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Distribution of cephalic electroreceptor organs in weakly electric South American knifefishes (Teleostei: Ostariophysi: Gymnotiformes)

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Sensory organs are generally fine-tuned to an organism's environment and ecological niche. Many examples of this environmentally influenced fine-tuning exist for sensory modalities, such as vision and audition, but this link is poorly understood for electroreception. This study investigates the distribution of electroreceptor pores on the heads of select members of the Gymnotiformes, Neotropical weakly electric knifefishes that use electric signals for orientation, communication, and prey localization. We evaluated the distribution and density of electroreceptors among select gymnotiform genera and discuss whether apparent differences could be consistent with ecological factors, such as habitat type and feeding behavior. Evidence for such patterns has been found in elasmobranchs; however, differences in the functional roles of the electrosensory system in gymnotiforms (e.g. electrocommunication) may alter these patterns within this diverse clade of freshwater fishes. Scanning electron microscopy was used to image the heads of specimens collected from diverse habitats. Pores associated with ampullary and tuberous electroreceptor organs were enumerated using digital image processing software and mean pore counts were compared across six different regions of the head. Previously unknown pore types and distribution patterns are described. Additionally, unique electroreceptor distributions were found in some species with specialized feeding modes. This study provides the first quantitative comparative analysis of electroreceptor distributions across multiple gymnotiform families and genera, providing an important step toward understanding the factors that have shaped the evolution of electroreception in this diverse group of Neotropical fishes.

Introduction

Sensory systems undergo strong selection to optimize how organisms obtain information about their environments. Organisms rely on sensory systems for orientation, detecting food, finding shelter, communicating with potential mates and rivals, and avoiding danger. Therefore, sensory organs are often specifically adapted to the aspects of an organism environment and ecological niche. For example, studies manipulating the light environment have demonstrated how critical aspects of vision, such as lens properties (Kröger et al., 2001), opsin expression (Fuller et al., 2005), and the relative abundance of photoreceptor cells (Shand et al., 2008) and their neural connectivity (Wagner & Kröger, 2005), can vary. Whereas sensory modalities such as vision have been studied extensively, the influence of environmental variation on electroreception is not well understood.

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concept originally proposed by Trujillo-Cenóz et al. (1984). If true, it is possible that electroreceptor distributions could reflect feeding strategies on the head and communication specialization on the trunk. However, there is compelling evidence that different EOD phases do not have compartmentalized functions (Schuster & Otto, 2002). It would be interesting to expand the interspecific comparison of electroreceptor distribution on the head to the rest of the body and with additional species that use specific microhabitats. In addition to more detailed ecological information (e.g. habitat conditions, diet), comparisons of electroreceptor tuning properties and pore distributions for additional species (Castello et al., 2000) would further elucidate the drivers of electroreceptor evolution. Beyond furthering the theoretical understanding of the evolution of sensory organs, these studies can generate practical information. For example, they provide valuable data for studies developing aquatic robots that use electric sensors for navigation, which often use bio-inspired estimates of electroreceptor densities for developing models of electrosensory space (Snyder et al., 2007; Neveln et al., 2013).

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