Manmade mangroves could get to the 'root' of the problem for threats to coastal areas

August 29 2018

Growing from a tangle of roots that twist their way out of the mud, mangrove trees naturally protect shorelines, shelter coastal ecosystem habitats and provide important water filtration. Credit: Florida Atlantic University

With threats of sea level rise, storm surge and other natural disasters, researchers from Florida Atlantic University's College of Engineering and Computer Science are turning to nature to protect humans from nature. They are developing innovative ways to guard coastlines and prevent scouring and erosion from waves and storms using bioinspired materials that mimic mangrove trees found along shores, rivers and estuaries in the tropics and subtropics. Growing from a tangle of roots that twist their way out of the mud, mangrove trees naturally protect shorelines, shelter coastal ecosystem habitats and provide important water filtration. In many cases, these roots trap sediments flowing down rivers and off the land, helping to stabilize the coastline.

Certain mangrove root systems even have the ability to dissipate tidal energy through unique hydrological flows and divert the energy of water in different directions reducing risk of coastal damage. Yet, to date, few studies have examined the fluid dynamics such as flow structure and drag force on mangrove roots.

For a study, published in the American Physical Society's journal, *Physical Review Fluids*, researchers singled out the red mangrove tree (*Rhizophora mangle*) from more than 80 different species of mangroves, because of its robust network of roots that can withstand extreme environmental conditions. The red mangrove provided the researchers with an ideal model for bioinspired shoreline applications.

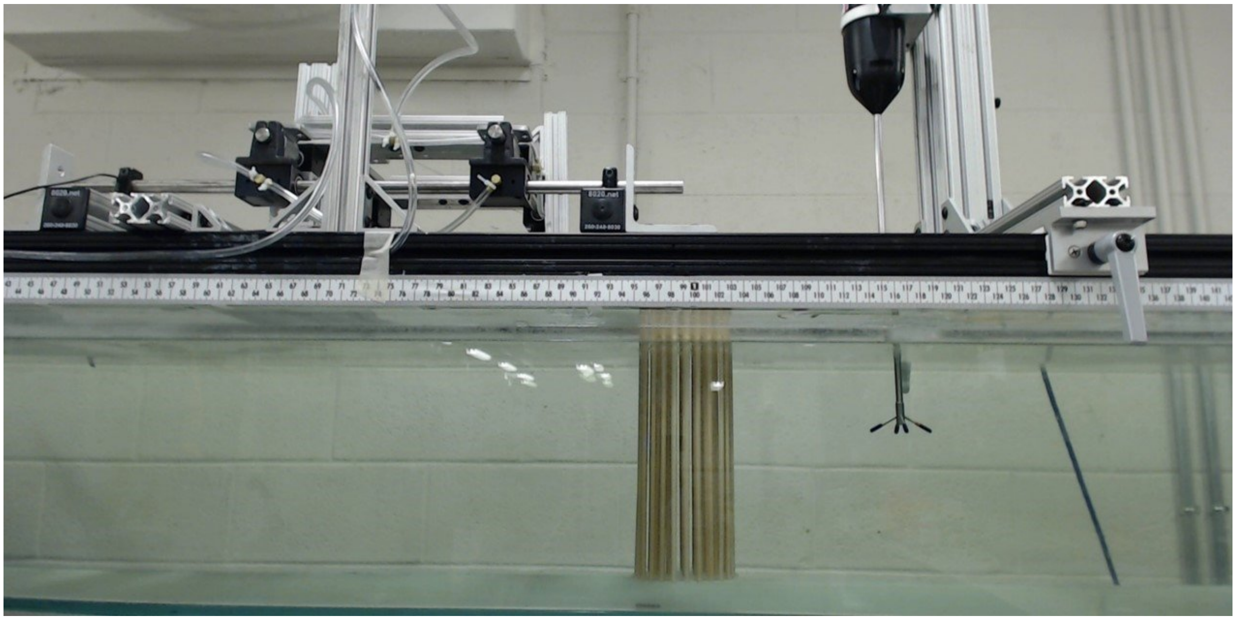
"Because of their strong structures, mangroves have survived for more than 8,000 years," said Amirkhosro Kazemi, Ph.D., lead author of the study and a post-doctoral fellow in FAU's Department of Ocean and Mechanical Engineering , who was awarded a Link Foundation fellowship and is working with Oscar Curet, Ph.D., co-author and an assistant professor in the department. "What is truly amazing about mangroves is that they can adjust to changes in rising sea levels by forming upward structures through a natural process of accumulating layers of mud carried by tides and other sources. It's their root system in particular that contributes to this resiliency and is what inspired us to research their complex hydrodynamics."

To better understand the mangrove tree's resilience and the fluid dynamics of its roots, Kazemi, Curet, and Keith Van de Riet, Ph.D., co-author and an assistant professor at the University of Kansas, modeled the complex mangrove roots as a network of circular cylinders called a patch. They performed a series of experiments varying key parameters such as length scale and porosity or flexibility. They used a water tunnel and flow visualization to determine how the diameter of the root, its flexibility and how porous the mangroves are affect the water. They studied the mangrove roots under different flow conditions to quantify how the flow structure would interact with the mangrove.

They looked at the effect of porosity and spacing measures between the roots, tested force and velocity in a water tunnel, and concurrently performed 2-D flow visualization.

The researchers performed direct drag force measurements and high-resolution particle image velocimetry to characterize the complex unsteady wake structure posterior to the arrays of the patch, which represents a simplified mangrove root model.

Results from the study show that for rigid roots, the drag force varied linearly with patch diameter and spacing between the roots. For flexible roots, the researchers discovered that a decrease in stiffness increased both the patch drag and the wake deficit behind the patch in a similar fashion as increasing the blockage of the patch. They have introduced a new length-scale (effective diameter) based on the wake signature to characterize the drag coefficient exerted on the patch for different porosities. The effective diameter incorporates the patch porosity, arrangement and individual root diameter in the patch. The results have proven that the effective diameter of the patch decreases as the porosity increases, giving rise to the Strouhal number—used in dimensional analysis that is a dimensionless number describing oscillating flow mechanisms.



Researchers used a water tunnel and flow visualization to determine how the diameter of the mangrove root, its flexibility and how porous the mangroves are affect the water. Credit: Florida Atlantic University

"With nearly 2.4 billion people worldwide living within 60 miles of an oceanic coast, this research is extremely important for vulnerable coastlines not just in Florida but across the globe," said Stella Batalama, Ph.D., dean of FAU's College of Engineering and Computer Science. "Improving our understanding of the hydrodynamics of mangrove roots will help to facilitate the incorporation of bioinspired mangrove-like structures that can be used for erosion control, coastal protection, and habitat reconstruction."

Although many low-lying areas have storm surge protection such as seawalls, these structures are expensive to build, cause their own set of environmental concerns, and obstruct the natural landscape. Information from this study has the potential to help scientists and engineers develop methods to design resilient bioinspired coastline structures. Natural shorelines are flexible, inexpensive, and adjustable, and the prototype the researchers have developed is scalable, smaller and simpler to use as well as more cost effective. Their systematic modeling provides the framework to engineer mangrove-like structures for coastal protection.

"Our findings could potentially be used to build artificial mangrove banks for coastal areas. For example, our experimental work could even be applied in a uniform tidal flow where water flows constantly as the result of sea level rise," said Kazemi. "We are currently working on a new model that will allow us to understand the flow in a more complex design."

More information: Amirkhosro Kazemi et al, Drag coefficient and flow structure downstream of mangrove root-type models through PIV and direct force measurements, *Physical Review Fluids* (2018). DOI: 10.1103/PhysRevFluids.3.073801

Provided by Florida Atlantic University