Pterosaur gigantism and the quadrupedal launch: how did the largest airborne animals get off the ground?

Supervisors: Professor Emily Rayfield, Dr Colin Palmer, Elizabeth Martin

Background
Giant azhdarchid pterosaurs were the largest vertebrates ever to fly. They are estimated to have had wingspans in excess of 10 m and to have weighed more than 250 kg (Witton 2013). By contrast the largest extant birds have wingspans of around 3 m and weigh around 20 kg. Fossil evidence (Argentavis magnificens and Pelagornis Sandersi) suggests that birds have flown with wingspans of 6-7 m and a mass of up to 70 kg, so even these giant extinct birds are dwarfed by the largest pterosaurs. It is now well established (Earls 2000, Henry et al 2005, Heers & Dial 2014) that when birds take off it is their legs that do most of the initial work to accelerate their bodies before the wings take over. In some species the legs can provide 80% or more of the force that propels the bird into the air. However, once a bird is airborne, the legs serve no useful purpose and act as payload or “baggage” (Heers & Dial 2014). Accordingly, birds must distribute body mass between legs and wings, with the trade-off dependent on the behavioural priorities (Heers & Dial 2014). Birds are victims of the modularity of their evolution (Gatesy & Dial 1996) and observation of the difficulties that large birds face in becoming airborne (swans, albatrosses, bustards) suggest that this may be an allometrically constrained factor that limits the maximum size of birds.

While pterosaurs may well have exhibited modular evolution, they adopted a quadrupedal stance, which meant that their forelimbs were used for both flight and locomotion, including launch, so carried less “baggage” once airborne. It is hypothesised that they adopted a quadrupedal launch behaviour that provided a long launch stroke and enabled them to recruit a large muscle mass to power the take-off (Habib 2008). The combined effect provided a powerful launch impulse, proportionately larger than that available to birds. While the underlying concept of the quadrupedal launch is now widely accepted amongst pterosaur workers, the kinematic and anatomical and details are poorly understood, which in turn means that estimates of available launch power are very imprecise. By increasing our understanding of the take-off process it will be possible shed new light on the role it played in pterosaur gigantism and to help refine our estimates of the maximum size they could have reached.

Fig. 1 Quadrupedal launch sequence of a large azhdarchid pterosaur.
Artist: James Brown;
Copyright: Colin Palmer
Objectives
The main objective of this proposal is to investigate the effectiveness of the quadrupedal launch and by comparing it with the bipedal launch of birds, test if it was one of the factors that enabled pterosaurs to become much larger than any bird, extant or extinct.
In more detail, the questions to be addressed are:
• What are the differences between the ground launch dynamics of birds and pterosaurs?
• How do these differences relate to the fundamental differences in morphology?
• How do they scale with size?
• How do these differences influence the upper limits to size?
• What is the most effective morphology to maximise launch capability?

Research activities
1. Create anatomically precise reconstructions of possible azhdarchid morphologies at 6 m, 9 m and 12 m wingspan.
2. Evaluate candidate kinematic simulation software packages (eg ADAMS, OpenSim, GaitSim).
3. Using the selected software, create a simple baseline bipedal launch model. Validate against published data for humans and birds.
4. Determine sensitivity to assumptions and modelling detail.
5. Modify baseline model to incorporate quadrupedal launch morphology.
6. Run a range of parametric tests to investigate the effect of varying muscle morphologies and power. Investigate the effects of varying size and determine the governing allometric relationships.
7. Create anatomically correct simulation models of the 6 m to 12 m azhdarchid forms, incorporating the lessons and constraints established in the earlier work.
8. Model quadrupedal launch capability.
9. Use result to investigate potential upper limits to size based upon launch capability.

The project would suit a student interested in palaeobiology, biomechanics and evolution. Backgrounds in zoology, geology, palaeobiology, biomechanics and engineering will be considered. The student will join the large and vibrant Bristol palaeobiology community and receive training in a range of anatomical and computational techniques.

References


