Palaeontologia Electronica
palaeo-electronica.org

Tyrannosaurus rex: An endangered species

Thomas D. Carr

ABSTRACT

Most fossils of *Tyrannosaurus rex* are commercially or privately owned. The market has depleted the scientific record of *T. rex* because vertebrate fossils that are not in public trusts are unavailable for scientific study. This ethical principle protects the integrity of vertebrate paleontology as a science by ensuring replicability and testability of observations. Unfortunately, scientists regularly publish on privately owned *T. rex* fossils. The goal of this study is to quantify the market's impact upon the sample size of *T. rex*. The data are from the primary literature, museum records, mainstream media, personal observation, and anecdote; specimens range from individual bones and teeth to nearly complete skeletons. There are 61 *T. rex* fossils in public trusts, whereas 71 are privately held. The rate of discovery of *T. rex* fossils made by commercial companies is twice as high as that of museums, and exploitation is heaviest in Montana and South Dakota. Of particular concern is the private ownership of juvenile and subadult specimens, the part of growth that is least understood, which make up 20% of privately held *T. rex*. The purchase of show-stopping fossils is problematic because *T. rex* skeletons command top dollar, from $1.55 million to $38.68 million USD, preventing most museums from acquiring the fossils. Only 11% of commercially collected *T. rex* fossils are in public trusts. The sample size of *T. rex* would be more than doubled (from 61 to 141) if it weren't for profit-driven commercial interests on private lands in the American West.

Thomas D. Carr. Department of Biology, Carthage College, 2001 Alford Park Drive, Kenosha, Wisconsin, 53140. tcarr@carthage.edu.

Keywords: *Tyrannosaurus;* commercial; private; public; ownership; ethics

Submission: 9 September 2023. Acceptance: 26 March 2025.

INTRODUCTION

The Problem

Vertebrate paleontology is at a point in history where it is faced with a society that considers it acceptable to sell rare nonrenewable fossil resources as luxury items, including skulls and skeletons of *Tyrannosaurus rex* (Keaten, 2023a). A high cultural status (=esteem sensu Chippindale and Gill, 2000) combined with the legal sale of fos-

Final citation: Carr, Thomas D. 2025. *Tyrannosaurus rex*: An endangered species. Palaeontologia Electronica, 28(1):a16. https://doi.org/10.26879/1337
palaeo-electronica.org/content/2025/5499-t-rex-endangered-species

sils collected from private lands in the American West has made *T. rex* a lucrative target for commercial interests and a desirable object d'art for private collectors. The problem of the commercialization of fossils has increased since Shimada et al. (2014) identified the market as one of the three greatest challenges to paleontology in the twenty-first century. Since fossils are the data, they belong in public trusts where all paleontologists have access (Shimada et al. 2014). The authors identified public misinformation about the problem of the commercial market and the lack of recognition of the problem among paleontologists as additional reasons for alarm (Shimada et al. 2014). Among fossils, dinosaurs are relatively rare and so the effect of sales to private individuals can decimate the sample size for a given species. As for living species, a substantial sample size of a fossil species is required to recover a statistically significant biological signal; for example, it is estimated that a sample size of 70 to 100 specimens of adult nonavian dinosaurs are required to statistically detect sexual dimorphism in a species with a high degree of dimorphism (Kościński and Pietraszewski, 2004; Hone and Mallon, 2017). However, most dinosaurs are known from a mere handful of specimens or only one fossil (Weishampel et al. 2004) and so maximizing sample size is a scientific priority.

The sale of *T. rex* fossils, in particular, results in data lost regarding the range of variation at all growth stages, stratigraphic position, taphonomy, and geological context. In recent years, new techniques and technologies have been used to rigorously investigate these areas of study (Currie, 2023); the loss of fossils and their locality information to the market deprives the science of advances that could be brought to bear on, and from, new fossils. The loss of dinosaur fossils has cascading effects up the chain of functional and ecological inferences that are drawn above the specimen level (Witmer, 1995). For a secure scientific footing, vertebrate paleontologists should be working with sample sizes that approximate the variation seen in a natural population. The fossil market works against this because it reduces the sample size that scientists ought to work with. The commodification of dinosaur fossils is an example of the collision between the social values of science, education, heritage, and history on the one hand, and commercial values on the other (Santucci et al. 2016). Often the non-commercial values are appropriated to enhance the market value of fossils (Roddy, 2022); in the end, the scientific enterprise experiences a substantial and measurable data loss to multimillion-dollar auctions.

At the heart of the issue are the principles that safeguard replication of scientific observations of vertebrate fossils, the most important of which is repository status. It is generally understood that a public repository is the institutional requirement for the storage and safekeeping of fossils far into the future. It has been argued that privately owned fossils should be studied and published on and if this bothers anyone, then the "simple, non-bureaucratic solution for dealing with scientific conclusions that cannot be reproduced or data that cannot be accessed - one can simply place less confidence in those conclusions" (Saitta, 2020, p. 7). This argument proposes the worst of all possible outcomes by opening the door to a future where we can have no confidence in results if the data (the fossils) are inaccessible for further study. The repository status of fossils is central to the legitimacy of vertebrate paleontology, and the goal here is to use *T. rex* to assess the threat to science that the commercial trade poses.

Dinosaur Fossils Have Become an Art Auction Staple

The loss of *T. rex* fossils is only one example of the larger problem of the surging luxury fossil market (Shimada et al. 2014; Demeulemeester and Stein, 2022; Roddy, 2022). In recent years, several high-profile international auctions have sold dinosaur skeletons as decorative art (Schultz, 2020; Robaglia, 2022; Keaten, 2023b). In addition to *T. rex*, the auction houses have sold skeletons of *Triceratops, Diplodocus, Allosaurus, Albertosaurus libratus, Stegosaurus,* and the extremely rare and bird-like *Deinonychus* (Goldstein, 2022; Robaglia, 2022). The high monetary value of dinosaur fossils is reinforced by previous auctions, and this should be expected to continue (Fourcade, 2011 cited in Jones, 2020; Cascone, 2024). The commodification of dinosaur fossils is enhanced by the art world that promotes them as exclusive decorative art (Christie's, 2020), and the noncritical interest in the fossil trade – and fossil collectors – that is taken by journalists and commentators (Hippensteel and Condliffe, 2013; Conniff, 2019; Gross, 2020). These messages drown out the scientific perspective, unless journalists are aware of the problems that the fossil trade presents for science, and reach out to paleontologists for comment (Barras, 2019; Geggel, 2022). The reaction on the scientific side is also represented by the press releases issued by the Society of Vertebrate Paleontology (SVP) that

in some cases has called on auction houses to limit their sales to public trusts, to no avail (SVP, 2020). Although the issue of the commercial trade in vertebrate fossils is not limited to the United States (e.g., Cisneros et al. 2022), the *T. rex* example is representative of how the market efficiently chisels away at the sample size of important fossil species.

The claims made by Shimada et al. (2014) about the negative effect of the commercial trade upon vertebrate paleontology, and the counter-claims made by commercial collectors (Larson N.L., 2008; Larson N.L. et al. 2014; Larson, P.L. and Russell, 2014; Larson, P.L., 2023) are recounted here in order to assess them as testable hypotheses in light of a comparison between the number of *T. rex* fossils in public trusts and those in commercial or private hands.

The Claims Made by Shimada et al. (2014)

Shimada et al. (2014) describe three testable claims about the effect of the commercial fossil market upon paleontology:

1. **Sales of fossils have increased, especially online.** Sales can be quantified by counting the number of fossils collected and sold per year.
2. **Fossils that are sold in high-profile auctions are not purchased by public trusts.** The outcome of auctions can be quantified through news reports.
3. **The sale of fossils results in a decline in collections-based research (=commercialization of fossils hurts the science of paleontology).** This can be quantified by counting and comparing the number of fossils that are unavailable (privately owned) and available (in public trust) to scientists.

Testable Claims Made by Commercial Interests

In contrast to Shimada et al. (2014), commercial collectors (Larson N.L., 2008; Larson N.L. et al. 2014; Larson, P.L. and Russell, 2014; Larson, P.L., 2023) and some scientists (Haug et al. 2020) have published testable claims that science benefits from the commercialization of fossils:

1. **More fossils are discovered in a shorter time frame (Larson N.L., 2008; Larson, P.L. and Russell, 2014).** This can be tested by comparing the rate of collection between public trusts and commercial enterprises. Implicit in this claim is that commercially collected fossils are rescued from erosion (Larson, P.L. and Russell, 2014), which is made explicit in Larson N.L. et al. (2014, p. 7), "There are untold numbers of fossils lost to the elements…every year." However, the logical fallacy of this claim is that this abundance of fossils will not necessarily be reposited in a public trust.
2. **Some commercially obtained fossils are intensely scientifically studied (Larson, P.L. and Russell, 2014).** This claim falls under the purview of scientific best practices; as set out by the SVP, privately owned fossils should not enter the scientific literature. However, several privately owned *T. rex* fossils have been published in peer-reviewed journals, and that issue is quantified and discussed below. However, since this practice contravenes best practices, it is not a valid argument for fossil commodification.
3. **The most significant fossil discoveries have ended up in museums (Larson, P.L. and Russell, 2014).** This can be tested by simply comparing the number of commercially collected fossils that are reposited in public trusts with those that are not. This claim is a primary focus of this work.

A similar argument is that "…fossil collections…are often eventually donated to their local museum" (Larson, P.L. and Russell, 2014, p. 5; Stein, 2019) or private collections are often sold museums (Larson N.L. et al. 2014), which is testable through counts of specimens, where they were reposited historically, and where they are currently reposited (i.e., their provenance; see definitions below).

4. **"Many [private collectors] readily donate specimens…to research programs" (Larson, P.L. and Russell, 2014, p. 5).** Haug et al. (2020) make a similar claim about amateur collectors, and they describe a positive culture of co-operation between amateur and professional paleontologists in Europe that is prevented in the USA by the market in dinosaur fossils. However, this claim is relevant only if "donate" means that the ownership of a specimen is transferred in perpetuity from a private collector to a public trust. This is a testable hypothesis that is investigated here.
5. **There should be "regulated amateur and commercial collecting be allowed on public lands" (Larson, P.L. and Russell, 2014, p. 5).** This claim can be assessed by the standard of where the fossils are reposited, which must be consistent with the repository conditions of the Code of Federal Regulations (Section 49; eCFAR, 2025). Haug et al. (2020) make a similar claim about the scientific benefits of legally unimpeded access to fossil-bearing deposits to

amateur collectors. It is difficult to envision such benefits in the American West where the financial incentives for commercial exploitation are so high. This line of argument is assessed here based on the repository criterion.

6. **Commercial collecting dates back to the 1700s, which justifies current practice (Larson N.L. et al. 2014; Winters, 2014).** Historically this may be true, but times have changed, where multimillion-dollar and high-profile auctions have priced public trusts out of obtaining scientifically significant specimens. This claim implies that the practices and market of the eighteenth century are unchanged to the present day, and, by inference, modern commercial practice is benign. Larson N.L. et al. (2014) make a series of similar claims that are based on the assumption of historical continuity: museums and universities are in the habit of buying fossils, from the 1600s to the present; purchased fossils are central to many of those collections; commercially supplied fossils have become type specimens; and commercial collectors have found most *T. rex* specimens. This continuity claim is testable, and it is pursued here.
7. **"…concerns about fossil commerce are predominantly a North American attitude" and "free enterprise…does not conflict with the science of paleontology (Larson N.L. et al. 2014, p. 3). "Indeed, fossil commerce enhances paleontological research [by working with an] institutional paleontologist" (Larson N.L. et al. 2014, p. 7).** These claims avoid the main concern dealt with here, specifically the actual impact of commercial activities on the sample size of rare fossil species. Whether or not attitudes are regional is irrelevant to the material effect of commercialization upon the science. Regardless, this claim can be quantified by comparing the number of commercially collected *T. rex* in public trusts with the number that aren't.
8. **Paleontology is an outlier among the sciences for having an issue with commercial collectors (Larson N.L. et al. 2014).** Whether or not that claim is true, the goal of this work is to assess whether there is rational ground for the conflict by comparing the repository status principle with the actual number of fossils lost to commercialization. Likewise, the related claims of "Our work does not undermine collections-based research…our efforts enhance and supplement academic endeavors" (Larson N.L. et al, 2014, p. 5) are tested by the same approach.
9. **Commercial collectors abide by the principles of the Association of Applied Paleontological Sciences (AAPS, 2025a; Larson N.L. et al. 2014, p. 5).** Of note are these two principles: "5. Report to the proper local authorities any significant discoveries of scientific or public interest." and "6. Strive to place specimens of unique scientific interest into responsible hands for study, research and preservation". It is the intent of this work to test whether these happen in practice.
10. **"There is an unfortunate misperception…that commercial collectors are only out for money and have little interest in science" and "…high price fossils are the exception, not the rule" (Larson N.L. et al, 2014, p. 6).** The recent high-profile and multimillion dollar auctions are relevant to the issue of commercialization and its interaction with the fine art world are examined here.

Goals

The goal of this article is to present a case study of the impact of the fossil market on the sample size of one species of dinosaur, namely *T. rex*. Aside from headline-grabbing auctions, the actual number of fossils lost to the market is something not usually documented in literature or in books on the topic (Shimada et al. 2014; Demeulemeester and Stein, 2022). In agreement with Roddy (2022) the unregulated collection and sale of dinosaur fossils from private land harms science because money is valued more than science, and the market is too expensive for museums to compete. Therefore, it is important to quantify the material harm (i.e., effect upon sample size) done to science by commercial interests.

The main goal of this work is to estimate the effect of the commercial trade of *T. rex* fossils upon science by counting and comparing the number of specimens collected by commercial outfits with those of public trusts. There are two secondary goals: (1) test the claim that the commercial trade facilitates the scientific study of *T. rex* (Larson N.L., 2008) and (2) quantify the frequency of privately-owned *T. rex* specimens that have been published in scientific literature. This case study does not discuss the illicit fossil trade (e.g., Raja and Dunne, 2023) as far as the published and unpublished record shows, the *T. rex* fossils documented here were collected within the limits of United States law, although legal disputes over ownership or

compensation between landowners and commercial companies do arise with some regularity (Vondracek, 2018; Mazurek, 2020). It is hoped that this contribution can serve as motivation and a model for other paleontologists to quantify the effect of the market on the taxa they study. Only then can it be assessed how broadly this issue applies across dinosaurs and other relatively rare vertebrate taxa. In short, this article seeks to answer the question raised by Roddy (2022, p. 480): "[Is the] collection of fossils for commercial gain…a blow to science[?]"

MATERIAL AND METHODS

A list of 61 scientifically informative specimens that are reposited in public trusts was compiled (Table 1). Carr (2020) was the primary source of specimens in public trusts, supplemented by fossils that were not included in that study. The book chapter written by Larson N.L. (2008) and the article published by Stein (2019) were the primary sources of specimens in commercial or private hands, supplemented by mentions of fossils in news reports, auction catalogs, and fossil dealer websites; first-hand observation; and word of mouth (Table 2). The number of commercially and privately owned fossils presented here is almost certainly an underestimate; given the secretive nature of the market, and the addition of new specimens found from year to year, it is less probable that this number is an overestimation. Specifically, it is nearly impossible to track privately held specimens. The data presented in Table 2 are likely missing some numbers of specimens, contain duplicates owing to specimen name changes, or have ghost specimens that do not exist that result from rumors. In short, the data presented here are an estimate of the impact commercialization has had on the sample size of *T. rex*.

The approach taken here is different from that of Stein (2019), which includes total counts of all specimens, including isolated bones and teeth held in collections of public trusts, commercial stockrooms, and private individuals. The criteria of this article is narrower, in that the many hundreds (or, possibly, thousands) of isolated bones and teeth are not counted. Instead, fossils that are judged scientifically informative in terms of ontogeny (sensu Carr, 2020) are counted here. This is of necessity, because of the many isolated teeth in collections only a small subset (incisiform teeth) contain ontogenetically informative variation (Carr, 2020). For this reason, my approach is different from that of Larson N.L. (2008), who defined a specimen as represented by 10 bones or more.

This report differs from Chippindale and Gill's (2000) approach to classical antiquities, in that the provenance and history (see definitions below) of the fossils are not quantified here. In recent years, the provenance of dinosaur fossils from the Hell Creek Formation means the specific depth it was found below the K/Pg boundary layer, which places a given fossil in the precise context of the overall succession of the geological unit (Scannella et al. 2014). The provenance and history of fossils are important, and the issue of provenance is a main criticism that paleontologists have of commercial fossil collectors (Santucci et al. 2016). Instead of a review of provenance, the goal here is to capture a snapshot of the number of fossils that are currently outside of the reach of science.

Ethical Framework

The ethical guidelines of the Society of Vertebrate Paleontology are followed here (https://vertpaleo.org), as well as the general scientific principle of reproducibility of observations.

Justification for Including Student-Written Articles

Several articles cited here were written by law school students (Mazurek, 2020; Paxton-Turner, 2020; Roddy, 2022). Since the authors are not academics, lawyers, or justices, these articles are not part of the canon of legal scholarship. Instead, there are essays that were written by undergraduate students, which were reviewed by their student colleagues, and published in online law school journals. Although these articles are not peer-reviewed literature, they are thoughtful engagements with the issue of the commercial fossil trade from a viewpoint outside of vertebrate paleontology. Of specific interest here is that they propose ideas to ameliorate the commercialization problem that science faces. Since these articles are publicly accessible, they are a part of the cultural zeitgeist, and so their insights and ideas are discussed here alongside other secondary sources.

Incomplete and Imprecise Nature of the Data Set

The world of the fossil trade is murky and it can only be observed indirectly. The specific challenge in writing this work was that not all fossils appear in the public record and those that do surface might undergo one or several name changes. Where unknown fossils will result in an underesti-

TABLE 1. List of 61 *Tyrannosaurus rex* specimens that were collected by, and are curated in, a public trust. Superscript T (^{T}) indicates type specimens, superscript J (^{J}) indicates juveniles.

#	Specimen number	State	parts preserved	Year collected
1	AMNH FARB 3982	SD	cervical centra	1892
2	NHMUK R7994	WY	incomplete skull, incomplete postcranium	1900
3	CM 9380^{T}	MT	incomplete skull, incomplete postcranium	1902
4	CM 1400	WY	incomplete skull, incomplete postcranium	1902
5	CM 9401	MT	lacrimal	1903
6	AMNH FARB 5027	MT	skull, incomplete postcranium	1908
7	AMNH FARB 5029	MT	incomplete skull, incomplete postcranium	1908
8	AMNH FARB 5117	WY	incomplete skull	1908
9	AMNH FARB 5050^{J}	MT	incomplete dentary	1909
10	CMNH 7541^{T,J}	MT	skull	1942
11	MOR 002	MT	incomplete skull, incomplete postcranium	1965
12	LACM 28471^{J}	MT	incomplete skull	1966
13	UCMP 137234	MT	lower jaws	1966
14	MOR 008	MT	incomplete skull	1967
15	LACM 23844	MT	incomplete skull, incomplete postcranium	1967
16	LACM 23845	MT	incomplete skull, incomplete postcranium	1967
17	TMM 41436-1	TX	maxilla	1970
18	UCMP 118742	MT	incomplete skull	1977
19	SDSM 12047	SD	incomplete skull, incomplete postcranium	1981
20	TMP 1981.012.0001	AB	incomplete skull, incomplete postcranium	1981
21	TMP 1981.006.0001	AB	skull, incomplete postcranium	1981
22	MOR 009	MT	incomplete postcranium	1981
23	NMMNH P-3698	NM	incomplete skull, incomplete postcranium	1983
24	UCMP 131583	MT	partial skull, partial postcranium	1984
25	UCMP 140418	MT	humerus	1984
26	MOR 555	MT	incomplete skull, incomplete postcranium	1990
27	RSM 2347.1^{J}	SK	maxilla	1991
28	DMNH 2827	CO	incomplete skull, incomplete postcranium	1992
29	UWGM 181	MT	incomplete skull, incomplete postcranium	1993
30	UCMP 140506	MT	partial postcranium	1993
31	RSM 2523.8	SK	incomplete skull, incomplete postcranium	1994
32	LPD 977-2	WY	partial skeleton	1992
33	MOR 980	MT	incomplete skull, incomplete postcranium	1997
34	MOR 1126	MT	partial skull, partial postcranium	2000
35	MOR 1131	MT	partial cranium	2000
36	MOR 1125	MT	incomplete skull, incomplete postcranium	2001
37	UCRC PV1	WY	incomplete postcranium	2001
38	UMNH 1100	UT	incomplete skull, incomplete postcranium	2001
39	MOR 1128	MT	incomplete skeleton	2001
40	BMRP 2002.4.1^{J}	MT	incomplete skull, incomplete postcranium	2001
41	BMRP 2001.4.70^{J}	MT	incomplete postcranium	2001
42	USNM 720145	MT	partial skull, incomplete postcranium	2002
43	MOR 1189^{J}	MT	hindlimbs	2002

TABLE 1 (continued).

#	Specimen number	State	parts preserved	Year collected
44	LACM 150167	MT	incomplete skull, incomplete postcranium	2003
45	BMRP 2006.6.4	MT	incomplete postcranium	2006
46	DDM 35.1[J]	MT	incomplete tibia	2006
47	MOR 2822	MT	incomplete skull	2006
48	MOR 2925	MT	partial postcranium	2007
49	RSM 2990.1	SK	lacrimal	2007
50	MOR 3028	MT	partial hindlimb	2010
51	MOR 3044	MT	partial maxilla	2010
52	MOR 6625	MT	partial dentary and maxilla	2010
53	TATE 2222	WY	incomplete postcranium	2011
54	DDM 344.1[J]	MT	frontal	2012
55	UWBM 99000	MT	skull, incomplete postcranium	2015
56	KUVP 156375[J]	MT	incomplete skull, incomplete postcranium	2015
57	KUVP 155809	MT	partial skull and skeleton	?
58	DDM 1536.8	MT	incomplete metatarsal III	2018
59	DDM 1562,14[J]	MT	first maxillary tooth	2018
60	DDM 1863.11[J]	MT	first maxillary tooth	2019
61	DDM 2355[J]	MT	partial skull, partial skeleton	2022

State/Province abbreviations: AB, Alberta, Canada; CO, Colorado; MT, Montana; ND, North Dakota; NM, New Mexico; SD, South Dakota; SK, Saskatchewan, Canada; TX, Texas; UT, Utah; WY, Wyoming.

mate of privately owned fossils, those that have had their name changed will result in an overestimate of the number, if the name changes unnoticed.

Another confound is the practice of listing several specimens under the same identification number. This is an issue with specimens that were listed on the now-defunct Theropoda Expeditions website, where three specimens were listed under the number TE-36 and two under TE-76. These specimens are treated separately here based on the information in the website, where it was stated that the specimens were collected from different localities. Indeed, one specimen of TE-36 was from Wyoming, whereas the others were from Montana. The single number for several specimens was presumably used to identify the composite skeleton cobbled together from different specimens, and that interpretation is followed here. Therefore, the TE specimen counts are not regarded here as overestimates.

Another issue is a set of specimens - KRex, JKRex, Ryker/Tyson, Barbara - that might be one and the same, but have had their nicknames changed. Although KRex, Ryker, and Tyson are regarded here as the same specimen, based on information from a confidential source, there is insufficient information to decide if Barbara is the same as JKRex and so they are treated separately here (Table 2); differences between the Tyson and Barbara mounts seen in photographs indicates they are not the same specimen, and so Barbara presumably does not include KRex material (see sources in Table 2).

Over the course of the writing of this manuscript, the data on privately held specimens has been revised several times as new information became available. Another limitation of the data is that the year and location of many commercially collected specimens is unknown, so the results regarding time and place are incomplete. Given the amount of commercial activity in the American West, the number of *T. rex* specimens is expected to increase from field season to field season, at a higher rate than public trusts. Considering these issues, the data presented here are an estimate of privately held specimens, as in any quantitative scientific study. Even if the data presented here are an order-of-magnitude underestimate of the true number of privately held fossils, readers can assess for themselves the extent of the impact of commercial trade on the sample size of *T. rex*.

TABLE 2. List of 71 commercially and privately held *Tyrannosaurus rex* specimens; the available information on "King Kong" is contradictory and so it appears twice (#10, #43). The three specimens with the same number, "TE-36," are indeed three separate specimens according to the now-defunct website. An asterisk (*) marks specimens that are outside of the United States; a superscript J (^{J}) indicates a juvenile specimen.

#	Specimen moniker	State	Year found / collected	Relative completeness	Source
1	Samson	SD	1992	skull and skeleton	Bonhams, 2009
2	Stan*	SD	1992	skull and skeleton	Larson N.L., 2008
3	Bowman	ND	1993	partial postcranium	Larson N.L., 2008
4	Duffy	SD	1993	skull and partial skeleton	Larson N.L., 2008
5	Double-O-seven	ND	1994	partial skull and skeleton	Larson N.L., 2008
6	Barnum	WY	1995	partial skull and skeleton	Larson N.L., 2008
7	Steven	SD	1995	partial skull and skeleton	Larson N.L., 2008
8	n/a	ND	1995	partial skull, partial skeleton	Bonhams, 2006
9	Foxy Lady	SD	1996	partial skull and skeleton	Larson N.L., 2008
10	Tinker/Rocky	SD	1997	skull and partial skeleton	Larson N.L., 2008; Poese, 2018
11	Ollie, Rex-A/King Kong	MT	1998	partial skull and skeleton	Larson N.L., 2008; Stein, 2019
12	Bill Alley *T. rex*	SD	1998	partial skull and skeleton	Larson N.L., 2008
13	Rex-C	SD	1999	partial skull and skeleton	Larson N.L., 2008
14	E. D. Cope	SD	2000	partial skull and skeleton	Larson N.L., 2008
15	Monty	WY	2000	partial skull and skeleton	Larson N.L., 2008
16	Tristan Otto*=Butch=Vallee/ Ciotka/Pangea specimen	MT	2001	skull and skeleton	Museum für Naturkunde, 2018 Robert Butch Vallee v. Terry Ciotka et al 2018 Renda, 2017
17	Wayne	SD	2004	partial postcranium	Larson N.L., 2008
18	Ivan	SD	2005	partial postcranium	McCoy, 2018
19	dentary ^{J}	-	2005	dentary	anecdote
20	pathologic humerus	-	2005	humerus	personal observation
21	Southwest Adventist specimen ^{J}	WY	2006	skull and skeleton	Dinosaur Science Museum, 2024
22	Dinoland Plus pelvis and leg	MT	2008	pelvis and leg	Dinoland Plus
23	maxilla ^{J}	MT	2009	maxilla	anecdote from eyewitness
24	TE-36/Roosevelt/Rosie A, B, C	MT	2012	partial skeleton	Theropoda Expeditions, 2017 Stoneberg, 2018
25	TE-36/Roosevelt/Rosie A, B, C	MT	2012	partial skeleton	Theropoda Expeditions, 2017 Stoneberg, 2018
26	TE-36/Roosevelt/Rosie A, B, C	WY	2012	partial skeleton	Theropoda Expeditions, 2017 Stoneberg, 2018
27	Russell	MT	2012		Theropoda Expeditions, 2017
28	Trinity/Garfield County 1	MT	2012	axial skeleton	Koller, 2023
29	TE-76	MT	2013	single bone	Theropoda Expeditions, 2017
30	TE-76	MT	2013	vertebrae	Theropoda Expeditions, 2017
31	Baby Bob/Son of Samson ^{J}	MT	2013	partial skull, partial skeleton	ebay
32	Victoria/Darwin/Shen	SD	2013	skull and skeleton	Trimble, 2019 Christie's, 2022
33	Trinity/Garfield County 2	MT	2013	axial and pelvic skeleton	Koller, 2023

TABLE 2 (continued).

#	Specimen moniker	State	Year found / collected	Relative completeness	Source
34	Trinity/Weston County	WY	2013	partial skull, partial skeleton	Koller, 2023
35	Titus*	MT	2014	partial skull and skeleton	My Nottingham News, 2021
36	TE-73/Rees	MT	2015	skull, caudal series	Theropoda Expeditions, 2017
37	TE-077	MT	2015	skull and jaws	Theropoda Expeditions, 2017
38	JKrex† (=Barbara?)	MT	2017		CK Preparations, 2021
39	Krex/Ryker/Tyson	MT	2018	skull and skeleton	CK Preparations, 2021 Tribe, T., 2023 Girardon, 2022
40	Chomper[J]	MT	2019	skull and skeleton	Shaw, 2023
41	Triebold juvenile [J]	MT	2021	skull and skeleton	Simons, 2020
42	Fossil Excavators “Beautiful Nightmare” maxilla [J]	ND	2021	maxilla	Olson, 2021 Dura, 2021
43	Fossil Excavators adult vertebrae	ND	2021	vertebrae	Olson, 2021 Dura, 2021
44	Leonard	-	2022	hind limb	PaleoAdventures, 2022
45	Cupcake [J]	-	-	skull	The amazing traveling dinosaur show, Ltd. Facebook page, 2014 [post dated: November 10, 2014]
46	King Kong	-	-	skull and skeleton	Stein, 2019
47	Regina	-	-		Carroll, 2014
48	braincase [J]	-	-	braincase	anecdote from eyewitness
49	Tag/Tad	-	-	skull and skeleton	Tie, 2018
50	Triebold *“Nanotyrannus”* [J]	SD	-	skull and skeleton	Triebold Paleontology, 2024
51	dentary [J]	-	-	dentary	personal observation in auction catalog
52	“misc parts”	-	-		AAPS, 2025b
53	Dynamo	-	-	skull	that dinosaur guy (@T rexcellence), 2021 [twitter post dated: April 14, 2021]
54	Metarex	-	-	-	Metarex, 2021
55	Jodi[J]	MT	-	partial skull and skeleton	Pangea Fossils Facebook page, 2023
56	n/a	SD	-		Vondracek, 2018
57	Peter/Torvik/Altmuhital	WY	-	partial skull and skeleton	Burnham et al. 2022 Dorr, 2021
58	Valerie	SD	-	skull and partial skeleton	Triebold Paleontology, 2024 Gorman, 2022
59	Maximus	SD	-	skull and jaws	Hilsman, 2022
60	Barbara† (=JKRex?)	MT	-	partial skull and skeleton	Aukland Museum, 2022
61	n/a	-	-	1 specimen	Babiarz Institute of Paleontological Sciences (Stein, 2019)
62	n/a	-	-	1 specimen	Anonymous 4, unknown collector (Stein, 2019)

TABLE 2 (continued).

#	Specimen moniker	State	Year found / collected	Relative completeness	Source
63	n/a	-	-	1 specimen	Mike Harris collections (Stein, 2019)
64	n/a	-	-	1 specimen	Poel (correct spelling?) collection (Stein, 2019)
65	n/a	-	-	1 specimen	Poel (correct spelling?) collection (Stein, 2019)
66	n/a	MT	-	-	anecdote
67	n/a	SD	-	-	anecdote
68	n/a	MT	-	maxilla and teeth	Bonhams, 2013
69	n/a	-	-	skull and jaws	Cruz, 2022
70	Casper[J]	WY	-	skull and jaws	Kokkegård, 2021
71	Glendive juvenile[J]	MT	-	pelvis	personal observation

See Table 1 for state/province abbreviations.

List of Primary Literature that Included Privately Owned *T. rex* specimens

The presence of privately owned *T. rex* specimens in scientific literature is a long-standing issue. The goal here was to provide an exhaustive list of publications drawn from English-language journals. The intent was not to call out specific scientists - indeed, the name of the author of this article appears in several of the articles as a primary author or co-author - but to provide an estimate of the breadth of the issue in terms of the types of studies (e.g., descriptive, functional morphology, etc.) that are, in whole or in part, based on privately owned fossils.

Terminology

Commercial company/outfit. A company that collects fossils from the field and sells them for profit.

Fossil dealer, commercial fossil dealer. An individual who sells fossils for profit.

Paleontologist. A scientist who publishes descriptive and analytical studies of fossil materials, and who is not a fossil dealer nor a member of a commercial company/outfit, nor a private collector of rare vertebrate fossils. A paleontologist adheres to the ethics of the scientific society of which they have membership, and the laws in the country where they do science.

Private collector. An individual or corporation that purchases fossils for their personal or corporate collection.

Privately owned. A fossil that is the personal property of an individual or corporation, is in the stockroom of a commercial company or fossil dealer, is in the collection of a museum that is not accredited by the American Alliance of Museums (AAM; US only), is in the collection of a museum that is not a repository the Bureau of Land Management or a state repository (US only), or is in a private museum that is not a recognized public trust.

Provenance. The original source of a specimen and its history of ownership (modified from Coggins, 1998 in Chippindale and Gill, 2000).

Public trust. A museum or university collection that, in the United States, is AAM accredited or is a state or federal repository, or some combination thereof.

Scientifically informative specimen. This can range from a single bone or tooth to a complete skull and skeleton; a specimen with sufficient information content to be included in an extensive osteological analysis such as published in Carr (2020).

Surface. The term used for the occasion that a privately held specimen first enters the public record (cf. Chippindale and Gill, 2000).

Institutional Abbreviations

AMNH, American Museum of Natural History (New York, NY, USA); **BHI**, Black Hills Institute of Geological Research, Inc. (Hill City, SD, USA); **BMRP**, Burpee Museum of Natural History (Rockford, IL, USA); **CM**, Carnegie Museum (Pittsburgh, PA, USA); **CMNH**, Cleveland Museum of Natural History (Cleveland, OH, USA); **DDM**, Dinosaur Discovery Museum (Kenosha, WI, USA); **FMNH**, Field Museum (Chicago, IL, USA); **HRS**, Hanson

Research Station (Newcastle, WY, USA); **KUVP**, Kansas University, Vertebrate Paleontology (Lawrence, KU, USA); **LACM**, Los Angeles County Museum of Natural History (Los Angeles, CA, USA); **LDP**, University of New Orleans (LA); **MOR**, Museum of the Rockies (Bozeman, MT USA); **NHMUK**, Natural History Museum (London, UK); **NMMNH**, New Mexico Museum of natural History and Science (Albuquerque, NM, USA); RSM, Royal Saskatchewan Museum (Eastend, SK, CAN); **SDSM**, South Dakota School of Mines and Technology (Rapid City, SD, USA); **TA**, Timescale Adventures Research and Interpretive Center (Bynum, MT, USA); **TATE**, Tate Museum (Caspar, WY, USA); **TMM**, Texas Memorial Museum (Austin, TX, USA); **TMP**, Royal Tyrrell Museum of Palaeontology (Drumheller, AB, CAN); **UCMP**, University of California Museum of Paleontology (Berkeley, CA, USA); **UCRC**, University of Chicago (Chicago, IL, USA); **UMNH**, Utah Museum of Natural History (Salt Lake City, UT, USA); **UWBM**, University of Washington Burke Museum (Seattle, WA, USA).

RESULTS

Effect of the Commercial Trade on the Sample Size of *Tyrannosaurus rex*

1. **Commercial and academic collection compared.** Over half of the sample size of *T. rex* (80 of 141 specimens, or 57%) has been collected by commercial outfits (Figure 1; Tables 2, 3). Of commercially collected specimens, only nine (11%) are in public trusts (Figure 2; Table 3). The remaining 89% are in stockrooms, private collections, or nonaccredited museums in the USA or overseas. The commercial exploitation of *T. rex* started in 1992 shortly after the discovery of Sue (FMNH PR2081) (Figure 3). Since then, commercial collection of *T. rex* fossils (n = 80) has overtaken public trusts (n = 34), such

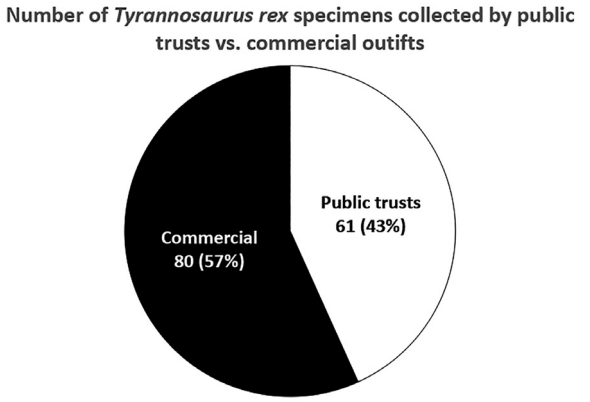

FIGURE 1. Comparison of the number of *Tyrannosaurus rex* fossils collected by commercial outfits with those collected by public trusts (as of October 2024).

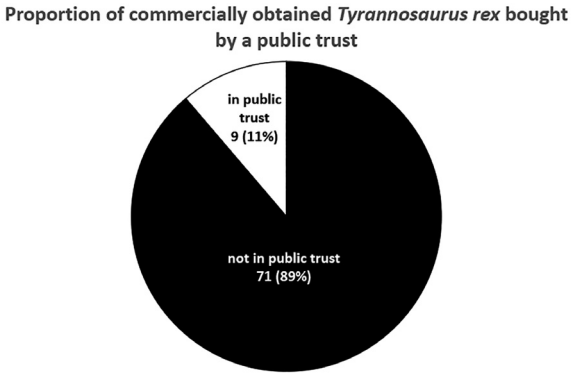

FIGURE 2. The number of commercially obtained *Tyrannosaurus rex* fossils that have been purchased by public trusts (as of October 2024).

TABLE 3. The nine commercially collected *Tyrannosaurus rex* specimens that were later accessioned into a public trust. Superscript J (^{J}) indicates juvenile specimens.

#	specimen number	company	state	parts preserved	year collected
1	FMNH PR2081	BHIGR	SD	skull, postcranium	1990
2	FMNH PR2411^{J}	BHIGR	SD	lacrimal	1990
3	FMNH tibia	BHIGR	SD	partial tibia	1990
4	FMNH partial dentary^{J}	-	-	partial dentary	-
5	Bucky	BHIGR	SD	incomplete skull, incomplete postcranium	2001
6	Wyrex	BHIGR	MT	incomplete skull, incomplete postcranium	2002
7	Trix	BHIGR (in part)	MT	skull, postcranium	2013
8	Fukui dentary	-	-	dentary	2018
9	Dueler^{J}	Phipps/BHIGR	MT	skull, postcranium	2006

See Table 1 for state/province abbreviations.

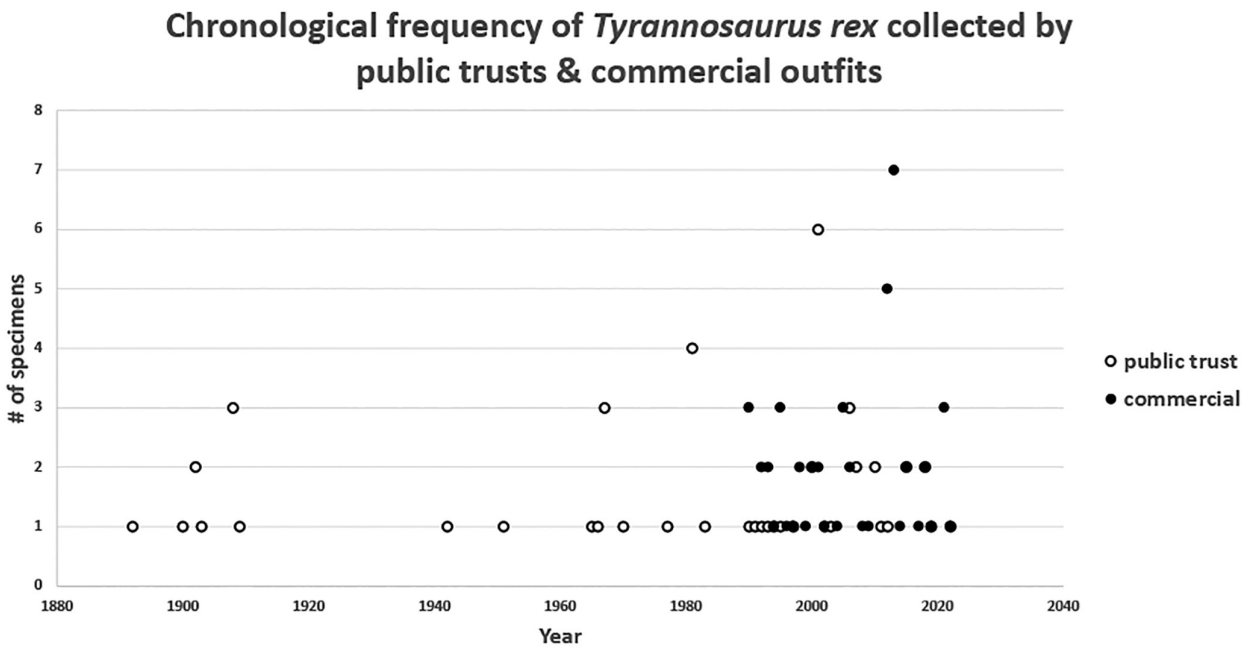

FIGURE 3. Chronological comparison of the number of *Tyrannosaurus rex* fossils collected by public trusts (white dots) and commercial outfits (black dots) (as of October 2024).

that they have found 2.4 times more *T. rex* specimens than public trusts. Commercial exploitation of *T. rex* happens in the Northern Rocky Mountain region of the United States, which is most active in Montana (n = 25) and South Dakota (n = 22) (Figure 4).

The high cultural profile of *T. rex* results in million-dollar prices for skeletons, a decisive obstacle to acquisition by most public trusts (Figure 5). Public trusts must rely on consortia of donors to purchase a multimillion-dollar specimen (Field Museum, 2018). Taken together, the mean price tag on a *T. rex* is USD $10.8M (Table 4). Over half of the sample size (n = 14) of *T. rex* juveniles are commercially or privately held, the growth stage that is least understood scientifically (Carr, 2020) (Figure 6). Of those, nine are represented by associated bones whereas the rest are isolated bones (Table 2).

2. ***T. rex* overseas.** Eighteen commercially obtained *T. rex* specimens have gone overseas (Table 5), presumably for good. Several of

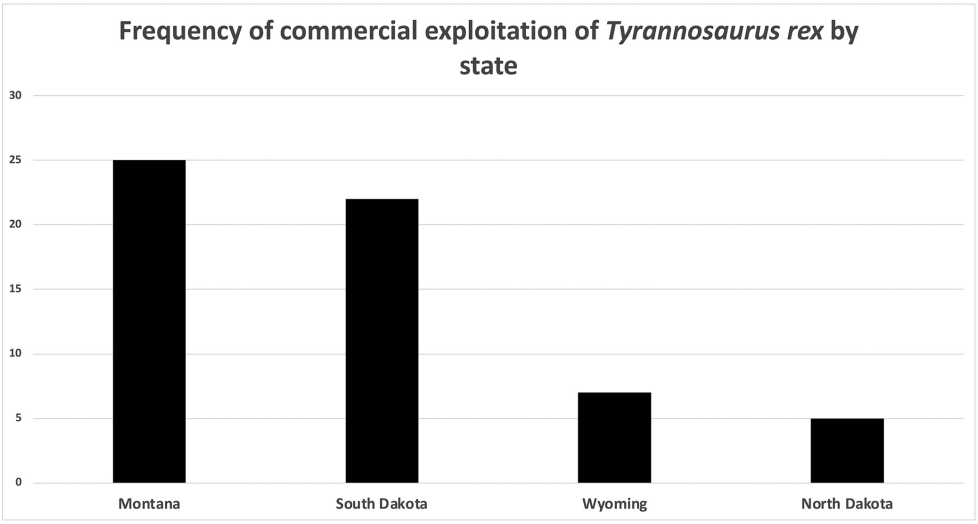

FIGURE 4. Regional commercial exploitation of *Tyrannosaurus rex* fossils by state (as of October 2024).

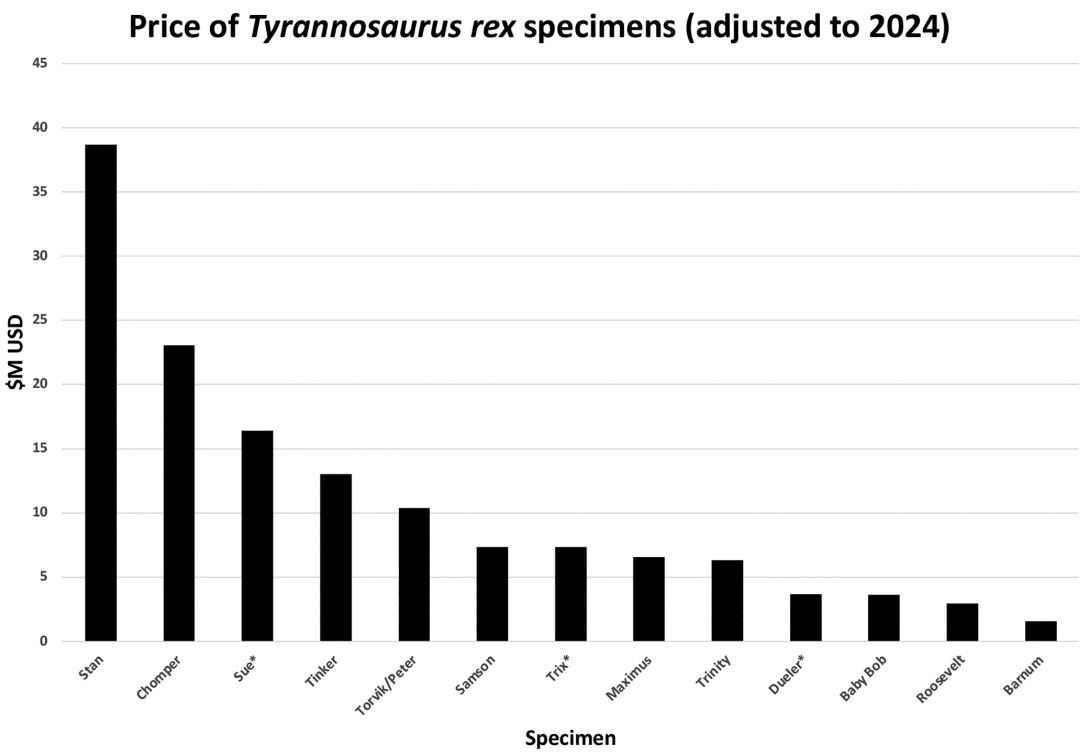

FIGURE 5. The cost (USD) of *Tyrannosaurus rex* fossils (as of October 2024). Asterisk (*) indicates specimens that are in a public trust. Original prices were adjusted to 2024 prices using usinflationcalculator.com.

TABLE 4. The prices of *Tyrannosaurus rex* specimens, with the original price and the current price adjusted for inflation. Asterisks indicate specimens that sold; including specimens that did not sell gives a more complete estimation of what the market expects for a *T. rex* fossil. The "Dueling Dinosaurs" were purchased for $6M, and the price of the *T. rex* is estimated here as half of that price. All prices are in USD; the US Inflation Calculator (https://www.usinflationcalculator.com/) was used to adjust for the difference in inflation between now and the year the prices were published. Data for "Barnum" is from Wikipedia (https://en.wikipedia.org/wiki/List_of_dinosaur_specimens_sold_at_auction). The price of Tinker was the amount on offer in 2014; the actual sale price is unknown.

Specimen moniker	Original Price	Year	Price adjusted to 2024	Deposition
Sue*	$8.36M	1997	$16.4M	Public trust
Barnum	$0.93M	2004	$1.55M	Private/commercial
Samson*	$5M	2009	$7.34M	Private
Tinker*	$9.8M	2014	$13.03M	Private/
Trix	$4.8M	2014	$6.38M	Public trust
Baby Bob/Son of Samson	$2.95M	2019	$3.63M	Commercial
Stan*	$31.8M	2020	$38.68	Private
Dueler*	$3M	2020	$3.65M	Public trust
Roosevelt	$2.39M	2020	$2.91M	Private/commercial
Peter/Torvik	$8.94M	2021	$10.39M	Private
Maximus*	$6.1M	2022	$6.56M	Private/commercial
Trinity*	$6.1M	2023	$6.3M	Private
Chomper	$22.34M	2023	$23.08M	Commercial
MEAN			$10.8M	

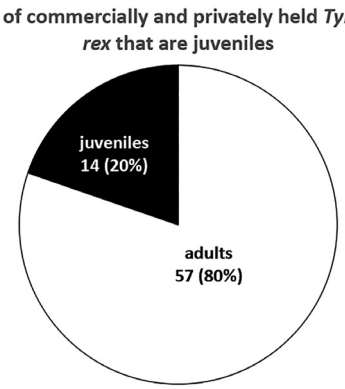

FIGURE 6. The number of juvenile *Tyrannosaurus rex* specimens currently held in commercial or private hands (as of October 2024).

these fossils are exhibited in bona fide museums (Museum fur Naturkunde; NZ Herald, 2022), whereas others are exhibited in shopping malls (Tie, 2018). The exhibit of privately owned *T. rex* in public museums is accompanied by media fanfare (Murray, 2021; NZ Herald, 2022) that does not discuss the ethics of privately owned dinosaur fossils. Although these privately owned fossils are on loan to museums and, in rare cases, the museum will assign a catalog number to the fossil, the specimens are owned by private individuals and so they are not available for scientific research.

TABLE 5. Summary of 19 commercially-obtained *Tyrannosaurus rex* specimens that, as of this writing, are outside of the United States. For sources see Table 2.

#	Specimen	Location
1	Barbara/JKRex	New Zealand
2	Cupcake	Canada
3	Dynamo	?
4	Fukui dentary	Japan
5	“misc parts”	United Kingdom
6	Altmuhital/Peter/Torvik	New Zealand
7	Regina	Middle East
8	Darwin/Shen/Victoria	Hong Kong
9	Tad/Tag	Hong Kong
10	Rocky/Tinker	Germany
11	Titus	United Kingdom
12	Trinity Garfield County 1	Switzerland
13	Trinity Garfield County 2	Switzerland
14	Trinity Weston County	Switzerland
15	Butch/Pangea/Tristan Otto	Germany
16	Trix	Netherlands
17	KRex/Ryker/Tyson	Japan
18	n/a	Mexico

3. **Data loss.** The scientific value of a fossil can be measured by its information content, which includes quantitative data such as measurements and ratios, and qualitative data such as the physical appearance of a structure. To quantify the information content of a *T. rex* skeleton here, the number of characters and character states from Carr (2020) were counted for each osteological part, and the ratio of character states to characters was calculated for each part and across the entire data (Table 6).

The growth series in Carr (2020) was based on the analysis of 1,850 characters that were scored for 44 specimens, ranging from single teeth and bones to nearly complete skulls and skeletons, and the skeleton was divided into 118 parts (Carr, 2020). Each character has at least two states, which results in a minimum state to character ratio of 2.0; the ratio is greater than this in multistate characters, indicating higher information content. The ratio enables the comparison of relative amount of information content for each region of the skeleton; for example, the body has two characters and six states, giving a ratio of 3 whereas the subnarial foramen is represented by one character that has three states, also giving a ratio of 3. Therefore, the relative information content between the body and the foramen is the same. This comparison finds that for every part of the skeleton, the information content is greater than 2.0 (1 character, 2 states), which is the lowest possible score.

A total of 4,005 character states was counted (Table 6), which is 2.2 times greater than the number of characters. The mean number of characters per part is 20.5, the mean number of states per part is 32.9, and the mean ratio of character states per character is 2.2. Therefore, each part of the skeleton, from teeth to bones to histological data, has information content; it cannot be said that any part is uninformative. In terms of numbers of characters, the most informative bone in each major skeletal region (skull, axial column, pectoral girdle and limb, pelvic girdle, and limb) is the maxilla (123), axis (71), scapula (25), and fibula (42), respectively.

Privately Owned *Tyrannosaurus rex* in the Scientific Literature

Despite the ethics guidelines of the SVP, paleontologists have published on privately owned *T. rex* fossils, most frequently from the Black Hills Institute of Geological Research, Inc. (Table 7).

TABLE 6. Summary of information content in the skeleton of *Tyrannosaurus rex*, based on the data set of Carr (2020). The ratio of the number of states to the number of characters for each element was taken to quantify mean information value content across all parts.

Part	# characters	# states	Ratio
Body	2	6	3
Skull	1	2	2
Snout	5	10	2
Bony palate	2	4	2
Bony naris	1	2	2
Subnarial foramen	1	3	3
Incisive foramen	1	2	2
External antorbital fenestra	2	6	3
Internal antorbital fenestra	2	4	2
Bony choana	6	12	2
Orbital fenestra	2	5	2.5
Palatine fenestra	3	6	2
Suborbital fenestra	1	3	3
Postorbital bar	4	8	2
Laterotemporal fenestra	1	2	2
Secondry laterotemporal fenestra	1	2	2
Adductor region	1	2	2
Dorsotemporal fossa	1	2	2
Paraquadrate foramen	1	2	2
Fossa for ventral pterygoid	1	3	3
Foramen magnum	1	2	2
External mandibular fenestra	1	2	2
Internal mandibular fenestra	1	3	3
Meckelian fossa	1	2	2
Nasolacrimal joint	1	2	2
Lacrimoprefrontal joint	1	2	2
Premaxilla	44	89	2
Maxilla	123	269	2.2
Nasal	42	89	2.1
Lacrimal	121	310	2.6
Jugal	77	180	2.3
Postorbital	71	152	2.1
Squamosal	63	129	2.1
Quadratojugal	45	97	2.2
Quadrate	28	58	2.1
Prefrontal	1	3	3.0
Frontal	89	205	2.3
Parietal	27	58	2.2
Vomer	17	36	2.1
Ectopterygoid	32	66	2.1
Palatine	49	120	2.5
Pterygoid	2	4	2.0
Epipterygoid	9	19	2.1
Supraoccipital	4	9	2.3
Otoccipital	15	31	2.1
Basioccipital	24	54	2.3
Basisphenoid	15	30	2.0
Subcondylar recess	1	2	2.0
Basisphenoid recess	1	2	2.0
Laterosphenoid	9	19	2.1
Endocranium	10	20	2.0
Braincase sutures	6	13	2.2
Mandibular ramus	1	2	2.0
Craniomandibular joint	1	2	2.0
Dentary	77	168	2.2
Surangular	36	77	2.1
Splenial	7	16	2.3
Angular	4	9	2.3
Prearticular	6	12	2.0
Dentition	18	44	2.4
Atlas intercentrum	27	57	2.1
Atlas neurapophysis	1	2	2.0
Axis	72	154	2.1
Postaxial cervicals	6	12	2.0
Cervical 3	10	20	2.0
Cervical 5	5	10	2.0
Cervical 6	4	8	2.0
Cervical 8	4	8	2.0
Cervical series	1	2	2.0
Dorsal vertebrae	10	21	2.1
Dorsal A	2	4	2.0
Dorsal B	3	6	2.0
Dorsal D	6	12	2.0
Dorsal E	4	8	2.0
Sacrum	4	8	2.0
Caudal vertebrae	6	12	2.0
Caudal 1	12	24	2.0
Caudal 2	3	6	2.0

TABLE 6 (continued).

Part	# characters	# states	Ratio
Caudal 3	13	26	2.0
Caudal 4	11	22	2.0
Caudal 5	23	26	2.0
Caudal 6	12	24	2.0
Caudal 7	12	24	2.0
Caudal 8	13	27	2.1
Caudal 9	17	34	2.0
Caudal 10	10	22	2.2
Caudal 11	13	27	2.1
Caudal 12	17	34	2.0
Caudal 13	14	28	2.0
Caudal 14	19	38	2.0
Caudal 15	13	26	2.0
Caudal 16	15	30	2.0
Scapulocoracoid	3	6	2.0
Scapula	25	52	2.1
Coracoid	21	45	2.1
Humerus	12	26	2.2
Ilium	20	40	2.0
Pubis	6	12	2.0
Ischium	12	24	2.0
Femur	9	20	2.2
Tibia	27	58	2.2
Fibula	42	94	2.2
Metatarsal II	10	26	2.6
Metatarsal III	22	49	2.2
Metatarsal IV	10	21	2.1
Metatarsal V	15	33	2.2
D I, PH 1	1	2	2.0
D II, PH 1	10	20	2.0
D II, PH 2	21	45	2.1
D III, PH 1	10	20	2.0
D III, PH 2	12	24	2.0
D IV PH 1	18	36	2.0
D IV PH 2	12	24	2.0
D IV PH 3	11	22	2.0
D IV PH 4	13	29	2.2
Pedal unguals	3	8	2.7
Growth rings	2	12	6.0
Growth rate	1	2	2.0
TOTAL	1,850	4,005	n/a
MEAN	20.5	33.9	2.2

This practice dates to at least 1995 and has continued through to the present day nearly every year since. Haug et al. (2020) argued that fossils in private collections are a service to science, but that assumes that they are on equal footing with public trusts. The auction of Stan the *T. rex* is a clear example that private collections, in part or in whole, are not immune to dissolution (Greshko, 2022; Raja and Dunne, 2023).

DISCUSSION

Summary of Results

The effect of the commercial trade of *T. rex* fossils upon science is decisive and negative: the sample size of scientifically available specimens is reduced by more than half. From this fact, the claim that commercial trade facilitates the scientific study of *T. rex* (Larson N.L., 2008) cannot be true. Since the market in dinosaur fossils has no end in sight, vertebrate paleontologists are faced with persistent issues that result from the trade, the American context, and arguments made in defense of the fossil trade and publication of privately owned fossils; the next section explicates those problems based on the claims made by Shimada et al. (2014) and the commercial sources cited above.

Testing the Claims of Shimada et al. (2014)

1. **Sales of fossils have increased, especially online.** Although online sales of large-ticket *T. rex* fossils have not happened, the frequency of *T. rex* appearing on the market has increased, especially since 2019, when each year one or more specimens are made available to buyers (Table 4).
2. **Fossils that are sold in high-profile auctions are not purchased by public trusts.** This claim is supported by the data; of the five *T. rex* sold at auction, only one lot (Sue + associated subadult tibia + associated juvenile lacrimal) was obtained by a public trust.
3. **The sale of fossils results in a decline in collections-based research.** The data collated here show that there are more *T. rex* fossils in commercial or private hands than in public trusts. Consequently, the sample sizes required for rigorous quantitative research is compromised. A decline of collections research per se does not happen, but the low sample size does compromise the scientific value of the research that is done on *T. rex*.

Table 7. Summary of commercially- or privately owned *Tyrannosaurus rex* specimens that have appeared in peer-reviewed scientific and technical articles. Asterisk (*) indicates articles in which BHI 4182 is given incorrectly as BHI 4812.

Specimen	Sources
BHI 116	Currie, 2003a
BHI 1266	Bates et al. 2009; Dececchi et al. 2020; Farlow et al. 2013
BHI 2033	Currie, 1998; Holtz, 1995
BHI 3033	Bates and Falkingham, 2012; Bates et al. 2009; Brown et al. 2015; Brusatte, et al. 2012; Campione et al. 2014; Carr, 2010; Carr and Williamson, 2004; Carr, et al. 2005; Carrano and Hutchinson, 2002; Currie, 1998, 2003a, 2003b; Currie et al. 2003; Dalman and Lucas, 2017; Dalman et al. 2024; Dececchi et al. 2020; Derstler and Myers, 2008; Happ, 2008; Hurum and Currie, 2000; Hurum and Sabath, 2003; Hutchinson et al. 2011; Larson N.L., 2008; Larson P.L., 2008a, 2008b, 2013; Larsson, 2008; Lautenschlager, 2015; Lipkin and Carpenter, 2008; Loewen et al. 2013; Longrich and Saitta, 2024; Molnar, 2008; Paul, 2008; Paul et al. 2022; Persons and Currie, 2011; Persons et al. 2020; Peterson and Daus, 2019; Rayfield, 2004; Reichel, 2010; Rothschild, 2013; Rothschild and Molnar, 2008; Samman, 2013; Smith et al. 2005; Snively et al. 2006; Snively and Russell, 2007; Stein and Triebold, 2013; Stevens et al. 2008; Thomson et al. 2013; Witmer and Ridgely, 2008, 2009
BHI 4100	Brown et al. 2015; Brusatte et al. 2012; Carr, 2010; Carr and Williamson, 2004; Gignac and Erickson, 2017; Larson N.L., 2008; Larson P.L., 2008a, 2008b, 2013; Molnar, 2008
BHI 4182	Brown et al. 2015*; Larson N.L., 2008; Larson P.L., 2008a, 2008b*, 2013
BHI 6219	Larson N.L., 2008
BHI 6230	Farlow et al. 2013; Lipkin and Carpenter, 2008; Molnar, 2008; Larson N.L., 2008; Larson P.L., 2008a, 2008b, 2013; Rothschild, 2013
BHI 6231	Larson P.L., 2008a
BHI 6232	Larson P.L., 2008a
BHI 6233	Larson P.L., 2008a
BHI 6235	Larson P.L., 2008a, 2013
BHI 6239	Larson N.L., 2008
BHI 6241	Larson P.L., 2013
BHI 6242	Larson P.L., 2008a
BHI 6243	Larson P.L., 2013
BHI 6248	Larson N.L., 2008
BHI 6402	Larson P.L., 2013
HRS specimens	Longrich and Saitta, 2024
Samson	Paul et al. 2022
Tristan Otto	Hamm et al. 2018, 2022; Paul et al. 2022; Sattler and Schwarz, 2019

Testing the Claims of Commercial Collectors

The results show that in the case of *T. rex*, vertebrate paleontology is on its back foot because it is unequivocally losing scientifically significant fossils to the commercial market. The 10 arguments posed by commercial interests that were described above are tested here based on the results of this survey.

1. **More fossils are discovered in a shorter time frame.** The results here find that; indeed, commercial interests have found more *T. rex* specimens since 1992 than public trusts have collected since 1892. However, the issue examined here is whether or not the commercially collected fossils are reposited in public trusts. The evidence shows that most *T. rex* fossils either stay in commercial stockrooms or they are in the collections of private individuals and so the high rate of commercial collection works against scientific interests, not for them. Therefore, the benefits of this claim are not supported by the evidence.
2. **Some commercially obtained fossils are intensely scientifically studied.** The results here find that this claim is true, but this practice contravenes scientific best practices as set out by the ethics guidelines of the SVP.
3. **The most significant fossil discoveries made by commercial entities have ended up in museums.** As pointed out above, and setting

aside the subjectivity in establishing what makes a fossil "the most significant," the majority of commercially collected *T. rex* - only nine of 80 fossils - do not wind up in public trusts. Therefore, this claim is not supported by the evidence.

4. **Many private collectors donate specimens to research programs.** This claim is not supported by the evidence - commercially collected specimens are obtained by museums through purchases (e.g., Sue, Dueler, Trix), not donations.
5. **There should be regulated amateur and commercial collecting on public lands.** The data here show that most commercially collected *T. rex* fossils (89%) do not wind up in public trusts; there is no reason to think that sales of dinosaur fossils to private individuals would not stop wherever fossils are collected, so this suggestion would not benefit science.
6. **Commercial collecting and the sale of fossils dates to the 1700s, so the practice should continue unimpeded.** The evidence collated here shows that most commercially collected *T. rex* fossils do not wind up in public trusts. There is a closer relationship between commercial collectors with auction houses and well-heeled individuals who purchase fossils than there is with public trusts. As such, this suggestion works against scientific interests.
7. **Concerns about fossil commerce are predominantly a North American attitude and free enterprise does not conflict with the science of paleontology.** Most commercially collected *T. rex* fossils are either in stockrooms or in private collections, so this set of claims is not supported by the data.
8. **Paleontology is an outlier among the sciences for having an issue with commercial collectors.** As with most of the claims assessed here, there is reason for academics to be wary of commercial collectors given that most commercially collected *T. rex* specimens are not reposited in public trusts.
9. **Commercial collectors abide by the principles of the AAPS.** The data shows that the specific principles regarding the reportage and deposition of specimens are not followed, since commercially collected specimens do not find their way into public trusts.
10. **There is an unfortunate misperception that commercial collectors are only out for money and have little interest in science and high price fossils are the exception, not the rule.** Commercially collected *T. rex* fossils are offered for sale, auctioned, or sold in the millions of dollars (Figure 5; Table 4) and most of the fossils do not make it into a public trust. Therefore, the evidence does not support these related claims.

SUMMARY

The evidence shows that commercial exploitation of *T. rex* fossils does not aid science because more than half the sample size has either been sold to private individuals or fossils sit in commercial stockrooms. Sample size, in addition to replication of observations, is a cornerstone of rigorous science; in the case of *T. rex*, the market has reduced the sample size to below the number required to quantitatively test hypotheses such as sexual dimorphism. In science, the value of dinosaur fossils is their information content and any new specimen is an opportunity to test previous hypotheses.

Although the quantification of information content presented here focuses on osteology, there are many other aspects of scientific study of *T. rex* skeletons to consider. The specimens lost to the market deprives science of better understanding *T. rex* in terms of histology and the inferences of growth and physiology that could be made from those data. Without the real specimens, science loses the isotopic data that are important for making secure inferences about diet, physiology, and paleoenvironment. This means that the real fossils cannot be replaced by casts or high-resolution CT-scans, or digital surface scans because scientifically informative data are present throughout a fossil.

In addition to the specimens, data loss includes the geological context of a fossil; in recent years, attention has become focused on the precise stratigraphic distribution of fossils in the Hell Creek Formation (Scannella et al. 2014). Without reliable locality data, commercially collected *T. rex* fossils cannot be put into the larger chronostratigraphic context with the rest of the faunal community (Santucci et al. 2016). Therefore, the commercial and private ownership of *T. rex* fossils has resulted in a tremendous amount of data loss since the entirety of the data - from the bones to the enclosing rock - are scientifically informative.

This scientific value of information content collides with the financial interests of commercial collectors, dealers, insurers, and auction houses, and it collides with the desires of a private collector to

possess a rare fossil. Although the phenomenon of the commodification of *T. rex* fossils only started in 1997 with the auction of Sue, the evidence shows that the private possession of them is not momentary. So far, none of the privately owned *T. rex* fossils have been donated to, or offered for purchase to a public trust, by a private estate. However, not enough time has elapsed to assess if transfer of *T. rex* fossils from a private collection to a public trust will be a trend or ever happen.

Finally, it is unclear whether the commercial trade effectively capitalizes on the scientific publications of privately owned fossils to enhance the value of their fossil wares. Either way, it is advisable for authors and editors to be more circumspect and rigorous regarding that questionable scientific practice, which is probably not limited to *T. rex*.

CONCLUSIONS

The evidence shows that the sample size of *Tyrannosaurus rex* has been damaged by commercial exploitation. In three brisk decades commercial interests have collected more scientifically significant fossils than the 132 years of collection made by public trusts. It is reasonable to assume that the number of *T. rex* reported here that were collected by commercial interests is an underestimation; other dinosaur species surface with regularity on the market, but their total numbers are unknown. The commercial exploitation of dinosaur fossils results in the concomitant loss of scientifically informative data. The evidence also shows that there is a lax scientific culture regarding the publication of data from privately owned *T. rex* fossils.

ACKNOWLEDGMENTS

I thank the editors of PE for facilitating the publication of this article. I also thank two anonymous reviewers for their constructive feedback that greatly improved the earlier drafts of the manuscript.

REFERENCES

AAPS. 2025a. AAPS Commercial Paleontology Code of Ethics. https://www.aaps.net/ethics.htm

AAPS. 2025b. Fossil specimens placed in museums and universities by professional (commercial) paleontology. 2 March 2025. The Journal of Paleontological Sciences. https://aaps-journal.org/Commercial-Contributions-to-Paleontology.html

The Amazing Traveling Dinosaur Show, Ltd. Facebook page. 2014. https://www.facebook.com/theamazingtravelingdinosaurshowltd/ [post dated: November 10, 2014]

Aukland Museum. 2022. https://web.archive.org/web/20221123123821/ https://www.aucklandmuseum.com/discover/research/barbara-the-t-rex

Barras, C. 2019. Baby tyrannosaur's eBay auction sparks outrage. Science News. 15 April 2019. https://doi.org/10.1126/science.aax7014

Bates, K.T., Manning, P.L., Hodgetts, D., and Sellers, W.I. 2009. Estimating mass properties of dinosaurs using later imaging and 3D computer modeling. PLoS ONE, 4:e4532. https://doi.org/10.1371/journal.pone.0004532

Bates, K.T. and Falkingham, P.L. 2012. Estimating maximum bite performance in *Tyrannosaurus rex* using multi-body dynamics. Biology Letters, 8:660–664. https://doi.org/10.1098/rsbl.2012.0056

Bonhams. 2006. *Tyrannosaurus rex* maxilla and teeth. 11 April 2006. https://www.bonhams.com/auctions/14423/lot/2073/

Bonhams. 2009. The *T. rex* known as Samson–one of the most complete https://www.bonhams.com/auctions/17517/lot/23/ specimens in existence. 3 October 2009. https://www.bonhams.com/auctions/17517/lot/23/

Bonhams. 2013. Superb https://www.bonhams.com/auctions/17517/lot/23/ maxilla with seven teeth - a recent discovery. 22 May 2013. https://www.bonhams.com/auction/21217/lot/2119/superb-tyrannosaurus-rex-maxilla-with-seven-teeth-a-recent-discovery/

Brown, C.M., VanBuren, C.S., Larson, D.W., Brink, K.S., Campione, N.E., Vavrek, M.J., and Evans, D.C. 2015. Tooth counts through growth in diapsid reptiles: implications for interpreting individual and size?related variation in the fossil record. Journal of Anatomy, 226:322–333. https://doi.org/10.1111/joa.12280

Brusatte, S.L., Carr, T.D., and Norell, M.A. 2012. The osteology of https://www.bonhams.com/auctions/17517/lot/23/, a gracile and long-snouted tyrannosaurid (Dinosauria: Theropoda) from the Late Cretaceous of Mongolia. Bulletin of the American Museum of Natural History 366:1–197. https://doi.org/10.1205/770.1

Burnham, B.A., Rothschild, B.M, and Nudds, J.R. 2022. Peter the https://www.bonhams.com/auctions/17517/lot/23/A paleontological study on a new specimen of https://www.bonhams.com/auctions/17517/lot/23/ named 'Peter'. https://www.aucklandmuseum.com/discover/research/peter_the_t-rex_scientific-report

Campione, N.E., Evans, D.C., Brown, C.M., and Carrano, M.T. 2014. Body mass estimation in on-avian bipeds using a theoretical conversion to quadruped stylopodial proportions. Methods in Ecology and Evolution 5:913–923. https://doi.org/10.1111/2041-210X.12226

Carr, T.D. 2010. A taxonomic assessment of the type series of https://www.bonhams.com/auctions/17517/lot/23/ and the identity of Tyrannosauridae (Dinosauria, Coelurosauria) in the https://www.bonhams.com/auctions/17517/lot/23/ bonebed from the Horseshoe Canyon Formation (Campanian-Maastrichtian, Late Cretaceous). Canadian Journal of Earth Sciences 47:1213–1226. https://doi.org/10.1139/E10-035

Carr, T.D. 2020. A high-resolution growth series of https://www.bonhams.com/auctions/17517/lot/23/ obtained from multiple lines of evidence. PeerJ 8:e9192. https://doi.org/10.7717/peerj.9192

Carr, T.D., and Williamson, T.E. 2004. Diversity of late Maastrichtian Tyrannosauridae (Dinosauria: Theropoda) from western North America. Zoological Journal of the Linnean Society 142:479–523. https://doi.org/10.1111/j.1096-3642.2004.00130.x

Carr, T.D., Williamson, T.E., and Schwimmer, D.R. 2005. A new genus and species of tyrannosauroid from the Late Cretaceous (Middle Campanian) Demopolis Formation of Alabama. Journal of Vertebrate Paleontology 25:119–143. https://doi.org/10.1671/0272-4634(2005)025[0119:ANGASO]2.0.CO;2

Carrano, M.T. and Hutchinson, J.R., 2002. Pelvic and hindlimb musculature of *Tyrannosaurus rex* (Dinosauria: Theropoda). Journal of Morphology, 253:207–228. https://doi.org/10.1002/jmor.10018

Carroll, L. 2014. Young T-rex could be yours for a cool $10 million. The National News. 5 October 2014. https://www.thenationalnews.com/uae/young-t-rex-could-be-yours-for-a-cool-10-million-1.256365

Cascone, S. 2024. https://www.bonhams.com/auctions/17517/lot/23/ skeleton sells for a whopping $44 million, a dinosaur auction record. Artnet. July 2024. https://news.artnet.com/art-world/44-million-stegosaurus-skeleton-sothebys-sale-2513335

Chippindale, C. and Gill, D.W.J. 2000. Material consequences of contemporary classical collecting. American Journal of Archaeology, 104:463–511. https://doi.org/10.2307/507226

Christie's. 2020. The life and times of STAN – one of the most complete https://www.bonhams.com/auctions/17517/lot/23/ skeletons ever found. https://www.christies.com/features/The-life-of-STAN-a-T-rex-excavated-in-1992-10872-7.aspx

Christie's. 2022. Shen the https://www.bonhams.com/auctions/17517/lot/23/The first https://www.bonhams.com/auctions/17517/lot/23/ skeleton ever to be offered at Auction in Asia. 29 September 2022. https://www.christies.com/presscenter/pdf/10652/Christie%E2%80%99s%20Hong%20Kong%20Proudly%20Presents%20SHEN%20THE%20T.%20REX_The%20First%20Tyrannosaurus%20Rex%20Skeleton%20Ever%20to%20be%20Offered%20at%20Auction%20in%20Asia_10652_1.pdf

Cisneros, J.C., Raja, N.B., Ghilardi, A.M., Dunne, E.M., Pinheiro, F.L., Fernández, O.R.R., Sales, M.A.F., Rodríguez-de la Rosa, R.A., Miranda-Martínez, A.Y., Gonzalez-Mora, S., González-Mora, S., Bantim, R.A.M., de Lima, F.J., and Pardo, J.D. 2022. Digging deeper into colonial paleontological practices in modern day Mexico and Brazil. Royal Society Open Science, 9:1–32. https://doi.org/10.1098/rsos.210898

CK Preparations. 2021. https://web.archive.org/web/20250223161548/https://ckpreparations.com/

Coggins, C.C. 1998. United States cultural property legislation: observations of a combatant. International Journal of Cultural Property 7:52–68. https://doi.org/10.1017/S0940739198770067

Conniff, R. 2019. Inside the homes (and minds) of fossil collectors. National Geographic. October 2019. https://www.nationalgeographic.com/culture/article/dinosaur-fossils-collector-feature

Cruz, A. 2022. Former mayor of San Pedro Garza and collector Mauricio Fernandez retires from social media due to health problems. PubliMetro. 16 June 2022. https://www.publimetro.com.mx/publimetro-tv/2022/06/16/mauricio-fernandez-garza-se-retira-de-las-redes-sociales-por-problemas-de-salud/

Currie, P.J. 1998. Possible evidence of gregarious behavior in tyrannosaurids. Gaia, 15:123–133. https://doi.org/10.7939/R3348GX03

Currie, P.J. 2003a. Cranial anatomy of tyrannosaurid dinosaurs from the late Cretaceous Alberta, Canada. Acta Paleontological Polonica 48:191–226. https://doi.org/10.7939/R3M90287B

Currie, P.J. 2003b. Allometric growth in tyrannosaurids (Dinosauria: Theropoda) from the upper Cretaceous of North America and Asia. Canadian Journal of Earth Sciences 40:651–665. https://doi.org/10.1139/e02-083

Currie, P.J. 2023. Celebrating dinosaurs: their behavior, evolution, growth, and physiology. Canadian Journal of Earth Sciences, 60:263–293. https://doi.org/10.1139/cjes-2022-0131

Currie, P.J., Hurum, J.H., and Sabath, K. 2003. Skull structure and evolution in tyrannosaurid dinosaurs. Acta Palaeontologica Polonica, 48:227–234. https://doi.org/10.7939/R31Z41S6Z

Dalman, S.G. and Lucas, S.G. 2017. On the Dentary in the Fukui Prefactural Dinosaur Museum of https://www.bonhams.com/auctions/17517/lot/23/ (Theropoda: Tyrannosauridae) from the Dinosaur Park formation (Upper Cretaceous) of Alberta, Canada. Memoir of the Fukui Prefectural Dinosaur Museum, 16:17–27.

Dalman, S.G., Loewen, M.A., Pyron, R.A., Jasinski, S.E., Malinzak, D.E., Lucas, S.G., Fiorillo, A.R., Currie, P.J., and Longrich, N.R. 2024. A giant tyrannosaur from the Campanian-Maastrichtian of southern North America and the evolution of tyrannosaurid gigantism. Scientific Reports, 14:22124. https://doi.org/10.1038/s41598-023-47011-0

Dececchi, A., Mloszewska, A., Holtz, Jr., T., Habib, M., and Larsson, H. 2020. The fast and the frugal: divergent locomotory strategies drive limb lengthening in theropod dinosaurs. PLoS One:e0223698. https://doi.org/10.1371/journal.pone.0223698

Demeulemeester, T. and Stein, K. 2022. Dinosaurs are Collectible. Digging for Dinosaurs: The Art, The Science. Lannoo, Belgium.

Derstler, K. and Myers, J.M. 2008. Preliminary account of the tyrannosaurid Pete from the Lance Formation of Wyoming, p.67–73. In Larson, P.L. and Carpenter, K. (eds.), https://www.bonhams.com/auctions/17517/lot/23/, the Tyrant King. Indiana University Press, Bloomington.

Dinoland Plus. T-rex, Nano Rex, and Special Items. https://www.dinolandplus.com/animal-index/view/category/t-rex-nano-rex-and-special-items

Dinosaur Science Museum. 2024. https://web.archive.org/web/20240624182650/https://dinosaurproject.swau.edu/museum/

Dorr, B. 2021. Torvik is finished! Construction of a spectacular https://www.bonhams.com/auctions/17517/lot/23/ skeleton completed. Wochen Zeitung. 13 December 2021.

https://www.wochenzeitung-online.de/torvik_ist_fertig_konstruktion_eines_spektakulaeren_trex_skeletts_abgeschlossen/

Dura, J. 2021. Rare fossils, potentially new dinosaurs uncovered at North Dakota dig site. The Bismarck Tribune. 23 October 2021. https://bismarcktribune.com/news/science/rare-fossils-potentially-new-dinosaurs-uncovered-at-north-dakota-dig-site/article_18b2787c-d6c7-549f-9321-587c9ecb95fd.html

eCFAR. 2025. Title 43/Subtitle A/Part 49–Paleontological Resources Preservation. https://www.ecfr.gov/current/title-43/subtitle-A/part-49

Farlow, J.O., Holtz Jr, T.R., Worthy, T.H., and Chapman, R.E. 2013. Feet of the fierce (and not so fierce): pedal proportions in large theropods, other non-avian dinosaurs, and large ground birds, p. 88–132. In Parrish, J.M., Molnar, R.E., Currie, P.J., and Koppelhus, E.B. (eds.), Tyrannosaurid Paleobiology. Indiana University Press, Bloomington.

Field Museum. 2018. Sue the *T. rex:* Get to know the dinosaur known as specimen FMNH PR2081. https://www.fieldmuseum.org/blog/sue-t-rex

Fourcade, H. 2011. Cents and sensibility: Economic valuation and the nature of "nature". American Journal of Sociology, 116:1721–1777. https://doi.org/10.1086/659640

Geggel, L. 2022. Spectacular https://www.bonhams.com/auctions/17517/lot/23/ skeleton may fetch $25 million at auction (the new owner gets to name it, too). Live Science. 2022, September 30. https://www.livescience.com/tyrannosaurus-rex-shen-auction

Girardon, C. 2022. Lyon: Ryker, the *T. rex* with the "traumatic life" will fascinate the public. 20 Minutes. 13 November 2022. https://www.20minutes.fr/culture/4009742-20221113-lyon-ryker-rex-vie-traumatisante-va-fasciner-public#xtor=RSS-149

Gignac, P.M. and Erickson, G.M. 2017. The biomechanics behind extreme osteophagy in *Tyrannosaurus rex*. Scientific Reports, 7:2012. https://doi.org/10.1038/s41598-017-02161-w

Goldstein, C. 2022. Christie's auctioned off a *Velociraptor* skeleton for $12.4 million, eviscerating its $6 million estimate. Artnet. 13 May 2022. https://news.artnet.com/art-world/dinosaur-skeleton-christies-2114482

Gorman, T. 2022. Woodland Park paleontology team discovers T. Rex fossil in South Dakota after 25-year search. CPR News. https://www.cpr.org/2022/10/30/woodland-park-paleontology-t-rex-fossil-discovery-south-dakota/

Greshko, M. 2022. Stan the *T. rex* found! World's most expensive fossil finds home in a new museum. National Geographic. 23 March 2022. https://www.nationalgeographic.com/science/article/stan-the-t-rex-found-worlds-most-expensive-fossil-finds-home-in-a-new-museum

Gross, M. 2020. Dealing with dinosaurs. Current Biology, 30:R1331–R1334. https://doi.org/10.1016/j.cub.2020.10.079

Hamm, C., Mallison, H., Hempe, O., Schwarz, D., Mews, J., Blobel, J., Issever, A.S., and Asbach, P. 2018. Efficiency, workflow and image quality of clinical computed tomography scanning compared to photogrammetry on the example of a *Tyrannosaurus rex* skull from the Maastrichtian of Montana, U.S.A. Journal of Paleontological Techniques, 21:1–13.

Hamm, C., Hampe, O., Mews, J., Günter, C., Milke, R., Witzmann, F., Savic, L., Hecht, L., Meister, S., Hamm, B., Asbach, P., and Diekoff, T. 2022. Quantitative dual-energy CT as a nondestructive tool to identify indicators for fossilized bone in vertebrate paleontology. Scientific Reports, 12:16407. https://doi.org/10.1038/s41598-022-20707-5

Happ, J. 2008. An analysis of predator-prey behavior in a head-to-head encounter between *Tyrannosaurus rex* and *Triceratops*, p. 355–370. In Larson, P.L. and Carpenter, K. (eds.), *Tyrannosaurus rex*, the Tyrant King. Indiana University Press, Bloomington.

Haug, C., Reumer, J.W.F., Haug, J.T., Arillo, A., Audo, D., Azar, D., Baranov, V., Beutel, R., Charbonnier, S., Feldmann, R., Foth, C., Fraaije, R.H.B., Frenzel, P., Gašparic, R., Greenwalt, D.E., Harms, D., Hyzný, M., Jagt, J.W.M., Jagt-Yzykova, E.A., Jarzembowski, E., Kerp, H., Kirejtshuk, A.G., Klug, C., Kopylov, D.S., Kotthoff, U., Kriwet, J., Kunzmann, L., McKellar, R.C., Nel, A., Neumann, C., Nützel, A., Perrichot, V., Pint, A., Rauhut, O.,

Schneider, J., Schram, F.R., Scheigert, G., Selden, P., Szwedo, J., van Bakel, B.W.M., van Eldijk, T., Vega, F.J., Wang, B., Wang, Y., Xing, L., and M. Reich. (2020). Comment on the letter of the Society of Vertebrate Paleontology (SVP) dated April 21, 2020 regarding “Fossils from conflict zones and reproducibility of fossil-based scientific data”: the importance of private collections. Palaontologische Zeitschrift, 94:413–429. https://doi.org/10.1007/s12542-020-00522-x

Hilsman, P. 2022. Sotheby’s to action one the most complete *T. rex* skulls ever discovered. UPI. 8 November 2022. https://www.upi.com/Top_News/US/2022/11/08/sothebys-tyrannosaurs-rex-auction/5581667924810/

Hippensteel, S. and Condliffe, S. 2013. Profiting from the past: Are fossils a sound investment? Geological Society of America Today, 23:27–29. https://doi.org/10.1130/GSATG179GW.1

Holtz, T.R., Jr. 1995. The arctometatarsalian pes, an unusual structure of the metatarsus of Cretaceous Theropoda (Dinosauria: Saurischia). Journal of Vertebrate Paleontology, 14:480–519. https://doi.org/10.1080/02724634.1995.10011574

Hone, D.W.E. and Mallon, J.C. 2017. Protracted growth impedes the detection of sexual dimorphism in non-avian dinosaurs. Palaeontology, 60:535–545. https://doi.org/10.1111/pala.12298

Hurum, J. H. and Currie., P.J. 2000. The crushing bite of tyrannosaurids. Journal of Vertebrate Paleontology, 3:619–691. https://doi.org/10.1671/0272-4634(2000)020[0619:TCBOT]2.0.CO;2

Hurum, J.H. and Sabath, K., 2003. Giant theropod dinosaurs from Asia and North America: skulls of *Tarbosaurus bataar* and *Tyrannosaurus rex* compared. Acta Palaeontologica Polonica, 48:161–190.

Hutchinson, J.R., Bates, K.T., Molnar, J., Allen, V., and Makovicky, P.J. 2011. A computational analysis of limb and body dimensions in *Tyrannosaurus rex* with implications for locomotion, ontogeny, and growth. PLoS ONE, 9:e97055. https://doi.org/10.1371/journal.pone.0026037

Jones, E.D. 2020. Assumptions of authority: the story of Sue the *T-rex* and controversy over access to fossils. History and Philosophy of the Life Sciences, 42:2. https://doi.org/10.1007/s40656-019-0288-4

Keaten, J.2023a. *T. rex* skeleton expected to fetch millions at Zurich auction. Phys Org. 18 April 2023a. https://phys.org/news/2023-04-rex-skeleton-millions-zurich-auction.html

Keaten, J. 2023b. *T. rex* fossil sells for more than $5M at Zurich auction. PBS News Hour. 18 April 2023. https://www.pbs.org/newshour/science/t-rex-fossil-sells-for-more-than-5m-at-zurich-auction

Kokkegård, H. 2021. DTU 3D scans of dinosaur skull. 23 April 2021. https://3dim-industry-portal.dtu.dk/news/nyhed?id=ffd517c9-e78f-407b-ae7d-88c31bc2da69

Koller Auctions. 2023. TRX-293 Trinity. https://kollerauktionen.auctioneersvault.com/catalogues/TRX-293/Kościński, K. and Pietraszewski, S. 2004. Methods to estimate sexual dimorphism from unsexed samples: a test with computer-generated samples. Anthropological Review, 67:33–55.

Kościński, K. and Pietraszewski, S. 2004. Methods to estimate sexual dimorphism from unsexed samples: a test with computer-generated samples. Anthropological Review, 67:33-55.

Larson, N.L. 2008. One hundred years of *Tyrannosaurus rex:* The skeletons, p. 1-55. In Larson, P.L. and Carpenter, K. (eds.), *Tyrannosaurus rex,* the Tyrant King. Indiana University Press, Bloomington.

Larson, P.L. 2008a. Variation and sexual dimorphism in *Tyrannosaurus rex,* p. 103–127. In Larson, P.L. and Carpenter, K. (eds), *Tyrannosaurus rex*, the Tyrant King. Indiana University Press, Bloomington.

Larson, P.L. 2008b. Atlas of the skull bones of *Tyrannosaurus rex*, p. 233–243. In Larson, P.L. and Carpenter, K. (eds.), *Tyrannosaurus rex,* the Tyrant King. Indiana University Press, Bloomington.

Larson, P.L. 2013. The case for *Nanotyrannus,* p. 15-53. In Parrish, M.J., Molnar, R.E., Currie, P.J., and Koppelhus, E.B. (eds.), Tyrannosaurid Paleobiology, Indiana University Press, Bloomington.

Larson, P.L. 2023. Preserving fossil resources: an elegant solution for the public and private sector. SVP 2023 Program Guide: 263.
Larson, P.L. and Russell, D. 2014. The benefits of commercial fossil sales to 21st-century paleontology. Palaeontologia Electronica, 17:1–7. https://doi.org/10.26879/142
Larson, N.L., Stein, W., Triebold, M., and Winters, G. 2014. What commercial fossil dealers contribute to the science of paleontology. Association of Applied Paleontological Sciences – Journal:1–10. https://www.aaps-journal.org/Fossil-Dealer-Contributions.html
Larsson, H.C. 2008. Palatal kinesis of *Tyrannosaurus rex*, p. 245–252. In Larson, P.L. and Carpenter, K. (eds.), *Tyrannosaurus rex,* the Tyrant King. Indiana University Press, Bloomington.
Lautenschlager, S. 2015. Estimating cranial musculoskeletal constraints in theropod dinosaurs. Royal Society Open Science, 2:150495. https://doi.org/10.1098/rsos.150495
Lipkin, C. and Carpenter, K., 2008. Looking again at the forelimb of *Tyrannosaurus rex*, p. 166–190. In Larson, P.L. and Carpenter, K. (eds.), *Tyrannosaurus rex,* the Tyrant King. Indiana University Press, Bloomington.
Loewen, M.A., Irmis, R.B., Sertich, J.J.W., Currie, P.J., and Sampson, S.D. 2013. Tyrant dinosaur evolution tracks the rise and fall of Late Cretaceous oceans. PLoS ONE, 8:e79420. https://doi.org/10.1371/journal.pone.0079420
Longrich, N.R. and Saitta, E.T. 2024. Taxonomic status of *Nanotyrannus lancensis* (Dinosauria: Tyrannosauroidea) – a distinct taxon of small-bodied tyrannosaur. Fossil Studies, 2:1–65. https://doi.org/10.3390/fossils2010001
Mazurek, S.K. 2020. The dinosaur in the living room: proposal to enable academic access to fossils discovered on private land. Fordham Intellectual Property, Media and Entertainment Law Journal, 31:272.
McCoy, D. 2018. *T. rex* Ivan opening as permanent display at Museum of World Treasures. Wichita Business Journal. 16 February 2018. https://www.bizjournals.com/wichita/news/2018/02/16/t-rex-ivan-opening-as-permanent-display-at-museum.html
Metarex. 2021. https://web.archive.org/web/20211101223514/https://metarex.io/
Molnar, R.E. 2008. Reconstruction of the jaw musculature of *Tyrannosaurus rex*, P. 254–281. In Larson, P.L. and Carpenter, K. (eds.), *Tyrannosaurus rex*, the Tyrant King. Indiana University Press, Bloomington.
Murray, J. 2021. 'Real' *T rex* goes on show in England for first time in over a century. The Guardian. 3 July 2021. https://www.theguardian.com/culture/2021/jul/03/real-t-rex-goes-on-show-in-england-for-first-time-in-over-a-century
Museum Für Naturkunde Berlin. 2018. Tristan Otto. https://www.museumfuernaturkunde.berlin/en/tristan-otto-0
My Nottingham News. 2021. World Exclusive *T. rex* Exhibition to Open in Nottingham. My Nottingham News. 27 April 2021. https://www.mynottinghamnews.co.uk/world-exclusive-t-rex-exhibition-to-open-in-nottingham/
NZ Herald. 2022. Double dinosaurs: *T-Rex* Barbara joins Peter at Auckland Museum. New Zealand Herald. 23 November 2022. https://www.nzherald.co.nz/nz/monstrous-attraction-for-auckland-museum/4VPWMEOUFJDX5CASUD6VT7HRM4/
Olson, D. 2021. Newly uncovered North Dakota fossils could stir *T. rex* vs. *Nanotyrannus* debate. The Dickinson Press. 23 October 2021. https://www.thedickinsonpress.com/news/newly-uncovered-north-dakota-fossils-could-stir-t-rex-vs-nanotyrannus-debate?fbclid=IwAR2IDpjNfifgwKtFkAuqjZdYFZBtQepAp4-
PaleoAdventures. 2022. https://www.youtube.com/watch?v=doJ9Ik3HDe0
Pangea Fossils Facebook page. 2023. https://www.facebook.com/story.php?story_fbid=801626918419683&id=100057171471688&_rdr

Paul, G.S. 2008. The extreme lifestyles and habits of the gigantic tyrannosaurid superpredators of the Late Cretaceous of North America and Asia, p. 307–354. In Larson, P.L. and Carpenter, K. (eds.), *Tyrannosaurus rex*, the Tyrant King. Indiana University Press, Bloomington.

Paul, G.S., Persons, W.S., and Van Raalte, J. 2022. The tyrant lizard king, queen and emperor: Multiple lines of morphological and stratigraphic evidence support subtle evolution and probable speciation within the North American genus *Tyrannosaurus*. Evolutionary Biology, 49:156–179. https://doi.org/10.1007/s11692-022-09561-5

Paxton-Turner, A.A. 2020. Fossil fortunes: Regulating commercial paleontology and incentivizing fossil discovery. Texas Environmental Law Journal 50:31–54.

Persons, W.S. and Currie, P.J. 2011. The tail of *Tyrannosaurus*: reassessing the size and locomotive importance of the M. caudofemoralis in non?avian theropods. The Anatomical Record: Advances in Integrative Anatomy and Evolutionary Biology, 294:119–131. https://doi.org/10.1002/ar.21290

Persons, W.S., Currie, P.J., and Erickson, G.M. 2020. An older and exceptionally large adult specimen of *Tyrannosaurus rex*. The Anatomical Record, 303:656-672. https://doi.org/10.1002/ar.24118.

Peterson, J.E. and Daus, K.N. 2019. Feeding traces attributable to juvenile *Tyrannosaurus rex* offer insight into ontogenetic dietary trends. PeerJ, 7:e6573. https://doi.org/10.7717/peerj.6573

Poese, K. 2018. *T-Rex* "Rocky" is now at home in Denkendorf. Skeleton gets permanent location in the Dinopark. Donaukurier. 31 July 2018. https://www.donaukurier.de/lokales/eichstaett/DKmobil-Denkendorf-Dinopark-Denkendorf-wochennl312018-T-Rex-Rocky-ist-jetzt-in-Denkendorf-zu-Hause;art575,3868520

Raja, N.B. and Dunne, E.M. 2023. Fossil trafficking, fraud, and fakery, p. 61–79. In N. Oosterman and Yates, D. (eds.), Art Crime in Context, Studies in Art, Heritage, Law, and the Market 6. https://doi.org/10.1007/978-3-031-14084-6_5

Rayfield, E.J. 2004. Cranial mechanics and feeding in *Tyrannosaurus rex*. Proceedings of the Royal Society of London. Series B: Biological Sciences, 271:1451–1459. https://doi.org/10.1098/rspb.2004.2755

Reichel, M. 2010. The heterodonty of *Albertosaurus sarcophagus* and *Tyrannosaurus rex*: biomechanical implications inferred through 3-D models. Canadian Journal of Earth Sciences, 47:1253–1261. https://doi.org/10.1139/E10-063

Renda, M. 2017. Incomplete *T. rex* fossil leads to contract dispute. Courthouse News Service. 2 June 2017. https://www.courthousenews.com/incomplete-t-rex-fossil-leads-contract-dispute/

Robaglia, B. 2022. Here's who buys dinosaur skeletons at auction and why. Barneby's Magazine. 13 December 2022. https://www.barnebys.com/blog/heres-who-buys-dinosaur-skeletons-at-auction-and-why

Robert Butch Vallee v. Terry Ciotka at al. Pacermonitor. 2018. https://urldefense.com/v3/__https://www.pacermonitor.com/public/case/21591599/Robert_Butch_Vallee_v_Terry_Ciotka_et_al__;!!DWqe1SB0EKY-!MiyFLZfcTN_dSgSee_89H7n9Kvy8GgPk3plQkRvfJ_wV94Db0JMhH1ZblBZUvkjr8Kluo0esrAZPBMltICkCJMprwg$

Roddy, B. 2022. Can you dig it? Yes, you can! But at what cost?: proposal for the protection of domestic fossils on private land. Texas A and M Journal of Property Law, 8:473–506. https://doi.org/10.37419/jpl.v8.i4.3

Rothschild, B.M. 2013. Clawing their way to the top: Tyrannosaurid pathology and lifestyle, p. 210-221. In Parrish, M.J., Molnar, R.E., Currie, P.J., and Koppelhus, E.B. (eds.), Tyrannosaurid Paleobiology, Indiana University Press, Bloomington.

Rothschild, B.M. and Molnar, R.E. 2008. Tyrannosaurid pathologies as clues to nature and nurture in the Cretaceous, p. 287–304. In Larson, P.L. and Carpenter, K. (eds.), *Tyrannosaurus rex*, the Tyrant King. Indiana University Press, Bloomington.

Saitta, E.T. 2020. The Society of Vertebrate Paleontology's publication policy is inconsistent with scientific epistemology. Unpublished manuscript. https://osf.io/preprints/paleorxiv/xmkhb

Samman, T. 2013. Tyrannosaurid Craniocervical Mobility: A preliminary qualitative assessment, p.195–210. In Parrish, M.J., Molnar, R.E., Currie, P.J., and Koppelhus, E.B. (eds.), *Tyrannosaurid Paleobiology*, Indiana University Press, Bloomington.

Santucci, V.L., Newman, P., and Taff, B.D. 2016. Toward a conceptual framework for assessing the human dimensions of paleontological resources. In Sullivan, R.M. and Lucas, S.G. (eds.), Fossil Record 5. New Mexico Museum of Natural History and Science Bulletin, 5:239–248.

Sattler, F. and Schwarz, D. 2019. Tooth replacement in a specimen of *Tyrannosaurus rex* (Dinosauria, Theropoda) from the Hell Creek Formation (Maastrichtian), Montana. Historical Biology 33:949–972. https://doi.org/10.1080/08912963.2019.1675052

Scannella, J.B., Fowler, D.W., Goodwin, M.B., and Horner, J.R. 2014. Evolutionary trends in *Triceratops* from the Hell Creek Formation, Montana. Proceedings of the National Academy of Sciences, 111:10245–10250. https://doi.org/10.1073/pnas.1313334111

Schultz, A. 2020. Christie's sells 'Stan' the *T. rex* for $27.5M. Barron's. 6 October 2020. https://www.barrons.com/articles/christies-sells-stan-the-t-rex-for-27-5m-01602036284

Shaw, A. 2023. Baby *T rex* at Frieze Masters seeks new home–for $20m. The Art Newspaper. 10 October 2023. Shaw, A. 2023. https://www.theartnewspaper.com/2023/10/10/baby-t-rex-at-frieze-masters-seeks-new-home

Shimada, K., Currie, P.J., Scott, E., and S.S. Sumida. 2014. The greatest challenge to 21st century paleontology: When commercialization of fossils threatens the science. Paleontologia Electronica, 17.1.1E:1–4. https://doi.org/10.26879/141

Simons, L.M. 2020. Fossil Wars. National Geographic. 2020. Simons, L.M. Fossil Wars. National Geographic. https://www.nationalgeographic.com/science/article/fossil-wars?fbclid=IwAR3RqkOH-UvL9QqBXEL1Xqb3U_xROPWmmCwvQARlEb4yQ6tFqCXt6Pgkx8o

Smith, J.B., Vann, D.R., and Dodson, P. 2005. Dental morphology and variation in theropod dinosaurs: implications for the taxonomic identification of isolated teeth. The Anatomical Record Part A: Discoveries in Molecular, Cellular, and Evolutionary Biology: An Official Publication of the American Association of Anatomists, *285*:699–736. https://doi.org/10.1002/ar.a.20206

Snively, E., Henderson, D.M., and Phillips, D.S. 2006. Fused and vaulted nasals of tyrannosaurid dinosaurs: implications for cranial strength and feeding mechanics. Acta Palaeontologica Polonica, 51:435–454.

Snively, E. and Russell, A.P. 2007. Functional morphology of neck musculature in the Tyrannosauridae (Dinosauria, Theropoda) as determined via a hierarchical inferential approach. Zoological Journal of the Linnean Society, 151:759–808. https://doi.org/10.1111/j.1096-3642.2007.00334.x

Stein, W.W. 2019. Taking count: A census of dinosaur fossils recovered from the Hell Creek and Lance Formations (Maastrichtian). The Journal of Paleontological Sciences, 8:1–42. https://www.aaps-journal.org/pdf/JPS.C.2019.01b.pdf

Stein, W.W. and Triebold, M. 2013. Preliminary analysis of a sub-adult tyrannosaurid skeleton from the Judith River Formation of Petroleum County, Montana, p. 55–77. In Parrish, M.J., Molnar, R.E., Currie, P.J., and Koppelhus, E.B. (eds.), Tyrannosaurid Paleobiology, Indiana University Press, Bloomington.

Stevens, K.A., Larson, P.L., Wills, E.D., and Anderson, A. 2008. Rex, sit: Digital modeling of *Tyrannosaurus rex* at rest, p. 193–204. In Larson, P.L. and Carpenter, K. (eds.), *Tyrannosaurus rex*, the Tyrant King. Indiana University Press, Bloomington.

Stoneberg, D. 2018. *T-rex* skeleton 'Roosevelt' on display in St. Helena's Erin Martin Design showroom. Napa Valley Register. 11 July 2018. https://napavalleyregister.com/news/local/t-rex-skeleton-roosevelt-on-display-in-st-helena-s/article_8fc92cf0-64d4-50bc-83bd-4d0bc91c0f38.html

SVP. 2020. Auction of *T. rex* "Stan." 24 September 2020. https://vertpaleo.org/wp-content/uploads/2021/01/SVP-letter-to-Christies-Auction-House.pdf

Theropoda Expeditions. 2017. https://web.archive.org/web/20170508091818/http://www.theropodaexpeditions.com:80/

Thomson, T.J., Irmis, R.B., and Loewen, M.A. 2013. First occurrence of a tyrannosaurid dinosaur from the Mesaverde Group (Neslen Formation) of Utah: implications for upper Campanian Laramidian biogeography. Cretaceous Research, 43:70–79. https://doi.org/10.1016/j.cretres.2013.02.006

Tie, A. 2018. How Hongkongers got to meet a 12-metre-long *T. rex* dinosaur. Style. 12 June 2018. https://www.scmp.com/magazines/style/news-trends/article/2150319/how-hongkongers-got-meet-12-metre-long-trex-dinosaur

Tribe, T.F. 2023. See the real *Tyrannosaurus rex* Tyson fossils at a rare exhibit in Tokyo. Tokyo Families. 10 March 2023. https://web.archive.org/web/20230407124232/https://tokyofamilies.net/2023/03/see-the-real-tyrannosaurus-rex-tyson-fossils-at-a-rare-exhibit-in-tokyo/

Triebold Paleontology. 2024. *Nanotyrannus lancensis*. https://www.trieboldpaleontology.com/dinosaurs/nanotyrannus-lancensis

Trimble, L. 2019. Is Grand Avenue changing? Phoenix New Times. 6 November 2019. https://www.phoenixnewtimes.com/arts/is-grand-avenue-changing-11379335

Vondracek, C. 2018. South Dakota *T. rex* dispute lands in court. Rapid City Journal. 19 June 2018. https://rapidcityjournal.com/news/local/south-dakota-t-rex-dispute-lands-in-court/article_5a5a188f-d4c6-51ab-a6c8-9275a13cbcae.html

Weishampel, D.B., Dodson, P., and H. Osmólska. 2004. The Dinosauria: Second Edition. University of California Press, Berkeley.

Winters, G. 2014. Fossil specimens placed in museums and universities by commercial paleontology. Journal of Paleontological Sciences. #7 Commentary page. https://aaps-journal.org/commercial-contributions-to-paleontology.html

Witmer, L.M. 1995. The extant phylogenetic bracket and the importance of reconstructing soft tissues in fossils p. 19–33. In Thomason, J.J. (ed.), Functional Morphology in Vertebrate Paleontology. Cambridge University Press, Cambridge.

Witmer, L.M. and Ridgely, R.C., 2008. The paranasal air sinuses of predatory and armored dinosaurs (Archosauria: Theropoda and Ankylosauria) and their contribution to cephalic structure. The Anatomical Record: Advances in Integrative Anatomy and Evolutionary Biology: Advances in Integrative Anatomy and Evolutionary Biology, 291:1362–1388. https://doi.org/10.1002/ar.20794

Witmer, L.M. and R.C. Ridgley. 2009. New insights into the brain, braincase and ear region of tyrannosaurs (Dinosauria, Theropoda) with implications for sensory organization and behavior. Anatomical Record, 292:1266–1296. https://doi.org/10.1002/ar.20983