Back to the sea - inner ears reveal ecomorphological adaptations in thalattosuchian crocodylomorphs

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A prime example of a major evolutionary transition are thalattosuchian crocodylomorphs. Known from the Early Jurassic to the Early Cretaceous, they evolved from terrestrial ancestors into the first radiation of marine crocodylomorphs. Basal thalattosuchians were semiaquatic, with a gharial-like body-plan, and are known from freshwater, brackish and coastal marine environments. However, the metriorhynchid sub-group radically modified their bauplan during their transition to an obligately pelagic lifestyle. This included evolving paddle-shaped limbs, a vertically orientated tail fluke, and smooth skin lacking scales and osteoderm 'armour'. While these osteological changes are well understood, little is known about how their neurosensory systems evolved during this transition. Cranial sensory organs are powerful ecological proxies, for example the inner ear, which is involved in hearing, equilibrium, balance, and head stabilisation. The vestibular system of the inner ear includes the three semicircular canals and the vestibule, and studies across a wide range of vertebrates show that inner ear morphology correlates with animal behaviour and lifestyles.

Based on computed tomography scans and three-dimensional bony labyrinth models of a broad sample of fossil and extant crocodylomorph taxa, we studied changes in the morphology of the inner ear vestibular system during the thalattosuchian land-to-sea transition. We found that the vestibular system changes significantly as crocodylomorphs moved from terrestrial to open ocean environments. Pelagic thalattosuchians (metriorhynchids) had dorsoventrally shorter labyrinths with wider semicircular canals and an enlarged vestibule compared to their terrestrial ancestors. This pelagic inner ear morphology evolved after the radical osteological changes to the postcranial skeleton, suggesting changes to sensory systems lag behind osteological ones during major evolutionary transitions. This parallels trends seen in other marine vertebrates, suggesting a common pathway for pelagic reptiles to adapt to marine life and a strong correlation between aquatic lifestyle and semicircular canal morphology.