THE JAPAN TSUNAMI

exploring its environmental aftershocks

by MARCUS ERIKSEN

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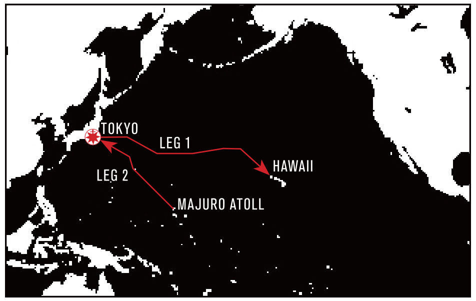
GHOST NET

A tangle of fishing debris and discarded plastics, likely drifting for a decade or more, attracts a host of marine life. Photograph by Tyler Mifflin



"Ghost net!" Hank yelled.

It's May 14, 2012, at 25°13N, 153°56E in the center of the western North Pacific Gyre, less than 1,000 nautical miles east of Tokyo.

"There's a masked booby sitting on top of it," another crew says.

It turns out to be a 450- to 500-lb. mass of tangled fishing net and line, with dozens of different pieces woven together by the sea. Underwater, the whole thing looks like an upside-down floral arrangement, with lead weights taking some lines straight down, and foam floats taking lines outward. Fish are everywhere–mahi mahi, amberjack, triggerfish–and circle beneath the ghost net.

After a long dive around it, we haul it aboard, shaking it like a giant piñata. More fish–a goby, five frogfish, hundreds of crabs, a shrimp, worms, nudibranchs, anemones, and brittle stars–fall to the deck. So do numerous fragments of commercial products, including toothbrushes, a cigarette lighter, and a couple of plastic straws. The bulk of these, and several pieces of fish-bitten bottles and assorted food wrappers, are lodged in a tangled gill net. Hank Carson from University of Hawaii collects 35 marine species in all.

There's great diversity of life and plastic here, creating a habitat where there wasn't one before. The tangled mass has also ensnared fish, evidenced by three triggerfish, which we find in varying stages of decomposition. I cringe at the thought that these tangled ghost nets likely catch more fish after they are lost than when they were in use. It is clear from this net's degradation that it has been at sea for perhaps a decade or more.

We have come to this part of the North Pacific Ocean to study the ecological impact of the March 11, 2011, tsunami, which sent 15 to 20-meter waves crashing into Japan's east coast, the violent surf triggered by a 9.1 Richter scale earthquake centered some 70 kilometers (43 miles) off Honshu's Oshika Peninsula. By all measure, it was the most powerful earthquake ever to have hit Japan, and one of the five most powerful earthquakes to rock the Earth since record-keeping began in 1900. That fateful March day, entire communities–and an estimated 15 to 20 million tons of material–were washed out to sea. More than 16,000 lives were lost, with many still unaccounted for.

As horrible as this disaster was, it has presented us with a chance to carry out an unrepeatable experiment in oceanography–an opportunity to test oceanographic models, which predict landfall of tsunami debris. To do this, our 5 Gyres Institute, in collaboration with the Algalita Marine Research Institute, has organized the Japanese Tsunami Debris Field Expedition.

We know that much of the tsunami debris was carried by the Kuroshio Current into the North Pacific Subtropical Gyre, an oceanwide vortex of clockwise currents that sequester floating trash. Since the disaster, hundreds of tsunami debris remnants have reached the North American shoreline from Northern California to Kodiak, Alaska. Among these are oyster farm floats, soccer balls, a fishing dock, one Harley Davidson in the back of an insulated container, and a 36-meter (120-foot) rusted fishing boat, scuttled soon after its discovery near British Columbia. All of these items are considered high-windage debris.

"Debris reacts differently to wind and current depending on how it is positioned in the water," says Nikolai Maximenko, of the International Pacific Research Center at the University of Hawaii. When and where debris arrives is largely based on variations in the direction and velocity of wind and current. "What you may find on your expedition is the low-windage, subsurface debris field," he told me shortly before we embarked on our expedition.

Our research goals are simple. We want to ground-truth this model in order to understand the lifecycle of diverse materials thrust into the ocean, what marine life colonizes this debris, and what the long-term ecological impact will be. Our expedition team of is made up of sailors, scientists, photographers, journalists, and environmentalists representing eight different countries. Our skipper, Rodrigo Olson from Ensenada, Mexico, has previously sailed the equivalent distance of ten circumnavigations around the equator.

To carry out the project, we have chartered the *Sea Dragon* from Pangaea Explorations for this mission. Originally named *CB 37*, the *Sea Dragon* and her sister ships were built for the 2000/04 Global Challenge race–a "wrong way," upwind circumnavigation. She was designed to thrive in the Southern Ocean and safely handle the world's worst sailing conditions. At 72 feet (22 meters) and 90,000 lbs. displacement, she can carry up to 14 crewmembers for extended journeys any place where water doesn't freeze. Pangaea Explorations founder Ron Ritter has committed her to conservation and exploration. She is the perfect vessel for where we want to go, what we want to do, and on the heels of typhoon season

We set sail from Majuro Atoll in the Marshal Islands on May 4,2012, local Independence Day. While children lined the one road that rings the island to watch the mayor and other dignitaries parade by, our crew of 13 made final provisions for our 2,600-nautical-mile voyage to Tokyo, and 3,800 more to Hawaii.

The *Sea Dragon* is dwarfed by a fleet of tuna ships nestled in the atoll as we head for blue water. It's balmy and muggy, forcing us to abandon sweltering bunks for a breeze in the shade of the full main sail.

It takes us a week to sail to Bikini Atoll, where we begin deploying our high-speed trawl, a net we designed to skim the sea surface at speeds up to 8 knots. With a 500-micron mesh net, that is 14 centimeters wide and 45 centimeters tall, it captures zooplankton, fish, and, much to our chagrin, abundant plastic. We alternate this trawl with the slower and wider manta trawl. By using both designs, we are able to collect a nearly continuous sample of the sea surface.

Expedition team member Robert J. Atwater hauls in the first trawl. The sample, captured in a detachable mesh sock on the end of the net, is a thin soup of zooplankton, fish larvae, and a few small fragments of degraded microplastic. We trawl the sea surface twice each day, with similar results, until somewhere around 21°N,156°E. There, the abundance of plastic dramatically increases, consistently higher than all previous samples collected thus far. We begin to see larger plastic fragments–fishing gear, buoys, and buckets, typical of the eastern garbage patch on the opposite side of the ocean between California and Hawaii. Then the weather shifts.

We arrive in Japan less than a week before Typhoon Maywar, the first of the summer season. With sustained 100 mph winds, we are content to be on land, but are well aware that Leg 2 to Hawaii can't wait until the next hurricane blows in. We change crew, re-provision the vessel, and repair a faulty alternator. With several days in port, we travel to Fukushima to volunteer with a relief agency, which is helping citizens return to their homes north of the ruptured reactor. For the crew, helping out local citizens provides an opportunity to put the research we plan to carry out on Leg 2, from Tokyo to Hawaii, into the perspective of human loss.

Waiting for us on the dock when we return are ten 20-liter bottles from Ken Buesseler of the Woods Hole Oceanographic Institute. Knowing we would be following the same route he sailed last year to study radioactive fallout from the Fukushima reactor, he has asked that we collect fresh samples. In 2011, Buesseler and his team detected the cesium isotope 134Cs along their Tokyo-to-Hawaii

NO ONE AT THE HELM

The bow of a Japanese fishing vessel lost in the March 2011 tsunami continues on its journey. Photograph by Rodrigo Olson.

transect, with a spike at 170°E longitude. Although the amounts are far below levels threatening to humans, they want to know if the radioactivity has moved and if it's detectable at all. Since 134Cs has a half-life of two years, so in ten years, or five half-lives, 97 percent of it will have decayed. Any 134Cs we find will be from Fukushima, since any remaining 134Cs from nuclear testing half a century ago has long since disappeared. We add water sampling to our goals for Leg 2.

On June 10, with Typhoon Maywar having passed, we drop our dock lines, hoping to outrace Typhoon Guchal, which was now forming off the Philippines. We decide to squeeze between the weather systems and race 1,000 nautical miles offshore to clear the Kuroshio Current.

Like the Gulf Stream of the North Atlantic, the Kuroshio is a warm water highway that tracks big storms northward along Japan's eastern shore. This storm is moving four times faster than we are. We do no research for the first five days, focusing instead on getting miles under our belt. There is no room for error. The sea always has the last word.

Unlike balmy, tropical Leg 1, the first few days of Leg 2 are wrought with nausea, caffeine withdrawl headaches, and bruises from navigating narrow passageways in what sometimes feels like being inside a washing machine. With a break in the weather we deploy the hi-speed trawl. Today's catch unveils a few unusual suspects. Among the flying fish, squid, salps, and jellies, there's a paper nautilus (*Argonauta argo*), the pelagic nudibranch *Glaucus atlanticus*, also known as the "sea swallow," Pacific viper-fish (*Chauliodus macouni*), and lantern fish (Myctophidae), which in previous research we've found to ingest microplastic particles. A multicolored panorama of microplastics, undistinguishable to product or country of origin, makes up the bulk of the material present in our samples.

With a careful eye on the skies, we plot a course eastward between 30°N and 32°N for 2,000 nautical miles (3,700 kilometers) through the southern half of the tsunami debris field. The two cyclones have withered, but then merged to create a persistent low-pressure system above 35°N, keeping us south. The crew keep busy trawling the seas for plastic, and first mate Jesse Horton becomes adept at scooping debris from the bow, netting a toothbrush and a comb in one hour, and occasionally a fragment with identifiable Japanese characters. We've begun timed observations. With a clipboard and a stopwatch, two people stare at the sea surface up to 20 meters off the beam on both sides recording everything they see.

"A big tire just went by!" Mandy Barker yells. We go back for it. It is not easy to turn the boat around when full sails are up. "Roll the jib and center the main," Rodrigo yells. There's a flurry of activity. Mandy keeps her eyes on the tire, now nearly a quarter kilometer behind us. "Ten degrees to port, 50 meters off the bow," crew yell to guide the boat to the tire. Using a scoop net, it's a struggle to haul the algae-covered light truck tire aboard, still inflated on the rim. Thirty small crabs drop to the deck. A bristle worm is wedged between the rim and the tire, and a dozen gooseneck barnacles sticking outward along the treads flail their legs, or cirri, grasping at the air. It's a small truck tire, unlike any seen on U.S. vehicles, with "Made in Japan" embossed on one side. The rim is well preserved on painted surfaces, but any exposed iron is nearly rusted through. In another year the tire would likely fill with water and sink.

Soon after, we scoop a piece of thatch the size of a large pizza box. Two layers of straw thatch, factory stitched with a thin sheet of blue foamed polystyrene insulation in the middle, is unmistakably a piece of traditional tatami mat from the floor of a Japanese home. Straw, like any other natural organic or wooden construction material, does not last long at sea. Wood-boring worms, known to plague ships for centuries, or seawater seeping into the space between plant tissues that trap air, will decrease the buoyancy and sink plant

A MIX OF MARINE LIFE AND PLASTIC FRAGMENTS. PHOTOGRAPH BY MANDY BARKER.

material. While none of the evidence provides certainty, the timing of decay, location in the debris field, and the lack of slow-growing colonial bryozoans give me confidence that these are remnants from the tsunami.

Just before sunset on June 22, at 29°11.9N, 170°35.2E, 1,587 nautical miles east of Tokyo, someone yells, "Boat!" Drifting in the southern tail of the Japanese tsunami debris field, the bow of a fishing vessel hovers vertically in the churning North Pacific Ocean. It's the forward half of a crushed fishing boat. Any excitement at finding the boat was muted by the real possibility that this boat belonged to someone who suffered—and perhaps perished—in the tsunami. Rodrigo and I dive in to investigate and film fish aggregating below. We count at least eight species, including amberjack, mahi mahi, and a pair of wahoo. They disperse when I get close and grab the rail of the boat for a closer look.

Expecting a bouquet of gooseneck barnacles, crabs, nudibranchs, and polychaete worms, I find only eight adult barnacles on the entire exposed surface, which sits two-thirds below the water. In one small, protected crack I see the diversity I was looking for, hidden from grazing triggerfish. It's unremarkably barren of colonizing marine life. We haul it aboard the *Sea Dragon*, and immediately send photographs to NHK Broadcasting in Japan. The three characters in the boat's name are literally translated as "bright," "door," and "ship." By the end of our trip the photographs are broadcast on Japanese TV across the country in search of the owner.

In 41 nonconsecutive hours spread over three weeks we catalog 690 pieces of debris, averaging one piece every 3.6 minutes. Roughly 60 percent are unidentified fragments of hard plastic or foamed polystyrene. The rest are unmistakable items—buckets, crates, flip-flops, a coffee cup, fishing floats and rope, plastic bags and bottles, bottle caps, a toy red pail in the shape of a castle, a syringe, a clothes hanger, a surfboard fin, a felt-tipped marker, a boot eerily laced to the top, and a few glass jars, bottles, bulbs, and fluorescent tubes. Only 2 percent is nonplastic, including glass, metal, and organic materials. It's extremely difficult to know when or from where debris has originated, but we are confident that three objects are from the tsunami: the truck tire, fragment of tatami mat, and the half fishing boat.

Rounding north of the Hawaiian Marine Monument, we exit the tsunami debris field for the remaining 1,200 nautical miles to Hawaii.

I meet Nikolai Maximenko in a coffee shop in Honolulu. His latest animations track tsunami debris with variations in windage. I show him the debris we found, all of which fits the low-windage profile. We realize that much of the debris hasn't made it across the ocean yet. But this doesn't mean we'll see an avalanche of trash anytime soon.

Comparing the high-windage debris model to low-windage, we see they do not go in the same direction. By early summer 2012, most of the high-windage debris had made its way across, pushed by wind to the shores of British Colombia, Alaska, Washington, and Oregon, according to Nikolai. Low-windage debris, influenced largely by current, behaves differently, moving southward into the California Current and the Eastern Garbage Patch. What we'll likely see in the years ahead is a trickle of debris reaching North American coastlines, and then an increase in degraded plastic pollution on the eastern shores of Hawaii, at places like the famed Kamillo and Kahuku beaches, where weekly beach cleanups can barely keep up with the never-ending waves of plastic littering the shore.

Over time, the tsunami debris will become indistinguishable from the background of trash in the gyre, noticeable as an increase in microplastics in future trawls. The impacts due to ingestion and entanglement are the same. The only response to a natural disaster is to care for the victims and pick up the pieces. This tsunami however, unlike any other in history, has left its mark on distant shores, and it's mostly plastic.