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Spinosaurus Spent Most of Its Life Underwater, 11,000-Measurement Yale Study Finds

Spinosaurus * Paleobiology * Evolutionary Biology

For more than a decade, paleontologists have debated how Spinosaurus aegyptiacus -- the 15-meter, sail-backed predator of mid-Cretaceous North Africa -- hunted its prey. One camp argued that the dinosaur plunged underwater like a giant crocodile or seal, while another contended that its tall neural sail and body shape limited it to wading along shallow riverbanks like a giant heron. A new study in Current Biology led by Yale University paleobiologist Caleb Gordon and colleagues at the Yale Peabody Museum brings big-data anatomy to the debate, concluding that Spinosaurus spent the vast majority of its life submerged underwater.

11,000 Measurements and WWII Radar Statistics

Historically, reconstructions of extinct animal lifestyles relied on small sets of skeletal traits or single biomechanical simulations, which often yielded conflicting answers depending on how soft tissue and air sacs were estimated. To overcome that limitation, the Yale team assembled a database of more than 11,000 anatomical measurements , high-resolution photographs, and micro-CT scans spanning hundreds of living and extinct four-limbed vertebrates (tetrapods) whose aquatic or terrestrial habits are well documented.

Focusing heavily on forelimb and hindlimb proportions alongside internal bone structure, the researchers trained machine-learning classification models to recognize how limb geometry shifts as land animals adapt to water -- a transition biologists call becoming secondarily aquatic . To evaluate how reliably each skeletal measurement separated swimmers from walkers, the team applied Receiver Operating Characteristic (ROC) signal-detection statistics , a mathematical framework originally developed during World War II to distinguish real naval radar targets from background ocean noise.

Built Like a Diver: Bone Ballast and Tail Propulsion

When the machine-learning models evaluated Spinosaurus , the dinosaur clustered squarely with animals that spend most of their lives submerged in water rather than shoreline waders. This limb-proportion signal aligns closely with three converging lines of anatomical evidence:

* Solid Bone Ballast (Osteosclerosis): Most predatory theropod dinosaurs, such as Tyrannosaurus rex and Allosaurus , had hollow limb bones filled with air spaces (pneumaticity) that kept their skeletons light on land. Micro-CT scans of Spinosaurus ribs and thigh bones reveal nearly solid cross-sections (bone compactness values around 0.968), acting like a scuba diver's weight belt to overcome buoyancy underwater.

* A Flexible, Paddle-Like Tail Fin: Complete tail vertebrae recovered from Morocco's 95-million-year-old Kem Kem river beds possess tall, slender spines over 60

centimeters high, forming a laterally flexible paddle capable of generating forward thrust in water.

* Submerged Sensory Adaptations: The dinosaur's external nostrils are positioned high up on the skull near the eyes -- allowing it to breathe while nearly hidden below the surface -- while its elongated, crocodile-like snout is pitted with tiny nerve openings (foramina) sensitive to water pressure ripples from swimming fish.

| Taxon / Ecological Group | | Bone Compactness (C g) | | Limb & Skeletal Regime | | Primary Propulsion | | Model-Inferred Habitat Zone |

| Spinosaurus aegyptiacus (Cretaceous spinosaurid) | | ~0.968 (solid osteosclerotic ballast) | | Shortened hindlimbs; submerged-specialist proportions | | Tall, flexible caudal tail fin + webbed feet | | Predominantly submerged river channels |

| Tyrannosaurus rex (Terrestrial theropod) | | ~0.480-0.560 (hollow, air-filled marrow cavity) | | Long, weight-bearing cursorial hindlimbs | | Bipedal terrestrial stride | | Fully terrestrial floodplains |

| Extant Crocodilians & Hippos (Submerged foragers) | | ~0.890-0.960 (heavy bone ballast) | | Stocky, shortened weight-ballasted limbs | | Lateral tail undulation / bottom-walking | | Submerged aquatic & benthic zones |

| Extant Herons & Storks (Shoreline waders) | | ~0.420-0.510 (lightweight pneumatic skeleton) | | Extremely elongated, slender stilt-like legs | | Bipedal wading & flight | | Shallow water margins (<0.5 m depth) |

| Mesosaurus tenuidens (Early Permian reptile) | | ~0.850 (thickened pachyostotic ribs) | | Amphibious limb proportions in Yale ML model | | Undulatory tail + terrestrial limb posture | | Semi-aquatic; unexpected time on land |

Surprising Reversals in Ancient Reptiles and River Ecosystems

Beyond Spinosaurus , the Yale dataset overturned longstanding assumptions about other prehistoric swimmers. Early Permian mesosaurs (Mesosaurus) -- small, 280-million-year-old reptiles long textbook-classified as the earliest fully aquatic reptiles -- showed limb proportions indicating they actually spent a surprising amount of time walking on land, much like modern semi-aquatic lizards or seals hauling out onto beaches.

For the mid-Cretaceous ecosystems of North Africa, confirming that Spinosaurus lived primarily underwater helps explain how the Kem Kem river system supported multiple giant apex predators at the same time. While multi-ton terrestrial carnivores such as Carcharodontosaurus hunted land-dwelling dinosaurs along the floodplains, Spinosaurus occupied the deep river channels -- preying on giant coelacanths, lungfish, and the car-sized sawfish Onchopristis with minimal competition on dry land.

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