# In the True Spirit of Science

***The Second Expedition to Kamilo and Hanalua Beach***

*Marine Debris is an emerging field of study, charting new territory. We know much about the movement of the large subtropical ocean gyres that collect debris in the garbage patches of the World Ocean, but so little about the transient currents that let masses of man-made debris escape out of the garbage patches and throw it onto such special places as Kamilo Beach, which has been called the "dirtiest beach on Earth."*
Nikolai Maximenko

There are no paved roads to Kamilo Beach in the Ka'ū district on the remote southern tip of the Island of Hawai'i. The beach is a sandy crescent that hugs a lava-terraced bay laced with tide pools and deep channels cut by powerful waves. Much of the terrace is above water during low tide and awash during high tide. The beach has made headlines, not for its good swimming or surfing, but for the huge amount of trash that keeps washing up on its narrow strip of white sand.

"A surreal picture…nearly no sand, only debris. You can't walk without treading on some kind of stuff thrown out by the ocean," describes IPRC Assistant Researcher **Axel Lauer** his first visit. "And this only 8 weeks after **Bill Gilmartin**, **Megan Lamson**, and their clean-up team from the Hawai'i Wildlife Fund Debris Project were here."

**Nearly no sand, only debris on Kamilo Beach.**

Why does Kamilo Beach collect so much debris? The search for answers led Lauer in summer 2011 to accompany Senior Researcher **Nikolai Maximenko**, a physical oceanographer at the IPRC, and his team on their trip to the notorious beach.

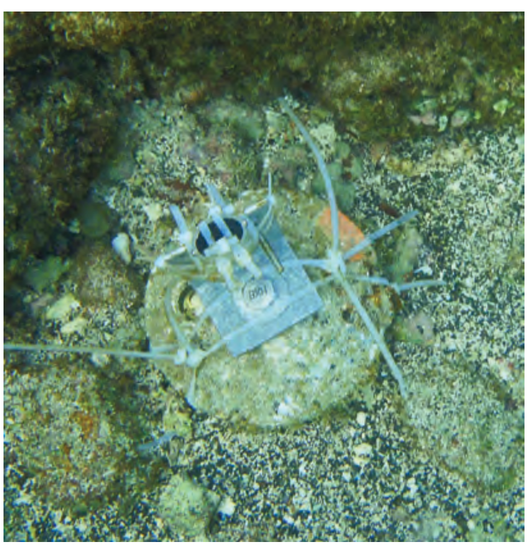
Maximenko became interested in marine debris when he realized that the thousands of drifting buoys, which oceanographers have been releasing over the past decades into the ocean to study its characteristics, are a form of marine debris. Studying the drifters' paths and their final demise, he developed a model to understand marine debris behavior and to track it. Since the March 2011 tsunami in Japan, he has adapted the model to study and track the debris swept by the tsunami into the ocean.

So it is no wonder that the stories of the massive trash collecting on Kamilo sparked Maximenko's interest, and in summer 2010 he took his team on its first exploration there. Now a year later, supported by funding from JIMAR, he is returning with a plan of action: gather more information about the currents inside Kamilo Bay and confirm his hunch that maybe the black lava rocks at nearby Hanalua Beach are sitting on much more plastic than a cursory look suggests.

## The Currents at Kamilo

On this second visit to Kamilo Beach, the team is hoping to get more clues about the currents in the bay. The summer before, they had installed with great difficulty temperature sensors in the hope that they would reveal something about the daily flow of water in the bay. What disappointment: The sensors are gone, washed away by the power of the ocean. Valuable observations that might have told a story about the currents are lost!

They have to install new sensors, but finding the plates is nearly as hard as mounting them on to the lava the year before, because they have become overgrown with algae and now look just like the rocky bottom (picture). Just when Assistant Researcher **Oleg Melnichenko** finally finds a plate, Maximenko sees a fin and a shadow flitting in the water behind Melnichenko. He yells a warning. But against the wind Melnichenko can't hear him. The fin swims by … and out to sea again! The new sensors get installed. Hopefully they will stay put and record data for a while.



Camouflaged temperature sensor and plate

Painted "bottle-drifters" in bush.

The "bottle–drifter" experiment is next. Back at the IPRC, the team had brainstormed about how to get more clues to the bay's currents. The usual instruments for studying currents are drifters with heavy, long drogues so that they stick out of the water only a little bit, and their movement reflects mostly the movements of the ocean and not the wind. But the team has no expensive drifters at their disposal. Such drifters would also be too big, too heavy, and their drogues would get entangled in no time in the rough lava-rock bottom of the bay. But what can they use in their place? How about soda bottles?

Now on site, they fill 2-litre coke bottles with sand and test how much sand the bottles need in order to float but not bob out of the water and ride before the wind like sailboats. Trial by error shows that bottles two-thirds full of sand will do it.

On the morning of day 2, the team arrives at Kamilo in eager anticipation: how will the drifter experiment work? Forty-three 2-litre coke bottles, filled two-thirds with sand and painted bright red or pink to see them against the blue ocean are to be dropped into the water far out in the bay. Sounds simple, but proves to be tricky. Melnichenko and UH Hilo Postdoctoral Fellow **Hank Carson** load the rubber dingy with bottles.

Hardly have they climbed in, the wind tips over the dingy and throws them into the shallow water with its sharp lava bottom. A second failed attempt, and they realize, the only way to get the bottles launched from the southern edge of the reef, is to swim them out pulling a net filled with bottles.

Anxiously watching from shore, the others notice a tongue of clear water that extends beyond the reef. It must mean a strong rip current leaving the bay. Warned, Melnichenko and Carson toss out the painted bottles just before reaching the

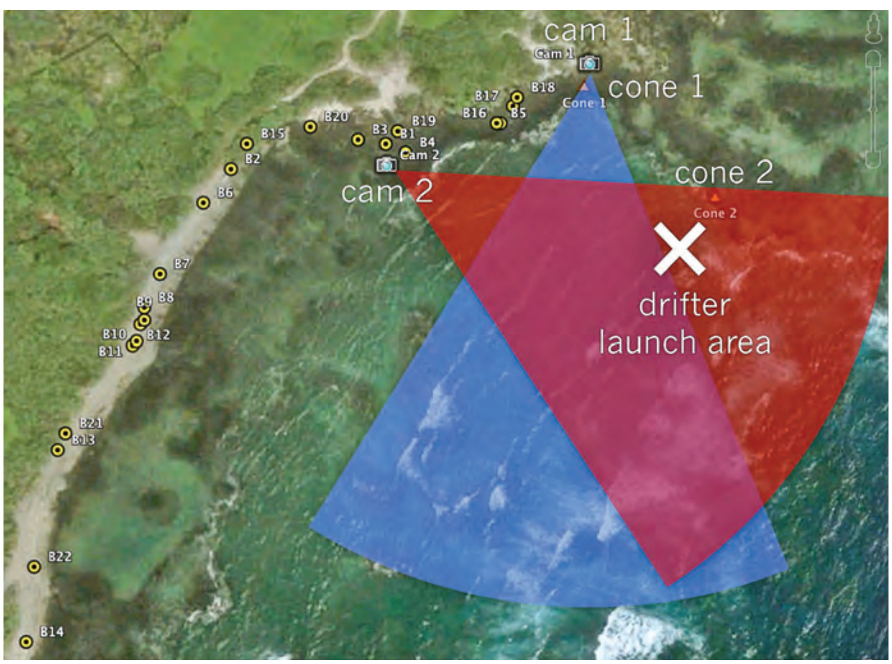
Swimming the bottles out to the reef.

dangerous rip. Thankfully, the rest of the bottles can be jettisoned from land, from the point projecting out into the bay (see “X” in image below).

The team had placed two cameras strategically along the shore and now, that the “drifters” are deployed, Scientific Computer Programmer **Jan Hafner** and Lauer take pictures every 10 seconds to see where the bottles go. These pictures are their “data” from which they hope to determine, using the triangulation method, the path taken by the bottles. This will turn out to be a lot more challenging than Lauer had imagined.

The bottles first float parallel to the shoreline far out in the bay. Then many get caught up in the rip current, which is so strong that it pushes the bottles against the wind beyond the reef. Will they drift further out to sea and join the subtropical gyre circulation and the Great Pacific Garbage Patch?

After a while the bottles appear again, riding on waves back across the reef. There must be an eddy that flows out and loops beyond the reef back again into the bay. The bottles eventually escape the eddy and drift toward shore. They land not in one or two spots, as might be expected, but widely dispersed along the whole beach. By the time the team has packed up for the day and is ready to leave, 26 of the 43 bottles have washed up on the beach. The remainder were picked up by **Megan Lamson** the next day. Though many bottles had ventured out beyond the reef, only one of the whole lot never returned.




Schematic view of the setup of the drifter experiment at Kamilo Beach. The camera positions are indicated as “cam 1” and “cam 2”, the two reference cones as “cone 1” and “cone 2”. The blue and red areas show the fields of view of the two cameras. Also shown is the drifter launch area marked with an “x” as well as the positions of the bottles (B1 to B20) that beached during the first two hours of the experiment.

Back at the IPRC, Lauer has to determine from the pictures the currents in the bay. This requires much ingenuity. He had not anticipated that the bottles would disappear in the waves for minutes at a time and that he wouldn’t be able to follow a single bottle from the place it was dropped into the water to shore. By counting the bottles that are visible and graphing their position in each and every of the 1,646 pictures, Lauer is able to develop a chart representing the overall flow pattern (Figure page 12). Violet-blue are the bottle positions at the beginning of the experiment, while red-yellow are the positions during the last half hour. The black lines with arrows show the approximate paths taken by the bottles. The graph shows what the team had suspected: a fair number of bottles circulate for a long time far out, at times floating beyond the reef. Viewing the sequence of pictures from each camera yields a choppy animation of the bottles’ travels toward the beach.

Lauer reflects on his results: “I don't think that the incoming tide alone was responsible that most of the bottles washed up on the beach again. When we dropped the bottles into the water, they were quickly taken out to sea in the strong rip current along the reef, but that current also seemed to bring them back in. The mini-gyres we saw within the bay certainly help to bring the junk from outside the bay ashore. The name ‘Kamilo’ means the twisting or swirling current in Hawaiian,

Bottle-drifters floating in the bay.

suggesting the Hawaiians have been aware for a long time what makes this place so special. And that we retrieved all the bottles except one also suggests that once something enters the bay, it tends not to leave. Although the bottles were dropped into water within 25 meters of each other, their path toward shore varied greatly as shown by how far apart they washed up along the shore."

He adds, "We learned a lot about the technical difficulties in conducting the experiment, and it gives us new ideas about what to try next."

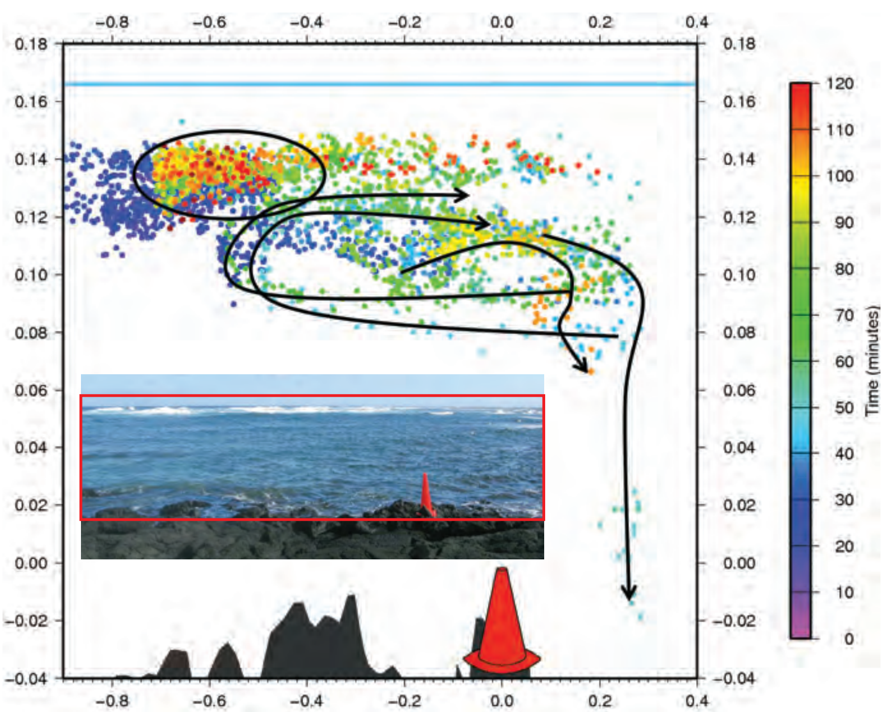
## The Hidden Plastic of Hanalua Beach

Driving last summer along the coast between Green Sand Beach and South Point revealed a rocky beach with surprisingly little debris compared to Kamilo Beach just a few miles away. Do the currents and winds keep the stuff away? Or do the retreating tides suck it back out? Melnichenko had noticed some plastic sticking out from under the rocks, and when he removed a few rocks, he saw a pile of plastic hidden underneath. On this trip, therefore, the team wants to find out what is buried below the rocks.

It is a brutally hot, sunny day. Thank goodness for the canopy that shades at least the 3 m x 3 m hole, which they are digging in order to get a rough estimate of the amount of plastic that has piled up on the beach. Their technique: with the top layer, about 30 cm deep, they pick up and get rid of all the rocks first and then collect the plastic found below the rocks. The plastic is stored in a bag and kept to be weighed back at the IPRC. In the next layer, they find the plastic pieces are so tiny, that the only way to collect them efficiently is to shovel the plastic-sand mixture into a bucket of water and then skim the floating plastic off the surface. This second layer reaches a depth of 60 cm. Again they store all the plastic from this layer in a huge plastic bag.

They dig much of the day. The work is grueling! They brainstorm: How about a vacuum cleaner the next time to suck up all the stuff?

Most surprising and frightening, as they dig deeper they are finding that the concentration of plastic increases. With their third layer, at a depth of about 90 cm, they call it quits. They place the plastic bags containing their hard-earned plastic trash into containers to take them back home to weigh. The containers are very, very heavy.




Positions of the bottles (colored dots) as seen from camera 1 during the first two hours of the experiment. The positions are given in coordinates relative to the tip of the red cone on the point of origin (0.0). The color shading of the dots represents the time of sighting in minutes after the bottles were released. The black arrows depict some of the bottle trajectories observed during the experiment. It is remarkable that, although many bottles were still far out after two hours, all bottles save one eventually returned.

The untouched surface.

The layer after removing the rocks.

Back at the IPRC, the carefully labeled bags are weighed and the weight of plastic per square foot at each layer of depth determined (see table). Their impression turns out to be right…the amount of plastic increases with depth. From this sample, they can now calculate how much plastic lies on the whole beach. The result of their calculations? At least 25 tons of plastic lie buried under the black, plastic-free-looking rocks at this beach that is about 200 meters long and 10 meters wide! This impressive figure is clearly an underestimation as the team did not even reach the depth of maximum density of plastic.

Perhaps it is not a difference in currents that makes Kamilo "the dirtiest beach" and Hanalua Beach look so clean by comparison, but rather the difference between a sandy and a rocky beach, where the plastic slips down between the crevices, gets ground up into smaller and smaller bits by the sharp rocks and sinks further and further down into the sand, creating a plastic carpet. As smaller rocks sink further down over time, they continue their plastic grinding.

The plastic collectors, from left Hank Carson, Nikolai Maximenko, Axel Lauer, Oleg Melnichenko, and Jan Hafner.

"This is so different from the science I usually do….sit in front of the computer screen and press keyboard buttons to run my modeling experiments," Lauer recalls. "To go explore in the outdoors, without knowing what we will find or how things will turn out is thrilling. Figuring out how to use the bottles as drifters, the challenge in deploying them, nervously watching how the bottles are swept out beyond the reef, worried that they might add to the plastic in the ocean, the hard work of digging in the sand and the astonishment of finding how much plastic is buried beneath the rocks, all that is energizing, challenging—that's the true spirit of science."

This story is based on an interview with IPRC Assistant Researcher Axel Lauer.

| Layer | Plastic density, kg/m$^3$ |
|---|---|
| 0-30 cm | 5.9 |
| 30-60 cm | 14.2 |
| 60-90 cm | 17.3 |

The density of plastic in kg per cubic meter in each of the 3 layers.