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The Aerodynamic Effects on Flight Patterns and the Evolutionary Changes in Pterosaurs

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Introduction

Pterosaurs ruled the sky for an interval of 144 million of years before a 6-mile wide asteroid wiped them from the face of the Earth. Early pterosaurs were the first vertebrates to achieve powered flight, and remained small-to-medium sized from the Triassic Period to the end of the Jurassic Period. During that interval, lasting from 210 million years ago to 66 million years ago, pterosaurs underwent a notable changes at the end of the Jurassic Period and through the Cretaceous Period. They were abruptly replaced by much larger forms, characterized by great size and peculiar head ornamentation, among other unique and notable morphological features. While many different explanations theorize why and how the features of the pterosaurs changed over the Cretaceous Period, the aerodynamic influences are neglected and poorly documented.

The motivation of this study is the sudden, rapid transition towards the end of the Jurassic Period from small forms to large forms and the appearance of large pterosaurs coincided with the appearance of birds. This work investigates the potential aerodynamic value of specific pterosaur features and the adaptive role they may have played in the diversity and success of the group. This work will move forward with the hope of discovering new insights to this great, ancient mystery.

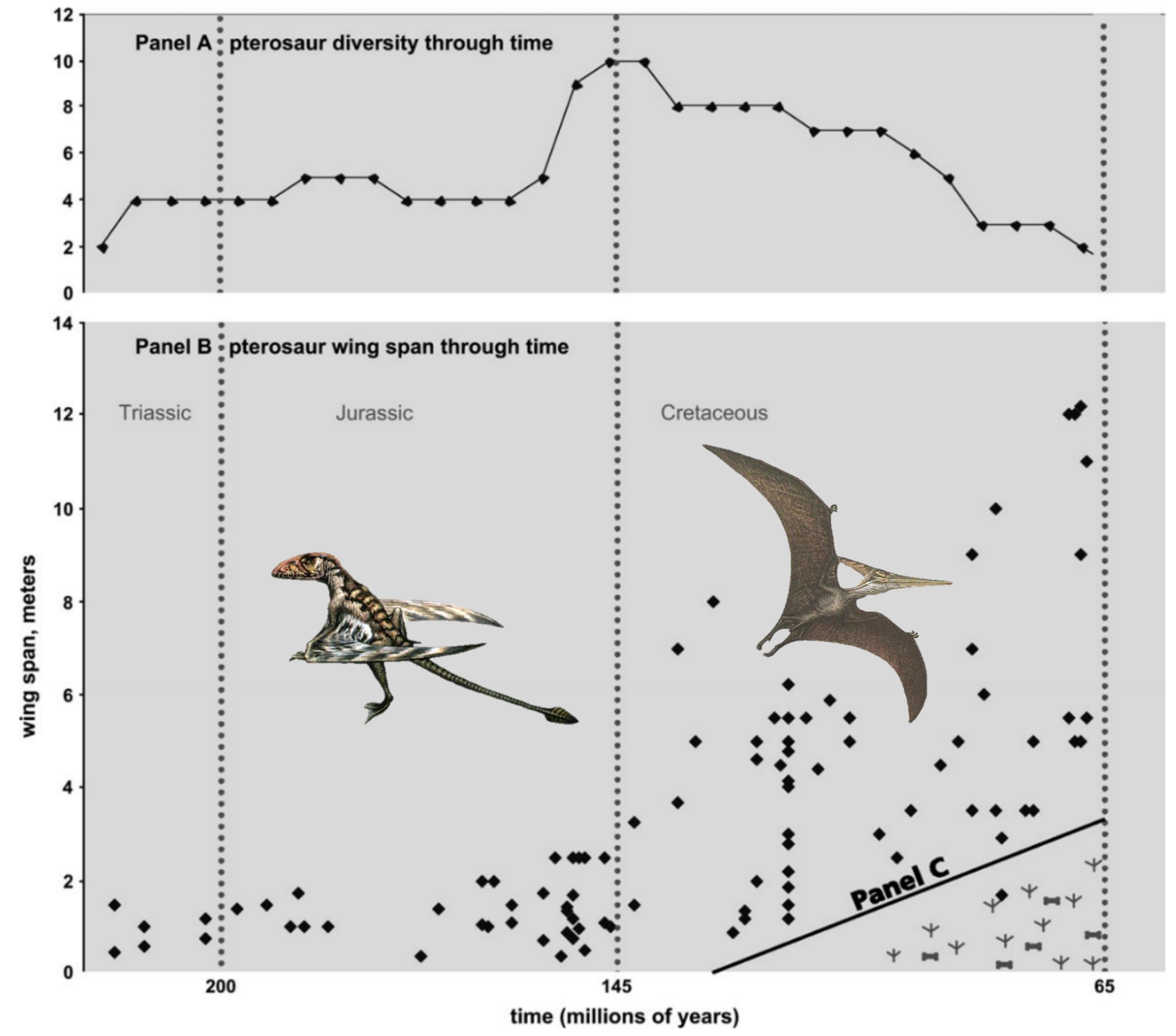

Figure 1. Pterosaurs through time. Panel (A) Pterosaur Taxonomy diversity from the mid-Triassic Period until the end of the Cretaceous Period. Panel (B) Adult wingspans for pterosaurs (C) Occurrence of fossil footprints and stem group modern birds in the last quarter of the Cretaceous. [1]. This figure indicates an increase in pterosaur size with an increase in the loss of small and medium sized pterosaurs.

Experimental Setup

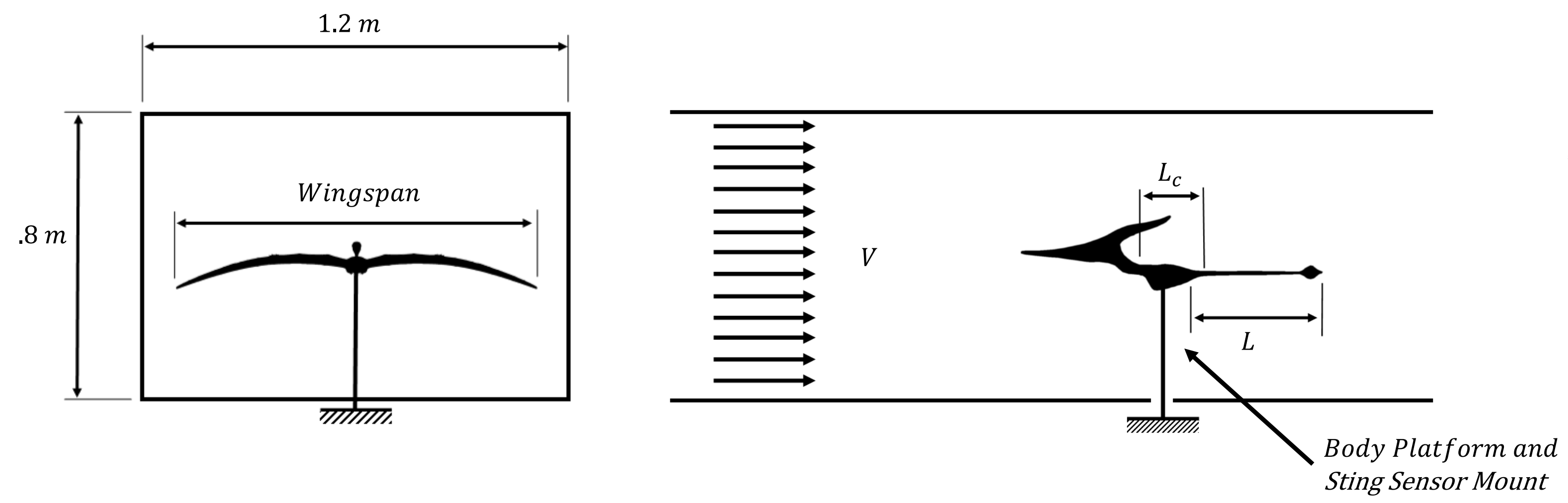

Figure 3. WET Lab Wind Tunnel Experimental Setup. L_c is the characteristic length used to determine the Reynolds number that is used to scale the features of interest to the model, L is the length of the feature of interest after scaled to the model.

Creatures and Features of Interest

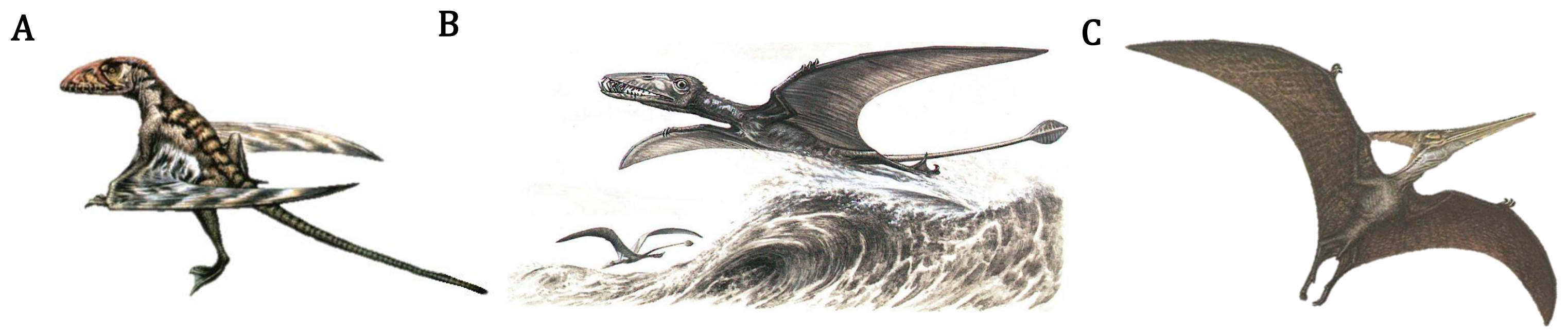

Figure 4. Pterosaurs of interest in experimental study: Rhamphorhynchoids: **A.** *Dimorphodon Macronyx* **B.** *Rhamphorhynchus Muensteri.* Pterodactyloids: **C.** *Pteranodon Longiceps.* Illustrations adapted from Wellenhofer (1991).

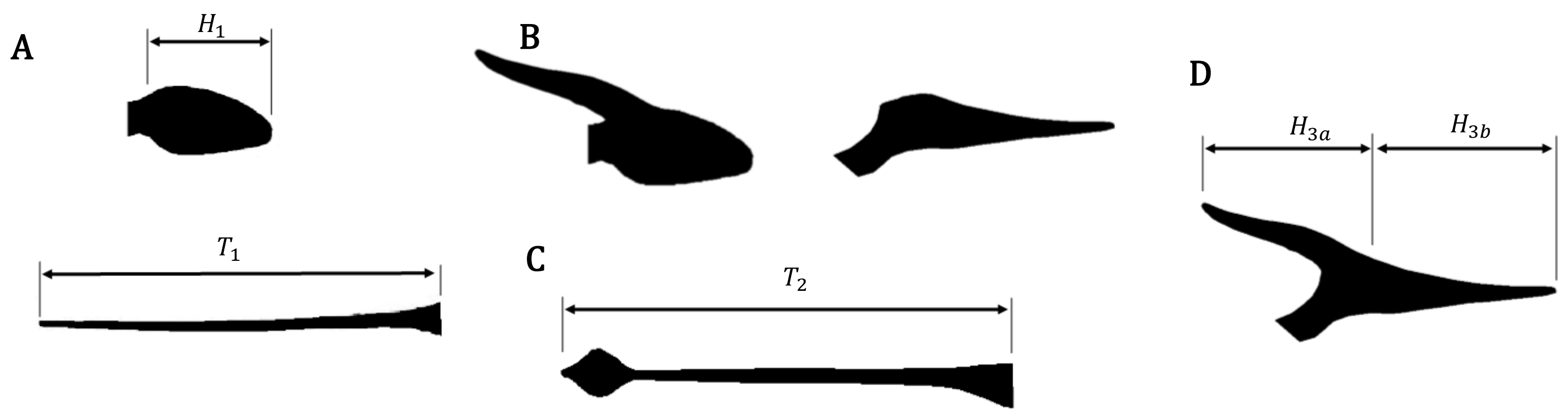

Figure 5. Features of interest in experimental study taken from pterosaurs of interest: (**A**) Snout and tail of *Dimorphodon Macronyx,* (**B**) morphed head features, (**C**) tail and fin of the *Rhamphorhynchus Muensteri, (***B**) crest and beak of the *Pteranodon Longiceps. L* is the length used to scale the features of interest to the model during experimentation. Reconstructions from Henderson (2010) for (**A**), (**C**), and Bramwell (1974) for (**D**)

Table 1. Lengths of the features of interest and the values used for scaling models. The model is first scaled to the model, then the features are scaled to the model by the non dimensional Reynolds number to maintain dynamic similarity in the testing condition to accurately represent flight of the creatures of interest.

		R. Muensteri.	*D. Macronyx.*	*P. Longiceps.*
Features of Interest	Tail Length (m):	0.52	0.47	-
	Head length (m):	0.16	0.23	0.96
	Head Max Height (m):	0.06	0.22	0.19
	Neck Length (m):	0.1	0.11	0.29
Scaling Parameters	Cruising Speed (m/sec):	6.4	6.4	13
	Torso Length (m):	0.24	0.23	0.41
	Reynolds Number :	1.15×10^7	1.10×10^7	4.00×10^7

Testing Platform

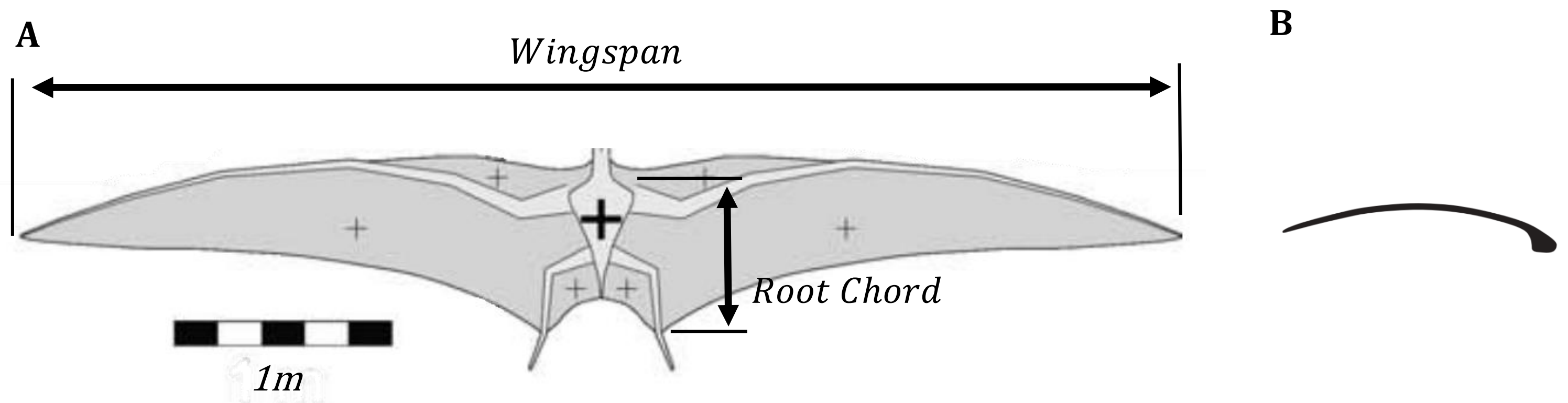

Figure 4. (A) The *Pteranodon* wing shape and body were chosen for the model basis that is held consistent throughout testing. Dimensions follow the reconstructions by Henderson (2010). **(B)** The wing section is also held consistent through testing, following the reconstructions by Palmer (2011).

Summary

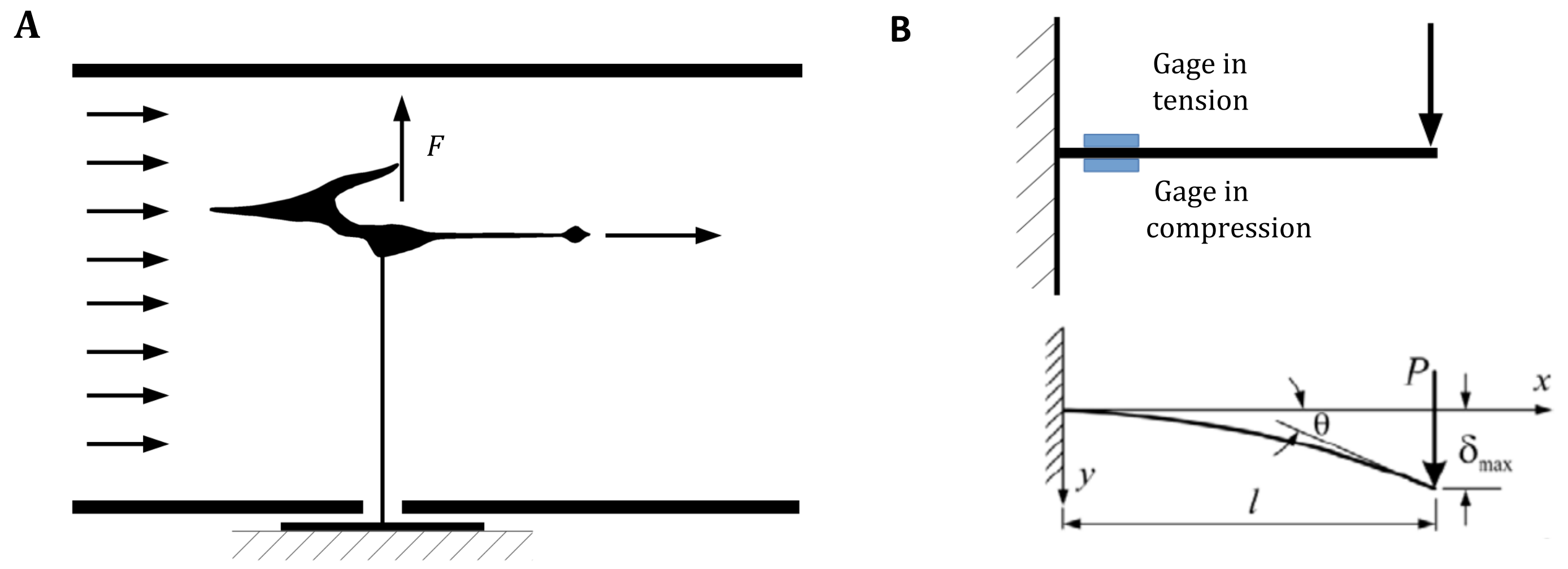

Figure 5. (A) Schematic of simplified sting mount used for finding aerodynamic forces acting on the model pterosaur. **(B)** A dual-bridge strain gage assembly measures the aerodynamic force based on cantilever beam equations and beam superposition theory. [2]

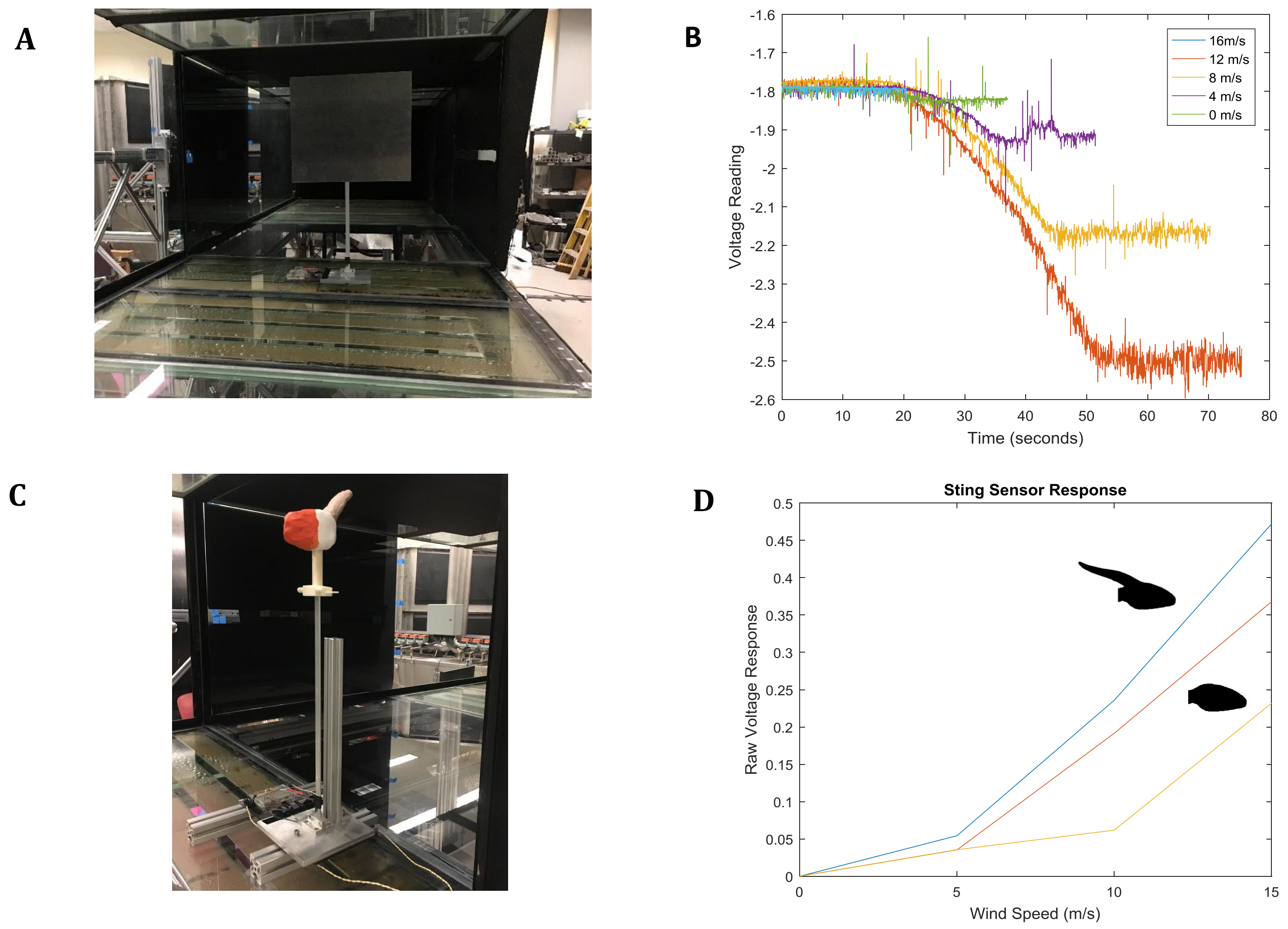

Figure 6. (A) Preliminary wind tunnel study for sensor sensitivity validation. The main objective was to determine is a simplified strain gage sting mount could be used to determine the coefficient of drag of a model mounted to the sensor. **(B)** Raw voltage reading of the sensor at several different tunnel speeds with a flat plate mounted perpendicular to the flow. (**C**) Preliminary testing setup to validate sting mount sensitivity to variations in the model's morphology that will occur through further experimentation. (**D**) Results from the experiment, showing an increase in sensor response to the changes in model parameters.

Figure 7. Preliminary 3D printing test, developed using photogrammetry, mesh manipulation software, and CAD. This small scale model uses the body for the testing platform, as seen in Figure 4, and the head of the *Dimorphodon Macronyx,.* as seen in Fig. 5 (**A**)

Further Work

With the sting sensor developed and validation complete, further exploration into the evolutionary changes can continue. The final testing platform can be printed as well as the various features of interest that will be changed throughout the experiment.

Utilizing a laser sheet, the downstream wakes effects will be observed of individual models as well as the models in formation flight. This will determine if the features of interest influenced the wakes effects that influence formation flight.

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