Mega-predator likely wasn't underwater hunter, researchers argue

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New evidence from UChicago paleontologists suggests that Spinosaurus, the largest known predatory dinosaur to roam the Earth, was adapted for hunting along shorelines instead of venturing deep underwater. Credit: James Gurney

,The hunting habits of Spinosaurus aegyptiacus, the largest known predatory dinosaur to roam the Earth, have been subject to intense scientific debate since detailed descriptions of its most complete fossils to date were published in 2014.

At the time, Spinosaurus was described as a "semiaquatic" predator that prowled the shoreline of Cretaceous-era rivers, wading into the muddy banks to ambush fish with its massive, crocodilian jaws and interlocking teeth.

More recent discoveries have pushed Spinosaurus further from the shore, with some researchers suggesting it was well-suited to pursuing prey out of the shallows and hunting deep underwater. These arguments are based on new fossils that suggest Spinosaurus had a fleshy, paddle-like tail for swimming and dense bones to help submerge it underwater.

A new paper by paleontologists from the University of Chicago and colleagues elsewhere, however, rejects this "aquatic hypothesis" as far-fetched. Using updated virtual reconstructions of its skeleton and body mass based on its fossils, they analyzed its ability to propel its prodigious bulk underwater and found that while Spinosaurus was indeed the scourge of the shoreline with many adaptations for life at the edge of the water, it would fail as a fully aquatic, agile, underwater predator.

"Do I think that this animal would have waded into water on a regular basis? Absolutely, but I don't think it was a good swimmer, nor capable of full submergence behavior," said Paul Sereno, a professor of organismal biology and anatomy at UChicago and lead author of the new study who co-led the initial Spinosaurus discovery in 2014. "This is simply not an animal that in your wildest dreams would be dynamic above water as a swimmer, much less underwater."

The new paper, titled matter-of-factly, "Spinosaurus is not an aquatic dinosaur," was posted as a preprint at bioRxiv and published Nov. 30 in the journal *eLife*.

Elusive from the beginning

Spinosaurus aegyptiacus has been an elusive creature since German paleontologist Ernst von Stromer discovered its skeleton in Egypt in 1915. With its elongated jaws and large sail protruding from the spine, Stromer initially proposed Spinosaurus as a bipedal, fish-eating predator. He put the fossils on display in Munich's Paleontological Museum, but they were destroyed during Allied bombing in World War II. All that was left were Stromer's notes and drawings. The giant Spinosaurus seemed lost in time.

Spinosaurus likely stood on its hind legs, with dense bones suited for walking upright. Credit: James Gurney

Decades later, miners in southeastern Morocco unearthed what appeared to be another Spinosaurus skeleton buried in sandstone rocks. Those fossils formed the basis of the 2014 study, published in *Science*, in which Sereno and his team analyzed the new fossils plus a partial skull and other specimens gathered from museums around the world, along with Stromer's original records and journal articles.

Their findings brought the team worldwide acclaim. They depicted Spinosaurus as a nearly 50-foot-long monster, with giant, interlocking slanted teeth for snatching fish, a long neck and trunk, short hind legs with muscular thighs, and enormous dorsal spines covered in skin that created its signature sail. The skull had small nostrils located farther back on the skull to allow it to breathe when partially submerged and crocodile-like neurovascular openings on its snout that may have been for receptors to sense movement in the water. Yet the researchers still viewed the beast as "semiaquatic," an animal best suited for land while venturing into shallow waters to feed.

Since those initial findings, researchers from the University of Portsmouth in the United Kingdom collected the nearly complete tail of the rediscovered skeleton, which was hidden in sediment to the side of the original bone quarry. The tail had tall, slender spines that that would have been covered with skin, a version of the sail along its back. In a 2020 *Nature* paper, the U.K. team proposed that Spinosaurus would have used this fleshy tail to propel itself like an eel through the water column as a fully aquatic predator.

This year, that same team published another paper in *Nature* that compared the density of Spinosaurus bones to a wide variety of living and extinct animals. They concluded that the dinosaur had very dense bone walls like penguins, suggesting it actually spent most of its time in water, using the heavier bones for ballast to submerge itself regularly in underwater pursuits.

A fearsome predator, but awkward swimmer

Meanwhile, Sereno and colleagues approached the question from several new angles, starting with a mistake in the 2014 paper ("I love to admit mistakes, especially when I can correct them myself," Sereno said). When they calculated the animal's center of gravity, the software didn't properly deduct mass to account for the volume of its lungs, pitching it forward and leading the team to believe it walked on all fours.

In the new research, Sereno and team constructed a fresh model of Spinosaurus from CT scans of its skeleton and fleshed it out with its musculature and body mass, based on modern reptiles. This time they made sure to account for the volume of its lungs, which positioned the center of gravity over its hips, allowing the usual two-legged (bipedal) stance like all other large-bodied dinosaurian predators. Sereno says dense bones make sense for such a large animal walking on two legs.

"The solid limbs are not there for ballast while swimming, but rather to support the great weight of the beast," he said.

The team also studied the biomechanics of the more complete tail structure and analyzed how useful it was for swimming. The team's expert in tail mechanics, Frank Fish from West Chester University in Pennsylvania, calculated the propulsion power of modern-day alligators and other reptiles that have muscular tails with bony spines like the newly discovered Spinosaurus tail. Using formulas often applied to calculate eel-like swimming in water, they extrapolated the swimming power a Spinosaurus could produce by flexing its tail and paddling with its feet.

They found that it would have been an order of magnitude less than an alligator, which tucks its limbs away as ineffective when swimming. Spinosaurus, with such a huge body mass, large sail, and hind legs

dangling behind, would have been resistant to forces underwater and far too rigid to power itself via aquatic undulation.

"We based our calculations on accurate renderings of the tail and foot and how those should scale up if it were built like crocodiles," Sereno said.

Spinosaurus too buoyant to go deep

The team also calculated that Spinosaurus would have been too buoyant to fully submerge itself regularly, needing 15 to 25 times the estimated power of its tail. The bone and muscle structure of the tail wouldn't have been flexible enough to propel it smoothly through water, unlike the fleshy tail flukes on whales or light, springy fish fins. The heavy, bony sail on its back also would have made it an awkward swimmer that struggled to right itself, unlike alligators and crocodiles that can easily spin and roll to pursue their prey.

Finally, Sereno's team turned to the geographic fossil record to argue that Spinosaurus could not be a highly specialized, fully aquatic predator. More of its fossils have been found in two inland basins in Niger, far from any prehistoric marine coastline. They were buried in riverbank deposits alongside other large herbivores and suggests that they lived along both marine and freshwater habitats.

In the new paper, the authors conclude that this evidence is a strong confirmation that Spinosaurus aegyptiacus is "a semiaquatic bipedal ambush predator that frequented the margins of both coastal and inland waterways."

More information: Paul C Sereno et al, Spinosaurus is not an aquatic dinosaur, *eLife* (2022). DOI: 10.7554/eLife.80092

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