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The Jumbo Carbon Footprint of a Surf-and-Turf Dinner

By Cheryl Lyn Dybas

What's the carbon footprint of an average shrimp-and-steak dinner?

If it comes from the conversion of mangrove forests to aquaculture and agriculture, it's 1,795 pounds of carbon dioxide. That's about the same amount of greenhouse gases produced by driving a fuel-efficient car from Los Angeles to New York City.

Clearcutting of tropical mangrove forests to create shrimp ponds and cattle pastures contributes significantly to greenhouse gases and global warming, according to findings reported in the May 2017 issue of *Frontiers in Ecology and the Environment*.

"The results mean that 1,603 pounds of carbon dioxide are released for every pound of shrimp, and 1,440 pounds of carbon dioxide for each pound of beef" from mangrove forest conversion, says J. Boone Kauffman, an ecologist at Oregon State University who led the project.

NEW MEASUREMENT: THE LAND-USE CARBON FOOTPRINT

Those numbers were obtained with a new measurement called the land-use carbon footprint. It records the amount of carbon stored in an intact mangrove forest, the greenhouse gas emissions from conversion of that forest to aquaculture or agriculture, and the quantity of the shrimp or beef produced over the life of the land's use.

"What we found was astounding," Kauffman says. "When you convert mangrove forests to shrimp ponds or cattle pastures, a remarkable amount of carbon is being emitted into the atmosphere. And the food productivity of these sites is not very high."

Scientists have the difficult task of clearly conveying the ecological consequences of forest and wetland losses to the public, state Kauffman and coauthors in their

Frontiers in Ecology and the Environment paper. "To address this challenge, we scaled the atmospheric carbon emissions from mangrove deforestation down to the level of an individual consumer."

The study was conducted on 30 relatively undisturbed mangrove forests and 21 adjacent shrimp ponds or cattle pastures. The sites were in Costa Rica, the Dominican Republic, Honduras, Indonesia, and Mexico. Shrimp ponds were sampled in all countries except Mexico, where the predominant land use was conversion to cattle pastures.

On the basis of measurements from these locations, "we determined that mangrove conversion results in GHG [greenhouse gas] emissions ranging between 1,067 and 3,003 megagrams of carbon dioxide equivalent per hectare," says Kauffman.

The decline in carbon storage from mangrove conversion to shrimp ponds or cattle pastures exceeded the researchers' original estimates.

Mangroves represent less than 1% of the world's tropical forests, scientists have found, but their degradation accounts for as much as 12% of the greenhouse gas emissions that come from tropical deforestation.

INSIDE A MANGROVE FOREST

Enter a mangrove forest. In this dark water world, trees with twisted limbs live double lives—one foot on land, the other in the sea.

Some 80 species of mangroves, also called mangals, thrive in saline coastal habitats in the tropics and subtropics. All take root in waterlogged soils where slow-moving currents allow sediment to accumulate.

Red, black, and white mangrove trees, along with buttonwoods, may grow along the same shoreline. Where these species are found together, each stakes out a spot.

Red mangroves are closest to the sea's edge; their prop roots extend into the water from branches above. The roots capture sediment, stabilizing the shore.

Farther inland are black mangroves with pneumatophores pointing upward from the soil. Pneumatophores supply oxygen in otherwise anaerobic sediments.

White mangroves, with no special root adaptations, are found in the interior mangrove forest, followed by buttonwoods in the upland transition area.

These forests-of-the-tide collectively cover a worldwide area of 53,190 km^2 in 118 nations—about 0.6% of all tropical forests. And that number is dropping.

Rates of mangrove deforestation over the past three decades have been dramatic, says Kauffman. "Mangroves are disappearing at the rate of about 1% per year." In places such as Southeast Asia, mangrove conversion to shrimp ponds is the greatest cause of these intertidal forests' decline.

MANGROVES: TOP ECOSYSTEM SERVICES PROVIDERS

Mangroves provide ecosystem services worth up to $57,000 USD per hectare per year and collectively sustain more than 100 million people, according to the United Nations Environment Programme report *The Importance of Mangroves: A Call to Action*.

The report estimates that deforestation of the world's mangroves results in annual economic damages of up to $42 billion.

From top to bottom: (1) Denuded mangrove forest in Madagascar. (2) Shrimp harvested from an Indonesian shrimp farm. (3) Shrimp pond in Brazil. *Courtesy of J. Boone Kauffman, Oregon State University*

Mangroves' most important ecosystem service, scientists say, may be mitigating climate change by removing greenhouse gases from the atmosphere. Like other plants, mangroves capture carbon dioxide and store it in their leaves, roots, and trunks (biomass) and in the soil. But unlike most other forests, mangroves do not have a maximum storage capacity. They continuously amass carbon in soil, where it can remain for millennia.

Mangroves are extremely productive ecosystems that can increase their biomass relatively quickly, trapping more carbon than other forest types. The upper meters of mangrove soils are primarily anaerobic—missing the organisms that decompose organic material and release carbon into the environment.

How much "blue carbon"—carbon captured by the world's coastal and ocean ecosystems—is stored in mangrove forests?

Researchers mapped mangroves and identified which ones contain the most blue carbon: mangals in Sumatra, Borneo, and New Guinea, and along the coasts of Colombia and northern Ecuador.

The findings were published in 2013 in the journal *Conservation Letters*. The results can help guide decisions about priority areas for mangrove conservation and rehabilitation, scientists say.

When mangrove forests are converted to agriculture or to aquaculture ponds, the majority of the carbon in their biomass and underlying soils is released into the atmosphere, joining other sources of greenhouse gases. Clearing even small tracts of mangroves generates high volumes of carbon dioxide.

"These forests have been absorbing carbon for the last 4,000 or 5,000 years, but now through deforestation they have become significant sources of greenhouse gas emissions," Kauffman says. "Because they store so much carbon, they're important sites for mitigating or slowing climate change."

HOW MUCH IS A MANGROVE FOREST WORTH?

An important question, say Kauffman and coauthors, is whether the value of the shrimp or beef produced from a former mangrove forest exceeds the value of the ecosystem services lost as a result of mangrove conversion. Those ecosystem services include maintaining high biodiversity, fisheries production, protection against storms and erosion, and carbon storage.

"Addressing this trade-off is the responsibility of governments and is the personal choice of the consumer, who should have access to information on the true costs and impacts of food production," the researchers write.

"A better understanding of land-use carbon footprints would provide context to make informed decisions about how our everyday lives affect land use and climate change."

And whether that surf-and-turf dinner is worth the price—in mangrove currency.

Background photo: Women in the Sundarbans mangrove forest, Bangladesh. From top to bottom on left: (1) Brazilian fisher with a mangrove forest in the background. (2) Abandoned fish pond showing mangrove devastation. (3) Dried-up shrimp pond in Brazil. *Courtesy of J. Boone Kauffman, Oregon State University*

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