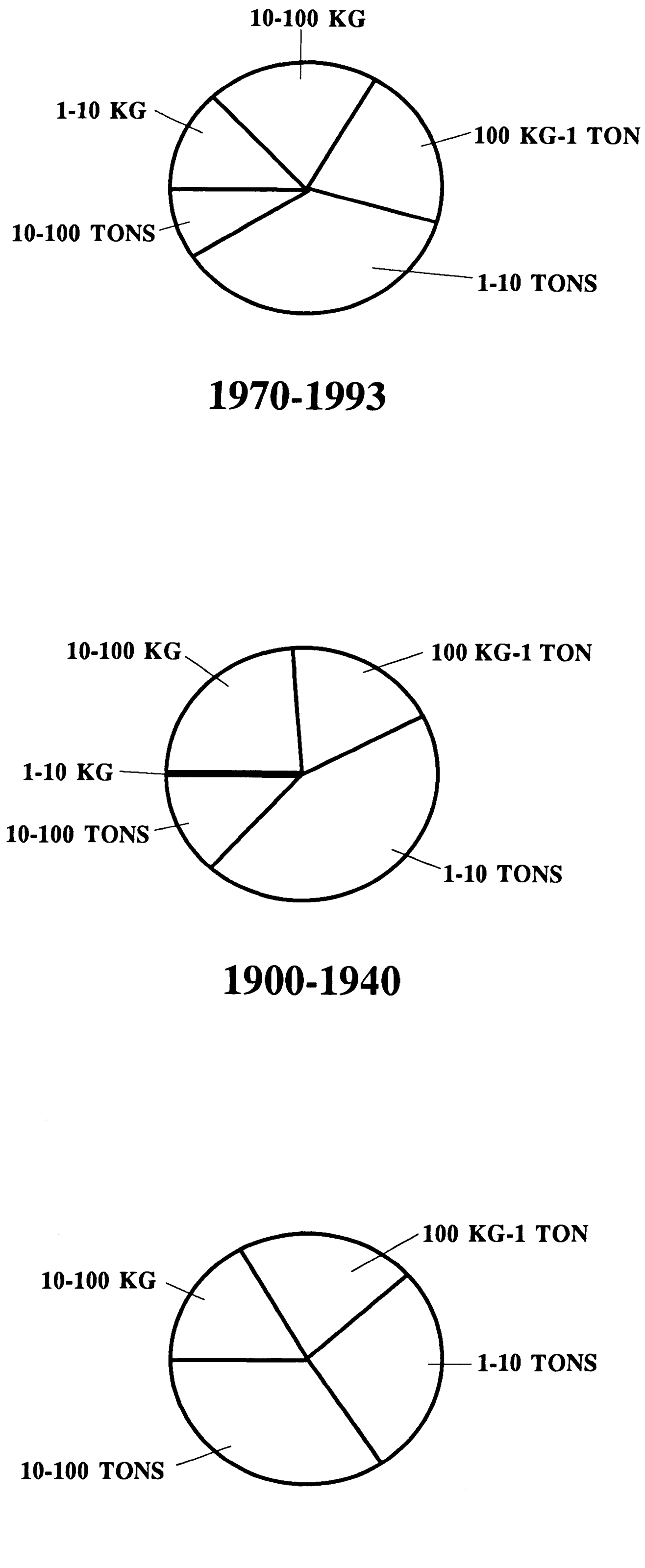

FIGURE 5. Body-weight categories of dinosaurs discovered during the three historical periods of maximal dinosaur-searching activity.

decline to 12% during the second period, and are 14% of the current period. These trends may indicate that early dinosaur researchers were more likely to collect giant dinosaurs, perhaps because museums sought large dinosaur specimens for display.

It can be concluded that dinosaurs repeatedly evolved to a large range of sizes. and exploited a variety of niches. The human factor in dinosaur exploration (Dodson and Dawson, 1991) has also found an expression in the sizes of dinosaurs that have been found over time.

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APPENDIX

Body weight categories of all dinosaur genera known from sufficient skeletal material for a body mass estimate. Abbreviations are as follows: body mass categories calculated from: M = scale model, P = pelvic height determination, F = femur diameter, f = femur length, H = humerus diameter, E = endocast volume. The asterisk (*) denotes body mass already estimated by cited author; all others are my estimates using the indicated information from the cited author(s). For the convenience of the reader, the genera are listed in the same order as they appear in Weishampel et al. (1992).

Genus	Higher taxon	Method	Weight	Reference
Staurikosaurus	Staurikosauridae	F	10–40 kg	Galton, 1977a
Herrerasaurus	Herrerasauridae	F	100–400 kg	Galton, 1977a
Ischisaurus	Herrerasauridae	F	40–70 kg	Reig, 1963
Aliwalia	(Dinosauria)	F	1–4 tons	Galton, 1985a
Ceratosaurus	(Ceratosauria)	F(*)	400–700 kg	Anderson et al., 1985
Sarcosaurus	(Ceratosauria)	F	40–70 kg	Huene, 1932
Segisaurus	(Ceratosauria)	P	4–7 kg	Callison, 1987
Dilophosaurus	(Ceratosauria)	F, P	100–400 kg	Welles, 1984
Liliensternus	(Ceratosauria)	F	100–400 kg	Huene, 1934
Coelophysis	(Ceratosauria)	F	10–40 kg	Raath, 1990
Syntarsus	(Ceratosauria)	F	10–40 kg	Raath, 1990
Acrocantosaurus	Allosauridae	F	1–4 tons	Stovall and Langston, 1950
Allosaurus	Allosauridae	F(*)	1–4 tons	Anderson et al., 1985
Chilantaisaurus	Allosauridae	F	1–4 tons	Hu, 1964
Piatnitzkysaurus	Allosauridae	F	100–400 kg	Bonaparte, 1984
Szechuanosaurus	Allosauridae	F	7–10 tons	Dong et al., 1983
Albertosaurus	Tyrannosauridae	M(*)	1–4 tons	Bakker, 1980
Alectrosaurus	Tyrannosauridae	P	0.7–1 ton	Brett-Surman, 1980
Daspletosaurus	Tyrannosauridae	F	7–10 tons	Russell, 1970
Nanotyrannus	Tyrannosauridae	P	400–700 kg	Bakker et al., 1988
Tarbosaurus	Tyrannosauridae	F, P	1–4 tons	Maleev, 1974
Tyrannosaurus	Tyrannosauridae	F(*)	4–7 tons	Anderson et al., 1985
Bahariasaurus	(Carnosauria)	F	1–4 tons	Stromer, 1934
Aublysodon	(Carnosauria)	F	1–4 tons	Lehman and Carpenter, 1990
Eustreptospondylus	(Carnosauria)	H	100–400 kg	Galton, 1982
Gasosaurus	(Carnosauria)	F	100–400 kg	Dong and Tang, 1985
Labocania	(Carnosauria)	P	1–4 tons	Molnar, 1974
Magnasaurus	(Carnosauria)	F	1–4 tons	Huene, 1926b
Megalosaurus	(Carnosauria)	H	1–4 tons	Galton and Jensen, 1979
Spinosaurus	(Carnosauria)	F	1–4 tons	Stromer, 1934
Stokesosaurus	(Carnosauria)	F	70–100 kg	Dodson et al., 1980
Yangchuanosaurus	(Carnosauria)	F	1–4 tons	Dong et al., 1983
Ornithomimus	Ornithomimidae	F, P	100–400 kg	Russell, 1972
Struthiomimus	Ornithomimidae	F(*)	100–400 kg	Anderson et al., 1985
Dromiceiomimus	Ornithomimidae	M(*)	100–400 kg	Russell and Beland, 1976
Archaeornithomimus	Ornithomimidae	P	40–70 kg	Brett-Surman, 1980
Gallimimus	Ornithomimidae	F	10–40 kg	Osmolska et al., 1972
Elaphrosaurus	(Ornithomimosauria)	F	100–400 kg	Janensch, 1925
Chirostenotes	Elmisauridae	F	40–70 kg	Currie and Russell, 1988
Oviraptor	Oviraptoridae	P	10–40 kg	Dodson, 1983
Ingenia	Oviraptoridae	F	40–70 kg	Barsbold et al., 1992
Caenagnathus	Caenagnathidae	P	10–40 kg	Dodson, 1983
Troodon	Troodontidae	P	10–40 kg	Osborn, 1924
Saurnithoides	Troodontidae	P	40–70 kg	Dodson, 1983
Deinonychus	Dromaeosauridae	F, P	70–100 kg	Ostrom, 1976
Dromaeosaurus	Dromaeosauridae	P	40–70 kg	Dodson, 1983
Saurornitholestes	Dromaeosauridae	P	10–40 kg	Dodson, 1983
Utahraptor	Dromaeosauridae	P	0.7–1 ton	Kirkland et al., 1993
Velociraptor	Dromaeosauridae	F	40–70 kg	Ostrom, 1969
Avimimus	(Theropoda)	P	1–4 kg	Callison, 1987
Coelurus	(Theropoda)	f(*)	10–40 kg	Dodson et al., 1980
Compsognathus	(Theropoda)	P(*)	400–700 kg	Callison, 1987
Deinocheirus	(Theropoda)	H	7–10 tons	Osmolska and Roniewicz, 1970
Ornitholestes	(Theropoda)	F, P	10–40 kg	Huene, 1932
Alvarezsaurus	(Theropoda)	F	4–7 kg	Bonaparte, 1991
Eoraptor	(Theropoda)	P	7–10 kg	Sereno et al., 1993

APPENDIX

Continued.

Genus	Higher taxon	Method	Weight	Reference
Microvenator	(Theropoda)	F	1–4 kg	Ostrom, 1970
Podokesaurus	(Theropoda)	P	10–40 kg	Huene, 1932
Walkeria	(Theropoda)	F	1–4 kg	Chatterjee, 1987
Baryonyx	(Theropoda)	H	1–4 tons	Charig and Milner, 1986
Carnotosaurus	(Theropoda)	F, P	1–4 tons	Bonaparte et al., 1990
Dryptosaurus	(Theropoda)	F	1–4 tons	Marsh, 1877
Erectopus	(Theropoda)	P	1–4 tons	Huene, 1923
Frenguellosaurus	(Theropoda)	F	100–400 kg	Brinkman and Sues, 1987
Indosaurus	(Theropoda)	F	400–700 kg	Huene and Matley, 1933; Chatterjee, 1978
Indosuchus	(Theropoda)	F	0.7–1 ton	Huene and Matley, 1933; Chatterjee, 1978
Marshosaurus	(Theropoda)	f	100–400 kg	Dodson et al., 1980
Metriacanthosaurus	(Theropoda)	F	0.7–1 ton	Huene, 1926a, b; Walker, 1964
Shanshanosaurus	(Theropoda)	F	100–400 kg	Dong, 1977
Tarascosaurus	(Theropoda)	F	7–10 kg	LeLoeuff and Buffetaut, 1991
Xenotarsosaurus	(Theropoda)	F	0.7–1 ton	Martinez et al., 1986
Xuanhanosaurus	(Theropoda)	P	0.7–1 ton	Dong, 1984b
Thecodontosaurus	Thecondosauridae	F, P	70–100 kg	Huene, 1932
Anchisaurus	Anchisauridae	F, P	10–40 kg	Galton and Cluver, 1976
Massospondylus	Massospondylidae	F, P	100–400 kg	Galton and Cluver, 1976
Yunnanosaurus	Yunnanosauridae	F	0.7–1 ton	Young, 1942
Ammosaurus	Plateosauridae	F, P	10–40 kg	Galton, 1971
Mussaurus (juv.)	Plateosauridae	F, H	100–400 g	Bonaparte and Vince, 1979
Plateosaurus	Plateosauridae	F	1–4 tons	Huene, 1932
Sellosaurus	Plateosauridae	F, P	100–400 kg	Galton and Cluver, 1976
Camelotia	Melanorosauridae	F	1–4 tons	Galton, 1985c
Euskelosaurus	Melanorosauridae	F	1–4 tons	Cooper, 1989
Lufengosaurus	Melanorosauridae	F	1–4 tons	Young, 1947
Melanorosaurus	Melanorosauridae	F	1–4 tons	Galton, 1985c
Riojasaurus	Melanorosauridae	F	1–4 tons	Galton, 1985c
Vulcanodon	Vulcanodontidae	F	10–40 tons	Cooper, 1984
Barapasaurus	Vulcanodontidae	F	10–40 tons	Jain et al., 1979
Kotasaurus	Vulcanodontidae	F	10–40 tons	Yadagiri, 1988
Cetiosaurus	Cetiosauridae	F, P	10–40 tons	Huene, 1932
Bellusaurus (juv.)	Vulcanodontidae	F	4–7 tons	Dong, 1990a
Haplocanthosaurus	Cetiosauridae	F	10–40 tons	Hatcher, 1903
Patagosaurus	Cetiosauridae	P	10–40 tons	Bonaparte, 1979
Shunosaurus	Cetiosauridae	F, P	7–10 tons	Dong and Tang, 1984
Omeisaurus	Cetiosauridae	F, P	10–40 tons	Dong et al., 1989
Brachiosaurus	Brachiosauridae	F, H(*)	10–40 tons	Anderson et al., 1985
Bothriospondylus	Brachiosauridae	F	40–70 tons	Lapparent, 1943
Pelorosaurus	Brachiosauridae	H	7–10 tons	Mantell, 1850
Pleurocoelus	Brachiosauridae	F	7–10 tons	Lapparent and Zbyszewski, 1957
Ultrasauros	Brachiosauridae	P	40–70 tons	Jensen, 1987
Chubutisaurus	Brachiosauridae	F, H	10–40 tons	Corro, 1975
Ischyrosaurus	Brachiosauridae	H	10–40 tons	Hulke, 1874
Camarasaurus	Camarasauridae	M(*)	10–40 tons	Bakker, 1980
Euhelopus	Camarasauridae	F, P	7–10 tons	Wiman, 1929
Tienshanosaurus	Camarasauridae	F	7–10 tons	Young, 1937
Opisthocoelicauda	Camarasauridae	F, H(*)	10–40 tons	Anderson et al., 1985
Diplodocus	Diplodocidae	F, H(*)	10–40 tons	Anderson et al., 1985
Barosaurus	Diplodocidae	F	10–40 tons	Janensch, 1961
Apatosaurus	Diplodocidae	F, H(*)	10–40 tons	Anderson et al., 1985
Dyslocosaurus	Diplodocidae	F	7–10 tons	McIntosh et al., 1992
Amphicoelias	Diplodocidae	F	40–70 tons	Cope, 1877
Seismosaurus	Diplodocidae	P	40–70 tons	Gillette et al., 1991
Amargasaurus	Diplodocidae	F	10–40 tons	Salgado and Bonaparte, 1991
Dicraeosaurus	Diplodocidae	F	10–40 tons	Janensch, 1961
Rebbachisaurus	Diplodocidae	F, H	10–40 tons	Lapparent, 1960

APPENDIX

Continued.

Genus	Higher taxon	Method	Weight	Reference
Mamenchisaurus	Mamenchisauridae	F	10–40 tons	Young, 1954
Titanosaurus	Titanosauridae	F	40–70 tons	Anderson et al., 1985
Magyarosaurus	Titanosauridae	F	0.7–1 ton	Huene, 1932
Laplatosaurus	Titanosauridae	F, H	7–10 tons	Powell, 1979
Andesaurus	Titanosauridae	F	40–70 tons	Calvo and Bonaparte, 1991
Saltasaurus	Titanosauridae	F	7–10 tons	Bonaparte and Powell, 1980
Aegyptosaurus	Titanosauridae	F	10–40 tons	Stromer, 1932
Alamosaurus	Titanosauridae	M(*)	10–40 tons	Bakker, 1980
Hypselosaurus	Titanosauridae	F	7–10 tons	Lapparent, 1947
Argyrosaurus	Titanosauridae	F	10–40 tons	Lydekker, 1893
Antarctosaurus	Titanosauridae	F	40–70 tons	Anderson et al., 1985
Tornieria	Titanosauridae	H	10–40 tons	Raath and McInotsh, 1987
Janenschia	Titanosauridae	F	10–40 tons	Wild, 1991; Fraas, 1908
Segnosaurus	Segnosauridae	F(?)	4–7 tons	Perle, 1979
Lesothosaurus	(Ornithischia)	P	4–7 kg	Callison, 1987
Pisanosaurus	(Ornithischia)	F	7–10 kg	Bonaparte, 1976
Scutellosaurus	(Thyreophora)	P	7–10 kg	Callison, 1987
Emausaurus	(Thyreophora)	P	40–70 kg	Haubold, 1991
Scelidosaurus	Scelidosauridae	F, P	400–700 kg	Marsh, 1896
Echinodon	(Thyreophora)	P(*)	0.7–1 kg	Callison, 1987
Huayangosaurus	Huayangosauridae	P	1–4 tons	Galton, 1992
Chialingosaurus	Stegosauridae	F	1–4 tons	Young, 1959
Chungkingosaurus	Stegosauridae	F	1–4 tons	Dong et al., 1983
Dacentrurus	Stegosauridae	F, P	1–4 tons	Galton, 1985b
Kentrosaurus	Stegosauridae	F, H(*)	1–4 tons	Russell et al., 1980
Lexovisaurus	Stegosauridae	F, P	1–4 tons	Galton, 1985b
Monkonosaurus	Stegosauridae	P	1–4 tons	Dong, 1990b
Stegosaurus	Stegosauridae	M(*)	4–7 tons	Bakker, 1980
Tuojiangosaurus	Stegosauridae	H	4–7 tons	Dong et al., 1983
Wuerhosaurus	Stegosauridae	P	1–4 tons	Dong, 1990b
Ankylosaurus	Ankylosauridae	F	4–7 tons	Coombs, 1978a
Euoplocephalus	Ankylosauridae	M(*)	1–4 tons	Bakker, 1980
Pinacosaurus	Ankylosauridae	H	1–4 tons	Maryanska, 1977
Saichania	Ankylosauridae	H	1–4 tons	Maryanska, 1977
Talarurus	Ankylosauridae	H	0.7–1 ton	Maryanska, 1977
Acanthopholis	Nodosauridae	F	400–700 kg	Galton, 1983
Denversaurus	Nodosauridae	P	1–4 tons	Bakker, 1980
Edmontonia	Nodosauridae	P	1–4 tons	Carpenter, 1990
Hoplitosaurus	Nodosauridae	F	1–4 tons	Galton, 1983
Hylaeosaurus	Nodosauridae	H	0.7–1 ton	Mantell, 1841
Nodosaurus	Nodosauridae	P	1–4 tons	Marsh, 1889
Panoplosaurus	Nodosauridae	M(*)	1–4 tons	Colbert, 1962; Coombs, 1978b
Sauropelta	Nodosauridae	F	1–4 tons	Coombs, 1978a
Silvisaurus	Nodosauridae	F, P	1–4 tons	Eaton, 1960
Heterodontosaurus	Heterodontosauridae	F, P	1–4 tons	Santa Luca et al., 1976
Drinker (juv.)	Hypsilophodontidae	F	1–4 kg	Bakker et al., 1990
Fulgorotherium	Hypsilophodontidae	F	10–40 kg	Huene, 1932
Gongbasaurus	Hypsilophodontidae	P	10–40 kg	Dong, 1989
Hypsilophodon	Hypsilophodontidae	F	40–70 kg	Galton and Jensen, 1975
Leaellynosaura	Hypsilophodontidae	F	7–10 kg	Rich and Rich, 1989
Orodromeus	Hypsilophodontidae	M(*)	7–10 kg	Dunham et al., 1989
Othnielia	Hypsilophodontidae	f(*)	7–10 kg	Dodson et al., 1980
Parksosaurus	Hypsilophodontidae	F(*)	40–70 kg	Anderson et al., 1985
Thescelosaurus	Hypsilophodontidae	F(*)	100–400 kg	Anderson et al., 1985
Yandusaurus	Hypsilophodontidae	F, P	4–7 kg	He, 1979
Tenontosaurus	(Ornithopoda)	F	1–4 tons	Forster, 1990
Dryosaurus	Dryosauridae	F	100–400 kg	Galton, 1981
Valdosaurus	Dryosauridae	F	10–40 kg	Galton and Taquet, 1982
Camptosaurus	Camptosauridae	M(*)	400–700 kg	Bakker, 1980
Iguanodon	Iguanodontidae	M(*)	4–7 tons	Colbert, 1962

APPENDIX

Continued.

Genus	Higher taxon	Method	Weight	Reference
Ouranosaurus	Iguanodontidae	F, P	1–4 tons	Taquet, 1976
Muttabarrosaurus	(Iguanodontia)	F	1–4 tons	Bartholomai and Molnar, 1981
Rhabdodon	(Iguanodontia)	F	1–4 tons	Lapparent, 1947
Gilmoreosaurus	Hadrosauridae	P	100–400 kg	Brett-Surman, 1980
Tanius	Hadrosauridae	F	1–4 tons	Wiman, 1929
Claosaurus	Hadrosauridae	F, P	0.7–1 ton	Lull and Wright, 1942
Hadrosaurus	Hadrosauridae	F	1–4 tons	Galton and Jensen, 1978
Kritosaurus	Hadrosauridae	F	1–4 tons	Lull and Wright, 1942
Maiasaura	Hadrosauridae	M(*)	4–7 tons	Dunham et al., 1989
Prosaurolophus	Hadrosauridae	F, P	1–4 tons	Lull and Wright, 1942
Saurolophus	Hadrosauridae	F	1–4 tons	Lull and Wright, 1942
Lophorhothon	Hadrosauridae	F	0.7–1 ton	Langston, 1960
Edmontosaurus	Hadrosauridae	F(*)	1–4 tons	Anderson et al., 1985
"*Anatosaurus*"	Hadrosauridae	F(*)	1–4 tons	Anderson et al., 1985
Anatotitan	Hadrosauridae	F, P	1–4 tons	Chapman and Brett-Surman, 1990
Bactrosaurus	Hadrosauridae	F, P	1–4 tons	Gilmore, 1933
Corythosaurus	Hadrosauridae	M(*)	4–7 tons	Colbert, 1962
Hypacrosaurus	Hadrosauridae	F(*)	1–4 tons	Anderson et al., 1985
Lambeosaurus	Hadrosauridae	F	1–4 tons	Morris, 1981
Parasaurolophus	Hadrosauridae	F	1–4 tons	Lull and Wright, 1942
Tsintaosaurus	Hadrosauridae	F	1–4 tons	Young, 1958
Goyocephale	Homalocephalidae	P	10–40 kg	Perle et al., 1982
Homalocephale	Homalocephalidae	F	10–40 kg	Maryanska and Osmolska, 1974
Gravitholus	Pachycephalosauridae	E	70–100 kg	Giffin, 1989
Majungatholus	Pachycephalosauridae	E	100–400 kg	Giffin, 1989
Ornatotholus	Pachycephalosauridae	E	70–100 kg	Giffin, 1989
Pachycephalosaurus	Pachycephalosauridae	E	0.7–1 ton	Giffin, 1989
Prenocephale	Pachycephalosauridae	F	70–100 kg	Maryanska and Osmolska, 1974
Stegoceras	Pachycephalosauridae	F	10–40 kg	Gilmore, 1924
Stygimoloch	Pachycephalosauridae	E	70–100 kg	Giffin, 1989
Psittacosaurus	Psittacosauridae	F	40–70 kg	Sereno and Shichin, 1988
Bagaceratops	Protoceratopsidae	F	7–10 kg	Maryanska and Osmolska, 1975
Leptoceratops	Protoceratopsidae	F, H(*)	100–400 kg	Anderson et al., 1985
Microceratops	Protoceratopsidae	F	4–7 kg	Maryanska and Osmolska, 1975
Montanoceratops	Protoceratopsidae	F	400–700 kg	Brown and Schlaikjer, 1942
Protoceratops	Protoceratopsidae	M(*)	100–400 kg	Colbert, 1962
Avaceratops (juv.)	Ceratopsidae	F, P	400–700 kg	Dodson, 1986
Brachyceratops	Ceratopsidae	F, P	100–400 kg	Lull, 1933
Centrosaurus	Ceratopsidae	F, P	1–4 tons	Lull, 1933
Monoclonius	Ceratopsidae	F, P	1–4 tons	Lull, 1933
Pachyrhinosaurus	Ceratopsidae	H	1–4 tons	Langston, 1975
Styracosaurus	Ceratopsidae	F, H(*)	1–4 tons	Anderson et al., 1985
Anchiceratops	Ceratopsidae	F, H	7–10 tons	Lull, 1933
Chasmosaurus	Ceratopsidae	P	1–4 tons	Lull, 1933
Pentaceratops	Ceratopsidae	M(*)	1–4 tons	Bakker, 1980
Triceratops	Ceratopsidae	M(*)	7–10 tons	Colbert, 1962