

of our forecasts are limited by now.’

NOAA and Mote have been field testing the smartphone-microscope-app system since November 2016 with help from four Mote volunteers who were trained to collect small water samples, place them onto a microscope slide, take videos with a smartphone attached to the microscope, and upload those videos to GCOOS to be automatically assessed for red tide algae cells. They reported about 500 times, giving project partners useful data for fine-tuning the software.

‘It was beneficial to train our volunteers and have them sample water during the red tide bloom, because we were working with concentrations of

Karenia brevis that scientists encounter during our regular monitoring efforts, and the public was encountering in real time,’ said Fanara. She and her staff are responsible for training volunteers. ‘We went through the process of training volunteers and learning how to optimize our training system by finding the most effective ways to help people learn how to homogenize a sample, place the sample on the slide and focus the microscope just right to get an acceptable video the algorithm could use. The volunteer network is one key to dependable data collection.’

Project partners plan to increase volunteer training this year and expand the program to Texas, where Master

Naturalist/Red Tide Rangers currently monitor some beaches for red tide.

Volunteer-gathered data will be uploaded to the GCOOS data portal, which provides real-time and near-real-time information on a variety of Gulf environmental conditions. ‘More data, over longer periods, means that we will be gaining a more precise picture of how red tides move in the Gulf of Mexico,’ Stumpf said. ‘In addition to providing better forecasts right now, we can also improve the accuracy of our forecast models.’

[Hayley Rutger \(hurutger@mote.org\)](mailto:hurutger@mote.org)
Content Development Manager Mote
Marine Laboratory and Aquarium
<https://mote.org>

On Aristotle’s observations of fish reproduction

By [Kostas Gantias](#) and [Eleni Voultsiadou](#).

The year is 348 BC. Aristotle is teaching the young Alexander about the fascinating world of fishes. He leans down to pass on some incredible science facts:

“There is a fish called rhinobatos [the guitarfish] which has the tail of rhine [the angelshark] and the head of batos [the ray] which originates from the interbreeding of these two fishes.”

“Did you know that the eel comes from the guts of the Earth?”

“Another strange fish called the pipefish, when spawning time comes, bursts asunder and the eggs emerge.”

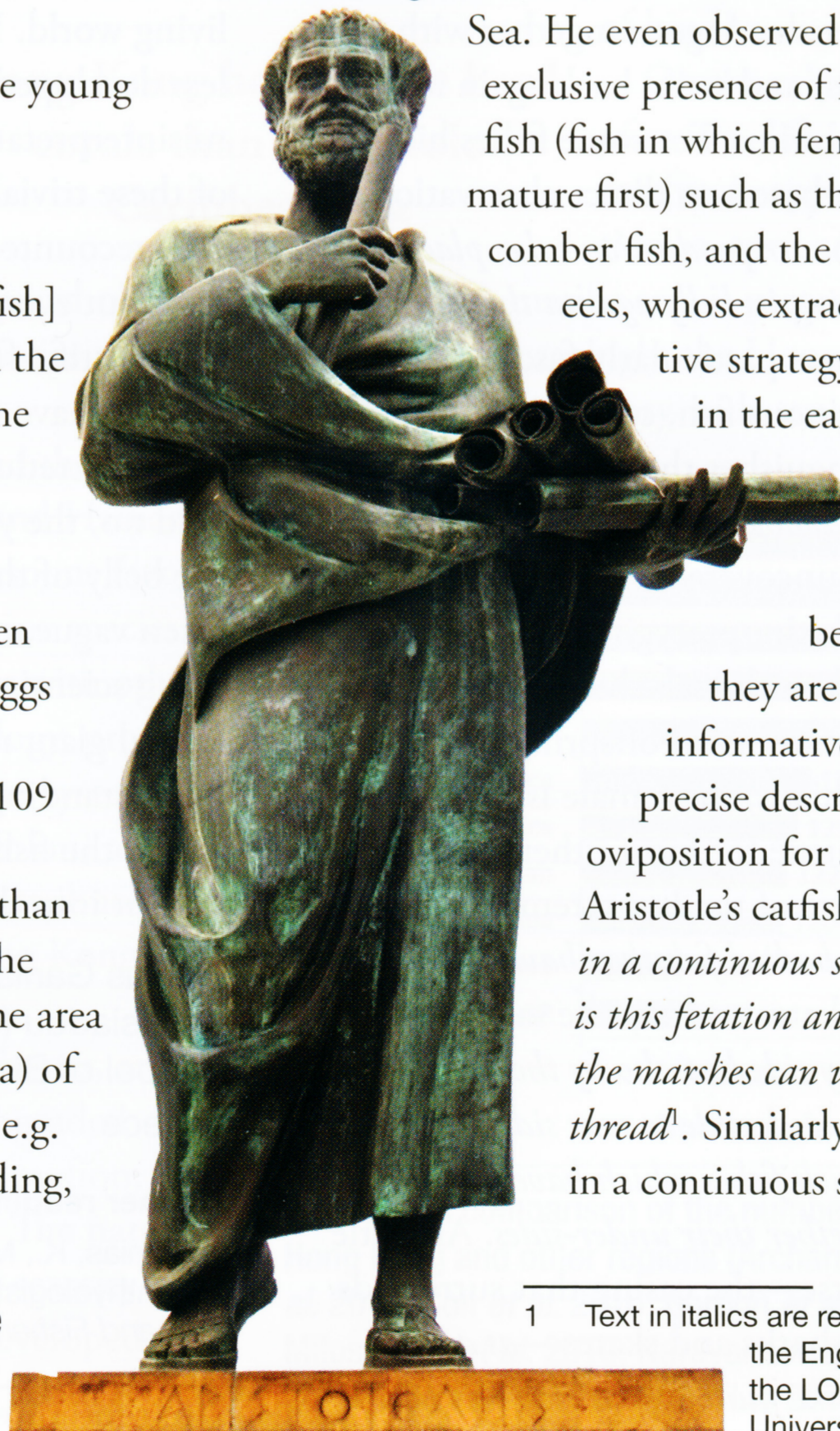
In his biological corpus, Aristotle identified 109 individual species of fish, and examined and described the reproductive life history of more than 40 species. Most of these descriptions refer to the timing (duration, seasonality, frequency) and the area (habitat type, bathymetric zone, geographic area) of breeding as well as to their reproductive mode, e.g. oviparity vs. viviparity, benthic vs. pelagic breeding,

and so forth. Even if these descriptions are mostly brief and general, Aristotle’s survey is impressively comparative showing his profound knowledge of fish life history.

For certain fishes with exceptional breeding patterns, Aristotle proceeded to more detailed descriptions such as the courtship and the parental care of the pipefish, the mating behaviour of stingrays and other rays and the reproductive migrations of scombrids from the Aegean to the Black

Sea. He even observed and tried to explain the exclusive presence of females in protogynous fish (fish in which female reproductive organs mature first) such as the red-pandora and the comber fish, and the lack of sexually mature eels, whose extraordinary reproductive strategy was only understood in the early 20th century.

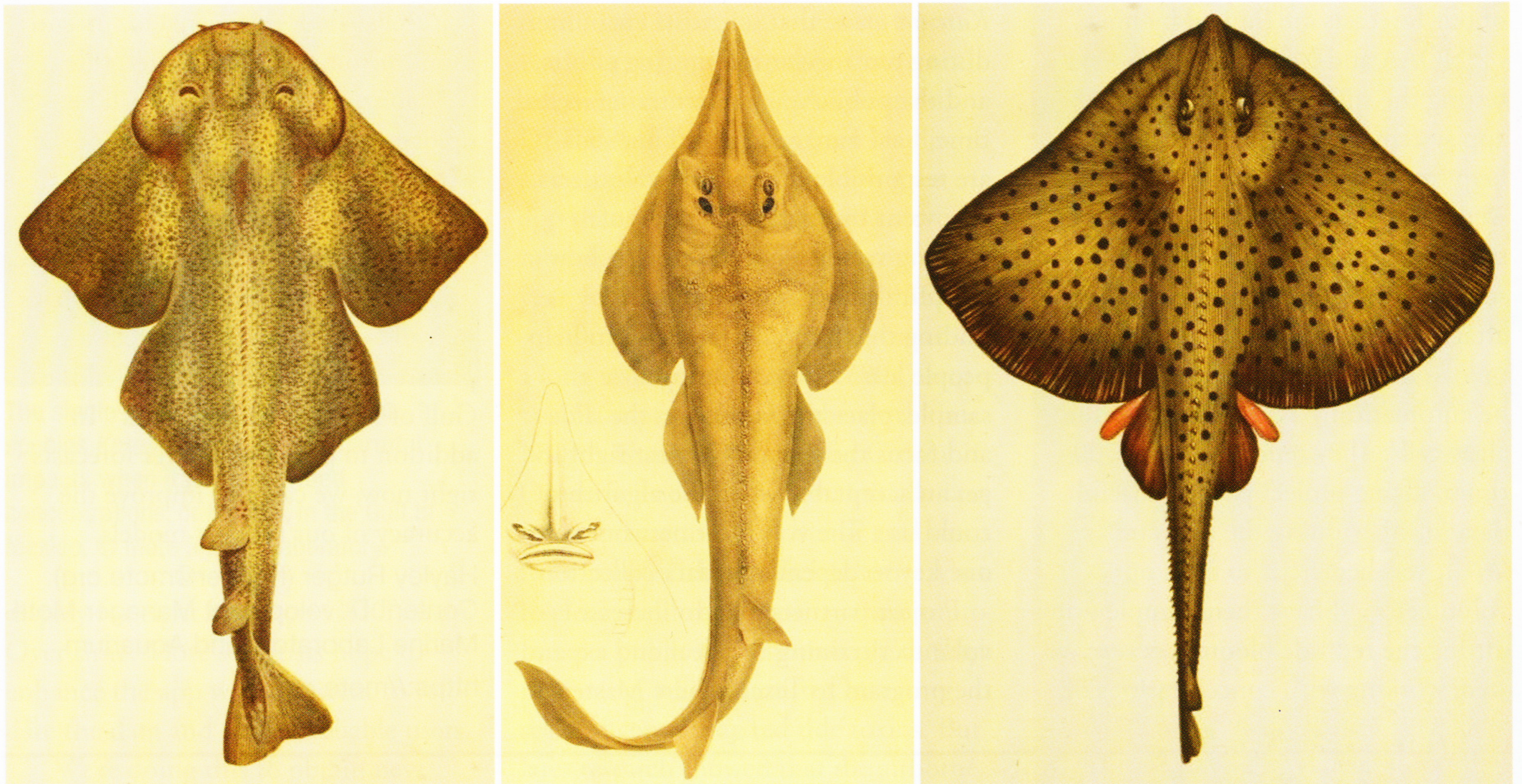
Aristotle’s descriptions of fish reproduction might sometimes be vague but for some species they are rather accurate and informative. For instance, he gives a precise description of the process of oviposition for some freshwater fish like Aristotle’s catfish which: *deposits its spawn in a continuous string, as frogs do; so twisted is this fetation and so even that fishermen in the marshes can unwind it off the reeds like thread*¹. Similarly, the perch deposits its eggs in a continuous string and: *spawns at*



Bronze statue of Aristotle by the modern artist George Tsaras, located at the campus of the Aristotle University in Thessaloniki, Greece.

© Eleni Voultsiadou.

¹ Text in italics are representative excerpts from the English translation of Aristotle by the LOEB classical Library, Harvard University.



Aristotle describes the rhinobatos (the guitarfish; middle) as having the tail of a rhine (angelshark; left) and the head of a batos (the ray; right). He suggested that rhinobatos originated from the interbreeding of these two fishes. Pictures from *A history of the fishes of the British Islands* By Jonathan Couch, Groombridge and Sons, 1862.

stagnant pads left behind by river floods and near the reedy parts of marshes. But even more astounding are descriptions for marine pelagic spawners like the bonito which spawn at the Black Sea. Their eggs are called *afxides* (from *afxanō* meaning to grow) because they grow in just a few days; their young leave the Black Sea and enter the Aegean together with *thynnides* (the young tunnies) and swim back again in spring, when they are fully grown bonitos. For some fishes his descriptions must have been based on direct observation, for example the sand smelt whose: *reproduction takes place close to the land and spawns by rubbing its belly against the sand.*

It appears that Aristotle was particularly fascinated by the reproduction of cartilaginous fish, calling them *selachia* in his works. Aristotle distinguishes the selachians from the other fish because they are *zootoka* (viviparous), they have cartilaginous skeletons and uncovered gills. He knew that fish with scales (*Lepidotoi*, Actinopterygii) are oviparous, producing more offspring than the selachians, and that there is a natural decrease in the number of offspring in favour of their size. In all the selachians, the female is larger than the male, while the same is true for most other fishes. His most detailed descriptions are of the hypotremata (*platei*), whom he describes as *wide-bodied fish that have their gills on the ventral surface*. For the skates and rays he says that they *copulate not only lying side by side but also by the mounting of the male upon the female, underside to rear side*. The angel shark, however, *and other such fishes which have a large tail copulate only by rubbing together their under-sides*. Aristotle describes the mermaid's purse—the casing that surrounds the fertilized eggs of many sharks and skates—as *a shell-like object, in which an egg-like fluid appears whose shape is*

similar to the tongues of an 'aulos'² and which has hair-like passages attached to its edges. When the ray has laid the egg and the shell has broken open, then the young emerges.

Aristotle was a highly intuitive person with a strong passion for observing and explaining anything related to the living world. However, scientific understanding was much less developed in his day and this is why one finds several misinterpretations about fish in his zoological works. Some of these trivial facts, such as the spontaneous generation of eels, recounted above, would have fascinated not only children but everyone for many centuries before being refuted by scientific facts. No, selachians do not have breasts but they do have nidamental (shell) glands which are involved in the secretion of their compact and protective egg capsule. And no, the young of the spiny dogfish do not return to the belly of their mother. Yes, Aristotle's descriptions are often vague, non-specific and maybe naïve to the eyes of smug scientists. Nonetheless, 2,400 years ago this intellectual giant made an immense contribution to the human understanding of nature, and his zoological corpus—in which the fishes feature significantly—offers an invaluable insight into the roots of modern biological knowledge.

Kostas Ganias (kganias@bio.auth.gr) and Eleni Voultsiadou (elvoults@bio.auth.gr) Department of Zoology, School of Biology, Aristotle University, 54124 Thessaloniki, Greece

Further reading

Ganias, K., Mezarli, C. and Voultsiadou, E. (in press) Aristotle as an ichthyologist: Exploring Aegean fish diversity 2,400 years ago. *Fish and Fisheries*.

² an ancient Greek wind instrument.