

# Battle of the bilge



If you're looking for something that embodies both the romance and the peril of globalization, consider ballast water. Marine ecologist James Carlton has been thinking about it since 1962, when he came across a tubeworm on a lakeshore in Oakland, CA. Not long afterwards, he noticed the same worm on display at a nature center, where a sign noted that the species originated in the South Pacific. "I was just 14, and I thought that was the coolest thing in the world", says Carlton. It has gotten cooler, or more nerve-racking, since then, depending on how you look at it.

As you read this, more than 40 000 ships are at sea, with thousands of species, strange and familiar, swimming in their ballast tanks. Carlton, Director of the Maritime Studies Program of Williams College and Mystic Seaport (Mystic, CT), says these stowaways are a leading reason why the world is now "itching with invasions".

Ocean shipping is revving up this process, with ever-expanding trade swapping ballast water among distant ports. According to Carlton, more than 2 million gallons of ballast water arrive in the US from foreign ports every hour, and as ships – the main vehicles of globalized trade – increase in size, number, and speed, they're delivering that water in greater volumes, and ensuring that more species survive the trip.

The tiny migrants include phytoplankton, zooplankton, and fish – "a whole marine bouillabaisse", says Carlton, who has found sea anemones, shrimp, sea squirts, and even baby hermit crabs afloat in ballast water. Some creatures arrive clinging onto the ships' hulls and others survive in the oily water slopping around on the decks, but most are transported in the ballast water. Carlton has caught them in plankton nets lowered deep into ballast tanks and with pumps and baited traps as well. In the past, Carlton had to talk his way aboard, but these days, researchers accompany the US Coast Guard, which regularly monitors ships' ballast-water management.

That's just one sign of mounting government alarm concerning this overly free exchange of species. The poster child of aquatic invasives is the zebra mussel, a hardy and rapidly multiplying Russian mollusk that arrived in North America circa 1988, and has since done US\$3 billion in damage to the Great Lakes region. Among other dirty tricks, the mussel colonizes the insides of pipes; one Michigan town lost water for 3 days as a result. After nearly two decades of suspense over when the mussel would migrate west, it was discovered in Nevada last January.

The zebra mussel spurred Congress to pass the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, which today compels ships entering US waters to exchange ballast water hundreds of miles from shore. But scientists, including Carlton, say much more is needed. Even ships that comply with the law may not do so completely, dumping only a fraction of the water they've taken on abroad. And many critters can lurk in sediment settled at the bottom of a tank, even after a thorough exchange; one Australian study found more than 300 million dinoflagellate cysts, which can cause

harmful algal blooms, in tank sediment. That's why several companies are racing to produce new ultraviolet light and deoxygenation technologies, though these are not yet in wide use.

"Every assessment indicates that the rate of marine introductions in US waters has increased exponentially over the past 200 years, and there are no signs that the numbers are leveling off", continues Carlton. "We're playing ecological roulette, with a constant spin of the wheel. What will the next invasion bring?"

Earlier this year, Congress introduced several new bills, including the Aquatic Invasive Species Research Act, that may further our understanding of the problem. Carlton, who has testified eight times before US legislators, and Stanford's Hal Mooney, an expert on the broader ecological threats of globalization, agree on the need for early warning and rapid-response programs to stem the tide of teeny invaders.

It's a grim subject, but Carlton still views traveling sea-creatures with the awe of a teenage beachcomber, a perspective that has no doubt sustained his enthusiasm for careful scrutiny of the issue over the course of his career. The founding editor of the international journal *Biological Invasions*, he recently wrapped up 10 years of work on a 3500-page encyclopedic survey of west coast marine life. Next, he plans to broaden research he began as a post-doc, examining the seaborne bioinvasions of New England that began in the time of the Vikings. "It's the story of how people spread across the world and took the flora and fauna with them", he says. "It's like looking at the bottom of your shoe and being surprised."

In many ways, the story of globalization is told in the transmission pathways of marine invaders. The jury is out on whether we can write a happier ending.

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