Review

Not peer-reviewed version

Functional Morphology and Paleoecology of Pteranodon: A Detailed Review

Tyler Hu *

Posted Date: 17 February 2025

doi: 10.20944/preprints202408.0360.v2

Keywords: functional morphology; paleoecology; Pteranodon; Late Cretaceous; Pterosaur; aerodynamic adaptations; ecological adaptations; cranial features; elongated cranial crest; sexual dimorphism; species identification; wing morphology; flight mechanics; dynamic soaring; wingspan; long-distance travel; feeding habits; dietary preferences; dental structure; jaw structure; piscivorous diet; fossil evidence; ecological models; paleoenvironment; predator; competitor; pterosaur evolution; pterosaur behavior

Review

Functional Morphology and Paleoecology of Pteranodon: A Detailed Review

Tyler Hu

Mission San Jose High School; drbball935@gmail.com

Abstract: This literature review provides a comprehensive analysis of the functional morphology and paleoecology of *Pteranodon*, a prominent genus of Pterosaur from the Late Cretaceous period. By synthesizing recent research findings with classic studies, this paper elucidates the aerodynamic and ecological adaptations of *Pteranodon*, which was one of the largest pterosaurs to ever soar the skies. The review examines the distinctive cranial features, including its elongated cranial crest and its implications for sexual dimorphism and species identification. Detailed analysis of wing morphology and limb proportions reveals insights into its flight mechanics, suggesting that *Pteranodon* was adapted for dynamic soaring, leveraging its expansive wingspan for efficient long-distance travel. Additionally, the paper explores *Pteranodon*'s feeding habits and dietary preferences based on dental and jaw structure, indicating a diet primarily consisting of fish and other aquatic prey. The review also integrates fossil evidence with ecological models to reconstruct the paleoenvironment of the Late Cretaceous, highlighting the role of *Pteranodon* in its ecosystem as both a predator and a competitor. This synthesis not only enhances our understanding of *Pteranodon*'s physiological and ecological roles but also contributes to broader discussions on pterosaur evolution and behavior.

Keywords: functional morphology; paleoecology; Pteranodon; Late Cretaceous; Pterosaur; aerodynamic adaptations; ecological adaptations; cranial features; elongated cranial crest; sexual dimorphism; species identification; wing morphology; flight mechanics; dynamic soaring; wingspan; long-distance travel; feeding habits; dietary preferences; dental structure; jaw structure; piscivorous diet; fossil evidence; ecological models; paleoenvironment; predator; competitor; pterosaur evolution; pterosaur behavior

---

Functional Morphology and Paleoecology of Pteranodon: A Detailed Review

Pteranodon was a prominent genus of Pterosaur from the Late Cretaceous period of the Mesozoic Era. While the dinosaurs ruled the land, avian pterosaurs like *Pteranodon* occupied the skies. Distinguished by its impressive wingspan, which could reach up to 7 m, *Pteranodon* was one of the largest pterosaurs of its time, with a standing height of around 1.8 m. Despite its large size, *Pteranodon* was relatively lightweight, with an estimated weight of around 0.025 metric tons.

Pteranodon's name, meaning "winged and toothless," reflects the notable absence of teeth in its beak, an adaptation that may have facilitated a piscivorous diet. Fossil evidence suggests that *Pteranodon* was a highly efficient flier, using its large, membranous wings to soar over ancient seas in search of fish and other marine prey. The crest on its head, which varied in shape and size between males and females, is believed to have played a role in sexual selection and species recognition. *Pteranodon*'s evolutionary success and wide geographic distribution highlight its significance in the diverse and dynamic ecosystems of the Late Cretaceous. Additionally. *Pteranodon*'s long, narrow wings were adapted for soaring rather than flapping, allowing it to cover vast distances with minimal energy expenditure. This efficient mode of travel would have been advantageous for locating food sources across the expansive seaways of the Cretaceous.

In this literature review, I will delve into the functional morphology and paleoecology of *Pteranodon*. I will begin with a detailed analysis of its morphology and the implications of these

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 17 February 2025 doi:10.20944/preprints202408.0360.v2

features on its lifestyle. I will then discuss the paleoecology of *Pteranodon*, including its Late Cretaceous environment and the ecological niche it occupied. Finally, I will conclude with an overall determination of the impact that the combination of *Pteranodon*'s morphology and paleoecology had on its successful lifestyle as an avian pterosaur.

Functional Morphology of Pteranodon

To properly understand the lifestyle of *Pteranodon*, we must first investigate its functional morphology and key characteristics. Several features enabled *Pteranodon* to be a successful organism in its Late Cretaceous ecosystem. Some of these attributes included large wings that were crucial for soaring over long distances, a long and toothless beak, an elongated skull, a prominent crest extending backward from the skull, hollow bones, a long and flexible neck, a well-developed pectoral girdle, and a short tail, all of which would have played significant roles in flight or social communication.

A study conducted by Brower (1983) involved the investigation of the aerodynamic function of *Pteranodon ingens*' wing. It was discovered that the wings of *Pteranodon ingens* were highly elongated, with an aspect ratio (wing length to width ratio) estimated to be 19.09. This high aspect ratio indicates that *Pteranodon* wings were adapted for efficient soaring. The wings had a thin and streamlined structure, which would have minimized drag during flight. The wing loading of *Pteranodon* was approximately 5.904 kg/m^2, indicating the pterosaur's ability to soar efficiently, findings similar to Bramwell & Whitfield (1974). As a result, *Pteranodon* likely used strong winds or elevated positions like cliffs to aid in takeoff. This is further proven by Heptonstall (1971), in which it was found that *Pteranodon ingens* was unable to take to the air without the assistance of wind, a feature that would require positioning at higher elevations associated with greater wind. These various examinations prove that *Pteranodon*'s wing morphology was key to its aerial dominance, enabling it to efficiently maneuver through the air and soar with minimal energy usage.

An investigation regarding *Pteranodon*'s cranial crest was yielded by Bennett (1992). Significant variation was identified in crest size and shape among *Pteranodon* specimens. This suggests that crest size and shape could be linked to sexual dimorphism, with males typically exhibiting larger and more elaborate crests compared to females, also noted by Anderson (2016). The crests could have also served as mechanisms of mate attraction and territorial defense, with larger and more elaborate crests symbolizing a healthier, stronger individual. Besides sexual dimorphism, the cranial crests may have also been used for aerodynamic purposes. The crest's position above the head may have acted as a vertical stabilizer, similar to the tail fin of a modern aircraft. This would reduce yaw movements and improve directional control. Additionally, the crest orientation, slightly inclined backward, also helped in smoothing the airflow over the body, reducing aerodynamic drag. Ontogenetic changes in crest morphology were also present, as crest size and shape changed significantly as individuals matured. Juvenile *Pteranodon* had smaller, less pronounced crests that developed into the characteristic elongated structures seen in adults.

Chatterjee & Templin (2004) conducted a comprehensive study on the posture, locomotion, and paleoecology of pterosaurs, focusing on their adaptations for flight and their ecological roles. The study detailed the flight mechanics of pterosaurs, including the muscle attachment sites on the sternum and the biomechanics of wing movement. Pterosaurs like *Pteranodon* had a highly developed pectoral girdle that supported powerful flight muscles, enabling sustained flight and efficient gliding. *Pteranodon* likely used a quadrupedal launch method, where it would vault into the air using its strong forelimbs and hindlimbs. The flexible neck of *Pteranodon* was an important adaptation for feeding, allowing it to reach down and capture fish while flying or perched. The toothless beak of *Pteranodon* can also be analyzed, examining its streamlined shape that was ideal for reducing drag during flight and efficient for catching fish. The lack of teeth suggests a specialization in a piscivorous diet, with the beak shape facilitating a swift snapping motion to catch prey.

Overall, the key morphological characteristics of *Pteranodon* provide valuable insight into the lifestyle of this ancient pterosaur. The wings of *Pteranodon* allowed it to efficiently maneuver through

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 17 February 2025 doi:10.20944/preprints202408.0360.v2

the air and soar with minimal energy usage. Meanwhile, its crests would have likely been used for display, as well as aerodynamic purposes. The muscles of *Pteranodon* enabled it to engage in powerful launches, and its beak and neck would have proven useful in catching fish during flight.

Paleoecology of Pteranodon

As we have analyzed the functional morphology of various features of *Pteranodon*, we will now examine its paleoecology and the role it played in its ecosystem. Some of these aspects include the niche it occupied, as well as its environment, diet, and behavior. Through this investigation of its paleoecology, we will be able to gain a deeper understanding of its overall lifestyle.

We can evaluate the implications of various features of *Pteranodon*. The elongated fourth finger might have served to support the wing membrane. As its wings had a high aspect ratio, this facilitated efficient soaring and minimized energy expenditure over long distances. The prominent keel on the sternum of *Pteranodon* would have provided a large surface area for the attachment of strong pectoral muscles. These muscles were crucial for the powerful wing strokes required during takeoff and sustained flight. The extensive pneumatization likely reduced the overall weight of *Pteranodon* and enhanced its flight capabilities. This adaptation was particularly evident in the lightweight yet strong construction of the wing bones. The beak was found to be elongated and streamlined, an adaptation that likely reduced drag during flight and facilitated the capture of fish. The shape and structure of the beak suggested a specialized feeding strategy focused on piscivory, a conclusion also arrived at by Bestwick et al. (2018) and inferred from Vecchia (2013) and Ősi (2011). We also explore the potential functions of the cranial crest, proposing that it may have played a role in sexual selection, species recognition, and aerodynamic stability. The variation in crest size and shape among different individuals was noted as significant for social interactions. The authors emphasized the importance of the long, flexible neck of *Pteranodon*, which allowed for a wide range of motion. This flexibility was crucial for effectively reaching and capturing prey while in flight or perched. Thus, these characteristics would have been of greatest use for a piscivorous diet that involved gliding over vast areas of the ocean, exploiting fish-rich environments easily.

Evidence like this is supported by numerous fossil specimens of *Pteranodon*. The primary fossil evidence for *Pteranodon* comes from the Niobrara Formation, a marine sedimentary deposit in North America. The presence of *Pteranodon* fossils in these marine deposits suggests that the pterosaur lived in or near marine environments. *Pteranodon*'s aerodynamic and morphological features suggested it could engage in both solitary and group foraging, depending on ecological pressures and resource availability. The formation includes evidence of ancient seaways, such as marine vertebrates and invertebrates, supporting the idea that *Pteranodon* was adapted to such habitats. The sedimentological characteristics of the Niobrara Formation, including fine-grained sediments and the presence of marine fossils like ammonites and sharks, further corroborate the interpretation of a marine habitat. These sediments indicate that *Pteranodon* lived in coastal or pelagic zones where it could exploit fish resources.

Fossil evidence related to pterosaur reproduction can be reviewed, including egg remains attributed to *Pteranodon*. Although direct fossils of *Pteranodon* eggs are rare, indirect evidence from related pterosaur species provided insights into reproductive behaviors. *Pteranodon*, like other pterosaurs, likely laid eggs that were incubated in a manner similar to modern reptiles and birds. Pterosaur eggs, which were often found in nesting sites, were relatively large and had a structure suited for incubation in coastal or terrestrial environments. Based on patterns observed in related pterosaur species and modern egg-laying reptiles, *Pteranodon* may have nested in colonies or used specific nesting sites. It is probable that *Pteranodon*'s nesting sites were likely situated in coastal or nearshore environments, where the pterosaur could have found suitable conditions for egg-laying and rearing young. This conclusion can be drawn from the broader context of pterosaur fossil distributions and nesting behaviors. *Pteranodon* might also have exhibited some form of parental investment in egg incubation and care of hatchlings.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 17 February 2025 doi:10.20944/preprints202408.0360.v2

Therefore, it is likely that *Pteranodon* employed a piscivorous diet, gliding over large areas of the vast ocean to hunt for fish and other marine creatures. Its crest was used both as a display and aerodynamic mechanism, and other features of its body such as its elongated beak would be used in its hunting techniques of quick swoops through the water. *Pteranodon* most likely lived in colonies or used specific nesting sites for egg incubation and laying. In addition, *Pteranodon* might have exhibited some form of parental investment in egg incubation and care of hatchlings.

Conclusion

Limitations on Existing Research

The existing research on *Pteranodon* offers significant insights into its functional morphology and paleoecology, yet it has notable limitations. A primary issue is the fragmentary nature of the fossil record, which can hinder accurate reconstructions of the pterosaur's full physical and behavioral characteristics. For instance, detailed studies on wing morphology and cranial crest function are based on incomplete specimens, which might not fully represent the variability within the species. Furthermore, aerodynamic models and functional analyses rely on simulations that may not capture all real-world variables, such as environmental conditions and individual behavioral differences. The interpretation of *Pteranodon*'s reproductive behavior and nesting habits also relies heavily on indirect evidence, as direct fossil evidence of eggs and nesting sites is scarce. Consequently, while these studies provide valuable information, they highlight the need for more comprehensive fossil discoveries and advanced research methods to address these gaps and enhance our understanding of *Pteranodon*'s role in its Late Cretaceous ecosystem.

Takeaway

Pteranodon, a prominent genus of pterosaur from the Late Cretaceous period, was a master of the skies, characterized by its remarkable wingspan of up to 7 meters and lightweight build. This large pterosaur, with a standing height of around 1.8 meters and a weight of approximately 0.025 metric tons, was uniquely adapted for soaring flight. Its toothless beak, an adaptation for a piscivorous diet, allowed it to efficiently capture fish while gliding over ancient seas. The elongated wings, with a high aspect ratio of about 15, facilitated minimal drag and energy-efficient soaring, while the flexible wing structure enabled it to adjust its shape for optimal aerodynamic performance. The cranial crest of *Pteranodon*, varying significantly between individuals, likely played roles in sexual selection, species recognition, and aerodynamic stability, contributing to the pterosaur's flight efficiency. Studies reveal that the crest could enhance lift and stability, reducing aerodynamic drag and improving maneuverability. Fossil evidence from the Niobrara Formation indicates that *Pteranodon* lived in marine environments, with its anatomy supporting both solitary and group foraging strategies. The pterosaur's nesting behavior, inferred from related species, suggests it might have used coastal or nearshore sites for egg-laying, potentially exhibiting some form of parental care. Overall, *Pteranodon*'s specialized morphology and behavior reflect its successful adaptation to a piscivorous diet and life in the dynamic ecosystems of the Late Cretaceous seas.

References

Anderson, E. C. (2016). Analyzing Pterosaur Ontogeny and Sexual Dimorphism with Multivariate Allometry.

Bennett, S. C. (1992). Sexual dimorphism of Pteranodon and other pterosaurs, with comments on cranial crests. *Journal of Vertebrate Paleontology*, *12*(4), 422-434.

Bestwick, J., Unwin, D. M., Butler, R. J., Henderson, D. M., & Purnell, M. A. (2018). Pterosaur dietary hypotheses: a review of ideas and approaches. *Biological Reviews*, *93*(4), 2021-2048.

Bramwell, C. D., & Whitfield, G. R. (1974). Biomechanics of pteranodon. *Philosophical Transactions of the Royal Society of London. B, Biological Sciences*, *267*(890), 503-581.

 doi:10.20944/preprints202408.0360.v2

Brower, J. C. (1983). The aerodynamics of Pteranodon and Nyctosaurus, two large pterosaurs from the Upper Cretaceous of Kansas. *Journal of Vertebrate Paleontology*, *3*(2), 84-124.

Chatterjee, S., & Templin, R. J. (2004). *Posture, locomotion, and paleoecology of pterosaurs* (Vol. 376). Geological Society of America.

Heptonstall, W. B. (1971). An analysis of the flight of the Cretaceous pterodactyl Pteranodon ingens (March). *Scottish Journal of Geology*, *7*(1), 61-78.

Ősi, A. (2011). Feeding-related characters in basal pterosaurs: implications for jaw mechanism, dental function and diet. *Lethaia*, *44*(2), 136-152.

Vecchia, F. M. D. (2013). Triassic pterosaurs. *Geological Society, London, Special Publications*, *379*(1), 119-155.