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The mysterious migration of eels: how the Earth's magnetic field guides them across the globe

Every year, billions of eels migrate from continental waters back to their oceanic birthplace to reproduce. Each species has one unique spawning area, located thousands of kilometers away from their continental feeding grounds. How eels find their way back to the spawning area is still a mystery as there are no obvious signposts that could guide them during their migration in the open ocean. Although never tested comprehensively until now, the geomagnetic field stands as the most likely candidate that eels could use to guide them. The research team has previously demonstrated that eels can sense and utilize magnetic fields to guide their movements. They now made a big step forward towards solving the puzzle of eel migrations: they detail how eels can make use of the geomagnetic patterns along their migratory routes to reach their spawning areas. Their new research describes a mechanism that fits with the lifecycle, biogeographic distribution and migrations of five species of anguillid eels.

Anguillid eels across the globe all have in common that their reproduction area is in the open ocean thousands of kilometers from their continental feeding grounds. Newly hatched larvae drift with oceanic currents until they reach coastal and freshwater habitats, where they grow for many years, sometimes up to 30. At the end of the growth period – after having accumulated sufficient energy reserves – they start their long journey back to their oceanic birthplace where they will meet other conspecifics and reproduce. In the fall season, millions of eels migrate down the rivers, overcoming many obstacles, to reach the sea. But once they are at sea, there are few signposts to guide them across the remaining thousands of kilometers. How do eels manage to find their spawning area – a needle in a haystack - in such a vast environment?

Lead author Caroline Durif, a Principal Research Scientist at Norway's Institute of Marine Research (IMR), was aware that the geomagnetic field has, for a long time, been proposed as a likely candidate as the main orientation cue. Yet, no one had ever investigated whether the local magnetic gradients allowed such navigation. Gradients of magnetic intensities and inclinations were found to be similar along the migratory routes of all species examined, even when they were in different hemispheres. Along with the other co-authors of the study, experts in sensory biology and fish migration, Durif lays out a five step mechanism that explains how anguillid eels reach their spawning area and meet their conspecifics no matter where, or when (relative to their arrival at the continental shelf, up to 30 or more years earlier) they started their journey. The universality of the mechanism is exciting but is not surprising given that these species of eel are believed to have one common ancestor and should, therefore, have developed the same navigation mechanism.

The five step mechanism postulates that larvae only need to imprint a certain target magnetic value (analogous to a certain altitude). Later, as adults, they would swim 'down the gradient' until they reach this target value. Once at the target (at the target 'latitude'), they would only need to continue swimming along a trajectory that stayed at that target value and they would arrive at the spawning area. This navigational strategy of “aiming off” (deliberately aiming to one side of a feature to avoid missing it) explains the seemingly puzzling behavior of previously tagged migratory eels that didn’t take a straight route to reach their spawning area. Rather, tagged eels swam straight towards lower latitudes, and then switched compass course.

This is fascinating theory, but would this orientation mechanism be reliable across centuries? The magnetic field features are known to change (slightly) over time. Thus, the authors also tested the additional challenge posed by magnetic secular variation. Young eels “imprinting” the magnetic characteristics of their birthplace would, years later, end up in a different area due to changing magnetic fields or so-called secular variation. They calculated that eels wouldn’t be off target by more than 300 kilometers from the original birthplace – and this could easily be overcome by the sheer number of eels (hundreds of millions) that follow the same route at the same time of the year.

The results of this study have important implications for current management programs. They imply that eels need to imprint the magnetic gradient encountered during their initial migration toward their feeding ground. Current recovery programs for the endangered European eel translocate juvenile eels freshly arrived in estuaries to locations where eels are depleted. If the recipient area is far from the collection site eels will not have experienced the magnetic cues necessary for their return spawning area. Thus, as adults, they will not contribute to the recovery of the stock.

The exact locations of eel spawning areas have never been discovered. “The reason may be that, as our model suggests, the location changes from year to year. If research vessels adopted the same strategy, following decreasing magnetic intensities then exploring the target isoline, they might finally solve the mystery”, says Caroline Durif.

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