

Institution: University of Edinburgh		
Unit of Assessment: 7		
Title of case study: Public Engagement shines a light on the rise and fall of the dinosaurs		
Period when the underpinning research was undertaken: 2013 - 2018		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): Steve Brusatte	Role(s) (e.g. job title): Professor of Palaeontology and Evolution	Period(s) employed by submitting HEI: 01/2013 - current
Period when the claimed impact occurred: January 2015 – December 2020		
Is this case study continued from a case study submitted in 2014? N		
1. Summary of the impact (indicative maximum 100 words) Research on the anatomy, biology, and evolution of dinosaurs by Prof. Stephen Brusatte at the University of Edinburgh has engaged a broad global audience through a range of media. Presenting the television programme <i>T. rex Autopsy</i>, broadcast worldwide, he used a novel approach of full-body model dissection to explain dinosaur anatomy. Brusatte's book <i>The Rise and Fall of the Dinosaurs</i> presented a new history of dinosaur evolution based on his research and sold over 150,000 copies worldwide, very high for a popular science book. He has been engaged as specialist advisor on <i>Jurassic World</i> since 2018 to ensure scientifically accurate dinosaurs appear in a blockbuster film. Beneficiaries include a diverse audience of the general public around the globe, including readers in languages that are under-engaged in popular science books; publishers; broadcasters and film makers.		
2. Underpinning research (indicative maximum 500 words) Brusatte's research has articulated a new view of dinosaur evolution: that key dinosaur groups rose to dominance gradually, that dinosaurs were more intelligent and better adapted than previously thought, and that major events in their evolution occurred in response to sudden environmental or ecological changes after long periods of background evolution. This view has been articulated to the public through the books, television programs, and film detailed in this Impact Case Study. Overall, this research has fundamentally changed our knowledge of this critical period significantly enough to require a new narrative for the rise and fall of the dinosaurs to be presented by the media to the general population. The research falls into three main categories. Redefining the evolution of birds from dinosaurs First, his work on dinosaur genealogy has produced a comprehensive phylogeny (family tree) of the bird-like dinosaurs, showing that birds are closely related to small, feathered 'raptors' like <i>Velociraptor</i> [3.1]. He performed novel statistical analyses, using this phylogeny and a large dataset of anatomical characteristics, to show for the first time that there is no clear anatomical distinction between birds and other dinosaurs, indicating that birds gradually evolved from dinosaurs over 100+ million years [3.1]. However, once a flight-worthy bird had emerged, these first birds then began evolving faster than other dinosaurs [3.1]. Brusatte's description of <i>Zhenyuanlong</i>, a new species of 'raptor' with feathers and wings, showed that wings evolved before flight, most likely as display structures [3.2]. Together, this work indicates that major evolutionary transitions occur after a period of		

gradual evolution finally permits organisms to evolve a new behaviour or lifestyle, which then allows them to suddenly evolve quicker.

Improved understanding of the natural history of the Tyrannosaurs family

Second, his work on the evolution of tyrannosaurs (the group of carnivorous dinosaurs including *T. rex* and its kin) has produced the largest and most comprehensive phylogeny (family tree) of the group [3.3]. This shows that tyrannosaurs began as small, human-sized, fast-running animals that were minor predators in their ecosystems, living more than 100 million years before *T. rex*. It was only towards the end of the Age of Dinosaurs that tyrannosaurs exploded to huge size, after their competitors went extinct due to environmental change. Brusatte's description of the new species *Timurlengia* [3.4] suggested that the evolution of big brains and keen senses helped these small tyrannosaurs take over the top predator role, and his description of the new species of long-snouted tyrannosaur *Qianzhousaurus* ('Pinocchio rex') [3.5] showed that the last living, large-bodied tyrannosaurs had various skull shapes that allowed them to feed on different foods.

Demonstrating high diversity of dinosaur populations prior to asteroid impact

Third, his work on the extinction of dinosaurs used cutting-edge statistical modelling to demonstrate that dinosaurs were highly diverse up until the asteroid impact that ended the Cretaceous period [3.6]. This provides the strongest evidence yet that the dinosaurs went extinct suddenly, that the asteroid was the primary culprit, and that mammals rapidly filled empty niches afterwards.

3. References to the research (indicative maximum of six references)

[3.1] Brusatte, S. L., Lloyd, G. T., Wang, S. & Norell, M. A. (2014). Gradual assembly of avian body plan culminated in rapid rates of evolution across the dinosaur-bird transition

Current Biology, 24, 2386-2392. doi:10.1016/j.cub.2014.08.034 [151 citations]

[3.2] Lü, J., & Brusatte, S. L. (2015). A large, short-armed, winged dromaeosaurid (Dinosauria: Theropoda) from the Early Cretaceous of China and its implications for feather evolution. *Scientific Reports*, 5, 11775 doi:10.1038/srep11775 [32 citations]

[3.3] Brusatte, S. L. & Carr, T. D. (2016). The phylogeny and evolutionary history of tyrannosauroid dinosaurs. *Scientific Reports*, 6, 20252 doi:10.1038/srep20252 [48 citations]

[3.4] Brusatte, S. L., Averianov, A., Sues, H.-D., Muir, A & Butler, I. B. (2016). New tyrannosaur from the mid-Cretaceous of Uzbekistan clarifies evolution of giant body sizes and advanced senses in tyrant dinosaurs. *Proceedings of the National Academy of Sciences*, 113, 3447-3452 doi:10.1073/pnas.1600140113 [20 citations]

[3.5] Lü, J., Yi, L., Brusatte, S. L., Yang, L., Li, H. & Chen, L. (2014). A new clade of Asian Late Cretaceous long-snouted tyrannosaurids. *Nature Communications*, 5, 3788. doi:10.1038/ncomms4788 [30 citations]

[3.6] Brusatte, S. L., Butler, R. J., Barrett, P. M., Carrano, M. T., Evans, D. C., Lloyd, G. T., Mannion, P. D., Norell, M. A., Peppe, D. J., Upchurch, P. & Williamson, T. E. (2015). The extinction of the dinosaurs. *Biological Reviews*, 90, 628-642 doi:10.1111/brv.12128 [79 citations]

The underpinning research listed was published in highly ranked academic journals (Scopus citations as of December 2020 shown above), and supported by peer-reviewed grants.

Examples include:

PI, Brusatte, S. (2014-2018). The end-Cretaceous extinction and Paleogene recovery of mammals: evolution during a period of intense environmental change. [FP7-PEOPLE-2013-CIG 630652]. *Marie Curie Career Integration Grant, EU*. EUR100,000.

PI, Brusatte, S. (2018-2023). The Rise of Placental Mammals: Dissecting an Evolutionary Radiation. [StG 2017 756226]. *ERC Starting Grant*. EUR1,418,195.

4. Details of the impact (indicative maximum 750 words)

Prof. Brusatte's research has transformed our knowledge of the rise and fall of the dinosaurs significantly sufficiently to require a new narrative. Prof. Brusatte's has presented his work on dinosaur evolution to a broad global audience through publishing, television, and film in a manner that is easily grasped but not 'dumbed down'. His outreach has reached millions of people globally, changed public perceptions of dinosaurs, and generated significant revenue for the creative industries.

Impact on publishing/economy and commerce

In June 2018 Brusatte published *The Rise and Fall of the Dinosaurs*, a popular science book telling the story of dinosaurs from origins to extinction and how scientists study dinosaurs [5.1]. The book articulates Brusatte's theories of dinosaur evolution, developed in his work from 2013-2018 [3.1-3.6], particularly the new view of dinosaur evolution as gradual and shaped by environmental change. Key chapters in the book linking to Brusatte's specific research outputs include those on the gradual transition between dinosaurs and birds [3.1-3.2], tyrannosaur evolution from small to large body size and the development of dinosaur intelligence [3.3-3.5], and the sudden extinction of dinosaurs [3.6].

The book has been translated into 20 languages and sold over 284,000 copies, including ca. 60,000 in the UK. These sales figures have seen it reach official bestseller lists (determined solely by sales) in its three major markets (*Sunday Times* bestseller in the UK; *New York Times* bestseller in the USA; *Globe & Mail* bestseller in Canada) [5.2]. The economic impact of the book is demonstrated through sales earnings estimated at 284,000 copies x GBP15 (average retail price of the various editions), giving a figure of ca. GBP4,260,000.

Many awards demonstrate that it was among the most influential science books of 2018. For example it was named the 'Science Book of the Year' by the UK *Times*, and voted by readers as the 'Best Science & Technology Book 2018' on Goodreads.com. It was also named a 'Best book of the Year' by outlets including *Smithsonian*, NPR *Science Friday*, *Popular Mechanics* and *Science News.*, and attracted significant media attention in the US, UK and Canada. The book's agent writes "*with this book, Steve Brusatte's research, scientific expertise, and field work are not only impacting students (and) the field of paleontology, but (also) the world at large*". [5.2].

Impact on public awareness and engagement:

Significance is supported by overwhelmingly positive reader reviews: on Goodreads the book has a score of 4.14/5 (17,800 reviews, among the highest number of reviews of any science book published over the last few years); on Amazon.com (USA) it has a score of 4.7/5 (1,413 ratings). Many of these reviews explicitly mention that the book reveals a new image of dinosaurs, different from what many people were taught in school. The book also received many positive professional reviews, including the following selection:

"If you ever loved a dinosaur, buy this book. ... Brusatte does for dinosaurs what E.O. Wilson did for ants and Carl Sagan for stars." - **Washington Times**

"This vivid book reanimates dinosaurs for a new generation.... A fine piece of writing." - **The Times (London)**

"A thrilling study. ... The best book on the subject since [the 1980s]. ... Brusatte writes with the authority of a man who ranks as one of the leading experts in his field." - **Sunday Times (London)**

"[A] Jurassic blockbuster. ... A gripping read in the best traditions of popular science. ... Infectiously ebullient." - **The Observer (London)**

"A masterpiece of science writing." - **Washington Post**

"Filled with vivid illustrations, historical accounts, and tales of paleontological expeditions, this book will change the way you think about dinosaurs." - **Gizmodo**

"Tells the epic tale of the dinosaurs rise to dominance and extinction, taking us on a thrilling journey back in time." - **National Geographic**

[5.2, 5.6].

Impact on filmmaking:

Following publication of the book Brusatte was approached to be the 'Paleontology Consultant' for the *Jurassic Park* movie franchise, and is now chief science advisor for the upcoming film *Jurassic World 3*, which is currently in production and will premier in June 2022. Thus far, Brusatte has closely worked with the Director/Producer and Production Designer, using his research on dinosaur anatomy **[3.3-3.5]** and feathered dinosaurs **[3.1-3.2]** to ensure that the dinosaurs, their sizes, and their skin and feathers are as realistic as possible within the constraints of a blockbuster film franchise **[5.3]**. The Director/Producer *"was blown away by Steve's modern new perspective on palaeontology; and was determined to have his collaboration on this Jurassic film to make sure we're presenting the most up to date scientific knowledge on dinosaurs"*. The team has also cited Brusatte's knowledge as *"invaluable to us as we developed script, story and design. Steve has signed off on the scientific accuracy of our dinosaur designs and characteristics during prep, shoot and also into post-production as we focus on franchise and toy lines"* **[5.3]**.

Impact on broadcasting:

Brusatte frequently participates in television documentaries. Three television programs in particular have included Brusatte in key roles, which he has used to articulate his theories on dinosaur evolution in engaging with the public.

In 2015 Brusatte was a presenter and scientific consultant for the program *T. rex Autopsy*, which was broadcast worldwide by the National Geographic Channel, with *"a reach of 440 million homes in 171 countries in 38 languages. It was one of the top 5 rating shows"* **[5.4]**. This program used the novel concept of building a life-sized, scientifically accurate *T. rex* model (skin, feathers, muscles, bones, internal organs) and then dissecting it, to teach the audience about the biology and evolution of *T. rex*. Brusatte's research on tyrannosaurs **[3.3-3.5]**, particularly on their skeletal anatomy **[3.3]** and large brains and keen senses **[3.4]**, were instrumental in building the model, and was articulated through his presenter role **[5.4]**, with the show's director highlighting *"unique insight that ensured the scientific accuracy of the programme... I am confident we produced the most realistic and scientifically accurate model of not only T. rex, but (also) any dinosaur that has ever appeared on television"* **[5.4]**. The show received positive reviews from critics, with one at Stuff.co.nz **[5.5]** calling it a *"brilliantly clever presentation...an informative guide to current thinking about dinosaur anatomy, using special effects and a forensic who-dunnit mystery format to catch viewers' attention."*

In 2017 Brusatte appeared in the BBC2 programme *The Day the Dinosaurs Died* (2017). The documentary told the story of the asteroid impact that killed the dinosaurs. Brusatte was filmed excavating fossils in New Mexico, where he discussed his research that showed that the dinosaurs went extinct abruptly and were rapidly replaced by mammals **[3.6]** **[5.7]**. The programme director asked Brusatte to participate *"because of your expertise on the evolution and extinction of the dinosaurs... as demonstrated through your record of scientific*

publications and popular books. Your role in the programme included critical insight that ensured scientific accuracy and engaging presentation. By working together, we produced what I believe to be the most realistic and up to date look at why dinosaurs died out 66 million years ago, when an asteroid hit the earth” [5.7].

The program was watched by over six million people on BBC2 in the UK and was among the top 120 watched documentaries on British television in 2017 [5.7]. It was later broadcast as a NOVA special on PBS in the USA, and translated into several languages.

In 2018, Brusatte was the chief consultant for the 10-part children's CBBC series *Deadly Dinosaurs*. His research on tyrannosaurs [3.3-3.5] and feathered dinosaurs [3.1-3.2] were used to ensure the accuracy of animations and the appropriate use of hands-on experiments to explain aspects of dinosaur evolution, like the strong bite forces of *T. rex*. The series was nominated for a BAFTA [5.8].

5. Sources to corroborate the impact (indicative maximum of 10 references)

[5.1] *The Rise and Fall of the Dinosaurs*: William Morrow (HarperCollins) – USA, Macmillan – UK. ISBN: 9780062490421

[5.2] Literary Agent, *Aevitas Creative Management*, (testimonial letter, January 2021)

[5.3] Director/Producer, *Arcadia Pictures Limited*, (testimonial letter, November 2020)

[5.4] Creative Director, *Spark TV Ltd*, (testimonial letter, 20/11/2020)

[5.5] TV review: T-Rex Autopsy <https://www.stuff.co.nz/entertainment/tv-radio/69265887/tv-review-t-rex-autopsy>

[5.6] Key reviews of *The Rise and Fall of the Dinosaurs*:

a) *Sunday Times*: https://www.thetimes.co.uk/magazine/culture/the-rise-and-fall-of-the-dinosaurs-the-untold-story-of-a-lost-world-by-steve-brusatte-our-evolving-knowledge-of-the-big-beasts-that-ruled-the-earth-review-3cldl0m5k?_ga=2.134435127.751965505.1524913733-1772628291.1522711859

b) *Times*: <https://www.thetimes.co.uk/edition/saturday-review/review-the-rise-and-fall-of-the-dinosaurs-by-steve-brusatte-ripping-yarns-from-the-age-of-dino-might-768wf8zsv>

c) *Observer/Guardian*: <https://www.theguardian.com/science/2018/may/13/steve-brusatte-palaeontologist-debt-gratitude-jurassic-park>

d) *Washington Post*: https://www.washingtonpost.com/outlook/how-the-cataclysm-that-obiterated-the-dinosaurs-gave-rise-to-humans/2018/06/01/9a85bd92-2eb8-11e8-b0b0-f706877db618_story.html?utm_term=.4f14c1489c12

e) *Spectator*: <https://www.spectator.co.uk/2018/05/we-still-live-in-the-age-of-dinosaurs/>

f) *New York Times*: <https://www.nytimes.com/2018/05/29/books/review/steve-brusatte-dinosaurs-rise-and-fall.html>

g) *Nature*: <https://www.nature.com/articles/d41586-018-04933-4>

h) *National Geographic*: <https://news.nationalgeographic.com/2018/06/why-now-is-the-best-time-ever-for-dinosaur-discoveries/>

[5.7] Producer/Director, *BBC Studios*, (testimonial letter 4/12/2020)

[5.8] *Deadly Dinosaurs* BAFTA nomination
<https://twitter.com/bafta/status/1054271646452846592?lang=en-gb> (22 October, 2018)