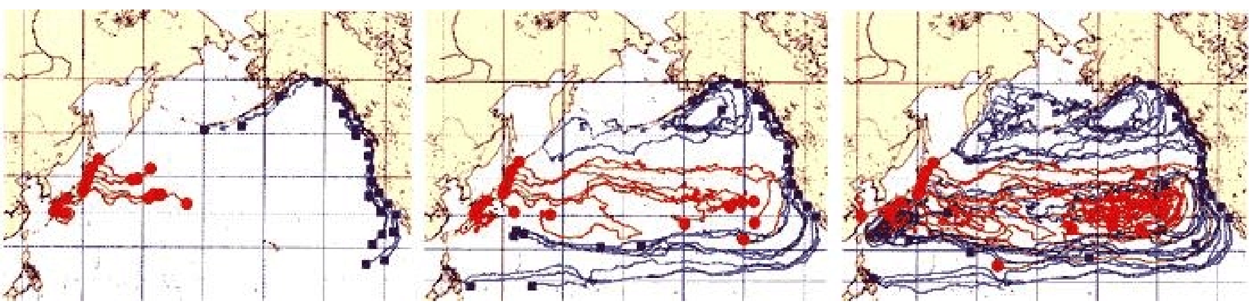
Trash in the Pacific Ocean

“Trashed
Across the Pacific Ocean, Plastics, Plastics, Everywhere
CHARLES MOORE / Natural History v.112, n.9, Nov03

http://www.mindfully.org/Plastic/Ocean/Moore-Trashed-PacificNov03.htm

Trash has always been tossed into the seas, but it has been broken down in a fairly short time into carbon dioxide and water by marine microorganisms. Now, however, in the quest for lightweight but durable means of storing goods, we have created a class of products—plastics—that defeat even the most creative and voracious bacteria.

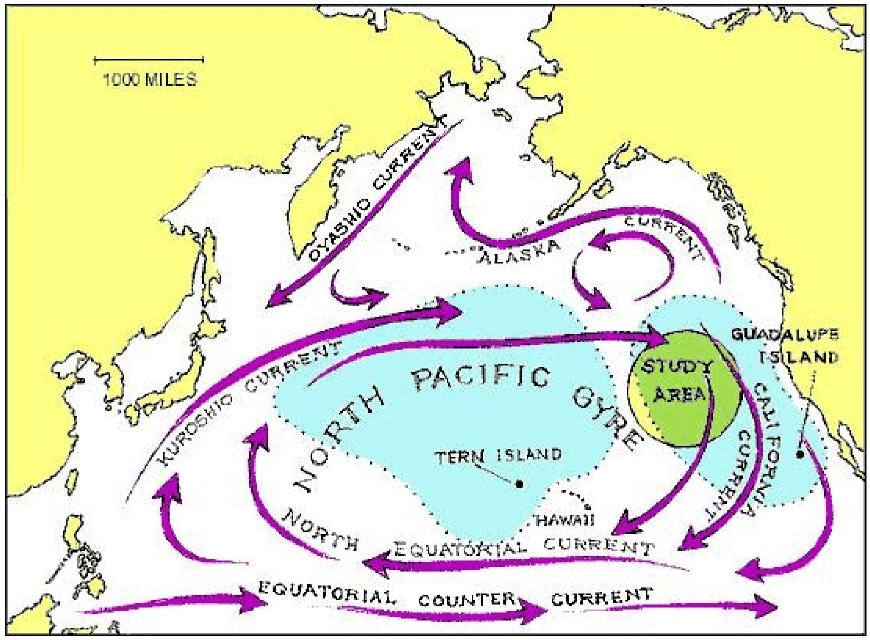
Unlike many discarded materials, most plastics in common use do not biodegrade. Instead they "photodegrade," a process whereby sunlight breaks them into progressively smaller pieces, all of which are still plastic polymers. In fact, the degradation eventually yields individual molecules of plastic, but these are still too tough for most anything—even such indiscriminate consumers as bacteria—to digest. And for the past fifty years or so, plastics that have made their way into the Pacific Ocean have been fragmenting and accumulating as a kind of swirling sewer in the North Pacific subtropical gyre.



Ocean Surface Current Simulator (OSCURS) model developed by W James Ingraham Jr., an oceanographer at the National Oceanic and Atmospheric Administration (NOAA), predicts the trajectory of drift originating along the coasts of the North Pacific rim. Drift from Japan is shown in red; drift from the United States, in blue. The diagrams show the position of drift after 183 days (left), three years (center), and ten years (right).

In the coastal ocean, bodies of water are naturally defined, in part, by the coasts they lie against. In the open ocean, however, bodies of water are bounded by atmospheric pressure systems and the currents those systems create. In other words, air, not land, defines the body of water. Because air pressure systems move, the body of water we wanted to survey would be moving as well.

The gyre we planned to survey is one of the largest ocean realms on Earth, and one of five major subtropical gyres on the planet. Each subtropical gyre is created by mountainous flows of air moving from the tropics toward the polar regions. The air in the North Pacific subtropical gyre is heated at the equator and rises high into the atmosphere because of its buoyancy in cooler, surrounding air masses. The rotation of the Earth on its axis moves the heated air mass westward as it rises, then eastward once it cools and descends at around 30 degrees north latitude, creating a huge, clockwise-rotating mass of air [see map at right].



Currents in the North Pacific move in a clockwise spiral, or gyre, which tends to trap debris originating from sources along the North Pacific rim. Plastics and other waste have accumulated in the region, which includes the foraging areas of Pacific bird colonies, such as that of the Tern Island albatross, shown in blue, and that of the Guadalupe Island albatross, shown in green.

The rotating air mass creates a high-pressure system throughout the region. Those high pressures depress the ocean surface, and the rotating air mass also drives a slow but oceanic-scale surface current that moves with the air in a clockwise spiral. Winds near the center of the high are light or even calm, and so they do not mix the floating debris into the water column. This huge region, what I call a "gentle maelstrom," has become an accumulator of debris from innumerable sources along the North Pacific rim, as well as from ships at sea.

The subtropical gyres are also oceanic deserts in fact, many of the world's land-based deserts lie at nearly the same latitudes as the oceanic gyres. Like their terrestrial counterparts, the oceanic deserts are low in biomass. On land the low biomass is caused by the lack of moisture; in oceanic deserts the low biomass is a consequence of great ocean depths.

In coastal areas and shallow seas, winds and waves constantly stir up and recycle nutrients, increasing the biomass of the food web. In the deep oceans, though, such forces have no effect; the bottom sequesters the nutrient-rich residue of millions of years of near-surface photosynthetic production, as well as the decomposed fragments of life in the sea, trapping them miles below the surface. Hence the major source of food for the web of life in deep ocean areas is photosynthesis.

But even in the clear waters that prevail in the subtropical gyres, photosynthesis is confined to the top of the water column. Sunlight attenuates rapidly with depth, and by the time it has gone only about 5 percent of the way to the bottom, the light is too weak to fuel marine plants. The net effect is a vast area poor in resources, an effect that makes itself felt throughout the food web. Top predators, such as tuna and other commercially viable fish don't hang out in the gyres because the density of prey is so low. The human predator stays away too: the resources that have drawn entrepreneurs and scientists alike to various regions of the ocean are not present in the subtropical gyres.

What does exist in the gyres is a great variety of filter-feeding organisms that prey on the ever-renewed crop of tiny plants, or phytoplankton. Each day the phytoplankton grow in the sunlit part of the water, and each night they are consumed by the filter feeders, a fantastic array of alien-looking animals called zooplankton. The zooplankton include chordate jellyfishes known as "salps," which are among the fastest-growing multicellular organisms on the planet. By fashioning their bodies into pulsating tubes, the salps are able, each day, to filter half the water column they inhabit, drawing out the phytoplankton and smaller zooplankton for food. But salps are gelatinous creatures with a low biomass, and so there is no market for them, either. Hence the realm they dominate, one of the largest uniform habitats on the planet, remains unexploited and largely unexplored.

Leecaster, Moore, and I came up with a plan to make a series of trawls with a surface plankton net, along paths within a circle with a 564-mile radius. The area of the circle would then be almost exactly 1 million square miles.

In August 1998 I set out with a four-member volunteer crew from Point Conception, California. heading northwest toward the subtropical gyre. Onboard Alguita was a manta trawl, an apparatus resembling a manta ray with wings and a broad mouth, which skimmed the ocean surface trailing a net with a fine mesh. ... We pulled in the manta after trawling three and a half miles.

What we saw amazed us. We were looking at a rich broth of minute sea creatures mixed with hundreds of colored plastic fragments-a plastic-plankton soup.

There was plenty of larger debris in our path as well, which the crew members retrieved with an inflatable dingy. In the end, we took about a ton of this debris on board. The items included

* a drum of hazardous chemicals;
* an inflated volleyball, half covered in goose-neck barnacles;
* a plastic coat hanger with a swivel hook;
* a cathode-ray tube for a nineteen-inch TV;
* an inflated truck tire mounted on a steel rim;
* numerous plastic, and some glass, fishing floats;

* a gallon bleach bottle that was so brittle it crumbled in our hands; and
* a menacing medusa of tangled net lines and hawsers

In 2001, in the Marine Pollution Bulletin, we published the results of our survey and the analysis we had made of the debris, reporting, among other things, that there are six pounds of plastic floating in the North Pacific subtropical gyre for every pound of naturally occurring zooplankton. Our readers were as shocked as we were when we saw the yield of our first trawl. Since then we have returned to the area twice to continue documenting the phenomenon. During the latest trip, in the summer of 2002, our photographers captured underwater images of jellyfish hopelessly entangled in frayed lines, and transparent filter feeding organisms with colored plastic fragments in their bellies.

Entanglement and indigestion, however, are not the worst problems caused by the ubiquitous plastic pollution. Hideshige Takada, an environmental geochemist at Tokyo University, and his colleagues have discovered that floating plastic fragments accumulate hydrophobic-that is, non-water-soluble-toxic chemicals. Plastic polymers, it turns out, are sponges for DDT, PCBs, and other oily pollutants. The Japanese investigators found that plastic resin pellets concentrate such poisons to levels as high as a million times their concentrations in the water as free-floating substances.

The potential scope of the problem is staggering. Every year some 5.5 quadrillion (5.5 x 1015) plastic pellets—about 250 billion pounds of them—are produced worldwide for use in the manufacture of plastic products. When those pellets or products degrade, break into fragments, and disperse, the pieces may also become concentrators and transporters of toxic chemicals in the marine environment. Thus an astronomical number of vectors for some of the most toxic pollutants known are being released into an ecosystem dominated by the most efficient natural vacuum cleaners nature ever invented: the jellies and salps living in the ocean. After those organisms ingest the toxins, they are eaten in turn by fish, and so the poisons pass into the food web that leads, in some cases, to human beings. Farmers can grow pesticide-free organic produce, but can nature still produce a pollutant-free organic fish? After what I have seen first hand in the Pacific, I have my doubts.

Many people have seen photographs of seals trapped in nets or choked by plastic six-pack rings, or sea turtles feeding on plastic shopping bags, but the poster child for the consumption of pelagic plastic debris has to be the Laysan albatross. The plastic gadgets one typically finds in the stomach of the bird-whose range encompasses the remote, virtually uninhabited region around the northwest Hawaiian Islands-could stock the checkout counter at a convenience store.

Bottle caps and other plastic objects are visible inside the decomposed carcass of this Laysan albatross on Kure Atoll, which lies in a remote and virtually uninhabited region of the North Pacific. The bird probably mistook the plastics for food and ingested them while foraging for prey.

On Midway Island in the Hawaiian chain, a bolus, or mass of chewed food, coughed up by one bird included many identifiable objects. By contrast, a bird on Guadalupe Island, which lies 150 miles off the coast of Baja California, produced a bolus containing only plastic fragments.

In Ingraham's OSCURS model, debris from the coast of Japan reaches the foraging area of the Hawaiian birds within a year. Debris from the West Coast of the United States, however, sticks close to the coast until it bypasses the foraging area of the Guadalupe birds, then heads westward to Asia, not to return for six years or more. The lengthy passage seems to give the plastic debris time to break into fragments.

The subtropical gyres of the world are part of the deep ocean realm, whose ability to absorb, hide, and recycle refuse has long been seen as limitless. That ecologically sound image, however, was born in an era devoid of petroleumbased plastic polymers. Yet the many benefits of modern society's productivity have made nearly all of us hopelessly, and to a large degree rationally, addicted to plastic. Many, if not most, of the products we use daily contain or are contained by plastic. Plastic wraps, packaging, and even clothing defeat air and moisture and so defeat bacterial and oxidative decay. Plastic is ubiquitous precisely because it is so good at preventing nature from robbing us of our hard-earned goods through incessant decay.

But the plastic polymers commonly used in consumer products, even as single molecules of plastic, are indigestible by any known organism. Even those single molecules must be further degraded by sunlight or slow oxidative breakdown before their constituents can be recycled into the building blocks of life. There is no data on how long such recycling takes in the ocean-some ecologists have made estimates of 500 years or more. Even more ominously, no one knows the ultimate consequences of the worldwide dispersion of plastic fragments that can concentrate the toxic chemicals already present in the world's oceans.

Ironically, the debris is re-entering the oceans whence it came; the ancient plankton that once floated on Earth's primordial sea gave rise to the petroleum now being transformed into plastic polymers. That exhumed life, our "civilized plankton," is, in effect, competing with its natural counterparts, as well as with those life-forms that directly or indirectly feed on them.

And the scale of the phenomenon is astounding. I now believe plastic debris to be the most common surface feature of the world's oceans. Because 40 percent of the oceans are classified as subtropical gyres, a fourth of the planet's surface area has become an accumulator of floating plastic debris. What can be done with this new class of products made specifically to defeat natural recycling? How can the dictum "In ecosystems, everything is used" be made to work with plastic?"
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http://orvalguita.blogspot.com/search?updated-min=2008-01-01T00%3A00%3A00-08%3A00&updated-max=2009-01-01T00%3A00%3A00-08%3A00&max-results=34

"Our study area of 2.5 million square (nautical) miles has an estimated 14 million metric tons of plastic floating around."

"...the "most polluted concentration" covers 2.5 million square miles of ocean, at roughly 5 grams per football field of area. And as you've noticed from our pix, most of the trash is small - particle size..."

"...students from West Lafayette asked if the majority came from large scale dumping directly into the ocean, or runoff from street litter.

According to data collected from coastal cleanups, 80% of the marine debris that washes up on beaches originates from land based sources – when street litter washes out to sea through storm drains, "urban runoff". Out here, much of the identifiable debris were seeing comes from the fishing industry – fishing floats, ropes, net fragments, and other derelict fishing gear. The majority though is made up of plastic fragments."

"For a solid two hours, we fished as fast as we could, pulling up floats, toothbrushes, plastic and glass bottles, a golf ball, a billiard ball, an unused glue stick for a hot glue gun, and several rope boluses filled with crabs and tiny striped fish - But most appalling was the plastic confetti. An endless stream of delicate, white snowflakes, like plastic powder coating the ocean's surface."

“Capping off a day of plastic bounty, we spotted our first ghost net early evening, at over a ton in weight, it was large enough to warrant deploying the satellite buoy NOAA provided, to track the nets' migration and possibly recover it and others of a similar nature before they wreak havoc on the resources of our newest National Park, located in the Northwest Hawaiian Islands.

What appeared from the surface a sizable, tangled nest of mismatched nets and imbedded debris was just the tip of the iceberg. Under water, this behemoth sank heavily, providing shelter to an array of marine life. A nautical nightmare in the making, with the potential to kill the endangered Hawaiian Monk Seal, the only tropical seal, and many other creatures, including corals.

Witnessing this up close, one can easily see how ghost nets wreak havoc on marine ecosystems, transporting invasive species, suffocating coral reefs, and entangling marine life. Our underwater photographer Joel Paschal spent 4 months with NOAA tracking and removing 40 tons of ghost nets, in which he recounted finding whale bones and blubber, turtle carcasses, and several live monk seals and turtles.”

“From concerned individuals, to those wondering if we might find some economic value in all of this floating plastic debris, people constantly ask if there isn’t some way to scoop, net, or filter this waste out. Its just…..too…..big. It’s like suggesting we sweep the United States. Or sift the Sahara desert. And as people have seen from our sample images, much of this debris is comprised of small pieces – fragments – that require a fine mesh to remove. Which means removing tons of plankton as well – the basis of the entire marine food chain. If only the debris were nicely contained in a big “trash island”, perhaps we could remove it. But it’s spread out over an incomprehensibly huge area. The terms “garbage patch” or “Texas-sized trash heap” conjure up tangible areas, when in fact this “plastic soup” extends throughout the gyre. Add to this the unknowns: how much plastic is building up on the sea floor, becoming incorporated into the benthic environment? Or throughout the water column? Add the sheer expense and difficulty of getting here – and the impossibility of cleaning up the gyre becomes clearer. We need to focus our efforts on prevention, as cleanup is simply not feasible at this time.”

“To P. Scheuster’s question about the potential health impacts of plastic: Understanding how much trash is out there (approximately 14 million metric tons spread out over 2.5 million square nautical miles), and the reality that it cannot be cleaned up, some still ask, “So what if it’s gross out there? It’s not in my backyard. What’s it got to do with me?” We believe we’ve demonstrated that it’s not only an environmental issue, but it’s also a human health, and tremendous moral issue.

Remember POPs, those persistent organic pollutants that float in the ocean, like DDT, PCBs and PAHs from the incomplete burning of fossil fuels? We recently published a paper “Persistent organic pollutants carried by synthetic polymers in the ocean environment” identifying significant amounts of these POPS sticking onto and being absorbed into plastic particles floating in the North Pacific Gyre. These carcinogenic compounds are not only found in plastic marine debris, but also in the bodies of the animals that consume them. Imagine all those filter feeders, like jellyfish, salps, barnacles, baleen whales, and thousands of different zooplankton, indiscriminately consuming plastic particles and possibly absorbing those POPs. We've seen it happen already in several seabirds and some invertebrates. Our organization and many other scientists are discovering that these pollutants and many others bioaccumulate in animal tissues, migrate up the food chain, and are likely to be found in the fish on your dinner plate. Bon appetit!"

"Paul S. asked, "Do you mean to say you trawl an area approximately 3 feet wide, 6 miles long, and come up with only 1/3 of an ounce of plastic?" We all chatted a bit about this during dinner – and may comment further in the coming weeks. For now, here's a response from Marcus:

"10 grams per 6 nautical mile trawl is a subjective estimate based on years trawling in and out of the North Pacific Gyre, near and far from shore. This is a rough estimate that might not seem like much, but you've got to consider the size of our playing field. Our trawl is three feet wide. A six nautical mile trawl covers a little less than two football fields. We're studying an area between latitudes 20 and 40, and longitudes 130 and 170, which is approximately 2.5 million square nautical miles, representing only a quarter of the North Pacific. Still, that covers almost 3 billion football fields (2,929,900,000). SO, if we're averaging 10 grams for every two football fields of area, then in ¼ of the Pacific we think there could be 14 ½ MILLION metric tons of plastic marine debris."

"We tried to develop a way to visualize the quantity of plastic distributed throughout the surface waters of the North Pacific Gyre. This is our calculation "done in the Field!"

See if you can follow our reasoning, do your own calculations, and come up with a mental picture that illustrates the magnitude of the problem. We'll give you our Formula, and some of our parameters and even enough numbers so you can check our math and do your calculations.

1) Firstly we needed to calculate the surface area sampled by an average Trawl with the Manta-Trawl. Our "average trawl" goes for two hours at a speed of 3 nautical miles per hour. The "mouth" of the trawl is just about 3 feet wide (95cm to be exact). A nautical mile is 6076 linear feet. What is your calculation of the surface area sampled in our average trawl. The Crew came up with 109,368 square feet. Are we together so far?

2) After consultation with the Captain, based on ten years of accumulated experience sampling the Gyre, we estimated the amount of plastic in the average trawl to be 1/3 ounce (the range is between 4 ounces to less than one ounce).

3) The next step in our formula was to calculate the number of Trawls in a square mile of ocean

surface. The number of square feet in a nautical square mile works out to 36,917,776 (thank you Kent!) square feet. We then divided this number by the surface area sampled in our average trawl, and concluded that a square mile of ocean surface is covered by 337.5 trawls.

4) How much plastic will be recovered in a 1 square mile surface trawl? Although we don't weight our trawl contents in the field. The specific gravity of the plastic is very close to the specific gravity of the water, so for our calculation we considered 1/3 of an ounce to weigh 10 grams.

5) Now to calculate the area of the North Pacific Gyre. More specifically the area covered by the various exploratory voyages of ORV Alguita. This region lies between 130 and 170 degrees west longitude, and between 20 and 40 degrees north latitude. This is going to take a little work on a nautical chart. But it's a good exercise in geophysics. The Crew's calculation was rounded off to 2,500,000 nautical miles.

6) We now have the amount of plastic per trawl, the number of trawls per nautical square mile, and the number of square miles in the North Pacific Gyre. So what is your calculation of the weight of plastic in the Gyre? In order to work towards our goal of "visualizing" this number, we converted grams to pounds and then pounds to Tons.

7) After you get the number of Tons of plastic in the Gyre, use your imagination and tell the Crew how you can develop your mental image. We'll post our estimate in the next blog as well as how each of us visualized this amount!

8) One thing to remember…. Don't be too critical of the Crew; remember, we're doing our calculations on the pitching deck of sailing boat... and it's our day off!"
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"With regard to the size of the debris-impacted area of the North Pacific subtropical gyre, loosely referred to as the Eastern Garbage Patch, I now believe that such a dubious distinction belongs to the whole of the gyre we are surveying. Ocean Surface Current models (OSCURS) by Jim Ingraham show Texas scale areas nicknamed garbage patches in the eastern and western North Pacific where much of the debris resides for decades. We have found that millions of square miles of ocean from 20N to 40N and from 135W to near the international date line, where we have done limited but extensive trawl sampling are significantly impacted, though outside the loose geographical limits of the EGB. In fact, the highest levels yet found by our team have been in the area bounded by 30-33N and 160-170W, an area not considered part of the EGB.

As far as the type of debris we're finding in this area, an interesting comparison is possible. The Laysan albatross was the first large scale sampler of the plastic plague in the North Pacific.

Its diet of natural debris and squid was supplemented with plastic debris not long after the beginning of the throwaway era. We have dozens of photos of Laysan albatross regurgitated stomach contents taken by Cynthia Vanderlip at Kure Atoll that contain objects you might find at the check out counter of a convenience store, and among the bottle caps, small bottles, cigarette lighters, pens and toothbrushes, are found plastic fragments of various sizes and colors. The manta trawls for zooplankton collection that we have been hauling 700 miles east of Kure Atoll contain a very similar mix. Some identifiable objects, such as a knife sheath, bottle cap, toothbrush, and plastic tub handle which we pulled up in our trawl samples were mixed in with many plastic fragments generated by larger objects that became embrittled over time. An answer to the question: "What kind of plastic do you find in the gyre?", might be: We find the same kind of plastic that Laysan albatross find. We offer these two pictures for comparison. (The image above is a sample from our manta trawl, below is the image of an albatross carcass containing plastics.)"

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"We're finding the highest levels of pollution in highly productive zones.

The significance of this is far greater than people may have realized. We are now seeing that the fragmented plastic debris issue is prevalent in areas of commercial significance. There is a greater urgency than ever before in getting governments involved in policy and legislation to deal with the issue. Unfortunately, in regions like the one we are currently studying, there is no political entity responsible, as we are in International waters, outside of any country's jurisdiction. As is the case with many issues of global ecological degradation, the Tragedy of the Commons comes into effect…"

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"...what Charles found during his free dive: Equally interesting to what we found in our Manta Trawl sample was what we didn't find. Or rather, what Charles collected with a hand held net, just beneath the Manta's 15 cm deep opening. "This sample here I got snorkeling has debris we'd never pick up with the Manta Trawl" Charles remarked as he surfaced, cupping a handful of particles in his net. "Taking our current sample sizes, and doubling or tripling them wouldn't be a stretch". Joel also noted most of the debris he saw diving was about a meter down.

When buoyant plastic particles are reduced far enough in size, they begin to lose buoyancy, and become incorporated into the water column. In a study of dispersion of oil droplets by breaking waves, it was found that at the 20 micron size class, the droplets lost buoyancy and behaved like the water they were mixed in. So its possible that with our current sampling, skimming the surface, we are missing large amounts of small plastic fragments. And our ratios, alarming as they are, may be fairly conservative. A sobering thought…..and perhaps a question for future research."

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" It really is difficult to comprehend the vastness of this phenomenon. There is still a common public misconception that the gyre is a "place", a detectable spot, when rather it is an enormous, extremely diffuse region…..being out here, seeing nothing but blue horizons day after day certainly helps."

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14 million metric tons is a huge amount of plastic that shouldn't be in the ocean but I want to know what to picture in my mind. Is the surface totally covered so that you can not even see the water? I don't like big numbers. Too often they are used to give an incorrect impression or aren't comprehendible. I like to break numbers down into easily understandable terms. My calculations showed about one ounce of plastic for each 12 x 12 foot section of that portion of the Pacific Ocean. This is, of course, just an average based on an estimate. Some are just tiny broken pieces of plastic. Other debris weighs several pounds.

In over a year of weekly outings in my boat in our inland waterways and the Gulf, I very rarely saw any debris in the water. So, this appears to be a huge problem with no reasonable way to clean up 2.5 million square miles of the Ocean.