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Predicting the Distribution of the Extinct Sea Bird Hesperornis

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Abstract

In the Late Cretaceous, North America was divided by a shallow epicontinental sea known as the Western Interior Seaway. Native life included various marine reptiles, fish, ammonites, and seabirds such as *Hesperornis*. Previous research has applied ecological niche modeling to discuss competition among large vertebrates in the seaway (mosasaurs and predatory fish) but ignored small vertebrates. The present study combined localities of *Hesperornis* fossils with sea surface temperature estimates to characterize the distribution of *Hesperornis* in the upper Great Plains. Temperature interpolation in ArcGIS and niche analysis in Maxent predicted that *Hesperornis* preferred warmer marine waters (highest suitability values) and may support the hypothesis that *Hesperornis* migrated between the paleo-Arctic and the lower Western Interior Seaway. Most of the study area, however, is homogenous in suitability, indicating the results are largely inconclusive. Additional ecosystem variables (e.g., biological interactions and rock type) will be applied in future analyses to describe the distribution of *Hesperornis*.

Introduction

An epicontinental sea referred to as the Western Interior Seaway (WIS) covered part of North America in the Late Cretaceous from the paleo-Arctic to the region now considered the Gulf of Mexico. The shallow marine environment was characterized by the deposition of the Pierre Shale Formation and correlated units such as the Bearpaw Shale during the Campanian (72-86 Ma; Schultz et al., 1980). Numerous transgressions and regressions occurred during the history of the WIS.

Ecological Niche Modeling (ENM) predicts habitat suitability through a combination of species occurrences with environmental factors, biotic interactions, and/or areas of accessible habitat (Myers et al., 2015). Limited applications of ENM to the WIS have focused on competition amongst large marine vertebrates (e.g., sharks and mosasaurs; Myers and Lieberman, 2010). The current study examined the utility of ENM in the WIS for small marine vertebrates with *Hesperornis*, an extinct flightless and toothed seabird (Fig. 1A), used to test the approach.

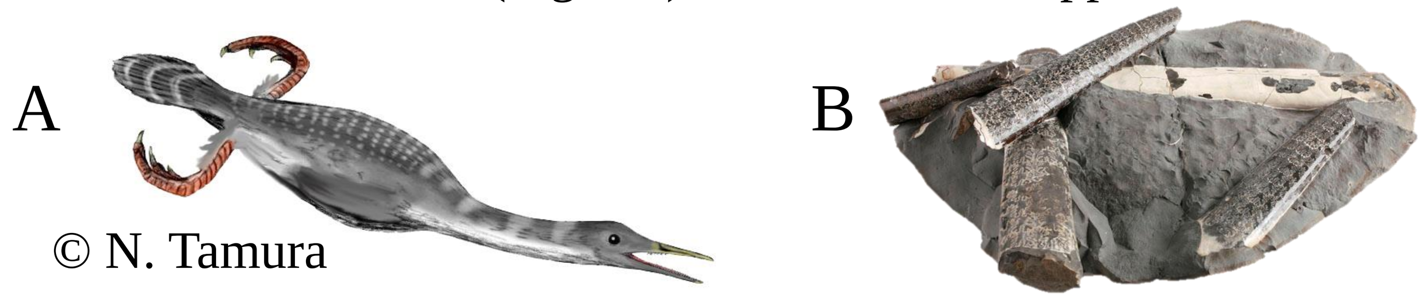

Figure 1. **A**, life reconstruction of *Hesperornis regalis* (Tamura, 2007); **B**, fossilized shells of *Baculites compressus* (The Children's Museum of Indianapolis, 2011).

Methodology

Data Set (Campanian)

- *Hesperornis* species occurrences
  - Localities were obtained for the upper Great Plains from the Paleobiology Database and checked against their referenced literature.
- Sea surface temperatures (SSTs) derived from:
  - $\delta^{18}O$ values in baculitid ammonites (Fig. 1B) and related cephalopods (one is Maastrichtian [~70.4 Ma] in age) as described in the literature.

For a source list of occurrence and SST data, contact the author of this poster.

Analysis

ArcGIS and GPlates were utilized for map construction and raster interpolation (ordinary kriging technique) of the SST data (Fig.2; Scotese, 2016; EarthByte Project et al., 2018). A habitat suitability map (Fig. 3) was generated in Maxent 3.4.1 (Phillips et al., 2018) from 10 replicates created through subsampling 25% of the *Hesperornis* occurrences for test data.

Results

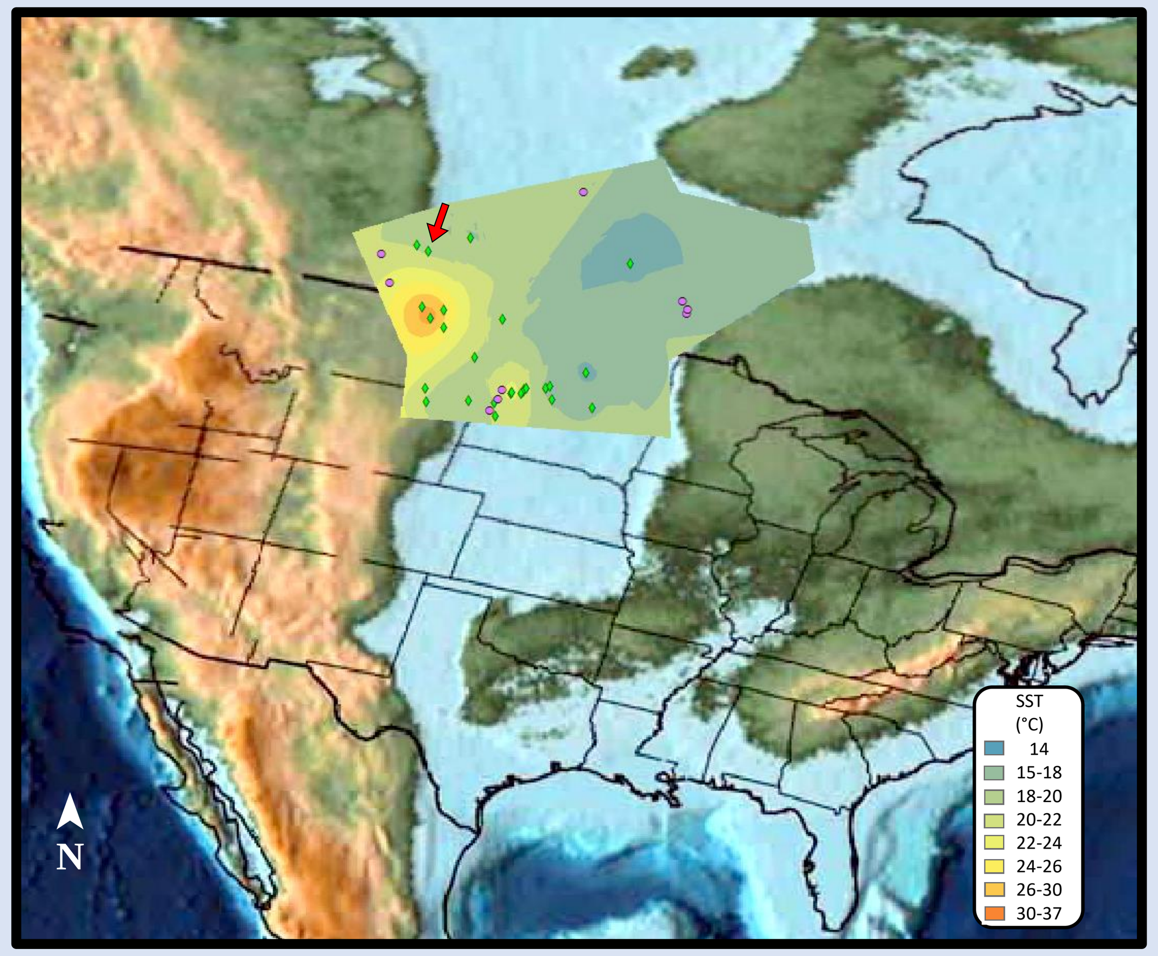

Figure 2. Data paleodistribution map (75 Ma, late Campanian) overlain by an SST raster interpolation. Paleogeographic map derived from Scotese (2016). Pink circles are *Hesperornis* occurrences. Green diamonds are SSTs. The arrow indicates a Maastrichtian SST. Warmer colors represent higher temperatures while cooler colors show lower temperatures.

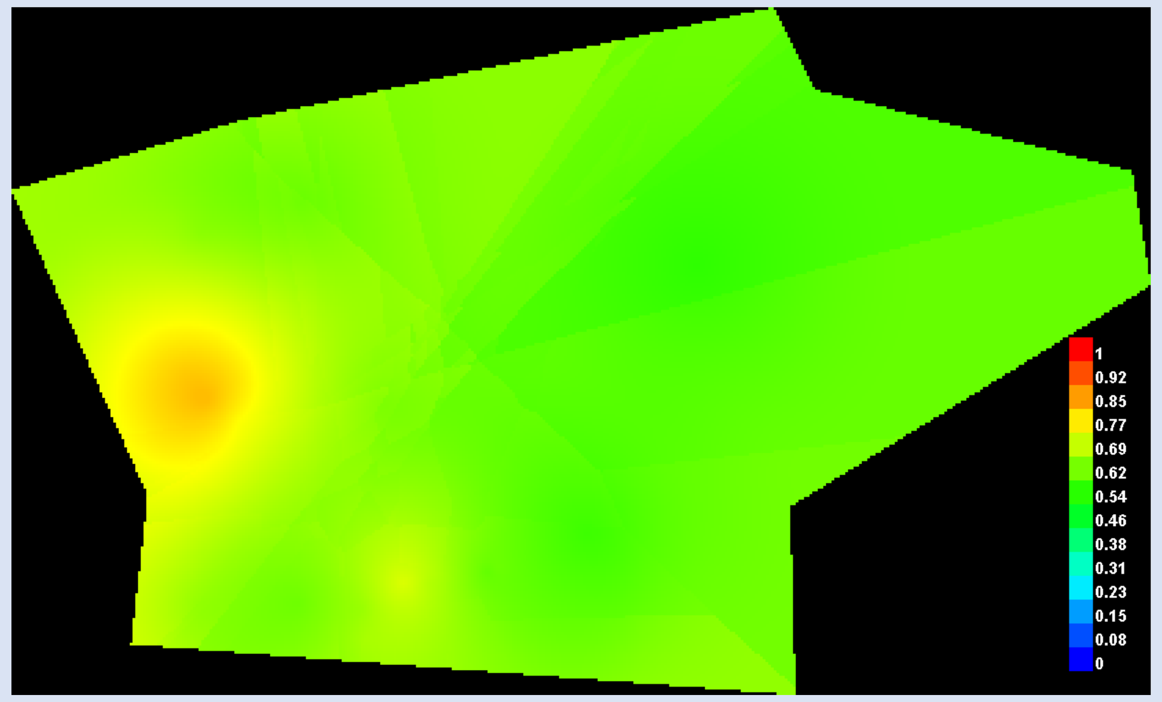

Figure 3. Average habitat suitability map produced by Maxent for *Hesperornis*. Values range from 0 (least suitable) to 1 (most suitable).

Discussion

Hesperornis was predicted by the Maxent model to prefer warmer marine waters in the west-central (≤ 37°C) and south-central (≤ 29.7°C) WIS polygon. The predicted least supportive habitat was in the northeast where colder SSTs (≥ ~13.7°C) were estimated. Suitability ranged from 54-85% but is mostly homogenous within the WIS polygon with only slight differences (≤ 15%). The largely inconclusive results are likely caused by sampling gaps in the current data set within south-central Canada, North Dakota, eastern Montana, and northeastern Wyoming.

Wilson and Chin (2014) hypothesize that *Hesperornis* migrated northward to reproduce or overwinter in the paleo-Arctic due to the high abundance of juveniles. A preference for warmer waters in the Maxent analysis may support the migration hypothesis, but testing requires SST and fossil occurrences from across the entire WIS and additional specimens within the study region.

Conclusions

ENM can be applied to the WIS, but increased sample sizes of fossil occurrence and SST proxy data throughout the WIS are required to more completely characterize the distribution of *Hesperornis*. Future work will further examine the controls on distribution by the addition of other ecosystem variables including rock/sediment type and associated faunal assemblages.

Acknowledgments

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