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Seabirds as Ecological Indicators in Late Cretaceous Marine Environments

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ABSTRACT

In modern marine ecosystems, seabirds are considered indicators of ecological hotspots because their biogeographic distribution is correlated with physical, chemical, and biological oceanographic factors. Pursuit diving seabirds – those that actively pursue prey underwater – are even more limited in distribution and closely tied to oceanographic factors, as diving ability is often gained at the expense of flight capabilities. Today, pursuit diving seabirds are generally restricted to waters cooler than 15ºC. By contrast, the Late Cretaceous was characterized by greenhouse climate and high sea levels that provided marine paleoenvironments with no modern analogs. Even though waters in the Western Interior Seaway (WIS) were warmer than 15ºC, they were host to pursuit diving seabirds called hesperornithiforms. The presence of hesperornithiforms in warm waters indicates that different biotic and abiotic factors affected Late Cretaceous epicontinental ecosystems than affect modern oceans. Together, ecosystem structure and the unique oceanographic factors characterizing epicontinental seas both contribute to differences in seabird biogeography between the Late Cretaceous and today.

INTRODUCTION & RESEARCH DESIGN

In modern marine environments, seabird density is correlated with oceanographic factors like primary production, sea surface temperature (SST), water depth, and distance to shore. Cairns et al. (2008) found that extant pursuit divers are limited to waters colder than 15ºC. Hesperornithiforms were a group of flightless pursuit diving birds that populated Northern Hemisphere epicontinental seas during the Late Cretaceous. They were particularly abundant in the Western Interior Seaway (WIS) of North America where waters are estimated to have been warmer than 15ºC (Figure 2). Given this, Late Cretaceous pursuit divers had distinctly different distributions than today's pursuit diving seabirds. The purpose of this study is to explore the relationship between hesperornithiforms and their environment in light of what is known about biotic and abiotic controls on modern pursuit diving seabird populations.

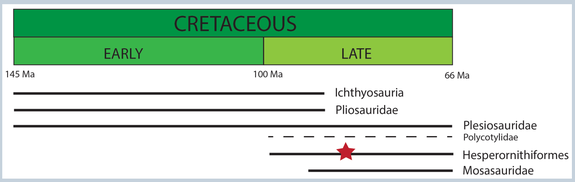

FIGURE 1. Temporal overlap among Hesperornithiforms and marine reptiles. Star denotes significant hesperornithiforms diversification.

RESULTS

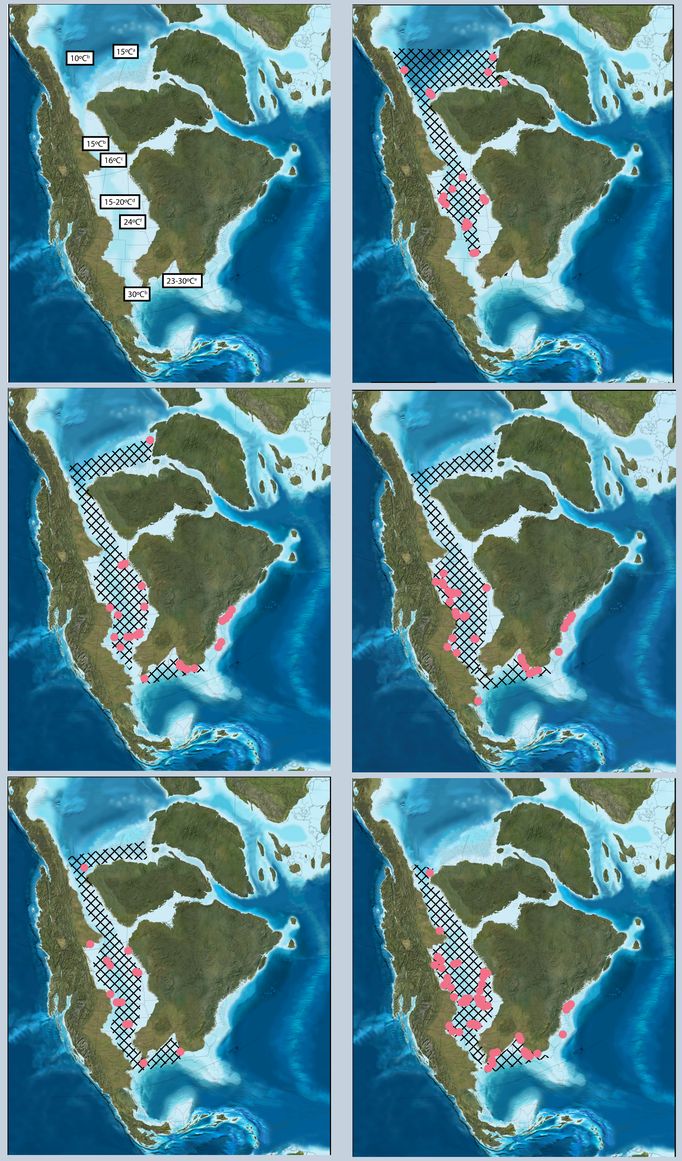

Figure 2. Estimated Sea Surface Temperatures (A) during the Campanian based on different proxies and models. Biogeographic range of (B) Hesperornithiformes, (C) Ichthyodectidae, (D) Lamniformes, (E) Polycotylidae, and (F) Mosasauridae clades during the Campanian. Dots on the maps represent fossil occurrences recorded in the Paleobiology Database (paleobiodb.org). Hesperornithiformes taxa searched include *Hesperornis*, *Parahesperornis*, *Canadaga*, *Baptornis*; Ichthodectidae taxa include Ichthyodectidae, *Xiphactinus* and *Ichthyodectes*; Lamniformes includes Lamniformes, *Cretoxyrhina* and *Squalicorax*. Polycotylids include Polycotylidae, *Dolichorhynchops* and *Trinacromerum*; mosasaurs include Mosasauridae, *Tylosaurus* and *Clidates*. A Campanian filter was applied to each search to constrain the age of fossil localities reported. Crosshatch regions represent WIS and southern range reconstructions based on database occurrences supplemented with the taxa list from Chin et al. (2008). [a](Jenkyns et al., 2004), [b](Hay et al., 1993), [c](Otto-Bliesner et al., 2002), [d](He et al., 2005), [e](Liu, 2009), [f](Dennis et al., 2013). Map © Colorado Plateau Geosystems 2013

DISCUSSION

Marine mammals were absent during the Late Cretaceous, but marine reptiles filled similar niches and hesperornithiforms shared ecospace with many large ectothermic predators in the WIS (Figure 2). Studies have shown that mosasaurs and plesiosaurs were not as efficient swimmers as marine mammal predators (Massare, 1988; Motani, 2002). Predation pressure was not strong enough to limit the seabird's distribution given the amount of time the two groups coexisted (Figure 1). Consequently, Late Cretaceous marine reptiles were perhaps not the ecologic equivalents of modern marine mammals, thereby exerting different evolutionary pressures that would have affected seabird ranges.

Hesperornithiforms lived in an environment with oceanographic conditions different from any today. Authors have suggested that SST affected hesperornithiform biogeography (Cumbaa et al., 2010; Nicholls and Russell, 1990). Modern seabird distribution is also correlated with distance to shore, water depth, and primary production (Ainley et al., 2005; Hunt et al., 1999; Weichler et al., 2004). The WIS was an environment that provided ample "real estate" for seabirds, with water depths around 200m (Hancock and Kauffman, 1979; McDonough and Cross, 1991) and an abundance of nearshore conditions. It is not until the transition to open ocean conditions that hesperornithiforms disappear from the ecosystem.

CONCLUSION

Fossil evidence coupled with SST reconstructions clearly show distinct differences in pursuit diving seabird biogeographic distributions. Late Cretaceous marine reptiles filled niches occupied by marine mammals in modern ecosystems, but they are not ecological equivalents. They did not exert the same competition and predation pressures as marine mammals. Additionally, Late Cretaceous epicontinental seas offered seabirds ideal habitats with high primary production, shallow water depths, and abundant shorelines – all factors associated with high diving seabird populations today.

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