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Climate change and evolution of growth in Late Cretaceous to Recent North American Esociformes

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Abstract

Relationships between climate change, growth characteristics (i.e., longevity, rate of growth, and maximum total length), and evolution are examined for Mesozoic, Cenozoic, and extant taxa of North American Esociformes. The proposition that temperature influenced speciation within Esocoidei, including the genus *Esox*, is supported by several findings: 1) Cretaceous esocoids have smaller centra and very different growth characteristics than *Esox* occurring after the K-T boundary; 2) a significant relationship exists between mean annual temperature and longevity for Tertiary *Esox*; 3) significant differences between growth characteristics of extinct and extant taxa indicate adaptations of fossil taxa for warmer climates; and 4) the latitudinal distribution of Tertiary *Esox* is positively correlated with temperature, except during the Early Eocene Thermal Maximum (EETM). The hypothesis that *E. (Kenoza)* evolved during the EETM is supported by: 1) early Eocene appearance of *E. (Kenoza)* osteology in *E. kronneri*; 2) similarity of the interaction of longevity and growth rate between *E. (Kenoza)* and some Paleocene and early Eocene fossils; 3) interpretation that early Eocene *Esox* from the Green River and Coalmont Formations inhabited temperatures exceeding those recorded for extant *E. (Esox)*; and 4) latitudinal discontinuity in the distribution of *Esox* at the EETM when *E. kronneri* appeared. The comparison of Cretaceous esocoids to extant umbrids suggests that the small size of umbrids is a primitive feature in Esocoidea. The larger size of extant *E. (Esox)* is interpreted as being derived for esocoids but a condition that is primitive for the genus.

Introduction

Esocoids are an important group of freshwater fishes that have their origins during the Mesozoic. They have inhabited North America at least since the Campanian (WILSON et al. 1992). In the fossil record they are more often represented by isolated centra (e.g., SMITH et al. 2000, BRINKMAN & NEUMAN 2002) and fish scales (WILSON 1981) than by complete skeletons (WILSON 1980, GRANDE 1999). The usefulness of isolated fragments may appear low, but isolated centra and scales can permit examination of aspects of ecology, life history characteristics, population dynamics, sexual maturity, growth, and mortality (e.g., THOMPSON & MCCUNE 1984; MICKLICH 1985, 2002; MARTÍN & SOLER GIJÓN 1999; NEWBREY & BOZEK 2003). While studies focusing on the growth of fishes are commonplace in extant fisheries, there has been little research into growth or other life history characteristics in fossil fishes. The objective of our research is to study growth of esocoids in order to identify evolutionary events and trends, and ultimately, to augment our understanding of the evolution of Esocoidei. Our thesis is that evolutionary events in Esociformes are driven in part by extreme climatic events. We also test GRANDE's (1999) hypothesis that temperature could be an ecological mechanism to explain speciation within the genus *Esox*. GRANDE based his hypothesis on extant geographic and thermal distributions and temperature-affected variation in phenotypically plastic numbers of vertebrae (FOWLER 1970).

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