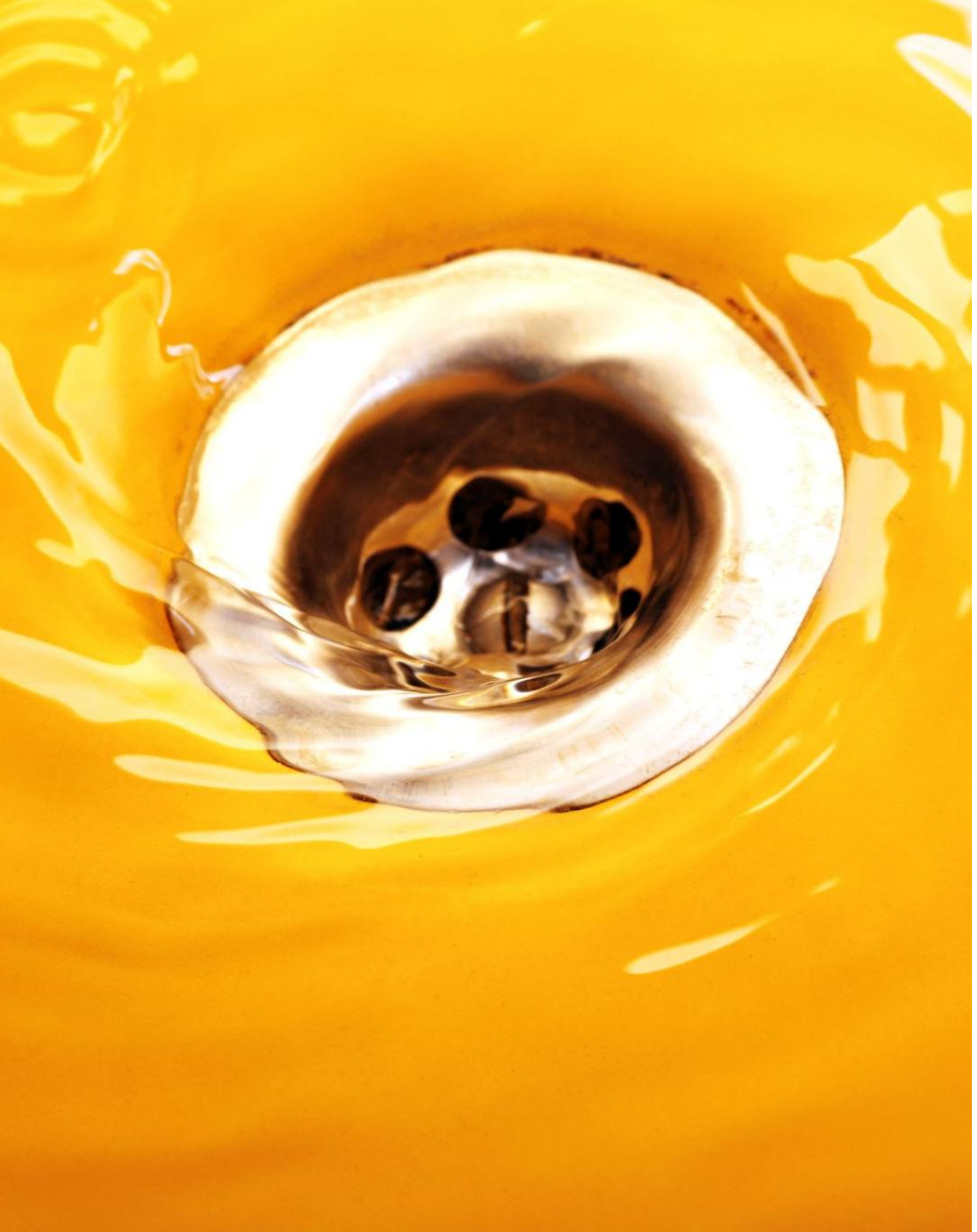
Four Questions About Water

ISSUES THAT WILL SHAPE THE 22ND CENTURY

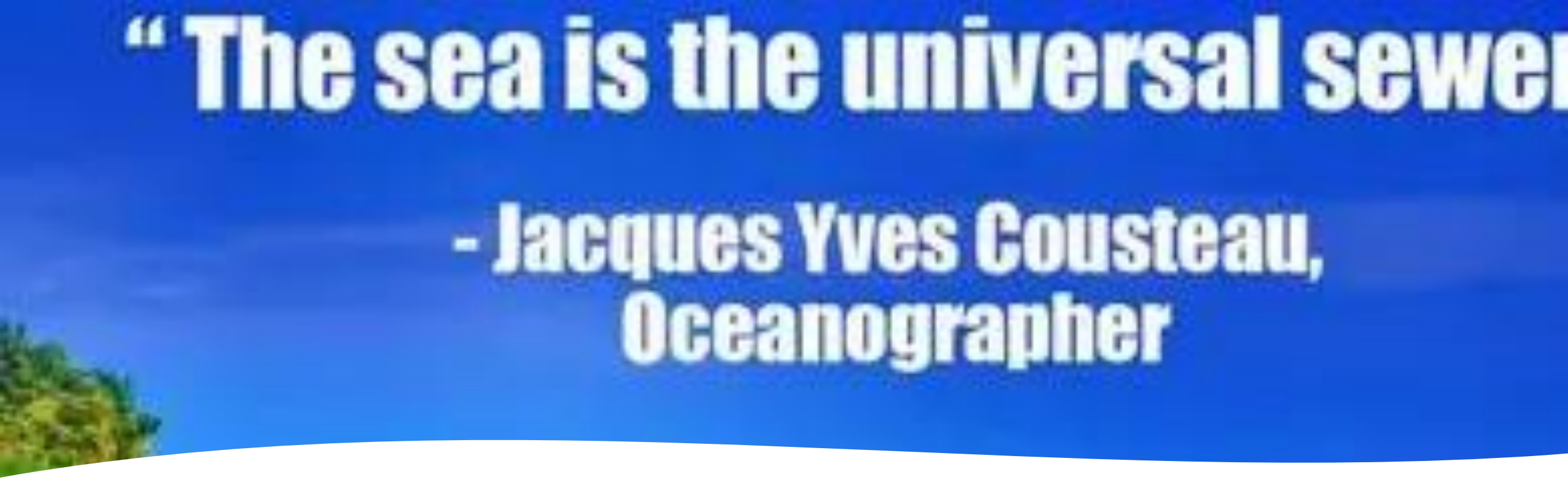
(and beyond)



Four Challenges

in Water Resources

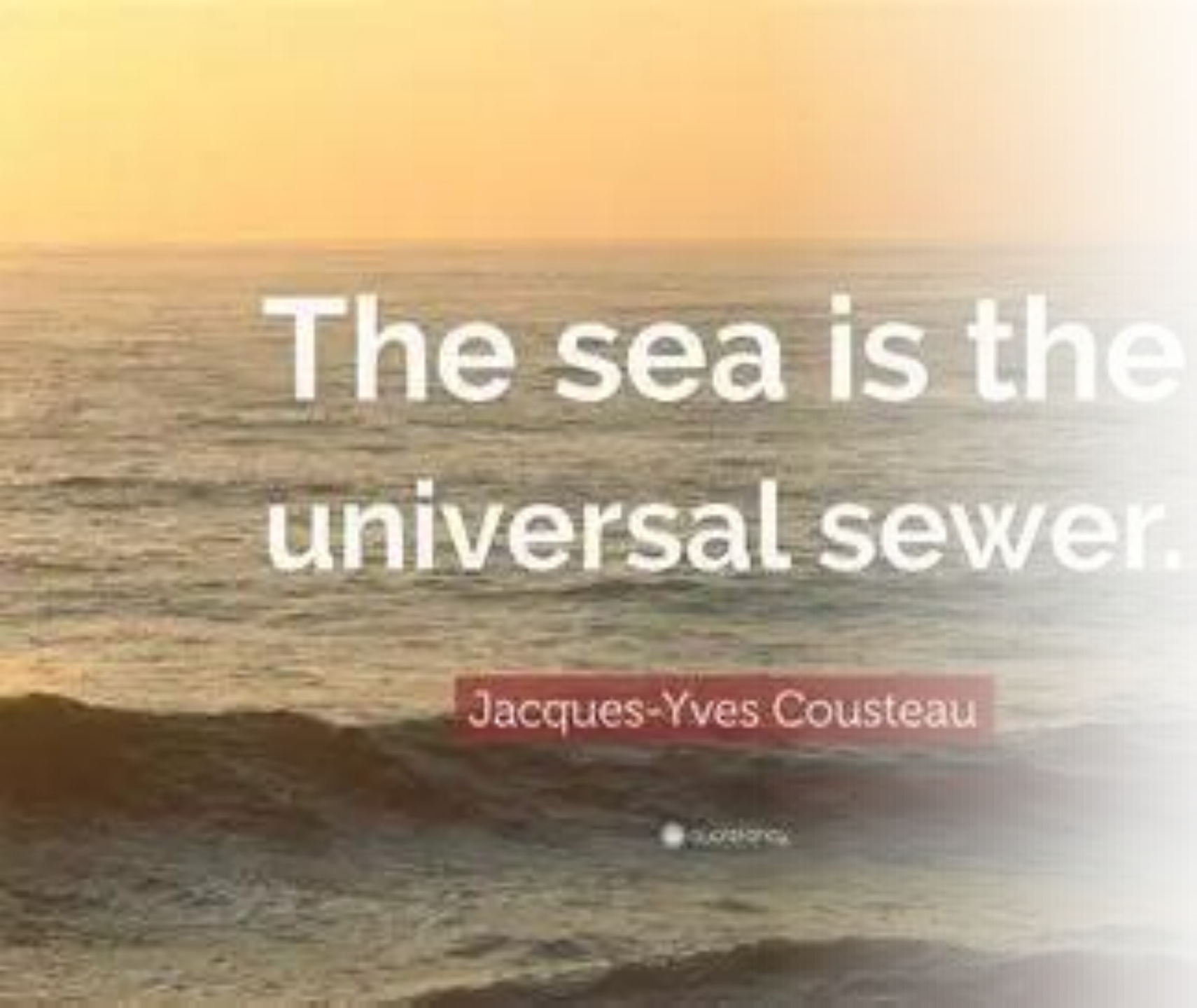
1. Is Water a Human Right?
2. How will Water Get to Growing Urban Areas?
3. **Can we Stop Destroying Surface Water Systems?**
4. Who Controls Water?



The Problem(s)

Three human activities are conspiring to degrade surface water bodies to the point where their basic biological functions are being threatened.

- Agrichemical discharges into surface waters from farms creating "dead zones" throughout the planet
- Discarding of plastics and wastes that end up in surface waters and, ultimately, collect in massive quantities in the oceans
- Oil spills (both chronic and acute) wreaking ecological devastation on aquatic life for generations



The Problem(s)

Individually, these activities are often presented as unconnected, and, historically, these activities were considered inconsequential.

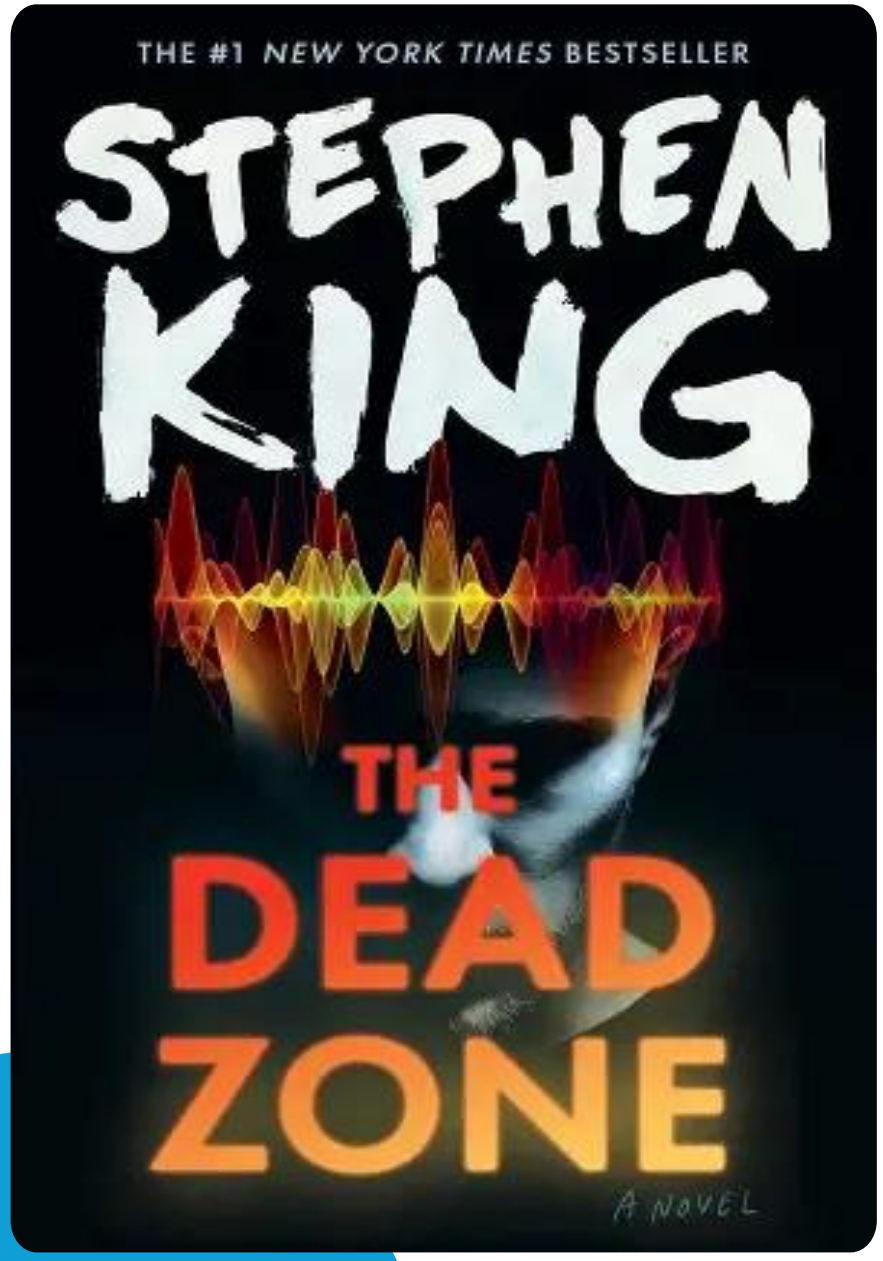
Politically and economically, these activities have been hard to quantify and, as such, beyond consideration.

That is not so anymore, or more accurately, it was always “not so”.

The Problem(s)

Most of these activities are having disastrous impacts on our oceans and on large inland lakes.

And most of these activities are easily (but not cheaply) managed.



Dead Zones

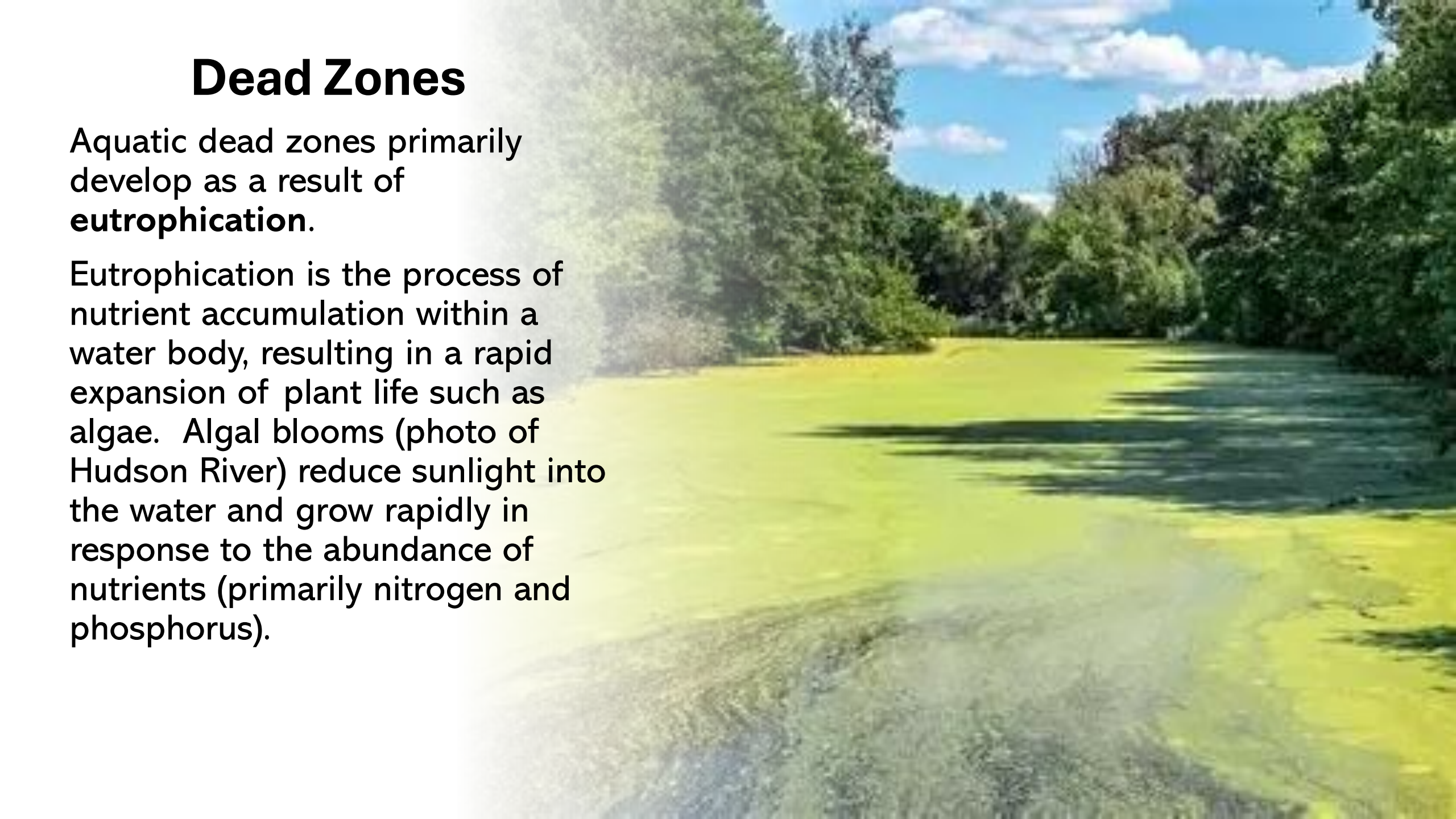
Ecologic “dead zones” are aquatic regions where oxygen concentrations have been depleted to levels insufficient to support life. These areas are also referred to as “OMZs” (oxygen minimum zones). Normal oxygen levels in a surface water body are around 8 mg/L; OMZs occur when oxygen levels are below 2mg/L.

In essence, dead zones are watery equivalents of deserts.

Dead Zones

Aquatic dead zones primarily develop as a result of **eutrophication**.

Eutrophication is the process of nutrient accumulation within a water body, resulting in a rapid expansion of plant life such as algae. Algal blooms (photo of Hudson River) reduce sunlight into the water and grow rapidly in response to the abundance of nutrients (primarily nitrogen and phosphorus).



Dead Zones

When the algae die, they settle on the bottom of the water body and become food for bacteria. This degradation process consumes virtually all of the available oxygen in the water column. Species existing within that water body dependent on oxygen for survival die off.

Heat is a major catalyst for this process; in the summer months, this process accelerates.

Dead Zones

While **eutrophication** is a natural process, human activity is often the catalyst for the creation of massive dead zones, for the nutrient loading necessary to expand these dead zones, and for the long-term perpetuation of these zones.

Anthropogenic nutrient loading is often (but not always) driven by agrichemicals. Fertilizers rich in nitrogen and phosphorus flow from farms, urban runoff, and wastewater into rivers and eventually into coastal waters. These nutrients trigger massive algal blooms that initially seem harmless but quickly become destructive. By one estimate, three times as much nitrogen and phosphorus is being "dumped" into oceans today than had been introduced pre-industrial times.

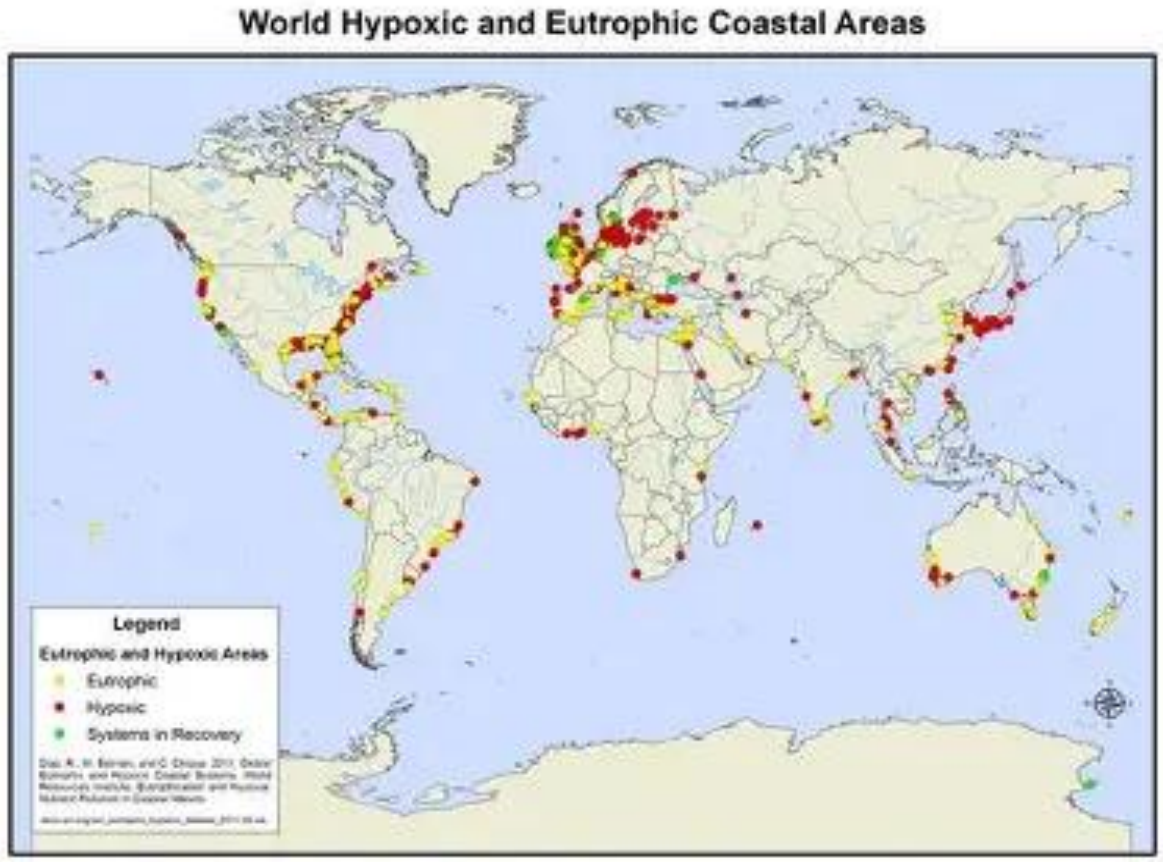
Dead Zones

“Dead zones” vary in size and depth throughout the year. About half of these zones are seasonal, meaning that they will “disappear” for at least a portion of the calendar year.

In 1995, an international study documented almost 200 defined areas around the world with consistent oxygen levels at or below 2 mg/L.

In 2008, an international study documented 400 such areas.

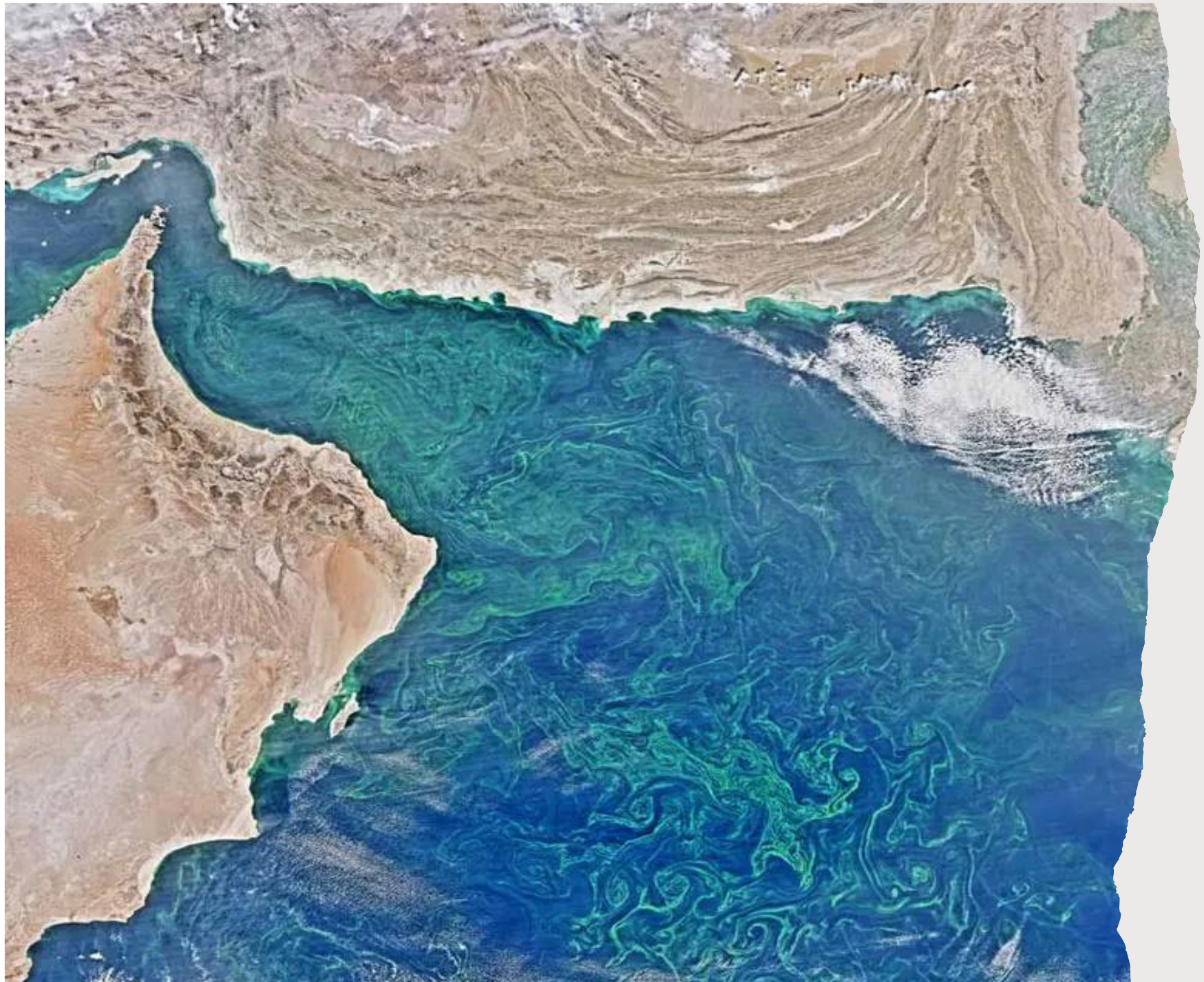
By 2012, this number had jumped to 515.



Dead Zones

These dead zones are generally the result of human activity. The total area of these zones will vary depending on weather patterns; the latest calculation (NOAA) identified about 100,000 square miles of surface water area.

Dead zones can exist in any water body (even moving ones) but they are most prevalent in areas shallower than 1,000 feet.



Dead Zones

The largest dead zone in the world is in the Gulf of Oman, Arabian Sea. A 2016 study conducted by Oman determined:

a) This Dead Zone was 63,700 square miles (slightly smaller than Florida);

b) The Dead Zone is almost entirely anoxic resulting in virtually no biological activity; and

c) This particular Dead Zone is expanding rapidly.

Photo from NASA Earth Observatory, 2016

Dead Zones

This dead zone is formed by both natural and anthropogenic causes. Monsoon winds keep nutrients from on-shore farming from moving further out to sea. Ship traffic (particularly oil tankers) add pollutants.

Dead Zones in the USA

Large-scale cultural eutrophication can and does occur in land-locked water bodies. Every year (generally from July to October), significant portions of Lake Erie are covered with algae as a direct result of excess phosphorus in agricultural runoff and nutrient/pesticide loading from urban areas.

Satellite image is from 2011.

Dead Zones in the USA

One of the world's most persistent "dead zone" is located at the mouth of the Mississippi River. The Zone is measured annually* by NOAA; in 2024, the Zone was almost 7000 square miles (larger than the states of Connecticut and Rhode Island combined).

* Funding for this activity has been cut as of Summer 2025.

Dead Zones in the USA

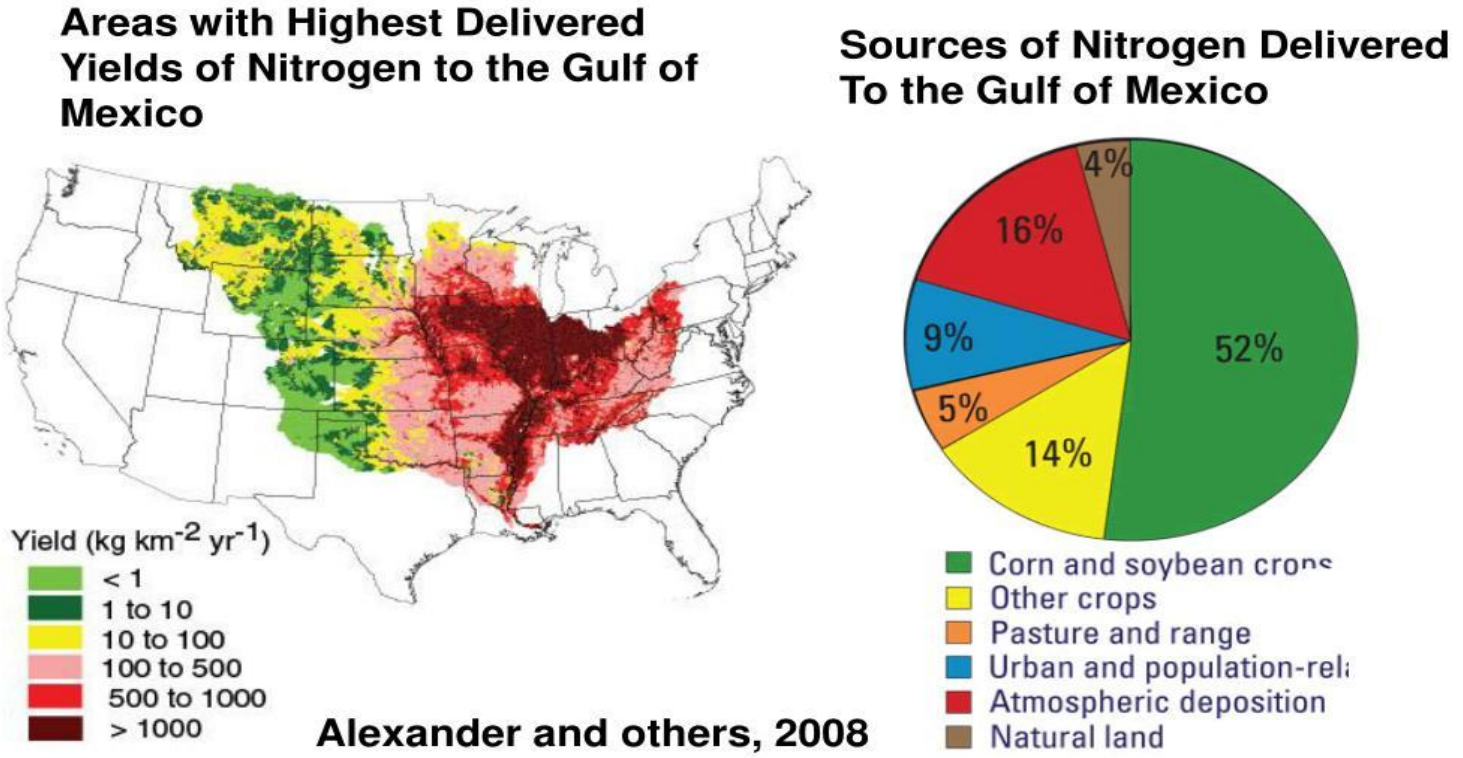
Scientists have known about the Gulf of Mexico dead zone since the 1970s, but the prevailing wisdom (driven at least in part by governmental reports from the USDA, the ACOE, and the US Public Health Service, had been that it was a seasonal event of little consequence.

But studies out of LSU and other regional institutions documented nutrient sources throughout the Mississippi watershed.

In 1987, an estimated 187 million fish died along the Louisiana coast.

In 2016, fed by runoff from heavy rains in the Midwest, the Gulf of Mexico dead zone had grown to over 6000 square miles.

Nutrient Delivery and Sources



Impacts of Dead Zones

Impacts at dead zones will depend on the length of time that anoxic conditions persist, how extensive oxygen depletion is, how robust the aquatic ecosystem is, and how sensitive the biota that live within that dead zone are.

Primary impacts are:

- Fish kills
- Reduction in photosynthetic activity
- Death of benthic organisms (e.g., oysters, clams and mollusks but also micro-organisms)

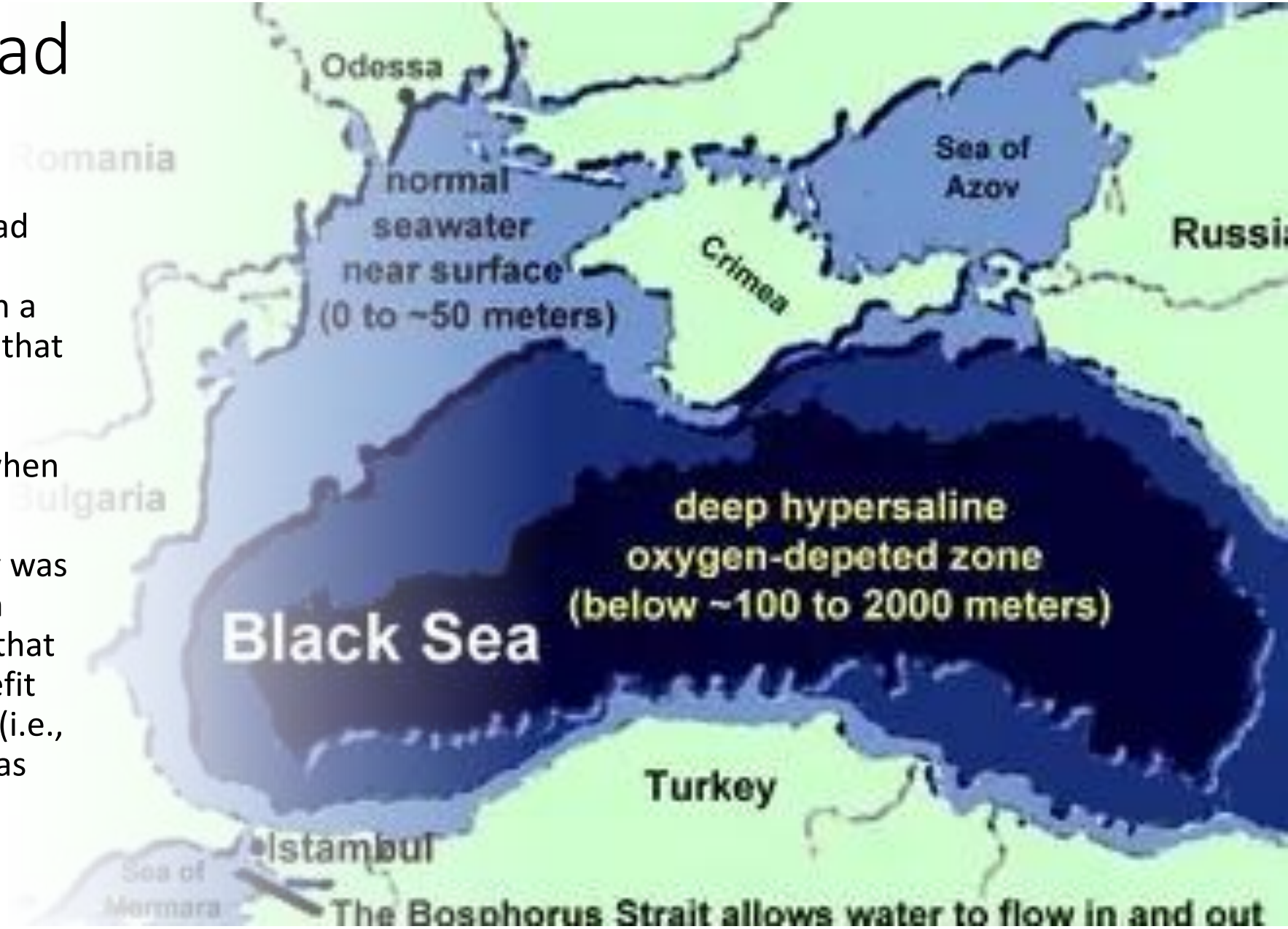
Impacts of Dead Zones

A 2017 study from Duke University documented the impact of hypoxic conditions in the Gulf on shrimp prices. Prices rose significantly during times of extreme hypoxia because of the death of shrimp or the stunting of their growth.

Impacts of Dead Zones

NOAA, estimates that the dead zone costs U.S. seafood and tourism industries $82 million a year. But even NOAA admits that this estimate is probably conservative. Fisherman are traveling further out to sea when the dead zone is present.

A more comprehensive study was completed in the Black Sea in 1999. That study concluded that the projected economic benefit from eliminating dead zones (i.e., reducing nitrogen loading) was $10B.



Impacts of Dead Zones

Secondary impacts include:

- Reduction in economic activity (e.g., oyster farm revenue)
- Reduction in tourism due to unsightliness of algal blooms (see photo of Chinese tourists at a Yellow Sea beach).
- Reduction in tourism due to odors
- Reduction in ecosystem resiliency
- Increase in costs of water treatment as key or keystone species become threatened
- Increase in greenhouse gases.

Dumping Wastes into the Ocean

It is against Federal and International laws to intentionally dump (or cause to be dumped) waste into the oceans. In 1988, the Marine Protection Act was modified as follows:

- it shall be unlawful for any person to dump into ocean waters, or to transport for the purposes of dumping into ocean waters, sewage sludge or industrial waste.

Despite Sting's romantic musings, messages in bottles are illegal.

Dumping Wastes into the Ocean

And yet such waste enters the oceans every day, the result of discarded waste around the world. Much of the illegally dumped waste and the litter originates in up-system streams, then on to rivers, and, ultimately, to the ocean.

According to the Ocean Blue Project (2025):

- Between 8 and 14 million tonnes of plastic enter the oceans every year and this volume is increasing, rising to 29 MMTs by 2040.
- Currently (2025) there is an estimated 200 million tonnes of plastic waste in the ocean and this volume is expected to double within 15 years.
- An estimated 80% of all waste entering the oceans originate from 1000 rivers.

Dumping Wastes into the Ocean

In total, there is an estimated 171 trillion pieces of plastic in the oceans today, according to a 2023 BBC report.

As a result, an estimated 100,000 marine mammals die each year from ingestion of plastics.

It has been estimated that 95% of all marine birds contain some levels of plastics within their bodies.

Dumping Wastes into the Ocean

This is an international problem (arguably more a world problem than a US problem). Millions of tons of solid waste enters waterways in southeast Asia (see photo of waste in the Indus River in Pakistan).

In Indonesia, only about 10% of all waste generated is managed properly according to a 2025 U. of Maryland study (43M tons in 2023).

Dumping Wastes into the Ocean

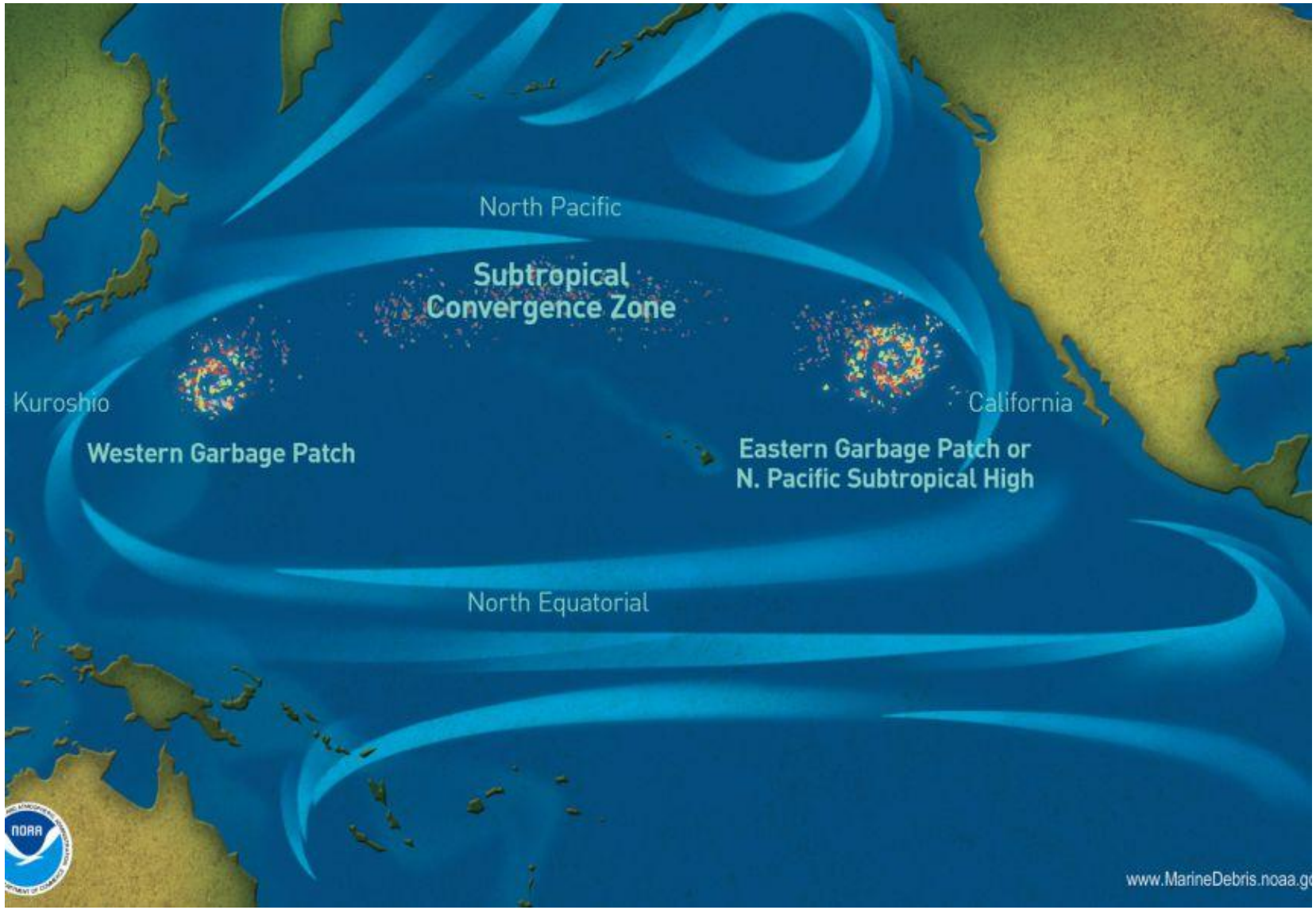
A recent (2024) study by Earth Action estimated the locations where plastics are entering the ocean.* Twelve countries, according to this study, were responsible for 60% of all plastic wastes entering the ocean. The top three, in order:

- China (2.7M tonnes)
- Philippines (1.7M tonnes)
- India (0.97M tonnes)

- Point of entry into the ocean and point of plastic generation or even plastic usage are different places. Since the US exports its plastic waste to Asian nations, at least some of the waste entering the oceans from SE Asia originated in the US.

Photo of a plastic-clogged river in the Philippines.

Dumping Wastes into the Ocean



The accumulation of wastes in the ocean collect in areas of limited current, called “Garbage Patches”. The largest of these “Patches” is located in the northern Pacific Ocean. A 2015 study estimates the size of this Patch to be 617,763 square miles (1.6 million square km), over two times the size of Texas.

A 2015 study suggestedthat some 1.8 trillion pieces of plastic are present in this “Patch” weighing nearly 90,000 tons. In 2025, these estimates were increased to 3.6 trillion pieces and 142,000 tons.

Dumping Wastes into the Ocean

According to *National Geographic*:

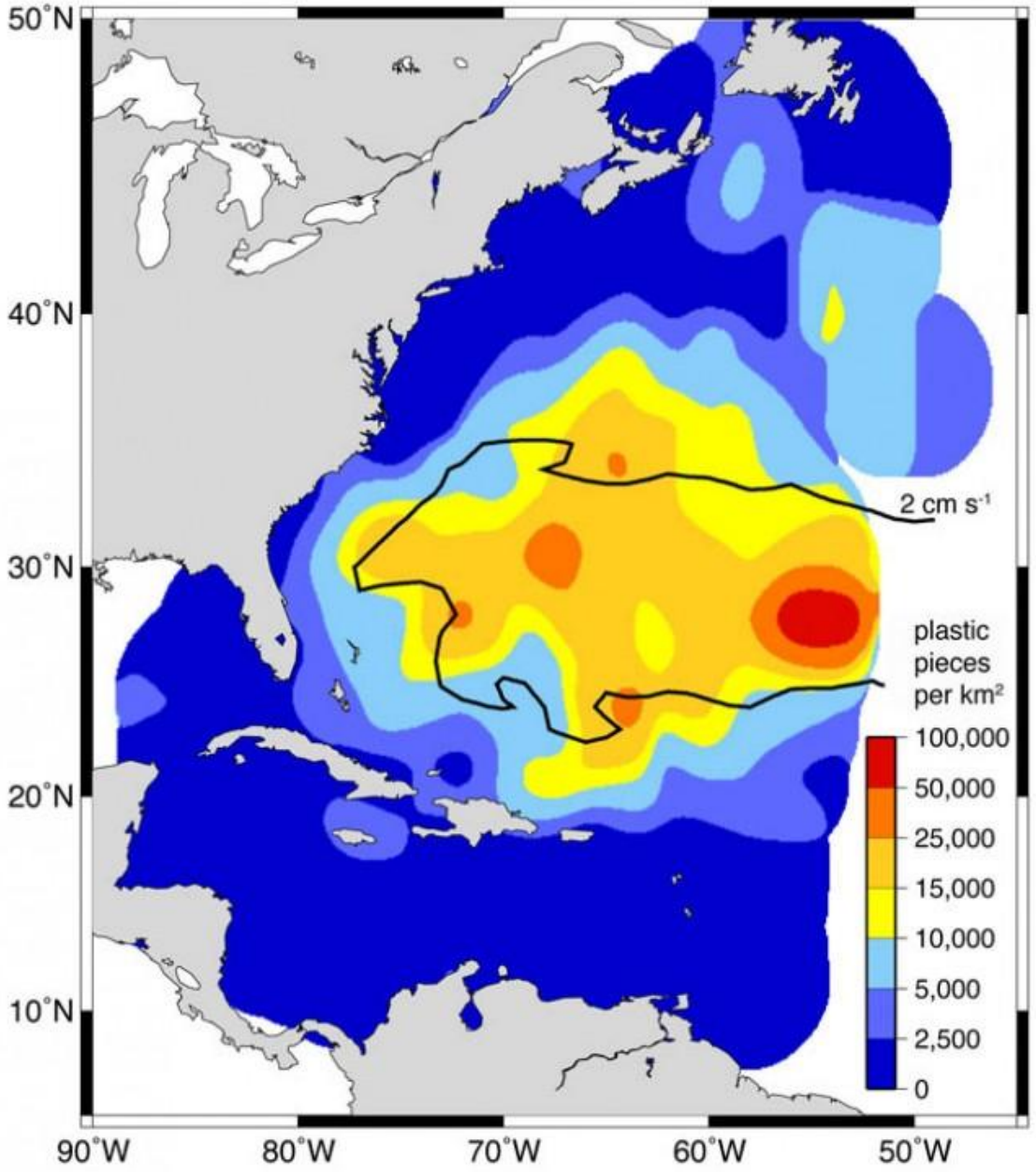
"[T]hese patches are almost entirely made up of micro-plastics. Micro-plastics can't always be seen by the naked eye. Even satellite imagery doesn't show a giant patch of garbage. The micro-plastics of the Great Pacific Garbage Patch can simply make the water look like a cloudy soup. This soup is intermixed with larger items, such as fishing gear and shoes."

Source: National Geographic (3/2023)

Dumping Wastes into the Ocean

A similar area of floating waste exists in the Atlantic Ocean:

- The patch is estimated to be hundreds of kilometers across in size, with a density of over 200,000 pieces of debris per square kilometer.
- Despite its enormous size and density, the patch is, more often than not, invisible to the naked eye and even satellite imaging. The photodegradable plastic that makes up the vast majority of the mass shrinks to smaller than .01 of an inch and is pushed under the surface of the water by deep waves.
- Principal impacts include the consumption of micro-plastics by aquatic organisms and the loss of phytoplankton production.



Impacts of Garbage in the Oceans

Plastics affect animals in all ecosystems, although the predominant focus has been on sea creatures.

According to the United Nations, at least 800 species worldwide are affected by marine debris and the annual death toll is staggering:

- Over 1 million sea birds
- Over 100,000 marine mammals
- Upwards of 100 Million fish and crustaceans

Impacts of Garbage in the Oceans

Plastic waste kills up to a million seabirds a year. As with sea turtles, when seabirds ingest plastic, it takes up room in their stomachs, sometimes causing starvation. Many seabirds are found dead with their stomachs full of this waste. Scientists estimate that 60 percent of all seabird species have eaten pieces of plastic, a figure they predict will rise to 99 percent by 2050.

Impacts of Garbage in the Oceans

The plastic degrades as it is exposed to sunlight (photodegradation), making the plastic available for uptake by marine life. Albatrosses are particularly susceptible to plastics because they skim the ocean surface for food, ingesting plastics directly or feeding the plastic to their young. Bird carcasses were the focus of a recent (2021) photo exhibition at the Smithsonian.

Impacts of Garbage in the Oceans

According to a 2021 study out of New Zealand, almost 75% of all albatross species are threatened or endangered with plastic waste being the principal stressor of these populations. In areas of known garbage patches and albatross populations (e.g., off the coast of Brazil), it is estimated that almost 20% of all deaths are the result of plastics ingestion.

Impacts of Garbage in the Oceans

Hermit crabs use the discarded shells of other animals to protect themselves. But when they go on their hunt for a new home or for food on polluted beaches, they can become trapped in trash—like bottles or cans—and die. This sets off a deadly chain reaction, because when they die, they emit a scent that tells other hermit crabs in the area that their shell is available to use. These crabs will follow that scent just to become entrapped and perish with the first hermit crab.

Impacts of Garbage in the Oceans

A research **expedition to two remote islands** found half a million hermit crabs had been killed by being trapped in trash.

Around 61,000 (2.447 crabs/m^2) and 508,000 crabs (1.117 crabs/m^2) are estimated to become entrapped in debris and die each year on Henderson Island and the Cocos (Keeling) Islands, respectively.

Impacts of Garbage in the Oceans

Micro-plastics are present in a significant percentage of ocean-caught fish.

One study (2023) documented micro-plastics in 34% of all fish caught in the English Channel.

Another study (2019) documented plastic particles in fish caught off the China coasts.

Portland State University (2025) documented the presence of plastics in 180 out of 182 fish products sold at US food markets.

Finally, there is a positive correlation between seafood consumption and total mass of plastic in the human body.

Oil Spills in the Oceans

Deepwater Horizon (2010)

– The teams believe that the current estimates are accurate to within 10 percent. They also reported that of the roughly 4.9 million barrels **(205,000,000 gallons)** that had been released from the well, about 800,000 had been captured by BP's containment efforts. That leaves over four million barrels that gushed into the Gulf of Mexico from April 20 to July 15. ***Source: NYTimes, August 3,2010***

Kuwaiti Oil Spill During First Gulf War (1991)

– The Iraqi army intentionally released oil into the Persian Gulf in an attempt to prevent US forces from landing. According to independent estimates, approximately 4 million barrels (168,000,000 gallons) were discharged. By April 1991, less than 1% of the released oil had been captured. No meaningful recovery operations have been conducted since then.

Exxon Valdez oil spill (1989)

Approx 10,000,000 US gallons

Oil Spills in the Oceans

But these events are highlights of an on-going disregard for a product (oil) that holds so much international value.

A 2025 study enumerated over 3500 “major” oil spills* that occurred from 1967 to 2023.

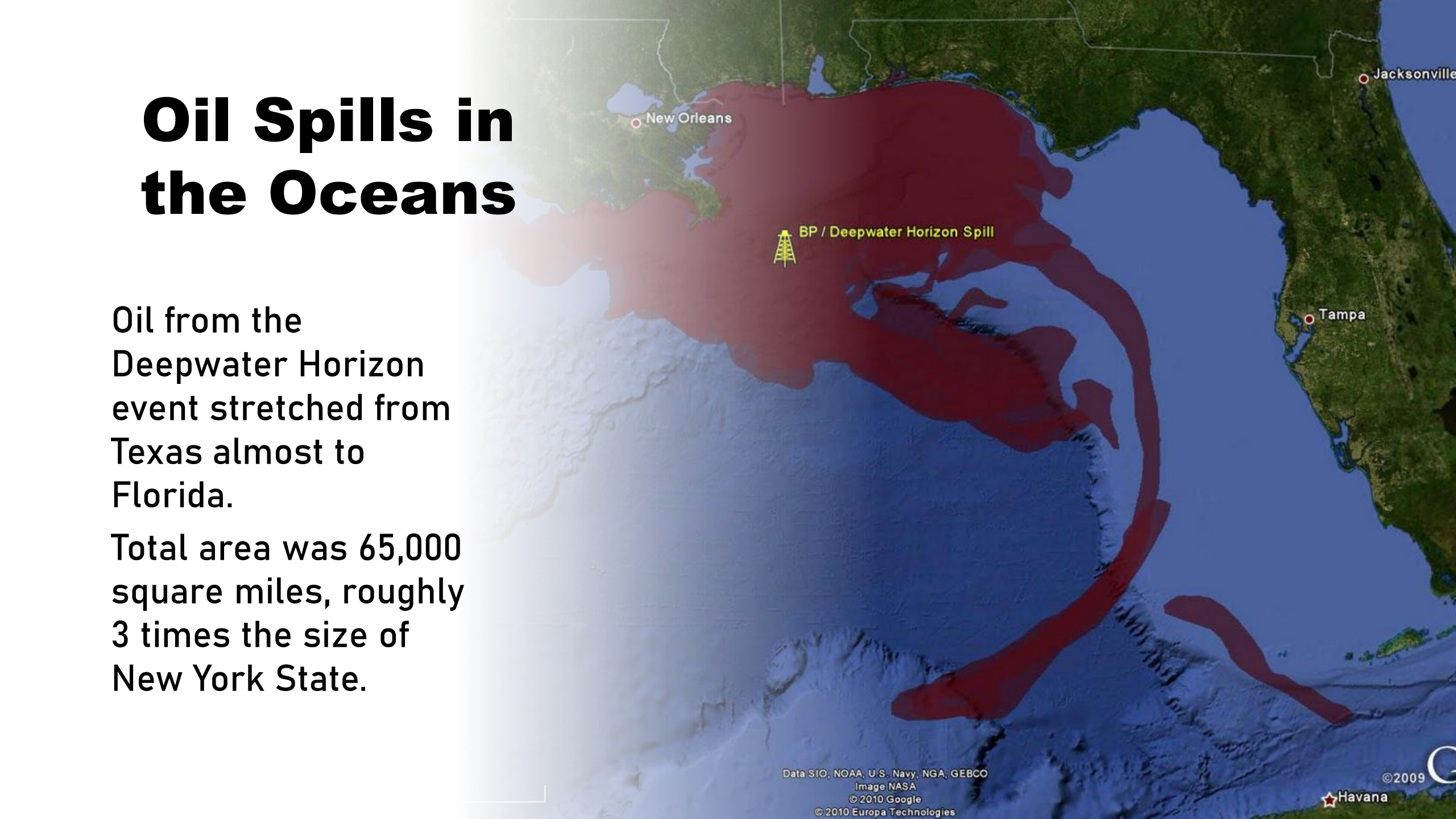
Finally, oil tankers are monitored for leakage. A 2025 study documented 134,000,000 gallons of oil spilled by tankers since 2000.


RAGING
Los Angeles Times
FINAL
DRIFTING OIL SMEARS BEACHES FOR 12 MILES

Oil Spills in the Oceans

Oil from the Deepwater Horizon event stretched from Texas almost to Florida.

Total area was 65,000 square miles, roughly 3 times the size of New York State.



Oil Spills in the Oceans

Affected Wildlife in the Gulf

Other Impacts from Deepwater Horizon

- 8 billion harvestable oysters lost
- 80,000 birds killed directly
- 166,000 sea turtles killed directly
- 50% decline in regional dolphin population
- Reduction in plant cover and grasses along 700+/- miles of shoreline
- Up to $800M in lost recreational revenue

Solutions

Societies utilize an array of strategies intended to address social concerns, “ills” or deficiencies.

These actions are arranged as follows:

- **Educate**
- **Regulate**
- **Manipulate**
- **Innovate**

Solutions: Educate

Knowledge is (sometimes) power and an informed member of society can (sometimes) change not only their individual behavior but the behavior of others.

Actions that can reduce the impacts detailed in todays discussion:

- Eliminate unnecessary consumption of plastic
- Educate community members on cumulative impacts of littering, fugitive oil spills, and lawn runoff.
- Educate decision-makers on above.

Solutions: Regulate

Government has the power to address each of these sources of ocean pollution.

Government also has the responsibility to enforce laws already in existence.

Actions that can reduce the impacts detailed in todays discussion:

- Strengthen “law of the Sea” rules to properly police and minimize illegal waste disposal
- Strengthen oil pollution regulations to increase penalties for fugitive releases
- Regulate nutrient loading into streams and rivers

Solutions: Manipulate

Existing economic structures can be used to encourage societal behavior to change.

Actions that can reduce the impacts detailed in todays discussion:

- Provide financial incentives for developing nations to manage waste disposal responsibly
- Encourage creative approaches to plastics collection through grants
- Increase disincentives (i.e., fines) for regulatory violations

Solutions: Innovate

Wealthy nations have the resource necessary to stimulate prive-sector solutions to environmental problems: money.

Actions that can reduce the impacts detailed in todays discussion:

- Design nutrient filtering systems along principal rivers to reduce nitrogen and phosphorus levels in dead zones.
- Promote plastics recycling programs to remove plastics from waterways in developing nations.
- Finance ocean-skimming operations to remove waste already accumulating in “garbage patches”.

Conclusions

Since the dawn of time, people have been throwing things (and other people) into the oceans. It was accepted wisdom that the oceans were so vast that human activity could not significantly impact its quality or its functionality.

They were, in theory, “too big to fail”.

Conclusions

But they are failing, a direct result of human activity.

Biological activity and biological diversity are both diminished.

Solutions are implementable but require international attention and cooperation.