Institution: University of Portsmouth

Unit of Assessment: 7 Earth Systems and Environmental Sciences

Title of case study: Public engagement with evolutionary science: pterosaurs hit the big and little screen

1. Summary of the impact

Research on the anatomy, physiology and palaeoecology of pterosaurs by the Palaeobiology Group at Portsmouth University has had a wide and acknowledged impact, underpinning the creation and production of block-buster and pioneering television and film productions worldwide. The impact of this work is recognised by Sir David Attenborough, and by the producers of such TV successes as *Walking With Dinosaurs* and *Flying Monsters 3D*. These award-winning productions, highlighting our work, have reached a global audience and supported the generation of millions of pounds by the UK TV and film industry. Whilst the income generated is highly significant, perhaps their greatest impact lies in fostering a positive view of science, particularly in young audiences, by bringing cutting-edge evolutionary science direct to the World's film and TV screens.

2. Underpinning research

Our research tests hypotheses about the functional morphology, palaeoecology and biogeography of pterosaurs using a combination of physical modelling, flume tank experimentation, basic comparative anatomy and mathematical modelling. The research has been undertaken by Drs Martill, Witton and Naish, with minor input from collaborators in Leicester and Sheffield. Within the scientific community our work, which included the first functional analysis of the palaeobiology of giant pterosaurs, is of interest to evolutionary biologists and vertebrate palaeontologists. This work was undertaken between 1998 and the present and led entirely by the University of Portsmouth group. It was coordinated by Martill (Reader) as team leader who supervised the work of Naish (PhD student and Res. Ass. to 2008) and Witton (PhD student and Post Doc. to 2011).

We investigated the mass of gigantic (~10 m) wingspan pterosaurs (**ref. 1**). In a new approach, the mass of the skeleton, muscle and viscera was determined anatomically at ~250 kg for a ten metre wingspan pterosaur: significantly higher than previously determined, and having considerable effects on flight mechanics and stall speed. Witton and Naish (2008) then evaluated the palaeoecology of giant pterosaurs, suggesting they were analogous to modern storks (**ref. 2**). This study provided a novel interpretation as azhdarchid pterosaurs were previously thought to have been piscivorous oceanic gliders.

We also examined the hypothesis that pterosaurs fed by skimming (**ref 3**). Such a feeding strategy is inefficient, requiring considerable energy expenditure for limited resource capture. We combined calculated stall speeds for pterosaurs previously considered to have been skim feeders, and modelled the effects of skimming at speeds above this on water turbulence and jaw strength in flume tanks. Our results excluded skimming for giant pterosaurs. We determined a completely different lifestyle in which these gigantic animals were dominantly terrestrial, and may have had an ecology comparable to modern (though much smaller) ground hornbills and secretary birds.

Many pterosaurs possess cranial crests located on the anterior rostrum, posterior rostrum or both (**ref. 4**). The functionality of these is controversial and includes possible involvement in thermoregulation, species recognition and sexual selection. A primary function in flight dynamics is considered unlikely, but a deleterious effect in flight performance may be a trade off with sexual prowess. We analysed the growth and development of a cranial crest in the genus *Tupuxuara* and found that cranial crest development involves the growth of the premaxilla over the cranium, including nasals, frontals and parietals, in progression through ontogeny (**ref. 5**). This supports a behavioural function rather than biomechanical.

The palaeobiology of prehistoric reptiles is derived entirely from analysis of their fossil remains,

and is severely limited by the completeness of this record. New discoveries allow us to build on, or challenge earlier ideas, while new methods of analysis such as CT scanning, allow us to investigate aspects previously only studied using destructive methodologies, or not studied at all. Our main findings have overturned models of pterosaur life strategies (**refs 2 and 4**). We have demonstrated that some achieved a wingspan >9m, perhaps >11m (**ref. 3**), and we have demonstrated that larger forms were far heavier than previously thought (**ref. 2**). These new estimates do not exclude larger pterosaurs from being volant (**ref. 6**).

3. References to the research

1. **Witton, M.** (2008) *A new approach to determining pterosaur body mass and its implications for pterosaur flight.* Zitteliana, B28. pp. 143-159. ISSN 1612-4138. Can be supplied on request.

2. **Witton, M. and Naish, D.** (2008) A reappraisal of azhdarchid pterosaur functional morphology and palaeoecology. PLoS ONE 3(5): e2271, DOI:10.1371/journal.pone.00022271

3. **Humphries, S., Bonser, R., Witton, M. and Martill, D.** (2007) *Did pterosaurs feed by skimming? Physical modelling and anatomical evaluation of an unusual feeding method.* PLoS Biology, 5 (8). e204. DOI:10.1371/journal.pbio.0050204; 9 citations by Oct 2013.

4. **Martill, D. M. and Naish, D.** (2006) Cranial crest development in the azhdarchoid pterosaur *Tupuxuara* with a review of the genus and tapejarid monophyly. Palaeontology, 49, 925-941. DOI: 10.1111/j.1475-4983.2006.00575.x; 27 citations by Oct 2013.

5. Tomkins, J., LeBas, N., **Witton, M., Martill, D. M. and Humphries, S.** (2010) Positive allometry and the prehistory of sexual selection. The American Naturalist, 176 (2). pp. 141-148. DOI: 10.1086/653001; 13 citations by Oct 2013.

6. **Witton, M. P.** and Habib, M. B. (2010) On the size and flight diversity of giant pterosaurs, the use of birds as pterosaur analogues and comments on pterosaur flightlessness. PLoS ONE, 5, e13982. doi: 10.1371/journal.pone.0013982

References 3,4,5 should be used to assess the quality of the research. Reference 3 used novel stall speed calculations and flume tank experiments to determine a completely different lifestyle for pterosaurs. The paper has been well-cited for the research field and viewed online 8717 times with 1749 pdf downloads (as of Oct. 2013). Reference 4, published in the leading palaeontology journal (IF 1.65), overturned existing models of pterosaur cranial development and has been very well cited (top 25% within Earth and Environmental Sciences). Reference 5 demonstrates a relationship between crest growth and sexual maturity. It has been very well cited (top 10% within Earth and Environmental Sciences) and is published in a highly-ranked (IF 4.55) journal.

4. Details of the impact

The dual impacts of this work lie in public engagement in evolutionary science and in supporting the generation of more than $10 M income for the UK TV and film industry.

Ever since the successful employment of modern CGI (computer generated image) techniques in animating prehistoric reptiles, first in Steven Speilberg's portrayal of Michael Crichton's *Jurassic Park* (Universal Pictures 1993), and subsequently in the novel "documentary" genre for Tim Hains' and Jasper James' *Walking With Dinosaurs* (BBC 1999), public interest in prehistoric reptiles, especially dinosaurs and pterosaurs, has soared. *Walking With Dinosuars* "began a new genre of TV programme, the animated documentary, from which there have been many spinoffs. The scientific input from the Portsmouth team was a key element of that success."[1.]

Since 2008, our work on pterosaurs has been directly incorporated into a BBC1 TV series and two

major film productions: *Planet Dinosaur* (BBC1: 2011), *Flying Monsters 3D* (Sky 3D: 2011) and *Walking With Dinosaurs: the 3D movie* (BBC, 20th Century Fox, National Geographic: to be released Christmas 2013). Martill and/or Witton were principal scientific consultants for these productions. In all of these productions, the pterosaurs are animated with morphology and ecology based directly on the work of the Portsmouth Group: the scientists constructed the physical models which were then developed in CGI.

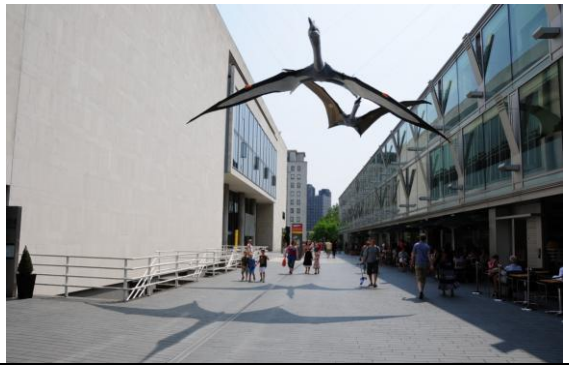
As documented below[2], Sir David Attenborough has noted the importance of this scientific work to such programmes: regarding *Flying Monsters*, he states that '*Dr Martill advised us throughout the film's production and gave it great authority*'. In a public interview, Anthony Geffen, CEO Atlantic Productions, stated that "the CG team worked for months with scientists"[3]. *Planet Dinosaur*, a six-part TV series[4] incorporates the terrestrialised ecology of azhdarchid pterosaurs as proposed in research by the Portsmouth group.

These programmes have received worldwide critical and public acclaim, as well as major commercial success. *Planet Dinosaur* received viewing figures of more than 4 million for episode 1 and around 2.9 million for subsequent episodes[4,5]. *Flying Monsters 3D* won awards from BAFTA (the first-ever Specialist Factual at the 2011 British Academy Television Awards) and the 2011 Jackson Hole Wildlife Film Festival (Best 3D Film) and is believed to have been one of the most successful documentary films ever made. The film was first screened on Christmas day 2011 on Sky 3D and has since been screened worldwide.

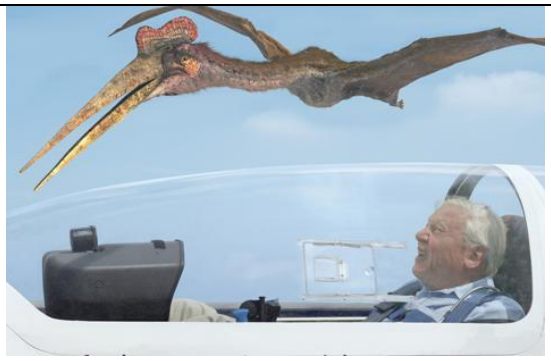
Using computer animations based on our research, *Flying Monsters 3D* was extremely successful ("Educational and fun" – Independent on Sunday; "Young dinosaur addicts will love this.." The Times[6,7]). By June 2013, the film had grossed $10,252,849 at the box office and is still showing in 84 cinemas world-wide. Natural History museums around the world (including the Smithsonian, the U.S. National Museum of Natural History and the Shanghai Science and Technology Museum) have regularly screened the film[8]. DVD sales figures (release date 07/11/2011) are not available but are expected to be high. *Walking With Dinosaurs 3D,* to be released Christmas 2013, is also expected to be a success.

In 2010 the Portsmouth team were invited to provide the "headline" exhibit for the Royal Society's 350th Anniversary Exhibition at London's Southbank[9]. Martill and Witton's remarkable reconstructions of azhdarchid pterosaurs were suspended around the exhibition hall, providing a dramatic focus for the events' 70,000 visitors[10] and for media coverage (Radio 4's *Today* programme covered the opening by focussing on the "flying dinosaurs").

Whilst the $10M+ income generated by these documentaries for the UK TV and film industry is highly significant, perhaps their greatest impact lies in bringing cutting-edge evolutionary science direct to the World's film and TV screens. Not only does this engage and inspire the next generation of scientists, but it also impacts the worldwide evolution/creationism debate and fosters a positive view of science, particularly in young audiences. The contribution of the Portsmouth team was to give these programmes the firm basis in state-of-the-art palaeontological science they needed for the success of their novel "documentary" format.



New restorations of azhdarchid pterosaurs exhibited on London's Southbank in celebration of 350 years of the Royal Society. Photo taken June 26, 2010, Southbank, London, by Mr Ben Rimmer. This restoration was built by Martill and Witton and is based on their research.



Sir David Attenborough's glider is overtaken by the Portsmouth University life restoration of Quetzalcoatlus northropi*, a gigantic azhdarchid pterosaur from the Cretaceous of Texas.*

5. Sources to corroborate the impact

1. Letter from CEO Wide-Eyed Entertainment and Producer: *Walking with Dinosaurs*. *Supports claim on Martill's importance to the novel "documentary" genre of Walking With Dinosaurs (1999) and the 3-D movie (released Christmas 2013):* "Without doubt, the Portsmouth vertebrate palaeontologists have had an important impact in prehistoric documentary TV and film production, not only in the UK, but internationally."

2. Letter from the BBC's most prominent wildlife broadcaster and former Director of Programming of BBC Television. *Provides evidence for the importance of Martill's work to the Flying Monsters programme, and for the widespread public interest in this area of science.*

3. http://library.creativecow.net/kaufman_debra/Flying-Monsters-3D/1 *Source of Anthony Geffen's public quote about the work of the CGI team with scientists.*

4. http://www.bbc.co.uk/programmes/p00l4m6s. *Shows images of the Portsmouth models in Planet Dinosaur.*

5. http://shareofvoice.wordpress.com/tag/planet-dinosaur-uk-viewing-figures/
Gives viewing figures for Planet Dinosaur.

6. http://www.youtube.com/watch?v=Qyf8v5bf-rA *Trailer for Flying Monsters.*

7. http://www.flyingmonsters3dmovie.com/media-coverage/#1-reviews *Supports the claim of critical success of the "edutainment" animated documentary Flying Monsters-3D*

8. http://press.nationalgeographic.com/2013/05/08/flying-monsters-10-million-box-office-revenue/. *Provides evidence for $10M + worldwide revenue for Flying Monsters 3D and on museum showings.*

9. http://www.bbc.co.uk/news/10322177 *Shows the Portsmouth University team's work on the Royal Society's 350th Anniversary exhibition at the South Bank, London*

10. http://royalsociety.org/uploadedFiles/Royal_Society_Content/stay-in-touch/inside-science/2010-11-08-Inside-Science.pdf *Link to Royal Society's "Inside Science" 350th Anniversary Edition with exhibition audience numbers and an article (p5) on the Portsmouth work.*