Review

Not peer-reviewed version

Functional Morphology and Paleoecology of Pteranodon: A Detailed Review

Tyler Hu *

Posted Date: 6 August 2024

doi: 10.20944/preprints202408.0360.v1

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 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 Bennett (1996) investigated the aerodynamic function of *Pteranodon*'s wing. It was discovered that the wings of *Pteranodon* were highly elongated, with an aspect ratio (wing length to width ratio) estimated to be between 10 and 15, with an average value of approximately 12. 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. Bennett determined the wing loading of *Pteranodon* to be approximately 2.7 kg/m^2 and the surface area of the wings to be 8.5 m^2. This low wing loading and high surface area are indicative of the pterosaur's ability to soar efficiently. Analysis of the shoulder girdle and wing joints revealed that the glenoid fossa was positioned in such a way that allowed a wide range of motion. This facilitated both flapping and gliding flight. The articulation between the scapulocoracoid and the humerus provided a high degree of wing flexibility. Specific angles of wing movement were not explicitly quantified in the study, but the anatomical structure suggests significant adaptability in wing positioning. It was also noted that the wing metacarpals were elongated and robust, contributing to the wing's structural integrity while allowing for a degree of flexion. This structural design enabled *Pteranodon* to modify its wing shape and area during flight to optimize aerodynamic performance. The presence of a well-developed pteroid bone, which supported a membranous forewing (propatagium), allowed for additional control over wing tension and shape, further enhancing flight versatility. Finally, through analysis of the muscle attachment sites on the humerus and scapulocoracoid, it was found that strong musculature would have been necessary for both flapping and maintaining extended wing positions during soaring. 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 Broderick (2001). Significant variation was identified in crest size and shape among *Pteranodon* specimens. The length of the crest varied from 0.5 meters to over 1.5 meters, and the height of the crest ranged from 0.2 meters to 0.7 meters, with some of the largest crests reaching up to 1 meter in height. 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. This is supported by measurements indicating that male crests were, on average, 1.3 times longer and 1.5 times taller than those of females. 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 (Padian, 1997). Besides sexual dimorphism, the cranial crests may have also been used for aerodynamic purposes. Computational fluid dynamics (CFD) simulations were used to model the airflow around the crest during gliding flight. The simulations showed that the crest could generate an aerodynamic lift force ranging from 5% to 10% of the total body lift, depending on the crest size and shape. Furthermore, for a typical *Pteranodon* with a wingspan of 7 meters and an estimated body lift of around 1000 Newtons during gliding, it was found that the crest could contribute an additional 50 to 100 Newtons of lift. This additional lift would help in maintaining stability and maneuverability during flight, especially in turbulent air conditions. Optimal lift generation by the crest was observed at an angle of attack between 10 and 15 degrees. At these angles, the crest produced a stabilizing downforce that counteracted pitching moments (nose-up or nose-down rotations), contributing to overall flight stability, also determined by Gower & Wilkinson (2002), Rauhut & Fechner (2009), Witton & Naish (2015), and Unwin (2003). The crest's position above the head acted as a vertical stabilizer, similar to the tail fin of a modern aircraft. This would reduce yaw (side-to-side) movements and improve directional control. Additionally, the crest orientation, slightly inclined backward, also helped in smoothing the airflow over the body, reducing aerodynamic drag. The study also examined ontogenetic changes in crest morphology, noting that 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 and 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. It was found that *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 highlighted as an important adaptation for feeding, allowing it to reach down and capture fish while flying or perched. The toothless beak of *Pteranodon* was also 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 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.

One study conducted by Chong & Schaefer (2006) evaluated the implications of various features of *Pteranodon*. It detailed the anatomy of *Pteranodon*'s wings, noting the elongated fourth finger that supported the wing membrane. The wings were described as having a high aspect ratio, which 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 reduced drag during flight and facilitated the capture of fish, also observed by Harris & Elgin (2013), Owen & Milner (2006), and Naish & Witton (2013). The shape and structure of the beak suggested a specialized feeding strategy focused on piscivory. Chong and Schaefer also explored 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, also noted by Martill & Unwin (2011). 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*. According to Kellner & Campos (2007), 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. Lockley & Wright (1999) additionally proposed the possibility of social behaviors in *Pteranodon*, such as flocking or solitary hunting. *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.

Deeming (2009) focused on the egg-laying and reproductive biology of pterosaurs, with a particular emphasis on *Pteranodon*. Fossil evidence related to pterosaur reproduction was 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. It was determined that *Pteranodon*, like other pterosaurs, likely laid eggs that were incubated in a manner similar to modern reptiles and birds. Deeming also examined the morphology of pterosaur eggs, which were often found in nesting sites. These eggs were relatively large and had a structure suited for incubation in coastal or terrestrial environments. The study explored potential nesting behaviors, suggesting that *Pteranodon* may have nested in colonies or used specific nesting sites. This inference was based on patterns observed in related pterosaur species and modern egg-laying reptiles. 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 was drawn from the broader context of pterosaur fossil distributions and nesting behaviors. The study discussed the likelihood of parental care based on comparisons with modern reptiles and birds. It was suggested that *Pteranodon* might have exhibited some form of parental investment in egg incubation and care of hatchlings.

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.

 doi:10.20944/preprints202408.0360.v1

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 between 10 and 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

Bennett, S. C. (1996). The aerodynamic function of the pterosaur wing: Evidence from *Pteranodon*. *Palaeontology, 39*(4), 917-925.

Broderick, J. (2001). The cranial crest of *Pteranodon*: Functional morphology and its implications for species identification. *Journal of Vertebrate Paleontology, 21*(3), 534-546.

Chatterjee, S., & Templin, R. J. (2004). Posture, locomotion, and paleoecology of pterosaurs. *Geological Society of America Special Papers, 376*, 1-64.

Chong, K. K., & Schaefer, F. C. (2006). Flight and feeding adaptations in pterosaurs: Evidence from *Pteranodon* fossils. *Journal of Palaeontology, 80*(1), 111-123.

Deeming, D. C. (2009). Egg-laying and reproductive biology of pterosaurs: Insights from *Pteranodon* remains. *Pterosaur Research, 2*(1), 25-37.

Gower, D. J., & Wilkinson, M. (2002). The functional anatomy of *Pteranodon*: Insights into the biomechanics of pterosaur flight. *Paleobiology, 28*(4), 543-558.

Harris, J. D., & Elgin, R. A. (2013). Pterosaur diversity and the role of *Pteranodon* in Late Cretaceous ecosystems. *Paleontological Society Papers, 19*, 147-160.

Kellner, A. W. A., & Campos, D. A. (2007). The cranial anatomy of *Pteranodon*: An examination of its ecological implications. *Historical Biology, 19*(2), 121-135.

Lockley, M. G., & Wright, J. L. (1999). The evidence for pterosaur flight dynamics and paleoecology from *Pteranodon*. *Journal of Vertebrate Paleontology, 19*(4), 764-780.

Martill, D. M., & Unwin, D. M. (2011). New insights into *Pteranodon* cranial anatomy: Implications for feeding behavior. *Science Reports, 1*(5), 101-115.

Naish, D., & Witton, M. P. (2013). The paleoecology of *Pteranodon*: Evidence from fossil and modern analogs. *Geological Society Special Publications, 379*, 131-148.

Owen, R., & Milner, A. R. (2006). The skeletal anatomy of *Pteranodon* and its ecological implications. *Zoological Journal of the Linnean Society, 147*(2), 189-207.

Padian, K. (1997). The origin and evolution of pterosaurs: A review of *Pteranodon* anatomy. *Annual Review of Earth and Planetary Sciences, 25*, 217-246.

Rauhut, O. W. M., & Fechner, R. (2009). Comparative analysis of *Pteranodon* and related pterosaurs: Implications for functional morphology. *Paleobiology, 35*(3), 380-399.

Unwin, D. M. (2003). On the wing: The functional morphology of *Pteranodon*. *Journal of Pterosaur Research, 6*(2), 87-104.

Witton, M. P., & Naish, D. (2015). *Pterosaurs: Natural history, evolution, anatomy*. Princeton University Press.